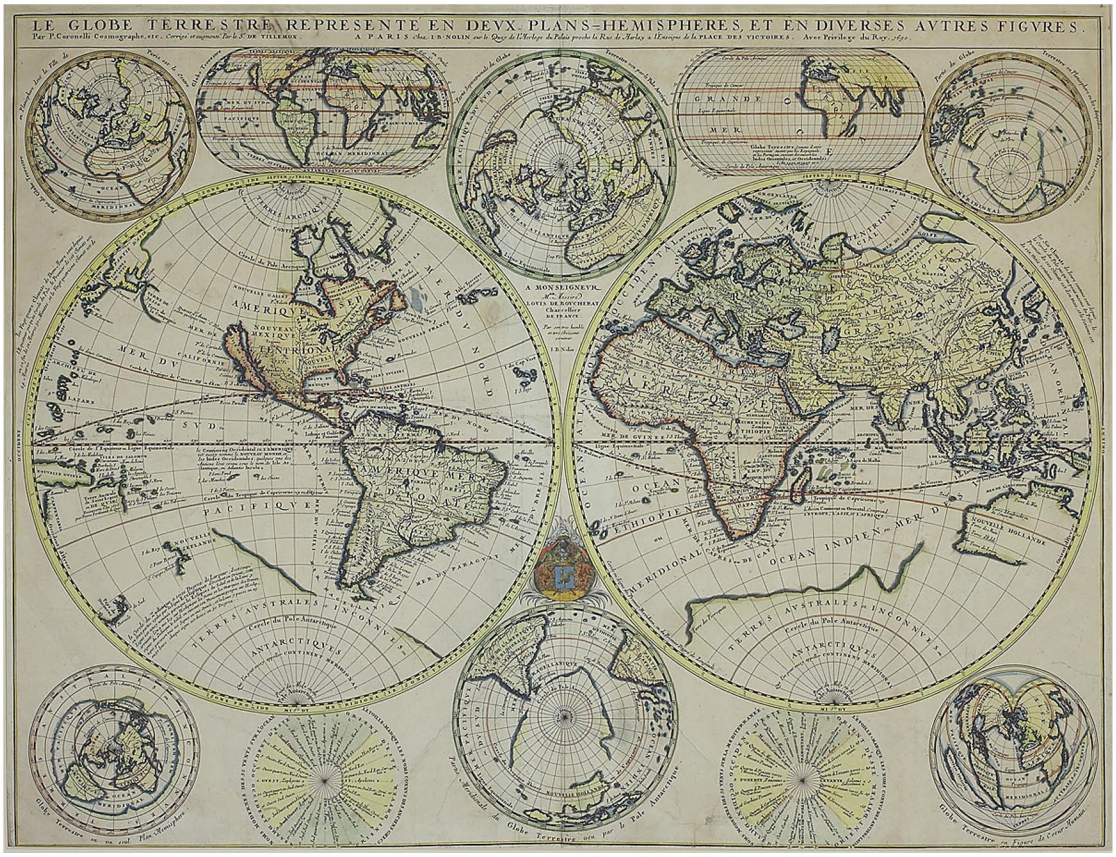
ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

RAPPORTI

Italian Greenhouse Gas Inventory 1990 -2020
National Inventory Report 2022



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Italian Greenhouse Gas Inventory 1990 -2020 National Inventory Report 2022

Rapporti 360/2022

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PREMESSA

Nell'ambito degli strumenti e delle politiche per fronteggiare i cambiamenti climatici, un ruolo fondamentale è svolto dal monitoraggio delle emissioni dei gas-serra.

A garantire la predisposizione e l'aggiornamento annuale dell'inventario dei gas-serra secondo i formati richiesti, in Italia, è l'ISPRA su incarico del Ministero dell'Ambiente e della Tutela del Territorio e del Mare, attraverso le indicazioni del Decreto Legislativo n. 51 del 7 marzo 2008 e del Decreto Legislativo n. 30 del 13 marzo 2013, che prevedono l'istituzione di un Sistema Nazionale, *National System*, relativo all'inventario delle emissioni dei gas-serra.

In più, come è previsto dalla Convenzione-quadro sui cambiamenti climatici per tutti i Paesi industrializzati, l'ISPRA documenta in uno specifico rapporto, il *National Inventory Report*, le metodologie di stima utilizzate, unitamente ad una spiegazione degli andamenti osservati.

Il *National Inventory Report* facilita i processi internazionali di verifica cui le stime ufficiali di emissione dei gas serra sono sottoposte. In particolare, viene esaminata la rispondenza alle proprietà di trasparenza, consistenza, comparabilità, completezza e accuratezza nella realizzazione, qualità richieste esplicitamente dalla Convenzione suddetta. L'inventario delle emissioni è sottoposto ogni anno ad un esame (*review*) da parte di un organismo nominato dal Segretariato della Convenzione che analizza tutto il materiale presentato dal Paese e ne verifica in dettaglio le qualità su enunciate. Senza tali requisiti, l'Italia sarebbe esclusa dalla partecipazione ai meccanismi flessibili previsti dallo stesso Protocollo, come il mercato delle quote di emissioni, l'implementazione di progetti con i Paesi in via di sviluppo (CDM) e l'implementazione di progetti congiunti con i Paesi a economia in transizione (JI).

Il presente documento rappresenta, inoltre, un riferimento fondamentale per la pianificazione e l'attuazione di tutte le politiche ambientali da parte delle istituzioni centrali e periferiche. Accanto all'inventario dei gas-serra, l'ISPRA realizza ogni anno l'inventario nazionale delle emissioni in atmosfera, richiesto dalla Convenzione di Ginevra sull'inquinamento atmosferico transfrontaliero (UNECE-CLRTAP) e dalle Direttive europee sulla limitazione delle emissioni. In più, tutto il territorio nazionale è attualmente coperto da inventari regionali sostanzialmente coerenti con l'inventario nazionale, realizzati principalmente dalle Agenzie Regionali e Provinciali per la Protezione dell'Ambiente.

Nonostante i progressi compiuti, l'attività di preparazione degli inventari affronta continuamente nuove sfide legate alla necessità di considerare nuove sorgenti e nuovi inquinanti e di armonizzare gli inventari prodotti per diverse finalità di *policy*. Il contesto internazionale al quale fa riferimento la preparazione dell'inventario nazionale costituisce una garanzia di qualità dei dati, per l'autorevolezza dei riferimenti metodologici, l'efficacia del processo internazionale di *review* e la flessibilità nell'adattamento alle nuove circostanze.

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EXECUTIVE SUMMARY

ES.1. Background information on greenhouse gas inventories and climate change

The United Nations Framework Convention on Climate Change (FCCC) was ratified by Italy in the year 1994 through law no.65 of 15/01/1994.
The Kyoto Protocol, adopted in December 1997, has established emission reduction objectives for Annex B Parties (i.e. industrialised countries and countries with economy in transition): in particular, the European Union as a whole is committed to an 8% reduction within the period 2008-2012, in comparison with base year levels. For Italy, the EU burden sharing agreement, set out in Annex II to Decision 2002/358/EC and in accordance with Article 4 of the Kyoto Protocol, has established a reduction objective of 6.5% in the commitment period, in comparison with 1990 levels.
Subsequently, on 1st June 2002, Italy ratified the Kyoto Protocol through law no.120 of 01/06/2002. The ratification law prescribed also the preparation of a National Action Plan to reduce greenhouse gas emissions, which was adopted by the Interministerial Committee for Economic Planning (CIPE) on 19th December 2002 (deliberation n. 123 of 19/12/2002). The Kyoto Protocol finally entered into force in February 2005. The first commitment period ended in 2012, with an extension, for fulfilling commitments, to 18th November 2015, the so called *true-up period*. The evaluation of the Kyoto Protocol, together with the commitments fulfilled by each Party, has been finalized by the UNFCCC Secretariat.
A new global agreement was reached in Paris in December 2015, for the period after 2020. The agreement aims to strengthen the global response to the threat of climate change by holding the increase in the global temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impact of climate change. On 5th October 2016, the threshold for entry into force of the Paris Agreement was achieved and the Paris Agreement entered into force on 4th November 2016.
To fulfil the gap 2013-2020, the 'Doha Amendment to the Kyoto Protocol' was adopted on 8th December 2012. The EU and its Member States have committed to this second phase of the Kyoto Protocol and established to reduce their collective emissions to 20% below their levels in 1990 or other chosen base years; this is also reflected in the Doha Amendment. The target will be fulfilled jointly with Iceland.
As a Party to the Convention and the Kyoto Protocol, Italy is committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs) as well as formulate and implement programmes to reduce these emissions.
In order to establish compliance with national and international commitments, the national GHG emission inventory is compiled and communicated annually by the Institute for Environmental Protection and Research (ISPRA) to the competent institutions, after endorsement by the Ministry for the Environment, Land and Sea. The submission is carried out through compilation of the Common Reporting Format (CRF), according to the guidelines provided by the United Nations Framework Convention on Climate Change and the European Union's Greenhouse Gas Monitoring Mechanism. As a whole, an annual GHG inventory submission shall consist of a national inventory report (NIR) and the common reporting format (CRF) tables as specified in the Guidelines on reporting and review of greenhouse gas inventories from Parties included in Annex I to the Convention, decision 24/CP.19, in FCCC/CP/2013/10/Add.3.
Detailed information on emission figures and estimation procedures, including all the basic data needed to carry out the final estimates, is to be provided to improve the transparency, consistency, comparability, accuracy and completeness of the inventory provided.
The national inventory is updated annually in order to reflect revisions and improvements in the methodology and use of the best information available. Adjustments are applied retrospectively to earlier years, which accounts for any difference in previously published data.
This report provides an analysis of the Italian GHG emission inventory communicated to the Secretariat of the Climate Change Convention and to the European Commission in the framework of the Greenhouse Gas Monitoring Mechanism in the year 2022, including the update for the year 2020 and the revision of the entire time series 1990-2019.
Concerning the reporting and accounting requirements, under the second commitment period of the Kyoto Protocol (KP CP2), each Party is required to submit a report, the initial report, to facilitate the calculation of its assigned amount and to demonstrate its capacity to account for its emissions and assigned amount (UNFCCC Decision 2/CMP.8). The ratification decision allows a joint initial report of the EU, its Member

States and Iceland, to be prepared by the European Commission, and individual initial reports of each Member States and Iceland. In its initial report, Italy describes the national assigned amount as well as the commitment period reserve.
The election of LULUCF activities under Article 3, paragraph 4, of the Kyoto Protocol for the commitment period 2013-2020 is also indicated in the same document; Italy has elected cropland and grazing land management activities.
Emission estimates comprise the seven direct greenhouse gases under the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, nitrogen trifluoride) which contribute directly to climate change owing to their positive radiative forcing effect and four indirect greenhouse gases (nitrogen oxides, carbon monoxide, non-methane volatile organic compounds, sulphur dioxide).
This report, the CRF files and other related documents are available on website at the address http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.

The official inventory submissions can also be found at the UNFCCC website https://unfccc.int/ghg-inventories-annex-i-parties/2022.

ES.2. Summary of national emission and removal related trends

Total greenhouse gas emissions, in CO_2 equivalent, excluding emissions and removals from land use, land use change and forestry, decreased by 26.7% between 1990 and 2020 (from 520 to 381 million of CO_2 equivalent tons).
The most important greenhouse gas, CO_2, which accounted for 79.3% of total emissions in CO_2 equivalent in 2020, showed a decrease by 31.2% between 1990 and 2020. CH_4 and N_2O emissions were equal to 11.2% and 5.1%, respectively, of the total CO_2 equivalent greenhouse gas emissions in 2020. Both gases showed a decrease from 1990 to 2020, equal to 13.4% and 28.4% for CH_4 and N_2O, respectively.
Other greenhouse gases, HFCs, PFCs, SF_6 and NF_3, ranged from less than 0.01% to 4.0% of total emissions.
Table ES.1 illustrates the national trend of greenhouse gases for 1990-2020, expressed in CO_2 equivalent terms, by substance and category.

Table ES.1. Total greenhouse gas emissions and removals in CO_2 equivalent [kt CO_2 eq]

GHG emissions	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 equivalent				
CO_2 excluding net CO_2 from LULUCF	439,550	449,826	470,487	502,255	436,117	361,163	349,005	339,233	302,279
CO_2 including net CO_2 from LULUCF	433,760	424,689	447,965	466,084	393,802	317,479	312,870	297,856	269,190
CH_4 excluding CH_4 from LULUCF	49,390	51,417	51,913	49,205	47,341	44,112	42,982	41,982	42,780
CH_4 including CH_4 from LULUCF	50,676	51,720	52,628	49,504	47,691	44,376	43,143	42,185	43,043
N_2O excluding N_2O from LULUCF	27,209	29,433	30,270	29,281	20,331	18,867	18,987	18,757	19,471
N_2O including N_2O from LULUCF	28,065	30,311	30,965	29,911	20,761	19,194	19,438	19,251	19,896
HFCs	444	927	2,489	7,619	12,055	15,403	16,496	16,871	15,876
PFCs	2,907	1,492	1,488	1,940	1,520	1,688	1,657	1,028	539
Unspecified mix of HFCs and PFCs	NO,NA	25	25	25	25	25	23	24	23
SF_6	408	680	604	550	394	472	452	440	264
NF_3	NA,NO	77	13	33	20	28	22	18	16
Total (excluding LULUCF)	**519,908**	**533,876**	**557,291**	**590,908**	**517,804**	**441,759**	**429,624**	**418,352**	**381,248**
Total (including LULUCF)	**516,260**	**509,920**	**536,177**	**555,667**	**476,268**	**398,666**	**394,102**	**377,672**	**348,847**

GHG categories	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 equivalent				
1. Energy	425,298	437,938	459,631	487,640	428,903	358,776	345,416	335,081	298,900
2. Industrial Processes and Product Use	40,422	38,316	39,123	47,211	36,964	33,233	34,604	33,985	31,049
3. Agriculture	36,900	37,649	36,682	34,192	31,555	31,207	31,460	31,354	32,685
4. LULUCF	-3,648	-23,956	-21,113	-35,241	-41,536	-43,093	-35,523	-40,680	-32,401
5. Waste	17,289	19,974	21,854	21,864	20,382	18,544	18,145	17,932	18,614
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)	**516,260**	**509,920**	**536,177**	**555,667**	**476,268**	**398,666**	**394,102**	**377,672**	**348,847**

ES.3. Overview of source and sink category emission estimates and trends

The energy sector is the largest contributor to national total GHG emissions with a share, in 2020, of 78.4%. Emissions from this sector decreased by 20.7% from 1990 to 2020. Substances with decrease rates were CO_2, whose levels reduced by 29.6% from 1990 to 2020 and accounts for 96.4% of the total in the energy sector, and CH_4 which showed a reduction of 42.0% but its share out of the sectoral total is only 2.2%; N_2O showed a decrease of 8.4% from 1990 to 2020, accounting for 1.4%. Specifically, in terms of total CO_2 equivalent, an increase in emissions was observed only in the other sectors, about 0.2%, from 1990 to 2020 which account for 26.5% of the total sectoral emissions in 2020; the transport sector (28.6% of the total energy emissions) showed a decrease of 16.4% from 1990 to 2020.

For the industrial processes sector, emissions showed a decrease of 35.3% from 1990 to 2020. Specifically, by substance, CO_2 emissions account for 44.0% and showed a decrease by 53.4%, CH_4 decreased by 73.6%, but it accounts only for 0.1%, while N_2O, whose levels share 2.0% of total industrial emissions, decreased by 91.3%. The decrease in emissions is mostly due to a decrease in chemical industry (due to the fully operational abatement technology in the adipic acid industry) and mineral and metal production emissions. A considerable increase was observed in F-gases emissions (about 345%), whose level on total sectoral emissions is 53.8%. It should be noted that, except for the motivations explained, the economic recession has had a remarkable influence on the production levels of most the industries and consequent emissions in the last years.

For agriculture, emissions refer mainly to CH_4 and N_2O levels, which account for 59.0% and 39.5% of the sectoral total, respectively; CO_2, on the other hand, shares only 1.5% of the total. The decrease observed in the total level of emissions (-11.4%) is mostly due to the decrease of CH_4 emissions from enteric fermentation (-13.0%), which account for 41.4% of sectoral emissions and to the decrease of N_2O from agricultural soils (-3.9%), which accounts for 33.1% of sectoral emissions.

As regards land use, land-use change and forestry, from 1990 to 2020 total removals in CO_2 equivalent considerably increased; CO_2 accounts for almost the total emissions and removals of the sector (98.0%).

Finally, emissions from the waste sector increased by 7.7% from 1990 to 2020, mainly due to an increase in the emissions from solid waste disposal on land (16.8%), which account for 76.6% of waste emissions. The most important greenhouse gas in this sector is CH_4 which accounts for 90.2% of the sectoral emissions and shows an increase of 8.6% from 1990 to 2020. N_2O emission levels increased by 31.0%, whereas CO_2 decreased by 81.9%; these gases account for 9.3% and 0.5% in the sector, respectively.

Table ES.2 provides an overview of the CO_2 equivalent emission trends by IPCC source category.

Table ES.2. Summary of emission trends by source category and gas in CO_2 equivalent [kt CO_2 eq.]

Category	1990	1995	2000	2005	2010	2015	2018	2019	2020
				kt CO_2 equivalent					
A. Energy: fuel combustion	**412,180**	**425,564**	**448,484**	**477,885**	**420,007**	**350,745**	**338,491**	**328,469**	**292,909**
CO_2: 1. Energy Industries	136,941	139,941	144,273	159,227	136,885	105,486	95,545	91,410	81,353
CO_2: 2. Manufacturing Industries and Construction	90,772	88,969	94,893	90,786	68,900	54,552	53,228	48,957	44,879
CO_2: 3. Transport	100,319	111,531	121,443	126,616	114,172	104,890	103,109	104,139	84,462
CO_2: 4. Other Sectors	76,042	75,580	79,169	92,324	90,908	77,684	78,727	76,069	74,583
CO_2: 5. Other	1,071	1,496	837	1,233	652	459	341	453	625
CH_4	2,444	2,701	2,468	2,301	3,159	3,004	2,921	2,938	2,799
N_2O	4,591	5,345	5,402	5,398	5,331	4,669	4,620	4,503	4,208
1B2. Energy: fugitives from oil & gas	**13,117**	**12,374**	**11,147**	**9,755**	**8,897**	**8,031**	**6,925**	**6,612**	**5,991**
CO_2	4,048	4,002	3,262	2,557	2,377	2,574	2,295	2,756	2,113
CH_4	9,058	8,360	7,873	7,185	6,508	5,447	4,620	3,847	3,871
N_2O	12	12	12	13	12	10	9	9	8
2. Industrial processes	**40,422**	**38,316**	**39,123**	**47,211**	**36,964**	**33,233**	**34,604**	**33,985**	**31,049**
CO_2	29,335	27,281	25,832	28,718	21,666	14,960	15,226	14,924	13,668
CH_4	129	134	73	74	60	42	44	41	34
N_2O	7,199	7,701	8,599	8,251	1,224	613	684	641	629
HFCs	444	927	2,489	7,619	12,055	15,403	16,496	16,871	15,876
PFCs	2,907	1,492	1,488	1,940	1,520	1,688	1,657	1,028	539
Unspecified mix of HFCs and PFCs	NO,NA	25	25	25	25	25	23.15	23.54	22.86
SF_6	408	680	604	550	394	472	452	440	264
NF_3	NA,NO	77	13	33	20	28	22.13	17.84	16.31
3. Agriculture	**36,900**	**37,649**	**36,682**	**34,192**	**31,555**	**31,207**	**31,460**	**31,354**	**32,685**
CO_2: Liming	1	1	2	14	18	14	15	16	10
CO_2: Urea application	465	512	525	507	335	425	405	396	472
CO_2: Other carbon-containing fertilizers	44	54	44	42	28	20	22	17	21
CH_4: Enteric fermentation	15,564	15,399	15,128	13,293	12,884	13,035	13,381	13,364	13,535
CH_4: Manure management	4,843	4,608	4,573	4,686	4,542	4,256	4,145	4,138	4,147
CH_4: Rice Cultivation	1,876	1,989	1,656	1,752	1,822	1,668	1,601	1,583	1,582
CH_4: Field Burning of Agricultural Residues	15	15	15	16	15	16	15	15	15
N_2O: Manure management	2,833	2,706	2,619	2,410	2,331	2,098	2,088	2,068	2,078
N_2O: Agriculture soils	11,254	12,361	12,116	11,468	9,575	9,672	9,784	9,752	10,820
N_2O: Field Burning of Agricultural Residues	4	4	4	4	4	4	4	4	4
4A. Land-use change and forestry	**-3,648**	**-23,956**	**-21,113**	**-35,241**	**-41,536**	**-43,093**	**-35,523**	**-40,680**	**-32,401**
CO_2	-5,790	-25,137	-22,522	-36,171	-42,316	-43,684	-36,135	-41,377	-33,089
CH_4	1,286	303	714	299	350	264	161	203	263
N_2O	856	878	695	630	430	328	451	494	425
6. Waste	**17,289**	**19,974**	**21,854**	**21,864**	**20,382**	**18,544**	**18,145**	**17,932**	**18,614**
CO_2	512	458	208	230	177	99	91	96	93
CH_4	15,461	18,212	20,126	19,898	18,350	16,644	16,254	16,056	16,797
N_2O	1,316	1,305	1,519	1,736	1,855	1,801	1,800	1,780	1,724
Total emissions (with LULUCF)	***516,260***	***509,920***	***536,177***	***555,667***	***476,268***	***398,666***	***394,102***	***377,672***	***348,847***
Total emissions (without LULUCF)	***519,908***	***533,876***	***557,291***	***590,908***	***517,804***	***441,759***	***429,624***	***418,352***	***381,248***

ES.4. Other information

In Table ES.3 NO_X, CO, NMVOC and SO_2 emission trends from 1990 to 2020 are summarised.
All gases showed a significant reduction in 2020 as compared to 1990 levels. The highest reduction is observed for SO_2 (-95.4%), while NO_X and CO emissions reduced by about 73.1% and 72.4%, respectively; NMVOC levels showed a decrease by 55.6%.

Table ES.3. Total emissions of indirect greenhouse gases and SO_2 [kt]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						kt					
NO_X	2,128	1,992	1,510	1,294	941	719	704	662	662	642	573
CO	6,796	7,071	4,750	3,467	3,073	2,266	2,191	2,258	2,049	2,060	1,873
NMVOC	1,993	2,058	1,630	1,340	1,116	897	880	921	894	888	885
SO_2	1,784	1,323	757	411	222	126	120	117	109	105	82

Sommario (Italian)

Nel documento “Italian Greenhouse Gas Inventory 1990-2020. National Inventory Report 2022” si descrive la comunicazione annuale italiana dell’inventario delle emissioni dei gas serra in accordo a quanto previsto nell’ambito della Convenzione Quadro sui Cambiamenti Climatici delle Nazioni Unite (UNFCCC), del protocollo di Kyoto. Tale comunicazione è anche trasmessa all’Unione Europea nell’ambito del Meccanismo di Monitoraggio dei Gas Serra.

Ogni Paese che partecipa alla Convenzione, infatti, oltre a fornire annualmente l’inventario nazionale delle emissioni dei gas serra secondo i formati richiesti, deve documentare in un *report*, il *National Inventory Report*, la serie storica delle emissioni. La documentazione prevede una spiegazione degli andamenti osservati, una descrizione dell’analisi delle sorgenti principali, *key sources*, e dell’incertezza ad esse associata, un riferimento alle metodologie di stima e alle fonti dei dati di base e dei fattori di emissione utilizzati per le stime, un’illustrazione del sistema di *Quality Assurance/Quality Control* a cui è soggetto l’inventario e delle attività di verifica effettuate sui dati.

Il *National Inventory Report* facilita, inoltre, i processi internazionali di verifica cui le stime di emissione dei gas serra sono sottoposte al fine di esaminarne la rispondenza alle proprietà di trasparenza, consistenza, comparabilità, completezza e accuratezza nella realizzazione, qualità richieste esplicitamente dalla Convenzione suddetta. Nel caso in cui, durante il processo di *review*, siano identificati eventuali errori nel formato di trasmissione o stime non supportate da adeguata documentazione e giustificazione nella metodologia scelta, il Paese viene invitato ad una revisione delle stime di emissione.

I dati di emissione dei gas-serra, i rapporti *National Inventory Report*, così come i risultati dei processi di *review*, sono pubblicati sul sito web del Segretariato della Convenzione sui Cambiamenti Climatici https://unfccc.int/ghg-inventories-annex-i-parties/2022.

La serie storica nazionale delle emissioni è anche disponibile sul sito web all’indirizzo: http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.

Da un’analisi di sintesi della serie storica dei dati di emissione dal 1990 al 2020, si evidenzia che le emissioni nazionali totali dei sei gas serra, espresse in CO_2 equivalente, sono diminuite del 26.7% nel 2020 rispetto al 1990. In particolare, le emissioni complessive di CO_2 sono pari al 79.3% del totale e risultano nel 2020 inferiori del 31.2% rispetto al 1990. Le emissioni di metano e di protossido di azoto sono pari a circa il 11.2% e 5.1% del totale, rispettivamente, e presentano andamenti in diminuzione sia per il metano (-13.4%) che per il protossido di azoto (-28.4%). Gli altri gas serra, HFC, PFC, SF_6 e NF_3, hanno un peso complessivo sul totale delle emissioni che varia tra lo 0.01% e il 4.0%; le emissioni degli HFC evidenziano una forte crescita, mentre le emissioni di PFC decrescono e quelle di SF_6 e NF_3 mostrano un incremento. Sebbene tali variazioni non siano risultate determinanti ai fini del conseguimento degli obiettivi di riduzione delle emissioni, la significatività del trend degli HFC potrebbe renderli sempre più importanti nei prossimi anni.

PART I: ANNUAL INVENTORY SUBMISSION

1. INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

In 1988 the World Meteorological Organisation (WMO) and the United Nations Environment Program (UNEP) established a scientific Intergovernmental Panel on Climate Change (IPCC) in order to evaluate the available scientific information on climate variations, examine the social and economical influence on climate change and formulate suitable strategies for the prevention and the control of climate change.

The first IPCC report in 1990, although considering the high uncertainties in the evaluation of climate change, emphasised the risk of a global warming due to an unbalance in the climate system originated by the increase of anthropogenic emissions of greenhouse gases (GHGs) caused by industrial development and use of fossil fuels. More recently, the scientific knowledge on climate change has firmed up considerably by the IPCC Fifth Assessment Report on global warming which states that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." and "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen." Hence the need of reducing those emissions, particularly for the most industrialised countries.

The first initiative was taken by the European Union (EU) at the end of 1990, when the EU adopted the goal of a stabilisation of carbon dioxide emissions by the year 2000 at the level of 1990 and requested Member States to plan and implement initiatives for environmental protection and energy efficiency. The contents of EU statement were the base for the negotiation of the United Nations Framework Convention on Climate Change (UNFCCC) which was approved in New York on 9th May 1992 and signed during the summit of the Earth in Rio de Janeiro in June 1992. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs) as well as formulate and implement programmes addressing anthropogenic GHG emissions. Specifically, Italy ratified the convention through law no.65 of 15/1/1994.

On 11/12/1997, Parties to the Convention adopted the Kyoto Protocol, which establishes emission reduction objectives for Annex B Parties (i.e. industrialised countries and countries with economy in transition) in the period 2008-2012. In particular, the European Union as a whole was committed to an 8% reduction within the period 2008-2012, in comparison with base year levels. For Italy, the EU burden sharing agreement, set out in Annex II to Decision 2002/358/EC and in accordance with Article 4 of the Kyoto Protocol, established a reduction objective of 6.5% in the commitment period, in comparison with the base 1990 levels.

Italy ratified the Kyoto Protocol on 1st June 2002 through law no.120 of 01/06/2002. The ratification law also prescribes the preparation of a National Action Plan to reduce greenhouse gas emission, which was adopted by the Interministerial Committee for Economic Planning (CIPE) on 19th December 2002 (deliberation n. 123 of 19/12/2002). The Kyoto Protocol finally entered into force on 16th February 2005.

The first commitment period ended in 2012, with an extension, for fulfilling commitments, to 18th November 2015, the so called *true-up period*. The evaluation of the Kyoto Protocol, together with the commitments fulfilled by each Party, has been finalized by the UNFCCC Secretariat.

A new global agreement was reached in Paris in December 2015, for the period after 2020. The agreement aims to strengthen the global response to the treat of climate change by holding the increase in the global temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impact of climate change. In order to achieve this long-term temperature goal, Parties aim to reach global peaking of GHG emissions as soon as possible and undertake rapid reductions so as to achieve a balance between anthropogenic emissions by sources and removals by sinks in the second half of this century. Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. On 5 October 2016, the threshold for entry into force of the Paris Agreement was achieved (at least 55 Parties to the Convention accounting in total for at least an estimated 55 percent of the total global greenhouse gas emissions, where "total global greenhouse gas emissions" means the most up-to-date amount communicated on or before the date of adoption of the Agreement). The Paris Agreement entered into force on 4 November 2016.

To fulfil the gap 2013-2020, the 'Doha Amendment to the Kyoto Protocol' was adopted on 8 December 2012. The amendment includes:

- New commitments for Annex I Parties to the Kyoto Protocol who agreed to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020;
- A revised list of greenhouse gases (GHG) to be reported on by Parties in the second commitment period; and
- Amendments to several articles of the Kyoto Protocol which specifically referenced issues pertaining to the first commitment period and which needed to be updated for the second commitment period.

The Doha Amendment entred into force on 28 October 2020.
During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the composition of Parties in the second commitment period is different from the first.
The EU and its Member States have committed to this second phase of the Kyoto Protocol and established to reduce their collective emissions to 20% below their levels in 1990 or other chosen base years; this is also reflected in the Doha Amendment. The target will be fulfilled jointly with Iceland.
In line with the Council's conclusions of 9 March 2012 and the offer of the Union and its Member States to take on an 80% target under the second commitment period, the emission levels of the Member States are equal to the sum of the annual emission allocations (AEA) for the period 2013-2020 determined pursuant to Decision No 406/2009/EC of the European Parliament and of the Council. That amount, based on global warming potential values from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, was determined under Annex II to Commission Decision 2013/162/EU and adjusted by Commission Implementing Decisions 2013/634/EU and 2017/1471/EU. The emission level for Iceland was determined in the Agreement with Iceland.
Member States are allowed certain flexibility in meeting their AEAs: overachievement in a given year can be carried over to subsequent years, up to 2020, and an emission allocation of up to 5% during 2013-2019 may be carried forward from the following year (Article 3.3 of Decision 406/2009/CE). Moreover, during 2013-2019 Member States may transfer part of their AEA for a given year to other Member States under certain conditions (Articles 3.4 and 3.5) and international credits can be used under certain quantitative and qualitative conditions (Article 5). In complying with the commitments of the Effort Sharing Decision, Italy used the flexibility of carrying over the surplus of AEAs for the years 2013, 2014 and 2015. In the period 2013-2018 Italy made no use of project credits and performed no transfers of AEAs to other Member States, therefore no specific information is reported according to Annex XIV and XV of Implementing Regulation 2014/749/EU.
The European Council adopted on 13 July 2015 the legislation necessary for the European Union to formally ratify the second commitment period of the Kyoto Protocol.
The Council adopted two decisions:

- Council Decision on the ratification of the Doha amendment to the Kyoto Protocol establishing the second commitment period, and
- Council Decision on the agreement between the EU, its Member States and Iceland, necessary for the joint fulfillment of the second commitment period of the Kyoto Protocol.

In parallel with the ratification by the EU, the Member States and Iceland finalised their national ratification processes.
As a Party to the Convention and the Kyoto Protocol, Italy is committed to develop, publish and regularly update national emission inventories as well as formulate and implement programmes to reduce these emissions. In order to establish compliance with national and international commitments, air emission inventories are compiled and communicated annually to the competent institutions.
Specifically, the national GHG emission inventory is communicated through compilation of the Common Reporting Format (CRF), according to the guidelines provided by the United Nations Framework Convention on Climate Change and the European Union's Greenhouse Gas Monitoring Mechanism (IPCC, 1997; IPCC, 2000; IPCC, 2003; IPCC, 2006; IPCC, 2014; EMEP/CORINAIR, 2007; EMEP/EEA, 2019).
The inventory is updated annually in order to reflect revisions and improvements in methodology and availability of new information. Recalculations are applied retrospectively to earlier years, which account for any difference in previously published data.
The submission also provides for detailed information on emission figures and estimation methodologies in the annual National Inventory Report.

As follows, this report is compiled according to the guidelines on reporting as specified in the document FCCC/CP/2013/10/Add.3, Decision 24/CP.19. An analysis of the 2020 Italian GHG emission inventory, and a revision of the entire time series from 1990, communicated in the framework of the annual submission under the UNFCCC and the Kyoto Protocol, is provided in the document. It is also the annual submission to the European Commission in the framework of the Greenhouse Gas Monitoring Mechanism.
Concerning the reporting and accounting requirements, under the KP CP2 each Party is required to submit a report, the initial report, to facilitate the calculation of its assigned amount and to demonstrate its capacity to account for its emissions and assigned amount (UNFCCC Decision 2/CMP.8). The ratification decision allows a joint initial report of the EU, its Member States and Iceland, to be prepared by the European Commission, and individual initial reports of each Member States and Iceland.
In its Initial Report, Italy specified its national assigned amount as well as the commitment period reserve. The election of cropland and grazing land management activities under Article 3, paragraph 4, of the Kyoto Protocol for the commitment period 2013-2020 is indicated in the same document.
Emission estimates comprise the six direct greenhouse gases under the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride) plus nitrogen trifluoride (NF_3) which contribute directly to climate change owing to their positive radiative forcing effect and four indirect greenhouse gases (nitrogen oxides, carbon monoxide, non-methane volatile organic compounds, sulphur dioxide).
The CRF files, the national inventory reports and other related documents are available at the address http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.
Information on accounts, legal entities, Art.6 projects, holdings and transactions is publicly available at: http://www.info-ets.isprambiente.it/index.php?p=publicinfo.
The internet address of the Italian registry is:
https://ets-registry.webgate.ec.europa.eu/euregistry/IT/index.xhtml.
The official inventory submissions can also be found at the UNFCCC website:
https://unfccc.int/ghg-inventories-annex-i-parties/2022.

The present document is the official submission, for the year 2022, under the UNFCCC and the Kyoto Protocol.

1.2 Description of the institutional arrangement for inventory preparation

1.2.1 National Inventory System

The National System for the Italian Greenhouse Gas Inventory was established by the Legislative Decree 51 of March 7th 2008 and confirmed by the Legislative Decree 30 of March 13th 2013.
Article 5.1 of the Kyoto Protocol established that Annex I Parties should have in place a National System since the end of 2006 for estimating anthropogenic greenhouse gas emissions by sources and removals by sinks and for reporting and archiving inventory information according to the guidelines specified in the UNFCCC Decision 20/COP.7. This decision is updated by Decision 24/CP19, which calling the system national inventory arrangements does not change the basic requests of functionality and operability.
In addition, the Decision of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions (EC, 2004) required that Member States established a national greenhouse gas inventory system since the end of 2005 at the latest and that the Commission adopts the EC's inventory system since 30 June 2006.
The 'National Registry for Carbon sinks', instituted by a Ministerial Decree on 1st April 2008, is part of the Italian National System and includes information on lands subject to activities under Article 3.3 and Article 3.4 of the Kytoto Protocol and related carbon stock changes. In agreement with the Ministerial decree art.4, the Ministry for the Environment, Land and Sea is responsible for the management of the National Registry for Carbon sinks. The Decree also provides that ISPRA and the former State Forestry Service, now Carabinieri Forestali, are involved by the Ministry as technical scientific support for specific activities as defined in the relevant protocol. ISPRA is responsible for the preparation of emission and removals estimates for the LULUCF sector and for KP LULUCF supplementary information under art.7.1 of the Kyoto Protocol. Following an update of the abovementioned Ministerial Decree, in 2013, the Institute for Services on

Agricultural and Agro-food Market (ISMEA[1]) has been designated for the technical coordination of the section related to cropland and grazing land management of the National Registry of Carbon Sinks.
The National Registry for Carbon sinks is the instrument to estimate, following the COP/MOP decisions and in accordance with the IPCC guidelines, the greenhouse gases emissions by sources and removals by sinks in the land subject to art. 3.3 and art. 3.4 activities of the Kyoto Protocol and to account for the net removals in order to allow the Italian Registry to issue the corresponding amount of RMUs.
Detailed information on the Registry is included in Annex 10, whereas additional information on activities under Article 3.3 and Article 3.4 of the Kyoto Protocol is reported in paragraph 1.2.2.
Moreover, in the context of the Kyoto Protocol commitments and its amendment ('Doha amendment') for the second Commitment Period (2013-2020), Italy adopted, in 2016, the Law N. 79/2016, "Ratification of the Doha amendment to the Kyoto Protocol", which establishes, according to article 12 of 525/2013/EU (the Monitoring Mechanism Regulation), the National system for policies, measures and emissions projections. ISPRA is also responsible of this system and, in cooperation with IMELS, collects all the information and data from the competent Ministries. Article 1 of the Decree implementing law N. 79 (9th December 2016), reports the list of information and data that are to be sent by the competent ministries to IMELS and ISPRA and also the timing for providing such information. With the establishment of this system, there has been a strengthening of roles and obligations for statistical data flow, some of which are useful for the inventory scope.
The Italian National System, currently in place, is fully described in the document 'National Greenhouse Gas Inventory System in Italy' (ISPRA, 2018). No changes with respect to the last year submission occurred in the National System.
A summary picture is reported herebelow.
As indicated by art. 14 bis of the Legislative Decree, the Institute for Environmental Protection and Research (ISPRA), former Agency for Environmental Protection and Technical Services (APAT), is the single entity in charge of the preparation and compilation of the national greenhouse gas emission inventory. The Ministry for the Environment, Land and Sea is responsible for the endorsement of the inventory and for the communication to the Secretariat of the Framework Convention on Climate Change and the Kyoto Protocol. The inventory is also submitted to the European Commission in the framework of the Greenhouse Gas Monitoring Mechanism.
The Institute prepares a document which describes the national system including all updated information on institutional, legal and procedural arrangements for estimating emissions and removals of greenhouse gases and for reporting and archiving inventory information. The document is updated when there is the need to describe an annual change occurred in the system. The reports are publicly available at http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.
A specific unit of the Institute is responsible for the compilation of the Italian Atmospheric Emission Inventory and the Italian Greenhouse Gas Inventory in the framework of the Convention on Climate Change and the Convention on Long Range Transboundary Air Pollution. The whole inventory is compiled by the Institute.
ISPRA is responsible for the general administration of the inventory and all aspects related to its preparation, reporting and quality management. Activities include the collection and processing of data from different data sources, the selection of appropriate emissions factors and estimation methods consistent with the IPCC Guidelines, the compilation of the inventory following the QA/QC procedures, the assessment of uncertainty, the preparation of the National Inventory Report and the reporting through the Common Reporting Format, the response to the review process, the updating and data storage.
Scientific and technical institutions and consultants may be engaged for ad hoc studies and researches aimed at improving both activity data and emission factors, at country level, for some specific activities.
Also there are different institutions responsible for statistical basic information and data publication, primary to ISPRA for carrying out estimates. These institutions are part of the National Statistical System (Sistan), which periodically provides official statistics at national level; moreover, the National Statistical System ensures the homogeneity of the methods used for official statistics through a coordination plan, involving the entire public administration at central, regional and local levels.
The National Statistical System is coordinated by the Italian National Institute of Statistics (ISTAT); other bodies, joining the National Statistical System, are the statistical offices of ministries, national agencies, regions and autonomous provinces, provinces, municipalities, research institutes, chambers of commerce, local

[1] ISMEA is a public body, providing support to public and private sector. According to DPR 31 March 2001, n. 200, ISMEA is part of the National Statistical System – SISTAN and of the National Agricultural Information System – SIAN.

governmental offices, some private agencies and private subjects who have specific characteristics determined by law.
The Italian statistical system was instituted on 6th September 1989 by the Legislative Decree n. 322/89, which established guiding principles and criteria for reforming public statistics. This decree addresses to all public statistical bodies and agencies which provide official statistics both at local, national and international level in order to assure homogeneity of the methods and comparability of the results. To this end, a national statistical plan which defines surveys, data elaborations and project studies for a three-year period was established to be drawn up and updated annually. The procedures to be followed with relation to the annual fulfilment as well as the forms to be filled in for census, data elaborations and projects, and how to deal with sensitive information were also defined.
The plan is deliberated by the Committee for addressing and coordinating statistical information (Comstat) and forwarded to the Commission for the assurance of statistical information; the Commission adopts the plan after endorsement of the Guarantor of the privacy of personal data.
Finally, the plan is approved by a Prime Ministerial Decree after consideration of the Interministerial Committee for Economic Planning (CIPE). The latest Prime Ministerial Decree approved the three-year plan for 2017-2019, updated for 2018 and 2019 (GU Serie Generale n.66, 20/03/2018); the last plan for 2020-2022 has been approved and is under the process of official publication. Statistical information and results deriving from the completion of the plan are of public domain and the system is responsible for wide circulation.
Ministries, public agencies and other bodies are obliged to provide the data and information specified in the annual statistical plan; the same obligations regard the private entities. All the data are protected by the principles of statistical disclosure control and can be distributed and communicated only at aggregate level even though microdata can circulate among the subjects of the Statistical System.
Sistan activity is supervised by the Commission for Guaranteeing Statistical Information (CGIS) which is an external and independent body. In particular, the Commission supervises: the impartiality and completeness of statistical information, the quality of methodologies, the compliance of surveys with EU and international directives. The Commission, established within the Presidency of the Council of Ministers, is composed of high-profile university professors, directors of statistical or research institutes and managers of public administrations and bodies, which do not participate at Sistan.
The main Sistan products, which are primarily necessary for the inventory compilation, are:

- National Statistical Yearbooks, Monthly Statistical Bulletins, by ISTAT (National Institute of Statistics);
- Annual Report on the Energy and Environment, by ENEA (Agency for New Technologies, Energy and the Environment);
- National Energy Balance (annual), Petrochemical Bulletin (quarterly publication), by MSE (Ministry of Economic Development);
- Transport Statistics Yearbooks, by MIT (Ministry of Transportation);
- Annual Statistics on Electrical Energy in Italy, by TERNA (National Independent System Operator);
- Annual Report on Waste, by ISPRA;
- National Forestry Inventory, by "Carabinieri Forestali"[2] .

The national emission inventory is also a Sistan product.
Other information and data sources are used to carry out emission estimates, which are generally referred to in Table 1.1 of the following section 1.4.

1.2.2 Institutional arrangement for reporting under Article 3, paragraphs 3 and 4 of Kyoto Protocol

The 'National Registry for Carbon sinks', instituted by a Ministerial Decree on 1st April 2008, is part of the Italian National System. In 2009, a technical group, formed by experts from different institutions (ISPRA, Ministry of the Environment, Land and Sea, Ministry of Agriculture, Food and Forest Policies and University of Tuscia), set up the methodological plan of the activities necessary to implement the registry and defined the relative funding. Several activities have been implemented and carried out; in particular IUTI (inventory of land use, see Annex 10) has been completed, resulting in land use classification, for all national territory.

[2] http://www.carabinieri.it/arma/oggi/organizzazione/organizzazione-per-la-tutela-forestale-ambientale-e-agroalimentare

Verification and validation activities have been undertaken and the resulting time series have been discussed with the institutions involved in the data providing; details are provided in paragraph 6.1 and in the Annex 10. Italy has elected cropland management (CM) and grazing land management (GM) as additional activities under Article 3.4 of the Kyoto Protocol. Following Decision 2/CMP.7, in the second commitment period forest management (FM) is a mandatory activity under Article 3.4. The description of the main elements of the institutional arrangement under Article 3.3 and activities elected under Article 3.4 is detailed in Annex 10. Italy selected to account for Article 3.3 and 3.4 elected activities at the end of the commitment period.

1.2.3 National Registry System

In March 2006 Italy started operating a national registry under Article 19 of Directive 2003/87/EC of the European Commission establishing the European Emission Trading Scheme (EU ETS). This registry was conceived for the administration of emissions allowances allocated to operators participating to the EU ETS and it was developed according to the UN Data Exchange Standards document. As a consequence, in October 2008, after the initialization process and a go-live phase with the UNFCCC, the registry established under Directive 2003/87/CE became part of the Kyoto system of registries, ensuring the precise tracking of holdings, issuances, transfers, cancellations and retirements of Kyoto units.

In 2012 all national registries of the EU Member States as well as the national registries of Norway, Liechtenstein and Iceland were grouped in a single central software system managed by the European Commission. The Consolidated System of European Registries, in short CSEUR, was developed together with the new EU registry on the basis the following modalities:

1. Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;
2. Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;
3. Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;
4. Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;
5. The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;
6. The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public is fulfilled by each Party through a publically available web page hosted by the Union registry;
7. All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:
    - With regards to the data exchange, each national registry connects to the ITL directly and establishes a secure communication link through a consolidated communication channel (VPN tunnel);
    - The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;
    - With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;
    - The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;
    - In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. Croatia was migrated and consolidated as of 1 March 2013. During the go-live process, all relevant transaction and holdings data were

migrated to the Union registry platform and the individual connections to and from the ITL were re-established for each Party.
A complete description of the consolidated registry has been provided in the common readiness documentation and specific readiness documentation for the national registry of the EU and all consolidating national registries. This description includes:

- Readiness questionnaire
- Application logging
- Change management procedure
- Disaster recovery
- Manual Intervention
- Operational Plan
- Roles and responsibilities
- Security Plan
- Time Validation Plan
- Version change Management

The documents above have been annexed to the National Inventory Report submission for year 2013.
A new central service desk has been set up to support the registry administrators of the consolidated system. The new service desk acts as 2nd level of support to the local support provided by the Parties. It also plays a key communication role with the ITL Service Desk with regards notably to connectivity or reconciliation issues.
With regards to the administration of the Registry, the Italian Government adopted Legislative Decree N. 47 of 9 June 2020, enforcing European Directive 2018/410/EC. According to the Decree ISPRA is responsible for the administration of the Italian part of the Union Registry and of the Kyoto National Registry; the Institute performs this task under the supervision of the National Competent Authority.
Legislative Decree 47/2020 also establishes that economic resources for the administration of the Registry are supplied to ISPRA by account holders paying a fee. The amount of such fees has been regulated by Ministerial Decree 6 December 2021.
ISPRA set up an operational unit for the administration of the National Registry. In the reporting period, eight people have been working in the unit:

- 1 chief of the unit;
- 4 employees in charge of Registry functions and operations, implementing Competent Authority's provisions, preparing documents and reports, providing support to users through a dedicated helpdesk;
- 1 employee assisting with legal and security issues;
- 1 employee for the design of BMS application facilitating the administrative tasks;
- 1 employee dedicated to paper documentation archiving and minor secretarial tasks.

A description of the Italian registry system is given in Annex 11.
Information on accounting of Kyoto Protocol units, including a summary of information reported in the standard electronic format (SEF) tables is provided in Chapter 10, while information on changes in the National Registry is reported in Chapter 12.
SEF tables including all data referring to unit holdings and transactions during the year 2021 can be found in Annex 8.

1.3 Brief description of the process of inventory preparation

ISPRA has established fruitful cooperation with a number of governmental and research institutions as well as industrial associations, which helps improving the accuracy of the estimates of some leading categories of the inventory. These activities aim at the improvement of provision and collection of basic data and emission factors, through plant-specific data, and exchange of information on scientific studies and new sources. Moreover, when in depth investigation is needed and a high uncertainty in the estimates is present, ISPRA may commit specific sector studies to ad hoc research teams or consultants.
The final aim is for ISPRA to improve the implementation of country specific methodologies and use of national emission factors and parameters.

ISPRA also coordinates with different national and regional authorities and private institutions for the cross-checking of parameters and estimates as well as with ad hoc expert panels in order to improve the completeness and transparency of the inventory.
The main basic data needed for the preparation of the GHG inventory are energy statistics published by the Ministry of Economic Development Activities (MSE) in the National Energy Balance (BEN), statistics on industrial and agricultural production published by the National Institute of Statistics (ISTAT), statistics on transportation provided by the Ministry of Transportation (MIT), and data supplied directly by the relevant professional associations.
Emission factors and methodologies used in the estimation process are consistent with the IPCC Guidelines and supported by national experiences and circumstances.
In addition to a new year, the entire time series from 1990 is checked and revised during the annual compilation of the inventory to meet the requirements of transparency, consistency, comparability, completeness and accuracy of the inventory. Measures to guarantee and improve these qualifications are undertaken and recalculations should be considered as a contribution to the overall improvement of the inventory.
In particular, recalculations are elaborated on account of changes in the methodologies used to carry out emission estimates, changes due to different allocation of emissions as compared to previous submissions and changes due to error corrections. The inventory may also be expanded by including categories not previously estimated if sufficient information on activity data and suitable emission factors have been identified and collected.
Information on the major recalculations is provided every year in the sectoral and general chapters of the national inventory reports.
In Figure 1.1 the most important steps to guarantee the continous improvement of the national GHG emission inventory are outlined.

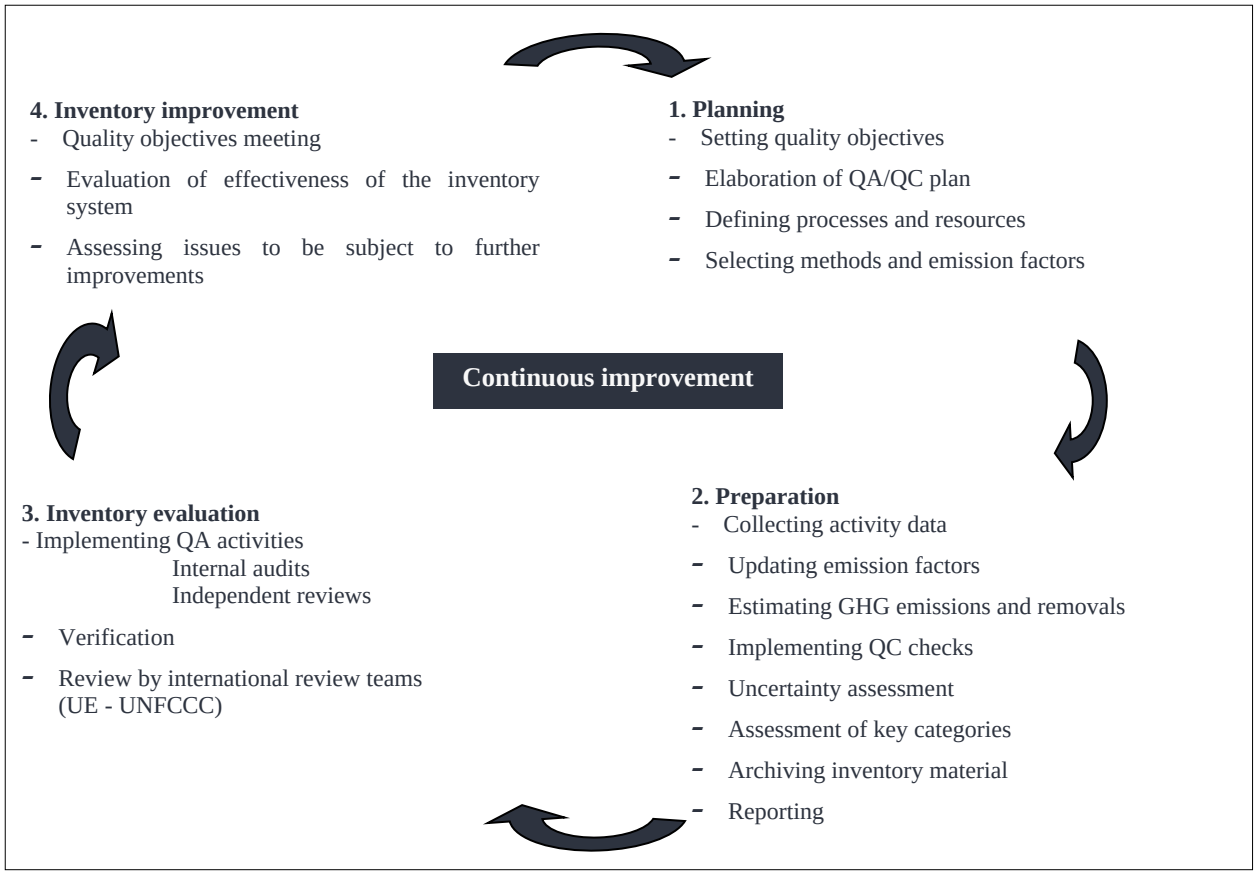


Figure 1.1 National Greenhouse Gas Inventory: annual inventory process

All the reference material, estimates and calculation sheets, as well as the documentation on scientific papers and the basic data needed for the inventory compilation, are stored and archived at the Institute. After each reporting cycle, all database files, spreadsheets and electronic documents are archived as 'read-only-files' so that the documentation and estimates could be traced back during the review process or the new inventory compilation year.

Technical reports and emission figures are publicly available on website at the address http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni.

1.4 Brief general description of methodologies and data sources used

A detailed description of methodologies and data sources used in the preparation of the emission inventory for each sector is outlined in the relevant chapters. In Table 1.1, a summary of the activity data and sources used in the inventory compilation is reported.
Methodologies are consistent with the IPCC Guidelines and EMEP/EEA Guidebooks (IPCC, 1997; IPCC, 2000; IPCC, 2003; IPCC, 2006; EMEP/CORINAIR, 2007; EMEP/EEA, 2016; EMEP/EEA, 2019); national emission factors are used as well as default emission factors from international guidebooks, when national data are not available. The development of national methodologies is supported by background documents.
In Table 1.2, a summary of the methods and emission factors used in the compilation of the Italian inventory is reported. A more detailed table, describing methods and emission factors for the key categories of the national inventory for 2019, is included in Annex 9.

Table 1.1 Main activity data and sources for the Italian Emission Inventory

SECTOR	ACTIVITY DATA	SOURCE
1 Energy		
1A1 Energy Industries	Fuel use	Energy Balance - Ministry of Economic Development Major national electricity producers European Emissions Trading Scheme
1A2 Manufacturing Industries and Construction	Fuel use	Energy Balance - Ministry of Economic Development Major National Industry Corporation European Emissions Trading Scheme
1A3 Transport	Fuel use Number of vehicles Aircraft landing and take-off cycles and maritime activities	Energy Balance - Ministry of Economic Development Statistical Yearbooks - National Statistical System Statistical Yearbooks - Ministry of Transportation Statistical Yearbooks - Italian Civil Aviation Authority (ENAC) Maritime and Airport local authorities
1A4 Residential-public-commercial sector	Fuel use	Energy Balance - Ministry of Economic Development
1B Fugitive Emissions from Fuel	Amount of fuel treated, stored, distributed	Energy Balance - Ministry of Economic Development Statistical Yearbooks - Ministry of Transportation Major National Industry Corporation
2 Industrial Processes and Product Use	Production data	National Statistical Yearbooks- National Institute of Statistics International Statistical Yearbooks-UN European Emissions Trading Scheme European Pollutant Release and Transfer Register Sectoral Industrial Associations
3 Agriculture	Agricultural surfaces Production data Number of animals Fertiliser consumption	Agriculture Statistical Yearbooks - National Institute of Statistics Sectoral Agriculture Associations
4 Land Use, Land Use Change and Forestry - LULUCF	Land classification Forest area, biomass increment and stock	IUTI (Inventory of Land Use) National Forestry Service (CFS) - National and Regional Forestry Inventory Statistical Yearbooks - National Institute of Statistics

SECTOR	ACTIVITY DATA	SOURCE
	agricultural management practices	National Information system on organic agriculture (SINAB); Annual Implementation Reports (RAE) and Annual Report on Operational Programs; EUROSTAT
	Fires	Universities and Research Institutes
5 Waste	Amount of waste	National Waste Cadastre - Institute for Environmental Protection and Research , National Waste Observatory

Table 1.2 Methods and emission factors used in the inventory preparation

SUMMARY 3 SUMMARY REPORT FOR METHODS AND EMISSION FACTORS USED

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		Unspecified mix of HFCs and PFCs		NF_3	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1. Energy	T1,T2,T3	CS,D,M	T1,T2,T3	CR,CS,D,M	T1,T2,T3	CR,D,M										
A. Fuel combustion	T1,T2,T3	CS,M	T1,T2,T3	CR,D,M	T1,T2,T3	CR,D,M										
1. Energy industries	T3	CS	T3	CR,D	T3	CR,D										
2. Manufacturing industries a	T2	CS	T2	CR,D	T2	CR,D										
3. Transport	T1,T2	CS,M	T1,T2,T3	CR,D,M	T1,T2,T3	CR,D,M										
4. Other sectors	T2	CS	T2	CR	T2	CR										
5. Other	T2	CS	T2	CR	T2	CR										
B. Fugitive emissions from fuels	T1,T2	CS,D	T1,T2	CR,CS,D	T1	D										
1. Solid fuels			T1,T2	CR,D												
2. Oil and natural gas	T1,T2	CS,D	T1,T2	CR,CS,D	T1	D										
C. CO_2 transport and storage																
2. Industrial processes	CR,CS,D,T1,T2,T3	CR,CS,D,M,PS	D,T1	CR,CS,D	CS,T3	CS,D,PS	CS,T2	CS,D,PS	CS,T2	CS,PS	CS,T2	CS,PS	CS	PS	T2	CS
A. Mineral industry	T2	CS,PS														
B. Chemical industry	D,T2,T3	CR,PS	D,T1	CR,CS,D	T3	D,PS	CS	PS	CS	PS						
C. Metal industry	T2	CR,CS,PS	D	CS,D			T2	PS								
D. Non-energy products from fuels and solvent use	CR,CS,T1,T2,T3	CR,CS,D,M,PS														
E. Electronic industry							T2	CS	T2	CS	T2	CS	CS	PS	T2	CS
F. Product uses as ODS substitutes							T2	CS,D								
G. Other product manufacture and use					CS	CS					CS,T2	CS,PS				
H. Other																
3. Agriculture	T1	D	T1,T2	CS,D	CS,T1,T2	CS,D										
A. Enteric fermentation			T1,T2	CS,D												
B. Manure management			T1,T2	CS,D	T2	CS,D										
C. Rice cultivation			T2	CS												
D. Agricultural soils[3]					CS,T1	CS,D										
E. Prescribed burning of savannas																
F. Field burning of agricultural residues			T1	CS,D	T1	CS,D										
G. Liming	T1	D														
H. Urea application	T1	D														
I. Other carbon-containing fertilizers	T1	D														
J. Other																
4. Land use, land-use change and fores	T1,T2,T3	CS,D	T1,T2	CS,D	T1,T2	CS,D										
A. Forest land	T1,T2,T3	CS,D	T2	CS,D	T2	CS,D										
B. Cropland	T1,T2	CS,D	T1	D	T1	D										
C. Grassland	T1,T2,T3	CS,D	T1	CS	T1	CS										
D. Wetlands	T1	D														
E. Settlements	T1	D			T1	D										
F. Other land																
G. Harvested wood products	T2	CS														
H. Other																
5. Waste	D,T1	CS,D	D,T1,T2	CR,CS,D	D,T1	CR,CS,D										
A. Solid waste disposal			T2	CS												
B. Biological treatment of solid waste			D	CS,D	D	D										
C. Incineration and open burning of waste	D,T1	CS,D	D,T1	CR,CS,D	D,T1	CS,D										
D. Waste water treatment and discharge			T1	D	T1	CR,D										
E. Other																
6. Other *(as specified in summary 1.A)*																

Use the following notation keys to specify the method applied:
D (IPCC default) **T1a, T1b, T1c** (IPCC Tier 1a, Tier 1b and Tier 1c, respectively) **CR** (CORINAIR) **M** (model)
RA (Reference Approach) **T2** (IPCC Tier 2) **CS** (Country Specific)
T1 (IPCC Tier 1) **T3** (IPCC Tier 3) **OTH** (Other)
If using more than one method within one source category, list all the relevant methods. Explanations regarding country-specific methods, other methods or any modifications to the default IPCC methods, as well as information

Use the following notation keys to specify the emission factor used:
D (IPCC default) **CS** (Country Specific) **OTH** (Other)
CR (CORINAIR) **PS** (Plant Specific) **M** (model)

Where a mix of emission factors has been used, list all the methods in the relevant cells and give further explanations in the documentation box. Also use the documentation box to explain the use of notation OTH.

Activity data used in emission calculations and their sources are briefly described here below.
In general, for the energy sector, basic statistics for estimating emissions are fuel consumptions provided in the Energy Balance by the Ministry of Economic Development. Additional information for electricity production is supplied by the major national electricity producers and by the major national industry corporation. On the other hand, basic information for road transport, maritime and aviation, such as the number of vehicles, harbour statistics and aircraft landing and take-off cycles are published by the National Institute of Statistics and the Ministry of Transportation in the relevant statistical yearbooks. Other data are communicated by different category associations.
In the last years, a lot of information on productions, fuel consumptions, emission factors and emissions in specific energy and industrial sub sectors is obtained from data collected by operators under the European Emissions Trading Scheme (ETS).
To implement the European Directive 2003/87/EC (EU, 2003), amended by Directive 2009/29/EC (EU, 2009) establishing the EU ETS, Italy, according to Legislative Decree n. 216/2006 (Legislative Decree, 2006) and Legislative Decree n. 51/2008 (MATTM, 2008), established the national registry and the national ETS commitee. The criteria of data reporting are defined by Decision 2007/589/EC (EC, 2007), Monitoring and Reporting Guidelines for GHG emissions under ETS, and adopted at national level by Deliberation of the national ETS Committee n. 14/2010 (MATTM, 2009).
In compliance with the above-mentioned legislations, independent certifications and verifications of activity data, emission data and emission factors are required. At national level, data verification has to be carried out by verifiers accredited by the national ETS Committee according to the ministerial decree DEC/RAS/115/2006. The verification of data submissions ensures reliability, credibility, and precision/accuracy of monitoring systems for data and any information relating emissions by plant.
Data from the Italian Emissions Trading Scheme database are incorporated into the national inventory whenever the sectoral coverage is complete; in fact, ETS data not always entirely cover energy categories whereas national statistics, such as the national energy balance and the energy production and consumption statistics, provide the complete basic data needed for the Italian emission inventory. Nevertheless, ETS data are entirely used to develop country-specific emission factors and check activity data levels.
For the industrial sector, the annual production data are provided by national sources and international statistical yearbooks, such as the FAO database on food balance.
Emission data collected through the National Pollutant Release and Transfer Register are also used in the development of emission estimates or taken into account as a verification of emission estimates for some specific categories. According to the Italian Decree of 23 November 2001, data (reporting period 2002-2006) included in the Italian pollutant emissions register were validated by competent authorities within 30 June each year and communicated by ISPRA to the Ministry for the Environment, Land and Sea every year and to the European Commission every three years according to EC Decision 2000/479 (two reporting cycles: data related to 2002 and 2004 were reported respectively in 2003 and in 2006). Since 2008 the national pollutant emissions register has been replaced by the national pollutant release and transfer register (the Italian PRTR) to comply with Regulation EC n.166/2006; data are collected annually at facility level and sent, after validation, by competent authorities to European Commission within 31 March every year for data referring to the previous year. These data are used for the compilation of the inventory whenever they are complete in terms of sectoral information; in fact, industries communicate figures only if they exceed specific thresholds; furthermore, basic data such as fuel consumption are not supplied and production data are not always split by product but reported as an overall figure. In any case, the Italian PRTR is a good basis for data checks and a way to facilitate contacts with industries which, in many cases, supply, under request, additional information as necessary for carrying out sectoral emission estimates.
In addition, final emissions are checked and verified also taking into account figures reported by industries in their annual environmental reports.
Both for energy and industrial processes, emissions of large industrial point sources are registered individually; communication also takes place in the framework of the European Directive on Large Combustion Plants, based upon detailed information such as fuel consumption. Other small plants voluntarily communicate their emissions which are also considered individually. For solvents, the amount of solvent use is provided by environmental publications of sectoral industries and associations.
ISPRA directly collects data from the industrial associations under the ETS and other European directives, Large Combustion Plant and PRTR, and makes use of these data in the preparation of the national inventory ensuring the consistency of time series.

For the other sectors, i.e. for agriculture, annual production data and number of animals are provided by the National Institute of Statistics and other sectoral associations.
For land use, land use change and forestry, forest areas are derived from national forest inventories provided by the Ministry of Agriculture, Food and Forest Policies (National Forest Service); the National Forest Service is also the provider of official statistics related to the areas subject to fires.
For waste, the main activity data are provided by the Institute for Environmental Protection and Research and the Waste Observatory.
Unpublished data are used only if supported by personal communication and confidentiality of data is respected.

As for data disclosure, the inventory team is obliged to ensure confidentiality of sensitive information by legislation when data are communicated under specific directives or confidentiality is requested by data providers. In the case of data collection under the ETS, E-PRTR, large combustion plants and other directives, the database of the complete information is available only to a specific group of authorised persons which has the legal responsibility for the respect of confidentiality issues. In other cases, each expert is responsible for the data received, and confidentiality. In any case, all data are placed on a password protected access environment at ISPRA and available only to authorised experts of the inventory team.
All the material and documents used for the inventory estimation process are stored at the Institute for Environmental Protection and Research. Activity data and emission factors as well as methodologies are referenced to their data sources. A 'reference' database has also been developed and used to increase the transparency of the inventory.

1.5 Brief description of key categories

A key category analysis of the Italian inventory is carried out according to the Approach 1 and Approach 2 described in the 2006 IPCC Guidelines (IPCC, 2006).
Following the IPCC guidelines, a key category is defined as an emission category that has a significant influence on a country's GHG inventory in terms of the absolute level and trend in emissions and removals, or both. Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of the total emissions or 90% of total uncertainty.
National emissions have been disaggregated into the categories proposed in the IPCC guidelines and reflecting specific national circumstances. Both level and trend analysis have been applied to the last submitted inventory; a key category analysis has also been carried out for the base year emission levels.
For the base year, 27 sources were individuated implementing Approach 1, whereas 30 sources were carried out by Approach 2. Including the LULUCF in the analysis, 33 categories were selected by Approach 1 and 35 by Approach 2. The description of these categories is shown in Table 1.3 and Table1.4.

Table 1.3 Key categories (excluding LULUCF) by the IPCC Approach 1 and Approach 2. Base year

Key categories (excluding the LULUCF sector)		
1.A.1	Energy industries - CO_2 gaseous fuels	L
1.A.1	Energy industries - CO_2 liquid fuels	L
1.A.1	Energy industries - CO_2 solid fuels	L
1.A.2	Manufacturing industries and construction - CO_2 gaseous fuels	L
1.A.2	Manufacturing industries and construction - CO_2 liquid fuels	L
1.A.2	Manufacturing industries and construction - CO_2 solid fuels	L
1.A.2	Manufacturing industries and construction - N_2O liquid fuels	L2
1.A.3.b	Transport - CH_4 Road transportation	L2
1.A.3.b	Transport - CO_2 Road transportation	L
1.A.3.b	Transport - N_2O Road transportation	L2
1.A.3.d	Transport - CO_2 Waterborne navigation	L1
1.A.4	Other sectors - CH_4 commercial, residential, agriculture biomass	L2
1.A.4	Other sectors - CO_2 commercial, residential, agriculture gaseous fuels	L
1.A.4	Other sectors - CO_2 commercial, residential, agriculture liquid fuels	L
1.A.4	Other sectors - N_2O commercial, residential, agriculture liquid fuels	L2
1.B.2.a	Fugitive - CO_2 Oil and natural gas - Oil	L1
1.B.2.b	Fugitive - CH_4 Oil and natural gas - Natural gas	L
1.B.2.c	Fugitive - CO_2 Oil and natural gas - venting and flaring	L2
1.B.2.d	Fugitive - CO_2 Oil and natural gas - Other - flaring in refineries	L2
2.A.1	Mineral industry- CO_2 Cement production	L
2.A.2	Mineral industry- CO_2 Lime production	L1
2.A.4	Mineral industry- CO_2 Other processes uses of carbonates	L1
2.B.1	Chemical industry- CO_2 Ammonia production	L1
2.B.2	Chemical industry- N_2O Nitric acid production	L1
2.B.3	Chemical industry- N_2O Adipic acid production	L
2.B.9	Chemical industry- PFCs Fluorochemical production	L2
2.C.1	Metal industry- CO_2 Iron and steel production	L1
2.C.3	Metal industry- PFCs Aluminium production	L
2.D	Non-Energy products from Fuels and Solvent Use - CO_2	L2
3.A.1	Enteric Fermentation- CH_4	L
3.A.2	Manure Management - CH_4	L
3.A.2	Manure Management - N_2O	L
3.C.4	Direct N_2O Emissions from Managed soils	L
3.C.5	Indirect N_2O Emissions from Managed soils	L
5.A	Solid waste disposal - CH_4	L
5.D	Wastewater treatment and discharge - CH_4	L
5.D	Wastewater treatment and discharge - N_2O	L2

L1 = level key category by Approach 1
T1 = trend key category by Approach 1
L2 = level key category by Approach 2
T2 = trend key category by Approach 2
L = level key category by Approach 1 and Approach 2
T = trend key category by Approach 1 and Approach 2

Table 1.4 Key categories (including LULUCF) by the IPCC Approach 1 and Approach 2. Base year

	Key categories (excluding the LULUCF sector)	
1.A.1	Energy industries - CO2 gaseous fuels	L
1.A.1	Energy industries - CO2 liquid fuels	L
1.A.1	Energy industries - CO2 solid fuels	L
1.A.2	Manufacturing industries and construction - CO2 gaseous fuels	L
1.A.2	Manufacturing industries and construction - CO2 liquid fuels	L
1.A.2	Manufacturing industries and construction - CO2 solid fuels	L
1.A.2	Manufacturing industries and construction - N2O liquid fuels	L2
1.A.3.b	Transport - CH4 Road transportation	L2
1.A.3.b	Transport - CO2 Road transportation	L
1.A.3.d	Transport - CO2 Waterborne navigation	L1
1.A.4	Other sectors - CH4 commercial, residential, agriculture biomass	L2
1.A.4	Other sectors - CO2 commercial, residential, agriculture gaseous fuels	L
1.A.4	Other sectors - CO2 commercial, residential, agriculture liquid fuels	L
1.A.4	Other sectors - N2O commercial, residential, agriculture liquid fuels	L2
1.B.2.a	Fugitive - CO2 Oil and natural gas - Oil	L1
1.B.2.b	Fugitive - CH4 Oil and natural gas - Natural gas	L
1.B.2.c	Fugitive - CO2 Oil and natural gas - venting and flaring	L2
2.A.1	Mineral industry- CO2 Cement production	L
2.A.2	Mineral industry- CO2 Lime production	L1
2.A.4	Mineral industry- CO2 Other processes uses of carbonates	L1
2.B.1	Chemical industry- CO2 Ammonia production	L1
2.B.2	Chemical industry- N2O Nitric acid production	L1
2.B.3	Chemical industry- N2O Adipic acid production	L
2.B.9	Chemical industry- PFCs Fluorochemical production	L2
2.C.1	Metal industry- CO2 Iron and steel production	L1
2.C.3	Metal industry- PFCs Aluminium production	L
2.D	Non-Energy products from Fuels and Solvent Use - CO2	L
3.A.1	Enteric Fermentation- CH4	L
3.A.2	Manure Management - CH4	L
3.A.2	Manure Management - N2O	L
3.C.4	Direct N2O Emissions from Managed soils	L
3.C.5	Indirect N2O Emissions from Managed soils	L
3.C.7	Rice cultivations - CH4	L1
4.A.1	Forest Land remaining Forest Land - CO2	L
4.A.2	Land Converted to Forest Land - CO2	L
4.B.1	Cropland remaining cropland – CO2	L2
4.B.2	Land Converted to Cropland - CO2	L2
4.C.1	Grassland Remaining Grassland - CO2	L
4.E.2	Land Converted to Settlements - CO2	L
4.E.2	Land Converted to Settlements - N2O	L2
5.A	Solid waste disposal - CH4	L
5.D	Wastewater treatment and discharge - CH4	L
5.D	Wastewater treatment and discharge - N2O	L2

L1 = level key category by Approach 1
T1 = trend key category by Approach 1
L2 = level key category by Approach 2
T2 = trend key category by Approach 2
L = level key category by Approach 1 and Approach 2
T = trend key category by Approach 1 and Approach 2

Applying the analysis to the 2020 inventory, without the LULUCF sector, 43 key categories were totally individuated, both at level and trend. Results are reported in Table 1.5.

Table 1.5 Key categories (excluding LULUCF) by the IPCC Approach 1 and Approach 2. Year 2020

	Key categories (excluding the LULUCF sector)	
1.A.1	Energy industries - CO2 gaseous fuels	L, T
1.A.1	Energy industries - CO2 liquid fuels	L, T
1.A.1	Energy industries - CO2 solid fuels	L, T
1.A.2	Manufacturing industries and construction - CO2 gaseous fuels	L, T
1.A.2	Manufacturing industries and construction - CO2 liquid fuels	L, T
1.A.2	Manufacturing industries and construction - CO2 solid fuels	L1, T
1.A.3.a	Transport - CO2 Civil Aviation	L1, T1
1.A.3.b	Transport - CH4 Road transportation	T2
1.A.3.b	Transport - CO2 Road transportation	L, T
1.A.3.d	Transport - CO2 Waterborne navigation	L1
1.A.4	Other sectors - CH4 commercial, residential, agriculture biomass	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture gaseous fuels	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture liquid fuels	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture other fossil fuels	L1, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture solid fuels	T1
1.A.4	Other sectors - N2O commercial, residential, agriculture biomass	L2, T
1.A.4	Other sectors - N2O commercial, residential, agriculture liquid fuels	L2
1.B.2.a	Fugitive - CO2 Oil and natural gas - Oil	L1
1.B.2.b	Fugitive - CH4 Oil and natural gas - Natural gas	L, T
1.B.2.d	Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	L2, T2
1.B.2.d	Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	T2
2.A.1	Mineral industry- CO2 Cement production	L, T
2.A.2	Mineral industry- CO2 Lime production	L1
2.A.4	Mineral industry- CO2 Other processes uses of carbonates	T1
2.B.1	Chemical industry- CO2 Ammonia production	T1
2.B.2	Chemical industry- N2O Nitric acid production	T
2.B.3	Chemical industry- N2O Adipic acid production	T
2.B.9	Chemical industry- HFCs Fluorochemical production	T2
2.C.1	Metal industry- CO2 Iron and steel production	T1
2.C.3	Metal industry- PFCs Aluminium production	T
2.D	Non-Energy products from Fuels and Solvent Use - CO2	L2
2.F.1	Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	L, T
2.F.2	Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	T2
2.F.3	Product uses as substitutes for ozone depleting substances - HFCs Fire protection	L, T
3.A.1	Enteric Fermentation- CH4	L, T
3.A.2	Manure Management - CH4	L
3.A.2	Manure Management - N2O	L
3.C.4	Direct N2O Emissions from Managed soils	L, T
3.C.5	Indirect N2O Emissions from Managed soils	L, T2
3.C.7	Rice cultivations - CH4	L1
5.A	Solid waste disposal - CH4	L, T
5.B	Biological treatment of Solid waste - N2O	L2, T2
5.D	Wastewater treatment and discharge - CH4	L
5.D	Wastewater treatment and discharge - N2O	L, T2

L1 = level key category, Approach 1
T1 = trend key category, Approach 1
L2 = level key category, Approach 2
T2 = trend key category, Approach 2
L = level key category, Approach 1 and Approach 2
T = trend key category, Approach 1 and Approach 2

If considering emissions and removals from the LULUCF sector, 45 key categories were individuated as reported in Table 1.6.

Table 1.6 Key categories (including LULUCF) by the IPCC Approach 1 and Approach 2. Year 2020

Key categories (including the LULUCF sector)		
1.A.1	Energy industries - CO2 gaseous fuels	L, T
1.A.1	Energy industries - CO2 liquid fuels	L, T
1.A.1	Energy industries - CO2 solid fuels	L, T
1.A.2	Manufacturing industries and construction - CO2 gaseous fuels	L, T
1.A.2	Manufacturing industries and construction - CO2 liquid fuels	L1, T
1.A.2	Manufacturing industries and construction - CO2 solid fuels	L1, T
1.A.3.b	Transport - CO2 Road transportation	L, T
1.A.3.d	Transport - CO2 Waterborne navigation	L1, T1
1.A.4	Other sectors - CH4 commercial, residential, agriculture biomass	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture gaseous fuels	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture liquid fuels	L, T
1.A.4	Other sectors - CO2 commercial, residential, agriculture other fossil fuels	L1, T
1.A.4	Other sectors - N2O commercial, residential, agriculture biomass	L2, T
1.B.2.a	Fugitive - CO2 Oil and natural gas - Oil	L1
1.B.2.b	Fugitive - CH4 Oil and natural gas - Natural gas	L, T
1.B.2.d	Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	L2, T2
2.A.1	Mineral industry- CO2 Cement production	L, T
2.A.2	Mineral industry- CO2 Lime production	L1
2.A.4	Mineral industry- CO2 Other processes uses of carbonates	T1
2.B.2	Chemical industry- N2O Nitric acid production	T1
2.B.3	Chemical industry- N2O Adipic acid production	T
2.B.9	Chemical industry- PFCs Fluorochemical production	L2
2.C.1	Metal industry- CO2 Iron and steel production	T1
2.C.3	Metal industry- PFCs Aluminium production	T
2.D	Non-Energy products from Fuels and Solvent Use - CO2	L2
2.F.1	Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	L, T
2.F.2	Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	T2
2.F.3	Product uses as substitutes for ozone depleting substances - HFCs Fire protection	L, T
3.A.1	Enteric Fermentation- CH4	L, T
3.A.2	Manure Management - CH4	L, T1
3.A.2	Manure Management - N2O	L
3.C.4	Direct N2O Emissions from Managed soils	L, T
3.C.5	Indirect N2O Emissions from Managed soils	L, T
3.C.7	Rice cultivations - CH4	L1
4.A.1	Forest Land remaining Forest Land - CO2	L, T
4.A.2	Land Converted to Forest Land - CO2	L, T
4.B.1	Cropland Remaining Cropland - CO2	T
4.B.2	Land converted to cropland – CO2	T2
4.C.1	Grassland Remaining Grassland - CO2	L, T
4.C.2	Land Converted to Grassland - CO2	L, T
4.E.2	Land Converted to Settlements - CO2	L, T
5.A	Solid waste disposal - CH4	L, T
5.B	Biological treatment of Solid waste - N2O	L2, T2
5.D	Wastewater treatment and discharge - CH4	L, T2
5.D	Wastewater treatment and discharge - N2O	L, T2

L1 = level key category, Approach 1
T1 = trend key category, Approach 1
L2 = level key category, Approach 2
T2 = trend key category, Approach 2
L = level key category, Approach 1 and Approach 2
T = trend key category, Approach 1 and Approach 2

Key category analysis for KP-LULUCF was performed according to section 2.3.6 of the 2014 IPCC KP Supplement (IPCC, 2014). Results are also reported in Table 9.18 of chapter 9.

CO_2 emissions and removals from *afforestation/reforestation* and *deforestation* activities (art. 3.3) and from *forest management* (art. 3.4) have been assessed as key categories. CO_2 emissions and removals from *cropland* and *grazing land management* are identified as key categories.
The analysis of key categories is used to prioritize improvements that should be taken into account for the next inventory submissions. First of all, it is important that emissions of key categories, being the most significant in terms of absolute weight and/or combined uncertainty, are estimated with a high level of accuracy. For the Italian inventory, higher tiers are mostly used for calculating emissions from these categories as requested by the IPCC Guidelines and the use of country specific emission factors is extensive. As reported in Table A9.1, in the Annex, there are only a few key categories which estimates do not meet these quality objectives, in terms of the methodology and the application of default emission factors.
Among these categories, prioritization is made on account of the actual absolute weight, the expected future relevance, the level of uncertainty and a cost-effectiveness analysis. Therefore, improvements are planned for the LULUCF sector as well as for maritime navigation category, which emissions are estimated with a Tier1 and with Tier 2 for few years, and has been selected as a priority after verification of the availability of annual detailed activity data, the evaluation of the resources and cost of the database to be implemented.
In addition to this evaluation, also categories estimated with higher tiers but affected by a high level of uncertainty are considered in the prioritization plan. For instance, activities were planned and are on going for HFC, PFC substitutes for ODS in order to improve the accuracy of the Italian inventory and reduce the overall uncertainty.

1.6 Information on the QA/QC plan including verification and treatment of confidentiality issues where relevant

ISPRA has elaborated an inventory QA/QC plan which describes specific QC procedures to be implemented during the inventory development process, facilitates the overall QA procedures to be conducted, to the extent possible, on the entire inventory and establishes quality objectives.
Particularly, an inventory QA/QC procedures manual (ISPRA, 2013) has been drawn up which describes QA/QC procedures and verification activities to be followed during the inventory compilation and helps in the inventory improvement. Furthermore, specific QA/QC procedures and different verification activities implemented thoroughly the current inventory compilation, as part of the estimation process, are figured out in the annual QA/QC plan (ISPRA, 2022 [b]). These documents are publicly available at ISPRA website http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.
Quality control checks and quality assurance procedures together with some verification activities are applied both to the national inventory as a whole and at sectoral level. Future planned improvements are prepared for each sector by the relevant inventory compiler; each expert identifies areas for sectoral improvement based on his own knowledge and in response to the UNFCCC inventory reviews and taking into account the result of the key category assessment.
The quality of the inventory has improved over the years and further investigations are planned for all those sectors relevant in terms of contribution to total CO_2 equivalent emissions and with a high uncertainty.
In addition to *routine* general checks, source specific quality control procedures are applied on a case-by-case basis focusing on key categories and on categories where significant methodological and data revision have taken place or on new sources.
Checklists are compiled annually by the inventory experts and collected by the QA/QC coordinator. These lists are also registred in the 'reference' database.
General QC procedures also include data and documentation gathering. Specifically, the inventory analyst for a source category maintains a complete and separate project archive for that source category; the archive includes all the materials needed to develop the inventory for that year and is kept in a transparent manner.
All the information used for the inventory compilation is traceable back to its source. The inventory is composed by spreadsheets to calculate emission estimates; activity data and emission factors as well as methodologies are referenced to their data sources. Particular attention is paid to the archiving and storing of all inventory data, supporting information, inventory records as well as all the reference documents. To this end, a major improvement which increases the transparency of the inventory has been the development of a 'reference' database. After each reporting cycle, all database files, spreadsheets and official submissions are archived as 'read-only' mode in a master computer.
Quality assurance procedures regard some verification activities of the inventory as a whole and at sectoral level. Feedbacks for the Italian inventory derive from communication of data to different institutions and/or at

local level. For instance, the communication of the inventory to the European Community results in a pre-check of the GHG values before the submission to the UNFCCC and relevant inconsistencies may be highlighted.
Every year, emission figures are also subjected to a process of re-examination once the inventory, the inventory related publications and the national inventory reports are posted on website, specifically www.isprambiente.gov.it, and from the communication of data to different institutions and/or at local level.
In some cases, sectoral major recalculations are presented and shared with the relevant stakeholders prior to the official submission.
For the energy and industrial sectors, different meetings have been held in the last years jointly with the industrial associations, the Ministries of the Environment and Economic Development and ISPRA in the framework of the European Emissions Trading Scheme (EU-ETS), for assessing carbon leakage in EU energy intensive industries and the definition of GHG emission benchmarks; also in this context, estimations of the emission inventory for different sectors have been presented.
ISPRA has also held different meetings with the industrial associations in the context of different European legislation. ISPRA collects data from the industrial associations and industrial facilities under the EU- ETS and other European legislation such as Large Combustion Plant Directive and E-PRTR Regulation. The inventory team manages all these data and makes use of them in the preparation of the national inventory ensuring the consistency of time series among data by the comparison of the information collected under the directives with other sources available before the first available years of data collected (2000 and 2002, reporting years for data collected under ETS and INES/PRTR facilities, respectively). Emissions and activity data submitted under the ETS are mandatorily subject to verification procedures, as requested and specified by the European Directive 2003/87/EC (art. 15 and Annex V). Also, the quality of the Italian PRTR data is guaranteed by art.9 of the Regulation 2006/166/EC and by art.3 (3) of the Presidential Decree n.157/2011.
In addition, ISPRA manages all this information in an informative system to help in highlighting the main discrepancies among data, and improving the time series consistency. The informative system is based on identification codes to trace back individual point sources in different databases.
Other specific activities relating to improvements of the inventory and QA/QC practises in the last year regarded the progress on the building of a unique database where information collected in the framework of different European legislation, Large Combustion Plant, INES/PRTR and Emissions Trading, are gathered together thus highlighting the main discrepancies in information and detecting potential errors. The actual figures are considered in an overall approach and used in the compilation of the inventory. In this regard main progress is the update of the administrative information to identify the facilities under the separate databases. A spreadsheet including the list of facilities from Large Combustion Plant, PRTR, ETS is updated every year: a comprehensive list of the facilities reporting to the three systems with the identification codes in use in the source datasets is used to check for un-matching facilities so as to detect possible mistakes in the administrative information or facilities which did not report to one or more registers. Moreover, the so called “EU Business Registry” has been launched under the Industrial Emission Directive at European Union level; this new registry will include the administrative data for all the facilities in the scope of the Industrial Emission Directive as far as permitting procedures, site visit and site inspections, thematic data reporting are concerned. The first step should have had administrative data reported to European Union in order to be included in the new European registry by the end of 2019 but delays are due to the upcoming emergencies; in the following years thematic data (emissions, releases, waste quantities, activity data; number of site visits, infringements etc.) will be also reported in compliance with the reporting decisions that will be adopted by the EU Commission.
ISPRA is also responsible for the provincial inventory at local scale; at now the provincial inventories at local scale for the years 1990, 1995, 2015 and 2019 are available. In fact, every 5 years, and now every 4 years, in the framework of the Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) under the Convention on Long-range Transboundary Air Pollution (CLTRAP), Parties have to report their national air emissions disaggregated on a 0.1°*0.1° grid. Specifically, ISPRA has applied a top-down approach to estimate emissions at provincial areas based on proxy variables. The results were checked out by regional and local environmental agencies and authorities; data are available at ISPRA web address http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/. Reports which describe detailed methodologies to carry out estimates are available (Liburdi et al., 2004; ISPRA, 2009). Comparisons between top-down and local inventories have been carried out during the last year and will continue in the next years; results are shared among the ‘local inventories’ expert group leading to an improvement in methodologies for both the inventories. ISPRA has also collaborated with local authorities to assess the participation of the Italian municipalities to the Covenant of

Mayors (http://www.isprambiente.gov.it/it/pubblicazioni/rapporti/stato-di-attuazione-del-patto-dei-sindaci-in-italia).
A specific procedure undertaken for improving the inventory regards the establishment of national expert panels (in particular, in road transport, LULUCF and energy sectors) which involve, on a voluntary basis, different institutions, local agencies and industrial associations cooperating for improving activity data and emission factors accuracy. Specifically, for the LULUCF sector, following the election of the 3.3 and 3.4 activities and on account of an in-depth analysis on the information needed to report LULUCF under the Kyoto Protocol, a Scientific Committee, *Comitato di Consultazione Scientifica del Registro dei Serbatoi di Carbonio Forestali,* constituted by the relevant national experts has been established by the Ministry for the Environment, Land and Sea in cooperation with the Ministry of Agriculture, Food and Forest Policies.
In addition to these expert panels, ISPRA participates in technical working groups within the National Statistical System. These groups, named *Circoli di qualità*, coordinated by the National Institute of Statistics, are constituted by both producers and users of statistical information with the aim of improving and monitoring statistical information in specific sectors such as transport, industry, agriculture, forest and fishing. As reported in previous sections, these activities improve the quality and details of basic data, as well as enable a more organized and timely communication.
The quality of the inventory has also improved by the organization and participation in sector specific workshops. Follow-up processes are also set up in the framework of the WGI and WG5 under the EC Monitoring Mechanism, which addresses to the improvement of different inventory sectors. In the last years, different workshops were held: on the management of uncertainty and how to proper use data from the European emissions trading scheme in the national greenhouse gas inventories; methodologies to estimate emissions from the agriculture and LULUCF sectors were also addressed, involving the Joint Research Centre, and from the waste sector, involving the European Topic Center on Resource and Waste Management, as well as from international bunkers, involving the International Energy Agency and EUROCONTROL. Presentations and documentation of the workshops are available on the website at the address: http://air-climate.eionet.europa.eu/meetings/past_html.
Especially in the last years, there has been an intensification of activities related to emission scenarios, and the importance of the emission inventory as a solid starting point is primary. The inventory is shared with the Ministry for the Environment, Land and Sea, and all the relevant Ministries and local authorities.
In this context, from 2011, a report concerning the state of implementation of commitments to reduce greenhouse gases emissions, and describing emission trend and projections, is prepared by the Ministry of the Environment in consultation with other relevant Ministries. The report is annexed to the economy and financial document (DEF) to be annually approved by the Government.
Expert peer reviews of the national inventory occur annually within the UNFCCC process, whose results and suggestions can provide valuable feedback on areas where the inventory should be improved. The last in country review occurred in 2021. The final report will be available at the relevant UNFCCC web site address FCCC/ARR/2021/ITA and details on the review processes and implementation of the comments and potential recommendations are described in Annex 12 and in relevant sections.
At European level, reviews of the European inventory are undertaken by experts from different Member States for critical sectoral categories in the context of the European GHG Monitoring Mechanism. Moreover, in the context of the European Effort Sharing Decision (EC, 2009) defining the 2020 emission limit of a Member State in relation to its 2005 emissions, a technical review was carried out in 2012 to review and verify emission data of each Member State, for the reference years 2005, 2008 and 2009, prior to determining their annual emission allocations. In 2016 another comprehensive review of Member States' inventories was carried out for the compliance years 2013 and 2014, and for the years 2005, 2008, 2009 and 2010. Also, in 2021, a detailed review of the Italian inventory was conducted. Following the main relevant recommendations, revisions of the estimates were implemented.
A bilateral independent review between Italy and Spain was undertaken in 2012, with a focus on the revision of the GHG inventories of both the Parties. Two in-country visits were held in 2012; the Italian team revised part of the energy sector of Spain, specifically the categories public power plants, petroleum refining plants, road transport and off-road, whereas the Spanish team revised the Industrial processes and solvent and other product use, and the LULUCF sectors of Italy. Results of these analyses are reported in a technical report. Aim of the review was to carry out a general quality assurance analysis of the inventories in terms of the methodologies, the EFs and the references used, as well as analysing critical cross cutting issues such as the details of the national energy balances and comparison with international data (Eurostat and IEA), and use of plant specific information.

In addition, an official independent review of the entire Italian greenhouse gas inventory was undertaken by the Aether consultants in 2013. Main findings and recommendations are reported in a final document, and regard mostly the transparency in the NIR, the improvement of QA/QC documentation and some pending issues in the LULUCF sector. These suggestions have been considered to improve the future submissions.
The preparation of environmental reports where data are needed at different aggregation levels or refer to different contexts, such as environmental and economic accountings, is also a check for emission trends. At national level, for instance, emission time series are reported in the Environmental Data Yearbooks published by ISPRA. Emission data are also published by the Ministry for the Environment, Land and Sea in the Reports on the State of the Environment and the National Communications as well as in the Demonstrable Progress Report. Moreover, figures are communicated to the National Institute of Statistics to be published in the relevant Environmental Statistics Yearbooks as well as used in the framework of the EUROSTAT NAMEA Project.
At European level, ISPRA also reports on indicators meeting the requirements of Article 3 (1)(j) of Decision N° 280/2004/EC. In particular, Member States shall submit figures on specified priority indicators and should submit information on additional priority and supplementary indicators for the period from 1990 to the last submitted year and forecasts for some specified years. National trends of these indicators are reported in the document 'Carbon Dioxide Intensity Indicators' (ISPRA, 2022 [c]).
Comparisons between emission estimates from industrial sectors and those published by the industry itself in their Environmental reports are carried out annually in order to assess the quality and the uncertainty of the estimates.
Additional consistency checks of data are carried out in the context of the European Regulation No 525/2013. EU Member States shall report in textual and tabular format on data inconsistencies.
For example, according to Art. 7(1)(m)(i) of the EU Regulation, data on air pollutants estimated under the UNECE Convention on Long-range Transboundary Air Pollution and those under the UNFCCC Convention should not exceed the difference of more than +/–5 % between the total emissions for a specific pollutant otherwise text and a tabular format should be compiled by the Member State. As shown in chapter 2, para 2.4, these differences for Italy are far under the threshold.
Other relevant articles of the EU Regulation for data consistency are Article 10, on emissions reported under the European ETS, Article 11 and Article 12 related to F-gases international energy data.
Specifically, Article 10 regards the consistency of reported GHG emissions under UNFCCC with data from the EU emissions trading system in tabular and textual form by category; the detailed table is included in Annex 13 of the NIR.
As for Article 11, on consistency of F-gas estimates with data reported under Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases, the verification process is still on progress due to the large amount of data and the difficulty to analyze the amount of F-gases actually used by the national operators. However, activities are already carried out on verification of average emission factors and activity data reported at sectoral level.
Article 12 of the EU Implementing Regulation obliges Memeber States to report textual information on the comparison between the reference approach calculated on the basis of the data included in the GHG inventory and the reference approach calculated on the basis of the data reported pursuant to Article 4 of Regulation (EC) No 1099/2008 of the European Parliament and of the Council (1) and Annex B to that Regulation (Eurostat energy data). If these differences are higher than +/– 2 %, in the total national apparent fossil fuel consumption at aggregate level for all fossil fuel categories, a tabular format shall also be compiled. For Italy these differences are below the determined threshold; also, these data are reported in Annex 13 for the year 2019.
A summary of all the main QA/QC activities over the past years which ensure the continuous improvement of the inventory is presented in the document 'Quality Assurance/Quality Control plan for the Italian Emission Inventory. Year 2021' (ISPRA, 2022 [b]).
A proper archiving and reporting of the documentation related to the inventory compilation process is also part of the national QA/QC programme.
All the material and documents used for the inventory preparation are stored at ISPRA.
Information relating to the planning, preparation, and management of inventory activities are documented and archived. The archive is organised so that any skilled analyst could obtain relevant data sources and spreadsheets, reproduce the inventory and review all decisions about assumptions and methodologies undertaken. A master documentation catalogue is generated for each inventory year and it is possible to track changes in data and methodologies over time. Specifically, the documentation includes:

- electronic copies of each of the draft and final inventory report, electronic copies of the draft and final CRF tables;

- electronic copies of all the final, linked source category spreadsheets for the inventory estimates (including all spreadsheets that feed the emission spreadsheets);
- results of the reviews and, in general, all documentation related to the corresponding inventory year submission.

After each reporting cycle, all database files, spreadsheets and electronic documents are archived as 'read-only' mode.
A 'reference' database is also compiled every year to increase the transparency of the inventory. This database consists of a number of records that references all documentation used during the inventory compilation, for each sector and submission year, the link to the electronically available documents and the place where they are stored as well as internal documentation on QA/QC procedures.

1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

The 2006 IPCC Guidelines (IPCC, 2006) define two approaches to estimating uncertainties in national greenhouse gas inventories: Approach 1, based on the error propagation equations, and Approach 2, corresponding to the application of Monte Carlo analysis.
For the Italian inventory, quantitative estimates of the uncertainties are calculated using Approach 1 which application is described in Annex 1, with or without emissions and removals from the LULUCF sector. Emission categories are disaggregated into a detailed level and uncertainties are therefore estimated for these categories.
For the 2020 total emission figures without LULUCF, an uncertainty of 3.1% in the combined global warming potential (GWP) total emissions is estimated, whereas for the trend between the base year and 2020 the analysis assesses an uncertainty by 2.2%.
Including the LULUCF sector into national figures, the uncertainty according to Approach 1 is equal to 4.5% for the year 2020, whereas the uncertainty for the trend is estimated to be 3.0%.
The small variation in the uncertainty levels, as compared the previous submission, is mainly due to the recalculation process and consequent different weights of the categories and relevant uncertainties.
The assessment of uncertainty has also been applied to the base year emission levels. The results show an uncertainty of 2.1% in the combined GWP total emissions, excluding emissions and removals from LULUCF, whereas it increases to 2.7% including the LULUCF sector.
Approach 2, Montecarlo analysis, was implemented in previous submissions to estimate uncertainty of some of the key categories of the Italian inventory. The description of the key categories to which the analysis was applied and the reference years are reported in Annex 1, Table A1.15. Most of the results prove that both approaches (Approach 1 and 2) produce comparable results and that uncertainty values derived by Approach 2 are lower than those derived from the application of Approach 1.
The aim of the study was to show that applying methods higher than the error propagation method does not make a significant difference in figures if information on uncertainty levels is not sufficiently detailed. Montecarlo was applied to CO_2 emissions from road transport and N_2O emissions from agricultural soils; in the first case measurements were available for emission factors so a low uncertainty was expected, in the other case, no information on EFs was available and a high uncertainty was supposed. A combination of Montecarlo and Bootstrap simulation was applied to CO_2 emissions, in consideration of the specific data availability assuming a normal distribution for activity data and for the emission factor of natural gas. The overall uncertainty of CO_2 emissions for road transport resulted in 2.1%, lower than that resulting from Approach 1 which estimated a figure of 4.2%; the reason of the difference is in the lower uncertainty resulting from the application of bootstrap analysis to the emission factor of diesel oil, all the other figures are very similar. For N_2O emissions from agricultural soils, a Montecarlo analysis was applied assuming a normal distribution for activity data and two tests one with a lognormal and the other with a normal for emission factors; the results with the normal distribution calculated an uncertainty figure equal to 32.4%, lower than the uncertainty by Approach 1 which was 102%; in the case of the lognormal distribution there were problems caused by the formula specified in the IPCC guidelines which is affected by the unit and needs further study before a throughout application.
The study will be progressively extended to other inventory categories but the importance of these results is that in neither of the cases does the uncertainty estimation of the national sectors result in an underestimation.
Other studies were conducted on uncertainty. Specifically, on the comparison of different methodologies to evaluate emissions uncertainty (Romano et al., 2004) and a study 'Evaluating uncertainty in the Italian GHG

inventory', presented at a EU workshop on Uncertainties in Greenhouse Gas Inventories, held in Finland in 2005.
QC procedures are also undertaken on the calculations of uncertainties in order to confirm the correctness of the estimates and that there is sufficient documentation to duplicate the analysis. The assumptions which uncertainty estimations are based on are documented for each category. Figures used to draw up uncertainty analysis are checked both with the relevant analyst experts and literature references and are consistent with the IPCC Guidelines (IPCC, 2000; IPCC, 2003; IPCC, 2006).
More in details, facility level data are used to check and verify information from the industrial sector; these data also include information from the European Emissions Trading Scheme, the Italian PRTR register which is also collected and elaborated by the inventory team. Most of the times there is a correspondence among activity data from different databases so that the level of uncertainty could be assumed lower than the one fixed at 3%; the same occurs for emission factors coming from measurements at plant level, and even in this case the uncertainty may be assumed lower than the predetermined level. Since the overall uncertainty of the Italian inventory is relatively low due to the prevalence of the energy sector sources, whose estimates derive from accurate parameters, out of the total, it has been decided to use conservative figures; this occurs especially for energy and industrial sectors. Details can be found at category level in the relevant sections.
The results of the uncertainty analysis, generally associated with a key category assessment by Approach 2, are used to prioritize improvements for the next inventory submissions.
Emissions of key categories are usually estimated with a high level of accuracy in terms of the methodology used and characterised by a low uncertainty; some exceptions may occur and categories estimated with higher tiers may be affected by a high level of uncertainty. For instance, in the agriculture sector, direct N_2O emissions from agricultural soils and indirect N_2O from nitrogen used in agriculture are affected by a high level of uncertainty especially in the emission factors notwithstanding the advanced tiers used.
For the categories with a high uncertainty, further improvements are planned whenever sectoral studies can be carried out.

1.8 General assessment of the completeness

The inventory covers all major sources and sinks, as well as direct and indirect gases, included in the IPCC guidelines.
Details are reported in Table 1.7 and Table 1.8. Sectoral and background tables of CRF sheets are complete as far as details of basic information are available. For instance, multilateral operations emissions are not estimated because no activity data are available.
Allocation of emissions is not consistent with the IPCC Guidelines only where there is no data available to split the information. For instance, for fugitive emissions, N_2O fugitive emissions from oil refining and storage activities are reported under category 1.B.2.d other, flaring in refineries. Further investigation will be arried out closely with industry about these figures.

Table 1.7 Source and sinks not estimated in the 2020 inventory

Sources and sinks not estimated (NE)[1]			
GHG	**Sector[2]**	**Source/sink category [2]**	**Explanation**
CH_4	Energy	1.A.1c Manufacture of solid fuel (biomass)	CH_4 emissions from charcoal production are not accounted for because of a lack of methodology in the 2006 IPCC Guidelines applicable to the type of furnace technology in use
N_2O	Energy	1.B Fugitive Emissions from Fuels/ 1.B.2 Oil and Natural Gas and Other Emissions from Energy Production/ 1.B.2.d Other /Geotherm	N_2O emissions are negligible
CO_2, CH_4, N_2O	Energy	1.D.2 Multilateral Operations	Information and statistical data are not available
CH_4	Agriculture	3.D Agricultural Soils	CH_4 emissions from managed soils have not been estimated because no methodology is available in the IPCC Guidelines.
CO_2, CH_4, N_2O	LULUCF	4.E Settlements/4(V) Biomass Burning 4.E Settlements	Emissions are considered insignificant, below 0.05% of the national total GHG emissions, and minor than 500 kt CO_2 eq.
CH_4, N_2O	Waste	5.C Incineration and Open Burning of Waste/ 5.C.2 Open Burning of Waste 5.C.2.1 Biogenic/ 5.C.2.1.a Municipal Solid Waste 5.C.2.2 Non-biogenic/ 5.C.2.2.a Municipal Solid Waste	Emission factors are under investigation

Table 1.8 Source and sinks reported elsewhere in the 2020 inventory

Sources and sinks reported elsewhere ("IE")[3]				
GHG	**Source/sink category**	**Allocation as per IPCC Guidelines**	**Allocation used by the Party**	**Explanation**
CO_2	1.AD Feedstocks, reductants and other non-energy use of fuels/Liquid Fuels/Gasoline	1.AD Liquid fuel/Gasoline/LPG/ Other Oil/Refinery feedstock/Residual oil	1.AD Liquid fuel/Naphta	National energy balances include only the input and output quantities from the petrochemical plants; so in the petrochemical transformation process the output quantity could be greater than the input quantity, in particular for light products as LPG, gasoline and refinery gas, due to chemical reactions. Therefore, it is possible to have negative values for some products (mainly gasoline, refinery gas, fuel oil). For this matter, for the reporting on CRF tables, these fuels have been added to naphtha.
N2O	1.B Fugitive Emissions from Fuels/ 1.B.2 Oil and Natural Gas and Other Emissions from Energy Production/ 1.B.2.a Oil/ 1.B.2.a.4 Refining / Storage	1.B.2.a.4 Refining/storage	1.B.2.d flaring in refineries	No information is available to split the emissions
CO_2	2.C Metal Industry/ 2.C.5 Lead Production	2.C.5. Lead Production	2.C.6 Zinc production	CO_2 emissions from the sole zinc and lead integrated plant in Italy have been estimated. The available data do not allow to distinguish between zinc and lead emissions.
HFC-125, HFC-134a, HFC-143a	2.F Product Uses as Substitutes for ODS/2.F.1 Refrigeration and air conditioning/ Transport Refrigeration	2.F.1 Refrigeration and air conditioning/ Transport Refrigeration	2.F.1 Refrigeration and air conditioning/ Commercial Refrigeration	Emissions from Transport Refrigeration are included in Commercial Refrigeration

Sources and sinks reported elsewhere ("IE")[3]				
GHG	**Source/sink category**	**Allocation as per IPCC Guidelines**	**Allocation used by the Party**	**Explanation**
HFC-134a HFC-245fa	2.F Product Uses as Substitutes for ODS/2.F.2 Foam Blowing Agents/2.F.2.a Closed Cells/HFC-134a and HFC-245fa	2.F.2.a Foam Blowing/closed cell/ HFC-245fa from disposal	2.F.2.a Foam Blowing/closed cell/ HFC-245fa from stocks	Emissions are included in emissions from stocks
HFC-227ea	2.F Product Uses as Substitutes for ODS/2.F.3 Fire Protection/HFC-227ea	2.F.3 Fire Protection/HFC-227ea from disposal	2.F.3 Fire Protection/HFC-227ea from stocks	Emissions are included in emissions from stocks
CO_2	4.A Forest Land/4.A.1 Forest Land Remaining Forest Land/4(V) Biomass Burning/Wildfires	4.A.1 4(V) Biomass Burning/Wildfires	4.A.1, Carbon stock change in living biomass	CO_2 emissions due to wildfires in forest land remaining forest land are included in table 4.A.1, Carbon stock change in living biomass, Losses
CO_2	4.A Forest Land/4.A.2 Land Converted to Forest Land/4(V) Biomass Burning/Wildfires	4.A.2 4(V) Biomass Burning/Wildfires	4.A.2, Carbon stock change in living biomass	CO_2 emissions due to wildfires in forest land remaining forest land are included in table 4.A.2, Carbon stock change in living biomass, Losses
N_2O	4.A Forest Land/4.A.1 Forest Land Remaining Forest Land/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers	4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers	3.D.1 Direct N2O emissions from managed soils	N inputs to managed soils are reported in the agriculture sector
CO_2	4.G Harvested Wood Products/Approach B/Approach B2/Total HWP from Domestic Harvest/HWP Produced and Exported/Solid Wood/Sawnwood and Wood panels	Solid Wood/Sawnwood and Wood panels in HWP Produced and exported	Solid Wood/Sawnwood and wood panels in HWP produced and consumed domestically	HWP produced and exported are included in the HWP produced and consumed domestically

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Description and interpretation of emission trends for aggregate greenhouse gas emissions

Summary data of the Italian greenhouse gas emissions for the years 1990-2020 are reported in Tables A8.1.1-A8.1.5 of Annex 8.

The emission figures presented are those sent to the UNFCCC Secretariat and to the European Commission in the framework of the Greenhouse Gas Monitoring Mechanism.

Total greenhouse gas emissions, in CO_2 equivalent, excluding emissions and removals from LULUCF, have decreased by 26.7% between 1990 and 2020, varying from 520 to 381 CO_2 equivalent million tons (Mt).

Table 2.1 shows the national greenhouse gases for 1990-2020, expressed in CO_2 equivalent terms and by substance; emissions are reported excluding and including emissions and removals from LULUCF.

Total emissions are also reported with indirect emissions which, for Italy, equals the total without indirect emissions

Table 2.1 Greenhouse gas emissions and removals from 1990 to 2020 by gas (Mt CO_2 eq.)

GHG emissions	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 equivalent				
CO_2 excluding net CO_2 from LULUCF	439,550	449,826	470,487	502,255	436,117	361,163	349,005	339,233	302,279
CO_2 including net CO_2 from LULUCF	433,760	424,689	447,965	466,084	393,802	317,479	312,870	297,856	269,190
CH_4 excluding CH_4 from LULUCF	49,390	51,417	51,913	49,205	47,341	44,112	42,982	41,982	42,780
CH_4 including CH_4 from LULUCF	50,676	51,720	52,628	49,504	47,691	44,376	43,143	42,185	43,043
N_2O excluding N_2O from LULUCF	27,209	29,433	30,270	29,281	20,331	18,867	18,987	18,757	19,471
N_2O including N_2O from LULUCF	28,065	30,311	30,965	29,911	20,761	19,194	19,438	19,251	19,896
HFCs	444	927	2,489	7,619	12,055	15,403	16,496	16,871	15,876
PFCs	2,907	1,492	1,488	1,940	1,520	1,688	1,657	1,028	539
Unspecified mix of HFCs and PFCs	NO,NA	25	25	25	25	25	23	24	23
SF_6	408	680	604	550	394	472	452	440	264
NF_3	NA,NO	77	13	33	20	28	22	18	16
Total (excluding LULUCF)	**519,908**	**533,876**	**557,291**	**590,908**	**517,804**	**441,759**	**429,624**	**418,352**	**381,248**
Total (including LULUCF)	**516,260**	**509,920**	**536,177**	**555,667**	**476,268**	**398,666**	**394,102**	**377,672**	**348,847**
Total (excluding LULUCF, with indirect)	**519,908**	**533,876**	**557,291**	**590,908**	**517,804**	**441,759**	**429,624**	**418,352**	**381,248**
Total (including LULUCF, with indirect)	**516,260**	**509,920**	**536,177**	**555,667**	**476,268**	**398,666**	**394,102**	**377,672**	**348,847**

Table 2.1 Greenhouse gas emissions and removals from 1990 to 2020 by gas (Mt CO_2 eq.)

The most important greenhouse gas, CO_2, which accounts for 79.3% of total emissions in CO_2 equivalent, shows a decrease by 31.2% between 1990 and 2020. In the energy sector, in particular CO_2 emissions in 2020 are 29.6% lower than in 1990.

In 2020, CH_4 and N_2O emissions are equal to 11.2% and 5.1% of the total CO_2 equivalent greenhouse gas emissions, respectively. CH_4 emissions have decreased by 13.4% from 1990 to 2020, while N_2O emissions have decreased by 28.4%.

As for other greenhouse gases, HFCs account for 4.2% of total emissions, PFCs and SF_6 are equal to 0.2% and 0.1% of total emissions, respectively; the weight of NF_3 is about 0.01%. Among these gases, HFCs show a strong increase in emissions, and the meaningful increasing trend will make them even more important in next years.

Figure 2.1 illustrates the national trend of greenhouse gases for 1990-2020, expressed in CO_2 equivalent terms and by substance; total emissions do not include emissions and removals from land use, land use change and forestry.

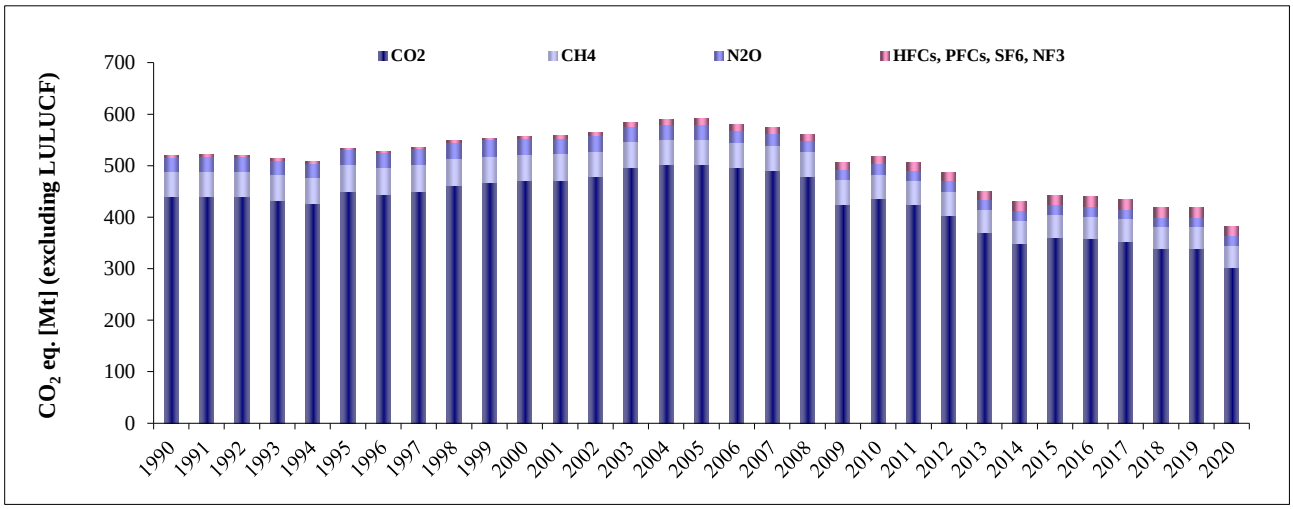


Figure 2.1 National greenhouse gas emissions from 1990 to 2020 (without LULUCF) (Mt CO_2 eq.)

The share of the different sectors, in terms of total emissions, remains nearly unvaried over the period 1990-2020. Specifically, for the year 2020, the greatest part of the total greenhouse gas emissions is to be attributed to the energy sector, with a percentage of 78.4%, followed by agriculture and industrial processes and product use, accounting for 8.6% and 8.1%, respectively, and waste contributing with 4.9% to total emissions.
Total greenhouse gas emissions and removals, including LULUCF sector, are shown in Figure 2.2 subdivided by sector.
In 2020, considering the total GHG emissions (including the absolute value of net LULUCF emissions/ removals), the percentage contribution of the sectors is: 72.3% for energy, 7.9% for agriculture, 7.8% for LULUCF, 7.5% for industrial processes and product use, and 4.5% for waste.

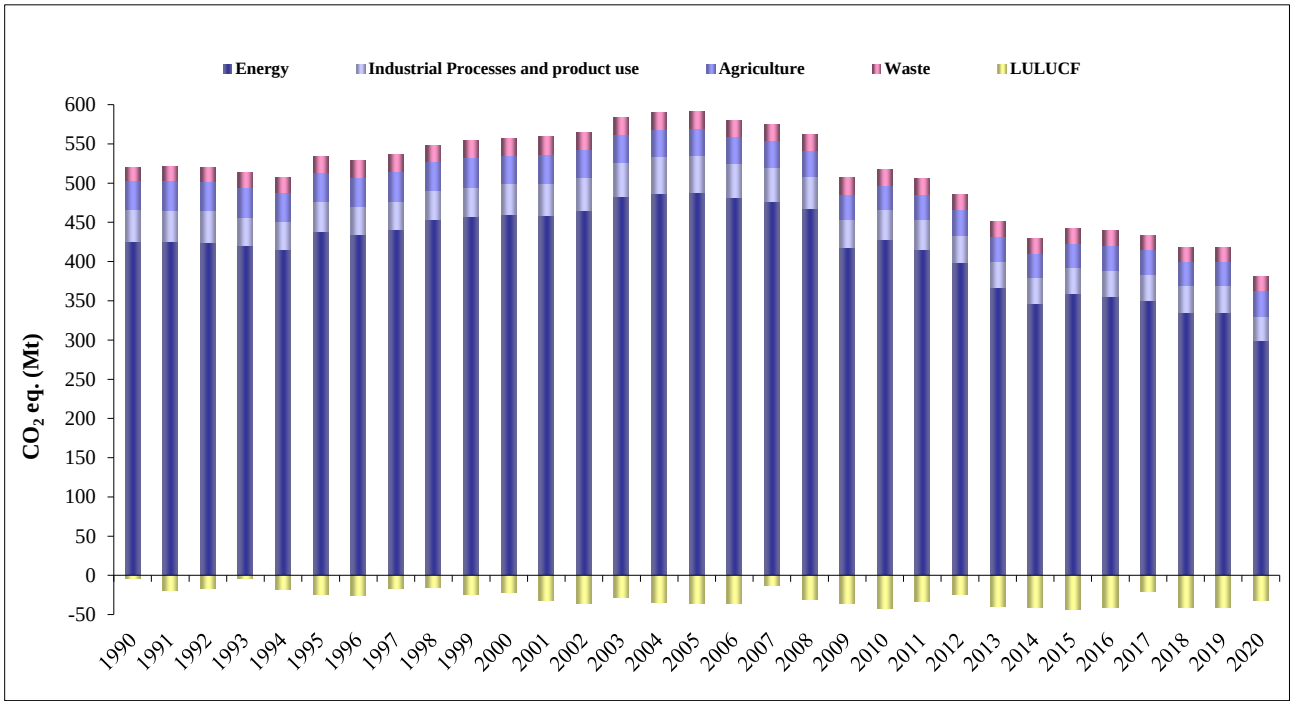


Figure 2.2 Greenhouse gas emissions and removals from 1990 to 2020 by sector (Mt CO_2 eq.)

2.2 Description and interpretation of emission trends by gas

2.2.1 Carbon dioxide emissions

CO_2 emissions, without LULUCF, decreased by 31.2% from 1990 to 2020, ranging from 440 to 303 million tons.

The most relevant emissions derive from transportation (27.9%) and energy industries (26.9%). Non-industrial combustion accounts for 24.9% and manufacturing and construction industries for 14.8%, while the remaining emissions derive from industrial processes (4.5%) and the other sectors (less than 0.9%).

The trend of CO_2 emissions by sector is shown in Figure 2.3.

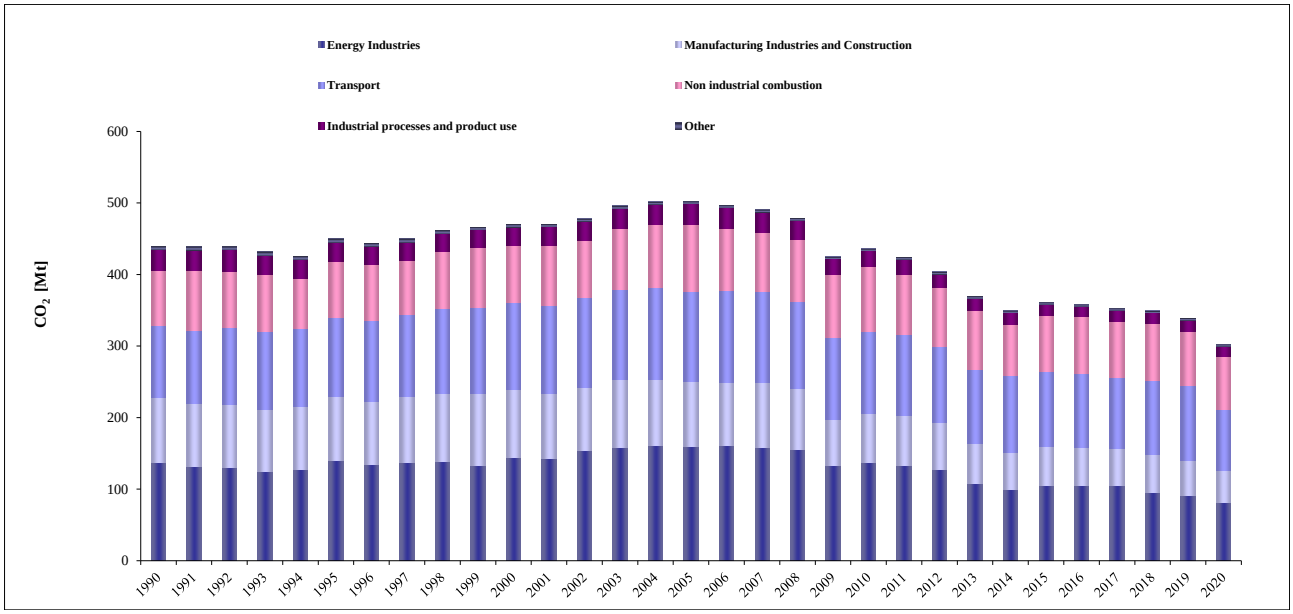


Figure 2.3 National CO_2 emissions by sector from 1990 to 2020 (Mt)

The main driver for the reduction of CO_2 emissions is the reduction in emissions observed in energy industries and manufacturing industries and construction; in the period 1990-2020, emissions from energy industries decreased by 40.6% while those from manufacturing industries and construction show a decrease of 50.6%. The transport sector has shown an increase of emissions until 2007 and then a decrease both for the economical recession and the penetration of vehicles with low fuel consumption. Non industrial combustion emission trend is driven by the annual climatic variation while emissions from industrial processes decreased by 53.4% mainly for the decrease of cement production.

Figure 2.4 illustrates the performance of the following economic and energy indicators:

- Gross Domestic Product (GDP) at market prices as of 2010 (base year 1990=100);
- Total Energy Consumption;
- CO_2 emissions, excluding emissions and removals from land-use change and forests;
- CO_2 *intensity*, which represents CO_2 emissions per unit of total energy consumption.

CO_2 emissions in the 1990s essentially mirrored energy consumption. A decoupling between the curves is observed only in recent years, mainly as a result of the substitution of fuels with high carbon contents by methane gas in the production of electric energy and in industry; in the last years, the increase in the use of renewable sources has led to a notable reduction of CO_2 intensity. The last year of the time series is a special year. The pandemic situation due to Covid-19 has led to a sharp fall in emissions but also a slowdown in economic growth.

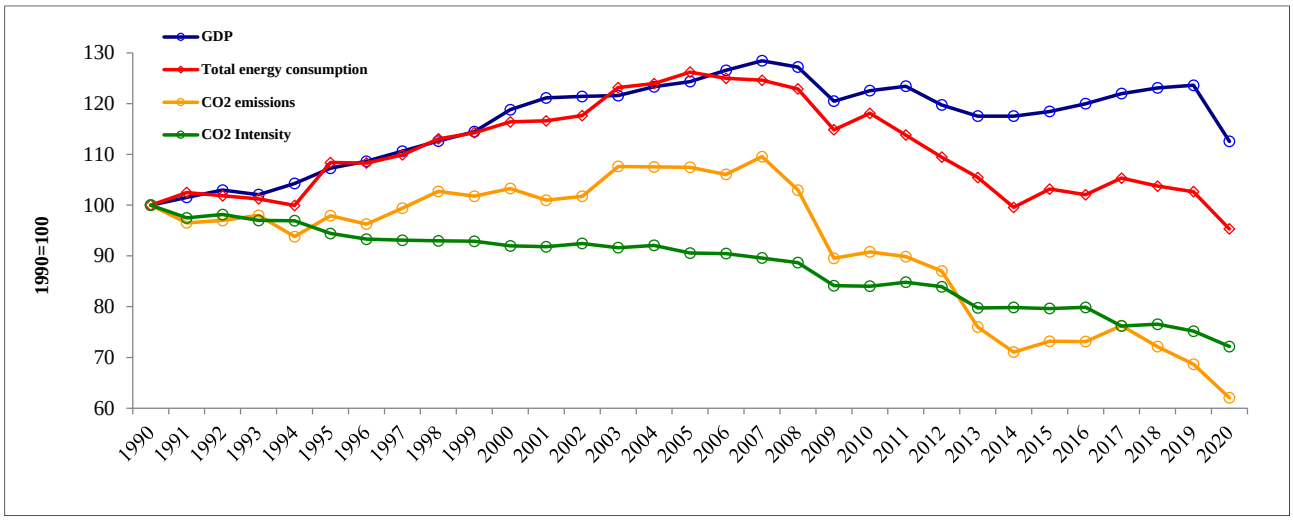


Figure 2.4 Energy-related and economic indicators and CO_2 emissions

2.2.2 Methane emissions

Methane emissions (excluding LULUCF) in 2020 represent 11.2% of total greenhouse gases, equal to 42.8 Mt in CO_2 equivalent, and show a decrease of 13.4% as compared to 1990 levels.

CH_4 emissions, in 2020, are mainly originated from the agriculture sector which accounts for 45.1% of total methane emissions, as well as from the waste (39.3%) and energy (15.6%) sectors.

Emissions in the agriculture sector regard mainly the enteric fermentation (70.2%) and manure management (21.5%) categories. The sector shows a decrease of emissions equal to 13.5% as compared to 1990, attributable widely to a reduction in livestock and the recovery of biogas for energy purposes (for swine and poultry).

Activities typically leading to emissions in the waste-management sector are the operation of dumping sites and the treatment of industrial wastewater. The waste sector shows an increase in CH_4 emission levels, equal to 8.6% compared to 1990; the largest sectoral shares of emissions are attributed to solid waste disposal on land (84.9%) and waste-water handling (14.1%), which show an increase equal to 16.8% and a decrease by 25.8%, respectively.

In the energy sector, the reduction of CH_4 emissions (-42.0%) is the result of two contrasting factors: on the one hand there has been a considerable reduction in emissions deriving from energy industries, transport, fugitive emissions from fuels (caused by leakage from the extraction and distribution of fossil fuels, due to the gradual replacement of natural-gas distribution networks), on the other hand a strong increase in the civil sector can be observed, as a result of the increased use of methane and biomass in heating systems. Figure 2.5 shows the emission figures by sector.

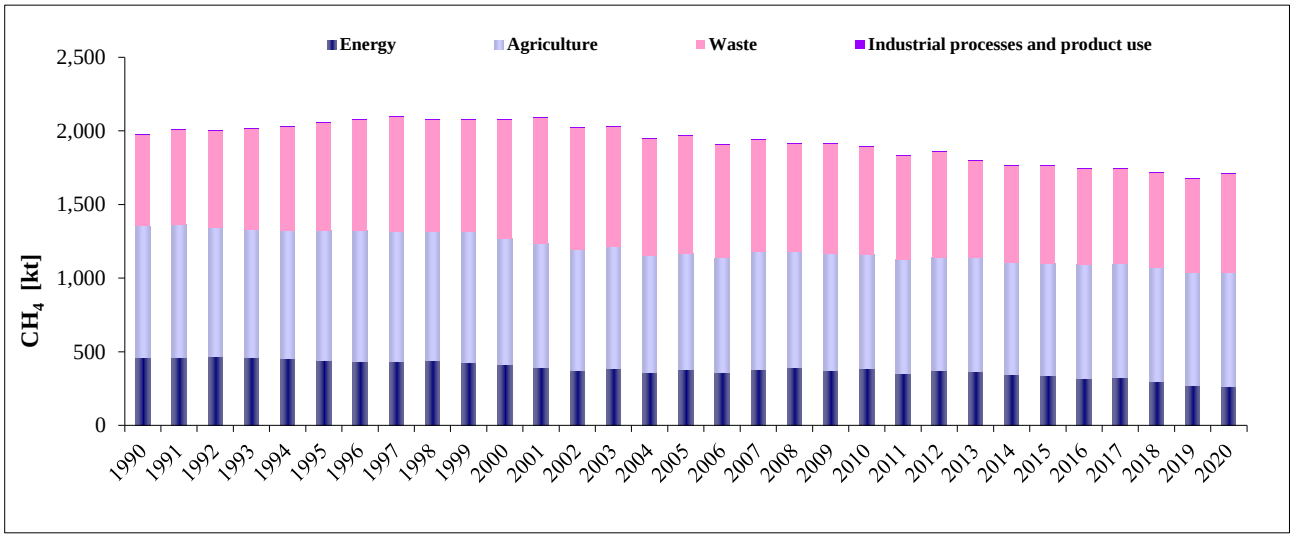


Figure 2.5 National CH_4 emissions by sector from 1990 to 2020 (kt)

2.2.3 Nitrous oxide emissions

In 2020, nitrous oxide emissions (excluding LULUCF) represent 5.1% of total greenhouse gases, with a decrease of 28.4% between 1990 and 2020, from 27.2 to 19.5 Mt CO_2 equivalent. The major source of N_2O emissions is the agricultural sector (66.3%), in particular the use of both chemical and organic fertilisers in agriculture, as well as the management of waste from the raising of animals. Emissions from the agriculture sector show a decrease of 8.4% during the period 1990-2020, due to a reduction in livestock number.

Emissions in the energy sector (21.7% of the total) show a decrease by 8.4% from 1990 to 2020; this trend can be traced primarily to the reduction of 47.6% in the manufacturing and construction industries (which account for 3.6% of the total N_2O emissions) due mainly to the reduction in the last years of cement production; the downward trend was counterbalanced by the increase of emissions by 35.4% in the other sectors category, which accounts for 12.1% of the total N_2O emissions, as a result of the increased use of biomass in heating systems.

For the industrial sector, N_2O emissions show a decrease of 91.3% from 1990 to 2020. The decrease is almost totally due to the introduction of abatement systems in the nitric and adipic acid production plants which drastically reduced emissions from these processes. A further component which has contributed to the reduction is the decreasing use of N_2O for medical purposes.

Other emissions in the waste sector (8.9% of national N_2O emissions) primarily regard the processing of industrial and domestic waste-water treatment and the biological treatment of solid waste.

Figure 2.6 shows national emission figures by sector.

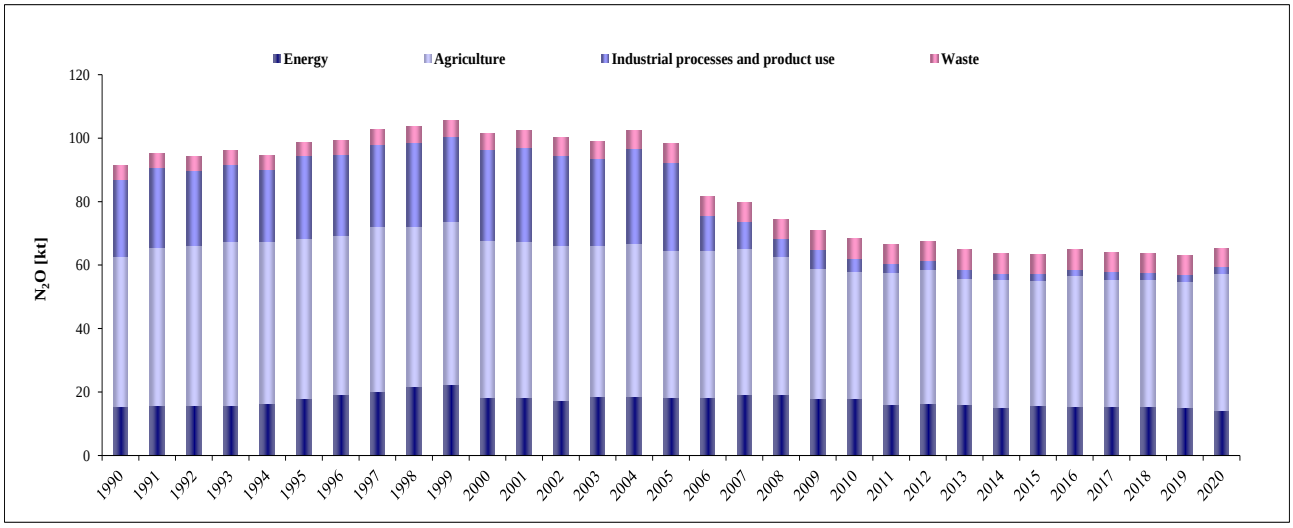


Figure 2.6 National N_2O emissions by sector from 1990 to 2020 (kt)

2.2.4 Fluorinated gas emissions

Italy has set 1990 as the base year for emissions of fluorinated gases, HFCs, PFCs, SF_6 and 1995 for NF_3. Taken altogether, the emissions of fluorinated gases represent 4.4% of total greenhouse gases in CO_2 equivalent in 2020 and they show a significant increase between 1990 and 2020. This increase is the result of different features for the different gases.

HFCs, for instance, have increased considerably from 1990 to 2020, from 0.4 to 15.9 Mt in CO_2 equivalent. The main sources of emissions are the consumption of HFC-134a, HFC-125, HFC-32 and HFC-143a in refrigeration and air-conditioning devices, together with the use of HFC-134a in pharmaceutical aerosols. Increases during this period are due both to the use of these substances as substitutes for gases that destroy the ozone layer and to the greater use of air conditioners in automobiles.

Emissions of PFCs show a decrease of 81.5% from 1990 to 2020. The level of PFC emissions in 2020 is equal to 1.0 Mt in CO_2 equivalent, and it is due to by product emissions in fluorchemical production (84.6%), and the use of the gases in the production of semiconductors (15.4%).

Emissions of SF_6 are equal to 0.3 Mt in CO_2 equivalent in 2020, with a decrease of 35.3% as compared to 1990 levels. In 2020, 70.4% of SF_6 emissions derive from the gas contained in electrical equipment, 16.0% from the use of this substance in accelerators and 13.6% from the gas used in the semiconductors manufacture. NF_3 emissions account for 0.004 Mt in CO_2 equivalent in 2020 and derive from the semiconductors industry.

The national inventory of fluorinated gases has largely improved in terms of sources and gases identified and a strict cooperation with the relevant industry has been established. Higher methods are applied to estimate

these emissions; nevertheless, uncertainty still regards some activity data which are considered of strategic economic importance and therefore kept confidential.

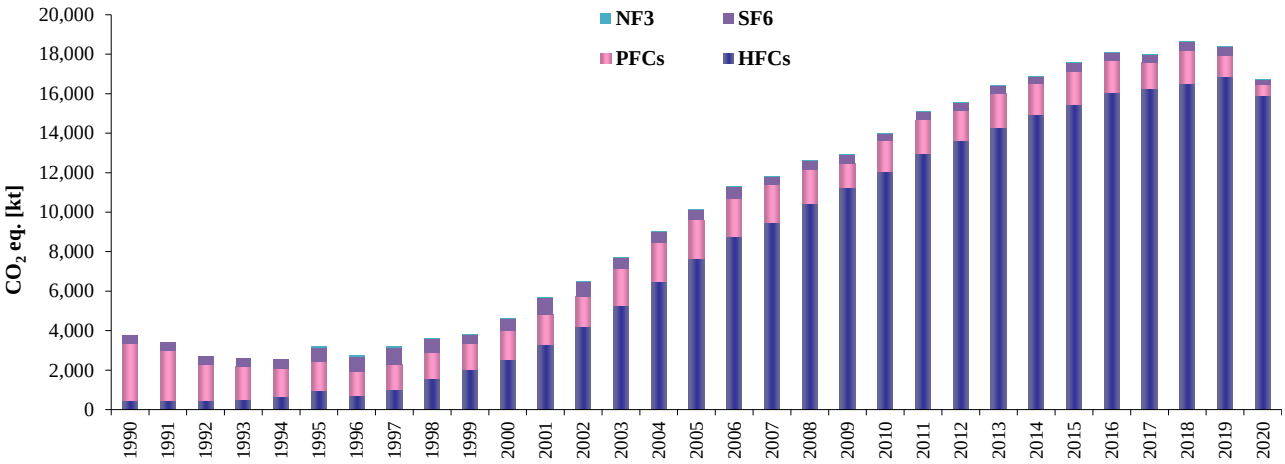


Figure 2.7 National emissions of fluorinated gases by sector from 1990 to 2020 (kt CO_2 eq.)

2.3 Description and interpretation of emission trends by source

2.3.1 Energy

Emissions from the energy sector account for 78.4% of total national greenhouse gas emissions, excluding LULUCF, in 2020.

Emissions in CO_2 equivalent from the energy sector are reported in Table 2.2 and Figure 2.8.

Table 2.2 Total emissions from the energy sector by source (1990-2020) (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 eq.				
Total emissions	**425,298**	**437,938**	**459,631**	**487,640**	**428,903**	**416,018**	**345,416**	**335,081**	**298,900**
Fuel Combustion (Sectoral Approach)	412,180	425,564	448,484	477,885	420,007	406,948	338,491	328,469	292,909
Energy Industries	*137,646*	*140,631*	*144,906*	*159,934*	*137,507*	*133,403*	*96,068*	*91,894*	*81,797*
Manufacturing Industries and Construction	*92,278*	*90,312*	*96,373*	*92,444*	*70,165*	*70,987*	*54,279*	*49,991*	*45,856*
Transport	*102,191*	*114,289*	*123,830*	*128,260*	*115,527*	*114,460*	*104,276*	*105,322*	*85,436*
Other Sectors	*78,924*	*78,767*	*82,494*	*95,924*	*96,115*	*87,552*	*83,517*	*80,794*	*79,178*
Other	*1,143*	*1,566*	*881*	*1,323*	*692*	*546*	*351*	*467*	*642*
Fugitive Emissions from Fuels	13,117	12,374	11,147	9,755	8,897	9,070	6,925	6,612	5,991
Solid Fuels	*132*	*74*	*97*	*90*	*86*	*92*	-	-	-
Oil and Natural Gas	*12,985*	*12,300*	*11,050*	*9,665*	*8,810*	*8,979*	*6,890*	*6,580*	*5,966*

From 2005, GHG emissions from the energy sector have been decreasing because of the policies adopted at European and national level to implement the production of energy from renewable sources. From the same year, a further shift from petrol products to natural gas in producing energy has been observed as a consequence of the starting of the EU greenhouse gas Emission Trading Scheme (EU ETS) on January 1st, 2005. From 2009, a further drop of the sectoral emissions is due to the economic recession. From 2008 to 2009 the decrease observed in GHG emissions is equal to -10.1% followed by an increase (+2.3%) only from 2009 to 2010; since then, except for the increase of 2.2% between 2014 and 2015, the annual variations are always negative until 2019.

Total greenhouse gas emissions, in CO_2 equivalent, show a decrease of about 29.7% from 1990 to 2020; in particular, an upward trend is noted from 1990 to 2004, with an increase by 14.5%, while between 2005 and 2020 emissions decreased by 38.7%.

The GHG with the highest impact, in the energy sector, is CO_2, accounting for 96.4% of the sectoral total, in 2020, whose levels have decreased by 29.6% from 1990 to 2020.
In 2020, CH_4 emissions account for 2.2% of te sectoral total. Their trend shows a decrease of 42.0% from 1990 to 2020, and it is driven by the combined effect of technological improvements that limit volatile organic compounds (VOCs) from tail pipe and evaporative emissions (for cars) and the expansion of two-wheelers fleet.
N_2O shows a decrease of 8.4% with a share out of the total equal to 1.4%, mainly driven by the technology development in road transport and to the switch from gasoline to diesel fuel consumption.
In general, for the sector, the decrease in emissions from 1990 to 2020 is driven by the reduction in the energy industries and manufacturing industries and construction, which, in 2020, account for 27.4% and 15.3% and reduced by 40.6% and 50.3%, respectively. Specifically, for the manufacturing industries and construction, the reason for the reduced emissions is the cut in production in some subsectors (e.g. chemical, construction and building materials, steel) due to the effects of the economic recession but also to an increase in efficiency, especially identified in the chemical sector. A small increase in emissions still occurs in other sectors subcategory (0.2%), which account for 26.5% in 2020; instead, the transport sector, accounting for 28.6%, in 2020, shows a decrease of 16.4%.
Road transport is the most relevant source in the transport sector, accounting in 2020 for 23.4% of total national CO_2 equivalent emissions.
The increase in other sectors sub-category, which refer mainly to emissions originated from energy use in the civil sector, is due to the increase in numbers and size of building with heating, and especially in the last few years, to the increase in other greenhouse gas emissions than CO_2 for the growing use of woody biomass and biogas for heating. Annual variations are also driven by the trend in weather conditions.
Details on these figures are described in the specific chapter.

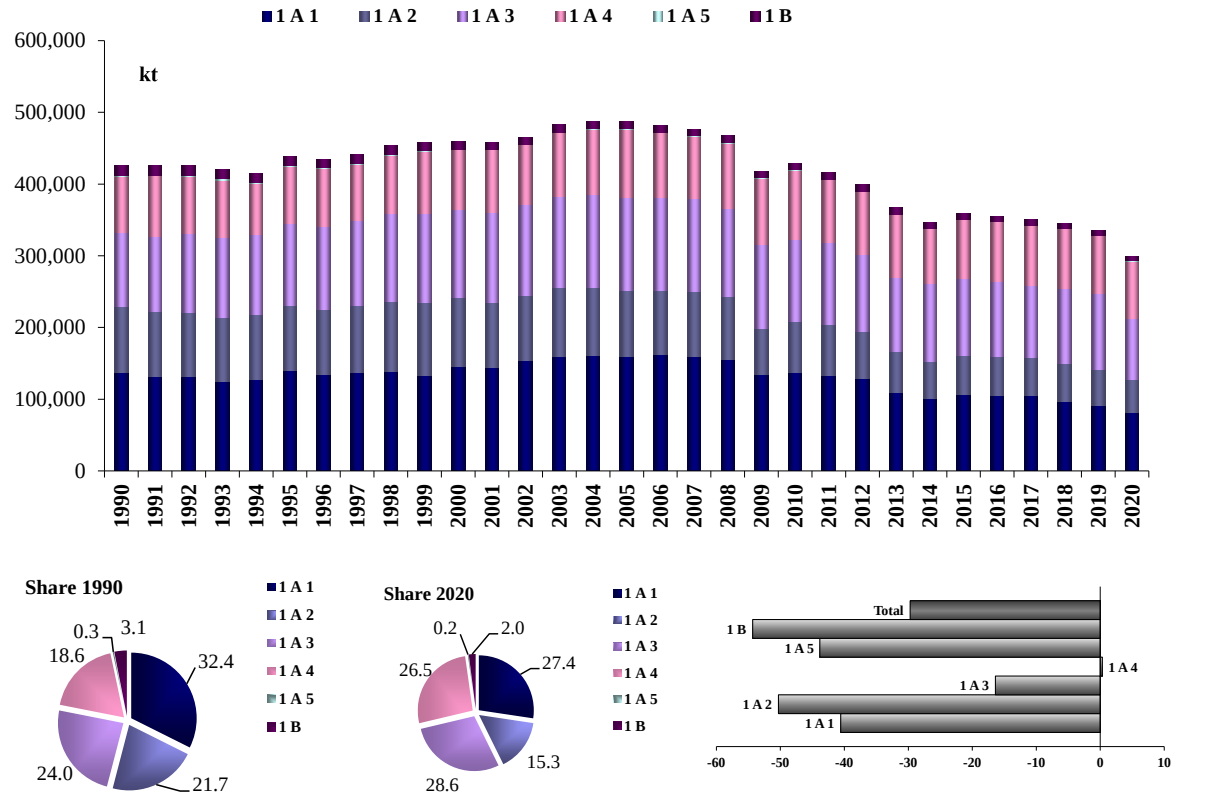


Figure 2.8 Trend of total emissions from the energy sector (1990-2020) (kt CO_2 eq.)

2.3.2 Industrial processes and product use

Emissions from the industrial processes and product use sector account for 8.1% of total national greenhouse gas emissions, excluding LULUCF, in 2020. Emission trends from industrial processes are reported in Table 2.3 and Figure 2.9.

Total emissions, in CO_2 equivalent, show a decrease of 23.2%, from 1990 to 2020. Taking into account emissions by substance, CO_2 and N_2O decreased by 53.4% and 91.3%, respectively; in terms of their weight out of the sectoral total emissions, CO_2 accounts for 44.0% and N_2O for 2.0%. CH_4 decreased by 73.6% but it accounts for only 0.1%.

The decrease in emissions is mostly to be attributed to a decrease in the mineral and chemical industries. Emissions from mineral production decreased by 52.8%, mostly for the reduction of cement production. The decrease of GHG emissions in the chemical industry (-81.9%) is due to the decreasing trend of the emissions from nitric acid and adipic acid production (the last production process sharply reduced its emissions, due to a fully operational abatement technology). On the other hand, from 1990 to 2020, a considerable increase is observed in F-gas emissions (338.4%), whose share on total sectoral emissions is 53.8% in the last reporting year. The main drivers of the increase are the consumptions of HFCs in refrigeration and air-conditioning devices, together with their use in pharmaceutical aerosols (see section 2.2.4). Details for industrial processes and product use emissions can be found in the specific chapter.

Table 2.3 Total emissions from the industrial processes sector by gas (1990-2020) (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2018	2019	2020
				kt CO_2 eq.					
Total emissions	**40,422**	**38,316**	**39,123**	**47,211**	**36,964**	**33,233**	**34,604**	**33,985**	**31,049**
CO_2	29,335	27,281	25,832	28,718	21,666	14,960	15,226	14,924	13,668
CH_4	129	134	73	74	60	42	44	41	34
N_2O	7,199	7,701	8,599	8,251	1,224	613	684	641	629
F-gases	3,759	3,200	4,620	10,167	14,015	17,617	18,650	18,380	16,718
HFCs	*444*	*927*	*2,489*	*7,619*	*12,055*	*15,403*	*16,496*	*16,871*	*15,876*
PFCs	*2,907*	*1,492*	*1,488*	*1,940*	*1,520*	*1,688*	*1,657*	*1,028*	*539*
Unspecified mix of HFCs and PFCs		*25*	*25*	*25*	*25*	*25*	*23*	*24*	*23*
SF_6	*408*	*680*	*604*	*550*	*394*	*472*	*452*	*440*	*264*
NF_3		*77*	*13*	*33*	*20*	*28*	*22*	*18*	*16*

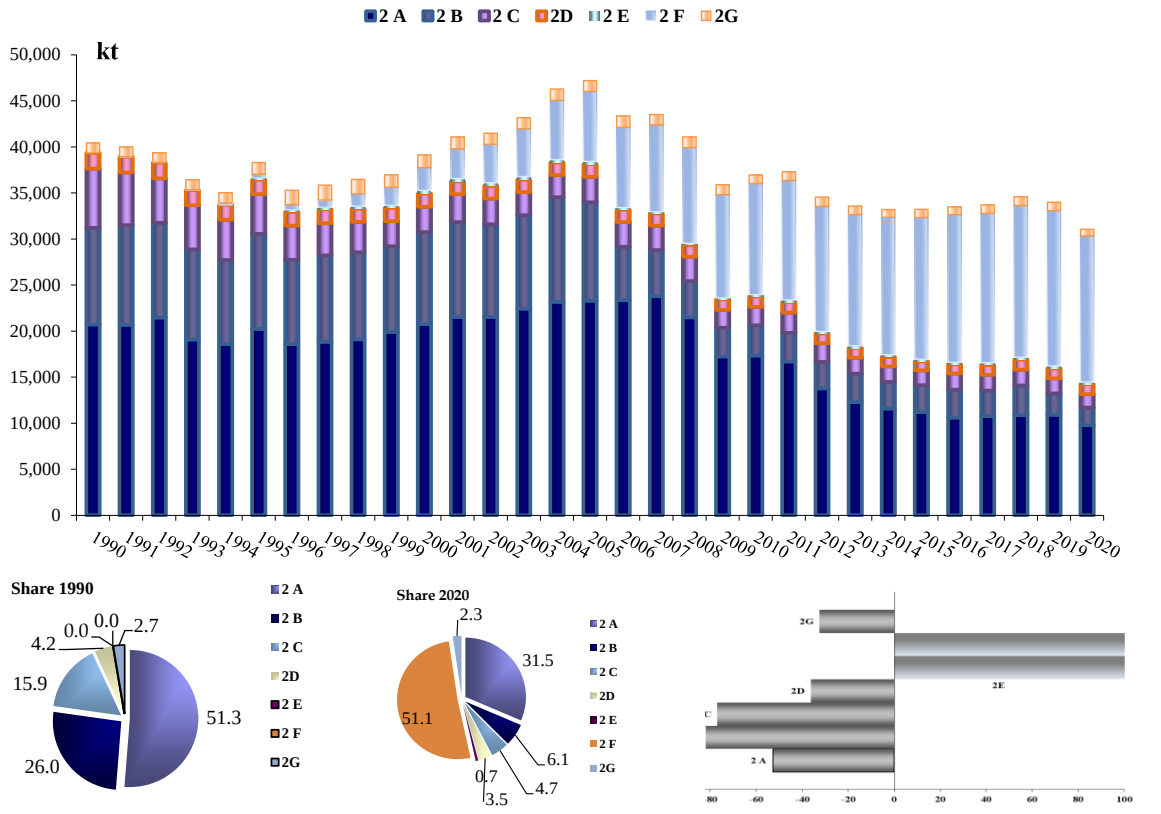


Figure 2.9 Trend of total emissions from the industrial processes sector (1990-2020) (kt CO_2 eq.)

2.3.3 Agriculture

Emissions from the agriculture sector account for 8.6% of total national greenhouse gas emissions, in 2020, excluding LULUCF. Emissions from the agriculture sector are reported in Table 2.4 and Figure 2.10.

Table 2.4 Total emissions from the agriculture sector by source (1990-2020) (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2018	2019	2020
	kt CO_2 eq.								
Total emissions	**36,900**	**37,649**	**36,682**	**34,192**	**31,555**	**31,207**	**31,460**	**31,354**	**32,685**
Enteric Fermentation	15,564	15,399	15,128	13,293	12,884	13,035	13,381	13,364	13,535
Manure Management	7,676	7,314	7,193	7,095	6,874	6,353	6,233	6,206	6,225
Rice Cultivation	1,876	1,989	1,656	1,752	1,822	1,668	1,601	1,583	1,582
Agricultural Soils	11,254	12,361	12,116	11,468	9,575	9,672	9,784	9,752	10,820
Field Burning of Agricultural Residues	19	18	18	20	19	20	19	19	19
Liming	1	1	2	14	18	14	15	16	10
Urea application	465	512	525	507	335	425	405	396	472
Other carbon-containing fertilizers	44	54	44	42	28	20	22	17	21

Emissions mostly refer to CH_4 and N_2O, which, in 2020, account for 59.0% and 39.5% of the total emissions of the sector, respectively. CO_2 accounts for the remaining 1.5% of total emissions. The decrease observed in total emissions (-11.4%) is mostly due to the decrease of CH_4 emissions from enteric fermentation (-13.0%) and to the decrease of N_2O (-3.9%) from agricultural soils; in 2020 these categories account for 41.4% and 33.1% of the total sectoral emissions, respectively.

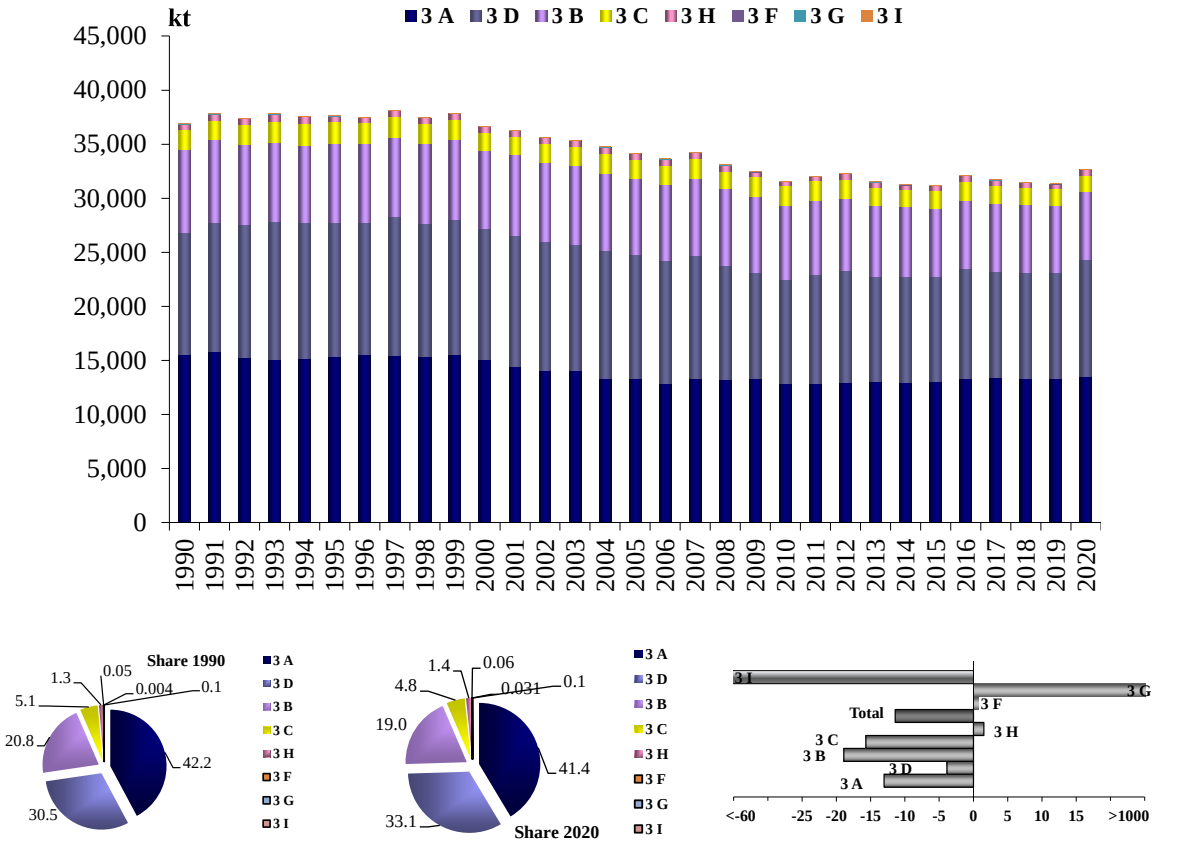


Figure 2.10 Trend of total emissions from the agriculture sector (1990-2020) (kt CO_2 eq.)

Main drivers behind these downward trends are the reduction in the number of animals, especially cattle in the whole period and the reductionof the use of nitrogen fertilizers, mainly due to the European Common Agricultural Policy (CAP) measures. In addition, a significant increase in the recovery of the biogas produced from animal manure and used in the energy sector has occurred in the last years. This biogas has been used for the electricity production and the combined electricity and heat production, thus contributing to the reduction of total emissions.
Detailed comments can be found in the specific chapter.

2.3.4 LULUCF

Emissions and removals from the LULUCF sector are reported in Table 2.5 and Figure 2.11.

Table 2.5 Total emissions from the LULUCF sector by source/sink (1990-2020) (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 eq.				
Total emissions/removals	**-3,594**	**-23,964**	**-21,082**	**-35,233**	**-41,522**	**-43,081**	**-35,532**	**-40,690**	**-32,396**
Forest land	-17,255	-31,001	-25,694	-34,541	-36,146	-39,221	-31,857	-36,255	-30,115
Cropland	1,712	686	-540	-1,893	-866	575	-577	-523	-14
Grassland	5,122	-1,907	-1,425	-6,126	-9,210	-9,400	-8,952	-8,046	-7,207
Wetlands	NE,NO	5	8	8	130	130	32	32	32
Settlements	7,145	8,941	6,982	7,804	4,688	4,735	5,555	5,563	5,569
Other land	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products	-388	-706	-454	-503	-142	89	264	-1,469	-669
Other (indirect N_2O soils)	70	18	40	17	23	11	4	8	9

LULUCF total removals, in CO_2 equivalent, show a high variability in the period, remarkably influenced by the annual fires occurrence and the related GHG emissions. CO_2 accounts for 98.0% of total emissions and

removals of the sector, as absolute weight. The key driver for the rise in removals is the increase of carbon stock in forest land. Further details for LULUCF emissions and removals can be found in the specific chapter.

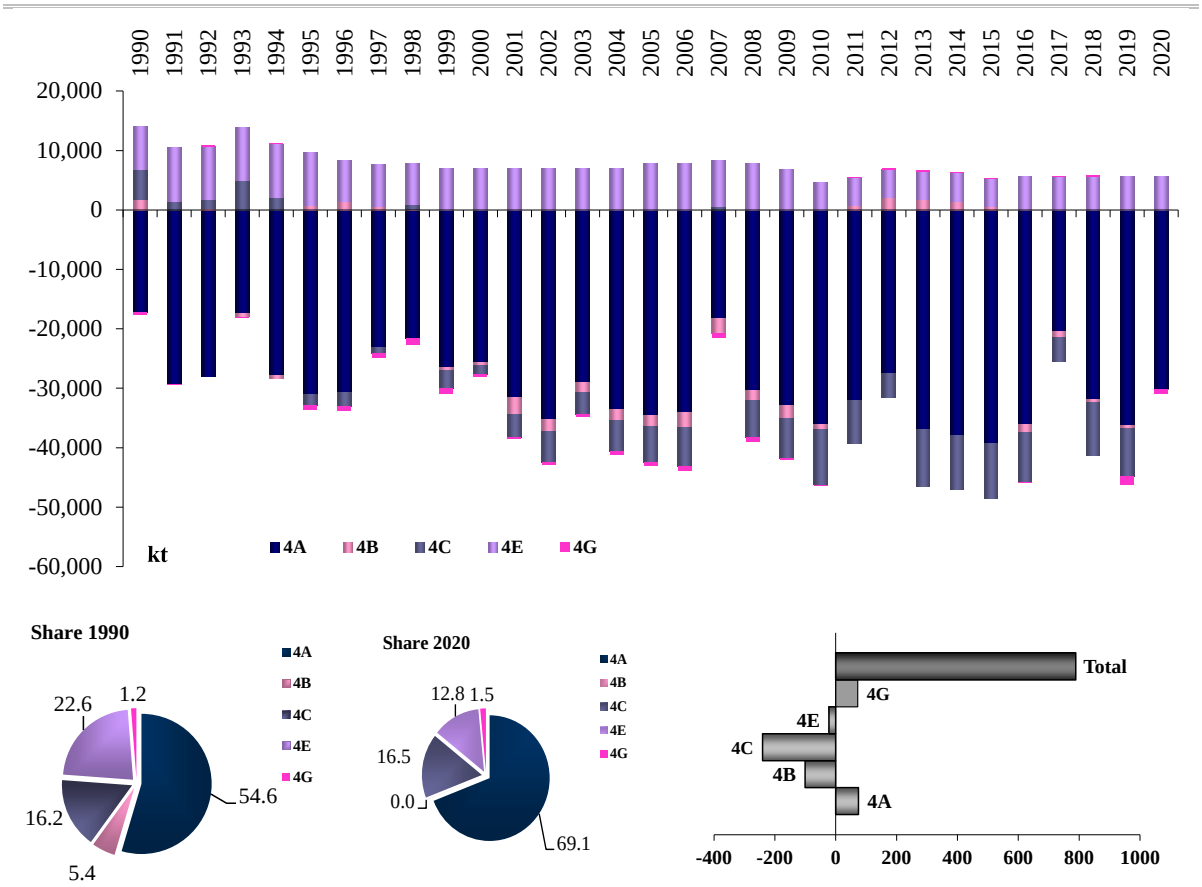


Figure 2.11 Trend of total emissions and removals from the LULUCF sector (1990-2020) (kt CO_2 eq.)

2.3.5 Waste

In 2020, emissions from the waste sector account for 4.9% of total national greenhouse gas emissions, excluding LULUCF.

Emissions from the waste sector are shown in Table 2.6 and Figure 2.12.

Table 2.6 Total emissions from the waste sector by source (1990-2020) (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2018	2019	2020
					kt CO_2 eq.				
Total emissions	**17,289**	**19,974**	**21,854**	**21,864**	**20,382**	**18,544**	**18,145**	**17,932**	**18,616**
Solid waste disposal	12,206	15,123	17,200	17,002	15,561	14,034	13,629	13,444	14,253
Biological treatment of solid waste	25	58	249	489	619	642	634	624	602
Incineration and open burning of waste	599	551	290	317	258	177	165	169	168
Waste-water treatment and discharge	4,459	4,243	4,115	4,056	3,943	3,690	3,717	3,694	3,593
Other	NA	NA	NA	NA	NA	NA	NA	NA	NA

Total sectoral emissions, in CO_2 equivalent, increased by 7.7% from 1990 to 2020. The trend is mainly driven by the increase in emissions from solid waste disposal (16.8%), accounting for 76.6% of the sectoral total in 2020, counterbalanced by the decrease of emissions from waste-water treatment (-19.4%), accounting for 19.3%.

Considering emissions by gas, the most important greenhouse gas is CH_4 which accounts for 90.2% of the sectoral total and shows an increase of 8.6% from 1990 to 2020. N_2O levels have increased by 31.0% while CO_2 decreased by 81.9%; in 2020, these gases account for 9.3% and 0.5%, respectively.

Further details can be found in the specific chapter.

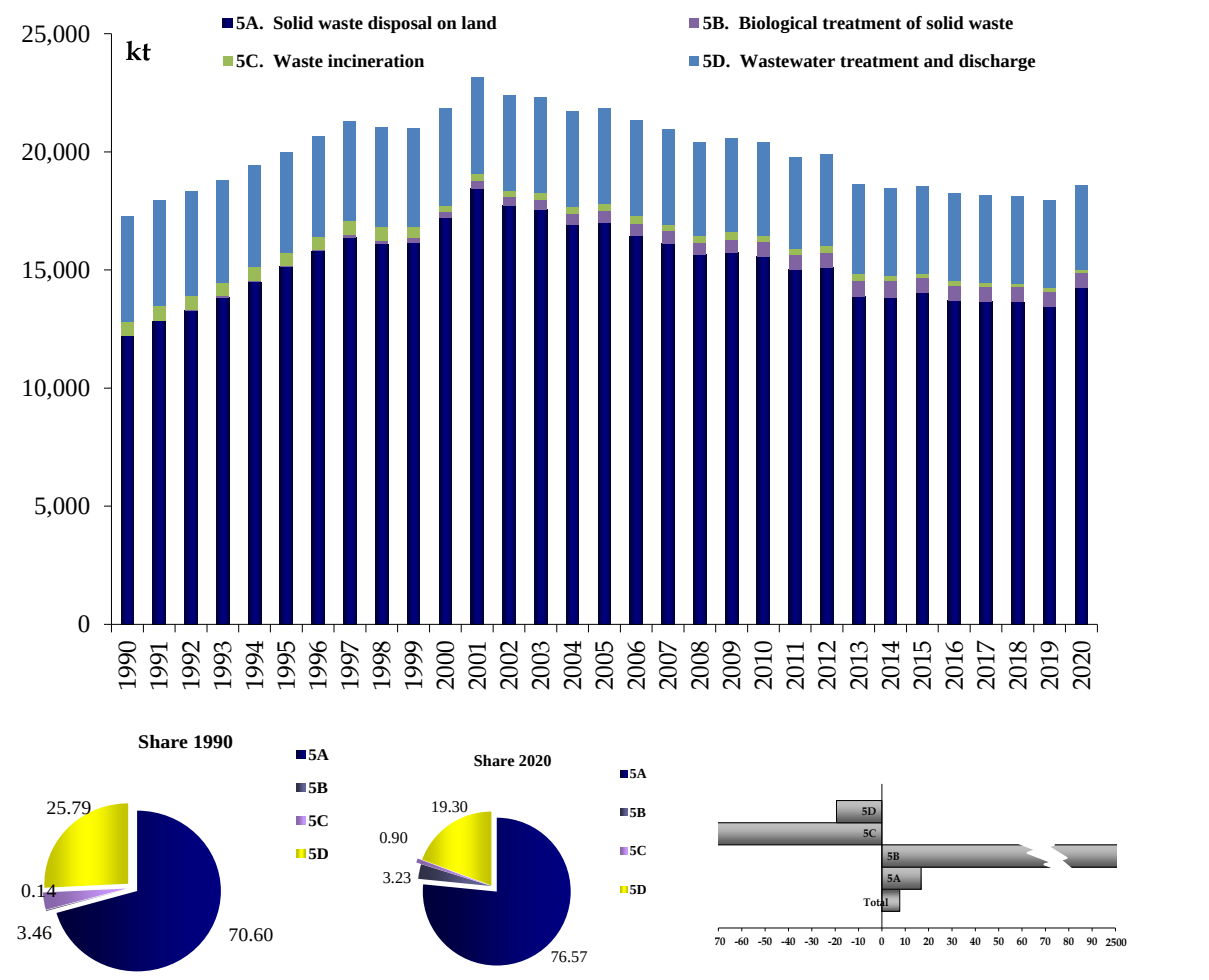


Figure 2.12 Trend of total emissions from the waste sector (1990-2020) (kt CO_2 eq.)

2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO_2

Emission trends of NO_X, CO, NMVOC and SO_2 from 1990 to 2020 are presented in Table 2.7 and Figure 2.13.

Table 2.7 Total emissions withour LULUCF for indirect greenhouse gases and SO_2 (1990-2020) (kt)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
					kt						
NO_X	2,128	1,992	1,510	1,294	941	719	704	662	662	642	573
CO	6,796	7,071	4,750	3,467	3,073	2,266	2,191	2,258	2,049	2,060	1,873
NMVOC	1,993	2,058	1,630	1,340	1,116	897	880	921	894	888	885
SO_2	1,784	1,323	757	411	222	126	120	117	109	105	82

All gases show a significant reduction in 2020 as compared to 1990 levels. The highest reduction is observed for SO_2 (- 95.4%), NO_X levels have reduced by 73.1%, while CO and NMVOC show a decrease by 72.4% and 55.6%, respectively. A detailed description of the trend by gas and sector as well as the main reduction plans can be found in the Italian National Programme for the progressive reduction of the annual national emissions of SO_2, NO_X, NMVOC and NH_3, as requested by the Directive 2001/81/EC.
The most relevant reductions occurred as a consequence of the Directive 75/716/EC, and successive ones related to the transport sector, and of other European Directives which established maximum levels for sulphur

content in liquid fuels and introduced emission standards for combustion installations. As a consequence, in the combustion processes, oil with high sulphur content and coal have been substituted with oil with low sulphur content and natural gas.

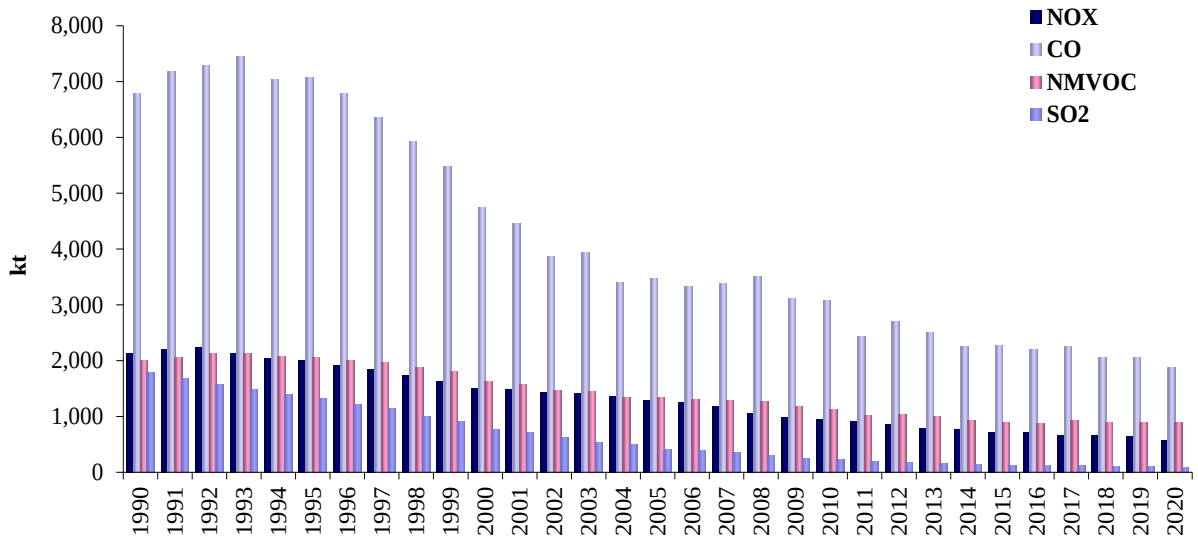


Figure 2.13 Trend of total emissions for indirect greenhouse gases and SO_2 (1990-2020) (kt)

It should be noted that these figures differ from the national totals reported under the *United Nations Economic Commission for Europe* (UNECE) *Convention on Long Range Transboundary Air Pollution* (CLRTAP). If considering total emissions excluding the LULUCF sector, differences are to be attributed to the different accounting of emissions from the civil aviation sector and from fires. In the national totals under CLRTAP, in fact, emissions from aviation are calculated considering all LTO cycles, both domestic and international, excluding entirely the cruise phase. If national figures comprise LULUCF, on the other hand, differences are also to be attributed to fires; under the UNFCCC national total with LULUCF includes emissions from fires from forest, grassland and cropland whereas they are not considered in the national total for CLRTAP.
Emission trends of NO_X, CO, NMVOC and SO_2, exluding LULUCF, communicated under UNECE CLRTAP are presented in Table 2.8.
In the context of the European Regulation No 525/2013, Art. 7(1)(m)(i), EU Member States shall report on the consistency of data on air pollutants under the UNECE Convention on Long-range Transboundary Air Pollution and those under the UNFCCC.
Differences in percentage terms between figures, without LULUCF, between the two Conventions are illustrated in Table 2.9.

Table 2.8 Total emissions for indirect greenhouse gases and SO_2 (1990-2020) (kt) under UNECE CLRTAP

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						kt					
NO_X	2,124	1,989	1,504	1,289	935	716	701	658	659	639	571
CO	6,797	7,072	4,751	3,467	3,073	2,267	2,192	2,259	2,050	2,061	1,873
NMVOC	1,993	2,058	1,630	1,340	1,116	897	881	921	894	888	885
SO_2	1,784	1,322	756	411	222	126	120	117	109	105	82

Table 2.9 Percentage differences between total emissions for indirect greenhouse gases and SO_2 under the UNFCCC and UNECE CLRTAP Conventions (1990-2020)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
NO_X	0.17%	0.17%	0.41%	0.40%	0.66%	0.49%	0.46%	0.48%	0.48%	0.49%	0.42%
CO	-0.01%	-0.01%	-0.02%	-0.01%	0.00%	-0.04%	-0.04%	-0.04%	-0.06%	-0.06%	0.01%
NMVOC	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	0.00%
SO_2	0.01%	0.02%	0.05%	0.10%	0.18%	0.16%	0.15%	0.16%	0.17%	0.17%	0.20%

2.5 Indirect CO_2 and nitrous oxide emissions

Indirect emissions are originated from the atmospheric oxidation of CH_4, CO and NMVOCs. Italy has chosen to report indirect CO_2 emissions from the oxidation of NMVOCs including them in the relevant categories of solvent use. Details on how they are converted into indirect CO_2, can be found in the sections on non-energy-related products from fuels. and solvents in Chapter 4.5.2. Since following this approach, it is not possible to automatically generate total emission figures with and without indirect CO2 emissions throught the Reporter software, these figures are reported in Table 2.1 of chapter 2 to adhere with paragraph 29 of the UNFCCC Annex I inventory reporting guidelines, and in response to the recommendation of the UNFCCC review process (I.5, UNFCCC, 2022 FCCC/ARR/2021/ITA).

Indirect emissions of N_2O take place as a result of two different nitrogen loss pathways. These pathways are the volatilization/emission of nitrogen as NH_3 and NO_X and the subsequent deposition of these forms of nitrogen as ammonium (NH_4+) and oxidised nitrogen (NO_X) on soils and waters, and the leaching and runoff of nitrogen from synthetic and organic nitrogen fertilizer inputs, crop residues, mineralization of nitrogen through land use change or management practices, and urine and dung deposition from grazing animals, into groundwater, riparian areas and wetlands, rivers. All NH_3 or NO_X anthropogenic emissions are potential sources of N_2O emissions.

Indirect N_2O emissions are estimated according to Equation 7.1 of the 2006 IPCC Guidelines (IPCC, 2006) on the basis of NO_X and NH_3 national emissions disaggreagated at sectoral level (ISPRA, 2021 [a]) and reported as memo item in the relevant sectors, except for the agriculture sector where emissions are already included in the national totals.

This method assumes that N_2O emissions from atmospheric deposition are reported by the country that produced the original NO_X and NH_3 emissions. In reality, the ultimate formation of N_2O may occur in another country due to atmospheric transport of emissions. Also, the method does not account for the probable lag time between NO_X and NH_3 emissions and subsequent production of N_2O in soils and surface waters. This time lag is expected to be small related to an annual reporting cycle.

3 ENERGY [CRF sector 1]

3.1 Sector overview

For the pollutants and sources discussed in this section, emissions result from the combustion of fuel. The pollutants estimated are: carbon dioxide (CO_2), NO_X as nitrogen dioxide, nitrous oxide (N_2O), methane (CH_4), non methane volatile organic compounds (NMVOC), carbon monoxide (CO), and sulphur dioxide (SO_2). The sources covered are:

- Electricity (power plants and industrial producers);
- Refineries (combustion);
- Chemical and petrochemical industries (combustion);
- Construction industries (roof tiles, bricks);
- Other industries (metal works factories, food, textiles, others);
- Road Transport;
- Shipping;
- Railways;
- Aircraft;
- Domestic;
- Commercial;
- Public Service;
- Fishing and Agriculture.

The national emission inventory is prepared using energy consumption information available from national statistics and an estimate of the actual use of the fuels. The latter information is available at sectoral level in many publications but the evaluation of emissions of methane and nitrous oxide is needed. Those emissions are related to the actual physical conditions of the combustion process and to environmental conditions.
The continuous monitoring of GHG emissions in Italy is not regular especially in some sectors; hence, information is not often available on actual emissions over a specific period from an individual emission source. Therefore, the majority of emissions are estimated from different information such as fuel consumption, distance travelled, or some other statistical data related to emissions.
Estimates for a particular source sector are calculated by applying an emission factor to an appropriate statistic. That is:

Total Emission = Emission Factor x Activity Statistic

Emission factors are typically derived from measurements on a number of representative sources and the resulting factor applied to the whole country.
For some categories, emissions data are available at individual site. Hence, emissions for a specific category can be calculated as the sum of the emissions from these point sources. That is:

Emission = Σ Point Source Emissions

However, it is necessary to carry out an estimate of the fuel consumption associated with these point sources, so that emissions from non-point sources can be estimated from fuel consumption data without double counting. In general, point source approach is applied to specific point sources (e.g. power stations, cement kilns, refineries). Most non-industrial sources are estimated using emission factors.
For most of the combustion source categories, emissions are estimated from fuel consumption data reported in the National Energy Balance (BEN) and from an emission factor appropriate to the type of combustion. However, the industrial category covers a range of sources and types, so the inventory disaggregates this category into several sub-categories, namely:

- Other Industry;
- Other Industry Off-road (see paragraph 3.6);
- Iron & Steel (Combustion, Blast Furnaces, Sinter Plant);
- Petrochemical industries (Combustion);
- Other combustion with contact industries: glass and tiles;
- Other industries (Metal works factories, food, textiles, others);

- Ammonia Feedstock (natural gas only);
- Ammonia (Combustion) (natural gas only);
- Cement (Combustion);
- Lime Production (non-decarbonising).

Thus, the estimate from fuel consumption emission factors refers to stationary combustion in boilers and heaters. The other categories are estimated by more complex methods discussed in the relevant sections. However, for these processes, where emissions arise from fuel combustion for energy production, these are reported under IPCC Table 1A. The fuel consumption of Other Industry is estimated so that the total fuel consumption of these sources is consistent with the national energy balance.
Fugitive emissions are also estimated and reported under 1B category and the relevant information are provided in paragraph 3.9.
From the 2015 submission, the UNFCCC Reporting Guidelines require estimating a new source category, emissions from the CO_2 storage and distribution category, but in Italy this activity and the relevant emissions do not occur yet.
According to the IPCC 2006 Guidelines (IPCC, 2006), electricity generation by companies primarily for their own use is auto-generation, and the emissions produced should be reported under the industry concerned. However, most national energy statistics (including Italy) report emissions from electricity generation as a separate category. The Italian inventory makes an overall calculation and then attempts to report as far as possible according to the IPCC methodology:

- auto-generators are reported in the relevant industrial sectors of section "1.A.2 Manufacturing Industries and Construction", including sector "1.A.2.g Other";
- refineries auto-generation is included in section 1.A.1.b;
- iron and steel auto-generation is included in section 1.A.1.c;
- autogeneration of energy and heat in the incinerators is reported in 1.A.4.a.

These reports are based on TERNA estimates of fuel used for steam generation connected with electricity production (TERNA, several years).
Emissions from waste incineration facilities with energy recovery are reported under category 1.A.4.a (Combustion activity, commercial/institutional sector), for the fossil and biomass fraction of waste incinerated in the other fuel and biomass subcategories respectively, whereas emissions from other types of waste incineration facilities are reported under category 5.C (Waste incineration).
In fact, energy recovered by these plants is mainly used for district heating of commercial buildings or is auto consumed in the plant. For 2020, 99% of the total amount of waste incinerated is treated in plants with energy recovery system. Although there are not data or a robust estimate of the share of waste used to produce electricity the available literature (ENEA-federAmbiente, 2012) provides that in 2010 the gross electricity production by urban waste incinerators was equal to 3887 GWh (net 3190 GWh) and the amount sent to the network was equal to only 121 GWh. To estimate CO_2 emissions, considering the total amount of waste incinerated in plants with energy recovery, carbon content is calculated, as described in paragraph 7.4.2, in the waste chapter. Different emission factors for municipal, industrial and oils, hospital waste, and sewage sludge are applied, as reported in the waste chapter, Tables 7.19-7.23. Waste amount is then converted in energy content applying the conversion factor resulting from data provided by TERNA and equal in 2020 to 11.4 GJ/t of waste. In 2020, the resulting average emission factor for the fossil part of waste is equal to 96.0 kg CO_2/GJ while for the biomass is equal to 82.1 kg CO_2/GJ.
Landfill gas recovered is used for heating and power in commercial facilities, the resulting emissions are reported under 1.A.4.a in biomass. In 2020, the resulting average emission factor is equal to 49.9 kg CO_2/GJ.
Biogas recovered from the anaerobic digester of animal waste is used for utilities in the agriculture sector and relative emissions are reported under 1.A.4.c in biomass. In 2020, the resulting average emission factor is equal to 53.9 kg CO_2/GJ.
Italy allocates these emissions to the 1.A.4 category because the energy produced in these plants, incinerators or landfills, as well as energy produced by biogas collection from manure and agriculture residue, is prevalently auto-consumed for heating and electricity of the buildings or animal recoveries, and only a few amount of energy produced goes to the electrical grid.

Emission trends

In 2020, the energy sector accounts for 95.3% of CO_2 emissions, 15.6% of CH_4 and 21.7% of N_2O. In terms of CO_2 equivalent, the energy sector shares 78.4% of total national greenhouse gas emissions excluding LULUCF.

Emission trends of greenhouse gases from the energy sector are reported in Table 3.1.

Table 3.1 GHG emission trends in the energy sector 1990-2020 (Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Total Energy	425.3	437.9	459.6	487.6	428.9	358.8	355.4	349.9	345.4	335.1	298.9
CO_2	409.2	421.5	443.9	472.7	413.9	345.6	342.8	337.2	333.2	323.8	288.0
CH_4	11.5	11.1	10.3	9.5	9.7	8.5	8.0	8.1	7.5	6.8	6.7
N_2O	4.6	5.4	5.4	5.4	5.3	4.7	4.6	4.6	4.6	4.5	4.2

Source: ISPRA elaborations

The emission trend is generally driven by the economic indicators as already shown in chapter 2.

From 2005, GHG emissions from the sector are decreasing as a result of the policies adopted at European and national level to implement the production of energy from renewable sources. From the same year, a further shift from petrol products to natural gas in producing energy has been observed as a consequence of the starting of the EU greenhouse gas Emission Trading Scheme (EU ETS) in January, 1st 2005.

From 2009, a further drop of the sectoral emissions is due to the economic recession. From 2008 to 2009 the decrease observed in total GHG emissions is equal to -10.6% indeed, followed by a slight increase, equal to +2.7% from 2009 to 2010; since then annual variations are always negative till 2015 where emissions increased of 3.6% with respect to 2014 due to a reduction in energy production by hydroelectric which resulted in an increase of energy production from thermoelectric plants to satisfy the energy demand. From 2016 to 2019 emissions from the sector decrease of 6.6% compared to the 2015 as a consequence of a shift from coal to natural gas fuel consumption for energy production. In 2020 there is a further significant decrease in emissions due to the pandemic and the consequent lock-down regime to which the country has been subjected.

In Table 3.2, the electricity production distinguished by source for the whole time series is reported on the basis of data supplied by the national grid operator (ENEL, several years; TERNA, several years). From 2010 to 2014 a drop in electricity generation from fossil fuels has been observed in Italy. The drop has been driven both by the economic recession and by the increase of renewable sources for energy production. The use of natural gas and coal is generally driven by the market; in 2011, from one side there was a minor availability (and higher prices) of natural gas imported by pipelines from Algeria and Libya, due to the "spring revolutions" occurring in these countries in that year, on the other side a new coal power plant, one of the largest in Italy, was fully operative with a production of around 12500 GWh explaining the increasing trend of electricity production from solid fuels.

In "other fuels" a multitude of fuels are included, as biomass, waste, biogas from agriculture residues and waste and synthesis gases from heavy residual or chemical processes. The breakdown is available to the inventory expert allowing emission estimations, but it is confidential and not published by the owner of the information, TERNA.

Table 3.2 Production of electricity by sources 1990-2020 (GWh)

Source	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
	GWh										
Hydroelectric	35,079	41,907	50,900	42,927	54,407	46,970	44,257	38,025	50,503	48,154	49,495
Thermoelectric	178,590	196,123	220,455	253,073	231,248	192,054	199,430	209,485	192,730	195,734	181,307
- solid fuels	32,042	24,122	26,272	43,606	39,734	43,201	35,608	32,627	28,470	18,839	13,380
- natural gas	39,082	46,442	97,607	149,259	152,737	110,860	126,148	140,349	128,538	141,687	133,683
- derivated gases	3,552	3,443	4,252	5,837	4,731	2,220	2,832	2,501	2,520	2,452	1,697
- oil products	102,718	120,783	85,878	35,846	9,908	5,620	4,127	4,083	3,289	3,453	3,175
- other fuels	1,196	1,333	6,446	18,525	24,138	30,151	30,715	29,924	29,914	29,302	29,373
Geothermic	3,222	3,436	4,705	5,325	5,376	6,185	6,289	6,201	6,105	6,075	6,026
Eolic and Photovoltaic	0	14	569	2,347	11,032	37,786	39,793	42,120	40,370	43,891	43,703
Total	216,891	241,480	276,629	303,672	302,062	282,994	289,769	295,830	289,709	293,853	280,531

Source: TERNA

More in general, the share of the total energy consumption by primary sources in the period 1990- 2020, reported in Table 3.3, shows an evident change from oil products and solid fuels to natural gas and renewable while the share of consumption of electricity is variable and driven by the market.

Table 3.3 Total energy consumptions by primary sources 1990-2020 (%)

Sources	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
	%										
renewable	0.7	0.9	1.1	2.0	4.3	8.8	8.7	10.5	10.4	10.6	11.5
solid fuels	9.6	7.9	6.9	8.6	8.0	8.0	7.2	5.9	5.5	4.2	3.6
natural gas	23.7	25.7	31.4	36.0	36.2	35.8	37.9	38.9	38.2	39.5	41.5
crude oil	56.2	54.9	49.5	43.1	38.5	36.7	35.8	35.0	35.1	35.0	32.0
primary electricity	9.8	10.5	11.1	10.3	13.1	10.8	10.3	9.8	10.8	10.7	11.4

Source: Ministry of Economic Development

Further analysis on the electricity generation time series and CO_2 emission factors are available at the following web address: http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view.

Recalculations

In 2015 submission, recalculations regarded the whole sector due to the application of the IPCC 2006 Guidelines which provide new default emission and oxidation factors for all the fuels. In particular, in the Guidelines (IPCC, 2006) oxidation factors are supposed to be equal to 1 for all the fuels. Time series have been reconstructed for all the fuels taking in account the default values proposed by the Guidelines and national circumstances. In Annex 6 more detailed information is provided especially with regard to time series of country specific CO_2 emission factors.

In 2022 submission some recalculations occurred as in the following.

The emission factor for natural gas has been updated for 2019 because of the update of the percentage of national biogas production. Updated emission factors are provided in Annex 6.

In the fugitive sector, the most relevant recalculation, that affects the last two years, is is the revision of average emission factor for natural gas distribution in medium and low pressure network

In 2022 submission the historical series has been revised mainly as a result of the upgrade of Copert model version used (from version 5.4.36 in last submission to 5.5.1 in submission 2022), which resulted in various methodological updates. Detailed information is reported in paragraph 3.5.3.

Waste fuel consumption for commercial heating activity data has been updated from 2018 because of the update of activity data for some industrial waste plants. Detailed information is reported in paragraph 3.6.

Recalculations affected the whole time series 1990-2019 for all gases.

Diesel oil fuel consumption for agriculture off-road and fishing has been updated for 2019 due to an error fixed.

The following table shows the percentage differences between the 2022 and 2021 submissions for the total energy sector and by gas.

Recalculation resulted for the energy sector in a decrease of GHG emissions in 1990 of 0.01% and in 2019 of 0.46%.

Table 3.4 Emission recalculations in the energy sector 1990-2019 (%)

Year	GHG	CO2	CH4	N2O
1990	-0.01	0.00	0.00	-0.52
1991	-0.01	0.00	0.00	-0.50
1992	-0.01	0.00	0.00	-0.48
1993	0.00	0.00	0.00	-0.37
1994	0.00	0.00	0.00	-0.17
1995	0.00	0.00	0.00	-0.07
1996	0.00	0.00	0.00	0.01
1997	0.00	0.00	0.00	0.03
1998	0.00	0.00	0.00	0.14
1999	0.00	0.00	0.00	0.12
2000	0.00	0.00	0.00	0.25
2001	0.00	0.00	0.00	0.27
2002	0.00	0.00	-0.01	0.25
2003	0.00	0.00	0.00	0.17
2004	0.00	0.00	0.00	0.10
2005	0.00	0.00	0.00	0.00
2006	0.00	0.00	0.00	-0.24
2007	0.00	0.00	0.00	-0.32
2008	-0.02	0.00	-0.94	-0.38
2009	-0.03	0.00	-1.10	-0.49
2010	-0.03	0.00	-1.20	-0.56
2011	-0.03	0.00	-1.07	-0.68
2012	0.04	0.07	-1.04	-0.64
2013	-0.07	-0.04	-0.94	-0.72
2014	-0.08	-0.05	-0.89	-0.86
2015	-0.07	-0.04	-0.99	-0.86
2016	-0.05	0.03	-3.09	-0.88
2017	-0.15	-0.02	-4.93	-0.87
2018	-0.16	-0.01	-5.87	-0.97
2019	-0.46	-0.17	-11.66	-2.27

Source: ISPRA elaborations

Key categories

Key category analysis, for the years 1990 and 2020, identified 24 categories at level or trend assessment with Approach 1 and Approach 2 in the energy related emissions.

In the case of the energy sector in Italy, a sector by sector analysis instead of a source by source analysis will better illustrate the accuracy and reliability of the emission data, given the interconnection between the underlying data of most key categories.

In the following box, key categories for 2020 are listed, making reference to the section of the text where they are quoted.

Key-categories identification in the energy sector with the IPCC Approach 1 and Approach 2 for 2020

KEY CATEGORIES	without LULUCF	with LULUCF	Relevant paragraphs	Notes
1 Transport - CO_2 Road transportation	L,T	L,T	3.5.3	Tables 3.21-3.29
2 Other sectors - CO_2 commercial, residential, agriculture gaseous fuels	L,T	L,T	3.6	Tables 3.32-3.35
3 Energy industries - CO_2 solid fuels	L,T	L,T	3.3	Tables 3.6-3.9
4 Energy industries - CO_2 gaseous fuels	L,T	L,T	3.3	Tables 3.6-3.9
5 Manufacturing industries and construction - CO_2 gaseous fuels	L,T	L,T	3.4	Tables 3.10-3.13

KEY CATEGORIES	without LULUCF	with LULUCF	Relevant paragraphs	Notes
6 Energy industries - CO_2 liquid fuels	L,T	L,T	3.3	Tables 3.6-3.9
7 Other sectors - CO_2 commercial, residential, agriculture liquid fuels	L,T	L,T	3.9	Tables 3.32-3.35
8 Manufacturing industries and construction - CO_2 liquid fuels	L,T	L1,T	3.4	Tables 3.10-3.13
9 Fugitive - CH_4 Oil and natural gas - Natural gas	L,T	L,T	3.9	Tables 3.40-3.46
10 Other sectors - CH_4 commercial, residential, agriculture biomass	L,T	L,T	3.6	Tables 3.32-3.35
11 Manufacturing industries and construction - CO_2 solid fuels	L1,T	L1,T	3.4	Tables 3.10-3.13
12 Other sectors - CO_2 commercial, residential, agriculture other fossil fuels	L1,T	L1,T	3.6	Tables 3.32-3.35
13 Other sectors - N_2O commercial, residential, agriculture biomass	L2,T	L2,T	3.6	Tables 3.32-3.35
14 Transport - CO_2 Waterborne navigation	L1	L1, T1	3.5.4	Table 3.30
15 Fugitive - CO_2 Oil and natural gas - Oil	L1	L1	3.9	Tables 3.40-3.46
16 Other sectors - N_2O commercial, residential, agriculture liquid fuels	L2		3.6	Tables 3.32-3.35
17 Other sectors - CO_2 commercial, residential, agriculture solid fuels	T1	T1	3.6	Tables 3.32-3.35
18 Transport - CH_4 Road transportation	T2		3.5.3	Tables 3.21-3.29
19 Fugitive - CH_4 Oil and natural gas - Other - flaring in refineries	L2, T2	L2, T2	3.9	Tables 3.40-3.46
20 Fugitive - CO_2 Oil and natural gas - Other - flaring in refineries	T2		3.9	Tables 3.40-3.46

With reference to the box, thirteen key categories (n. 2-8, 10-13, 16-17) are linked to stationary combustion and to the same set of energy data: the energy sector CRF Table 1.A.1, the industrial sector, Table 1.A.2 and the civil sector Tables 1.A.4a and 1.A.4b.
Ten out of thirteen key categories refer to CO_2 emissions, two categories refer to CH_4 and N_2O emissions from the use of biomass in the residential sector, the last category refers to N_2O emissions from liquid fuels in other sectors.
All these sectors refer to the national energy balance (MSE, several years [a]) for the basic energy data and the distribution among various subsectors, even if more accurate data for the electricity production sector can be found in TERNA publications (TERNA, several years). Evolution of energy consumptions/emissions is linked to the activity data of each sector; see paragraph 3.3, 3.4 and 3.6 and Annex 2 for the detailed analysis of those sectors.
Electricity production is the most “dynamic” sector and the energy emissions trend, for CO_2, N_2O and CH_4, is mainly driven by the thermoelectric production, see Tables A2.1 and A2.4 for more details.
In the following table emissions in kt of CO_2 equivalent for stationary combustion key categories at level assessment are summarized.
From 1990 to 2020, an increase in use of natural gas instead of fuel oil and gas oil in stationary combustion plants is observed; it results in a decrease of CO_2 emissions from combustion of liquid fuels and an increase of emissions from gaseous fuels used in the different sectors. Coal and coke for residential heating has been banned and reduced to 0.
The increase of CH_4 emissions from other sector reflects the increase of the use of biomass for residential heating.

Table 3.5 Stationary combustion, GHG emissions in 1990 and 2020 (kt CO_2 eq)

	1990	2020
Energy industries - CO2 liquid fuels	81,197	14,415
Energy industries - CO2 solid fuels	38,647	15,613
Other sectors - CO2 commercial, residential, agriculture liquid fuels	38,274	13,610
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	36,338	55,195
Manufacturing industries and construction - CO2 liquid fuels	32,805	8,677
Manufacturing industries and construction - CO2 gaseous fuels	32,234	30,744
Manufacturing industries and construction - CO2 solid fuels	25,732	4,985
Energy industries - CO2 gaseous fuels	16,954	51,148
Other sectors - CH4 commercial, residential, agriculture biomass	996	2,153
Other sectors - N2O commercial, residential, agriculture liquid fuels	996	760
Manufacturing industries and construction - N2O liquid fuels	926	395
Other sectors - CO2 commercial, residential, agriculture solid fuels	899	0
Other sectors - N2O commercial, residential, agriculture biomass	531	1,156
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	530	5,778

Source: ISPRA elaborations

Another group of key categories (n. 1, 14, 18) referred to the transport sector, with basic total energy consumption reported in the national energy balance and then subdivided in the different subsectors with activity data taken from various statistical sources; see paragraph 3.5, transport, for an accurate analysis of these key sources. This sector also shows a remarkable increase in emissions in the '90s, in particular CO_2 from air transport and road transport, as can be seen in Table 3.19 and Table 3.28, respectively. In the last years CO_2 emissions from road transport started to decrease as a consequence of the economical crisis and the reduction of the average fuel consumption per kilometre of the new vehicles. The trend of N_2O and CH_4 emissions is linked to technological changes occurred in the period.
Finally, the last four key categories (n. 9, 15, 19 and 20) refer to oil and gas operations. For this sector basic overall production data are reported in the national balance but emissions are calculated with more accurate data published or delivered to ISPRA by the relevant operators, see paragraph 3.9.
Most of the categories described are also key categories for the years 1990 and 2020 taking into account LULUCF emissions and removals.

3.2 Methodology description

Emissions are calculated by the equation:

$$E(p,s,f) = A(s,f) \times e(p,s,f)$$

where
$E(p,s,f)$ = Emission of pollutant p from source s from fuel f (kg)
$A(s,f)$ = Consumption of fuel f by source s (TJ-t)
$e(p,s,f)$ = Emission factor of pollutant p from source s from fuel f (kg/TJ-kg/t)

The fuels covered are listed in Table A2.2 in Annex 2, though not all fuels occur in all sources. Sector specific tables specify the emission factors used.
Emission factors are expressed in terms of kg pollutant/ TJ based on the net calorific value of the fuel.
The carbon factors used are based on national sources and are appropriate for Italy. Most of the CO_2 emission factors have been crosschecked with the results of specific studies that evaluate the carbon content of the imported/produced fossil fuels at national level. A comparison of the current national factors with the IPCC ones has been carried out; the results suggest quite limited variations in liquid fuels and some differences in natural gas, explained by basic hydrocarbon composition, and in solid fuels.
Monitoring of the carbon content of the fuels nationally used is an ongoing activity at ISPRA. The principle is to analyse regularly the chemical composition of the used fuel or relevant activity statistics, to estimate the carbon content and the emission factor. National emission factors are reported in Table 3.12 and Table 3.21. The specific procedure followed for each primary fuel (natural gas, oil, coal) is reported in Annex 6.

In response to the review process of the Initial report of the Kyoto Protocol, N_2O and CH_4 stationary combustion emission factors were revised, in the 2006 submission, for the whole time series taking into account default IPCC (IPCC, 1997; IPCC, 2000) and CORINAIR emission factors (EMEP/CORINAIR, 2007). Then the emission factors have been compared also with those reported in the 2006 IPCC Guidelines where the default ones are more or less the same of those available in the IPCC 1996 guidelines. In the following table the comparison at fuel level is provided.

EF (g/GJ)	CH4						N2O							
	IPCC 1996	IPCC 2006	EMEP/ CORINAIR	expert Judgement	**Emission Inventory electricity**	**Emission Inventory industry**	IPCC 1996	IPCC 2006	IPCC 2006 upper level	EMEP/ CORINAIR	EMEP/ CORINAIR industry with contact	expert Judgement	**Emission Inventory electricity**	**Emission Inventory industry**
coal	1	1	1.5 - 15	2.4	**1.5**	**1.5**	1.4	1.5	5	5.0 - 30	3.0 - 12.0	1.3 - 7.5	**7**	**1.4**
natural gas	1	1	0.3 - 4	1.0 - 3	**1.5**	**1**	0.1	0.1	0.3	0.1 - 3	1.0 - 3.0	0.09 - 0.85	**1.5**	**1.5**
fuel oil	3	3	0.1 - 10	3	**3**	**3**	0.6	0.6	2	1.4 - 14.8	2.0 - 15.0	2.6 - 3.3	**2.6**	**1.4**
gasoil/orimulsion		3	0.1 - 8		**1.5**	**0.1**		0.6	2	0.6 - 14				
LPG		1	1 - 2.5		**1**	**1**		0.1		1.0 - 14			**1.4**	**1.4**
petcoke		3			**1.5**	**1.5**		0.6		1.4 - 14	3.0 - 14.0		**1.4**	**1.4**
wood	30	30	1.0 - 40		**30**	**28**	4	4		4.3	4.0 - 14.0		**14**	**14**
biomass/waste	30	30	4.0 - 40		**5**	**5**	4	4		4			**9**	**9**

The emission factors should apply for all years provided there is no change in the carbon content of fuel over time. There are exceptions to this rule:

- transportation fuels have shown a significant variation around the year 2000 due to the reformulation of gasoline and diesel to comply with the EU directive, see Table 3.21;
- the most important imported fuels, natural gas, fuel oil and coal show variations of carbon content from year to year, due to changes in the origin of imported fuel supply; a methodology has been set up to evaluate annually the carbon content of the average fuel used in Italy, see Annex 6 for details;
- derived gases produced in refineries, as petcoke, refinery gas and synthesis gas from heavy residual fuel, in iron and steel integrated plants, as coke oven gas, blast furnaces gas and oxygen converter gas, and in chemical and petrochemical plants have been calculated from 2005 on the basis of the analysis of information collected by the plants in the framework of EU ETS, see Annex 6 for details.

The activity statistics used to calculate emissions are fuel consumptions provided annually by the Ministry of Economic Development (MSE) in the National Energy Balance (MSE, several years [a]), by TERNA (TERNA, several years) for the power sector and some additional data sources to characterise the technologies used at sectoral level, quoted in the relevant sections.

Activity data collected in the framework of the EU ETS scheme do not cover the overall energy sector, whereas the official statistics available at national level, such as the National Energy Balance (BEN) and the energy production and consumption statistics supplied by TERNA, provide the complete basic data needed for the emission inventory.

Italian energy statistics are mainly based on the National Energy Balance. The report is reliable, by international standards, and it may be useful to summarize its main features:

- it is a balance, every year professional people carry out the exercise balancing final consumption data with import-export information;
- the balance is made on the energy value of energy carriers, taking into account transformations that may occur in the energy industries (refineries, coke plants, electricity production);
- data are collected regularly by the Ministry of Economic Development, on a monthly basis, from industrial subjects;
- oil products, natural gas and electricity used by industry, civil or transport sectors are taxed with excise duties linked to the physical quantities of the energy carriers; excise duties are differentiated in products and final consumption sectors (i.e. diesel oil for industrial use pays duties lower than for transportation use and higher than for electricity production; even bunker fuels have a specific registration paper that state that they are sold without excise duties);
- concerning energy consumption information, this scheme produces highly reliable data: BEN is based on registered quantities of energy consumption and not on estimates; uncertainties may be present in the effective final destination of the product, but total quantities are reliable;
- coal is an exception to this rule, it is not subject to excise duties; consumption information is estimated; anyway, it is nearly all imported and a limited number of operators use it and the Ministry of Economic Development monitors all of them on a monthly basis.

The energy balances of fuels used in Italy, published by the Ministry of Economic Development (MSE, several years [a]), compare total supply based on production, exports, imports, stock changes and known losses with the total demand; the difference between total supply and demand is reported as 'statistical difference'. In Annex 5, 2020 data communicated by Italy to the Joint Questionnaire OECD/IEA/EUROSTAT in the format revisited by EUROSTAT are reported, while the full time series is available on website: http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp. Some differences between data communicated to the international organizations and EUROSTAT publication have been observed and are under investigation; they should mainly due to the use of default instead of country specific energy conversion factors and different classification criteria of fuels.
Data submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT have been used for solid, liquid and gaseous fuel consumptions. At the time it was not possible to reconstruct the entire time series at category level and data from national energy balance (BEN) have been also used for this purpose. Moreover, the complete use of the energy data provided by the MSE to the Joint Questionnaire is planned in substitution, as possible, of the national energy balances.
Some inconsistencies have been found in data communicated at Eurostat and referring to the ninety years, especially in the sectoral distribution of fuels; in these cases, the information already available in the national energy balances has been maintained because of considered more reliable and consistent in the time series.
In Annex 5, 2020 data derived by the Joint Questionnaire OECD/IEA/EUROSTAT are reported in the format revisited by EUROSTAT. Some differences between data communicated to the international organizations and EUROSTAT publication have been observed and are mainly due to the use of default instead of country specific energy conversion factors and different classification criteria of fuels. In the 2020 submission data submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT have been used reconstructing the time series for all the fuels as planned in the previous submission.
Additionally, to fossil fuel, the Joint Questionnaire reports commercial wood and straw combustion estimates for energy use, biodiesel and biogas. The estimate of GHG emissions is based on these data and on other estimates (ENEA, several years) for non commercial wood use. Carbon dioxide emissions from biomass combustion are not included in the national total as suggested in the IPCC Guidelines (IPCC, 2006) but emissions of other GHGs and other pollutants are included. CORINAIR methodology (EMEP/EEA, 2016) includes emissions from the combustion of wood in the industrial and domestic sectors as well as the combustion of biomass in agriculture.
The inventory includes also emissions from the combustion of lubricants based on data collected from waste oil recyclers and quoted in the energy balance; from 2002 onwards, this estimate is included in the column “Refinery feedstock”, row “Productions” (MSE, several years [a]) Primary fuels. From 2001 onwards, it has been necessary to use also these quantities to calculate emissions in the reference approach, so as to minimize differences with sectoral approach. From 2001, the energy balances prepared by MSE include those quantities in the input while estimating final consumption; this procedure summarizes a complex stock change reporting by operators. According to the IPCC 2006 Guidelines (IPCC, 2006), in the emission inventory, in the energy sector are reported only emissions from the combustion of lubricants in two strokes engines while the other emissions are reported in the IPPU sector.

3.3 Energy industries

A detailed description of the methodology used to estimate greenhouse gas emissions from electricity production under 1.A.1.a, 1.A.1.b and 1.A.1.c is reported in Annex 2. Basic data, methodology and emission factors used to estimate emissions are derived from the same sources. In the following sub-paragraphs additional information on the specific categories are supplied.
In this category, gaseous fuels refer to natural gas while solid fuels mainly to coal used to produce energy and derived gases used in the integrated iron and steel plants; liquid fuels include residual oil fuel consumption used for energy production in power plants and different fuels used in refineries. The CO_2 implied emission factor trend for the sector is driven by the liquid fuel consumption in the petroleum refining industry (95% of the total of liquid) where many fuels, with very different emission factors, are used, such as refinery gas, that have an average emission factor value equal to 56.1 t/TJ, and petroleum coke with an average emission factor equal to 97.1 t/TJ. In the last years, due also to the economical crisis, a reduction in the consumption of synthesis gas from heavy residual fuels (in 2020 the average emission factors t CO_2/TJ values are about 80.5 and 102.9 for heavy residual fuels and synthesis gas respectively) is observed, resulting in the interannual variations. Emission factors time series for these fuels are reported in Annex 6.

3.3.1 Public Electricity and Heat Production

3.3.1.1 Source category description

This paragraph refers to the main electricity producers that produce electricity for the national grid. From 1998 onwards, the expansion of the industrial cogeneration of electricity and the split of the national monopoly have transformed many industrial producers into "independent producers", regularly supplying the national grid. These producers account in 2020 for 92.8% of all electricity produced with combustion processes in Italy (TERNA, several years).

No data on consumption/emissions from heat production is reported in this section. In Italy, only limited data do exist about producers working for district heating grids; most of the cogenerated heat is produced and used on the same site by industrial operators. Therefore, data on heat production is not reported here but in Table1.A(a)s2 for industry and Table1.A(a)s4 for district heating. In TERNA yearly publication, heat cogenerated while producing electricity is reported separately. Unfortunately, no details are reported on the final use of cogenerated heat, so it can be used in the inventory preparation just to cross check the total fuel amount with other sources as EU ETS or the consumption of fuels in the industry reported in BEN.

Under biomass, wood and charcoal consumption and relevant emissions are reported until 2007; CO_2 emission factor is shown in Table 3.12 while CH_4 and N_2O emission factors are equal to 30 g/GJ and 4 g/GJ respectively. From 2008 also bioliquid fuel is used and included under biomass (CH_4 and N_2O emission factors equal to 12 g/GJ and 2 g/GJ respectively), resulting in the decrease of the average emission factor.

Other fuels subcategory refer mainly to fuel consumptions of other liquid, solid and gaseous fuels such as industrial wastes (83.5 tCO_2/TJ), that are more than half of the total TJ of the subcategory, as plastics, rubber, and solvents, synthesis gas from heavy residual (102.9 tCO_2/TJ in 2020) and other liquid fuels (76.5 tCO_2/TJ in 2020); the average CO_2 emission factor has been calculated for the whole time series and it is equal to 94.5 t/TJ in 2020.

CO_2 implied emission factor trend of liquid fuels for this category is driven by the mix of high and low sulphur fuel oil consumptions that is changed in the years as a consequence of the adoption of air quality European Directives introducing air pollutants ceilings at the stacks, and the policies at national level which established stringent ceiling for new and old plants and a timing scheduled for their implementation. The CH_4 implied emission factor is the weighted average of gasoil and residual oil emission factors equal to 1.5 g/GJ and 3 g/GJ respectively. The general decreasing trend is due to the minor use of fuel oil for energy production, at the minimum in the last years, while the amount of gasoil, which is related to the start up of power plants and to the gasoil used in stationary engines, has a more stable trend.

3.3.1.2 Methodological issues

The data source on fuel consumption is the annual report "Statistical data on electricity production and power plants in Italy" ("Dati statistici sugli impianti e la produzione di energia elettrica in Italia"), edited from 1999 by the Italian Independent System Operator (TERNA, several years). The reports refer to the total of producers and the estimate of the part belonging to public electricity production is made by the inventory team on the basis of detailed electricity production statistics by industrial operators. Data on total electricity production for the year 2020 are reported in Annex 2. For the time series, see previous NIR reports. The emission factors used are listed in Table 3.12.

Another source of information is the National Energy Balance (MSE, several years [a]), which contains data on the total electricity producing sector. The data of the national energy balance (BEN) are also used to address the statistical survey of international organizations, OECD, IEA and Eurostat. Both BEN and TERNA publications could be used for the inventory preparation, as they are part of the national statistical system and published regularly.

A detailed analysis of both sources is reported in Annex 2. TERNA data appears to be more suitable for inventory preparation. From year 2005 onwards a valuable source of information is given by the reports prepared for each industrial installation subject to EU ETS scheme. These reports are prepared by independent qualified verifiers and concern the CO_2 emissions, emission factors and activity data, including fuel used. ISPRA receives copy of the reports from the competent authority (Ministry of Environment) and has been able to extract the information relative to electricity production. The information available is very useful but not fully covering the electricity production sector or the public electricity production. The EU ETS does not include all installations, only those above 20 MWe, it is made on a point source basis so the data include electricity and heat production while the corresponding data from TERNA, concerning only the fuel used for

electricity production, are commercially sensitive, confidential and they are not available to the inventory team. Anyway, the comparison of data collected by TERNA with those submitted to the EU ETS allows identifying possible discrepancies in the different datasets and thus providing the Ministry of Economic Development experts with useful suggestions to improve the energy balance.
For verification purposes a rather complex calculation sheet has been used to estimate CO_2 emissions, and also N_2O and CH_4 emissions (APAT, 2003[a]).
Moreover, the model has also been able to estimate the energy/emissions data related to the electricity produced and used on site by the main industrial producers. These data are reported in the other energy industries, Tables 1.A.1.b and 1.A1.c, and in the industrial sector section, Tables 1.A.2. More detailed information is supplied in Annex 2.
In Table 3.6, fuel consumptions and emissions of 1.A.1.a category are reported for the time series. Table 3.6 shows a decrease in fuel consumption and overall decrease in GHG emissions. However, a slower increase is observed in CH_4 emissions due to the increase in use of natural gas and biomass.

Table 3.6 Public electricity and heat production: Energy data (TJ) and GHG emissions, 1990-2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Fuel consumption (TJ)	1,441,741	1,472,753	1,554,810	1,709,208	1,480,778	1,205,336	1,205,807	1,260,762	1,147,923	1,146,779	1,056,626
GHG (Gg)	109,072	110,730	109,546	115,849	97,553	79,339	76,678	78,506	70,560	67,353	60,217
CO_2 (Gg)	108,670	110,335	109,193	115,445	97,195	78,922	76,289	78,127	70,207	67,034	59,921
CH_4 (Gg)	3.8	4.0	3.6	4.0	3.6	4.2	4.3	4.3	4.1	4.1	4.1
N_2O (Gg)	1.0	1.0	0.9	1.0	0.9	1.0	0.9	0.9	0.8	0.7	0.7

Source: ISPRA elaborations

In 2020, consumption is fairly in line with the previous year's data taking in account the pandemic. Moreover, it has been possible to observe a shift from coal to natural gas for energy production in the last years.
As the main data source refers to the whole electricity production sector, the uncertainty and time-series consistency, source-specific QA/QC and verification, recalculations and planned improvements are all addressed in Annex 2.

3.3.2 Refineries

3.3.2.1 Source category description

This subsector covers the energy emissions from the national refineries (14 plants in 2020), including the energy used to generate electricity for internal use and exported to the national grid by power plants that directly use off-gases or other residues of the refineries. These power plants are generally owned by other companies but are located inside the refinery premises or just sideway. In 2020 the power plants included in this source category have generated 6.7% of all electricity produced with combustion processes in Italy.
The energy consumption and emissions are reported in CRF Table 1.A.1.b. Parts of refinery losses, flares, are reported in CRF Table 1.B.2.a and c, using IPCC emission factors.

3.3.2.2 Methodological issues

The consumption data used for refineries come from BEN (MSE, several years [a]); the same data are also reported by Unione Petrolifera, the industrial category association (UP, several years). From 2005 onwards, also the EU ETS "verified reports" cover almost the entire sector, for energy consumptions, combustion emissions and process emissions. Other sources of information are the yearly reporting obligations for the large combustion plants under European Directive (LCP) and the E-PRTR Regulation; both data collections include most of refineries but not all the emission sources.
The available data in BEN specify the quantities of refinery gas, petroleum coke and other liquid fuels (MSE, several years [a]).

For the part of the energy and related emissions due to the power plants, the source is TERNA (see Annex 2 for further details). The quota of total energy consumption from electricity production included in category 1.A.1.b is estimated by the electricity production model on the basis of fuels used and plant location.
All the fuel used in boilers and processes, the refinery "losses" and the reported losses of crude oil and other fuels (that are mostly due to statistical discrepancies) are considered to calculate emissions. Fuel lost in the distribution network is accounted for here and not in the individual end use sector. From 2002 particular attention has been paid to avoid double counting of CO_2 emissions checking if the refinery reports of emissions already include losses in their energy balances. IPCC Tier 2 emission factors and national emission factors are used as reported in Table 3.12.
From 2008, TERNA modified the detailed table of fuel consumption and related energy produced introducing a more complete list of fuels. Aim of the change was to revise the consumption values of waste fuels which are very important for estimating the contribution of renewable to electricity production and consequently greenhouse gases.
In Table 3.7, a sample calculation for the year 2020 is reported, with energy and emission data.

Table 3.7 Refineries, CO_2 emission calculation, year 2020

	Consumption, TJ				CO_2 emissions, Gg			
REFINERIES	Petroleum coke	Ref. gas	Liquid fuels	Natural gas	Petroleum coke	Ref. gas	Liquid fuels	Natural gas
energy		28,216	56,748	66,267		1,584	4,928	3,838
furnaces	20,427	83,283	6,053		1,983	4,676	434	
TOTAL				260,994				17,444

Source: ISPRA elaborations

From 2005, the weighted average of CO_2 emission factor reported by operators in the context of the EU ETS scheme is used for petroleum coke, refinery gas and synthesis gas from heavy residual fuels. The trend of the implied emission factor is driven by the mix of the fuels used in the sector. The main fuels used are refinery gases, fuel oil and petroleum coke, which have very different emission factors, and every year their amount used changes resulting in an annual variation of the IEF. The increase in the last years, with respect to the nineties, of the consumption of fuels with higher carbon content, as petroleum coke and synthesis gas obtained from heavy residual fuels, explains the general growth of the IEF for liquid fuel reported in the CRF for this sector.
In the following box, liquid fuel consumptions of 1.A.1.b category disaggregated by fuel are reported.

Liquid fuel consumptions in petroleum refining (TJ), 1990-2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Refinery gas	119,123	136,305	124,549	153,036	153,739	132,688	116,862	124,126	126,697	128,601	111,499
Naphta	218	784	4,441	2,613	3,353	87	0	0	0	0	3
Pet coke	28,495	28,634	40,623	50,180	49,415	30,094	21,858	29,677	26,376	26,736	20,427
Synthesis gas	0	0	36,425	65,021	78,628	61,763	63,282	57,676	58,694	50,912	56,572
Fuel oil	76,881	89,310	84,589	75,301	49,275	16,296	31,134	11,231	4,855	3,657	3,684
LPG	1,243	1,151	2,026	3,408	2,717	1,704	1,566	3,089	2,471	3,346	2,497
Gasoil	43	43	5,338	11,317	897	0	0	0	0	0	0
Gasoline	0	0	0	0	0	0	0	0	0	0	0
Total	226,003	256,228	297,992	360,875	338,025	242,631	234,702	225,798	219,093	213,253	194,683

3.3.2.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from refineries is estimated to be about 4.2% in annual emissions; a higher uncertainty, equal to 50.1%, is calculated for CH_4 and N_2O emissions because of the uncertainty levels attributed to the related emission factors.
Montecarlo analysis has been carried out to estimate uncertainty of CO_2 emissions from stationary combustion of solid, liquid and gaseous fuels emissions, resulting in 5.1%, 3.3% and 5.8%, respectively. Normal distributions were assumed for all the parameters. A summary of the results is reported in Annex 1.
In Table 3.8 GHG emissions from the sector in the years 1990, 1995, 2000, 2005, 2010, 2015-2020 are reported.

Table 3.8 Refineries, GHG emission time series

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 emissions, Mt	15.8	18.0	22.2	27.9	28.3	20.9	21.3	20.6	19.7	19.0	17.4
CH_4 emissions, Gg	0.40	0.46	0.59	0.69	0.69	0.48	0.51	0.45	0.43	0.41	0.39
N_2O emissions, Gg	0.45	0.51	0.60	0.73	0.69	0.50	0.49	0.47	0.46	0.45	0.41
Refinery, total, Mt CO_2eq	16.0	18.1	22.4	28.1	28.5	21.1	21.5	20.8	19.8	19.1	17.6

Source: ISPRA elaborations

An upward trend in emission levels is observed from 1990 to 2010 explained by the increasing quantities of crude oil processed and the complexity of process used to produce more environmentally friendly transportation fuels. Liquid fuel consumptions have reached a plateau in 2010 and they are now in a downward trend that is expected to continue, due to the reduced quantities of crude oil processed and electricity produced and to the gradual substitution with natural gas fuel consumption.

3.3.2.4 Source-specific QA/QC and verification

Basic data to estimate emissions have been reported by national energy balance and the national grid administrator. Data collected under other reporting obligations that include refineries (EU ETS, LCP and E-PRTR databases) have been used to cross-check the energy balance data, fuels used and emission factors. Differences and problems have been analysed in detail and solved together with Ministry of Economic Development experts, who are in charge of preparing the National Energy Balance.

3.3.2.5 Source-specific recalculations

No recalculations occur for this category.

3.3.2.6 Source-specific planned improvements

No specific improvements are planned for the next submission.

3.3.3 Manufacture of Solid Fuels and Other Energy Industries

3.3.3.1 Source category description

In Italy, all the iron and steel plants are integrated, therefore there is no separated reporting for the different part of the process. A few coke and "manufactured gas" producing plants were operating in the early nineties and they have been reported here. Only one small manufactured gas producing plant is still in operation from 2002.

In this section, emissions from power plants, which use coal gases, are also reported. In particular, we refer to the electricity generated in the iron and steel plant sites (using coal gases and other fuels). In 2020 the power plants included in this source category have generated about 1.6% of all electricity produced with combustion processes in Italy.

With regard to the manufacture of other solid fuels, in Italy, charcoal was produced in the traditional way until the sixties while now it is prevalently produced in modern furnaces (e.g with the VMR system) where exhaust gases are collected and recycled to produce the energy for the furnace itself. This system ensures good management of the exhausts and the temperature, so that any waste of energy is prevented, and emissions are kept to a minimum. So CH_4 emissions from the production of charcoal are not accounted for, and the notation key NE is used in the reporting, also considering that the emission factor available in the Revised 1996 IPCC Guidelines, in Table 1-14 vol.3 (IPCC, 1997), refers to production processes in developing countries not applicable to our country anymore. Moreover, in the IPCC Good Practice Guidance as well as in the IPCC 2006 Guidelines no guidance is supplied for charcoal production.

3.3.3.2 Methodological issues

Fuel consumption data for the sector are reported in the BEN (MSE, several years [a]). Fuels used to produce energy are also reported with more detail as for fuel disaggregation level by TERNA (TERNA, several years). From 2005 onwards, also the EU ETS "verifier's reports" cover almost the entire sector, for energy consumptions, combustion emissions and process emissions. Other sources of information are the yearly

reporting obligations for the large combustion plants under European Directive (LCP) and for facilities under the E-PRTR Regulation; both reporting obligations include most of the iron and steel integrated plants and the only coke producing plant but not all the emission sources.
A carbon balance is done, as suggested by the IPCC good practice guidance, to avoid over or under estimation from the sector. In Annex 3 further details on carbon balances of solid fuels and derived gases used are reported.
The high-implied emission factor for solid fuels is due to the large use of derived steel gases and in particular blast furnace gas to produce energy. These gases have been assimilated to the renewable sources and incentives are still provided for their use.
Other fuels are used in co-combustion with coal gases to produce electricity and they are reported by TERNA, see Annex 2. From 2008, natural gas and fuel oil consumptions reported in the CRF for this sector, are those communicated by the operators of the plants included in the sector in the framework of the EU ETS scheme. The consumptions of these fuels, especially for natural gas, are higher than those reported for the previous years. Fuel consumption reported in the sector is subtracted from the total fuel consumption to produce energy, guaranteeing that over and under estimation are avoided.
CH_4 emissions from coke ovens are estimated on the basis of production data to take in account additional volatile emissions due to the specific process. Average emission factors are calculated on the basis of information communicated by the four (three in the last years) plants under the E-PRTR registry.

3.3.3.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from integrated iron and steel plants is estimated to be about 4.2% in annual emissions; a higher uncertainty, equal to 50.1%, is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.
Montecarlo analysis has been carried out to estimate uncertainty of CO_2 emissions from stationary combustion of solid, liquid and gaseous fuels emissions, resulting in 5.1%, 3.3% and 5.8%, respectively. Normal distributions have been assumed for all the parameters. A summary of the results is reported in Annex 1. In Table 3.9 GHG emissions from the sector in the years 1990, 1995, 2000, 2005, 2010, 2015-2020 are reported.

Table 3.9 Manufacture of solid fuels, GHG emission time series

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 emissions, Mt	12.5	11.6	12.9	15.9	11.4	5.6	6.8	5.8	5.6	5.4	4.0
CH_4 emissions, Gg	4.9	3.8	2.4	1.3	0.6	0.5	0.5	0.4	0.4	0.4	0.3
N_2O emissions, Gg	0.12	0.10	0.09	0.12	0.08	0.04	0.05	0.04	0.04	0.04	0.03
Total, Mt CO_2eq	12.6	11.8	12.9	16.0	11.5	5.6	6.8	5.8	5.7	5.4	4.0

Source: ISPRA elaborations

The trend of CO_2 and N_2O emissions is driven by the production trends combined with an increase in energy consumption required by more energy intensive products. In 2009 a strong reduction of emissions is observed due to the effects of the economic recession that in 2010 and 2011 has partially recovered. In 2012 a further drop occurred for the economic crisis and for environmental constrains of the main iron and steel integrated plants that should reduce its productions. In 2015 a drop is still observed (around 1.7 Mt CO_2) consistently with the production activities reduction of the main iron and steel integrated plants.
The trend of CH_4 emissions is driven by the coke production trend, decreased from 6.4 Mt in 1990 to 1.2 Mt in 2020 and by the renewal of the production plants. In particular, the strong reduction of CH_4 emissions in the last years is the result of the renewal of the coke production plants in Taranto, started in 2005, and the implementation of best available technologies to reduce volatile organic compounds. In 2009, as well as in 2013, national coke production has reduced of about 40% with respect to the previous year, determining a loss in efficiency of the production plants and an increase of emissions by product unit (IEF) for those years. A similar effect was also recorded in 2020 due to the reduction in production also linked to the pandemic and the limitation of production activities.

3.3.3.4 Source-specific QA/QC and verification

Basic data to estimate emissions have been reported by national energy balance and the national grid administrator. Data collected under other reporting obligations that include integrated iron and steel plants, such as EU ETS Directive, LCP and E-PRTR databases, have been used to cross-check the energy balance data, fuels used and emission factors. Differences and problems have been analysed in detail and solved

together with Ministry of Economic Development experts, which are in charge to prepare the National Energy Balance. In particular, in the national PRTR register the integrated plants report every year the CO_2 emitted at each stage of the process, coke production, sinter production and iron and steel production, which result from separate carbon balances calculated in each phase of the production process. Moreover, total CO_2 emissions reported in the E-PRTR by the operators are equal to those reported under the EU ETS scheme.
The detailed analysis and comparison of the different data reported improved the allocation of fuel consumption and CO_2 emissions between 1.A.1.c and 1.A.2.a sectors. From the 2010 submission, in fact, coking coal losses for transformation process and related emissions have been reallocated under 1.A.1.c instead of 1.A.2.a.

3.3.3.5 Source-specific recalculations

Minor recalculations occur in the last years, specially in 2019, because of the update of CO_2 emission factor for natural gas.

3.3.3.6 Source-specific planned improvements

No specific improvements are planned for the next submission.

3.4 Manufacturing industries and construction

3.4.1 Sector overview

Included in this category are emissions which originate from energy use in the manufacturing industries included in category 1.A.2. Where emissions are released simultaneously from the production process and from combustion, as in the cement, lime and glass industry, these are estimated separately and included in category 2.A.
All greenhouse gases as well as CO, NO_X, NMVOC and SO_2 emissions are estimated.
In 2020, energy use in industry account for 14.8% of total national CO_2 emissions, 0.6% of CH_4, 3.6% of N_2O. In term of CO_2 equivalent, the manufacturing industry shares 12.0% of total national greenhouse gas emissions. Three key categories have been identified for this sector in 2020, for level and trend assessment, using both the IPCC Approach 1 and Approach 2:

Manufacturing industries and construction - CO_2 gaseous fuels (L, T);
Manufacturing industries and construction - CO_2 solid fuels (L, T);
Manufacturing industries and construction - CO_2 liquid fuels (L1, T).

All these categories are key categories for 1990 at level assessment, with and without LULUCF. N_2O from liquid fuels, is key category for 1990 only including the uncertainty estimates.
In the following Table 3.10, GHG emissions connected to the use of fossil fuels, process emissions excluded, are reported for the years 1990, 1995, 2000, 2005, 2010 and 2015-2020. Industrial emissions show oscillations related to economic cycles.

Table 3.10 Manufacturing industry, GHG emission time series

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 emissions, Gg	90,772	88,969	94,893	90,786	68,900	54,552	53,365	52,143	53,228	48,957	44,879
CH_4 emissions, Gg	6.69	6.92	6.01	6.48	5.68	11.21	11.30	11.17	10.97	11.46	11.01
N_2O emissions, Gg	4.49	3.92	4.46	5.02	3.77	2.69	2.55	2.51	2.61	2.51	2.36
Industry, total, Gg CO_2 eq	92,278	90,312	96,373	92,444	70,165	55,634	54,407	53,172	54,279	49,991	45,856

Source: ISPRA elaborations

In Table 3.11 emissions are reported by pollutant for all the subsectors included in the sector.

Table 3.11 Trend in greenhouse gas emissions from the manufacturing industry sector, 1990-2020

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (Gg)											
1.A.2.a Iron and Steel	25,255	24,201	22,537	19,289	15,708	10,629	11,550	9,832	10,166	9,827	8,004
1.A.2.b Non-Ferrous Metals	735	879	1,249	1,176	1,105	999	1,000	1,080	1,140	1,114	1,036
1.A.2.c Chemicals	21,428	18,658	18,102	17,240	16,404	11,142	11,139	11,346	11,597	9,084	8,671
1.A.2.d Pulp, Paper and Print	3,108	4,185	4,253	5,457	5,148	4,872	4,789	5,027	4,916	4,975	4,665
1.A.2.e Food	3,891	5,095	6,282	6,017	4,132	3,444	3,350	3,705	3,517	3,455	3,472
1.A.2.f Non-metallic minerals	21,045	17,461	21,407	25,271	18,099	14,007	12,855	11,598	11,899	10,915	10,347
1.A.2.g Other	15,310	18,490	21,062	16,338	8,303	9,459	8,682	9,555	9,994	9,587	8,683
CH_4 (Mg)											
1.A.2.a Iron and Steel	3,795	4,226	3,093	3,304	2,880	2,062	2,280	1,969	1,803	1,797	1,449
1.A.2.b Non-Ferrous Metals	13	15	26	24	19	18	18	19	20	19	18
1.A.2.c Chemicals	876	725	643	533	542	328	320	320	335	238	219
1.A.2.d Pulp, Paper and Print	77	93	115	154	92	107	102	108	105	109	98
1.A.2.e Food	105	127	174	429	731	7,639	7,567	7,717	7,641	8,239	8,238
1.A.2.f Non-metallic minerals	1,412	1,276	1,463	1,624	1,197	842	811	824	834	831	778
1.A.2.g Other	408	461	493	412	219	215	199	219	235	224	208
N_2O (Mg)											
1.A.2.a Iron and Steel	411	414	366	396	294	200	218	181	183	177	148
1.A.2.b Non-Ferrous Metals	13	16	24	23	20	18	18	19	20	19	18
1.A.2.c Chemicals	404	322	314	317	329	207	193	190	200	133	122
1.A.2.d Pulp, Paper and Print	64	82	80	102	90	86	83	87	86	87	81
1.A.2.e Food	52	53	76	87	47	172	167	176	172	180	180
1.A.2.f Non-metallic minerals	2,644	2,285	2,630	2,986	2,183	1,427	1,352	1,360	1,370	1,368	1,286
1.A.2.g Other	906	751	974	1,110	807	579	517	501	576	544	520

Source: ISPRA elaborations

A general trend of reduction in emissions is observed from 1990 to 2020; some sub sectors reduced sharply (iron and steel, non metallic minerals), other sub sectors (non ferrous metals, pulp and paper) increased their emissions. In 2009 an overall reduction of emissions for all the sectors occurred due to the effects of the economic recession. In 2010 production levels restored for iron and steel, but a further significant drop is noted in 2013 due to environmental constraints of the main integrated iron and steel plant in Italy, located in Taranto, which had to reduce its steel production level. Non metallic minerals emission trend is driven by the cement industry which strongly reduced its production levels in 2009 and further in 2013, in relation to the economic recession and the crisis of building construction sector; a further decrease of this sector is observed in 2016 and 2017. The increasing trend of CH_4 emissions in the last years especially for food industry is driven by the increase of biomass used as a fuel in this sector with a peak in 2014 and in 2019-2020. The decreasing trend

of CO_2 and N_2O in the last years is driven by the trend of non-metallic minerals industry emissions due to the reduction trend of cement productions.

3.4.2 Source category description

The category 1.A.2 comprises seven sources: 1.A.2.a Iron and Steel, 1.A.2.b Non-Ferrous Metals, 1.A.2.c Chemicals, 1.A.2.d Pulp, Paper and Print, 1.A.2.e Food, 1.A.2.f Non-metallic minerals, 1.A.2.g Other.

Iron and steel

The main processes involved in iron and steel production are those related to sinter and blast furnace plants, to basic oxygen and electric arc furnaces and to rolling mills.

Most of emissions are connected to the integrated steel plants, while for the other plants, the main energy source is electricity (accounted for in 1.A.1.a) and the direct use of fossil fuels is limited to heating – re heating of steel in the intermediate part of the process.

There were four integrated steel plants in 1990 that from 2005 are reduced to two, with another plant that still has a limited production of pig iron. Nevertheless, the steel production in integrated plants has not changed significantly in the 1990-2008 period due to an expansion in capacity of the two operating plants. From 2015 only one integrated plant remains in operation. The maximum production was around 11 Mt/y in 1995 and in 2005-2008, with lower values in other years and the lowest of 3.4 Mt in 2020.

It has to be underlined that the integrated steel plants include also the cogeneration of heat and electricity using the recovered "coal gases" from various steps of the process, including steel furnace gas, BOF gas and coke oven gas. All emissions due to the "coal gases" used to produce electricity are included in the electricity grid operator's yearly reports and are accounted in the category 1.A.1.c. No detailed information is available for the heat produced, so the emissions are included in source category 1.A.2.a.

With the aim to avoid double counting process emissions resulting from the iron and steel subcategory are reported in the industrial processes sector. CH_4 emissions are estimated for each emitting activities according to the classification of activities described in the EMEP/EEA guidebook and consequently allocated at the combustion or industrial processes sector in consideration of the relevant methodological issues. More in details, CH_4 process emissions for pig iron and steel production are already allocated to the industrial processes sector as well as fugitive CH_4 emissions from coke production that are reported under fugitive emissions while CH_4 emissions from the combustion of fuels are allocated to the energy sector.

This subsector is one of the most important of 1.A.2 category and accounts, in 2020, for 17.6% of total 1.A.2 GHG emissions, and 2.1% of total national emissions.

Non-Ferrous Metals

In Italy, the production of primary aluminium stopped in 2013 (and was 232 Gg in 1990) while secondary aluminium accounts for 350 Gg in 1990 and 570 Gg in 2020. These productions, however, use electricity as the primary energy source so the emissions due to the direct use of fossil fuels are limited.

The sub sector comprises also the production of other non-ferrous metals, both primary and secondary copper, lead, zinc and others; but also those productions have a limited share of emissions. Magnesium production is not occurring. The bulk of emissions are due to foundries that prepare mechanical pieces for the engineering industry or the market, using all kinds of alloys, including aluminium, steel and iron.

Chemicals

CO_2, CH_4 and N_2O emissions from chemical and petrochemical plants are included in this sector.

In Italy there are petrochemical plants integrated with a nearby refinery and stand alone plants that get the inputs from the market. Main products are Ethylene, Propylene, Styrene.

In particular, ethylene and propylene are produced in petrochemical industry by steam cracking. Ethylene is used to manufacture ethylene oxide, styrene monomer and polyethylene. Propylene is used to manufacture polypropylene but also acetone and phenol. Styrene, also known as vinyl benzene, is produced on industrial scale by catalytic dehydrogenation of ethyl benzene. Styrene is used in the rubber and plastic industry to manufacture through polymerisation processes such products as polystyrene, ABS, SBR rubber, SBR latex. Except for ethylene oxide, whose production has stopped in 2002, the other productions of the above-mentioned chemicals still occur in Italy. Activity data are stable from 1990 to 2012, with limited yearly variations along the timeseries and a reduction in the last years.

Chemical industry includes non organic chemicals as chlorine/soda, sulphuric acid, nitric acid, ammonia. A limited production of fertilizers is also present in Italy. From 1990 to 2020 the sum of productions of this source category has greatly reduced: in 2020 it was less than half of the production in 1990.
This source category does include some emissions from the cogeneration of electricity. Due to the transformation of some of those plants in power plants directly connected to the grid, and so reported in category 1.A.1.a, the percentage of the category 1.A.2.c CO_2 emissions due to electricity generation has reduced from 1990 to 2020. This subsector accounts, in 2020, for 19.0% of total 1.A.2 GHG emissions, and 2.3% of total national emissions.

Pulp, Paper and Print
Emissions from the manufacturing of paper are included in this source category. In Italy the manufacture of virgin paper pulp is rather limited, with a production feeding less than 5% of the paper produced in 2019. Most of the pulp was imported in 1990, while in 2020 half of the pulp used is produced locally from recycled paper. The paper production is expanding and activity data (total paper produced) were 6.2 Mt in 1990 and 8.5 Mt in 2020. The printing industry represents a minor part of the source category emissions.
This source category includes also the emissions from the cogeneration of electricity. Due to the transformation of some of those plants in power plants directly connected to the grid (and so reported in category 1.A.1.a), the percentage of the category 1.A.2.d CO_2 emissions due to electricity generation has strongly reduced from 1990 to 2020.

Food
Emissions from the food production are included in this source category. In Italy the food production industry is expanding. A comprehensive activity data for this sector is not available; more in detail while energy data are those reported in the national energy balance for this sector, information at subsector and technological level is not available and only few plants are part of the ETS; energy fuel consumption was estimated to be 62 PJ in 1990 and 113 PJ in 2020, about half of energy consumptions derives from biomass. Value added at constant prices has increased of 0.6% per years from 1990 to 2003 and almost constant from 2004.
This source category also includes emissions from the cogeneration of electricity. Due to the transformation of those plants in power plants directly connected to the grid, and so reported in category 1.A.1.a, the percentage of the category 1.A.2.e CO_2 emissions due to electricity generation has reduced from 1990 to 2020.

Non-metallic minerals
This sector, which refers to construction materials, is quite significant in terms of emissions due to the energy intensity of the processes involved. Construction materials subsector includes the production of cement, lime, bricks, tiles and glass. It comprises thousands of small and medium size enterprises, with only few large operators, mainly connected to cement production. Some of the production is also exported. The description of the process used to produce cement, lime and glass is reported in chapter 4, industrial processes.
The fabrication of bricks is a rather standard practice in most countries and does not need additional description; fossil source is mainly natural gas. A peculiar national circumstance is the fabrication of tiles, in which are involved many specialised “industrial districts” where many different independent small size enterprises are able to manufacture world level products for both quality and style, exported everywhere. Generally speaking, the processes implemented are efficient with reference to the average European level and use mostly natural gas as the main fossil source since the year 2000.
The activity data of industries oriented to so different markets are, of course, peculiar to each subsector and it is difficult to identify a common trend. The productions of cement, lime and glass are the most relevant from the emissions point of view.
This subsector is the most important of 1.A.2 category and accounts, in 2020, for 23.4% of total 1.A.2 GHG emissions, and 2.8% of total national emissions.

Other

This sector comprises emissions from many different industrial subsectors, some of which are quite significant in Italy in terms of both value added and export capacity.

In particular, engineering sectors (vehicles and machines manufacturing) is the main industrial sub sector in terms of value added and revenues from export and textiles was the second subsector up to year 2000.

The remaining "other industries" include furniture and other various "made in Italy" products that produce not negligible amounts of emissions.

This source category includes also emissions from the cogeneration of electricity. Due to the transformation of some of those plants in power plants directly connected to the grid, reported in category 1.A.1.a, the percentage of the category 1.A.2.g CO_2 emissions due to electricity generation has reduced in the last years. This subsector accounts, in 2020, for 19.3% of total 1.A.2 GHG emissions, and 2.3% of total national emissions.

3.4.3 Methodological issues

Energy consumption for this sector is reported in the BEN (see Annex 5). The data comprise specification of consumption for 13 sub-sectors and more than 25 fuels. These very detailed data, combined with industrial production data, allow for a good estimation of all the fuel used by most industrial sectors, with the details required by CRF format. With reference to coal used in the integrated steel production plants the quantities reported in BEN are not used as such but a procedure has been elaborated to estimate the carbon emissions linked to steel production and those attributable to the coal gases recovered for electricity generation, as already mentioned in paragraph 3.4.1. The detailed calculation procedure is described in Annex 3. Moreover, a part of the fuel input is considered in the estimation of process emissions, see chapter 4 for further details.

The balance of fuel (total consumption minus industrial processes consumption) is considered in the emission estimate; CO_2 emission factors used for 2020 are listed in Table 3.12. The procedure used to estimate the national emission factors is described in Annex 6. These factors account for the fraction of carbon oxidised equal to 1.00 for solid, liquid and gaseous fuels, as suggested by the IPCC 2006 guidelines (IPCC, 2006).

For some fuels as natural gas, coal and residual oil, country specific emission factors are available for the whole time series; so, their time series takes into account different oxidation factors according to the improving of combustion efficiency occurred in the nineties, but considering the value equal to 1.00 from 2005.

For petroleum coke, synthesis gas from heavy residual, refinery gases, iron and steel derived gases, coking coal, anthracite, coke oven coke from 2005, and for residual gases from chemical processes, from 2007, CO_2 emission factors have been calculated based on the data reported by operators under the EU ETS scheme. See Annex 6 for further details.

For the other fuels, where national information was not available, default emission factors provided by the IPCC 2006 Guidelines have been used (IPCC, 2006).

Table 3.12 Emission Factors for Power, Industry and Civil sector

	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Liquid fuels			
Crude oil	73.300	3.101	3.069
Jet gasoline	70.000	3.101	2.931
Jet kerosene	71.500	3.153	2.994
Petroleum Coke in industry*	93.368	3.126	3.909
Petroleum Coke in refineries*	97.082	3.442	4.065
Gasoil	74.100	3.186	3.102
Orimulsion	77.000	2.118	3.224
Fuel oil*	76.497	3.143	3.203
Heavy residual in refineries*	80.466	3.134	3.369
Synthesis gas from heavy residual*	102.912	0.870	4.309
Residual gases from chemical processes*	46.417	1.686	1.943
Other chemical gases*	59.303	2.537	2.483
Gaseous fuels			
Natural gas*	57.918	1.986 (sm^3)	2.425
Solid fuels			
Steam coal*	94.014	2.356	3.936
"sub-bituminous" coal	96.100	1.816	4.024
Lignite	101.000	1.202	4.229
Coking coal*	94.947	2.966	3.975
Anthracite*	104.757	2.964	4.386
Coke oven coke*	107.471	3.181	4.500
Biomass			
Solid Biomass*	(94.600)	(0.962)	(3.961)
Derived Gases			
Refinery Gas*	56.146	2.639 (sm^3)	2.351
Coke Oven Gas*	45.854	0.844 (sm^3)	1.920
Oxygen converter Gas*	195.877	1.353(sm^3)	8.201
Blast furnace*	251.043	0.883 (sm^3)	10.511
Other fuels (fossil)			
Municipal solid waste*	95.953	1.093	4.575
Industrial solid waste*	79.915	2.070	3.346
*country specific emission factors			

Source: ISPRA elaborations

Other sources of information are the yearly survey performed for the E-PRTR, since 2003, and the EU ETS; both surveys include main industrial operators, but not all emission sources. In particular from 2005 onwards the detailed reports by operators subject to EU ETS constitute a valuable source of data, as already said above with reference to oxidation factors and average emission factors.

In general, in the industrial sector, the ETS data source is used for cross checking BEN data. Energy/emissions data from EU ETS survey of industrial sectors should be normally lower than the corresponding BEN data because only part of the installations / sources of a certain industrial sub sector are subject to EU ETS. In case of missing sources or lower figures in the BEN than ETS, at fuel sector level, a verification procedure is carried out.

Since 2007 data, ISPRA verifies actual data from both sources and communicates potential discrepancies to MSE. Thus, a verification procedure is started that can eventually modify BEN data. However, we underline that EU ETS data do not include all industrial installations and cannot be used directly to estimate sectoral emissions for a series of reasons that will be analyzed in the following, sector by sector.

Biomass fuel consumption in the sector is driven by the use of wood in the non-metallic subcategory and biogas from agriculture residues in the food subcategory. The trend of the implied emission factors are driven in the last years by the exponential increase of the biogas fuel consumption, observed mainly in the food processing industry, and the strong decrease of wood consumption in industry, as supplied by the national energy balance (MSE, several years [a]).

Other fuels include industrial waste fuel consumption reported in the non-metallic mineral sub category. The use of industrial waste in manufacturing industries is linked to the use in the last 10 years in cement production plants and refers to the consumption of RDF (Refuse-derived Fuel), plastics, tyres, waste oils and solvents. The average emission factor time series is reported in Table A6.12 of Annex 6 and it have been derived from data reported to the ETS by the plants using that fuel.

Iron and steel
For this sector, all main installations are included in EU ETS, but only from 2013 all sources of emissions are included. In the previous years only part of the processes of integrated steel making was subject to EU ETS, in particular the manufacturing process after the production of row steel was excluded up to 2007 and only the lamination processes have been included from 2008.
So the EU ETS data have been of limited use for this subsector and the procedure set up starting from the total carbon input to the steel making process, is the most comprehensive one to estimate the emissions to be reported in 1.A.2.a, see Annex 3 for further details.
Of course, data available from EU ETS are used for cross-checking the national energy balance data, with an aim to improve the consistency of the data set.
These plants are also reported in E-PRTR, but not all sources are included.
The low implied emission factors and annual variations in the average CO_2 emission factor for solid fuel are due to the fact that both activity data and emissions reported under this category include the results of the carbon balance (see Annex 3 for further details). The implied emission factor for the sub sector for 2020 is equal to 57.2 t/TJ and the trend is quite stable with figures around 60 t/TJ. CH_4 implied emission factor is equal to 10.4 kg/TJ in 2020 and it is higher than the default emission factors because of the specificities of the in-process combustion activities. The sintering process is a pre-treatment step in the production of iron in which metal ores, coke and other materials are roasted under burners, involving the mixing of combustion products and/or the fuel with the product or raw materials (EMEP/EEA, 2019). Apart from combustion emissions, the heating of plant feedstock and product can lead to substantial CH_4 emissions which are to be accounted for in the combustion process.

Non-Ferrous Metals
These plants are mostly excluded from EU ETS; primary aluminium producing plants should have been included from 2013, but the only Italian plant closed in the same year. These production processes are also in the scope of the E-PRTR survey, which collects also information concerning emissions to air, but since these facilities usually do not exceed the emission thresholds for mandatory reporting the information regarding emissions to air is not reported by the operators. According to the national Energy Balance no solid fuels have been used since 2016 in this subsector.

Chemicals
The use of EU ETS data for this subsector is rather complex because generally chemical plants are excluded from EU ETS while petrochemical plants, which report also under the E-PRTR, are included from 2013. In this case, the data set is used for cross checking BEN data. As mentioned in paragraph 3.4.1, also a small amount of emissions connected to the production of electricity for the onsite use is reported in source 1.A.2.c, basic data are taken from TERNA reports and the relative subsector amount is estimated with a model.
In this category, biomass refers to the steam wood fuel consumption as available in the BEN. The relevant CO_2 emission factor is reported in Table 3.12 above.
Fuel consumptions of derived chemical and petrochemical fuels, which could be considered as petrol derived fuels, were reported in the past in the “other fossil fuels” category for chemicals industries. With the aim to improve the comparison between reference and sectoral approaches, these fuels have been reported under the liquid fuel category. The average CO_2 emission factor at sectoral level for liquid fuels is driven by the weight of synthesis gases from chemical processes fuel consumptions. The relevant CO_2 emission factor is reported in Table 3.12 above.

Pulp, Paper and Print
Most of the operators in the paper and pulp sector are included in EU ETS, while only a few of the printing installations are included.
CH_4 and N_2O emissions from biomass fuel consumption in the sector, are included in the inventory on the basis of the biomass fuel consumption reported in the annual environmental report by the industrial association (ASSOCARTA, several years) and to the EU ETS. Statistics on biomass fuel consumption appears from 1998. According to the information supplied by the industrial association of the sector, ASSOCARTA, a few plants started to use biomass from 1998. The use of biomass has an increasing trend till 2008 while in 2009 the use of biomass sharply reduced with a further reduction in the following years to return in the last years at the same level of 2009. From 2008 information is directly reported by the production plants in the framework of the EU ETS and a reduction in the IEF is observed as a consequence of increase in energy efficiency of the biomass

fuel used. For the years from 1990 to 1997 the use of biomass for energy purposes in the pulp and paper industry has been assumed not occurring. Biomass fuel consumption includes especially black liquor, from 1998 to 2007, but also industrial sludge and biogas from industrial organic wastes. From 2013 only biogas is included and, in 2020, CO_2 emission factor is equal to 52.8 t/TJ.

Food
Emissions from the food production are included in this source category. A comprehensive activity data for this sector is not available; the subsector comprises many small and medium size enterprises, with thousands of different products. Limited info on this sector can be found in ETS survey, the sector is not included in the scope of ETS.
Liquid fuel refers to fuel oil and LPG fuel consumption driving the variability of the average emission factors. For the years up to 2002, solid fuel consumption was mainly related to the consumption of coke and small amount of lignite. From 2012 the fuel consumption and relevant emission factors refers only to anthracite.
Biomass includes fuel consumption of steam wood and biogas from food industrial residual. The CH_4 implied emission factor time series is driven by the mix of these fuels. In this sector emissions are prevalently from biogas from food industry residual or in the paper industry, with an EF of CH_4 equal to 152 kg/TJ, while in the other manufacturing industries biomass refers to wood and similar with an emission factor for CH_4 equal to 28 kg/TJ.
CH_4 emissions from biogas fuel combustion take in account the technology used to produce energy and heat from biogas combustion, usually stationary engines, which is not fully efficient and results in higher emissions of VOC, CO and PM. The emission factor is reported in the Corinair Guidebook (EMEP/CORINAIR, 2007) as the maximum for stationary engines. We plan to collect the relevant information at plant level to update this emission factor taking into account the improvement in technology in the last years with respect to the nineties.
Biogas has an emission factor for N_2O, equal to 3 kg/TJ.

Non-metallic minerals
This sector comprises emissions from many different industrial subsectors, some of which are subject to EU ETS and some not. Construction material subsector is energy intensive and it is subject to EU ETS. In the national energy database, the data for construction material are reported separately and they can be cross cheeked with ETS survey. However, in the construction material subsector, there are many small and medium size enterprises, so the operators subject to ETS are only a part of the total.
Biomass includes wood fuel consumption and other non conventional fuels especially used in the construction material subsector. CH_4 emission factor is equal to 27.5 kg/TJ and refers to the use of these non conventional fuels for the cement production (EMEP/EEA, 2009).
Industrial waste fuel consumption is also included in this subcategory; CH_4 and N_2O emission factors are equal to 3 kg/TJ and 15 kg/TJ respectively.

Other
This sector comprises emissions from many different industrial subsectors, mainly not subject to EU ETS.

3.4.4 Uncertainty and time-series consistency
The combined uncertainty in CO_2 emissions for this category is estimated to be about 4% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors and the difference in emission factors between the industrial subsectors, sources 1.a.2.a-g.
Montecarlo analysis has been carried out to estimate uncertainty of CO_2 emissions from stationary combustion of solid, liquid and gaseous fuels emissions, resulting in 5.1%, 3.3% and 5.8%, respectively. Normal distributions have been assumed for all the parameters. A summary of the results is reported in Annex 1.
Time series of the industrial energy consumption data are contained in the BEN time series and in the CRFs and are reported in the following table.

Table 3.13 Fuel consumptions for Manufacturing Industry sector, 1990-2020 (TJ)

	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
1.A.2 Manufacturing Industries and Construction	**1,367,598**	**1,393,148**	**1,506,841**	**1,464,862**	**1,116,234**	**913,309**	**905,904**	**911,498**	**859,048**	**794,738**
a. Iron and Steel	397,841	378,482	373,499	371,192	299,536	182,846	177,110	175,448	169,960	139,913
b. Non-Ferrous Metals	11,916	14,708	20,276	19,774	18,537	16,968	18,498	18,612	18,240	17,309
c. Chemicals	320,112	288,273	279,930	257,657	241,697	169,257	173,544	176,039	142,570	138,574
d. Pulp, Paper and Print	50,730	70,189	73,713	94,498	88,256	83,986	86,684	84,964	86,227	80,591
e. Food Processing, Beverages and Tobacco	62,370	84,987	103,004	99,007	73,493	108,704	112,957	109,709	113,370	113,441
f. Non-metallic minerals	278,929	255,293	306,930	363,170	261,735	201,447	182,529	186,520	172,083	163,528
g. Other	245,699	301,216	349,489	259,564	132,980	150,100	154,582	160,207	156,599	141,383

Source: ISPRA elaborations

Emission levels observed from 1990 to 2005 are nearly constant with some oscillations, linked to the economic cycles and reflecting develop of national sectoral industries, as paper and food. After year 2005 the general trend is downward, with oscillations due to the economic cycles but also reflecting the delocalisation of productions in some specific sectors as chemicals and textile industry, see Table 3.11 above. The underlining reason for the reduced emissions is the reduced industrial output, and the increase in energy efficiency. For the iron and steel sector as well as for the non metallic minerals sector, a drop is observed in the last years coherent with the reduction of the production activities in the main national iron and steel integrated plants and in the cement production industry respectively.

3.4.5 Source-specific QA/QC and verification

Basic data to estimate emissions have been reported by national energy balance and the national grid administrator. Data collected by other surveys that include EU-ETS and E-PRTR surveys have been used to cross – check the energy balance data, fuels used and EFs. Differences and problems have been analysed in details and solved together with MSE experts.

The energy data used to estimate emissions reported in Table 1.A.2 have two different levels of accuracy:

- in general, they are quite reliable and their uncertainty is the same of the BEN; as reported in Annex 4 the BEN survey covers 100% of import, export and production of energy; the total industrial consumption estimate is obtained subtracting from the total the known energy quantities (obtained by specialized surveys) used in electricity production, refineries and the civil sector.
- the energy consumption at sub sectoral level (sources 1.A.2.a-g) is estimated by MSE on the basis of sample surveys, actual production and economic data; therefore, the internal distribution on energy consumption has not the same grade of accuracy of the total data.

3.4.6 Source-specific recalculations

Recalculations occur in the last years because of the update of natural gas emission factor.

3.4.7 Source-specific planned improvements

With the aim to improve the comparison with the international statistics and the relevant definition and classification of fuels we are progressively updating the emission inventory adopting the energy balance activity data provided by the Italian Ministry of Economic Development to the international organization after verification that these time series data reflect the relevant emission inventory categories.

A revision of biomass and waste fuel consumption time series is planned for the next submission on the basis of energy data communicated by the Ministry of Economic Development to the Joint Questionnaire OECD/IEA/EUROSTAT, after a verification and comparison with data up to now used and available in the National Energy Balance reports (MSE, several years [a]). National Energy Balances are available in Italy from 1970 with the same format and comparable data. The submissions to the international questionnaire in some cases follow different rules and different allocation of fuel consumptions. The comparison is oriented to avoid that the use of international statistics results in a loss of information already used for the emission inventory. Moreover, we will check where along the time series changes occurred and for which matter (simple updates of annual data or something related to the different reporting rules).

3.5 Transport

This sector shows a decrease in emissions only in the last years, reflecting the trend observed in fuel consumption for road transportation, which accounts for more than 92% of GHG sectoral emissions. The mobility demand and, particularly, the road transportation share have increased in the period from 1990 to 2019, although since 2008 emissions from this sector begin to decrease. Due the pandemic occurred during year 2020, the mobility demand sharply lowered, mainly corresponding to the lockdown periods.
In 2020 the sector is responsible of 22.4% of total national GHG emissions and 28.6% of the GHG energy sector emissions.
Emissions increase of about 26.8% from 1990 to 2007 and show a decrease of about 18.7% from 2007 to 2019; despite of an inversion of the trend between 2013 and 2014, a further reduction is observed between 2015 and 2017, while 2018-2019 emissions show an upward trend because of a general growth of economy. Year 2020 shows a reduction of 18.9% and 16.4% in comparison with the years 2019 and 1990 respectively. In 2012 a drop is observed in CO_2 emissions due to a sharp reduction of gasoline and diesel fuel consumption for road transport, explained mainly by the economic crisis, contributing to the reduction of movements of passengers and goods, and in a minor way by the penetration in the market of low consumption vehicles.
The time series of CO_2, CH_4 and N_2O emissions, in Mt CO_2 equivalent, is reported in Table 3.14; figures comprise all the emissions reported in table 1.A.(a)s3 of the CRF. Emission estimates are discussed below for each sub sector. The trend of CH_4 and N_2O emissions is impacted by the evolution of the technologies in the road transport sector and the distribution between the different fuels consumption.

Table 3.14 GHG emissions for the transport sector (Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 Mt CO_2eq	100.32	111.53	121.44	126.62	114.17	104.89	103.71	99.63	103.11	104.14	84.46
CH_4 Mt CO_2eq	0.90	1.02	0.77	0.51	0.31	0.23	0.21	0.20	0.20	0.20	0.17
N_2O Mt CO_2eq	0.97	1.74	1.62	1.14	1.05	0.95	0.96	0.94	0.97	0.98	0.81
Total, Mt CO_2 eq.	**102.19**	**114.29**	**123.83**	**128.26**	**115.53**	**106.07**	**104.88**	**100.77**	**104.28**	**105.32**	**85.44**

Source: ISPRA elaborations

CO_2 from road vehicles is key category both in 1990 and 2020, in level and trend (Tier 1 and Tier 2) with and without LULUCF.
CO_2 from waterborne navigation is key category both in 1990 and 2020, in level (Tier 1) with and without LULUCF and in trend (Tier1) with LULUCF.

3.5.1 Aviation

3.5.1.1 Source category description

The IPCC methodology requires the estimation of emissions for category 1.A.3.a.i International Aviation and 1.A.3.a.ii Domestic Aviation, including figures both for the cruise phase of the flight and the landing and take-off cycles (LTO). Emissions from international aviation are reported as a memo item, and are not included in national totals.
Civil aviation contributes mainly in rising CO_2 emissions. CH_4 and N_2O emissions also occur and are estimated in this category but their contribution is insignificant.

In 2020 total GHG emissions from this source category were about 1.4% of the national total emissions from transport, and about 0.3% of the GHG national total (in terms of CO_2 only, the share is almost the same).
From 1990 to 2019, GHG emissions from the sector increased by 59.3%, due to the expansion of the aviation transport mode. Considering the sharp movements' reduction occurred in year 2020 due to the global pandemic, the aviation sector decreased by 20% in comparison with 1990. Since 2010 to 2019 a reduction is observed in GHG emissions, equal to -19.6% due both to the reduction of domestic flights and to an increase of energy efficiency in the new aircrafts. Considering the year 2020, the total reduction amounts to -59.6%, in comparison with 2010 emissions. Focusing on the period 2010-2020, after the minimum GHGs emissions registered in years 2015-2016, there is a rise in the emissions from aviation in years 2017-2019, related to the growth rates in the number of domestic flights. Year 2020 is thus to be considered apart because of the exceptional global conditions.
CO_2 emissions deriving from civil aviation do not represent a key category neither in 2020 nor in 1990, in level and trend, with and without LULUCF.

3.5.1.2 Methodological issues

According to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2000; IPCC, 2006) and the Guidebook (EMEP/CORINAIR, 2007; EMEP/EEA, 2019), a national technique has been developed and applied to estimate emissions.
The current method estimates emissions from the following assumptions and information.
Activity data comprise both fuel consumptions and aircraft movements, which are available in different level of aggregation and derive from different sources as specified here below:

- Total inland deliveries of aviation gasoline and jet fuel are provided in the national energy balance (MSE, several years [a]). This figure is the best approximation of aviation fuel consumption, for international and domestic use, but it is reported as a total and not split between domestic and international and include fuel used for engines and airframe testing;
- Data on annual arrivals and departures of domestic and international landing and take-off cycles at Italian airports are reported by different sources: National Institute of Statistics in the statistics yearbooks (ISTAT, several years [a]), Ministry of Transport in the national transport statistics yearbooks (MIMS, several years), the Italian civil aviation in the national aviation statistics yearbooks (ENAC/MIMS, several years), which report total national and international commercial air traffic, scheduled and not scheduled flights including charter and air taxi, EUROCONTROL flights data time series 2002 – 2020 (EUROCONTROL, several years).

An overall assessment and comparison with EUROCONTROL emission estimates was carried out which led to an update of the methodology used by Italy for this category. Data on the number of flights, fuel consumption and emission factors were provided by EUROCONTROL in the framework of a specific project funded by the European Commission, and quality checked by the European Environmental Agency and its relevant Topic Centre (ETC/ACM), aimed at improving the reporting and the quality of emission estimates from the aviation sector of each EU Member State under both the UNFCCC and LRTAP conventions. The Advanced Emissions Model (AEM) was applied by EUROCONTROL to derive these figures, according to a Tier 3 methodology (EMEP/EEA, 2019).
EUROCONTROL fuel and emissions time series cover the period 2005-2020, while the number of flights is available since 2002. In this year submission, EUROCONTROL data, related to the number of flights in Italy, have been used to update the national inventory from 2002, while fuel and emissions data have been used since 2005.
For the time series from 1990 to 1999, figures for emission and consumption factors are derived by the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007), both for LTO cycles and cruise phases, taking into account national specificities. These specificities derived from the results of a national study which, taking into account detailed information on the Italian air fleet and the origin-destination flights for the year 1999, calculated national values for both domestic and international flights for the same year (Romano et al., 1999; ANPA, 2001; Trozzi et al., 2002 (a)) on the basis of the default emission and consumption factors reported in the EMEP/CORINAIR guidebook. These national average emissions and consumption factors were therefore used to estimate emissions for LTO cycles and cruise both for domestic and international flights from 1990 to 1999.
Specifically, for the year referred to in the survey, the method estimates emissions from the number of aircraft movements broken down by aircraft and engine type (derived from ICAO database if not specified) at each of the principal Italian airports; information about whether the flight is international or domestic and the related distance travelled has also been considered.

A Tier 3 method has been applied for 1999. In fact, figures on the number of flights, destination, aircraft fleet and engines have been provided by the local airport authorities, national airlines and EUROCONTROL, covering about 80% of the national official statistics on aircraft movements for the relevant years. Data on 'Times in mode' have also been supplied by the four principal airports and estimates for the other minor airports have been carried out on the basis of previous sectoral studies at local level. Consumption and emission factors are those derived from the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). Based on sample information, estimates have been carried out at national level from 1990 to 1999 considering the official statistics of the aviation sector (ENAC/MIMS, several years) and applying the average consumption and emission factors.
From 2005, fuel consumption and emission factors were derived from the database made available to EU Member States by EUROCONTROL, as previously described. These data were used for updating fuel consumption factors, and emission factors of all pollutants. For the period between 1999 and 2005, where relevant, a linear interpolation has been applied to calculate these parameters.
Estimates were carried out applying the consumption and emission factors to the national official aviation statistics (ENAC/MIMS, several years) and EUROCONTROL data on movements from 2002 (EUROCONTROL, several years).
In general, to carry out national estimates of greenhouse gases and other pollutants in the Italian inventory for LTO cycles, both domestic and international, consumptions and emissions are calculated for the complete time series using the average consumption and emission factors multiplied by the total number of flights. The same method is used to estimate emissions for domestic cruise; on the other hand, for international cruise, consumptions are derived by difference from the total fuel consumption reported in the national energy balance and the estimated values as described above and emissions are therefore calculated.
The fuel split between national and international fuel use in aviation is then supplied to the Ministry of the Economical Development to be included in the official international submission of energy statistics to the IEA in the framework of the Joint Questionnaire OECD/EUROSTAT/IEA compilation together with other energy data.
Data on domestic and international aircraft movements from 1990 to 2020 are shown in Table 3.15 where domestic flights are those entirely within Italy.
Since 2002, emission time series have been updated on the basis of EUROCONTROL flights data, considering departures from and arrivals to all airports in Italy, regarding flights flying under instrument flight rules (IFR), including civil helicopters flights and excluding flights flagged as military, when the above flights they can be identified while, from 1990 to 2001, data from ENAC have been used (ENAC/MIMS, several years).

Table 3.15 Aircraft Movement Data (LTO cycles)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Domestic flights	172,148	185,220	319,748	350,140	354,520	280,645	277,872	281,498	284,627	288,470	151,156
International flights	147,875	198,848	303,608	381,206	406,990	425,410	446,817	462,896	484,764	502,764	172,835

Source: ISTAT, several years [a]; ENAC/MIMS, several years; Eurocontrol, several years.

Emission factors are reported in Table 3.16 and Table 3.17.
CO_2 and SO_2, emission factors (in kg/TJ) depend on the fuel quality and they have been assumed according to the information available in literature that the quality of jet fuel does not change in the period. CO_2emission factors are those in the 2006 IPCC Guidelines (IPCC, 2006), while SO_2emission factor is equal to 1 kg/t of fuel.
For N_2O, because of emission factors are not available at engine/airplane level in the relevant EMEP and IPCC Guidelines which are based on the ICAO database, and the 2006 IPCC Guidelines default value has been used, equal to 2 kg/TJ (IPCC, 2006).
For the other gases, including CH_4, emission factors depend on the technologies and vary in the time series according to the surveys as already described in this paragraph.

Table 3.16 CO_2 and SO_2 emission factors for Aviation (kg/t) 1990-2020

	CO_2[a]	SO_2
Aviation jet fuel	849	1.0
Aviation gasoline	839	1.0

a Emission factor as kg carbon/t.

Table 3.17 Non-CO_2 emission factors for Aviation (2020)

	Units	CH_4	N_2O	NO_x	CO	NMVOC	Fuel
Domestic LTO	kg/LTO	0.126	0.051	7.639	6.201	0.942	589.200
International LTO	kg/LTO	0.160	0.065	10.720	7.226	0.948	749.400
Domestic Cruise	kg/t fuel	-	0.087	15.106	4.444	0.635	-
International Cruise	kg/t fuel	-	0.077	15.994	2.005	0.267	-
Aircraft Military[a]	kg/t fuel	0.400	0.200	15.800	126.000	3.600	-

Source: ([a]) EMEP/CORINAIR, 2007; EMEP/EEA 2019; Eurocontrol, several years

Total fuel consumptions, both domestic and international, are reported by LTO and cruise in Table 3.18.

Table 3.18 Aviation jet fuel consumptions for domestic and international flights (Gg)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						Gg					
Domestic LTO	111	120	208	233	227	168	166	169	179	180	89
International LTO	130	175	258	269	296	328	344	355	382	399	130
Domestic cruise	357	384	654	666	704	526	527	544	563	580	291
International cruise	1,246	1,688	2,297	2,456	2,534	2,745	2,962	3,230	3,461	3,584	1,087

Source: ISPRA elaborations

Emissions from military aircrafts are also estimated and reported under category 1.A.5.b Other.
The methodology to estimate military aviation emissions is simpler than the one described for civil aviation since LTO data are not available in this case. As for activity data, total consumption for military aviation is published in the petrochemical bulletin (MSE, several years [b]) by fuel. Emission factors are those provided in the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). CO_2 and SO_2 emission factors depend on fuel properties; as regards CO_2, according to the adoption of the 2006 IPCC Guidelines, emission factors have been calculated assuming that 100% of the fuel carbon is oxidized to CO_2. Therefore, emissions are calculated by multiplying military fuel consumption data for the EMEP/CORINAIR default emission factors shown in Table 3.17.

3.5.1.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from aviation is estimated to be about 3% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.
Time series of domestic emissions from the aviation sector is reported in Table 3.19.
An upward trend in emission levels is observed from 1990 to 2019 which is explained by the increasing number of LTO cycles. Nevertheless, the propagation of more modern aircrafts in the fleet slows down the trend in the most recent years. In year 2020 a downward trend is observed.

Table 3.19 GHG emissions from domestic aviation

		1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2	*Gg*	1,493.1	1,588.5	2,718.2	2,839.4	2,958.5	2,166.8	2,164.1	2,226.5	2,321.1	2,378.8	1,194.8
CH_4	*Mg*	26. 9	27.7	47.9	52.8	52.7	36.5	36.1	36.7	39.0	39.4	19.8
N_2O	*Mg*	41.8	44.4	76.0	79.4	82.8	60.6	60.5	62.3	64.9	66.5	33.4

Source: ISPRA elaborations

3.5.1.4 Source-specific QA/QC and verification

Data used for estimating emissions from the aviation sector derive from different sources: local airport authorities, national airlines operators, EUROCONTROL and official statistics by different Ministries and national authorities.
Different QA/QC and verification activities are carried out for this category.
As regards past years, the results of the national studies and methodologies, applied at national and airport level, were shared with national experts in the framework of an *ad hoc* working group on air emissions instituted by the National Aviation Authority (ENAC). The group, chaired by ISPRA, included participants

from ENAC, Ministry of Environment, Land and Sea, Ministry of Transport, national airlines and local airport authorities. The results reflected differences between airports, aircrafts used and times in mode spent for each operation.
Currently, verification and comparison activities regard activity data and emission factors. In particular, the number of flights has been compared considering different sources: ENAC, ASSAEROPORTI, ISTAT, EUROCONTROL and verification activities have been performed on the basis of the updated EUROCONTROL data on fuel consumption and emission factors resulting in an update and improving of the national inventory.
Furthermore, there is an ongoing collaboration and data exchange with regional environmental agencies on this issue.

3.5.1.5 Source-specific recalculations

No recalculations occurred respect to last submission.

3.5.1.6 Source-specific planned improvements

Improvements for next submissions are planned on the basis of the outcome of the ongoing quality assurance and quality control activities, in particular with regard to the results of investigation about data and information deriving from different sources, in particular further assessment of EUROCONTROL data, and comparison with ISTAT information.

3.5.2 Railways

The electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under category 1.A.1.a Public Electricity.
Emissions from diesel trains are reported under the IPCC category 1.A.3.c Railways. Estimates are based on the gasoil consumption for railways reported in BEN (MSE, several years [a]), and on the methodology Tier1, and emission factors from the EMEP/EEA Emission Inventory Guidebook 2019 (EMEP/EEA, 2019).
As regards the use of lubricants in diesel locomotives in railways, according to the review process and to the 2006 IPCC Guidelines, emission estimates from lubricants have been reported under IPPU instead of under the energy sector, except for lubricants related to the use in two stroke engines in road transport.
Fuel consumption data are collected by the Ministry of Economic Development, responsible of the energy balance, from the companies with diesel railways. The activity is present only in those areas without electrified railways, which are limited in the national territory. The trend reflects the decrease of the use of these railways. Because of low values, emissions from railways do not represent a key category.
Carbon dioxide and sulphur dioxide emissions are calculated on fuel based emission factors using fuel consumption data from BEN. The CO_2 emission factors for diesel fuel derive from ad hoc studies about the properties of transportation fuels sold in Italy, performed by ISPRA since the nineties, and whose results are representative and applicable with reference to three different time phases: 1990 – 1999; 2000 – 2011; 2012 – 2019; since 2020 (Innovhub, several years).
Values for SO_2 vary annually according to the variation of the sulphur-content of fuels produced, imported and commercialized, and it is yearly monitored according to legislative constraints; moreover, it is officially communicated to the European Commission in the framework of European Directives on fuel quality (ISPRA, several years). Emissions of CO, NMVOC, NO_x, N_2O and methane are based on the EMEP/EEA methodology (EMEP/EEA, 2019) taking into account the implementation of the relevant European Directives to reduce atmospheric pollutants. The emission factors shown in Table 3.20 are aggregate factors so that all factors are reported on the common basis of fuel consumption.

Table 3.20 Emission factors for railway in 2020 (kg/t)

	CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
				kg/t			
Diesel trains	3,140	0.18	1.24	52.4	10.7	4.65	0.015

Source: EMEP/EEA,2019; IPCC, 2006

GHG emissions from railways accounted in 2020 for about 0.18% of the total transport sector emissions.
No recalculation occurred in this submission.
No specific improvements are planned for the next submission.

3.5.3 Road Transport

3.5.3.1 Source category description

This section addresses the estimation of emissions related to category 1.A.3.b Road transportation.
In 2020, total GHG emissions from this category were about 92.1% of the total national emissions from transport, 26.3% of the energy sector and about 20.6% of the GHG national total.
From 1990 to 2020, GHG emissions from the sector decreased by 16.3%. This trend is explained by multiple factors: on one side a strong increase starting from 1990 until 2007 (27.8%), due to the increase of vehicle fleet, total mileage and consequently fuel consumptions and on the other side, in the last years, from 2007 onwards, a decrease in fuel consumption and emissions basically due to the economic crisis (emissions from 2007 to 2019 decrease of about -18.7%); then, during last year, from 2019 to 2020, there has been a sharp reduction in emissions, amounting to approximately -19.4%, as a result of the pandemic crisis.
CO_2 emissions from road transport are key category, both in 1990 and in 2020, with approach 1 and approach 2, with and without LULUCF, at level and trend assessment.
CH_4 emissions are key category: in 1990 in level with approach 2 with and without LULUCF; in trend with approach 2 without LULUCF.
N_2O emissions are key category in 1990 in level with approach 2 without LULUCF.
Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive related emission factors and road traffic data.
Emissions from biomass fuel consumption are included and reported: as regards biodiesel, under diesel fuel category, as regards bioethanol under gasoline fuel category and as regards biogas under natural gas fuel category. Biomass fuel refers prevalently to the use of biodiesel which is mixed with diesel fuel, to the use of bioethanol mixed with gasoline fuel and to the use of biogas mixed with natural gas.
CO_2 emissions are calculated on the basis of the amount of carbon in the fuel. In the model used to calculate emissions, the fuel consumption input, which is balanced with the fuel consumption estimated by the model, includes both fossil and bio fuels; then CO_2 emissions related to biomass are subtracted to the total with the aim to be reported under biomass.
CH_4 and N_2O emissions depend on the technology of vehicles and have been calculated on the basis of more detailed information regarding the type and technology of vehicles and the associated fuel consumption.
Methane emission trend is due to the combined effect of technological improvements that limit VOCs from tail pipe and the expansion of the fleet. It has to be underlined that in Italy there is a remarkable fleet of motorbikes and mopeds (about 10 million vehicles in 2020) that use gasoline and it increased of about 52% since 1990 (this fleet not completely complies with strict VOC emissions controls).

3.5.3.2 Methodological issues

According to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2000; IPCC, 2006) and the EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019), a national methodology has been developed and applied to estimate emissions; COPERT methodology is used and country specificities are taken into account according to Tier 3 of IPCC Guidelines, such as the physic-chemical characterization of fossil fuels used in Italy and the peculiar structure of the circulating fleet.
The model COPERT 5 (updated version 5.5.1, September 2021) has been used and applied for the whole time series in 2022 submission. COPERT 5 introduced over the years upgrades both from software and methodological point of view (https://www.emisia.com/utilities/copert/versions/).
Several new methodological features had been introduced respect to the previous model COPERT 4.
As regards fuel, updates concerned: fuel energy instead of fuel mass calculations; distinction between primary and end (blends) fuels, automated energy balance.
Regarding vehicle types, updated vehicle category naming, new vehicle types and emission control technology level, have been introduced.
As regards emission factors, one function type and the possibility to distinguish between peak/off-peak urban, have been implemented.
Main methodological innovations introduced since version 5.4.36, used in last submission, relate: introduction of Solid Particle Number (SPN23) emission factors for all vehicle categories; updated PM exhaust emission factor; the calculation of N_2O and NH_3 emissions for PC LPG & CNG and Urban Buses CNG has been corrected; NFR export has been corrected; the calculation of HM emissions has been corrected; fuel consumption from fossil part of biofuels is reported in the CRF export (sheet: “Other fossil fuels”); correction

of NOx emission factors for PC Diesel PHEV (Euro 6d-temp and 6d); hot emission factors for Quad & ATVs and Micro-cars have been corrected; furthermore various software upgrades have been implemented.
Italian road vehicles electricity consumption data, introduced in last COPERT version, derives from Eurostat database (https://ec.europa.eu/eurostat/data/database).
As regards CO_2 emissions from catalytic converters using urea (reported under category 2.D.3), Italian road transport emissions estimation about CO_2 from urea based catalysts is implemented in the model used.
In particular, for diesel passenger cars Euro 6 and light duty trucks Euro 6, the consumption of urea is assumed to be equal to 2% of fuel consumption; for diesel heavy duty trucks and buses, the consumption of urea is assumed to be equal to 6% of fuel consumption at Euro 4 and Euro 5 level and equal to 3.5% at Euro 6 level.
With regard to the purity (the mass fraction of urea in the urea-based additive), the default value of thirtytwo and half percent has been used (IPCC, 2006).
Methodologies are described in the following, distinguishing emissions calculated from fuel consumption and traffic data.

3.5.3.2.1 Fuel-based emissions

Emissions of carbon dioxide and sulphur dioxide from road transport are calculated from the consumption of gasoline, diesel, liquefied petroleum gas (LPG) and natural gas and the carbon or sulphur content of the fuels consumed. Consumption data have been updated according to data officially communicated to the Joint Questionnaire OECD/IEA/EUROSTAT.
Consumption data for the fuel consumed by road transport in Italy are taken from the BEN (MiSE, MiTE, several years [a]), in physical units (taking into account the use in road transportation, in machinery as regards gasoline, in commercial and public service, and subtracting the quantities for military use in diesel oil and off-road uses in petrol).
Monitoring of the carbon content of the fuels used in Italy is an ongoing activity at ISPRA (Italian Institute for Environmental Protection and Research). The purpose is to analyse regularly the chemical composition of the used fuels or relevant commercial statistics to estimate the carbon content/emission factor (EF) of the fuels. With reference to the whole inventory, for each primary fuel, a specific procedure has been established.
As regards road transport, Italy country-specific CO_2 emission factors values for gasoline, diesel fuel and LPG, derive from ad hoc studies about the properties of transportation fuels sold in Italy and whose results are representative and applicable with reference to four different time phases: 1990 – 1999; 2000 – 2012; 2013 – 2019; since 2020 (Innovhub – Fuel Experimental Station surveys, several years).
As regards natural gas, the national market is characterized by the commercialisation of gases with different chemical composition in variable quantities from one year to the other. The methodology used to estimate the average EF for natural gas per year is based on the available consumption data, referring to the lower heat value (each year the quantities of natural gas imported or produced in Italy are published on the web at http://dgerm.sviluppoeconomico.gov.it/dgerm/bilanciogas.asp, MiSE, MiTE, several years).
Emissions of CO_2, expressed as kg carbon per tonne of fuel, are based on the H/C and O/C ratios of the fuel.
The increase in fuel consumption due to air conditioning use implies that extra CO_2 emissions in g/km are calculated as a function of temperature and relative humidity; nevertheless because of CO_2 emissions depend on total statistical fuel consumption, there is not impact on the CO_2 officially reported but instead on other pollutants.
Emissions of SO_2 are based on the sulphur content of the fuel, on the assumption that all the sulphur in the fuel is transformed completely into SO_2. As regards heavy metals (exhaust emissions of lead have been dropped because of the introduction of unleaded gasoline), apparent fuel metal contents (COPERT default) are used in the emissions calculation; for the non-exhaust share, values take into account also of lubricant content and engine wear (EMEP/EEA, 2019).
Fuel consumption data derive basically from the National Energy Balance (MiSE, MiTE, several years [a]); supplementary information is taken from the Oil Bulletin (MiSE, MiTE, several years [b]). As regards biofuels, the consumption has increased in view of the targets to be respected by Italy and set in the framework of the European directive 20-20-20. The trend of biodiesel is explained by the fact that this biofuel has been tested since 1994 to 1996 before entering in production since 1998. The consumption of bioethanol is introduced since 2008, according to data resulting in the BEN.
Values of the fuel-based emission factors for CO_2 from consumption of petrol and diesel fuels are shown in Table 3.21. These factors account for the fraction of carbon oxidised for liquid fuels equal to 1, as suggested by the 2006 IPCC guidelines (IPCC, 2006). From the nineties, different directives regulating the fuel quality in Europe have been implemented (Directive 93/12/EC, Directive 98/70/EC, Directive 2003/17/EC and Directive 2009/30/EC), in parallel with the evolution of vehicle fleet technologies; this resulted in remarkable

differences in the characteristic of the fuels, including the content of carbon, hydrogen and oxygenates, parameters needed to derive the CO_2 emission factors.
The final report on the physic-chemical characterization of fossil fuels used in Italy, carried out by the Fuel Experimental Station, that is an Italian Institute operating in the framework of the Department of Industry, has been used since 2015 submission, with the aim to improve fuel quality specifications. Fuel information is also updated on the basis of the annual reports published by ISPRA about the fuel quality in Italy.
The COPERT tool "CO_2 Correction" aimed at CO_2 correction based on type approval CO_2 emission factors, has been applied for passenger cars, from Euro 4 onwards. Since 2010 data published by EEA have been used about monitoring CO_2 emissions from new passenger cars (https://www.eea.europa.eu/themes/transport/co2-emissions-from-new-passenger-cars). For the years 2006 – 2009, Italian Ministry of Transport data have been used.
A specific survey was also conducted to characterize the national fuel used in 2000-2001.
Regarding 1990-1999, a study has been done to evaluate the use of the default emission factors reported in the IPCC Guidelines 1996 in consideration of the available information on national fuels. Emission factors from the Guidelines have been considered representative for diesel and LPG while for gasoline a country specific emission factor has been calculated taking into account the IPCC default values and the specific energy content of the national fuels. For further details see the relevant paragraph in Annex 6.
Values for SO_2 vary annually as the sulphur-content of fuels change and are calculated every year for gasoline and gas oil and officially communicated to the European Commission in the framework of European Directives on fuel quality (ISPRA, several years); these figures are also published by the refineries industrial association (UP, several years). Directive 2003/17/EC introduced for 2005 new limit for S content in the fuels, both gasoline and diesel, 50% lower than the previous ones.

Table 3.21 Fuel-Based Emission Factors for Road Transport

National emission factors	Mg CO_2 /TJ	Mg CO_2/Mg
Mtbe	73.072	-
Gasoline, 1990-'99, interpolated emission factor	71.034	3.123
Gasoline, test data, 2000-2012b,c	71.864	3.143
Gasoline, test data, 2013-2019c	73.338	3.140
Gasoline, test data, 2020c	73.081	3.152
Gas oil, 1990-'99, IPCC OECDa	73.274	3.129
Gas oil, engines, test data, 2000-2012b,c	73.892	3.171
Gas oil, engines, test data, 2013-2019c	73.648	3.151
Gas oil, engines, test data, 2020c	73.510	3.150
LPG, 1990-'99, IPCCa Europe	64.350	3.000
LPG, test data, 2000-2019b,c	65.592	3.026
LPG, test data, 2020c	65.984	3.026
Natural gas (dry) 1990	55.822	-
Natural gas (dry) 2020	57.918	-

a Revised 1996 IPCC Guidelines for National GHG Inventories, Reference Manual, ch1, tables 1-36 to 1-42
b APAT, 2003 [b]
c Emission factor in kg carbon/tonne, based on Fuel Experimental Station (Innovhub, several years)

Emissions of CO_2 and SO_2 can be broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants. The current inventory used fuel consumption factors expressed as grams of fuel per kilometre for each vehicle type and average speed calculated from the emission functions and speed-coefficients provided by the model COPERT 5 (EMISIA SA, 2021). Mileage and fuel consumptions calculated from COPERT functions are shown in Table 3.22 for each vehicle, fuel and road type in Italy in 2020.

Table 3.22 Average fuel consumption and mileage for main vehicle category and road type, year 2020

		Fuel Consumption (TJ)				Mileage (kveh_km)			
		Urban	**Rural**	**Highway**	***TOTAL***	**Urban**	**Rural**	**Highway**	***TOTAL***
Passenger Cars	Petrol	69,506	99,918	36,825	*206,249*	19,848,889	54,022,562	19,076,356	92,947,807
Passenger Cars	Petrol Hybrid	3,956	3,336	1,914	*9,206*	1,462,259	2,339,614	1,072,323	4,874,197
Passenger Cars	Diesel	101,902	223,899	113,452	*439,253*	31,820,917	108,288,682	54,229,287	194,338,887
Passenger Cars	Diesel Hybrid	616	1,370	1,289	*3,275*	277,666	981,086	592,354	1,851,105
Passenger Cars	LPG Bifuel	21,015	23,830	15,204	*60,049*	5,786,528	11,507,628	5,735,015	23,029,171
Passenger Cars	CNG Bifuel	12,927	9,683	6,623	*29,233*	2,859,379	4,098,444	2,573,442	9,531,265
Light Commercial Vehicles	Petrol	1,251	1,155	409	*2,815*	204,705	450,352	163,764	818,822
Light Commercial Vehicles	Diesel	40,424	55,345	26,182	*121,951*	9,258,649	20,369,028	7,406,919	37,034,597
Heavy Duty Trucks	Petrol	2	4	1	*7*	199	598	199	997
Heavy Duty Trucks	Diesel	24,132	49,138	118,886	*192,156*	1,846,317	5,866,640	13,541,464	21,254,421
Buses	Diesel	7,906	6,032	15,412	*29,350*	537,632	629,809	1,908,517	3,075,957
Buses	Diesel Hybrid	276	18	-	*294*	23,021	2,558	-	25,579
Buses	CNG	2,892	213	-	*3,105*	149,027	16,559	-	165,586
Mopeds	Petrol	2,044	876	-	*2,920*	2,721,228	1,166,241	-	3,887,469
Motorcycles	Petrol	18,907	9,142	1,607	*29,655*	12,064,472	7,037,609	1,005,373	20,107,454

Source: ISPRA elaborations
Notes: Biodiesel included in diesel; bioethanol included in gasoline; biogas included in natural gas.

3.5.3.2.1.1 Biofuels used and fossil fuel fraction in biodiesel

In Italy, biodiesel, biogasoline and biogas are used in road transportation and the respective emissions have been estimated in the Inventory.
As regards biodiesel and biogasoline, almost all the commercial gasoline is practically still substantially an E0 (in 2020 the share of biogasoline is 0.3%, respect to the total road gasoline consumption), while the distributed diesel reaches up to 5-7% by volume of biodiesel in diesel fuel (in 2020 the share of biodiesel is 6.7%, respect to the total road diesel consumption). That is because Italian producers/refineries have decided since the beginning of the introduction of the obligations on biofuels to focus on biodiesel rather than on ethanol to comply with the European/Italian obligations to introduce bio-fuels on the market.
Biogasoline represents to date a minimum percentage out of the total gasoline including biogasoline consumption. According to the Renewable energy Directive (2009/28/EC) the amount of biogasoline reported in the Energy balance is equal to the renewable part of the fuel, calculated as the 37% of the total volume placed on the market.
Biodiesel has been tested since 1994 to 1996 before entering in production since 1998.
Until 2020 submission, biodiesel emissions from the fossil component of the fuel were calculated on the basis of the percentage 5.5% indicated in the IPCC Working Group I "Note on fossil carbon content in biofuels" (prepared by Ioannis Sempos, 10 October 2018), according to which the "the fossil part of the FAME ranges from 5.3 to 5.5%".
Since submission 2021, the assessment of the biofuel origin has been carried out and CO_2 emissions from fossil fuel content of biofuels in Italy have been estimated by the implementation of the COPERT tool "fossil fuel fraction in biodiesel". In particular, the estimation is based on the Country specific data regarding the share of FAME in biodiesel (equal to 87.74% in 2020), deriving from data and information reported by Italy under Council Directive (EU) 2015/652 laying down calculation methods and reporting requirements pursuant to Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels.
Moreover biogas road consumption has been taken into account in the Inventory, representing about 11% of total road natural gas consumption in 2020. It is reported only for the last reporting year 2020 in the IEA - Eurostat – UNECE Energy Questionnaire.

3.5.3.2.1.2 The fuel balance process

An automatic fuel balancing procedure is implemented in COPERT 5 to ensure that the breakdown of fuel consumption by each vehicle type calculated on the basis of the fuel consumption factors once added up matches the BEN figures for total fuel consumption in Italy (adjusted for off-road consumption).
In COPERT 5 the automatic energy balance process has been introduced and it has been applied for this submission. This simulation is started up having the target to equalize calculated and statistical consumptions, separately for fuel, at national level, with the aim to obtain final estimates the most accurate as possible. Once all data and input parameters have been inserted and all options have been set reflecting the peculiar situation of the Country, emissions and consumptions are calculated by the model in the detail of the vehicle category legislation standard; then the aggregated consumption values so calculated are compared with the input statistical national aggregated values (deriving basically from the National Energy Balance, as described above), with the aim to minimize the deviation.

3.5.3.2.2 Traffic-based emissions

Emissions of NMVOC, NO_X, CO, CH_4 and N_2O are calculated from emission factors expressed in grams per kilometre and road traffic statistics estimated by ISPRA on the basis of data released from: Ministry of Transport (MIMS, several years), the Automobile Club of Italy (ACI, several years), the National Association of Cycle-Motorcycle Accessories (ANCMA, several years), the National Institute of Statistics (ISTAT), the National Association of concessionaries of motorways and tunnels (AISCAT).
The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven under test cycles with different average speeds calculated from the emission functions and speed-coefficients provided by COPERT 5 (EMISIA SA, 2021). This source provides emission functions and coefficients relating emission factors (in g/km) to average speed for each vehicle type and Euro emission standard derived by fitting experimental measurements to polynomial functions. These functions were then used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types.
Since 2020 submission, country specific hot emission factors for Euro 6 Small and Medium LPG passenger cars have been applied for: CO, NO_X, VOC, PM Exhaust, FC, CH_4, NH_3, deriving from tests on five Euro 6 b/c bifuel LPG passenger cars (Innovhub, 2018).
N_2O emission factors derive from the application of COPERT 5 v.5.5.1 model (EMISIA SA, 2021).
Tier 3 is implemented, according to which N_2O is connected to the aftertreatment devices, such as catalytic converters and diesel particle filters. N_2O emissions are significant for catalyst vehicles, in particular when the catalyst is under partially oxidizing conditions, when the catalyst has not reached its light-off temperature yet or when the catalyst is aged. So N_2O emissions depend on the vehicle age or cumulative mileage. Moreover, aftertreatment ageing depends upon the fuel sulphur level. Hence, different emission factors are explained by the variation in fuel sulphur content and in the driving conditions (EMEP/EEA, 2019). COPERT model version 5.5.1 reports an emission factor equal to 0 for conventional LPG passenger cars, for conventional diesel passenger cars and light duty vehicles and for CNG Buses, while for heavy duty and diesel buses vehicles, as well as for CNG passenger cars, for gasoline passenger cars, light and heavy duty vehicles, mopeds and motorcycles, emission factors are available in the model. Because of those zero values, noticeable variations may appear between IEF referred to consecutive years where the fleet consists just of conventional vehicles and Euro 1 vehicles; such differences are then explained by the different share of Euro 1 vehicles out of the total. As regards newer vehicles, N_2O emissions may derive as a byproduct from SCR systems, this issue needs to be monitored to reveal how much this is could be a problem in real world conditions (EMEP/EEA, 2019).
The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications in the national road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of vehicles on the road powered by different fuels and in terms of the fraction of vehicles on the road relating to the different emission regulations which applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet.
It is beyond the scope of this paper to illustrate in details the COPERT 5 methodology: in brief, the emissions from motor vehicles fall into three different types calculated as hot exhaust emissions, cold-start emissions, and evaporative emissions for NMVOC; in addition, not exhaust emissions for PM, BC and heavy metals deriving from road vehicle tyre and brake wear and road abrasion are contemplated.
Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, type of fuel the engine runs on, the driving profile of the vehicle on a journey and the emission regulations applied when the vehicle was first registered as this defines the type of technology the vehicle is equipped with.

For a particular vehicle, the drive cycle over a journey is the key factor which determines the amount of pollutant emitted.
Key parameters affecting emissions are acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, studies have shown that for modelling vehicle emissions over a road network at national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (EMISIA, 2020). Emission factors for average speeds on the road network are then combined with the national road traffic data.
Emissions are calculated from vehicles of the following types:

- Gasoline passenger cars;
- Diesel passenger cars;
- LPG passenger cars;
- CNG passenger cars;
- Petrol Hybrid passenger cars;
- Diesel Hybrid passenger cars;
- Gasoline Light Commercial Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes);
- Diesel Light Commercial Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes);
- Rigid-axle Heavy Duty Trucks (GVW > 3.5 tonnes);
- Articulated Heavy Duty Trucks (GVW > 3.5 tonnes);
- Diesel Buses and coaches;
- Diesel Hybrid Buses;
- CNG Buses;
- Mopeds and motorcycles.

Basic data derive from different sources.
Detailed data on the national fleet composition are found in the yearly report from ACI (ACI, several years), used from 1990 to 2006, except for mopeds for which estimates have been elaborated on the basis of National Association of Cycle-Motorcycle Accessories data on mopeds fleet composition and mileages (ANCMA, several years).
Starting from 2013 submission, specific fleet composition data were provided by the MIMS for all vehicle categories from 2007 onwards. The Ministry of Transport in the national transport yearbook (MIMS, several years) reports mileages time series. Furthermore, since 2015 MIMS supplies information relating the distribution of old gasoline cars over the detailed vehicles categories (PRE ECE; ECE 15/00-01; ECE 15/02; ECE 15/03; ECE 15/04; information obtained from the registration year; data used for the updating of the time series since 2007).
Since 2014, MIMS supplies updated information relating the reallocation of not defined vehicles categories (data used for the updating of the time series since 2007).
MIMS data have been used relating to: the passenger cars (“Petrol Hybrid” passenger cars category are introduced from 2007 onwards, the mini petrol (Gasoline < 0.8 l) passenger cars subsector is introduced since 2012 and diesel small (Diesel<1.4 l) subsector since 2007 onwards, in addition to the gasoline, diesel, LPG, CNG traditional ones); the diesel and gasoline light commercial vehicles; the breakdown of the heavy duty trucks, buses and coaches fleet according to the different weight classes and fuels (for HDT almost exclusively diesel, a negligible share consists of gasoline HDT vehicles; diesel for coaches; diesel, diesel hybrid and CNG for buses); the motorcycles fleet in the detail of subsector and legislation standard of both 2-stroke and 4-stroke categories.
Fleet values for urban buses have been updated according to the updating of the data on urban public buses, published on CNIT (Ministry of Transport, several years).
The National Institute of Statistics carries out annually a survey on heavy goods vehicles, including annual mileages (ISTAT, several years [b]).
The National Association of concessionaries of motorways and tunnels produces monthly statistics on highway mileages by light and heavy vehicles (AISCAT, several years).
The National General Confederation of Transport and Logistics (CONFETRA, several years) and the national Central Committee of road transporters (Giordano, 2007) supplied useful information and statistics about heavy goods vehicles fleet composition and mileages.
In the following Tables 3.23, 3.24, 3.25 and 3.26 detailed data on the relevant vehicle mileages in the circulating fleet are reported, subdivided according to the main emission regulations.

Table 3.23 Passenger Cars technological evolution: circulating fleet calculated as stock data multiplied by effective mileage (%)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
PRE ECE, pre-1973	0.04	0.03	0.01	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002
ECE 15/00-01, 1973-1978	0.10	0.04	0.01	0.005	0.003	0.003	0.003	0.002	0.002	0.003	0.002
ECE 15/02-03, 1978-1984	0.30	0.15	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ECE 15/04, 1985-1992	0.55	0.55	0.28	0.10	0.04	0.03	0.02	0.02	0.02	0.02	0.02
PC Euro 1 - 91/441/EEC, from 1/1/93	0.001	0.24	0.27	0.17	0.05	0.02	0.02	0.01	0.01	0.01	0.01
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.39	0.32	0.21	0.12	0.10	0.09	0.08	0.07	0.06
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.31	0.20	0.13	0.12	0.11	0.10	0.09	0.08
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.09	0.44	0.37	0.35	0.33	0.31	0.28	0.27
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.04	0.25	0.24	0.23	0.21	0.18	0.17
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.06	0.13	0.19	0.26	0.25	0.24
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2019 - 2020)	-	-	-	-	-	-	-	-	-	0.09	0.14
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

a. Gasoline cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Conventional, pre-1993	1.00	0.92	0.36	0.06	0.01	0.004	0.003	0.003	0.003	0.003	0.003
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.08	0.10	0.03	0.01	0.002	0.002	0.001	0.001	0.001	0.001
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.54	0.22	0.05	0.02	0.02	0.01	0.01	0.01	0.01
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.57	0.31	0.15	0.14	0.11	0.09	0.08	0.08
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.12	0.55	0.41	0.38	0.37	0.30	0.28	0.26
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.07	0.36	0.32	0.30	0.30	0.28	0.27
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	0.0001	0.05	0.14	0.21	0.29	0.28	0.27
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2019 - 2020)	-	-	-	-	-	-	-	-	-	0.06	0.10
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

b. Diesel cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Conventional, pre-1993	1.00	0.90	0.71	0.47	0.04	0.01	0.01	0.01	0.01	0.01	0.01
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.10	0.20	0.26	0.02	0.01	0.01	0.01	0.01	0.004	0.004
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.09	0.19	0.08	0.03	0.03	0.02	0.02	0.02	0.01
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.06	0.08	0.05	0.04	0.04	0.03	0.03	0.02
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.01	0.75	0.46	0.42	0.38	0.35	0.31	0.29
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.03	0.36	0.34	0.32	0.30	0.28	0.26
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.08	0.15	0.09	0.11	0.13	0.13
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	-	0.14	0.18	0.23	0.22
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d (2020 and later)	-	-	-	-	-	-	-	-	-	-	0.05
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

c. Lpg cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
PC Conventional - Euro 4	1.00	1.00	1.00	1.00	0.91	0.58	0.54	0.51	0.47	0.44	0.42
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.09	0.32	0.31	0.31	0.30	0.29	0.29

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.10	0.15	0.10	0.12	0.14	0.14
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	-	0.08	0.10	0.13	0.12
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d (2020 and later)	-	-	-	-	-	-	-	-	-	-	0.04
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
d. CNG cars technological evolution											
	2007	**2008**	**2009**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	1.00	1.00	0.65	0.54	0.22	0.07	0.04	0.03	0.02	0.01	
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	0.35	0.46	0.61	0.42	0.27	0.18	0.11	0.07	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	0.16	0.51	0.13	0.15	0.15	0.09	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	0.56	0.64	0.72	0.44	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d (2020 and later)	-	-	-	-	-	-	-	-	-	0.39	
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
e. Hybrid Gasoline cars technological evolution (from 2007 onwards)											
	2007	**2008**	**2009**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 a/b/c	1.00	1.00	1.00	1.00	1.00	1.00	0.69	0.42	0.11	0.04	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	0.31	0.58	0.89	0.39	
PC Euro 6 (Since EC 715/2007, from 9/1/2015) - Euro 6 d (2020 and later)	-	-	-	-	-	-	-	-	-	0.57	
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
e. Hybrid Diesel cars technological evolution (from 2007 onwards)											

Source: ISPRA elaborations on ACI and MIMS data

Table 3.24 Light Duty Vehicles technological evolution: circulating fleet calculated as stock data multiplied by effective mileage (%)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Conventional, pre 10/1/94	1.00	0.93	0.63	0.35	0.08	0.06	0.06	0.06	0.05	0.03	0.03
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.07	0.22	0.17	0.10	0.04	0.04	0.04	0.03	0.02	0.02
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.15	0.15	0.30	0.15	0.15	0.14	0.12	0.06	0.06
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.31	0.26	0.19	0.19	0.18	0.15	0.11	0.10
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.25	0.32	0.32	0.32	0.28	0.24	0.22
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.00	0.22	0.20	0.17	0.19	0.17	0.16
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 a/b/c	-	-	-	-	-	0.02	0.05	0.09	0.06	0.11	0.10
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 d-temp (2018 - 2020)	-	-	-	-	-	-	-	-	0.11	0.25	0.32
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
a. Gasoline Light Commercial Vehicles technological evolution											
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Conventional, pre 10/1/94	1.00	0.92	0.55	0.23	0.07	0.02	0.02	0.02	0.01	0.01	0.01
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.08	0.21	0.11	0.05	0.02	0.02	0.01	0.01	0.01	0.01
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.23	0.20	0.18	0.07	0.06	0.04	0.03	0.02	0.02
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.45	0.34	0.21	0.18	0.12	0.09	0.07	0.06
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.34	0.33	0.29	0.27	0.23	0.18	0.17

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.01	0.35	0.37	0.35	0.34	0.33	0.30
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 a/b/c	-	-	-	-	0.00	0.01	0.07	0.19	0.12	0.17	0.15
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 d-temp (2018 - 2020)	-	-	-	-	-	-	-	-	0.16	0.22	0.29
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
b. Diesel Light Commercial Vehicles technological evolution											

Source: ISPRA elaborations on ACI and MIMS data

Table 3.25 Heavy Duty Trucks and Buses technological evolution: circulating fleet calculated as stock data multiplied by effective mileage (%)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Conventional, pre 10/1/93	1.00	0.90	0.67	0.39	0.20	0.02	0.02	0.02	0.02	0.01	0.01
HDT Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.10	0.10	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01
HDT Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.22	0.27	0.15	0.08	0.07	0.06	0.05	0.05	0.04
HDT Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.27	0.36	0.34	0.31	0.28	0.25	0.22	0.20
HDT Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.07	0.10	0.09	0.08	0.08	0.07	0.07
HDT Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.18	0.38	0.37	0.36	0.34	0.33	0.32
HDT Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI A/B/C	-	-	-	-	-	0.07	0.13	0.19	0.25	0.25	0.23
HDT Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	-	-	0.06	0.12
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
a. Heavy Duty Trucks technological evolution											
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Conventional, pre 10/1/93	1.00	0.93	0.65	0.34	0.13	0.01	0.01	0.01	0.01	0.01	0.004
Buses Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.07	0.07	0.08	0.04	0.01	0.01	0.01	0.00	0.01	0.005
Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.28	0.32	0.27	0.14	0.13	0.11	0.08	0.08	0.07
Buses Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.26	0.34	0.38	0.35	0.32	0.28	0.25	0.24
Buses Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.12	0.13	0.12	0.11	0.11	0.11	0.10
Buses Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.11	0.28	0.28	0.29	0.27	0.27	0.26
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI A/B/C	-	-	-	-	-	0.05	0.10	0.16	0.24	0.22	0.21
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	-	-	0.06	0.11
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
b. Diesel Buses technological evolution											
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Urban CNG Buses Conventional, pre 10/1/93; Urban CNG Buses Euro I - 91/542/EEC Stage I, from 10/1/93	1.00	1.00	0.11	0.01	0.003	0.003	0.003	0.002	0.002	0.001	0.001
Urban CNG Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.89	0.20	0.10	0.05	0.04	0.04	0.03	0.03	0.02
Urban CNG Buses Euro III - 2000 Standards, 99/96/EC, from 10/1/2001; Urban CNG Buses Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	0.79	0.09	0.07	0.07	0.07	0.06	0.06	0.05
Euro V - 2008 Standards, 99/96/EC, from 10/1/2009; EEV (Enhanced environmentally friendly vehicle; ref. 2001/27/EC and 1999/96/EC line C, optional limit emission values); Urban CNG Buses Euro VI – EC 595/2009, from 12/31/2013	-	-	-	-	0.81	0.88	0.88	0.89	0.90	0.91	0.93
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
c. CNG Buses technological evolution											
		2007	**2008**	**2009**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI A/B/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.21	0.16	

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	-		0.79	0.84
Total		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
d. Diesel Hybrid Buses technological evolution (from 2007 onwards)											

Source: ISPRA elaborations on ACI and MIMS data

Table 3.26 Mopeds and motorcycles technological evolution: circulating fleet calculated as stock data multiplied by effective mileage (%)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Mopeds and motorcycles - Conventional	1.00	1.00	0.86	0.43	0.18	0.11	0.10	0.11	0.11	0.11	0.10
Mopeds and motorcycles - Euro 1	-	-	0.14	0.30	0.20	0.14	0.13	0.13	0.11	0.11	0.10
Mopeds and motorcycles - Euro 2	-	-	-	0.22	0.35	0.34	0.33	0.30	0.30	0.23	0.22
Mopeds and motorcycles - Euro 3	-	-	-	0.04	0.27	0.42	0.43	0.41	0.38	0.41	0.39
Mopeds and motorcycles - Euro 4	-	-	-	-	-	-	0.01	0.05	0.10	0.14	0.18
Mopeds and motorcycles - Euro 5	-	-	-	-	-	-	0.0000002	0.0000002	0.0000005	0.0002	0.007
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: ISPRA elaborations on ACI, ANCMA and MIMS data

Average emission factors are calculated for average speeds by three driving modes: urban, rural and motorway, combined with the vehicle kilometres travelled and vehicle categories.
ISPRA estimates total annual vehicle kilometres for the road network in Italy by vehicle type, see Table 3.27, based on data from various sources:

- Ministry of Transport (MIMS, several years) for rural roads and on other motorways; the latter estimates are based on traffic counts from the rotating census and core census surveys of ANAS;
- highway industrial association for fee-motorway (AISCAT, several years);
- local authorities for built-up areas (urban).

Table 3.27 Evolution of fleet consistency and mileage

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
All passenger vehicles (including moto), total mileage (10^9 veh-km/y)	350	412	455	453	450	444	445	447	442	445	354
Car fleet (10^6)	27	30	32	34	36	37	38	38	39	40	40
Moto, total mileage (10^9 veh-km/y)	30	41	42	42	36	33	31	28	27	28	24
Moto fleet (10^6)	7	7	9	9	9	10	10	10	10	10	10
Goods transport, total mileage (10^9 veh-km/y)	69	76	83	104	83	62	60	51	65	66	59
Truck fleet (10^6), including LDV	2	3	3	4	5	5	5	5	5	5	5

Source: ISPRA elaborations
Notes: The passenger vehicles include passenger cars, buses and moto; the moto fleet includes mopeds and motorcycles; in the goods transport light commercial vehicles and heavy duty trucks are included.

When a vehicle engine is cold, it emits at a higher rate than when it has warmed up to its designed operating temperature. This is particularly true for gasoline engines and the effect is even more severe for cars fitted with three-way catalysts, as the catalyst does not function properly until the catalyst is also warmed up. Emission factors have been derived for cars and LCVs from tests performed with the engine starting cold and warmed up. The difference between the two measurements can be regarded as an additional cold-start penalty paid on each trip a vehicle is started with the engine (and catalyst) cold.
Evaporative emissions of gasoline fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC and methane emissions from road transport. Nevertheless, the contribution of evaporative emissions to total NMVOC emissions decreased significantly since the introduction of carbon canisters. Breathing losses through the tank vent and fuel permeations and leakages are considered the most important sources of evaporative emissions. The estimation of evaporative emissions takes into account three different mechanisms: diurnal emissions (depending on daily temperature variations),

running losses (during the vehicles use) and hot soak emissions (following the vehicles use). The process of fuelling of vehicles is not considered here. The procedure for estimating evaporative emissions of NMVOCs takes account of gasoline volatility, the absolute ambient temperature and temperature changes, the characteristics of vehicles design; the driving pattern is also significant for hot soak emissions and running losses (EMEP/EEA, 2019).

3.5.3.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from road transport is estimated to be about 4% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions because of the uncertainty levels attributed to the related emission factors.

Montecarlo analysis has been carried out by EMISIA[3] on behalf of the Joint Research Centre (Kouridis et al., 2010) in the framework of the study "Uncertainty estimates and guidance for road transport emission calculations" for 2005 emissions; a summary of main results of study are reported in Annex 1. The study shows an uncertainty assessment, at Italian level, for road transport emissions on the basis of 2005 input parameters of the COPERT 4 model (v. 7.0).

The following Table 3.28 summarizes the time series of GHG emissions in CO_2 equivalent from road transport, highlighting the evolution of this source, characterized by an upward trend in CO_2 emission levels from 1990 to 2007, which is explained by the increasing of the fleet, total mileages, and fuel consumptions and by a decreasing trend from 2007 onwards, due, on one side, to the economical crisis, and on another side, to the propagation of the number of vehicles with low fuel consumption per kilometre. In 2019, with respect to 2007, a reduction in total mileages, fuel consumptions (gasoline and diesel) and consequently CO_2 emissions has been noted. During last year, from 2019 to 2020, there has been a sharp reduction in emissions, amounting to approximately -19.4%, as a result of the pandemic crisis.

CH_4 and N_2O emission trends are consequence of the penetration of new technologies according to the main emission regulations. Specifically, CH_4 and more in general VOC emissions have reduced along the time series due to the introduction of VOC abatement devices on vehicles, in agreement with the legislation emission limits, and the rate of penetration of the new vehicles into the national fleet.

The time series of N_2O emissions and implied emission factors are prevalently driven by the fleet composition and the penetration rate of the new vehicles/technologies. Moreover, in the COPERT model, N_2O emission factors depend also on the sulphur content of the fuel. In particular, significant drops of emissions and implied emission factors are observed in 1999-2000 and in 2004-2005 which are explained by the different fuel specifications in those years due to the application of the relevant European Directives on fuel quality.

The sulphur content (%wt) in gasoline was 0.04 and 0.007 respectively in 1999 and 2000 and 0.0055 and 0.0025 respectively in 2004 and 2005 and changed from 0.0226 in 2004 to 0.0035 in 2005 for diesel oil.

Table 3.28 GHG emissions from road transport (kt CO_2 equivalent)

		1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2	Gg	92,331.7	103,532.1	111,524.5	117,111.9	104,658.7	98,346.6	96,863.4	92,743.9	95,773.5	96,604.1	77,832.0
CH_4	Gg CO_2 eq	867.1	975.7	729.8	469.7	278.7	208.1	194.2	182.4	179.7	186.4	147.9
N_2O	Gg CO_2 eq	838.1	1,612.5	1,488.5	1,025.2	943.6	890.8	894.1	865.3	891.1	900.0	737.4
Total	Gg CO_2 eq	94,037.0	106,120.3	113,742.8	118,606.9	105,881.0	99,445.5	97,951.8	93,791.5	96,844.2	97,690.5	78,717.2

Source: ISPRA elaborations

3.5.3.4 Source-specific QA/QC and verification

Data used for estimating emissions from the road transport sector derive from different sources, including official statistics providers and industrial associations.

A specific procedure undertaken for improving the inventory in the sector regards the establishment of a national expert panel in road transport which involves, on a voluntary basis, different institutions, local agencies and industrial associations cooperating for improving activity data and emission factors accuracy. In this group, emission estimates are presented annually, and new methodologies are shared and discussed. Reports and data of the meetings can be found at the following address:

[3] EMISIA: www.emisia.com

http://groupware.sinanet.isprambiente.it/expert_panel/library. In addition, road transport emission factors are shared and publicly available on the website http://www.sinanet.isprambiente.it/it/sia-ispra/fetransp.
Besides, time series resulting from the recalculation due to the application of COPERT have been discussed over time with national experts in the framework of an ad hoc working group on air emissions inventories. The group is chaired by ISPRA and includes participants from the local authorities responsible for the preparation of local inventories, sectoral experts, the Ministry of Environment, Land and Sea, and air quality model experts. Recalculations are comparable with those resulting from application of the model at local level. Top-down and bottom-up approaches have been compared with the aim to identify the major problems and future possible improvements in the methodology to be addressed (emission estimates at the link: https://emissioni.sina.isprambiente.it/serie-storiche-emissioni/).

3.5.3.5 Source-specific recalculations

The annual update of the emissions time series from road transport implies a periodic review process.
In 2022 submission the historical series has been revised mainly as a result of the upgrade of COPERT model version used (from version 5.4.36 in last submission to 5.5.1 in submission 2022), which resulted in various methodological updates, the main ones being: introduction of Solid Particle Number (SPN23) emission factors for all vehicle categories; updated PM exhaust emission factor; the calculation of N_2O and NH_3 emissions for PC LPG & CNG and Urban Buses CNG has been corrected; NFR export has been corrected; the calculation of HM emissions has been corrected; fuel consumption from fossil part of biofuels is reported in the CRF export (sheet: "Other fossil fuels"); correction of NOx emission factors for PC Diesel PHEV (Euro 6d-temp and 6d); hot emission factors for Quad & ATVs and Micro-cars have been corrected. Furthermore various software upgrades have been implemented.
Italian road vehicles electricity consumption data derive from Eurostat database (https://ec.europa.eu/eurostat/data/database). COPERT input road electricity consumption data have been calibrated on the basis of the vehicles categories using electricity actually included in COPERT classification. The change of the version was also the chance for a general revision of input data and parameters.
The analysis has been updated on the basis of the results of the survey, carried out by Innovhub, on the fuels used in road transport in Italy in 2020. In particular, the results obtained for biodiesel in 2020 have been used to update the entire fuel specifications historical series (previously, in the absence of country specific parameters, Eurostat Energy Balance parameters were used).
The results of the studies, carried out over the years, about the properties of transportation fuels sold in Italy, for consistency reasons respect to the procedure applied for the other Inventory sectors, are considered representative with reference to four different time phases: 1990 – 1999; 2000 – 2012; 2013 – 2019; since 2020 (Innovhub – Fuel Experimental Station surveys, several years).
Respect to last submission, biogas road consumption has been taken into account in the Inventory, reported only for the last reporting year 2020 in the IEA - Eurostat – UNECE Energy Questionnaire (about 11% of total road natural gas consumption).
Natural gas estimates have been revised since 2017 according to the revision of parameters applied for the estimation of emissions from this fuel for the whole Inventory.
The CO_2 correction procedure has been revised considering in the practical application only the CO2 emission values corresponding to the NEDC cycle.
Respect to last submission, the estimation of the allocation of the Euro 6 circulating fleet (among the categories Euro 6 a/b/c, Euro 6 d-temp and Euro 6 d) has been revised according the classification reported on the EMEP/EEA air pollutant emission inventory guidebook 2019 (Update Oct. 2021) due to the fact that between COPERT version 5.2.2 classification (previously kept as term of reference) and the current version 5.5.1 there was a change in the Euro 6 standards allocation to year registrations.
N_2O emissions, deriving from COPERT model version 5.5.1, have been revised: emissions have been estimated for LPG passenger cars (since Euro 1) and for CNG passenger cars, but N_2O emissions have not been attributed to CNG Buses.
Emissions from fossil fuel content of biofuel are estimated, by COPERT model version 5.5.1, not only for CO_2 (as well as in last submission), but also for CH_4 and N_2O (CRF categories: "1.A.3.b.i Other Fossil Fuels", "1.A.3.b.ii Other Fossil Fuel", "1.A.3.b.iii Other Fossil Fuel").
Mopeds circulating fleet estimation has been revised since 2012 in accordance with data provided by the Ministry of Transport for 2020, in order to address insistencies related to old and not classified vehicles in Ministry of Transport database.
Estimation of urban buses fleet data has been updated since 2019 in consequence of the updating of Ministry of transport statistics. The estimation of the buses fleet data has been revised since 2007 in relation to the

urban/extra-urban split with reference to data and information about vehicles radiations per bus category, supplied from Ministry of Transport.
According to the 2006 IPCC Guidelines, emission estimates from lubricants have been reported under IPPU except lubricants used in two stroke engines in road transport; so CO_2 emissions from lubricants have been detailed and attributed just to the two stroke engines in road transport ("1.A.3.b.iv, Other liquid fuels"), calculated by COPERT model, while the remaining share has been considered in the IPPU sector.
Differences between 2022 and previous submission, for road transport GHG emissions, account for -0.03% in 1990 and -0.05% in 2019; the recalculations registered for the driver carbon dioxide values are 0% in 1990 and -0.002% in 2019; as regards methane, discrepancies vary from -0.000002% in 1990 to +0.4% in 2019; emissions of nitrous oxide show variations of -2.8% in 1990 and -5.0% in 2019.
In Table 3.29 the recalculation time series is reported for all gases.

Table 3.29 Emission recalculations in road transport 1990 - 2019 (%)

Year	CO_2	CH_4	N_2O
1990	0.000000%	-0.000002%	-2.787162%
1991	0.000000%	-0.000002%	-2.581524%
1992	0.000000%	0.000009%	-2.283560%
1993	0.000000%	0.000009%	-1.662824%
1994	0.000000%	0.000417%	-0.656233%
1995	0.000000%	0.000285%	-0.232112%
1996	0.000000%	0.000303%	0.033121%
1997	0.000000%	0.000030%	0.086458%
1998	0.000000%	0.000226%	0.360224%
1999	0.000000%	0.000306%	0.281490%
2000	0.000000%	0.000561%	0.910051%
2001	0.000000%	0.000899%	0.974629%
2002	0.000000%	0.001232%	0.871383%
2003	0.000000%	0.001881%	0.679320%
2004	0.000000%	0.002183%	0.378435%
2005	0.000000%	0.001872%	0.028294%
2006	0.000000%	0.002068%	-1.240694%
2007	0.000000%	0.002980%	-1.760655%
2008	0.000000%	0.006447%	-2.179399%
2009	0.000000%	0.009796%	-2.734112%
2010	0.000000%	0.011188%	-3.099658%
2011	0.000000%	0.011134%	-3.405330%
2012	0.456841%	1.304355%	-3.347885%
2013	0.000299%	0.130661%	-3.708942%
2014	0.000242%	0.075551%	-4.023615%
2015	0.000183%	0.047148%	-4.282334%
2016	0.000197%	0.045978%	-4.448349%
2017	-0.002367%	-0.016299%	-4.434613%
2018	-0.003208%	0.043143%	-4.748493%
2019	-0.002461%	0.438711%	-4.989627%

Source: ISPRA elaborations

3.5.3.6 Source-specific planned improvements

Improvements for the next submission will be connected to the possible new availability of data and information regarding activity data, calculation factors and parameters, new developments of the methodology and the update of the software.

3.5.4 Navigation

3.5.4.1 Source category description

This source category includes all emissions from fuels delivered to water-borne navigation.
Mainly CO_2 emissions derive from this category, whereas CH_4 and N_2O emissions are less important.
Emissions from navigation constituted 5.5% of the total GHG in the transport sector in 2020 and about 1.2% of the national total (considering CO_2 only, the share of emissions from navigation out of the total is almost the same). GHG emissions decreased by -15.6% from 1990 to 2020, because of the reduction in fuel consumed in harbour and navigation activities; the number of movements, showing an increase since 1990, reverses the trend in recent years, to become rather stable between 2015 and 2017, with an upward trend in the 2018-2020. CO_2 from waterborne navigation is key category both in 1990 and 2020, in level (Tier 1) with and without LULUCF and in trend (Tier1) with LULUCF.

3.5.4.2 Methodological issues

Emissions of the Italian inventory from the navigation sector are carried out according to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2000; IPCC 2006) and the EMEP/EEA Guidebook (EMEP/EEA, 2019). In particular, a national methodology has been developed following the EMEP/EEA Guidebook which provides details to estimate emissions from domestic navigation, specifying recreational craft, ocean-going ships by cruise and harbour activities; emissions from international navigation are also estimated and included as memo item but not included in national totals (EMEP/EEA, 2019). Inland, coastal and deep-sea fishing are estimated and reported under 1.A.4.c. International inland waterways do not occur in Italy.
The methodology developed to estimate emissions is based on the following assumptions and information.
Activity data comprise both fuel consumptions and ship movements, which are available in different level of aggregation and derive from different sources as specified here below:
Total deliveries of fuel oil, gas oil and marine diesel oil to marine transport are given in national energy balance (MSE, several years (a)) but the split between domestic and international is not provided;
Naval fuel consumption for inland waterways, ferries connecting mainland to islands and leisure boats, is also reported in the national energy balance as it is the fuel for shipping (MSE, several years (a));
Data on annual arrivals and departures of domestic and international shipping calling at Italian harbours are reported by the National Institute of Statistics in the statistics yearbooks (ISTAT, several years (a)) and Ministry of Transport in the national transport statistics yearbooks (MIMS, several years).
As for emission and consumption factors, figures are derived by the EMEP/EEA guidebook (EMEP/EEA, 2019), both for recreational and harbour activities and national cruise, taking into account national specificities as the structural characteristic of national harbours, including typical times for manoeuvring and time spent in the harbour as well as the distribution of ships in terms of ferries, container ships, cargo. These specificities derive from the results of a national study which, taking into account detailed information on the Italian marine fleet and the origin-destination movement matrix for the year 1997, calculated national values (ANPA, 2001; Trozzi et al., 2002 (b)) on the basis of the default emission and consumption factors reported in the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007) and they have not been changed too much in the last years.
National average emissions and consumption factors were therefore estimated for harbour and cruise activities both for domestic and international shipping from 1990 to 1999. In 2009 submission the study was updated for the years 2004, 2005 and 2006 in order to consider most recent trends in the maritime sector both in terms of modelling between domestic and international consumptions and improvements of operational activities in harbour (TECHNE, 2009). On the basis of the results, national average emissions and consumption factors were updated from 2000.
Specifically, for the years referred to in the surveys, the current method estimates emissions from the number of ships movements broken down by ship type at each of the principal Italian ports considering the information of whether the ship movement is international or domestic, the average tonnage and the relevant distance travelled.
For those years, in fact, figures on the number of arrivals, destination, and fleet composition have been provided by the local port authorities and by the National Institute of Statistics (ISTAT, 2009), covering about 90% of the official national statistics on ship movements for the relevant years. Consumption and emission factors are those derived from the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007) and refer to the Tier 3 ship movement methodology that takes into account origin-destination ship movements matrices as well as technical information on the ships, as engine size, gross tonnage of ships and operational times in harbours.

Based on sample information, estimates have been carried out at national level for the relevant years considering the official statistics of the maritime sector.
In general, to carry out national estimates of greenhouse gases and other pollutants in the Italian inventory for harbour and domestic cruise activities, consumptions and emissions are calculated for the complete time series using the average consumption and emission factors multiplied by the total number of movements.
On the other hand, for international cruise, consumptions are derived by difference from the total fuel consumption reported in the national energy balance and the estimated values as described above and emissions are therefore calculated.
For maritime transportation only by Directive 1999/32/EC European Union started to examine environmental impact of navigation and in particular the sulphur content of fuels. This directive was amended by Directive 2005/33/EC that designated Baltic Sea, English channel and north sea as sulphur emission control areas (SECA) limiting the content of sulphur in the fuel for these areas and introducing a limit of 0.1% of the sulphur content in the fuel used in EU harbours from 2010.
EU legislation combined with national normative resulted in the introduction of a limit of sulphur content in maritime gasoil equal to 0.2% (2% before) from 2002 and 0.1% from 2010 while for fuel oil some limits occur only from 2008 (maximum sulphur content of 1.5 % in harbour) and from 2010, 2% in domestic waters and 1% in harbour. For inland waterways, which include the navigation on the Po River and ferry-boats in the Venice lagoon, the same legislation is applied.
The composition of the fleet of gasoline fuelled recreational craft distinguished in two strokes and four strokes engine distribution is provided by the industrial category association (UCINA, several years); the trend of the average emission factors takes into account the switch from two strokes to four strokes engines of the national fleet due to the introduction in the market of new models. In 2000, the composition of the fleet was 90% two stroke engine equipped and 10% four stroke while in the last year four strokes engines are about 53% of the fleet. Gasoline fuel consumption for recreational crafts is not available on the National Energy balance for the last years so it is estimated on the basis of the fleet which has not significantly changed in the last years.
The fuel split between national and international use in maritime transportation is then supplied to the Ministry of the Economical Development to be included in the official international submission of energy statistics to the IEA in the context of the Joint Questionnaire OECD/EUROSTAT/IEA compilation together with other energy data. A discrepancy with the international bunkers reported to the IEA still remains, especially for the nineties, because the time series of the energy statistics to the IEA are not updated.

3.5.4.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from maritime is estimated to be about 3% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.
Estimates of fuel consumption for domestic use, in the national harbours or for travel within two Italian destinations, and bunker fuels used for international travels are reported in Table 3.30. Time series of domestic GHG emissions for waterborne navigation are also shown in the same table.
An upward trend in emission levels is observed from 1990 to 2000, explained by the increasing number of ship movements. Nevertheless, the operational improvements in harbour activities and a reduction in ship domestic movements inverted the tendency in the last years.

Table 3.30 Marine fuel consumptions in domestic navigation and international bunkers (Gg) and GHG emissions from domestic navigation (Gg CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Gasoline for recreational craft (Gg)	182	210	213	199	169	90	90	88	88	87	86
Diesel oil for inland waterways (Gg)	20	23	20	25	18	27	27	29	28	24	19
Fuels used in domestic cruise navigation (Gg)	778	706	811	740	725	525	558	533	578	621	667
Fuel in harbours (dom+int ships) (Gg)	748	693	818	759	744	539	572	547	593	637	684
Fuel in international Bunkers (Gg)	1,403	1,287	1,306	2,147	2,175	1,782	2,075	2,266	2,243	2,072	1,752
Emissions from National Navigation (Gg)											
CO_2 (Gg)	5,470	5,163	5,903	5,459	5,249	3,750	3,957	3,798	4,080	4,343	4,624
CH_4 (Gg CO_2 eq.)	35	38	38	34	28	16	17	16	16	17	17
N_2O (Gg CO_2 eq.)	38	35	41	38	37	27	29	28	30	32	34
Total (Gg CO_2 eq.)	**5,543**	**5,236**	**5,983**	**5,531**	**5,315**	**3,794**	**4,003**	**3,842**	**4,126**	**4,391**	**4,676**

Source: ISPRA elaborations

3.5.4.4 Source-specific QA/QC and verification

Basic data to estimate emissions are reconstructed starting from information on ship movements and fleet composition coming from different sources. Data collected in the framework of the national study from the local port authorities, carried out in 2009 (TECHNE, 2009), were compared with the official statistics supplied by ISTAT, which are collected from maritime operators with a yearly survey and communicated at international level to EUROSTAT. Differences and problems were analysed in details and solved together with ISTAT experts. Different sources of data are usually used and compared during the compilation of the annual inventory.

Besides, time series resulting from the recalculation have been presented to the national experts in the framework of an ad hoc working group on air emissions inventories. The group is chaired by ISPRA and includes participants from the local authorities responsible for the preparation of local inventories, sectoral experts, the Ministry of Environment, Land and Sea, and air quality model experts. Top-down and bottom-up approaches have been compared with the aim to identify the potential problems and future improvements to be addressed. There is also an ongoing collaboration and data exchange with regional environmental agencies on this issue.

3.5.4.5 Source-specific recalculations

Recalculations, respect to the previous submission, were made regarding updated data on total fuel consumptions, starting from year 2012. Moreover, the number of ships arrived in domestic harbours from 2017 have been updated.

3.5.4.6 Source-specific planned improvements

Further improvements will regard a verification of activity data on ship movements and emission estimates with regional environmental agencies, especially with those more affected by maritime pollution. In particular, we plan to build an emission estimation database which calculate every year emissions at harbor level taking in account of the information officially provided by Italy to Eurostat per type of ship, class of tonnage and movement statistics.

3.5.5 Other transportation

3.5.5.1 Source category description

This category includes all emissions from fuels delivered to the transportation by pipelines and storage of natural gas. Mainly CO_2 emissions derive from this category, as well as the other relevant pollutants typical of a combustion process, such as SO_X, NO_X, CO and PM. CH_4 and N_2O emissions are also estimated. This category is not a key category.

3.5.5.2 Methodological issues

Emissions from pipeline compressors are carried out according to the IPCC Guidelines and are estimated on the basis of natural gas fuel consumption used for the compressors and the relevant emission factors. The amount of fuel consumption is estimated on the basis of data supplied for the whole time series by the national operators of natural gas distribution (SNAM, several years; STOGIT, several years) and refers to the fuel consumption for the gas storage and transportation; this consumption is part of the fuel consumption reported in the national energy balance in the consumption and losses sheet (MSE, several years [a]). Emission factors are those reported in the EMEP/EEA Guidebook for gas turbines (EMEP/CORINAIR, 2007), except for CO_2 for natural gas which is the country specific value used for the whole energy sector reported in Table 3.12. Emissions communicated by the national operators in their environmental reports are also taken into account to estimate air pollutants.

3.5.5.3 Uncertainty and time-series consistency

The combined uncertainty is estimated to be about 3% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.

Fluctuations and time series are driven both by the general trend of total natural gas fuel consumed (and transported) and by the annual fluctuation of the storage activities, which are driven by the price fluctuation of the natural gas.

Natural gas fuel consumption for pipeline compressors increased from 7,359 TJ in 1990 to 11,646 TJ in 2020 with a peak of 19,098 TJ in 2010. GHG emissions follow the same trend of fuel consumption.

Table 3.31 Pipelines transport consumptions (Tj) and GHG emissions (Gg CO_2 eq.)

Pipeline transport	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Consumption (TJ)	7,359	11,556	15,367	15,940	19,098	9,662	11,597	13,141	13,770	11,739	11,646
Emissions from Pipelines (Gg)											
CO2 (Gg CO2 eq.)	410.78	646.63	864.51	900.21	1,106.63	556.84	674.27	762.19	796.56	677.87	674.54
CH4 (Gg CO2 eq.)	0.46	0.72	0.96	1.00	1.19	0.60	0.72	0.82	0.86	0.73	0.73
N2O (Gg CO2 eq.)	6.58	10.33	13.74	14.25	17.07	8.64	10.37	11.75	12.31	10.49	10.41
Total (Gg CO2 eq.)	**417.82**	**657.68**	**879.21**	**915.46**	**1,124.90**	**566.09**	**685.36**	**774.76**	**809.73**	**689.10**	**685.68**

Source: ISPRA elaborations

3.5.5.4 Source-specific QA/QC and verification

Basic data to estimate emissions are reconstructed starting from information on fuel consumptions coming from different sources. Fuel consumptions reported by the national operators for this activity are compared with the amount of natural gas internal consumption and losses reported in the energy balance. Starting from the length of pipelines, the average energy consumptions by kilometre are calculated and used for verification of data collected by the operators. Energy consumptions and emissions by kilometre calculated on the basis of data supplied by the main national operator (SNAM, several years) are used to estimate the figures for the other operators when their annual data are not available.

3.5.5.5 Source-specific recalculations

No specific recalculations were performed concerning this source.

3.5.5.6 Source-specific planned improvements

No further improvements are planned.

3.6 Other sectors

3.6.1 Sector overview

In this paragraph sectoral emissions are reported, which originate from energy use in the civil sector included in category 1.A.4. Commercial, institutional, residential, agriculture/forestry/fisheries, and emissions from military mobile activities which are also included in category 1.A.5. All greenhouse gases as well as CO, NOx, NMVOC and SO_2 emissions are estimated.

In 2020, energy use in other sectors (considering the total of 1.A.4. Other sectors and 1.A.5. Other) account for 24.9% of CO_2, 5.2% of CH_4, 12.2% of N_2O of total national emissions. In term of CO_2 equivalent, other sectors share 20.9% of total national greenhouse gas emissions and 26.7% of total GHG emissions of the energy sector.

The trend of greenhouse gas emissions is summarised in Table 3.32. Emissions are reported in Gg for CO_2, and in Mg for CH_4 and N_2O. A general increase in emissions is observed from 1990 to 2000, due to the increase in activity data (numbers and size of building with heating); a sharp increase is observed in 2005 due to exceptionally cold weather conditions. CH_4 and N_2O emissions increase in the period is due to the growing use of woody biomass and biogas for heating. CH_4 and N_2O emissions of category 1.A.4.c are driven by the use of biomass in the agriculture sector, both wood and biogas, for heating of greenhouse and aquaculture plants; according to the national energy balance, wood biomass fuel started to be consumed in 2000 while biogas from agriculture residues sharply increased in the last years. Details on the total amount of crop residues generated and the share of the crop residue amounts used for different purposes (for energy referring to permanent crops residuos) are reported in Annex 7, Figure A.7.1.

Table 3.32 Trend in greenhouse gas emissions from the other sectors, 1990-2020

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (Gg)											
1.A.4a. Commercial/ Institutional	11,902	14,070	17,230	23,424	28,296	22,766	23,246	23,235	24,897	24,305	23,443
1.A.4b. Residential	55,788	52,756	53,824	60,441	55,267	47,982	48,338	47,998	46,401	44,735	44,075
1.A.4c. Agriculture/ Forestry/ Fisheries	8,352	8,754	8,115	8,459	7,345	6,935	7,011	7,031	7,428	7,029	7,065
1.A.5 Other (Not elsewhere specified)	1,071	1,496	837	1,233	652	459	515	326	341	453	625
CH_4 (Mg)											
1.A.4a. Commercial/ Institutional	604	879	1,993	3,068	3,978	4,473	4,638	4,556	4,512	4,551	4,227
1.A.4b. Residential	43,781	50,032	52,554	55,508	98,593	87,873	84,898	92,672	85,859	85,635	82,510
1.A.4c. Agriculture/ Forestry/ Fisheries	1,264	946	669	592	774	2,383	2,496	2,570	2,622	2,710	2,791
1.A.5 Other (Not elsewhere specified)	173	223	126	160	65	54	64	39	42	56	79
N_2O (Mg)											
1.A.4a. Commercial/ Institutional	311	413	614	911	1,167	1,143	1,159	1,148	1,197	1,170	1,149
1.A.4b. Residential	3,014	3,172	3,303	3,521	5,261	4,659	4,527	4,859	4,540	4,501	4,348
1.A.4c. Agriculture/ Forestry/ Fisheries	2,515	2,757	2,610	2,685	2,373	2,327	2,383	2,396	2,535	2,391	2,413
1.A.5 Other (Not elsewhere specified)	225	215	135	291	131	59	53	43	32	43	49

Source: ISPRA elaborations

Seven key categories have been identified for this sector for 2020, for level and trend assessment, using both the IPCC Approach 1 and Approach 2:

Other sectors - CO_2 commercial, residential, agriculture gaseous fuels (L, T);
Other sectors - CO_2 commercial, residential, agriculture liquid fuels (L, T);
Other sectors - CH_4 commercial, residential, agriculture biomass (L, T);
Other sectors - CO_2 commercial, residential, agriculture other fossil fuels (L1, T);
Other sectors - N_2O commercial, residential, agriculture biomass (L2, T);
Other sectors - N_2O commercial, residential, agriculture liquid fuels (L2);
Other sectors - CO_2 commercial, residential, agriculture solid fuels (T1).

All these categories, except N_2O emissions from liquid fuels and CO_2 emissions from solid fuels, are also key category including the LULUCF estimates in the key category assessment.

3.6.2 Source category description

This category includes four sources: 1.A.4.a. Commercial/ Institutional, 1.A.4.b. Residential, 1.A.4.c. Agriculture/ Forestry/ Fisheries and 1.A.5 Other (Military).
The estimation procedure follows that of the basic combustion data sheet. Emissions are estimated from the energy consumption data and the emission factor illustrated in Table 3.12.
Emissions from off-road sources are estimated and they are reported under the relevant sectors. The methodology of these estimates is discussed in the next paragraph 3.6.3 *Others.*

Commercial/ Institutional
Emissions from this sector arise from the energy used directly in the institutional, service and commercial buildings, mainly for heating. Additionally, this category includes all emissions due to the non-renewable part of wastes used in electricity generation.
In the other fuel subcategory, the amount of fossil waste burnt in incinerators with energy recovery is reported. Emissions from these plants are allocated in the commercial /institutional category because of the final use of heat and electricity production which is mainly used for district heating of commercial buildings or is auto consumed in the plant. In fact, until the early 2000s, electricity and heat produced by incinerators have been prevalently used to satisfy the energy demand from connected activities: heating of buildings, domestic hot water and electricity for offices. This is still true for industrial and hospital incinerators, meanwhile municipal

solid waste incinerators have increased the amount of energy provided to the grid from the early 2000s until now. Although there are not data or a robust estimate of the share of waste used to produce electricity the available literature (ENEA-federAmbiente, 2012), provide that in 2010 the gross electricity production by urban waste incinerators was equal to 3,887 GWh (net 3,190 GWh) and the amount sent to the network was equal to only 121 GWh.
Biomass refers to the consumption of biomass waste, biogas recovered for energy purposes from landfill and sludge treatments and wood and steam wood; from 2002 to 2005 minor amounts of biodiesel fuel consumption are also included. In Table 7.12 in the waste sector chapter the amount of waste and biogas fuel consumptions for 2020 are reported.
In 2020, this sector has a share of 6.3% of total GHG national emissions excluding LULUCF.

Residential
Emissions from this sector arise from the energy used directly in residential buildings, mainly for heating. The sector includes emission from off-road household and gardening machinery.
Biomass refers to wood and steam wood fuel consumption.
In 2020, this sector has a share of 12.4% of total GHG national emissions.

Agriculture/ Forestry/ Fisheries
This subsector includes all emissions due to the direct fossil fuel use in agriculture, mainly to produce mechanical energy, the fuel use in fisheries and for the machinery used in the forestry sector.
Up to 1999, biomass included only biogas recovered for energy purposes from the storage of animal manure and agriculture residuals, while from 2000, as reported in the National Energy Balance, a huge amount of wood has been consumed affecting implied emission factors.
In 2020, this sector has a share of 2.1% of total GHG national emissions.

Others
Emissions from military aircraft and naval vessels are reported under 1A.5.b Mobile.
The methods of estimation are discussed in paragraphs 3.5.1 and 3.5.4 for aviation and maritime respectively.
In 2020, this sector has a share of 0.2% of total GHG national emissions.

3.6.3 Methodological issues
For this sector, energy consumptions are reported in the national energy balance separating commercial and public services, residential and agriculture-fisheries.
Emissions from 1.A.4.b Residential and 1.A.4.c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. Emissions estimations from off-road sources are discussed later in this paragraph. Emissions from fishing vessels are estimated from fuel consumption data (MSE, several years [a]). Emission factors are shown in Table 3.12.
In the solid fuel subcategory, the following fuels are included: steam coal, coke oven coke and gas work gas. Since eighties there has been a sharp reduction in the use of these fuels due to air quality national legislation (in 1990 they accounted for about 1.1 % of total energy consumption of 1.A.4 category) and a further decrease is observed between 1997 and 1998 in consequence of the banning of coal used in residential heating in urban areas.
CH_4 emission factors used are those reported in the 1996 CORINAIR handbook, vol.1, for coal, equal to 200 kg/TJ (EMEP/CORINAIR, 1996), and in the EMEP/CORINAIR Guidebook for coke oven coke, equal to 15 kg/TJ which is the maximum value of emission factor for solid fuels without specification, and gas work gas, equal to 5 kg/TJ assuming the maximum value for natural gas (EMEP/CORINAIR, 2007). No more solid fuels are used for heating purposes from 2013.
The EMEP/CORINAIR Guidebook, now EMEP/EEA, is updated every two- three years according to the resources available but only for air pollutants emission factors; for greenhouse gas emission factors a general reference to the IPCC Guidelines is provided. For non-CO_2 GHG emissions, at the detailed level of fuel and technology, EMEP/CORINAIR remains the best source of information.
For liquid fuel, the average emission factors are driven by the mix of fuel consumptions used in heating boilers, prevalently LPG, but also gasoil and fuel oil which was used especially in the past.
For these fuels the respective CH_4 emission factors have been used: LPG 1 kg/TJ, fuel oil 3 kg/TJ and gasoil 7 kg/TJ.
Regarding natural gas, the country specific CH_4 emission factor is equal to 2.5 kg/TJ.

All these emission factors have been calculated on the basis of the default and range emission factors published in the Guidebook EMEP/CORINAIR taking into account country specific circumstances by means of the type of boilers where these fuels are burnt. In the 2006 IPCC Guidelines emission factors for residential/commercial/institutional boilers are equal to those reported for manufacturing industrial boilers (e.g natural gas default emission factor is equal to 1 for all the sources of combustion) while it is assumed that these emissions should be different according to the technology and size of the boilers. The EMEP/CORINAIR Guidebook takes in account these differences and for that they have been used as a reference.
In the following box the default emission factors reported in the Guidebook EMEP/CORINAIR are shown and compared with the national ones.

Liquid and gaseous fuel CH_4 default emission factors(kg/TJ) (EMEP/CORINAIR, 2007)

Fuel	EMEP/CORINAIR default EF	Range	IPCC default EF	National EF
LPG	-	1 - 2.5	1	1
Gasoil	0.6	0.1 - 8	3	7
Fuel oil	1.6	0.1 - 10	3	3
Natural gas	1.2	0.3 - 4	1	2.5

Average implied emission factors for other fuels, which refer to fossil waste, vary on an annual basis. For CO_2, the variation occurs from 1990, as a consequence of the mix of wastes used in incinerators, such as urban wastes, industrial, hospital, and oil wastes; for non-CO_2 gases, emission factors reported in EMEP/EEA (EMEP/EEA, 2016) applied at plant level have been considered, but specifically for CH_4 and N_2O this use does not result in changes of the implied emission factors because values are the same for the different kind of wastes, and emission factors are equal to 5.3 kg/TJ and 8.8 kg/TJ, respectively. In 2020 CO_2, average emission factor was equal to 96.0 kg/GJ.
Regarding biomass fuel consumption in the following box CO_2, CH_4 and N_2O emission factors used in the national inventory for the different type of fuels are reported. CH_4 and N_2O emission factors derive from the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007), and the implied emission factors fluctuate as a function of the mix of fuels (wood, biogas, waste and biodiesel).
Regarding CO_2 from waste, fossil fraction emissions are distinguished by biomass to include them in the national totals. CO_2 emission factors are built based on carbon content in each type of waste: municipal waste, industrial waste, oil, sludge and hospital. Biogas emission factors are calculated starting from the stoichiometric carbon value equal to 750 kg C/t and annual energy efficiencies provided by Terna (Terna, several years) for the respective use in commercial and agriculture sectors. Wood and steam wood average CO_2 emission factor is derived taking in account the typical national wood used and it is applied for the whole timeseries. Implied emission factors result from the mix of biomass fuels used for each category (1A4a, 1A4b, 1A4c).

Biomass CO_2, CH_4 and N_2O emission factor for 2020 (kg/TJ)

Fuel	CO_2	CH_4	N_2O
Wood	94600	320	14
Biogas landfills and sludge treatment	50442	153	3
Biogas agricolture residuos	53921	153	3
Waste	82096	5	9
Biodiesel	79600	12	2

Others
In this paragraph, the methodology used to estimate emissions from a range of portable or mobile equipment powered by reciprocating diesel or petrol driven engines is summarized. They include agricultural equipment such as tractors and combined harvesters; construction equipment such as bulldozers and excavators; domestic

lawn mowers; aircraft support equipment; and industrial machines such as portable generators and compressors. In the CORINAIR inventory, they are grouped into four main categories (EMEP/CORINAIR, 2007):

- domestic house & garden
- agricultural power units (includes forestry)
- industrial off-road (includes construction and quarrying)
- aircraft support.

Those categories are mapped to the appropriate IPCC classes: Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

Estimates are calculated using a modification of the methodology given in EMEP/CORINAIR (EMEP/CORINAIR, 2007). This involves the estimation of emissions from around seventy classes of off-road source using the following equation for each class:

$$Ej = Nj \cdot Hj \cdot Pj \cdot Lj \cdot Wj \cdot (1 + Yj \cdot aj /2) \cdot ej$$

where

Ej = Emission of pollutant from class j (kg/y)
Nj = Population of class j
Hj = Annual usage of class j (hours/year)
Pj = Average power rating of class j (kW)
Lj = Load factor of class j
Yj = Lifetime of class j (years)
Wj = Engine design factor of class j
aj = Age factor of class j (y^{-1})
ej = Emission factor of class j (kg/kWh)

For gasoline engine sources, evaporative NMVOC emissions are also estimated as:

$$Evj = Nj \cdot Hj \cdot evj$$

where
Evj = Evaporative emission from class j kg
evj = Evaporative emission factor for class j kg/h

Population data have been revised based on a survey of machinery sales (Frustaci, 1999). Machinery lifetime is estimated on the European averages, see EMEP/CORINAIR (EMEP/CORINAIR, 2007), the annual usage data were taken either from industry or published data (EEA, 2000). The emission factors used came mostly from EMEP/CORINAIR and from Samaras (EEA, 2000). The load factors were taken from Samaras (EEA, 2000).

It was possible to calculate fuel consumptions for each class based on fuel consumption factors given in EMEP/CORINAIR (EMEP/CORINAIR, 2007). Comparison with known fuel consumption for certain groups of classes (e.g., agriculture and construction) suggested that the population method overestimated fuel consumption by factors of 2-3, especially for industrial vehicles.

Estimates were derived for fuel consumptions for the years 1990-2020 for each of the main categories:

A. Agricultural power units: Data on gas oil consumption were taken from ENEA (ENEA, several years). The consumption of gasoline was estimated using the population method for 1995 without correction. Time series is reconstructed in relation to the fuel used in agriculture.
B. Industrial off-road: The construction component of the gas oil consumption was calculated from the Ministry of Production Activities data (MSE, several years [a]) on buildings and constructions. The industrial component of gas oil was estimated from the population approach for 1995. Time series is reconstructed in relation to the fuel use in industry.
C. Domestic house & garden: gasoline and diesel oil consumption were estimated from the EMEP/CORINAIR population approach for 1995. Time series is reconstructed in relation to the fuel use in agriculture.

Emissions from off-road sources are particularly uncertain. The revisions in the population data produced higher fuel consumption estimates. The gasoline consumptions increased markedly but they are still only a tiny proportion of total gasoline sales.

3.6.4 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions in "Other sectors" is estimated to be about 3% in annual emissions; a higher uncertainty is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.

Montecarlo analysis has been carried out to estimate uncertainty of CO_2 emissions from stationary combustion of solid, liquid and gaseous fuels emissions, resulting in 5.1%, 3.3% and 5.8%, respectively. Normal distributions have been assumed for all the parameters. A summary of the results is reported in Annex 1. Estimates of fuel consumption used by other sectors in 2020 are reported in Table 3.33.

Table 3.33 Trend in fuel consumption for the other sector, 1990-2020 (TJ)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						TJ					
1.A.4a. Commercial/ Institutional	206,427	247,440	306,088	419,507	489,018	400,596	402,607	402,594	428,941	421,094	402,697
1.A.4b. Residential	1,002,597	1,004,192	1,037,175	1,172,398	1,222,588	1,078,886	1,070,744	1,093,507	1,045,196	1,019,775	997,350
1.A.4c. Agriculture/ Forestry/ Fisheries	114,638	121,163	111,486	116,933	103,172	107,101	108,630	109,423	115,090	110,434	111,532
1.A.5 Other	14,840	20,814	11,595	16,947	9,001	6,388	7,183	4,531	4,754	6,317	8,733

Source: ISPRA elaborations

In the following Table 3.34, total GHG emissions connected to the use of fossil fuels and waste derived fuels are reported for the whole time series. Total emissions from the sector are reported in Gg for CO_2, and in Mg for CH_4 and N_2O. An increase in emissions is observed from 1990 to 2000, due to the increase in activity data (numbers and size of building with heating); a sharp increase can be observed in 2005 due to exceptionally cold weather conditions. CH_4 and N_2O emissions increase in the period due to the growing use of woody biomass for heating.

Table 3.34 Other sectors, GHG emission time series 1990-2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (Gg)	77,113	77,076	80,006	93,557	91,560	78,143	79,111	78,590	79,068	76,522	75,208
CH_4 (Mg)	45,822	52,079	55,342	59,329	103,409	94,784	92,095	99,837	93,036	92,951	89,607
N_2O (Mg)	6,065	6,557	6,662	7,408	8,931	8,188	8,123	8,445	8,304	8,105	7,960
GHG (Gg CO_2 eq)	80,066	80,332	83,375	97,248	96,807	82,953	83,833	83,603	83,868	81,261	79,820

Source: ISPRA elaborations

In Table 3.35, other sectors emissions are summarized according to main categories. From 1990 to 2020, an increase in the use of natural gas instead of fuel oil and gas oil in stationary combustion plants is observed; it results in a decrease of CO_2 emissions from combustion of liquid fuels and an increase of emissions from gaseous fuels. CH_4 and N_2O emissions increase in the period due to the increasing use of woody biomass for heating.

Table 3.35 Other sectors, GHG emissions in 1990 and 2020

		1990	2020
CO_2 other sectors liquid fuels	Gg	39,346	14,235
CO_2 other sectors solid fuels	Gg	899	0
CO_2 other sectors gaseous fuels	Gg	36,338	55,195
CO_2 other sectors other fuels	Gg	530	5,778
CH_4 other sectors	Mg	45,822	89,607
N_2O other sectors	Mg	6,065	7,960

Source: ISPRA elaborations

3.6.5 Source-specific QA/QC and verification

Basic data to estimate emissions are reported by national energy balance and the national grid administrator (for the waste used to generate electricity).
The energy data used to estimate emissions reported in table 1.A.4 have different levels of accuracy:

- the overall sum of residential and institutional/service/commercial energy consumption is quite reliable and their uncertainty is the same of the BEN; the quantities of fuels used for those economic sectors are routinely reported by main suppliers and the data are well documented;
- the energy consumption for agriculture and fisheries is also routinely reported by energy statistics and the underlying data are quite reliable because the energy use for those sectors has special taxation regimes and they are accounted for separately;
- The energy use for military and off roads is instead partly reported and partly estimated with models, as described in paragraph 3.6.3 others.

3.6.6 Source-specific recalculations

Some recalculations have been done in this submission.
The NCV for LPG and gasoil have been updated based on country specific data.
Waste fuel consumption for commercial heating activity data has been updated from 2018 because of the update of activity data for some industrial waste plants resulting in further recalculations.

3.6.7 Source-specific planned improvements

The implementation of updated emission factors from small combustion of biomass is planned.

3.7 International bunkers

The methodology used to estimate the quantity of fuels used from international bunkers in aviation and maritime navigation has been illustrated in the relevant transport paragraphs, 3.5.1 and 3.5.4.
The methodology implements the IPCC guidelines according to the available statistical data.

3.8 Feedstock and non-energy use of fuels

3.8.1 Source category description

In Table 3.36 and 3.37 detailed data on petrochemical and other non-energy use for the year 2020 are given. The tables refer to all products produced starting from fossil fuels, solid, gas or liquid, and used for “non energy” purposes. A national methodology is used for the reporting and estimation of avoided emissions.

3.8.2 Methodological issues

The quantities of fuels stored in products in the petrochemical plants are calculated on the basis of information contained in a detailed yearly report, the petrochemical bulletin, by Ministry of Economic development (MSE, several years [b]). The report elaborates results from a detailed questionnaire that all operators in Italy fill out monthly. The data are more detailed than those normally available by international statistics and refer to:

- input to plants;
- quantities of fuels returned to the market;
- fuels used internally for combustion;
- quantities stored in products.

National petrochemical balance includes information on petrochemical input entering the process and used for the production of petrochemical products, and petrochemical plants output, returns to the market, losses and internal consumption. Due to chemical reactions in the petrochemical transformation process, the output

quantity of some fuels could be greater than the input quantity; in particular, it occurs for light products as LPG, gasoline and refinery gas, and for fuel oil. Therefore, for these fuels it is possible to have negative values of the balance. For this matter, with the aim to allow the reporting on CRF tables, these fuels have been added to naphta. The amount of fuels recovered from the petrochemical processes and returning on the market are considered as an output, because consumed for transportation or in the industrial sectors, and no carbon is stored.
In Table 3.36 and Table 3.37 the overall results and details by product are reported respectively.
In Table 3.36 the breakdown of total petrochemical process is reported; the percentages referring to the "net" input are calculated on the basis of the total input subtracting the quantity of fuels as gasoil, LPG, fuel oil and gasoline which return on the market because produced from the petrochemical processes.
In Table 3.37 the input to the petrochemical processes in petrochemical plants and the relevant losses, internal consumption and return to the market are reported, at fuel level, allowing the calculation of the quantity stored in products, subtracting the output (returns to the market, losses and internal consumption) from the input (petrochemical input). Carbon stored, for all the fuels, is therefore calculated from the amounts of fuels stored (in tonnes) multiplied by the relevant emission factors (tC/t) reported in Table 3.37.
An attempt was made to estimate the quantities stored in products according to the IPCC 1996 Guidelines, Reference Manual, ch1, tables 1-5 (IPCC, 1997), multiplying the IPCC percentage values in tables 1-5 of the Guidelines by the amount of fuels reported as "petrochemical input" in Table 3.37. The resulting estimate of about 4,905 Gg of products, for the year 2020, is 60% larger than the quantities reported, 2,846 Gg.
Non-energy products amount stored from refineries, and other manufacturers, are reported in the national energy balance (MSE, several years [a]) and the carbon stored is estimated with emission factors reported in Table 3.38. For lubricants the net carbon stored results from the difference between the amount of lubricants and the amount of recovered lubricant oils. The energy content has been calculated on the basis of the IPCC default values. Minor differences in the overall energy content of these products occur if the calculation is based on national parameters instead of IPCC default values.
In the CRF tables the fuel input amount is reported so that the fractions of carbon stored could be derived. As these fractions are derived from actual measurements, they do not correspond to any default values and may vary over time.

Table 3.36 Other non-energy uses, year 2020

Breakdown of total petrochemical flow				
	Petrochemical Input	Returns to refinery/market	Internal consumption / losses	Quantity stored in products
ALL ENERGY CARRIERS, Gg	7,814	3,485	1,483	2,846
% of total input		44.6%	19.0%	36.4%
% of net input			34.3%	65.7%

Source: ISPRA elaborations

Table 3.37 Petrochemical, detailed data from MSE, year 2020 (MSE, detailed petrochemical breakdown)

FUEL TYPE	**Petroch. Input**	**Returns to refinery/ market**	**Internal consumption / losses**	**Quantity stored in products**	**% on total input**	**% on net input**	**Emission factor (IPCC)**
	Gg	**Gg**	**Gg**	**Gg**			**t C / t**
LPG	256	330	9	-83			0.8146
Refinery gas	211	170	650	-609			0.7781
Virgin naphtha	3,878	0	0	3,878			0.8900
Gasoline	1,093	1,772	5	-685			0.8379
Kerosene	976	805	0	171			0.8606
Gas oil	208	158	4	47			0.8696
Fuel oil	244	129	110	5			0.8534
Petroleum coke	0	0	0	0			0.8666
Others (feedstock)	289	121	54	114			0.8462
Losses	0	0	0	0			0.8462
Natural gas	658	0	650	8			0.7612
total	7,814	3,485	1,483	2,846	36%	66%	

Source: ISPRA elaborations

Table 3.38 Other non-energy uses, year 2020, MSE several years [a]

NON ENERGY FROM REFINERIES	Quantity stored in products	Energy content IPCC '96	Total energy content	Emission factor
	Gg	TJ/Gg	PJ	Gg C / Gg
Bitumen + tar	3,083	40.19	123.9	0.8841
lubricants	1,013	40.19	40.7	0.8038
recovered lubricant oils	109	40.19	4.4	0.8038
paraffin	96	40.19	3.8	0.8368
others (benzene, others)	633	40.19	25.4	0.8368
Totals	4,934		198.3	

Source: ISPRA elaborations

At national level, this methodology seems the most precise according to the available data. The European Project "Non Energy use-CO_2 emissions" ENV4-CT98-0776 has analysed our methodology performing a mass balance between input fuels and output products in a sample year. The results of the project confirm the reliability of the reported data (Patel and Tosato, 1997).

3.8.3 Uncertainty and time-series consistency

In Annex 4, the time series for comparison between reference and sectoral approach are reported showing percentage differences in a limited range.

3.8.4 Source-specific QA/QC and verification

Basic data to estimate emissions are directly provided to ISPRA by MSE. The energy data used to estimate emissions have a high level of accuracy because they summarize the results of a 100% legally binding monthly survey of all the concerned operators.

3.8.5 Source-specific recalculations

According to the review process the amount of non biomass waste have been corrected for the whole time series.

3.9 Fugitive emissions from solid fuels, oil and natural gas

3.9.1 Source category description

Fugitive emissions of GHG arise during the stages of fuel production, from extraction of fossil fuels to their final use. Emissions are mainly due to leaks or other irregular releases of gases from the production and transformation of solid fuels, the production of oil and gas, the transmission and distribution of gas and from oil refining.

Solid fuels category implies mainly methane emissions, while oil and natural gas categories include carbon dioxide and nitrous oxide too.

In 2020, GHG emissions from this source category account for 1.6% out of the total emissions and 2% of emissions in the energy sector. Trends in fugitive emissions are summarised in Table 3.46.

The results of key category analysis are shown in the following box.

Key-category identification in the fugitive sector with the IPCC Approach 1 and Approach 2

Year		IPCC category	without LULUCF	with LULUCF
2020	CH_4	Oil and natural gas - Natural gas	L, T	L, T
	CH_4	Oil and natural gas – Flaring in refineries	L2, T2	L2, T2
	CO_2	Oil and natural gas – Oil	L1	L1
	CO_2	Oil and natural gas – Flaring in refineries	T2	-
1990	CH_4	Oil and natural gas - Natural gas	L	L
	CO_2	Oil and natural gas – Oil	L1	L1
	CO_2	Oil and natural gas - Venting and flaring	L2	L2
	CO_2	Oil and natural gas – Flaring in refineries	L2	-

As for 2020 CH_4 emissions are key categories for natural gas according to level and trend assessment with Approach 1 and Approach 2, with and without LULUCF; CH_4 emissions for flaring in refineries are key categories according to level and trend assessment with Approach 2, with and without LULUCF; CO_2 emissions for oil are key category for level with Approach 1, with and without LULUCF; CO_2 emissions for flaring in refineries are key category for trend with Approach 2 without LULUCF.
As for the base year, CH_4 emissions are key categories for natural gas following both the Approaches, with and without LULUCF; CO_2 emissions are key categories for oil only with Approach 1, while CO_2 emissions are key categories for venting and flaring only with Approach 2 (both with and without LULUCF); CO_2 emissions from flaring in refineries are key category with Approach 2 only without LULUCF.

Fugitive CH_4 and CO_2 emissions reported in 1.B.1 refer to coal mining for only two mines with very low production in the last ten years. One mine is underground and produces coal and the other one, a surface mine, produces lignite. The underground mine stopped the extraction activities between 1994 and 1999, whereas the surface mine stopped the activity in 2001. CH_4 emissions from solid fuel transformation refer to fugitive emission from coke production in the iron and steel industry, which is also decreasing in the last years. N_2O emissions from 1.B.1 are not occurring.

Fugitive CO_2 emissions reported in 1.B.2 refer prevalently to fugitive emissions in refineries during petroleum production processes, e.g. fluid catalytic cracking and sulphur recovery plants and flaring, but include also emissions from the exploration, production, transport and distribution of oil and natural gas.
CH_4 emissions reported in 1.B.2 refer mainly to the production of oil and natural gas and to the transmission in pipelines and distribution of natural gas, while N_2O emissions refer to flaring in the production of oil and natural gas and in refineries and emission from exploration.
For the completeness of the related CRF tables, in particular 1.B.2, the N_2O emissions in refining and storage are reported under flaring in refineries as shown in the following Table 3.39.

Table 3.39 Completeness of N_2O fugitive emissions

1.B. 2.a. Oil		
iv. Refining/storage	N_2O	Included in 1.B.2.d flaring in refineries

3.9.2 Methodological issues

Coal mining and handling
CH_4 emissions from coal mining have been estimated on the basis of activity data published on the national energy balance (MSE, several years [a]) and emission factors provided by the IPCC guidelines (IPCC, 2006). Mining and post mining emissions have been calculated. As for CH_4 emissions from mining and post mining the average emission factors of the 2006 IPCC Guidelines (IPCC, 2006) have been selected, $18m^3/t$ and $2.5m^3/t$, respectively. As concerns CO_2 emissions the calculations have been carried out considering the species profile in coal mine gas by literature data (EMEP/CORINAIR, 2007). The coal gas composition considered is 80% of CH_4 and 6% of CO_2 by volume (Williams, 1993).
As for closed or abandoned mines there are no methods for estimating emissions from surface mines at present (IPCC, 2006). As for the only one underground mine closed from 1994 to 1999, there are no data for a country based approach to estimate fugitive emissions during the closure period. The emission estimations are carried out applying Tier 2 of the 2006 IPCC Guidelines for bituminous mines with 100% of gassy parameter.

Solid fuel transformation
CH_4 emissions from coke production have been estimated on the basis of activity data published in the national statistical yearbooks (ISTAT, several years [a]) and emission factors reported in the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) taking in account the information provided by the relevant operators in the framework og the EPRTR registry and the ETS, as addressed in paragraph 3.3.3 of this chapter.
With regard to the manufacture of other solid fuels, in Italy charcoal was produced in the traditional way until the sixties while now it is prevalently produced in modern furnaces (e.g with the VMR system) where exhaust gases are collected and recycled to produce the energy for the furnace itself. This system ensures good management of the exhausts and the temperature, so that any waste of energy is prevented and emissions are

kept to a minimum. So CH_4 emissions from the production of charcoal are not accounted for also considering that the emission factor available in the Revised 1996 IPCC Guidelines, in Table 1-14 vol.3 (IPCC, 1997), refers to production processes in developing countries not applicable to our country anymore. Moreover in the IPCC Good Practice Guidance as well as in the IPCC 2006 Guidelines no guidance is supplied for charcoal production.

Oil transport and storage and refining

Fugitive emissions from oil refining are estimated starting from the total crude oil losses as reported in the national energy balance. Emissions have been reported in the Refining/Storage category (1.B.2.a.iv); they occur prevalently from processes in refineries.

Fugitive emissions from oil transport have been calculated according with the amount of transported oil (MIT, several years) and emission factors published on the IPCC guidelines (IPCC, 2006).

Most of the crude oil is imported in Italy by shipment and delivered at the refineries by pipelines as offshore national production of crude oil. Table 3.40 provides the length of pipelines for oil and the amount of oil products transported since 1990.

Table 3.40 Length of pipelines for oil transport (km) and amount of transported oil products (Gg)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020*
Length of pipelines (km)	4,140	4,235	4,346	4,328	4,291	4,022	4,012	4,021	4,018	4,018	3,931
Amount transported (Gg)	94,600	102,274	116,803	133,024	128,854	110,369	112,031	114,124	115,685	114,451	99,295

Source: MIT

***provisional values**

Emissions in refineries have been estimated on the basis of activity data published in the national energy balance (MSE, several years [a]) or supplied by oil and gas industry association (UP, several years) and operators especially in the framework of the European Emissions Trading Scheme (EU-ETS), and emission factors published on the IPCC Guidelines (IPCC, 2006).

Fugitive CO_2 emissions in refineries are mainly due to catalytic cracking production processes, sulphur recovery plants, flaring and emissions by other production processes including transport of crude oil and oil products. Emissions are calculated on the basis of the total crude oil losses reported in the national energy balance. These emissions are then distributed among the different processes on the basis of average emission factors agreed and verified with the association of industrial operators (UP) and yearly updated, from 2000, on the basis of data supplied by the plants in the framework of the European Emissions Trading Scheme. In particular in the EU-ETS context, refineries report CO_2 emissions for flaring and for processes separately.

In Table 3.41, the time series of crude oil losses published in the BEN and crude oil processed in Italian refineries are shown.

Table 3.41 Refineries activities and losses

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Crude Oil losses (Mg)	1,004	937	757	576	584	664	574	627	603	767	550
Crude oil processing (Gg)	93,711	91,014	98,003	106,542	94,944	79,148	77,510	80,312	78,878	77,605	65,517

Source: MSE, UP

Oil and gas exploration

CO_2, CH_4, and N_2O fugitive emissions from oil and natural gas exploration have been calculated according with the number of exploration wells (MSE, several years [c]) and emission factors published on the IPCC Good practice Guidance (IPCC, 2000) as no emission factors for number of wells were available in 2006 IPCC guidelines. There are no EFs in the 2006 IPCC Guidelines when the only activity data available are the number of wells. In the IPCC good practice guidance, the tier 1 methodology and default EFs are based on the number of wells, whereas in the 2006 IPCC Guidelines, they are based on the volume of oil production. If overall oil production were used as a proxy in estimating emissions from oil and gas exploration, there would be an overestimation. Moreover, current oil production is mainly onshore, while exploration is now being done offshore, and the methodology in the 2006 IPCC Guidelines does not reflect this situation. The relationship between exploration/drilling activity and production volume applies when the two activities occur within the

same bed. In the case of onshore production and offshore exploration, the onshore production is not necessarily related to the exploration, and only offshore exploration is recorded.
Emissions factors for drilling, testing and servicing have been used for productive wells, while only emissions factor for drilling has been used for non productive wells.

Oil and gas production and processing
CH_4 emissions from the production of oil and natural gas as well for natural gas processing have been calculated according with activity data published on national energy balance (MSE, several years [a]), data by oil and gas industry association (UP, several years), data supplied by operators, and emission factors published on the IPCC guidelines (IPCC, 2006).
CH_4 emission factors for the whole time series have been calculated taking into account this information also for oil venting and flaring and for gas flaring.
For CO_2, the IPCC default emission factor has not been modified for each category, as no specific information is available.
N_2O emissions from flaring in oil and gas production have been estimated on the basis of activity production data and emission factors reported in the IPCC guidelines (IPCC, 2006).
As regards the decline of CH_4 IEF for natural gas production and processing, gas companies stated that along the time there has been an increasing awareness to reduce GHG emissions and new emergency management systems have been implemented periodically in order to reduce emissions from venting. Moreover, with the updating of management systems, more accurate methods to estimate vented gas have been adopted by the main gas company at regular intervals.

In Table 3.42, the time series of national production of oil and gas are reported. Natural gas production should further reduce in the next years.

Table 3.42 National production of oil and natural gas

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Oil (Gg)	4,668	5,236	4,586	6,111	5,106	5,470	3,760	4,148	4,684	4,279	5,424
Natural gas (Mm^3)	17,296	20,383	16,766	11,962	8,265	6,877	6,021	5,657	5,553	4,983	4,417

Source: MSE

Natural gas transmission and distribution
CH_4 and CO_2 emissions from the transmission in pipelines and distribution of natural gas have been estimated on the basis of activity data published by industry, the national authority, and information collected annually by the Italian gas operators. In other word the most relevant information is the amount of natural gas transmitted/distributed and the methane emissions reported by operators in their environmental reports or communicated to ISPRA.
The emissions communicated by main operators are estimated separately for transmission/distribution taking into account known lengths and materials of pipelines just to calibrate the model used to estimate fugitive emissions from minor operators.
Emission estimates take into account the information on: the amount of natural gas distributed (ENI, several years [a]; SNAM, several years); length of pipelines, distinct by low, medium and high pressure and by type, cast iron, grey cast iron, steel or polyethylene pipelines (AEEG, several years); natural gas losses reported in the national energy balance (MSE, several years [a]); methane emissions reported by operators in their environmental reports (ENI, several years [b]; EDISON, several years; SNAM, several years).
CO_2 emissions have been calculated considering CO_2 content in the leaked natural gas.
The average natural gas chemical composition has been calculated from the composition of natural gas produced and imported.
Main parameters of mixed natural gas, as calorific value, molecular weight, and density, have been calculated as well. Data on chemical composition and calorific value are supplied by the main national gas providers for domestic natural gas and for each country of origin.

Table 3.43 shows average data for national pipelines natural gas.

Table 3.43 Average composition for pipelines natural gas and main parameters

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
HCV (kcal/m_3)	9,156	9,193	9,215	9,261	9,325	9,303	9,351	9,340	9,334	9,336	9,340
NCV (kcal/m_3)	8,255	8,290	8,320	8,354	8,412	8,391	8,444	8,433	8,427	8,428	8,432
Molecular weight	17.03	17.19	17.37	17.45	17.46	17.34	17.53	17.44	17.34	17.29	17.33
Density (kg/Sm_3)	0.72	0.73	0.74	0.74	0.74	0.73	0.74	0.74	0.73	0.73	0.73
CH_4 (molar %)	94.30	93.36	92.22	91.93	92.04	92.72	91.54	92.08	92.64	92.92	92.79
NMVOC (molar %)	3.45	4.09	4.84	5.35	5.74	5.26	6.17	5.93	5.62	5.49	5.63
CO_2 (molar %)	0.22	0.20	0.18	0.49	0.75	0.70	0.65	0.67	0.74	0.64	0.88
Other no carbon gas (molar %)	2.03	2.34	2.76	2.24	1.48	1.32	1.64	1.33	1.00	0.95	0.70
CH_4 (weight %)	88.83	87.14	85.16	84.53	84.54	85.81	83.79	84.72	85.68	86.23	85.88
NMVOC (weight %)	7.33	8.62	10.00	10.73	11.27	10.34	12.03	11.51	10.87	10.64	10.78
CO_2 (weight %)	0.57	0.51	0.47	1.23	1.89	1.78	1.62	1.70	1.88	1.63	2.25
Other no carbon gas (weight %)	3.27	3.74	4.37	3.51	2.30	2.08	2.55	2.07	1.56	1.50	1.09

More in details, emissions are estimated separately for the different phases: transmission in primary pipelines and distribution in low, medium, and high pressure network, losses in pumping stations and in reducing pressure stations (including venting and other accidental losses) with their relevant emission factors, considering also information regarding the length of the pipelines and their type.
Emissions from low pressure distribution include also the distribution of gas at industrial plants and in residential and commercial sector; data on gas distribution are only available at an aggregate level thus not allowing a separate reporting.
In addition, emissions from the use of natural gas in housing are estimated and included. Emissions calculated are compared and balanced with emissions reported by the main distribution operators.
Finally, the emission estimates for the different phases are summed and reported in the most appropriate category (transmission/distribution).

Table 3.44 provides the trend of natural gas distribution network length for each pipeline material and the average CH_4 emission factor.

Table 3.44 Length of low and medium pressure distribution network (km) and network emission factors for CH_4

Material	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Steel and cast iron (km)	102,061	131,271	141,848	154,886	198,706	203,116	204,062	204,890	205,273	206,855	208,044
Grey cast iron (km)	24,164	23,229	21,314	15,080	4,658	2,398	2,163	2,088	2,063	2,061	2,061
Polyethylene (km)	775	7,300	12,550	31,530	49,663	56,943	57,883	59,368	59,358	59,593	59,854
Total (km)	**127,000**	**161,800**	**175,712**	**201,496**	**253,027**	**262,457**	**264,108**	**266,346**	**266,693**	**268,509**	**269,959**
CH_4 Emission Factors (kg/km)	**1,958**	**1,417**	**1,228**	**1000**	**703**	**540**	**522**	**516**	**469**	**383**	**371**

More details on the methodology used and on the basic information collected from operators are reported in a technical paper carried out by ISPRA in order to assess emissions from the whole natural gas distribution grid (Contaldi, 1999).
The study addressed natural gas leakages, pipelines material, and operating pressure with data of 1995. All main gas operators were involved. An estimation model was set up in order to approximate the known gas emissions from the main operators and total emissions for year 1995. Emission factors distinct by pressure (low, medium and high) and material (cast iron, grey cast iron, steel or polyethylene) was applied to achieve the goal. Emission factors from Battelle study for former West Germany was applied, cross checked with operator's data and modified where it is needed. The emission factors of minor operators (Other in the next table) are "worsened" to take account for lower quality standard.
The pipelines emission factors for transmission and distribution used for emission estimates are reported in the following box:

Leakage emission factors of natural gas for transmission and distribution in pipelines by material and pressure (2020).

Material	***Pressure***		
	High	***Medium***	***Low***
	m^3/km		
Steel	516.1	454.5	339.7
Cast iron	-	538.3	518.3
Grey cast iron	-	-	5,887.0
Polyethylene	-	-	313.5

High pressure natural gas leakage factor concerns transmission network. SNAM is the main operator for national gas transmission and import-export. Medium and low pressure leakage factors concern distribution network. ITALGAS and 2iRetegas (ex ENEL) are the main operators for gas distribution. They publish annually environmental reports with amount of natural gas conveyed and total leaks. Moreover, SNAM provides to ISPRA chemical composition and energy content of national gas imported and produced. In 2020 SNAM accounts for about 93% of national pipelines length and about 99% of transported gas. ITALGAS and 2iRetegas account for about 54% of distribution network length and about 47% of distributed gas. There are about 210 operators distributing natural gas. ARERA is the National Authority for Energy, Networks and Environment. Starting from 2000 ARERA issues a yearly report with information on pipelines and network length, operating pressure, and network type concerning pipelines material. The estimation model calibrated on the main operators was used to estimate fugitive emissions from minor operators. Natural gas leaks by main operators and average composition of natural gas are used to estimate fugitive emissions. For minor operators, lower quality standard and higher specific emission factors for network material, venting, and other accidental losses were considered. So EFs for distribution are generated by combining measured data obtained directly from the main gas operators with calibrated estimates from smaller operators.

In order to take account of different sources of emissions (LNG regasification plants, compression stations, pipeline import/transmission and distribution, venting, and other accidental losses) the total leaks communicated by main operators and those estimated for minor operators are distributed resulting in implied emission factors for the other sources of emissions than transmission and distribution.

In the following box, 2020 implied emission factors for transmission and distribution sources are reported:

Implied emission factors (2020)

Tranmission	***LNG regassification***	0.21 Mm^3 NG / Gm^3 NG imported
	Pipeline compression station	0.16 Mm^3 NG / Gm^3 NG transported
	Pipeline	516.1 m^3/km (See previous table for high pressure pipelines)
	Venting and other accidental losses	0.071 Mm^3 NG / Gm^3 NG transported
Distribution	***Pipeline***	See previous table for medium and low pressure pipelines
	Venting and other accidental losses	0.117 Mm^3 NG / Gm^3 NG distributed

Furthermore, fugitive emissions due to the use of natural gas at home are considered and estimated with an emission factor equal to *36 kg CH_4 / TJ* natural gas distributed.
The estimation model used to estimate fugitive emissions is updated every year considering data published by ARERA on pipelines and it is calibrated with annual leakage data published by main operators in their environmental reports.

The next graph shows the CH_4 emission factors time series since 1990 for natural gas transmission and distribution compared with the respective default EFs provided by IPCC guidelines (2006). As for the transmission the national EFs are between the range of default values. The national distribution emission factors are approaching the default value that includes fugitive and venting sources but are still more than three times higher.

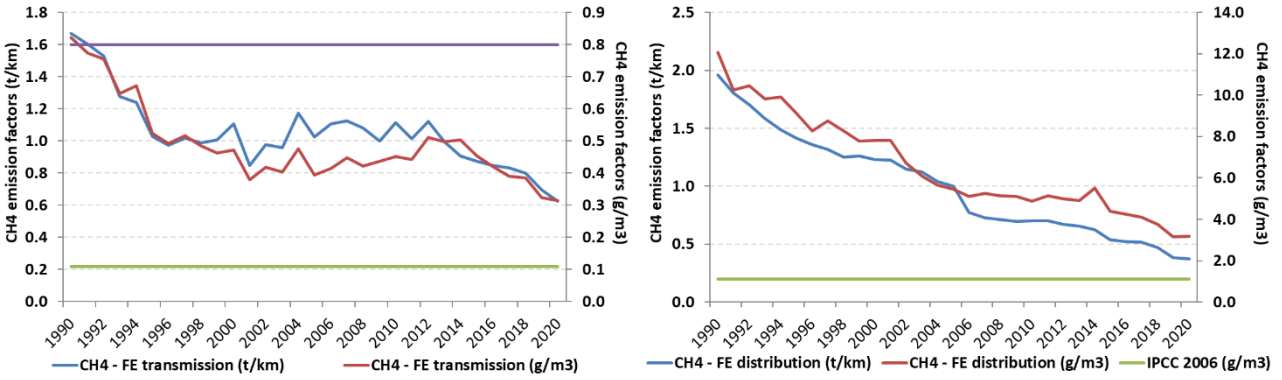


Figure 3.1 Trend of CH_4 emission factors for natural gas transmission and distribution compared with the respective default EFs (IPCC, 2006).

However, it should be considered that a significant share of natural gas does not go through the distribution network but is instead directly transported to industrial sites, including plants for energy production. According to ARERA gas distribution is also fulfilled by network operating at pressure between 5 and 24 bar which is part of the transmission network. This configuration explains why the amount of natural gas being distributed is less than 50% of the natural gas transmitted in the whole time series and shows how it is more useful to consider the matched EFs for transmission and distribution as illustrated in the next graph.

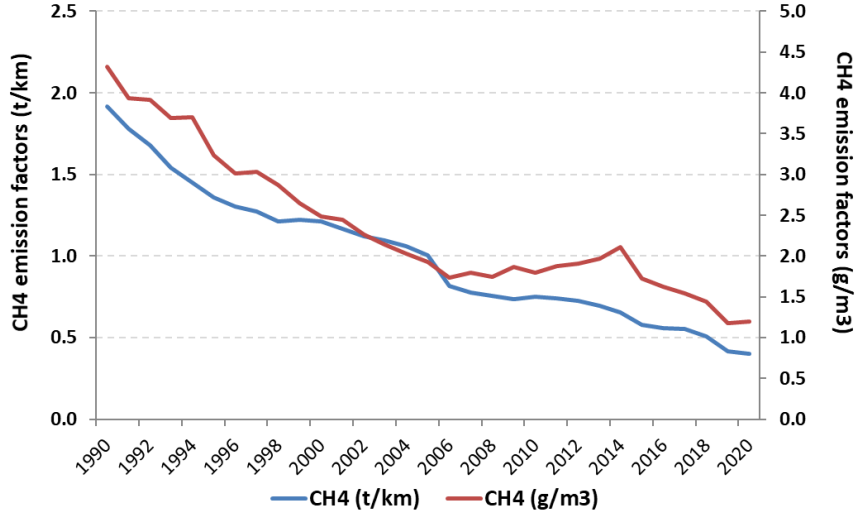


Figure 3.2 Trend of the matched CH_4 emission factors for transmission and distribution of natural gas

The different trends between the two unit of measures are explained by variable composition of natural gas along the time series as CH_4 content and average density.

Geothermal energy

Geothermal fluids can, depending on the site, contain greenhouse gases such as CO_2 and CH_4 and other minor gases such as H_2S, H_2, NH_3 and N_2. As the geothermal energy is a renewable source it is considered carbon neutral so while the CO_2 emissions of are not accounted the emissions of CH_4 are evaluated.

In Italy the geothermal energy extraction for electricity production occurred up to now only in Tuscany. Starting with this submission CH_4 emissions have been estimated for the whole time series according to monitoring data of the tuscanian environmental agency (ARPAT, several years). ARPAT issues a yearly report with CH_4 flux measures (kg/h) on a sample of power plants. There are no data on the operating hours for each plant so the flux measures are summed up and multiplied by the average operating hours for all geothermal plants, the only available data, to obtain the total emitted amount for the sampled plants. In orther to smooth the sampling distorsion (i.e. in some year only plants with higher flux are sampled that would give an overestimation) for each year the average flux measures of the previous three years are considered for not sampled plants so obtaining an extended sample. The total emitted amount for all plants is calculated dividing the estimated amount for the extended sample plants by their power and multiplying such quantity by the total operating power.

3.9.3 Uncertainty and time-series consistency

The uncertainty in CO_2, CH_4, and N_2O emissions is quite differentiated for sources as shown in Table 3.45.

Table 3.45 Activity data (AD) and emission factor (EF) uncertainties for CO_2, CH_4, and N_2O emissions

	CO_2		CH_4		N_2O	
	AD	**EF**	**AD**	**EF**	**AD**	**EF**
Solid fuels	3%	10%	3%	50%	NA	NA
Oil and natural gas – Oil					3%	50%
Oil and natural gas – Natural gas					NA	NA
Oil and natural gas – Venting and flaring	50%	10%	50%	50%	50%	50%
Oil and natural gas – Flaring in refineries						

Montecarlo analysis was applied to estimate uncertainty of CH_4 emissions; the resulting figure was 17.2% for 2009. Normal distributions have been assumed for most of the parameters; at the same time, whenever assumptions or constraints on variables were known this information has been appropriately reflected on the choice of type and shape of distributions. A summary of the results is reported in Annex 1. No variation could be conceived on assumptions as concern probability distributions and standard deviations.
Fugitive emissions, in CO_2 equivalent, account for 2% out of the emissions in the energy sector in 2020. CH_4, CO_2, and N_2O emissions show a reduction from 1990 to 2020 by 47.8%, 62.7%, and 31.6% respectively.
The overall decrease of CO_2 fugitive emissions is mainly driven by the reduction in crude oil losses in refineries.
The trend of CH_4 and CO_2 fugitive emissions from solid fuels is related to the extraction of coal and lignite that in Italy is quite low. The decrease of CH_4 fugitive emissions from oil and natural gas is due to the reduction of losses for gas transportation and distribution, because of the gradual replacement of old grey cast iron pipelines with steel and polyethylene pipelines for low and medium pressure network. The CH_4 fugitive emissions from geothermal energy extraction show a relevant increase since 1990 (+208%) as result of the increase of emission factor (+64.7%) due to the entry into operation of bigger plants with higher flux values.
As regards the flaring activity from oil and gas production, and flaring in refineries N_2O emissions show a reduction since 1990 by 34.3%.
Fugitive emissions since 1990 are reported in Table 3.46.

Table 3.46 Fugitive emissions from solid fuels and oil & gas (Gg CO_2 eq.)

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2											
Solid fuels	0.4	0.1	0.3	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Oil and natural gas	4,047	4,002	3,262	2,557	2,377	2,574	2,189	2,351	2,295	2,756	2,113
CH_4											
Solid fuels	132	74	97	90	86	52	49	37	34	32	26
Oil and natural gas	8,735	8,082	7498	6761	6,050	4,916	4,515	4,395	4,020	3,321	3,258
Geothermal energy	191	203	278	334	371	478	532	522	566	493	587
N_2O											
Oil and natural gas	12	12	12	13	12	10	9	10	9	9	8
Total emissions	**13,117**	**12,374**	**11,147**	**9,755**	**8,897**	**8,031**	**7,294**	**7,315**	**6,925**	**6,612**	**5,991**

3.9.4 Source-specific QA/QC and verification

Different data sources are used for fugitive emissions estimates: official statistics by Economic Development Ministry (MSE, several years [a], [c]), by Transport of Infrastructure Ministry (MIT, several years); national authorities (AEEG, several years; ISTAT, several years [a]), gas operators (ENI, several years [b]; EDISON, several years; SNAM, several years), and industrial association for oil and gas (UP, several years).

CH_4 flux data to estimate fugitive emissions from geothermal energy extraction are yearly registered by regional environmental agency of Tuscany for a sample of geothermal power plants (ARPAT, several years). Concerning CO_2 fugitive emissions from refineries activities, the estimates are balanced with the amount of crude oil losses reported in the national energy balance (MSE, several years [a]).
CH_4 emissions from transmission and distribution of natural gas are verified considering emission factors reported in literature and detailed information supplied by the main operators (ENI, several years [b]; Riva, 1997).

3.9.5 Source-specific recalculations

The sources involved in the recalculations that affect the whole fugitive emission sector are:

- 1.B.2.a; 1.B.2.c Venting, oil; 1.B.2.c Flaring, oil – Updated data have been provided by oil&gas company concerning upstream emissions since 2016;
- 1.B.2.b - The recalculation affects the years 2008-2019 for different reasons. The recalculation is due to a fixed mistake in the conversion formula from natural gas leakage to methane. Starting from 2008 the methane density has been estimated with average net calorific value of 8190 kcal/mc but the formula for distribution leakage still used the old density value, calculated with real average net calorific value.
  Moreover, for 2019 recalculation new data about natural gas leakage have been provided by one of the main distribution operator (more than 25% of distributed natural gas and more than 26% of network length). Such operator reports the natural gas leakage from its network in the annual environmental report. The 2020 report introduce a massive change in the amount of leakage value due to the methodology change. Up to 2019 there was a parametric estimation according to the specific emission factors by network material, operation pressure and sample direct measures. Starting from 2020 a new methodology has been applied. The new methodology is based on data of gas leakage collected with the technology Cavity Ring-Down Spectroscopy (CRDS) Picarro. Such technology is about 1000 times more sensitive than the old one and represents a more robust evolution of estimations with respect to the parametric approach. The new methodology was also applied to review the 2019 leakage with a substantial difference as compared to the estimate issued with the 2019 report (more than 4 times less than the previous estimate).
- 1.B.2.d Geotherm - The recalculation affects the years 2019 for the update of a provisional emission factor used in the previous submission.

The updated data affect the estimates of CO_{2eq} emissions between -1% in 2008 and -11.9% in 2019 compared to the previous submission. The change is maily due to 1.B.2.b and 1.B.2.a sources.

3.9.6 Source-specific planned improvements

Further improvements are planned for the next submission. An expert team with the operator has been set to establish criteria and approach to validate the consistency of the time series.

4 INDUSTRIAL PROCESSES AND PRODUCT USE [CRF sector 2]

4.1 Sector overview

By-products or fugitive emissions, which originate from industrial processes, are included in this sector. Where emissions are released simultaneously from the production process and from combustion, as in the cement industry, these are estimated separately and included in category 1.A.2.

All greenhouse gases as well as CO, NO_X, NMVOC and SO_2 emissions are estimated.

CO_2 emissions related to NMVOC from solvent use in paint application, degreasing and dry cleaning, chemical products manufacturing or processing and other use, are estimated.

N_2O emissions are also estimated, which arise from chemical industry (2B) and from "other product manufacture and use (2G). As for CRF sector 2G, the use of N_2O occurs in medical applications, such as anaesthesia, and in the food industry, where N_2O is used as a propelling agent in aerosol cans, specifically those for whipped cream. Emissions from the use of N_2O in explosives are also included.

In 2020 industrial processes and product use account for 4.52% of CO_2 emissions, 0.08% of CH_4, 3.23% of N_2O, 100% of PFCs, HFCs, SF_6 and NF_3. In terms of CO_2 equivalent, industrial processes and product use contribute 8.1% to the total national greenhouse gas emissions.

The trends of greenhouse gas emissions from the industrial processes sector are summarised in Table 4.1.

Emissions are reported in kt for CO_2, CH_4 and N_2O and in kt of CO_2 equivalent for F-gases.

An increase in HFC emissions is observed from 1990 to 2020, while CO_2 emissions from chemical and metal and mineral industry reduced sharply in the period.

Table 4.1 Trend in GHG emissions from the industrial processes and product use sector, 1990-2020 (kt)

Gas/Subcategory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (kt)	**29,334.9**	**27,280.6**	**25,831.8**	**28,718.1**	**21,665.5**	**14,960.3**	**14,719.3**	**14,939.4**	**15,225.9**	**14,923.6**	**13,668.2**
2A. Mineral Products	20,720.5	20,239.7	20,749.0	23,304.7	17,341.5	11,203.1	10,595.4	10,771.0	10,878.3	10,911.6	9,780.4
2B. Chemical Industry	2,524.2	1,584.0	1,356.4	1,635.0	1,361.9	1,219.7	1,427.9	1,435.0	1,573.7	1,314.5	1,358.5
2C. Metal Production	4,377.9	3,902.7	2,305.3	2,419.4	1,833.8	1,562.9	1,710.5	1,675.1	1,681.5	1,602.3	1,438.6
2D. Non-energy products from fuels and solvent use	1,712.4	1,554.2	1,421.1	1,358.9	1,128.3	974.7	985.6	1,058.3	1,092.5	1,095.2	1,090.7
CH_4 (kt)	**5.2**	**5.4**	**2.9**	**3.0**	**2.4**	**1.7**	**1.9**	**1.8**	**1.8**	**1.7**	**1.4**
2B. Chemical Industry	2.5	2.7	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
2C. Metal Production	2.7	2.7	2.6	2.7	2.2	1.5	1.7	1.6	1.6	1.5	1.2
N_2O (kt)	24.2	25.8	28.9	27.7	4.1	2.1	2.1	2.3	2.3	2.1	2.1
2B. Chemical Industry	21.5	23.4	25.5	25.0	2.1	0.5	0.4	0.5	0.4	0.4	0.4
2G. Other product manufacture and use	2.6	2.5	3.3	2.7	2.0	1.6	1.7	1.9	1.9	1.7	1.7
HFCs (kt CO_2 eq.)	**444**	**927**	**2,489**	**7,619**	**12,055**	**15,403**	**16,030**	**16,114.4**	**16,248.8**	**16,641.6**	**15,637.7**
2B. Chemical Industry	444.0	548.7	26.4	24.3	1.0	1.3	1.2	1.2	1.4	1.1	0.9
2C. Metal Production	0.0	0.0	0.0	0.0	2.1	10.2	10.4	10.3	9.7	5.8	5.4
2E. Electronics Industry	0.0	6.1	8.7	7.2	10.7	9.5	8.7	9.0	6.9	9.6	8.6
2F. Product Uses as Substitutes of ODS	0.0	371.9	2,453.8	7,587.7	12,041.6	15,382.2	16,009.8	16,093.8	16,230.8	16,625.0	15,622.8
PFCs (kt CO_2 eq.)	**2,906.9**	**1,492.3**	**1,488.5**	**1,939.9**	**1,520.4**	**1,688.3**	**1,613.7**	**1,313.7**	**1,657.3**	**1,027.6**	**560.3**
2B. Chemical Industry	931.7	1,041.4	991.5	1,547.4	1,300.6	1,551.9	1,492. 8	1,192.4	1,511.3	869.8	417.5
2C. Metal Production	1,975.1	349.9	230.8	212.1	99.1	0.0	0.0	0.0	0.0	0.0	0.0
2E. Electronics Industry	0.00	100.1	266.2	180.4	120.6	136.4	120.9	121.3	146.0	157.8	142.8
SF_6 (kt CO_2 eq.)	**6,939.2**	**12,801.7**	**8,850.3**	**9,532.3**	**7,948.5**	**9,735.7**	**7,957.6**	**8,081.1**	**9,208.2**	**8,727.1**	**5,013.2**
2B. Chemical Industry	228.0	228.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2C. Metal Production	0.0	0.0	164.2	80.8	16.7	0.0	0.0	0.0	0.0	0.0	0.0

Gas/Subcategory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2E. Electronics Industry	0.0	14.9	61.9	57.2	30.6	47.3	52.7	66.0	50.1	60.0	42.8
2G. Other Products Manufacture and Use	6,711.2	12,558.8	8,624.2	9,394.4	7,901.2	9,688.4	7,904.9	8,015.1	9,158.1	8,667.1	4,970.4
NF_3 (kt CO_2 eq.)	**0.0**	**76.6**	**13.3**	**33.4**	**20.2**	**28.4**	**34.0**	**23.5**	**22.1**	**17.8**	**15.8**
2E. Electronics Industry	0.0	76.6	13.3	33.4	20.2	28.4	34.0	23.5	22.1	17.8	15.8
Unspecified mix of HFCs and PFCs (kt CO2 eq.)	**0.0**	**25.0**	**25.0**	**25.0**	**25.0**	**25.0**	**25.0**	**25.0**	**23.2**	**23.5**	**22.9**

Fourteen key categories have been identified for this sector, for level and trend assessment, using both the Approach 1 and Approach 2. The results for 2020 are reported in the following table 4.2.

Table 4.2 Key-category identification in the industrial processes sector with the IPCC Approach 1 and Approach 2 for 2020

KEY CATEGORIES			without LULUCF	with LULUCF
2A	CO_2	Emissions from cement production	L, T	L, T
2A	CO_2	Emissions from lime production	L1	L1
2A	CO_2	Emissions from other process uses of carbonates	T1	T1
2B	CO_2	Emissions from ammonia production	T1	-
2B	N_2O	Emissions from adipic acid production	T	T
2B	N_2O	Emissions from nitric acid production	T	T1
2B	HFCs	Emissions from fluorochemical productions	T2	-
2B	PFCs	Emissions from fluorochemical productions	-	L2
2C	CO_2	Emissions from iron and steel production	T1	T1
2C	PFC	Emissions from Aluminium production	T	T
2D	CO_2	Emissions Non-Energy products from fuels and solvent use	L2	L2
2F	HFCs	Emissions from substitutes for ODS- Refrigeration and air conditioning	L, T	L, T
2F	HFCs	Emissions from substitutes for ODS- Foam blowing agents	T2	T2
2F	HFCs	Emissions from substitutes for ODS- Fire protection	L, T	L, T

CO_2 emissions from cement, lime and other carbonate uses are included in category 2A; N_2O emissions from adipic acid, nitric acid and CO_2 emissions from ammonia refer to 2B; CO_2 emissions from iron and steel production and PFC emissions from aluminium production are included in 2C; CO_2 emissions from non-energy products from fuels and solvent use are included in 2D; HFCs from substitutes for ODS are included in 2F and HFC and PFC emissions from fluorchemical production are included in 2B. Methane emissions from the sector are not a key source. Most of these categories are also key categories in the 1990 assessment.

For the industrial processes sector, emissions and background data collected in the framework of the European Emissions Trading Scheme, the National Pollutant Release and Transfer Register (Italian PRTR) have been used either directly in the estimation process or as verification of emission estimates, improving national emissions factors as well as activity data.

Emissions and activity data submitted under the ETS are mandatorily subject to verification procedures, as requested and specified by the European Directive 2003/87/EC (art. 15 and Annex V). In compliance with the above-mentioned legislation, independent certifications and verifications of activity data, emission data and emission factors are required. At national level, data verification must be carried out by verifiers accredited by the national ETS Committee according to the ministerial decree DEC/RAS/115/2006. The verification of data submissions ensures reliability, credibility, and precision/accuracy of monitoring systems for data and any information relating emissions by plant. The guidelines for reporting under ETS are aligned to the 2006 IPCC Guidelines.

The Italian legislation implementing EPER Decision included a legislative decree and a Ministry decree providing guidelines for reporting by the Italian EPER facilities. The Italian legislation implementing Regulation (EC) 166/2006 is a Decree of the President of the Republic (DPR n.157/2011). Annexed to the DPR n.157/2011 is a guideline for the reporting by the Italian PRTR facilities.

Both guidelines for the reporting by the Italian EPER/PRTR facilities provide the list and description of the information to be reported, which includes: activity data (mandatory), total releases exceeding the reporting threshold values (mandatory); total off-site transfers of pollutant exceeding the reporting thresholds (mandatory); total off site transfers of waste exceeding the reporting thresholds (mandatory).
Releases/transfers information to be reported by facility operators can be based (in compliance with national and EU legislation) on measurement, calculation, estimation. In the case that operators report information based on measurements/calculation they are requested to communicate also what methodology has been applied to measure/calculate total releases/transfers.
As for activity data reporting under the national PRTR, no detailed requirements have been included in the national PRTR legislation and guidelines, although some general guidance is provided and followed by operators. The operator is expected to report the best available information concerning activity data for each reporting year, basically the amount produced, manufactured or treated in the reporting year shall be reported.
It is appropriate to consider also that most facilities in the scope of EPER/PRTR are also in the scope of EU and national legislation concerning the permitting procedures, monitoring and control obligation for industrial facilities larger in size. The quality of information reported by the facilities under the national EPER/PRTR is assessed by the competent authorities, the same authorities are usually involved also in the permitting procedure of these facilities, thus cross checks of information concerning AD and emissions are expected by the national legal framework.
Since emissions data reported under the national EPRTR can be measured, calculated or estimated, the European PRTR Guidance Document and the national guideline for reporting to the national PRTR include also references to the IPCC Guidelines methodologies.
The collection of facility reports under the national EPER/PRTR is a task that ISPRA has to carry out by law. The national inventory team is in the same unit of ISPRA where the national EPER/PRTR is managed, the inventory team has full access to the whole national dataset of the Italian EPER/PRTR without restrictions on the type of information (AD and emissions of each reporting facilities are available for the inventory team).
Italian EPER/PRTR data (emissions and transfers of pollutants, transfers of wastes) are publically available on the internet at the European Industrial Emissions Portal https://industry.eea.europa.eu/ (in compliance with the legislation, activity data of the reporting units are not disclosed to the public).
Data from the ETS and EPRTR databases are incorporated into the national inventory whenever the sectoral coverage is complete; in fact, not always data entirely cover the relevant categories whereas national statistics provide the complete basic data needed for the Italian emission inventory. Nevertheless, these data are entirely used to develop country-specific emission factors and check activity data levels.

4.2 Mineral Products (2A)

4.2.1 Source category description

In this sector CO_2 emissions from the following processes are estimated and reported: cement production, glass production, lime production and other processes uses of carbonates.

Cement

Cement production (2A1) is the main source of CO_2 emissions in this sector. As already mentioned, it is a key source both at level and trend assessment with and without LULUCF, also considering uncertainty, and accounts for 2.34% of the total national emissions.
During the last 15 years, in Italy, changes in cement production sector have occurred, leading to a more stable structure. The oldest plants were closed, wet processes were abandoned in favour of dry processes so as to improve the implementation of more modern and efficient technologies. The effects of the global recession period have led at national level to facilities closedowns and many conversions from full cycle to grinding plants. Since 2011 Italy has become the second cement producer country in the EU 28 because of the reduction of clinker production in the last years.
The picture of the cement sector in 2020 has 17 companies (54 plants of which: 30 full cycle and 24 grinding plants, i.e. in 2020 two full cycle plants were closed and one grinding plant was added compared to 2019) operating in Italy: multinational companies and small and medium size enterprises (operating at national or only at local level) are present in the country.

The operating plants are located as follows: 42.6% is in northern Italy, 14.8% is in the central regions of the country and 42.6% is in the southern regions and in the islands. The active sintering rotary kilns belong to the "dry" or of "semidry" types.

In Italy different types of cement are produced; Federbeton/AITEC, the national cement association, has been characterising the national production in 2020 as follows: 71% is CEM II (Portland composite cement); 15% is CEM I (ordinary Portland cement); 12% is CEM IV (pozzolanic cement) and 2% is CEM III (blastfurnace cement). Clinker production has been decreasing since 2007, although from 2016 to 2019 the production values have kept very close to the amount manufactured in 2016, in 2020 clinker production shows -6.0% compared to 2019 (Federbeton/AITEC [1], several years). Clinker demand in cement production was about 74% in 2020 (consumption of clinker out of production of cement).

Lime

In 2020, CO_2 emissions from lime production is key category at level assessment, with and without LULUCF, following the Approach 1.

CO_2 emissions occurring from processes where lime is produced account for 0.53% of the total national emissions. Lime production can also occur, beside lime industry, in different industrial sectors such as iron and steel making, pulp and paper production, soda ash production, sugar production; lime can also be used in a number of processes concerning wastewater treatment, agriculture and the neutralization of acidic emissions in the industrial flue gases. In particular, the other relevant lime productions accounted for in Italy are those occurring in the iron and steel making process and in the sugar production process. (although lime production&use at sugar mills occurs without release of CO_2, since CO_2 released from decarbonization is used with lime in the purification of the sugar molasses).

Lime is basically produced by calcination of limestone (calcium carbonate) or dolomite (calcium/magnesium carbonate) at 900°C. The process leads to quicklime and CO_2 emissions according to the following reaction:

$$CaCO_3 + MgCO_3 + heat \rightarrow CaO + MgO + 2CO_2$$

CO_2 is released because of the process reaction itself and also because of combustion to provide energy to the process. CaO and MgO are called quicklime. Quicklime, together with water, give another product of the lime industry which is called calcium hydroxide $Ca(OH)_2$.

CO_2 emissions estimation is related to lime production in mineral industry and it also includes the production of lime to feed other industrial processes (e.g. iron and steel making facilities).

The number of lime production facilities has been relevantly changing through the years as shown in the table 4.3:

Table 4.3 Lime production facilities (number)

	1990	2003	2010	2013	2014	2015	2016	2017	2018	2019	2020
Lime facilities (n.)	85	46	35	32	29	25	26	25	25	25	25

Figures from 2010 onwards are based on the number of facilities reporting under the EU-ETS. Moreover, 46% of the plants is in the southern regions and in the islands, 39% is in the northern regions and 15% in the central regions. The number of operating kilns has also decreased significantly through the years (about 171 in 1990, 75 in 2003). During the nineties, lime industry invested in technology implementation to replace the old kilns with regenerative and high efficiency kilns, rotary kilns are no longer used.

Concerning fuel consumptions, about 80% of the national lime industry uses natural gas, about 20% uses coke.

Other processes uses of carbonates (limestone and dolomite use in brick and tiles; fine ceramics; paper industry and power plants)

This category is key category in 2020 at trend assessment, with and without LULUCF, following the Approach 1.

CO_2 emissions are also related to the use of carbonates in different industrial processes, and they account for 0.18% of the total national emissions. Limestone or dolomite can be added in different steps of the production process to obtain the desired product features (i.e. colour, porosity). Sometimes carbonates in limestone and dolomite may have to be calcined ("dead burned") in order to be added to the manufacturing process. Limestone and dolomite are also used in paper production process and in the treatment of power plants flue gases. A steep decrease in the production processes and the relevant use of limestone can be observed between

2007 and 2009; use of limestone has been decreasing more gradually since 2009; the overall decrease being mainly driven by limestone and dolomite use in the brick and tiles sector. Mineral (stone) wool production which occurred in Italy along the years 1993-2009 is included in emission estimates for the energy sector. Stone wool has not been produced in Italy since 2009. This category includes also the whole time series for CO_2 emissions from other uses of soda ash.

Glass production

Glass industry in Italy can be characterised with regard to four glass product types: flat glass, container glass, borosilicate and lead/crystal glass. Flat glass is produced in facilities mainly located in the North; container glass is produced in facilities located all over the country; glass fibres and wool are produced in the North. About 70 companies carry out activities related to glass industry in Italy, about 30 companies carry out glass production processes in about 50 production units.

With regard to glass chemical composition, the national glass production consists of 95% soda-lime glass, 4% borosilicate glass and 1% lead/crystal glass.

The main steps of the production process in glass industry are the following:

- raw materials storage and batch formulation;
- melting of the formulated batch at temperature ranging from 1400°C to 1600°C, in different furnaces according to the type of glass product;
- forming into glass products at specific temperature ranges;
- annealing of glass products to prevent weak glass due to stress.

The formulated batch is generally melted in continuous furnaces, whose size and features are related to the types of glass production. In Italy 80% of the glass industry production is carried out using natural gas as fuel, other fossil fuels consumption is limited to low sulphur content oil. Emissions are basically released by the high temperature melting step and depend on the type of glass product, raw materials and furnaces involved in the production process. Main pollutants are: dust, NO_x, SO_x, CO_2; occasionally and depending on the specific production process, heavy metals, fluorides and chlorides gases could be released. CO_2 emissions are mainly related to the decarbonisation of carbonates used in the process (soda ash, limestone, dolomite) during the melting phase, accounting for 0.15% of the total national emissions. The use of scrap glass (recycled cullets) in the production processes has been increasing in Italy since 1998 thus contributing to the reduction of emissions from decarbonation and from the melting phase.

In the table 4.4, values of the rate of glass recycling from 1998 are reported (COREVE, several years).

Table 4.4 Rate of glass recycling

	1998	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rate of glass recycling (%)	38.8	46.9	57.2	58.4	62.9	70.9	70.8	70.3	70.9	71.4	73.9	73.4	77.4	78.6

4.2.2 Methodological issues

IPCC Guidelines are used to estimate emissions from this sector (IPCC, 1997; IPCC, 2000; IPCC, 2006).

Activity data are supplied by industries and/or provided in the national statistical yearbooks (ISTAT, several years [a]). Emission factors are those provided by the IPCC Guidelines (IPCC, 1997; IPCC, 2000; IPCC, 2006), by other international Guidebooks (EMEP/EEA, 2013; USEPA, 1997), or they are derived by data communicated at plant level.

Cement

CO_2 emissions from cement production are estimated using the IPCC Tier 2 approach.

Activity data comprise data on clinker production provided by the Italian ministry of the economic development (MSE, several years [a]). More in details from 1990 to 2008 official statistics provided by ISTAT have been used (ISTAT, several years [a]). From 2009, ISTAT clinker and cement statistics have not been provided in time for the official submission anymore, so a different source of information has been used. In particular, data on clinker and cement productions, based on a plant-by-plant monthly collection, were officially provided by the Italian Ministry for the Economic Development, at national and regional level, and made available up to the last inventory submission in 2018 at the Ministry website which is no longer available. These production data were cross checked with EPRTR and ETS data and with ISTAT statistics when available. Clinker production provided by the Ministry for the Economic Development seems to be more reliable than statistics published by ISTAT that are based on a sample survey with quite a low response and

data gaps are estimated by linear interpolation. Since the last inventory submissions, activity data referring to cement/clinker production (starting from year 2017) have been taken from the data reported to the national ETS.
Emission factors are estimated on the basis of information provided by the Italian Cement Association (Federbeton/AITEC, several years[a]) and by cement facilities in the framework of the European pollutant release and transfer register (E-PRTR) and the European emissions trading scheme (EU-ETS). In this latter context, cement production facilities reported fuel consumption, raw materials and emissions, split between combustion process and decarbonising process and complying with a clinker kiln input method which is based on IPCC methodology.
From 1990 to 2000 the resulting emission factor for cement production is equal to 532 kg CO_2/t clinker, based on the average CaO content in the clinker and taking into account the contribute of carbonates and additives. This value was assumed as representative of the Italian clinker manufacturing process by AITEC (AITEC, 2004) and officially reported to the Italian Ministry of Environment, Land and Sea in order to set the national circumstances for the implementation of the European-Emissions Trading Scheme (EU-ETS) in our country. The value was calculated by the industrial association on the basis of a tool provided by the World Business Council for Sustainable Development, available on website at the address http://www.ghgprotocol.org/files/ghgp/tools/co2_CSI_Cement_Protocol-V2.0.pdf and data from some big Italian plants.
From 2001 to 2004, emission factors are the result of a linear interpolation of CO_2 IEF for 2000 and 2005.
From 2005, emission factors are based on the data reported within the frame of the EPER/EPRTR and EU-ETS. Based on emissions and activity data (which includes the average CaO content in the clinker produced and the use of carbonates and additives) reported and verified under the EU-ETS the resulting emission factor has been fluctuating for the last fifteen years as shown in Figure 4.1: it resulted in a minimum equal to 518 kg CO_2/t clinker in 2008, and a maximum in the period equal to 531 kg CO_2/t clinker in 2007 and a value around 525 kg CO_2/t in the following years. Since 2016 the CO_2 IEF has been ranging between 520÷525 kg CO_2/t clinker, in 2020 the values is 527 kg CO_2/t clinker. The average emission factor varies year per year also as a consequence of the different operating circumstances (e.g. quality of the raw materials and operating conditions) at the Italian clinker facilities.
The information related to activity data and emissions for the clinker facilities reporting to the national ETS system have been processed. The range of uncertainty based on data communicated by the plants is about 5% in the period 2005-2009, about 4% in the period 2010-2015, about 6% in 2016, 5% in 2017 and 3% in 2018 and in 2019, 5.5% in 2020.

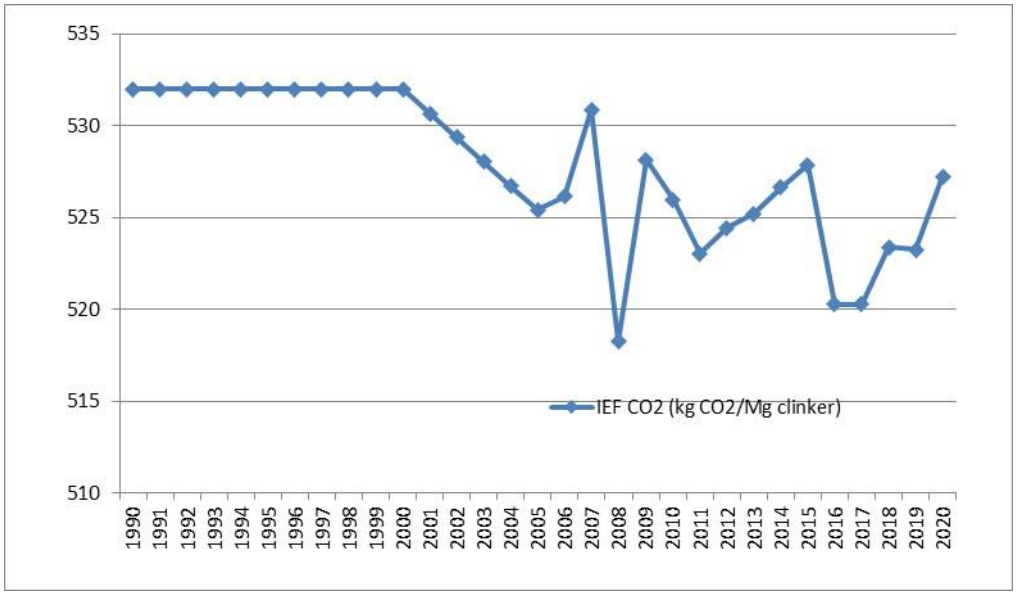


Figure 4.1 CO_2 IEF from decarbonation in clinker production, 1990-2020

In addition to this, Federbeton/AITEC has been reporting the overall consumption of natural raw materials by the national cement industry and also the replacement of natural raw material (either in the raw meal for the clinker manufacture or in the ground mix for the different cement types) with alternative materials in the Italian cement facilities, so:

- Specific consumption of natural raw materials has been varying for the last years;
- The rate of replacement of natural raw materials has been varying for the last years.

In 2020 approximately 7.0% of natural raw material was replaced by about 1.51 Mt non raw materials (0.64 Mt non hazardous wastes and 0.87 Mt secondary raw material) (Federbeton/AITEC[b], 2021). Most of the alternative materials consist of already decarbonised materials. The use of decarbonised material in amounts varying year by year in clinker kilns contributes explaining the fluctuations in the trend of the CO_2 IEF from decarbonisation.

In table 4.5 the amounts of natural raw material consumption for the years 2009-2020 have been reported together with the amounts of secondary raw materials and the replacement rates in the same years.

Table 4.5 Replacement of natural raw materials by secondary raw materials at the Italian cement facilities

RAW MATERIALS DEMAND	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Natural raw materials (Mt)	43.6	43.4	40.4	34.2	29.8	25.1	23.5	25.4	27.5	25.4	23.7	21.6
Secondary raw materials (Mt)	1.9	1.8	1.9	2.3	1.9	1.7	1.5	1.6	1.8	1.5	1.6	1.5
Natural raw material/ clinker (t/t)	1.73	1.72	1.68	1.78	1.76	1.59	1.51	1.72	1.85	1.72	1.57	1.61
Replacement of natural raw material (%)	4.0	4.3	4.3	6.8	6.7	6.3	6.5	6.4	6.7	6.0	6.7	7.0

(source: Federbeton/AITEC, several years[b])

Regarding industry data verification, the available activity data for the cement/clinker production in Italy are consistent to the information supplied by the Italian cement industry association, to data reported under the national PRTR and also to data collected in the frame of the national ETS. Emission data reported under the different obligations are in accordance with all the facilities.

The number of clinker facilities reporting under EPRTR and ETS are shown in table 4.6 together with the corresponding number of operating facilities according to the cement association (AITEC).

Table 4.6 Clinker facilities reporting under EPRTR and ETS

Clinker facilities	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Reporting to the national PRTR (n)	52	53	53	54	53	50	50	51	47	37	34	32	30	30	29	27
Reporting under the national ETS (n)	52	53	54	54	52	52	51	51	48	39	36	32	32	31	31	29
Number of clinker manufacturers in Italy (AITEC)	59	59	60	60	58	58	57	56	50	40	37	33	33	32	32	30
PRTR/AITEC (%)	88	90	88	90	91	86	88	91	94	93	92	97	94	94	91	90
ETS/AITEC (%)	88	90	90	90	90	90	89	91	96	98	97	97	97	97	97	97

In the framework of the EU-ETS register 29 cement facilities reported referred to 2020 whilst 27 reported releases to air under the EPRTR register. These figures out of 30 operating facilities according to Federbeton/AITEC represent more than 99% of total national clinker production. Generally, when the number of ETS clinker facilities is lower than Federbeton/AITEC figure, information concerning localization and production capacity is available for the facilities out of the scope of EU-ETS. AITEC reports every year the number of operating cement/clinker facilities in Italy and the cement production of the whole sector. Under the EU-ETS, cement plants communicate emissions and activity data split between energy and processes phases and specifying the amount of carbonates and additives which are constituents of the raw meal complying with a “clinker kiln input” approach; both activity data and emissions are independently verified and certified as requested by the EU-ETS directive. The implied CO_2 emission factor is applied to the total national clinker production.

Basically, CO_2 emissions time series is related to clinker production time series. Specifically, main decreases in the national production of cement industry, which well reflects the trend of the national economy, can be observed for the years 1992-1994; an increase in production can be observed from 1996 to 2001 and from 2002 to 2007, while a significant decrease in the production is observed for 2007- 2009 and 2011-2017 due to the effects of the economic crisis and the significant reduction in the number of authorizations to build between 2005 and 2015 (-84%). A weak increase in the number of new permits to build was recorded also in 2019, whilst the restrictions to fight SARS-COVID-2 Pandemic in 2020 resulted in a new decrease in production at national level. Practically, the same variations can be observed in CO_2 emissions trend. In order to enhance the transparency of the inventory, in Figure 4.2 clinker production and CO_2 emissions time series are shown.

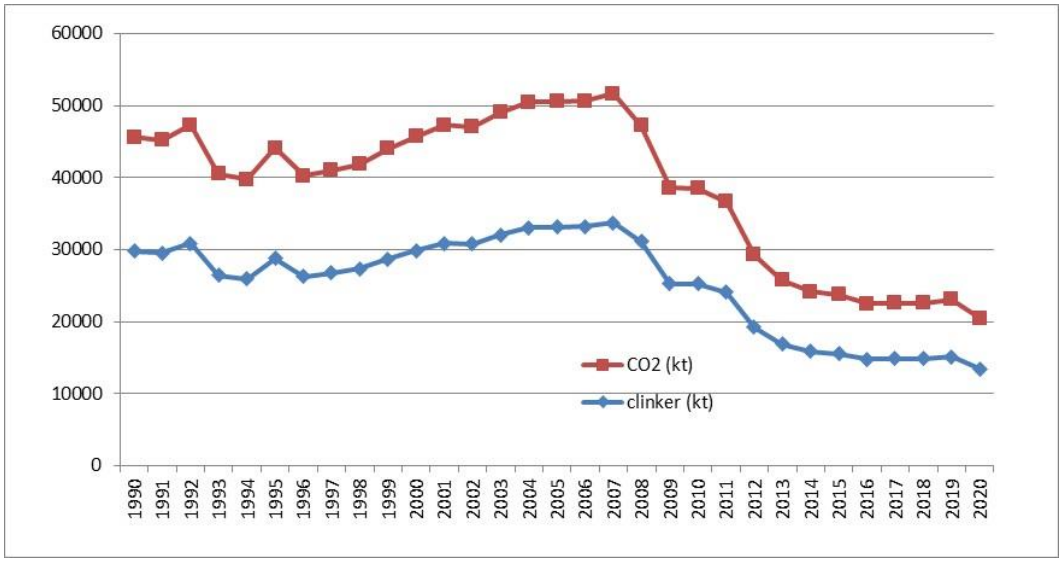


Figure 4.2 Trend of clinker production and CO_2 emissions 1990-2020 (kt)

Lime

CO_2 emissions from lime have been estimated on the basis of production activity data supplied by ISTAT up to 2008 (ISTAT, several years [a]) and by operators in the frame of the ETS reporting obligations from 2009.
ISTAT reported till 2005 lime production data on the national Statistical Yearbook with the footnote explaining that the figure covered 80% of the national total lime production and not including auto produced lime in sugar mills and in the iron and steel plants.
From 2005 to 2008 lime productions has been provided to ISPRA for the emission inventory but not published. For the inventory purpose these statistics have been used, properly adjusted as indicated by ISTAT, adding non-marketed lime productions where non-marketed lime is assumed to be equal to the manufacture of lime at iron & steel sites and sugar mills. The information referring to the annual amount of non-marketed lime is supplied by the operators of such facilities under the national pollutant release and transfer register (PRTR).
From 2009, only production indexes have been supplied by ISTAT; no other information has been published by ISTAT till 2014 when lime productions for the last years were made available but these data seem not consistent with the production index supplied by the same institute for the same years. For these reasons ETS data has been used from 2009.
All the national lime production plants are part of the EU-ETS and their production data is certified while data published by ISTAT are based, as for clinker and cement production, on a sample survey including production and economical information with quite a low response index and data for not responding plants are estimated by linear interpolation. There is no evidence of lime facilities not included in the ETS, with exception of plants located at sugar mills which are included in the estimates.
CO_2 emissions from lime production and use in other industrial processes (e.g. iron and steel production, sugar mills) have been also considered. Emission factors have been based on detailed information supplied by lime facilities in the framework of the European emission trading scheme and by the national lime industrial association (CAGEMA, 2005). Specifically, the value of the emission factor from 1990-2000 has been officially supplied to the Italian Ministry of Environment, Land and Sea by the industrial association (CAGEMA, 2005), in order to set the national circumstances for the implementation of the European-Emissions Trading Scheme (EU-ETS).
From 2001 to 2004, emission factors are the result of a linear interpolation of CO_2 IEF for 2000 and 2005.
From 2005, information available in the frame of the ETS reporting obligation has made activity data (including fuels and raw materials such as carbonates and additives, in compliance with a “lime kiln input” approach) available for the Italian lime industry at facility level together with CO_2 emissions data (combustion and process emissions). Both activity data and CO_2 emissions are certified and independently verified as requested by the EU-ETS legislation.
The CO_2 implied emission factor varies year by year because of the natural raw material fed to the kilns at facility level including different CaO and MgO contents. In table 4.7, CaO and MgO contents for the years 2009-2020 are reported; these figures refer only to the production plants, excluding autoproduction.

Table 4.7 CaO and MgO oxides content for lime production (%)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CaO content (%)	96.9	96.7	96.2	93.6	94.4	89.8	90.7	97.1	97.7	95.5	88.8	84.1
MgO content (%)	3.1	3.3	3.8	6.4	5.6	10.2	9.3	2.9	2.3	4.5	11.2	15.9

Other processes uses of carbonates (Limestone and dolomite)

CO_2 emissions from other process uses of carbonates are related to the use of limestone and dolomite in bricks, tiles and ceramic production, paper production and also in the treatment of flue gases from power plants. In Italy only limestone is used for the activities included in this category, brick and tiles, fine ceramic, and pulp and paper production and power plant flue gases treatment, while no dolomite use is documented. In the present submission the whole timeseries for CO_2 emissions from other uses of soda ash are included and allocated under this category, based on the activity data and emissions information reported by facilities in the scope of the national ETS. In 2020 about 85.6% of the total carbonates accounted for in this category has been used in the production processes of bricks and tiles, about 6.2% for the fine ceramic material, 6.7% in the treatment of flue gases in the power plants, about 0.3% in the paper industry and 1.0% is the share of the other uses of soda ash.

CO_2 emissions have been estimated for the whole time series on the basis of the IPCC default value for limestone equal to 0.44 t/t; the overall CO_2 emission time series is mainly driven by the CO_2 emissions from the use of limestone in the bricks and tiles sector.

In the CRFs the total amount of carbonates accounted for in this category used in these processes is reported.

Detailed production, consumption, activity data and emission factors have been supplied in the framework of the European emissions trading scheme and relevant data are annually provided by the Italian bricks and tiles industrial association and by the Italian ceramic industrial associations (ANDIL, 2000; ANDIL, several years; ASSOPIASTRELLE, several years; ASSOPIASTRELLE, 2004, Confindustria Ceramica, several years). Even though the EU ETS has not been in operation for the whole time-series relevant information concerning the use of carbonates was made available in the communications to the Italian Ministry for Environment, Land and Sea to get the overview of the sector for the national ETS to be implemented.

Mineral (stone) wool production has been also taken into account and CO_2 emissions have been estimated but they are included under Energy sector because it is not possible to identify the share of emissions related to the process aspects and the share of emissions related to the energy aspects (the IPCC 2006 Guidelines do not provide any indications concerning this issue). Mineral wool production in Italy took place in Sardinia at one facility during the years from 1993 to 2009 where the production was considered not profitable any longer and the facility was closed down.

Glass

CO_2 emissions from glass production have been estimated taking into account, from 1990 to 2004, production data published by ISTAT on the National Statistical Yearbooks (ISTAT, several years [a]); from 2005 ISTAT statistics have not been available anymore and consistent figures published by the national glass industry association have been used (Assovetro, several years). Glass wool production is included for the whole time series.

In table 4.8, the complete time series of the national inventory for glass production is reported for the different types of glass.

Table 4.8 Glass production time series (Mg)

Type	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
Flat glass	816,406	879,750	1,009,367	1,183,310	921,619	838,019	870,440	1,054,763	1,034,234	965,859
Container glass	2,609,826	3,094,893	3,417,851	3,716,509	3,656,425	3,936,885	4,177,711	4,287,283	4,485,190	4,429,110
Glass wool	105,029	119,120	139,421	129,958	115,332	86,929	87,208	98,805	99,552	88,319
Other glass	247,684	165,213	362,970	298,000	369,730	381,900	403,520	420,102	414,087	392,316

Since 2000, information provided by operators under the national ETS has been used to develop emissions estimation and relevant CO_2 emission factors. CO_2 emissions from the decarbonation, considering the national circumstances concerning the use of cullets (recycled scrap glass which does not cause CO_2 emissions) in the production processes, have been estimated.

In 2020, CO_2 emission factor has been estimated equal to 97 t CO_2/t, based on the information supplied under the European emissions trading scheme by 50 out of 52 facilities.

4.2.3 Uncertainty and time-series consistency

The uncertainty in CO_2 emissions from cement, lime, other process uses of carbonates and glass production is estimated to be equal to 10.4% from each activity, resulting from 3% and 10% for activity data and emission factor, respectively. Official statistics of activity data for these categories are quite reliable when compared to the activity data reported by facilities under different data collections, thus leading to the considered uncertainty level for the activity data. The uncertainty level for emission factors is equal to the maximum level reported in the IPCC Good Practice Guidance (IPCC, 2000) for the cement production; this is a conservative estimation because the range of values of the emission factors of the Italian cement plants would lead to a lower uncertainty level.
Montecarlo analysis has been applied to estimate uncertainty of CO_2 emissions from cement for 2009. The resulting figure is equal to 10.0%. Normal distributions have been assumed for the parameters and information deriving from the ETS has been considered in defining the shape of the distributions. A summary of the results is reported in Annex 1.
In Tables 4.9 and 4.10, the production of mineral products and CO_2 emission trend is reported.

Table 4.9 Production of mineral products, 1990 – 2020 (kt)

Activity data	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						kt					
Cement production (decarbonizing)	29,786	28,778	29,816	33,122	25,239	15,527	14,762	14,822	14,820	15,119	13,389
Glass (decarbonising)	3,779	4,259	4,930	5,328	5,063	5,244	5,347	5,541	5,914	6,033	5,876
Lime (decarbonizing)	2,583	2,873	2,760	3,447	2,789	2,348	2,328	2,510	2,518	2,420	2,178
Other processes use of carbonates (Limestone and dolomite use)	5,781	5,292	5,143	6,087	3,580	1,886	1,712	1,619	1,524	1,426	1,230

Table 4.10 CO_2 emissions from mineral products, 1990 – 2020 (kt)

CO_2 emissions	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						kt					
Cement production (decarbonizing)	15,846	15,310	15,862	17,403	13,276	8,196	7,680	7,711	7,757	7,912	7,059
Glass (decarbonizing)	453	511	611	768	559	534	512	552	604	597	569
Lime (decarbonizing)	1,877	2,090	2,013	2,456	1,932	1,643	1,649	1,795	1,847	1,776	1,611
Other processes use of carbonates (Limestone and dolomite use)	2,544	2,328	2,263	2,678	1,575	830	753	712	671	627	541

Emission trends are generally related to the production level, which has been decreasing for the last years mainly because of the economic recession. In particular, the trend of carbonates used in power plants for flue gases treatment, is driven by the use of coal in the operating power plants.

4.2.4 Source-specific QA/QC and verification

CO_2 emissions have been checked with the relevant industrial associations.
Both activity data and average emission factors are also compared every year with data reported in the national EPER/E-PRTR registry and in the European emissions trading scheme (EU-ETS).
Under the EU-ETS, operators are requested to report activity data and CO_2 emissions as information verified and certified by auditors who check for consistency to the reporting criteria.
Activity data and emissions reported under EU-ETS and EPER/EPRTR are compared to the information provided by the industrial associations. In particular, comparisons have been carried out for cement, lime, limestone and dolomite, and glass sectors. The general outcome of this verification step shows consistency among the information collected under different legislative framework and the information provided by the relevant industrial associations.

Information reported under the EU-ETS has allowed for estimating CO_2 emissions from other uses of soda ash, the whole time series is included in the present submission and allocated under the "Other processes use of carbonates" category.

4.2.5 Source-specific recalculations

Recalculations occurred for the categories included in "Mineral Products" for this inventory submission, specifically CO_2 from Lime (decarbonizing) from 2006 to 2019 was recalculated to exclude CO_2 from lime production at sugar mills (since it is not released), Glass (decarbonizing) in 2019 was recalculated due to an update of the activity data for the same year, Other process uses of carbonates in 2019 due to an update of the activity data for the same year, as shown in table 4.11.

Table 4.11 Recalculation (%) in CO_2 from Lime, Glass (decarbonizing) and Other process uses of carbonates

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2														
Lime (decarbonizing)	-1,64	-1,41	-1,42	-2,63	-1,92	-1,08	-1,36	-0,92	-1,26	-0,92	-1,04	-1,98	-1,16	-1,19

	2019
CO_2	
Glass (decarbonizing)	- 0,01

4.2.6 Source-specific planned improvements

Further investigations concerning the replacement of natural raw material in lime production are planned.

4.3 Chemical industry (2B)

4.3.1 Source category description

CO_2, CH_4, N_2O, HFCs and PFCs emissions from chemical productions are estimated and included in this sector.

Adipic acid

Adipic acid production is a multistep process which starts with the oxidation of cyclohexanol using nitric acid and Cu catalysts according to the following reaction:

$$C_6H_{11}OH + 2HNO_3 \rightarrow HOOC(CH_2)_4COOH + N_2O + 2H_2O + energy$$

Adipic acid is then used to produce nylon or is fed to other production processes. Together with adipic acid, N_2O is produced and CO_2 is one of the by-products (Radici Chimica, 1993).

Emissions data from adipic acid production are provided and referenced by one plant, which is the only producer in Italy (Radici Chimica, several years). Specifically, for N_2O, in 2020, adipic acid production is a key category at trend assessment, both with Approach 1 and Approach 2, with and without LULUCF. These emissions account for 21% of total N_2O emissions in 2005, 2.4% in 2010, 0.6% in 2015 and 0.41% in 2020; the notable decrease in share is due to the fact that the technology to reduce N_2O emissions has become fully operational at the existing producing facility since 2007.

N_2O emissions have relevantly decreased thanks to the implementation of a catalytic abatement system (pilot scale plant). The use of thermally stable catalysts in the pilot plant has allowed the treatment of highly N_2O concentrated flue gas from the adipic acid production plant, reducing the volume of treated gas and the size of the pilot plant itself. The abatement system is generally run together with the adipic acid production process. In 2004 this system was tested for one month resulting in complete decomposition of N_2O; in 2005 the catalytic process was started only at the end of the year because of technical changes in the system; in 2006 the abatement system had been operating continuously for 9 months (3 months were needed for maintenance and technical changes) leading to the decomposition of 92% (efficiency of the abatement system while in operation) of N_2O emissions. Since 2007 the operating time has been about 11 months (about one month was

needed for maintenance operations) and the N_2O emissions abatement system while in operation has reached an efficiency exceeding 98% (Radici Chimica, several years). In 2011 further emissions reduction was achieved thanks to technical improvements implemented in the production process during 2010:

- the number of scheduled outages of the adipic acid production process is reduced (from about 1/month to 2/year);
- the abatement system is set to reach the operating level more quickly than in the previous years.

These two achievements allow reducing the significance of N_2O peak emissions related to the start&stop phases. Moreover, an emission monitoring and recording system was implemented in compliance with Decision 2007/589/EC (Radici Chimica, 2013).
Also CO_2 emissions are estimated from this source.

Ammonia production
In 2020 CO_2 emissions from ammonia production are also a key category, at trend assessment with the Approach 1without LULUCF.
In Italy only one facility has been producing ammonia since 2009 as a consequence of the resizing of the production at national level after the crisis of the largest fertilizer producer, Enichem Agricoltura, and as a consequence of the international financial crisis in the last years. Two facilities had been producing ammonia in Italy up to 2008, in 2009 one plant stopped the production and was decommissioned in the following years. Ammonia is obtained after processing in ammonia converters a "synthesis gas" which contains hydrogen and nitrogen. CO_2 is also contained in the synthesis gas, but it is removed in the decarbonising step within the ammonia production process. Part of CO_2 is recovered as a by-product and part is released to atmosphere. Recovered CO_2 can either be used as input for different production processes (e.g. urea or calcium nitrate lines; liquefaction of CO_2 plant) on site or can be sold to technical gas manufacturers. The results of the investigation concerning the recovered CO_2 were accounted for in the previous submissions: operators provided the information used to revise both the emissions and the EF time series (YARA, several years). The amount of recovered CO_2 from ammonia production (which is fed to urea production processes) has been also reported in the CRF since the last submissions.

Nitric acid
In early nineties seven facilities manufactured nitric acid, but since 2003 the production has been carried on only in three plants. In 2008 another plant stopped nitric acid production and the reconversion of the plant is currently under negotiation, so since 2009 nitric acid production has been carried out in two plants only. Nitric acid is produced from ammonia by catalytic oxidation (with air) of NH_3 to NO_2 and subsequent reaction with water. Currently the reactions involved take place in low and medium pressure processes.
In 2020, N_2O emissions from nitric acid production are key source for trend assessment with both Approach 1 and 2 without LULUCF, and trend with Approach 1 with LULUCF, as they show a relevant decrease in emissions from 1990 due to a reduction in production. Moreover, as far as YARA facility is concerned, the decrease in N_2O emissions is also related to the implementation of catalytic N_2O decomposition in the oxidation reactors a YARA De-N_2O patented technology, based on the use of CeO_2 catalyst (YARA, several years), while the improvements in the monitoring system of N_2O emissions at the other facility has been affecting N_2O emissions estimation time series for the very last years.

Carbon black
Three facilities have been carrying out this production which consists basically on cracking of feedstock oil (a mixture of PAH) at 1200 – 1900 °C. Together with black carbon, tail gas is a by product of the process. Tail gas is a mixture of CO, H_2, H_2O, NO_x, SO_x and H_2S; it is generally burnt to reduce the emissions to air and to recover energy to be used in the production process.
CO_2 emissions from carbon black production have been estimated on the basis of information supplied directly by the Italian production plants also in the framework of the EU ETS for the last years.

Ethylene, Ethylene oxide, Propylene, Styrene
Ethylene, ethylene oxide, propylene and styrene productions belong to the organic chemical processes. In particular, ethylene is produced in petrochemical industry by steam cracking to manufacture ethylene oxide, styrene monomer and polyethylenes. Ethylene oxide is obtained via oxidation of ethylene and it is largely used as precursor of ethylene glycol and in the manufacture of surfactants and detergents. Propylene is obtained by cracking of oil and it is used to manufacture polypropylene but also acetone and phenol. Styrene, also known as vinyl benzene, is produced on industrial scale by catalytic dehydrogenation of ethyl benzene. Styrene is

used in the rubber and plastic industry to manufacture through polymerisation processes such products as polystyrene, ABS, SBR rubber, SBR latex.
Except for ethylene oxide production, which has stopped in 2002, the other productions of the above-mentioned chemicals still occur in Italy.
As far as ethylene, ethylene oxide and propylene are concerned, Syndial Spa (former Enichem) and Polimeri Europa (Syndial, several years; Polimeri Europa, several years) were the main producers in Italy up to 2006. Since 2007 Polimeri Europa (the parent company name changed intoVersalis in 2012) has become the main producer for those products in Italy, while it has been the main producer of styrene since 2002.

Titanium dioxide
Titanium dioxide (TiO_2) is the most used white pigment especially for paint and plastic industries. As described also in the IPCC Guidelines, two main production routes are available:

- the chloride route, which has both "combustion" and "process" emissions;
- the sulphate process, whose emissions are only related to the combustion of fuels.

In Italy there is only one facility where this production occurs and titanium dioxide is produced through the sulphate process. The "sulphate process" involves the use of sulphuric acid to concentrate the input raw mineral in terms of titanium dioxide content, then selective precipitation and calcination allow getting the final product. Main process chemical reactions can be summarised like in the following box:

$$FeTiO_3 + 2H_2SO_4 \rightarrow FeSO_4 + TiO.SO_4 + 2H_2O$$
$$TiO.SO_4 + 2H_2O \rightarrow TiO_2.H_2O + H_2SO_4$$
$$TiO_2.H_2O + heat \rightarrow TiO_2 + H_2O$$

In the past submissions CO_2 emissions from titanium dioxide production were estimated on the basis of information (activity data and CO_2 emissions level) supplied directly by the Italian manufacturer in the framework of the reporting obligation to the EPRTR and EU-ETS registers. The estimates for the whole time series was wrongly accounted under IPPU (2B6) thus leading to double accounting. Since the last submission the time series for CO_2 emissions is not accounted under 2B6 and the notation key "NO" has been reported in the CRF because no process emissions are originated by the sulphate process.

Caprolactame production
Caprolactame is a monomer used in the industrial production of nylon-6. It can be obtained by catalytic oxidation of toluene and cycloexane. The process releases N_2O.
N_2O emissions from caprolactame production have been estimated and reported and are related to only one producing plant, which closed in 2003.

Calcium carbide production and use
Calcium carbide production process takes place in electric furnaces, CaO and coke are fed to the furnace and the product is obtained according to the following reaction:

$$CaO+3C \rightarrow CaC_2+CO$$

CARBITALIA S.p.A. is the only facility which can operate calcium carbide production in Italy (CARBITALIA S.p.A., 2009). It produced calcium carbide up to 1995, when it stopped the production because of the increasing price of electricity. The plant still exists and it is maintained, but since 1995 it has just been supplying calcium carbide bought abroad. About 95% of the total CaC_2 sold in Italy is used to manufacture acetylene, the remaining share is bought by foundries for the desulphuration of steel or spheroidal pig iron (CARBITALIA S.p.A., 2021). CO_2 emissions from manufacture and use of calcium carbide have been estimated and accounted for along the whole time series.

Soda Ash production and use
In Italy only one facility operates soda ash production via Solvay process. Solvay process allows producing soda ash through the conversion of sodium chloride into sodium carbonate using calcium carbonate and ammonia. CO_2 is released and calcium chloride is the waste.

Up to the second half of year 2000 in the unit for the production of peroxidates there was one sodium carbonate line and a sodium perborate line which was then converted to sodium carbonate production. Soda ash is also used in glass production processes.

Fluorochemical production

The sub-sector fluorochemical production consists of two sources, "By-product emissions" and "Fugitive emissions".

PFC emissions from fluorochemical production is a key source at level assessment using Approach 2 with LULUCF; also HFC emissions is a key source at trend assessment, only using Approach 2 without LULUCF.

The production of halocarbons and SF_6 took place in two facilities in Italy up to 2008 (Spinetta Marengo and Porto Marghera). Since the very beginning of 2005 the plant in Spinetta Marengo has not been producing SF_6 any longer. In the first quarter of 2008 the production plant at Porto Marghera has stopped its activity, since then there is only one facility in Italy where HCFC22 is produced.

Within by-product emissions, HFC23 emissions are released from HCFC22 manufacture, CF_4 emissions are released from SF_6 and HCFC22/TFM productions, whereas C_2F_6 and HFC143a emissions are released from the production of C_3F_6 (and also CFC115) and HFC134a, respectively. Production of CFC115 was carried out only in one facility and stopped in 1998. Since the very beginning of 2005 Spinetta Marengo plant has not been producing SF_6 any longer.

Production of HFC125, HFC134a, HFC227ea and SF_6 lead to fugitive emissions of the same gases. In particular, production of HFC227ea only occurred in 1999.

The share of F-gas emissions from the fluorochemical production in the national total of F-gases was 42.6 % in the base-year (1990), and 2.5% in 2020.

4.3.2 Methodological issues

Adipic acid

Italian production figures and emission estimates for adipic acid have been provided by the process operator (Radici Chimica, several years) for the whole time series. Emissions estimates provided by the operator are based on the IPCC default EF, so the values provided and the estimates in the Italian emissions inventory are, basically, the result of the same methodology.

More specifically, N_2O emissions from adipic acid production (category 2B3) have been estimated using the default IPCC emission factor equal to 0.30 kg N_2O/kg adipic acid produced, from 1990 to 2003.

Since 2004 the operator has started to study how to introduce an abatement system; although emission estimates provided by the operator have still been based on the IPCC default emission factor (0.30 kg N_2O/kg adipic acid produced), the operating hours of the abatement system and the abatement rates have also been included in the estimation process. The abatement system is generally run together with the adipic acid production process. In 2004, the N_2O catalytic decomposition abatement technology has been tested so that the value of emission factor has been reduced taking into account the efficiency and the time, one month, that the technology operated.

From the end of 2005 the abatement technology is fully operational; the average emission factor in 2006 is equal to 0.05 kg N_2O/kg adipic acid produced and the abatement system had been operating continuously for 9 months; since 2007 the average emission factor has been 0.03 kg N_2O/kg adipic acid produced and the operating time of the abatement system has been 11 months.

Technical improvements in operating the production process and the abatement system have allowed achieving significant reduction in N_2O emissions since 2009 (Radici Chimica, 2013): in 2010 the average emission factor was 0.018 kg N_2O/kg adipic acid produced while in 2011-2013 the average EF is around 0.005 kg N_2O/kg adipic acid produced with the abatement rate exceeding 98%.

In 2015 the average EF is around 0.0045 kg N_2O/kg adipic acid while in 2019 is 0.0034 kg N_2O/kg adipic acid.

Thus, both for the period 1990-2005 and from 2006 up to 2011 the estimates are provided according to the IPCC Good Practice Guidance (default EF has been used when no abatement system was operational; abatement rates have been considered in estimating emission values since 2006). The operator reports also under EPER/E-PRTR both adipic acid production and the N_2O emissions related to this production; adipic production and N_2O emissions have been also reported by the operator to the national competent authority for the ETS (the facility was included in the ETS system in 2013) together with additional information such as abatement rates and operating times. Since 2011 the implementation of a new monitoring system has also enabled the reporting of better-quality emissions data in terms of nitrogen and nitrous oxides emissions.

Based on information from the national PRTR and ETS, EFs are calculated for the plant, the resulting value is checked and verified by the formula included in the following box (based on the IPCC default EFs for adipic acid production, abatement rate and operating time of the abatement technology at the facility). In the formula the average emission factor is calculated subtracting from the default EF (0.300 kg N_2O/kg adipic acid produced) the default EF multiplied by the abatement technology rate and by the operating time factor, parameters and resulting EF values are indicated for the years from 2005 to 2011.
The EFs submitted for the adipic acid production in the CRF and the EFs calculated for the plant in table 4.12 are practically the same along those years.

Table 4.12 N_2O emission factors submitted vs calculations based on efficiency and utilization details

Parameter/Year	2005	2006	2007	2008	2009	2010	2011
EFp (IPCC default)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
A	0.925	0.9212	0.965	0.986	0.986	0.986	0.986
T	0.14	0.8825	0.93	0.91	0.91	0.952	0.999
EFs (average EF)	0.26	0.056	0.031	0.031	0.031	0.019	0.005

Values resulting according to the following formula

$$(1-A*T)*EFp = EFs$$

Where:
A= Abatement rate provided by the operator
EFp= N_2O Emission Factor for Adipic Acid production (kg N_2O /kg adipic acid prod)
T = operating time of the abatement system/ operating time of the adipic acid production line
EFs = N_2O actually released Emission Factor submitted (kg N_2O released/kg adipic acid prod)

CO_2 emissions from this source have been estimated according to the information communicated by the operator.
Up to 2019 submission, the estimates were calculated following the Tier 2 approach, since the 2020 submission and following the ERT recommendation during the 2019 in country review, Tier 2 is implemented up to 2012 estimates while Tier 3 is reported for the estimates related to the last part of the time series (from 2013 onwards), because AD and CO_2 emissions reported by the operator in the framework of the national ETS have been used. Measurements of plant specific information under the national ETS are not available for the period 1990-2012, so Tier 3 cannot be implemented for the whole time series, but the consistency of the time series is not affected because there is only one operator for the national production of adipic acid in Italy.

Ammonia
Ammonia production data are published in the international industrial statistical yearbooks (UN, several years), national statistical yearbooks (ISTAT, several years [a]) and from 2002 they have been checked with information reported in the national EPER/E-PRTR registry. More in detail for 1990-1999 the amount of ammonia produced was published on the UN "Industrial Commodity Statistics Yearbook" (UN, several years), while for the years 2000 and 2001 production indexes published by ISTAT were applied. Since 2002 national production of ammonia in Italy has been collected at facility level. The number of ammonia facilities in Italy is known along the whole time series so it is possible to make sure that the national emissions estimation from this source is consistent to the sum of emissions from the ammonia facilities.
Since 2009 only one facility has been producing ammonia in Italy and reporting data to the national PRTR.
Recovered CO_2 has been investigated with the cooperation of the operators and the resulting information has been used to revise the whole CO_2 emission time series and the emission factors. The analysis has allowed understanding that CO_2 emissions recovered from ammonia production are used to produce urea and technical gases. According to 2006 IPCC Guidelines the CO_2 recovered for technical gases should be accounted for emission and included in the estimate while that for producing urea should be reported in the relevant consumption categories. In particular, for the years 1990-2001, CO_2 emission factor has been calculated on the basis of information reported by the production plants for 2002 and 2003 in the framework of the national EPER/E-PRTR registry and considering also the amounts of CO_2 recovered since the beginning of the recovery operations. CO_2 reported to the national EPER/E-PRTR registry has been used for the previous years under the assumption, verified with the operator, that no change in technology at facilities have occurred along the period (YARA, 2007). Since 2002, the average emission factors result from data reported by the plants in the national EPER/E-PRTR and calculated taking in account the gas consumed for the reforming process; the plant supplies the recovered CO_2 detailed data allowing the proper application of the IPCC methodology.
Because of production of Urea and Ammonia are separate processes, when they are carried out in the same facility the CO_2 EF for Ammonia production, according to the IPCC 2006 GL, is based on the amount of CO_2 released from the production of ammonia, the amount of CO_2 recovered and sold as technical gas and the

amount of ammonia produced. The recovery of CO_2 fed to Urea production, instead, has to be subtracted in the calculation of the EF. The resulting CO_2 EF could vary according to the decision of the operators in terms of increase/decrease of CO_2 recovered to be sold as technical gas or fed to Urea production. For example, in 2013-2015 the amounts of CO_2 fed to Urea production and the amount of CO_2 for technical gas decreased, consequently the overall amount of CO_2 released from ammonia production increased; moreover the fluctuation of ammonia manufactured in the same years has to be considered: production of ammonia increased in 2014, then it fell in 2015 while in 2019 the amount produced was to the same as in 2013.
Table 4.13 shows the time series for the average CO_2 emission factor.

Table 4.13 Ammonia production, time series for the average CO_2 EF (t CO_2/t ammonia production)

	1990-2001	2002	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EF (t CO_2/t ammonia production)	1.30	1.34	1.32	1.27	1.18	1.08	1.16	1.17	1.25	1.14	1.09	1.11	1.14	1.10

Following the ERT recommendation of the 2019 UNFCCC in country review, Italy has investigated on the final uses of urea at national level.
The operator of the facility producing ammonia and urea has provided us with the final markets of urea in Italy and an estimation of those market shares in 2020: SCR engines (9.8%); NOx abatement systems (2.0%); Industry ("industry-no-glue" and "industry-glue", 4.0%) and fertilizers (84.2%).
The indicated final uses can be divided into emissive sources (SCR engines; NOx abatement systems and Fertilizers) and non emissive sources (industry-glue and industry-no glue). The emissive sources already included in the national inventory are the same as those indicated by YARA, so, as far as urea uses are concerned, the completeness of the inventory is verified.
Natural gas is used as feedstock in the ammonia production plants and the amount of fuel used is included in the energy balance under the no energy final consumption sector (see Annex 5), therefore double counting does not occur.

Nitric acid
With regard to nitric acid production (2B2), production figures at national level are published in the national statistical yearbooks (ISTAT, several years [a]), while at plant level they have been collected from industry (Norsk Hydro, several years; YARA, several years; Radici Chimica, several years). The number of nitric acid facilities in Italy is known along the whole time series so it is possible to make sure that the national emissions estimation from this source is consistent to the sum of emissions from the nitric acid facilities. In 1990 there were seven production plants in Italy; three of them closed between 1992 and 1995, and another one closed in 2004, one more closedown in 2008 has left two plants still operating.
The N_2O average emission factors are calculated from 1990 on the basis of the emission factors provided by the existing production plants in the national EPER/E-PRTR registry, applied for the whole time series, and default IPCC emission factors for low and medium pressure plants attributed to the plants, now closed, where it was not possible to collect detailed information. Thus, N_2O emissions are estimated at plant level also considering the operating unit level, if necessary. Activity data have been collected at plant level for the whole time series. Unit specific default IPCC EFs have been used for plants closed in the nineties because it was not possible to collect more detailed information. For the other plants, data supplied in the framework of the EPER/EPRTR registry have been used: for the years 1990-2000 EFs at unit level have been calculated as an average of 2001-2004 data provided by operators in the EPER/EPRTR register. For the years 2001-2012 EPRTR data were used to calculate the national EF; since the 2020 inventory submission the activity data and the emissions reported under ETS from 2013 onwards have been used thus moving from a Tier 2 approach to a Tier 3 approach as requested by the ERT during the in-country review (2019). Tier 3 cannot be implemented along the whole time series because the nitric acid facilities entered the national ETS in 2013 and there isn't enough information available to support a Tier 3 for years before 2013. The implementation of different Tiers along the time series does not affect the consistency of the time series because there are only two operators for the national production of nitric acid in Italy both reporting the same AD under the national EPRTR and ETS registers.

Table 4.14 Nitric acid production, time series for the average N_2O EF (kg N_2O/t nitric acid production)

	1990	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EF (kgN_2O/Mg nitric acid)	6.49	7.08	2.29	2.94	1.21	1.32	1.11	0.86	0.40	0.31	0.39	0.49	0.42	0.34	0.29

Relevant reductions in N_2O emissions have been observed since 2008. Specifically, in 2008 the implementation of catalyst N_2O abatement technology in one of the major production plants (i.e. in one unit of that plant) has led to a significant decrease in total N_2O emissions from nitric acid production, consequently a relevant reduction in the IEF can be observed too (YARA, several years) as shown in table 4.14: the implied emission factor for 2008 is in fact 2.29 kg N_2O/Mg nitric acid production (the abatement rate in one plant was 82% so far); in 2010 the implied emission factor is 1.21 kg N_2O/Mg nitric acid production and in 2020 it is 0.29 kg N_2O/Mg nitric acid; the relevant decrease is due to the installation of the abatement technology in the other unit of the same producing facility (YARA, several years) and to the technical improvements implemented in 2011 as far as monitoring of emissions is concerned at the second nitric acid facility (Radici Chimica, 2013). Sampling circumstances at the facility may affect the reported N_2O emission values: sampling in times very close to catalyst exhaustion generally leads to higher N_2O concentration in the process flue gases, this seems to have occurred for N_2O emissions in 2011 according to the operator (Radici Chimica, several years).

Caprolactame

N_2O emissions from caprolactame have been estimated on the basis of information supplied by the only plant present in Italy, production activity data published by ISTAT (ISTAT, several years [a]) and production and emission data reported in the national EPER/E-PRTR registry. For the years 2002 and 2003 activity data and emissions were reported by the operators to the national EPER register. For 1990-2001 no facility level specific information was available for the inventory team, only the amount of caprolactame manufactured in Italy was known. Based on the 2002 emission factor and after discussion with the technical expert at the facility an emission factor equal to 0.3 kg N_2O/Mg caprolactame production was assumed for 1990-2001. The plant closed in 2003.

Carbon Black

CO_2 and CH_4 emissions from carbon black production process have been estimated with a Tier 2 approach and plant specific data. Plant specific information (AD and emissions) has been supplied by the Italian production facilities in the framework of the national EPER/E-PRTR registry and the European emissions trading scheme, total AD and total emissions allow for calculating the EFs values to be used in the estimation process.
In 1996 a change in the production technology in the existing plants caused a reduction of CH_4, NMVOC, NO_x, SO_x and PM_{10} emissions. As for CH_4 emissions, in the present submission 2006 IPCC Guidelines default value for CH_4 emission factor (manufacturing process with thermal treatment) has been applied for this category and considered for the years since 1996 due to the performance of additional QA/QC procedures (specifically, the results of the technical review in the framework of Article 19(1) of the European Regulation No 525/2013). Table 4.15 include the values of the implied emission factor for CO_2 (t CO_2/t carbon black production) from 2005 to 2020.

Table 4.15 Carbon black production, time series for the average CO_2 EF (t CO_2/t carbon black production)

	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020
EF (t CO_2/t Carbon black)	2.56	2.57	2.51	2.59	2.49	2.48	2.45	2.46	2.32	2.24	2.25	2.35	2.24	2.26	2.27

Ethylene, Ethylene oxide, Propylene, Styrene

Ethylene, ethylene oxide, propylene and styrene productions belong to the organic chemical processes, which are source of methane emissions.
For ethylene activity data have been provided by the Italian producers, specifically: for 1990-2001 by the sectoral industrial association (Unione Petrolifera, several years) and since 2002 by the manufacturing companies (Syndial, several years; Polimeri Europa/Versalis, several years). For ethilene oxide activity data have been provided by the manufacturing company for the whole time series (Enichem, several years); this

production stopped in 2001. Propylene production activity data are reported in the UN "Industrial Commodity Statistics Yearbook" (UN, several years) for the years 1990-1994; since 1995 data have been provided by the manufacturing companies (Enichem, several years; Syndial, several years; Polimeri Europa/Versalis, several years). Regarding Styrene, for the years 1990-1994, UN international statistics have been used (UN, several years). From 1995 the amount of styrene is supplied every year to the inventory team by the Italian producer at plant level (Enichem, several years; Polimeri Europa/Versalis, several years).
For ethylene and propylene production, CH_4 emission factor is calculated, for the whole time series, on the basis of the EPRTR data submitted by the plants. In the framework of the E-PRTR registry, facilities manufacturing ethylene in Italy reported activity data and emissions following the E-PRTR classification. In particular, for these plants, CH_4 emissions, for these productions, were below the reporting threshold (which for methane is set to 100 t/year). Assuming that emissions of each plants were equal to the maximum value (threshold), 100 t/year, the emission factor resulted in 0.085 kg/t; this value has been used along the whole time series.
For Styrene CH_4 emissions, no specific information concerning the years 1990-1994 was available, so the EMEP/CORINAIR default emission factor (EMEP/EEA, 2007) has been applied (0.025 kg/t equal to 10% of total VOC emissions). Based on the information included in the Environmental Reports by the Italian producer (Enichem, several years), and confirmed by the operators, CH_4 emissions did not occur from 1995.
Methane emission factor for ethylene oxide production used for the whole time series (1990-2001) is equal to 6.841 kg/t as supplied by the air and waste management association (APEM, 1992).

Titanium dioxide
Titanium dioxide (TiO_2) is one of the most widely used white pigments with the main application in paint manufacture and in other relevant sectors of the manufacturing industry (e.g. plastic industry). Two main production routes are available: the chloride route, which has both "combustion" and "process" emissions; the sulphate process, whose emissions are only related to the combustion of fuels. The sulphate process, in facts, involves the use of sulphuric acid to treat the raw material and obtain the final product (TiO_2), according to the following chemical reactions:

$$FeTiO_3 + 2H_2SO_4 \rightarrow FeSO_4 + TiO.SO_4 + 2H_2O$$
$$TiO.SO_4 + 2H_2O \rightarrow TiO_2.H_2O + H_2SO_4$$
$$TiO_2.H_2O + heat \rightarrow TiO_2 + H_2O$$

In Italy there is only one facility where titanium dioxide production occurs. Emissions are estimated according to the Tier 2 approach and plant specific data are used to develop the estimates. The plant operator supplies the amount of TiO_2 produced and the emissions levels, so the average EF can be calculated and used for the inventory purposes. Activity data and emissions are provided by the framework of the EPRTR register. The data are supplied in compliance with the methodologies indicated in the EPRTR Guidance Document (and to the national PRTR guidance).
The facility concerned is also in the scope of the environmental permitting process; the competent authorities set a control and monitoring plan (stating which parameters and how to monitor them), the operators have to comply with the plan and the information resulting from the data collection for the plan are also used for the reporting to EPRTR. IPCC methodologies are referenced within the guidance documents as part of the methodologies to measure/calculate/estimate the information to the EPRTR. Information related only to the boiler activity is reported to the EU-ETS.
Additional information concerning the type of production route implemented at the facility was obtained and revealed that only the sulphate process is implemented at the titanium dioxide facility. In the present submission the time series for CO_2 under 2B6 was replaced by the notation key "NO" in the CRF because the sulphate process does not lead to process emissions. CO_2 emissions from fuels combustion in titanium dioxide production by sulphate process occur but they have to be accounted for under the "Energy" sector.

Calcium carbide
CO_2 emissions from calcium carbide production process and use have been estimated on the basis of the activity data provided by the sole Italian producer/retailer (CARBITALIA SPA, 2021). Activity data relating to the manufacture of calcium carbide are referred to the years from 1990 to 1995 when the production stopped; activity data concerning the use of calcium carbide have been provided for the whole time series too. The

default IPCC CO_2 emission factors (IPCC, 2006) have been used to estimate the emissions from manufacture and use along the whole time series.

Soda ash

CO_2 emissions from soda ash production have been estimated on account of information available about the Solvay process (Solvay, 2003), which is the technology applied for the production of soda ash in Italy, whereas those from soda ash use are included in glass production.

Soda ash production has been carried out at one facility in Italy; the facility is included in the scope of the national EPER/PRTR so the information concerning activity data and emissions of this facility has been made available for the years from 2002 up to now. For 1990-2001 the amount of soda ash produced was published on the UN "Industrial Commodity Statistics Yearbook" (UN, several years).

The CO_2 emission factor for those years is based on the estimation process of the GHG emissions inventory of Spain and on the information that Solvay has made available to the Spanish inventory team for a plant with the same technology as the Italian one. Since 2002 the emission factor is based on the data reported yearly by the Italian operator under the national EPER/PRTR and under ETS (preliminary data for years 2005-2009 and official data since 2013).

Fluorochemical production

For both source categories, "By-product emissions" and "Fugitive emissions", the IPCC Tier 2 method is used, based on plant-level data. The communication is supplied annually by the only national producer, and includes productions, emissions, import and export data for each gas (Solvay, several years). CF_4 emissions represent additional by product emissions together with HFC23 emissions (those being well referenced instead). The operator supplied all the relevant information for a better understanding of the activities taking place at the site of Spinetta Marengo and to help the inventory team to allocate CF_4 emissions from HCFC22 production properly. The industrial site of Spinetta Marengo hosts not only Solvay but also other Companies and is in the scope of EPRTR, IPPC permitting procedure and Seveso European Legislation. At the facility the monitoring system has 27 devices to perform gas chromatography analysis and about 540 monitoring points at the site. The resulting monitoring data flow, which regard other pollutants, is sent via web to the regional agency for the environmental protection (ARPA Piemonte).

In particular, the operator explained that HCFC22 production has been carried out in Spinetta Marengo since '50s and up to 1990 part of HCFC22 was probably also sold as a marketable product. Since 1990 practically all the HCFC22 produced has been the input for the TFM (tetrafluoroethylene monomer) production process (by pyrolisis of HCFC22 at 600 °C), the TFM has been then used to produce TFE (tetrafluoroethylene, C_2F_4) and PTFE (polytetrafluoroethylene), HFP (hexafluoropropylene) and the other different fluoropolymers and fluoroelastomers. All the fluorinated flue gases from the different production lines are collected and treated in a centralized abatement unit (thermal oxidation system), specifically designed for the Spinetta Marengo plant, working at a temperature of 1400 °C with a residence time of the gases minor of 2 seconds. The abatement unit is run continuously and allows reducing F-gas emissions not depending on the operating level of the main production process. In the treated flue gases CF_4 is still present (65% of CF_4 released to air pass through the abatement system untreated for thermodynamic reasons; 35% of CF_4 released to air is formed during the reactions occurring in the abatement unit). Estimations of CF_4 emissions released to air have been then reported to the national PRTR since 2007. The operator has provided the time series for the activity data from 2002 to 2010 (HCFC22 and TFM), since the activity data for the years before 2002 are not retrievable (the property of the facility has changed over the years before 2002 and the administrative systems and softwares have also been changed many times); in order to complete the activity data time series for the period 1990-2001 a linear increasing production level was assumed from 1990 to 2002. The ratio relating TFM production to HCFC22 production in 2002 has been taken also over the years 2001 back to 1990 to estimate the TFM productions. CF_4 emission factor for 2007 was set constant in order to estimate the CF_4 time series over the years from 1990 to 2006. CF_4 emissions time series have been then included in the estimates under the CRF category 2.B.9.a.1 (By-product emissions from production of HCFC22).

In order to provide detailed information on the methodology applied for this category, CF_4 emissions estimation from HCFC22 can be summarised as follows:

- For the years 2007-2010 by-product CF_4 emissions from HCFC22 production has been supplied by the operator (through the national PRTR). Based on data reported to the national PRTR since 2007 and the activity data concerning HCFC production, the TFM/HCFC22 ratio along the time series, the EF for by-product CF_4 emission has been calculated.

- CF_4 EF (by-product emissions from HCFC22 production) for 2007 has been set as default value for the period 1990-2006 in order to estimate by-product CF_4 emissions consistently along the whole time series.
- Activity data for the facilities are available for the years 2002-2010, so the missing activity data were estimated based on the HCFC22 production capacity of the facility in 1990 and 2002 HCFC22 production figure assuming a linear increasing production level within the years. The TFM/HCFC22 ratio for 2002 was assumed as a default ratio to estimate TFM production consistently from 1990 and 2002.
- By product CF_4 emissions were estimated by applying the EF derived in point 2) to the TFM production levels along the years 1990-2002.

HFC23 is a by product of the HCFC22 production process, the HFC23/HCFC22 rate is about 3%. The abatement system, as previously mentioned, allows for treating all the fluorinated flue gases, vented gases originated in the processes at the facility before being released to air. Since 1989 the abatement system has allowed to reduce HFC23 released to air, up to 1996 HFC23 emissions had been about 30 t/y. In 1996 the abatement system was improved with a second operating unit, since 1996 the abatement rate has been 99.99% thus reducing drastically HFC23 emissions close to zero. The operator communicated that for a HCFC22 production of 30,000 tons, HFC23 theoretical residual emissions are less than 100 kg; a monitoring analysis has measured about 10 kg of HFC-23 in one year (Spinetta Marengo, 2011).
C_2F_6 and HFC143a emissions are released from the production of C_3F_6 (and also CFC115) and HFC134a, respectively. Fluorochemical were produced in one plant (Porto Marghera) and progressively stopped in the last years. More in details C_3F_6 (and also CFC115) production stopped in 1998 while HFC134a production stopped in 2007. Data production and emission figures have been provided by the company (Solvay Fluor, several years).
Production of HFC-125, HFC-134a, HFC-227ea and SF_6 lead to fugitive emissions of the same gases. In particular production of HFC-227ea only occurred in 1999. Emissions figures have been communicated by the operator (Solvay Fluor, several years).

4.3.3 Uncertainty and time-series consistency

The uncertainty in N_2O emissions from adipic and nitric acid and caprolactame production and in CO_2 emissions from ammonia and for other chemical production is estimated by 10.4%, for each activity, as combination of uncertainties related to activity data (3%) and emission factors (10%).
Uncertainty level for activity data is an expert judgement, taking into account the basic source of information, while the uncertainty level for emission factors is equal to the level reported in the IPCC Good Practice Guidance (IPCC, 2000) for the adipic and nitric acid N_2O emissions and for CO_2 emissions from other industrial processes.
The uncertainty in F-gas emissions from fluorocarbons production is estimated to be 50.2% in annual emissions, 5% and 50% concerning respectively activity data and emission factors.
In Tables 4.16 and 4.17, the production of chemical industry, including non-key sources, and emission trends are reported. An overview of the emissions per compound from fluorochemical production is given for the 1990-2020 period.
In general, total emission trends for all the chemical productions have been affected by fluctuations in productions along the time series (and by reductions in productions over the years 2007-2009, except for adipic acid and titanium dioxide activity data), whenever abatement technologies (e.g. nitric acid since 2008) or closures of plants cannot be regarded to as the specific causes for the decreasing emissions. In 2012 an increase in ammonia and soda ash productions determined an increase in CO_2 emissions estimates compared to previous year.

Table 4.16 Production of chemical industry, 1990 –2020 (kt)

Activity data	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
						kt					
2B.1 - Ammonia	1,455	592	414	607	505	396	564	587	611	465	599
2B.2 - Nitric acid	1,037	588	556	572	417	390	426	437	447	421	447
2B.3 - Adipic acid	49	64	71	75	85	82	83	87	86	76	73
2B.4 - Caprolactame	120	120	111	-	-	-	-	-	-	-	-
2B.5 - Calcium carbide production	12	7	7	7	6	4	4	4	4	4	3
2B.6 - Titanium dioxide	58	69	72	60	70	60	61	68	63	63	51
2B.7 - Soda ash production and use	610	1,070	1,000	915	620	880	916	935	909	898	851
2B.8b - Ethylene	1,466	1,807	1,771	1,721	1,551	1,187	1,252	1,191	1,266	1,040	1,046
2B.8d - Ethylene oxide	61	54	13	-	-	-	-	-	-	-	-
2B.8f - Carbon black	184	208	221	214	205	205	212	220	228	210	188
2B.8g - Styrene	365	484	613	520	524	547	512	479	545	511	501
2B.8g.i - Propylene	774	693	690	1,037	880	630	643	616	658	538	531
2B.9 – HCFC 22 production	20	23	26	27	21	26	24	25	29	23	18

Table 4.17 CO_2, CH_4 and N_2O emissions from chemical industry, 1990 – 2020 (kt) and HFCs, PFCs per compound 1990 - 2020 (kt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (kt)											
Ammonia	1,891.50	769.60	537.91	802.29	639.77	495.54	642.73	642.41	678.76	531.26	659.36
Calcium carbide	26.28	14.24	7.70	8.01	6.63	4.59	4.57	4.70	4.89	3.96	3.79
Carbon black	422.05	477.48	508.83	548.22	510.38	462.39	496.94	494.76	542.04	476.56	426.33
Titanium dioxide	-	-	-	-	-	-	-	-	-	-	-
Adipic acid	1.33	1.72	1.93	1.50	1.76	1.82	1.85	1.93	1.92	1.70	1.62
Soda ash production and use	183.00	321.00	300.00	275.00	203.33	255.35	281.79	291.20	346.05	300.99	268.37
CH_4 (kt)											
Carbon black	1.84	2.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ethylene	0.12	0.15	0.15	0.15	0.13	0.10	0.1011	0.10	0.11	0.09	0.09
Propylene	0.07	0.06	0.06	0.09	0.07	0.05	0.05	0.05	0.06	0.05	0.05
Styrene	0.01	-	-	-	-	-	-	-	-	-	-
Ethylene oxide	0.42	0.37	0.09	-	-	-	-	-	-	-	-
N_2O (kt)											
Nitric acid	6.73	4.22	4.09	5.44	0.51	0.12	0.17	0.21	0.19	0.14	0.13
Adipic acid	14.77	19.09	21.42	19.59	1.58	0.37	0.22	0.25	0.21	0.26	0.27
Caprolactame	0.04	0.04	0.03	-	-	-	-	-	-	-	-
kt CO_2 eq.											
HFC 23	444.00	444.00	1.25	1.30	1.01	1.26	1.18	1.23	1.41	1.14	0.90
HFC 143a	-	26.82	4.47	4.92	-	-	-	-	-	-	-
CF4	882.92	992.62	991.47	1,547.42	1,300.64	1,551.90	1,492.78	1,192.38	1,511.26	869.80	417.54
PFC C2÷C3 (C2F6)	48.80	48.80	-	-	-	-	-	-	-	-	-
Total F-gas by product emissions	1,375.72	1,512.24	997.19	1,553.64	1,301.65	1,553.16	1,493.96	1,193.61	1,512.66	870.94	418.44
HFC 125	-	35.00	3.50	4.20	-	-	-	-	-	-	
HFC 134a	-	42.90	17.16	13.87	-	-	-	-	-	-	
HFC 227ea	-	-	-	-	-	-	-	-	-	-	
SF_6	114.00	114.00	-	-	-	-	-	-	-	-	
Total F-gas fugitive emissions	*114.00*	*191.90*	*20.66*	*18.07*	-	-	-	-	-	-	
Total F-gas emissions from fluorochemical production	**1,489.72**	**1,704.14**	**1,017.85**	**1,571.71**	**1,301.65**	**1,553.16**	**1,493.96**	**1,193.61**	**1,512.66**	**870.94**	**418.44**

HFC23 emissions from HCFC22 had been drastically reduced since 1996 due to the installation of a second thermal oxidation system in the facility located in Spinetta Marengo (the only facility currently producing HCFC22 in Italy). Productions and emissions from 1990 to 1995 are constant as supplied by industry; from 1996, untreated leaks have been collected and sent to the thermal oxidation system, thus allowing reduction of emissions under 100 kg (E.F. 3.3 g of HFC23/t of HCFC22). CF_4 by-product emissions in HCFC22 production process have been fully investigated, information supplied by the operator has allowed estimating emissions for the whole time series. This information about productions and emissions is yearly directly updated by the producer, and it is also reported in the framework of the national PRTR register, confirming that the technology is fully operating. In 2020 a drastic reduction of CF_4 emission has occurred: as part of Solvay's commitment to reducing greenhouse gas emissions, a new project for the abatement of CF_4 by thermo-oxidation has been developed.
PFC (C_2F_6) by-product emissions and SF_6 fugitive emissions were constant from 1990 to 1995 (4 t/y for C_2F_6 emissions; 5 t/y for SF_6 emissions) and from 1996 to 1998 (1 t/y for C_2F_6 emissions; 2 t/y for SF_6 emissions) and have eventually reduced to zero since 1999 due to the stop of the CFC115 production in one facility and the upgrade of the thermal oxidation system mentioned above in the other facility. Besides, SF_6 production has stopped since the 1st of January 2005.
Regarding fugitive emissions, emissions of HFC125 and HFC134a have been cut in 1999 thanks to a rationalisation in the new production facility located in Porto Marghera, whereas HFC143 released as by-products from the production of HFC134a has been recovered and commercialised. The relevant productions in Italy which originate these fugitive emissions stopped in the first quarter of 2008.

4.3.4 Source-specific QA/QC and verification

Emissions from adipic acid, nitric acid, ammonia and other chemical industry production have been checked with the relevant process operators and with data reported to the national EPER/E-PRTR registry. Emissions and activity data for adipic acid, nitric acid and ammonia productions have also been checked against the relevant information reported by operator to the national competent authority for the ETS, the resulting consistency of both emissions and activity data for those sectors is the outcome of this control. In addition to this, in the present submission activity data for Nitric Acid and Adipic Acid from ETS have been used to update the time series from 2013 onwards in order to support the application of Tier 3 in CO_2 and N_2O emissions estimates. Additional QA/QC was performed on the inventory of CO_2 and CH_4 emissions from the production of carbon black (Aether ltd, 2013) thus leading to the improvements of the emissions estimate in 2014 submission. CH_4 emissions from carbon black manufacturing have been revised in the last submissions, from 1996 onwards, as an outcome of the technical expert review performed at EU level in the framework of the internal EU inventory review process.
As requested by the ERT, investigations concerning the final uses of urea in Italy and the amount of urea used in the inventory against the apparent consumption are ongoing.
Emissions from fluorochemical production have been checked with data reported to the national EPER/E-PRTR registry. CF_4 emissions have been then accounted for along the whole time series for category 2B9.

4.3.5 Source-specific recalculations

Minor recalculations for Calcium carbides occurred for 2019 because of the update of the activity data communicated by the national operator. In the case of soda ash negligible recalculation occurred for the update of the activity data in 2019.

Table 4.18 Recalculation (%) for CO_2 (calcium carbide)

	2019
CO_2	
Calcium carbide	-2.70

4.3.6 Source-specific planned improvements

A detailed balance of the natural gas reported in the energy balance, as no energy fuel consumption, and the fuel used for the production processes in the petrochemical sector is planned.
Further investigations about final market shares of urea in Italy are planned in order to check the amount of urea used in the inventory against the apparent consumption in Italy.

4.4 Metal production (2C)

4.4.1 Source category description

The sub-sector metal production comprises five sources: iron and steel production, ferroalloys production, aluminium production, magnesium foundries and zinc/lead production; CO_2 emissions from iron and steel production are key sources at trend assessment with the Tier1 for 2020 with and without LULUCF; PFC emissions from aluminium production are key sources only at trend assessment, whereas in the base year PFC emissions were key sources also at level assessment while CO_2 emissions from iron and steel production were key sources at level assessment only with the Tier1.

In 2020, the share of CO_2 emissions from metal production accounts for 0.5% of the national total CO_2 emissions, and 10.5% of the total CO_2 from industrial processes. The share of CH_4 emissions is, in 2020, equal to 0.07% of the national total CH_4 emissions while N_2O emissions do not occur. The share of F-gas emissions from metal production out of the national total F-gas levels was 52.5% in the base-year and has decreased to 0.03% in the year 2020.

Iron and steel

The main processes involved in iron and steel production are those related to sinter and blast furnace plants, to basic oxygen and electric furnaces.

The sintering process is a pre-treatment step in the production of iron where fine particles of metal ores are agglomerated. Agglomeration of the fine particles is necessary to increase the passageway for the gases during the blast furnace process and to improve physical features of the blast furnace burden. Coke and a mixture of sinter, lump ore and fluxes are introduced into the blast furnace. In the furnace the iron ore is increasingly reduced and liquid iron and slag are collected at the bottom of the furnace, from where they are tapped. The combustion of coke provides both the carbon monoxide (CO) needed for the reduction of iron oxide into iron and the additional heat needed to melt the iron and impurities.

The resulting material, pig iron (and also scrap), is transformed into steel in subsequent furnaces which may be a basic oxygen furnace (BOF) or electric arc furnace (EAF).

Oxygen steelmaking allows the oxidation of undesirable impurities contained in the metallic feedstock by blowing pure oxygen. The main elements thus converted into oxides are carbon, silicon, manganese, phosphorus and sulphur.

In an electric arc furnace steel is produced from polluted scrap. The scrap is mainly produced by cars shredding and does not have a constant quality, but the recent stringent legislation and the adoption of BAT (Best Available Techniques) in scrap management allow an input with better product characteristics.

The iron and steel cycle is closed by rolling mills with production of long products, flat products and pipes.

In 1990, there were six integrated iron and steel plants in Italy. In 2014, there were only three of the above-mentioned plants, one of which lacking sintering facilities and another one not equipped with a BOF. Since 2015 there are only two plants because the plant without sinter production has been closed. In 2020, oxygen steel production represents about 16.5% of the total production and the arc furnace steel the remaining 83.5% (FEDERACCIAI, several years).

Currently, long products represent about 48% of steel production in Italy, flat products about 41% and pipes the remaining 12%. In 2020 long production has been equal to 11.2 Tg with a decrease of 9.6% over the previous year and still below 33.0% compared to 2008; flat production has been equal to 9.5 Tg with a decrease of 16.2% on the previous year and of 32.2% compared to 2008 level. Most of the flat production derives from one only integrated iron and steel plant, while in steel plants equipped with electric ovens, almost all located in the northern regions, long products are produced predominantly (e.g. carbon steel, stainless steels) and seamless pipes (only one plant) (FEDERACCIAI, several years).

CO_2 emissions from steel production refer to carbonates used in basic oxygen furnaces and crude iron, carbonates, *coals* and electrodes in electric arc furnaces. CO_2 emissions from pig iron production refer to carbonates used in sinter and pig iron production. CO_2 emissions from iron and steel production due to the fuel consumption in combustion processes are estimated and reported in the energy sector (1A2a) to avoid double counting.

CH_4 emissions from steel production refer to blast furnace charging, basic oxygen furnace, electric furnaces and rolling mills. CH_4 emissions from coke production are fugitive emissions during solid fuel transformation

and have been reported under 1B1b category while CH_4 emissions from the combustion of fuels are allocated in the energy sector.

Ferroalloys

Ferroalloy is the term used to describe concentrated alloys of iron and one or more metals such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. Usually, alloy formation occurs in electric arc furnaces (EAF) and CO_2 emissions occur during oxidation of carbon still present in coke and because of consumption of the graphite electrodes.

In early nineties there were 13 plants producing various kinds of ferroalloys: FeCr, FeMn, FeSi, SiMn, Si-metal and other particular alloys, but since 2001 the production has been carried on only in one plant (ISPESL, 2005). The last remaining plant in Italy produces mainly ferro-manganese and silicon-manganese alloys but in 2015 the facility did not work.

Aluminium

From primary aluminium production CO_2 and PFCs (CF_4 and C_2F_6) are emitted. PFCs are formed during a phenomenon known as the 'anode effect', when alumina levels are low.

In 1990 primary aluminium production in Italy was carried out in 5 sites where different technologies were implemented:

- Fusina: Point Fed Prebake and Side Work Prebake (up to 1995);
- Portovesme: Point Fed Prebake and Side Work Prebake (up to 1990);
- Bolzano: Vertical Stud Soderberg;
- Fusina 2 and Porto Marghera: Side Work Prebake.

Since then, the implemented technology has been upgraded from Side Work Prebake to Point Fed Prebake; while three old plants stopped the operations in 1991 (Bolzano) and in 1992 (Fusina 2 and Porto Marghera). Since 2000 Alcoa has replaced ENIRISORSE in operating the plants.

Up to 2010, two primary aluminium production plants, which use a prebake technology with point feeding, characterised by low emissions, have operated. Only one plant, located in Portovesme, was operating until 2012 (99.5 kt of primary aluminium). In 1990, primary aluminium production was 232 kt. In 2020 the plant did not produce primary aluminium. The plant is stopped but not dismantled: in 2018 the new Company Sider Alloys has taken over Portovesme plant from Alcoa, that is currently under renovation. The restart of the renovated plant is scheduled for 2022.

Magnesium foundries

In the magnesium foundries, SF_6 is used as a cover gas to prevent oxidation of molten magnesium. In Italy there is only one plant, located in the north, which started its activity in September 1995.

Since the end of 2007, SF_6 has been replaced by HFC125, due to the enforcement of fluorinated gases regulations (EC, 2006; UE, 2014) which, however, allow for the use of SF_6 in annual amounts less than 1 Mg. HFC125 emissions also occurred and, in 2010, they were equal to 605 kg. Since 2011 HFC125 has been replaced by HFC134a (3,757 kg of emissions in 2020).

Zinc production

Since 1998, in Italy there is just an integrated plant for the zinc and lead production which cover the entire production of zinc and of primary lead. In 2013, this plant began to submit data in the framework of ETS reporting data subdivided in combustion and process emissions; consequently, a survey has been started to investigate time series for process emissions resulting in CO_2 emissions from 1990 to 2020. CO_2 emissions are referred both to zinc and lead production.

4.4.2 Methodological issues

CO_2 and CH_4 emissions from the sector have been estimated on the basis of activity data published in the national statistical yearbooks (ISTAT, several years [a]), data reported in the framework of the national EPER/E-PRTR registry and the European Emissions Trading Scheme, and supplied by industry (FEDERACCIAI, several years; ALCOA, several years). Emission factors reported in the EMEP/EEA Guidebook (EMEP/EEA, 2009), in sectoral studies (APAT, 2003; CTN/ACE, 2000) or supplied directly by industry (FEDERACCIAI, 2004; ALCOA, 2004; Italghisa, 2011) have been used.

Iron and steel

CO_2 emissions from iron and steel production refer to the carbonates used in sinter plants, in blast furnaces and in steel making plants to remove impurities; they are also related to the steel and pig iron scraps, carbonates, *coals* and graphite electrodes consumed in electric arc furnaces.

Basic information for this sector derives from different sources in the period 1990-2020.

Activity data are supplied by official statistics published in the national statistics yearbook (ISTAT, several years [a]) and by the sectoral industrial association (FEDERACCIAI, several years).

For the integrated plants, emission and production data have been communicated by the two largest plants for the years 1990-1995 in the framework of the CORINAIR emission inventory, distinguished by sinter, blast furnace and BOF, and by combustion and processes emissions. From 2000, CO_2 emissions and production data have been supplied by all the plants in the framework of the ETS scheme, for the years 2000-2004 disaggregated for sinter, blast furnace and BOF plants, from 2005 specifying carbonates and fuels consumption and related CO_2 emissions. For 2002-2020 data have also been supplied by all the integrated iron and steel plants in the framework of the European EPER/E-PRTR registry not distinguished for combustion and processes. Qualitative information and documentation available on the plants allowed reconstructing their history including closures or modifications of part of the plants; additional qualitative information regarding the plants collected and checked for other environmental issues or directly asked to the plant permitted to individuate the main driving of the emission trends for pig iron and steel productions. Finally, since 2017, national experts have also been involved in the process of elaboration of the "monitoring and control plan" for the largest integrated plant in Italy in the framework of IPPC permit, allowing other terms of comparison and verification.

Time series of carbonates used in basic oxygen furnaces have been reconstructed on the basis of the above-mentioned information resulting in no emissions in the last years. In fact, carbonates have been substituted by autoproduced lime avoiding CO_2 emissions. Indeed, as regards the largest Italian producer of pig iron and steel, lime production has increased significantly from 2000 to 2008 by about 250,000 over 410,000 tonnes and the amount introduced in basic oxygen furnaces was, in 2004, about 490,000 tonnes (ILVA, 2006). In 2009 lime production, for the same plant, is equal to 216,000 tonnes but also steel production has sharply decreased because of the economic recession; in the following years lime production increased again up to 390,000 but in the last years it decreased because the plant went into receivership. Emissions from lime production in steel making industries are reported in 1.A.2 Manufacturing Industries and Construction category and in 2.A Mineral production respectively for the combustion and processes emissions.

Concerning the electric arc furnaces, additional information on the consumption of scraps, pig iron, graphite and electrodes and their average carbon content has been supplied together with the steel production by industry for a typical plant in 2004 (FEDERACCIAI, 2004) and checked with other sectoral study (APAT, 2003). On the basis of these figures an average emission factor has been calculated and applied for the period 1990 - 2003. Since 2004, the same scheme as the previous period has been followed but using data becoming from ETS and related to the amounts of pig iron, metallurgical coke, graphite, anthracite, dolomite, limestone and electrodes for 33 plants in 2020. The availability of data for each plant has allowed also the application, for a first attempt, of the Tier 3 methodology (IPCC, 2006) that demonstrated the soundness of estimates.

On account of the amount of carbonates estimated in sinter plants, average emission factor was equal in 1990 to 0.15 t CO_2/t pig iron production, while in 2020 it reduced to 0.08 t CO_2/t pig iron production. The reduction is driven by the increase in the use of lime instead of carbonates in sinter and blast furnaces in the Italian plants. Emissions are reported under pig iron because they are emitted as CO_2 in the blast furnaces producing pig iron. CO_2 average emission factor in basic oxygen furnaces results in 1990 equal to 0.079 t CO_2/t steel production, while from 2003 is null.

CO_2 average emission factor in electric arc furnaces, equal to 0.035 t CO_2/t steel production, has been calculated on the basis of the Tier 2 of the 2006 IPCC Guidelines (IPCC, 2006) taking into account the pig iron and graphite electrodes used in the furnace and the amount of carbon stored in the final product. The same emission factor has been used for the period 1990 - 2003. Since 2004 ETS data have been used, in this way it has been possible to evaluate the contribute of anthracite and metallurgical coke producing an emission factor equal 0.054 t CO_2/t of steel in 2020. The amount of carbon stored in steel produced with EAF has been considered and subtracted from the carbon balance (see Annex 3). Implied emission factors for steel production reduced from 0.053 to 0.045 t CO_2/t steel production, from 1990 to 2020, due to the reduction in the basic oxygen furnaces.

CO_2 emissions due to the consumption of coke, coal or other reducing agents used in the iron and steel industry have been accounted for as fuel consumption and reported in the energy sector, including fuel consumption of

derived gases; in Annex 3, the energy and carbon balance in the iron and steel sector, with detailed explanation, is reported.
During the last in country review, Italy reported on the results of a survey which found that there is no accurate information by which to disaggregate the emissions between energy and process. Coke is the only irreplaceable material in the blast furnace as it has several roles:

- the combustion of coke produces carbon monoxide which is responsible for the reduction of iron ores;
- the combustion of coke generates the heat needed to melt the iron ore;
- coke mechanically supports the charge allowing the crossing of the reducing gas;
- coke allows the process of carburation of liquid iron by lowering its melting point.

These are intrinsic properties of the coke and cannot be separated one from the other, all the coke when burning simultaneously produces energy in the form of heat and CO as a reducing agent.
As any arbitrary disaggregation would not reflect the real situation, the ERT agreed that leaving the total emissions from the use of coke in the iron and steel industry in the energy sector is appropriate. Ultimately, carbon plays the dual role of fuel and reductant and it is very important not to double-count the carbon from the consumption of coke or other reducing agents if this is already accounted for as fuel consumption in the energy sector. For this reason, a balance is made between the coal used for coke production and the quantities of derived fuels used in various sectors. The iron and steel sector gets the resulting quantities of energy and carbon after subtraction of what is used for electricity generation, non energy purposes and other industrial sectors (see Annex 3).
The amount of carbon stored in steel produced in integrated plants has been considered and subtracted from the carbon balance (see Annex 3). The amount of carbon contained in steel has been estimated on the basis of EN standard and, from 2005, with emission trading data. Carbon stored is equal to 48,511 tonnes of CO_2 in 1990 and equal to 10,462 Mg in 2020.
CH_4 emissions from steel production have been estimated on the basis of emission factors derived from the specific IPPC BREF Report (IPPC, 2001 available at http://eippcb.jrc.es), sectoral study (APAT, 2003) and the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) and refer to blast furnace, basic oxygen furnace, electric furnaces and rolling mills.

Ferroalloys

CO_2 emissions from ferroalloys have been estimated on the basis of activity data published in the national statistical yearbooks (ISTAT, several years [a]) until 2001. Time series of ferroalloys activity data have been reconstructed from 2002 on the basis of statistical information (ISTAT, 2003), personal communication (Italghisa, 2011) and on the basis of production data communicated to E-PRTR register and to ETS from the only plant of ferroalloys in Italy. The comparison between E-PRTR and ETS data revealed some differences: further investigation led to a direct contact with the plant and to rectify the incorrect activity data.
The average emission factor has been calculated according to the IPCC Guidelines (IPCC, 2006) taking into consideration the different types of ferroalloys produced. The splitting up of national production in different types of ferroalloys was obtained from U.S. Geological Survey until 2001 (USGS, several years). Since 2002 only one plant of ferroalloys is located in Italy and different types of production are reconstructed on the basis of information listed above. This information is reported in the table 4.19.

Table 4.19 Splitting up of ferroalloys national production and IPCC 2006 emission factors

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015-2020	IPCC 2006 EF
Ferroalloy (%)											kg/t
FeCr	0.30	0.26	-	-	-	-	-	-	-	-	1,300
FeMn	0.24	0.10	0.28	0.50	0.40	0.60	0.36	0.29	0.61	-	1,500
FeSi	0.02	-	-	-	-	-	-	-	-	-	4,800
SiMn	0.32	0.53	0.62	0.50	0.60	0.40	0.64	0.71	0.39	-	1,400
Si-Metal	0.06	0.05	0.03	-	-	-	-	-	-	-	5,000
Other	0.07	0.06	0.07	-	-	-	-	-	-	-	5,000

Implied emission factor for ferroalloys has been reduced from 1.90 to 1.46 t CO_2/t ferroalloys production, from 1990 to 2014 as a consequence of the sharp reduction in ferroalloys production, which is characterized by high emission factors (ferro-silicon and silicon-metal alloys). The simultaneous reduction of total production (from

about 200 kt to 16 kt) has resulted in CO_2 emissions decreasing from 395 Kt in 1990 to 24 Kt in 2014. Since 2015 the plant did not work.

Primary aluminium production

PFC emissions from aluminium production have been estimated using both Tier 1 and Tier 2 - IPCC methodologies. The Tier 1 has been used to calculate PFC emissions from 1990 to 1999, while Tier 2 has been used since 2000; the use of different methods along the period is due to the lack of detailed data for the years previous to 2000.

Although a number of attempts have been tried over the last years by the inventory team to retrieve the 1990-1999 historical operating data, it is not possible to retrieve the information: Alcoa cannot provide operating data for the period from 1990 to 1999 as the plants were managed by a different company not operating anymore. Thus the decision to use both tiers, which was supported by previous review processes, confirming the transparency, accuracy and conservativeness of this approach.

PFC emissions, specifically CF_4 and C_2F_6, have been calculated on the basis of information provided by national statistics (ENIRISORSE, several years; ASSOMET, several years) and the national primary aluminium producer (ALCOA, several years), with reference to the documents drawn up by the International Aluminium Institute (IAI, 2003; IAI 2006) and the IPCC Guidelines (IPCC, 2006).

Tier 1 method has been used to calculate PFC emissions related to the entire period 1990-1999. The emission factors for CF_4 and C_2F_6 were provided by the main national producer (ALCOA, 2004) based on the IAI document (IAI, 2003).

The Tier 1 method used by ALCOA is based on the IAI methodology, which collected anode effect data from 1990 up to 2000, accounting also for reductions in specific emission for all technology categories (specific factors for Point Fed Prebake cells have been considered to estimate emissions).

In 1990 at the five production sites the following technologies were implemented:

- Fusina: Point Fed Prebake (16% of the cells) and Side Work Prebake (84% of the cells);
- Portovesme: Point Fed Prebake (84% of the cells) and Side Work Prebake (16% of the cells);
- Bolzano: Vertical Stud Soderberg (100% of the cells)
- Fusina 2 and Porto Marghera: Side Work Prebake (100% of the cells).

The EFs for PFCs were then calculated by ALCOA as weighted arithmetic mean values of EFs for the different technologies (IAI, 2003), the weights representing the implemented technologies.

In the following tables (Tables 4.20, 4.21) the emission factors and the default parameters used are reported; site specific values are confidential but they have been supplied to the inventory team and taken into account in the estimation process.

Table 4.20 Historical default Tetrafluoromethane (CF_4) emission values by reduction technology type (IAI, 2003)

	Technology specific emissions (kg CF_4 / t Al)		
	1990 - 1993	**1994 - 1997**	**1998 – 1999**
Point Fed Prebake	0.3	0.1	0.08
Side Work Prebake	1.4	1.4	1.4
Vertical Stud Søderberg	0.6	0.5	0.4

Table 4.21 Multiplier factor for calculation of Hexafluoroethane (C_2F_6) by technology type (IAI, 2003)

	Technology multiplier factor
Center Work Prebake	0.17
Point Fed Prebake	0.17
Side Work Prebake	0.24
Vertical Stud Søderberg	0.06

PFC emissions for the period from the year 2000 are estimated by the IPCC Tier 2 method, based on default technology specific slope factors and facility specific anode effect minutes. Site-specific values (CF_4 and C_2F_6 emissions) and default coefficients (slope coefficients for CF_4 and C_2F_6) were provided by the main national producer (ALCOA, several years). Moreover, from 2005 certificated emission values and parameters, including anode effects, have been communicated under EU-ETS (ALCOA, 2010).

In Table 4.22 slope coefficients used for CF_4 and C_2F_6 are reported. ALCOA uses these values suggested by International Aluminium Institute (IAI, 2006), in accordance to the coefficients reported in the IPCC 2006 Guidelines (IPCC, 2006).

Table 4.22 CF_4 and C_2F_6 Slope Coefficients (IAI, 2006)

Type of Cell	CF_4	C_2F_6
	Slope Factor (kg PFC/tAl/AE-minutes/cell day)	
Center Work Prebake	0.143	0.0173

Anode Effects (minutes/cell day)

	2000	2005	2006	2007	2008	2009	2010	2011	2012
Primary Aluminium Plant	0.96	0.87	0.74	1.00	0.55	0.81	0.60	0.53	0.31

CO_2 emissions from aluminium production have been also estimated on the basis of activity data provided by industrial association (ENIRISORSE, several years; ASSOMET, several years) and default emission factor reported by industry (ALCOA, 2004) and by the IPCC Guidelines (IPCC, 1997) which refer to the prebaked anode process.
Emission factor has been assumed equal to 1.55 t CO_2/t primary aluminum production for the years 1990-2001, on the basis of data provided by the producer for 2002; this value is also consistent with the emission factors contained in the IPCC Guidelines and in the Aluminium Sector Greenhouse Gas Protocol. Since 2002 the emission factor has been calculated on account of information from the relevant plant supplied to the national EPER/EPRTR registry (emissions and productions). Therefore, thanks to the availability of this additional information, CO_2 emission estimations have been carried out by the operator since 2002 according to the criteria defined by the International Aluminium Institute (IAI) and are given by the following three components:

- Electrolysis Emissions from Prebake Anode
- Pitch Volatile Matter Oxidation from Pitch Coking
- Bake Furnace Packing Material

This detailed information is not available for previous years (1990-2001) so the Tier 2 approach can not be extended to those years and Tier 1 has to be used. Although a number of attempts have been tried for the last years by the inventory team to retrieve the same information related to 1990-2001, those data cannot be retrieved. Therefore, the Tier1+Tier2 approach allows ensuring the quality of the estimates and also the consistency of the CO_2 emissions time series depending on the quality of the available information.
In the following tables (Tables 4.23, 4.24) the emission factors and the default parameters used are reported; site specific values are confidential but they have been supplied to the inventory team.

Table 4.23 Coefficients used for estimation of CO_2 from aluminium production with Tier 2 by plant

	Baked Anode Properties		
	Sulphur	**Ash**	**Impurities**
	Weight %	*Weight %*	*Weight %*
Portovesme	ssv*	Ssv	DV** = 0.4
Fusina	DV = 1.6	Ssv	DV = 0.4

* site specific value
** default value

Table 4.24 Coefficients used for estimation of CO_2 from aluminium production with Tier 2 by plant

	Pitch content in green anodes	**Hydrogen content in pitch**	**Recovered tar**	**Packing coke consumption**	**Sulphur content of packing coke**	**Ash content of packing coke**
	Weight %	*Weight %*	*kg/t BAP*	*t Pcc/ t BAP*	*Weight %*	*Weight %*
Portovesme	ssv*	ssv	DV** = 0	DV = 0.05	DV = 3	DV = 5
Fusina	ssv	DV = 4.45	DV = 0	DV = 0.05	DV = 3	DV = 5

* site specific value
** default value

Magnesium Production
For SF_6 used in magnesium foundries, according to the IPCC Guidelines (IPCC, 2006), emissions are estimated from consumption data made available by the company (Shiloh Industries Italia, several years), assuming that all SF_6 used is emitted. In 2007, SF_6 has been used partially, replaced in November by HFC125, due to the enforcement of fluorinated gases regulation (EC, 2006). This regulation allows for the use of SF_6 in annual amounts less than 850 kg starting from 1 January 2008; for this reason, SF_6 was still reported together with HFC 125 emissions for the years 2008, 2009 while for 2010 only HFC125 was reported. Since 2011 HFC134a was replaced HFC125.

Zinc production

Until the 2016 submission, emissions from lead and zinc production have been reported only in 1.A.2 because of the lack of information about process emissions. Since 2013, ETS data contain info about the sole integrated plant in Italy but, as it is an integrated plant, it is not possible to distinguish zinc from lead emissions, so in CRF tables IE is reported for category 2.C.5 Lead production and CO_2 emissions are reported in 2.C.6 Zinc production.

Starting from ETS activity and CO_2 emissions data for the period 2013 – 2017, it has been possible to reconstruct the time series on the basis of different sources as this plant already submitted its data to INES/E-PRTR register since 2002 (but without the distinction between combustion and process) and on the basis of activity data and info on the technological evolution provided by industrial association (ENIRISORSE, several years; ASSOMET, several years). In the period 1990 – 2020 activity data and CO_2 emissions show a decreasing trend, in particular emissions decrease from 500 Mg in 1990 to 224 Mg in 2020 and the IEF change from 1.56 to 1.27 kgCO_2/Mg of Pb and Zn.

4.4.3 Uncertainty and time-series consistency

The combined uncertainty in PFC emissions from primary aluminium production is estimated to be about 20% in annual emissions, 3% and 20% concerning respectively activity data and emission factors; the uncertainty for HFC emissions from magnesium foundries is estimated to be about 20%, 3% for activity data and 20% for emission factors. The uncertainty in emissions from iron and steel, ferroalloys and zinc production is estimated to be 10.4%.

In Table 4.25 emission trends of CO_2, CH_4 and F-gases from metal production are reported. The decreasing of CO_2 emissions from iron and steel sector is driven by the use of lime instead of limestone and dolomite to remove impurities in pig iron and steel and by the production level while CO_2 emissions from aluminium, zinc and ferroalloys are driven mainly by the production levels.

In Table 4.26 the emission trend of F-gases per compound from metal production is given. PFC emissions from aluminium production decreased because of the closure of three old plants in 1991 and 1992 and the update of technology for the two plants still operating. The decreasing of SF_6 consumption in the magnesium foundry from 2003 is due to the abandonment of recycling plant and the optimisation of mixing parameters.

Table 4.25 CO_2, CH_4 and F-gas emissions from metal production, 1990 – 2020 (kt)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (kt)											
Iron and steel	3,124	2,897	1,280	1,656	1,343	1,327	1,473	1,408	1,436	1,357	1,215
Aluminium production	359	276	295	299	250						
Ferroalloys	395	230	229	89	77						
Zinc production	500	500	501	375	164	236	237	267	245	245	224
CH_4 (kt)											
Pig iron	2.13	2.10	2.02	2.06	1.54	0.91	1.09	0.91	0.87	0.83	0.61
Steel	0.58	0.60	0.60	0.67	0.63	0.62	0.64	0.69	0.71	0.68	0.61
PFC (kt CO_2 eq.)											
Aluminium production	1,975	350	231	212	99	-	-	-	-	-	
SF_6 (kt)											
Magnesium foundries			0.0072	0.0035	0.0007	-	-	-	-	-	
HFC125 (kt)	-										
Magnesium foundries					0.0006	-	-	-	-	-	
HFC134a (kt)	-										
Magnesium foundries						0.0071	0.0073	0.0072	0.0068	0.0040	0.0038

Table 4.26 F-gas emissions per compound from metal production in kt CO_2 equivalent, 1990 – 2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
	kt CO_2 eq.										
CF_4 (PFC-14)	1,465.8	268.1	192.4	176.8	82.7	-	-	-	-	-	-
C_2F_6 (PFC-16)	509.4	81.8	38.4	35.3	16.5	-	-	-	-	-	-
Total PFC emissions from aluminium production	*1,975.1*	*349.9*	*230.8*	*212.1*	*99.2*	-	-	-	-	-	-
SF_6 emissions from magnesium foundries	-	-	*164.2*	*80.8*	*16.7*	-	-	-	-	-	-
HFC-125 emissions from magnesium foundries	-	-	-	-	*2.1*	-	-	-	-	-	-
HFC-134a emissions from magnesium foundries	-	-	-	-	-	*10.2*	*10.4*	*10.3*	*9.7*	*5.8*	*5.4*
Total F-gas emissions from metal production	**1,975.1**	**349.9**	**395.0**	**292.9**	**118.0**	**10.2**	**10.4**	**10.3**	**9.7**	**5.8**	**5.4**

In response to the 2010 review process (UNFCCC, 2010), a more robust Tier 1 comparison has been evaluated in order to strengthen the conservativeness of combined Tier 1 and Tier 2 approaches.
In particular, as suggested by previous review processes, several comparisons were analysed, using Tier 1 and Tier 2 approach, and under Tier 1 approach using different emission factors available from the following references (IAI, 2003; IAI, 2006; IPCC 2000):

1. 2003 International Aluminium Institute document, supplied by ALCOA to calculate emissions from 1990 to 1999 and actually used by the Party;
2. the updated 2006 International Aluminium Institute document, which agree with new 2006 IPCC Guidelines;
3. 2000 IPCC Good Practice Guidance.

In Tables 4.27 and 4.28 CF_4 and C_2F_6 default emission factors (Tier 1) and slope coefficient data (Tier 2) by technology are reported, distinguished for different reference sources.

Table 4.27 Default CF_4 and C_2F_6 Emission Factors

	CF_4 (kg/t)				C_2F_6 (kg/t)			
Plant Technology	**IAI 2003**	**IAI 2006**	**GPG 2000**	**GL 2006**	**IAI 2003**	**IAI 2006**	**GPG 2000**	**GL 2006**
CWPB	0.4	0.4	0.31	0.4	0.17	0.04	0.04	0.04
PFPB	0.3*	-	-	-	0.17*	-	-	-
SWPB	1.4	1.6	1.7	1.6	0.24	0.4	0.17	0.4
VSS	0.6	0.8	0.61	0.8	0.06	0.04	0.061	0.04
HSS	0.7	0.4	0.6	0.4	0.09	0.03	0.06	0.03

***This value refer to period 1990 – 1993 (see Table 4.6)**

Table 4.28 Default CF_4 and C_2F_6 Slope Coefficients

	CF_4 (kg PFC / t Al / AE minutes/cell day)				C_2F_6 (kg PFC / t Al / AE minutes/cell day)			
Plant Technology	**IAI 2003**	**IAI 2006**	**GPG 2000**	**GL 2006**	**IAI 2003**	**IAI 2006**	**GPG 2000**	**GL 2006**
CWPB	0.14	0.143	0.14	0.143	0.018	0.0173	0.018	0.0173
PFPB	-	-	-	-	-	-	-	-
SWPB	0.29	0.272	0.29	0.272	0.029	0.0685	0.029	0.0685
VSS	0.067	0.092	0.068	0.092	0.003	0.0049	0.003	0.0049
HSS	0.18	0.099	0.18	0.099	0.018	0.0084	0.018	0.0084

Worthy of remark is that, lacking specific plant data, IAI 2003 is the only document including emission factors for Point Fed Prebake technology, which is the technology implemented at the only remaining production site since 1990. Moreover, as reported in this document, IAI proposed lowest accuracy default method departs from the IPCC default method. In the IPCC default method, a single specific emission value is specified for each of four reduction technology categories: Center Work Prebake, Side Work Prebake, Vertical Stud Søderberg and Horizontal Stud Søderberg. The IPCC expert working panel mostly based these default factors on 1990 average IAI anode effect data and the average technology specific slope factors. IAI survey data collected since the publication of the original IPCC default values shows substantial reductions over the period 1990 to 2000 in specific emissions in all technology categories. In addition, it has been shown that among the

overall category of Center Work Prebake cells, the more modern Point Fed Prebake cells have made progress at a faster rate than for the older bar broken Center Work Prebake cells. Thus the original category has been broken into two separate types.
This is one of the most important reasons that convinced Italy to use IAI 2003 default emission factors over the period 1990-1999, as indicated also by ALCOA, instead of IPCC Guidelines (IPCC, 2006) default emission factors. As reported in a recent publication supplied by ECOFYS (ECOFYS, 2009), currently all new aluminium plants are designed according to Point Fed Prebake technology and the first improvement in the primary aluminium industry advancement is to replace current technologies with PFPB. Other technologies, Vertical Stud Søderberg, Center Work Prebake and Side Work Prebake are expected to be gradually replaced by PFPB. Only 20% of the existing plants had not yet been upgraded to PFPB in EU27. Moreover, the mean implied emission factor value for CF_4 over the period 2000-2012 is 0.12 (kg/t), comprised between 0.3 and 0.1 kg/t indicated in IAI 2003 for PFPB technology (see Table 4.6).
Figures 4.3 and 4.4 report the comparison in CF_4 emissions time series following Tier 1 and Tier 1 + Tier 2: in each diagram the emissions time series out of different source for EFs are compared.

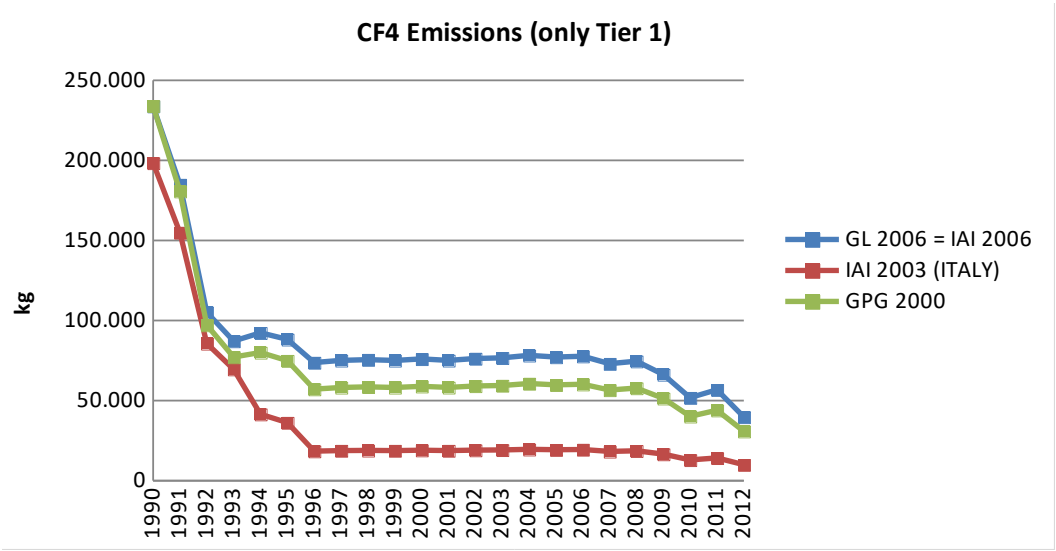


Figure 4.3 CF_4 emissions (only Tier 1)

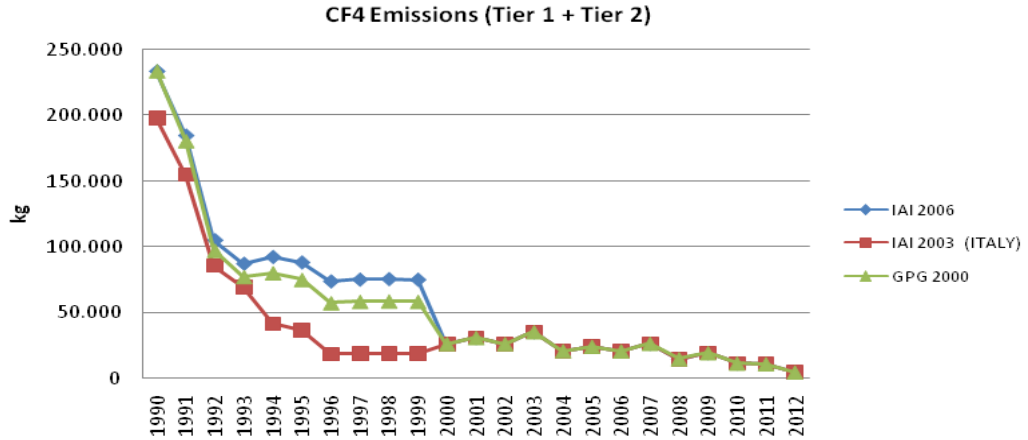


Figure 4.4 CF_4 emissions (Tier 1+Tier 2)

As for consistency, the Tier 1 + Tier 2 approach in estimating emissions is more reliable in producing the time series because it allows to use site specific data provided by the operator from 2000 onwards (and the use of the best available data is a good practice). Moreover, emission factor values reported in the IPCC Good Practice Guidance or in the 2006 IAI document (mean implied emission factor is 0.12 kg/t) lead to higher values for the emissions time series than those calculated out of emission factor values in 2003 IAI document (0.08 kg/t supplied by ALCOA and used by the Party), which means that national estimates can be considered conservative for the period. So for 1990 the use of EFs from IAI 2003, red line, results in CF_4 emission levels lower than those estimated by using the other EF references. This comparison was already done during the

compilation of the 2006 submission and the Initial Report, which resulted in the establishment of the assigned amount.
Tier1 (1990-1999) and Tier 2 (2000-2012) time series are also better linked using IAI 2003 EFs (see Figure 4.3) because of the minor gap from 1999 to 2000 since the mean implied emission factor value for CF_4 over the period 2000-2012 is 0.12 (kg/t), comprised between 0.3 and 0.1 kg/t indicated in IAI 2003 for PFPB technology (see Table 4.6).
For this reason, the use of the combined Tier1+Tier2 approach, in this case, is conservative.

4.4.4 Source-specific QA/QC and verification
Emissions from the sector are checked with the relevant process operators. In this framework, primary aluminium production supplied by national statistics (ENIRISORSE, several years; ASSOMET, several years) and the only national producer ALCOA (ALCOA, several years), in addition with data reported in a site-specific study (Sotacarbo, 2004), have been checked. Moreover, emissions from magnesium foundries are annually compared with those reported in the national EPER/E-PRTR registry while for the iron and steel sector emissions reported in the national EPER/E-PRTR registry and for the Emissions Trading Scheme are compared and checked. Emissions from primary aluminium production have been also checked with data reported under EU-ETS.

4.4.5 Source-specific recalculations
There are no significant recalculations for this category in the 2022 submission.

4.4.6 Source-specific planned improvements
The analysis of data reported in the IPPC permits of the integrated plant for zinc and lead production should allow a better allocation between zinc and lead emissions.

4.5 Non-energy products from fuels and solvent use (2D)

4.5.1 Source category description
The sub-sector comprises the following sources: lubricant use, paraffin wax, and other categories which include the use of urea, asphalt roofing and paving with asphalt and solvent use. CO_2 emissions from this category is a key source at level assessment with Approach 2 without and with LULUCF and at trend assessment with Approach 2 only with LULUCF considering the uncertainty; in 1990 it was a key category at level assessment.

Lubricant use
Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. Under this category, emissions originated by lubricant use in industry and white lubricants and lubricants used for insulating purposes have been considered, CO_2 and NMVOC emissions have been estimated for the whole time series. Emissions from lubricant use in vehicles have been accounted for in the Energy Sector.

Paraffin wax
Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. Paraffin waxes are categorised by oil content and the amount of refinement. About 60-70% of the total amount of paraffin waxes produced in the EU area is used to manufacture candles. Nowdays about 95% of candles are paraffin wax candles; 3% are stearic candles and the remaining 2% is made of beeswax. Slack oils could enter the manufacturing process thus potentially resulting into the emissions of SOx and PAH.

Use of urea
Urea can be used in Selective Catalyst Reduction (SCR) systems to reduce NOx emissions from combustion. SCR systems are generally applied to engines (vehicles) and also to industrial combustion (e.g. Power Plants).

CO_2 emissions originated by the use of urea in SCR systems have been estimated and reported in this sub-sector.

Asphalt roofing and road paving with asphalt
In Italy 14 facilities have been producing bitumen roofing membranes and about 87 facilities operate in the production and laying of asphalt mix products for road paving. SITEB, the Italian asphalt and road association is the relevant source of information for these two source categories. NMVOC emissions have been estimated for these two source categories along the whole time series.

Solvent use
The use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various NMVOC and CO_2 emissions, after oxidation of NMVOC in the atmosphere.
Methodologies for estimating NMVOC emissions can be found in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2009). Also some indications on the subcategories to include in the 'solvent use' category are reported in the 2006 IPCC guidelines (IPCC, 2006), which are the following: solvent use in paint application, degreasing and dry cleaning, manufacture and processing of chemical products, other solvent use, such as printing industry, glues application, use of domestic products.

4.5.2 Methodological issues
Lubricant use
The use of lubricants in industrial engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector.
NMVOC and CO_2 emissions are reported for this category.
CO_2 emissions for the whole time series are calculated based on a Tier 1 approach considering the average Lower Heating Value (LHV) of lubricants, the average ODU factor and the average carbon content of lubricants (Equation 5.2 IPCC Guidelines 2006):

$$CO_2\ Emissions = LC \cdot CC_{Lubricant} \cdot ODU_{Lubricant} \cdot 44/12$$

where
LC= lubricant consumption
$CC_{lubricant}$= carbon content
$ODU_{lubricant}$= oxidation factor
44/12= mass ratio CO_2/C

Statistics related to the total amount of lubricants consumed in Italy are officially provided by MSE every year in the petrochemical bulletin (MSE, several years [b]) but no details concerning different kind of lubricants are available thus allowing us only for a Tier 1 approach; LHV, Carbon Content and ODU factors used are the default values included in the IPCC 2006 Guidelines are taken. The activity data for this subcategory is the total consumption of lubricants minus the amount of lubricants used in 2-stroke engines (which is derived from reversing COPERT equation to estimate CO_2 emissions in 2-stroke engines).
Emissions from the use of lubricants in 2-stroke engines have been accounted for in the Energy Sector.
NMVOC emissions for the whole times eries have been estimated too, based on the total lubricants consumption and a NMVOC EF= 28 kg NMVOC/tons of lubricant (EMEP/EEA, 2013). The whole time series for NMVOC emissions has been revised in the present submission as a consequence of the review of the activity data time series.

Paraffin wax
In Italy paraffin waxes are mostly used in the manufacture of candles, although a number of different applications (e.g. food production and many others) could have paraffin waxes as an input. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles). No other use of paraffin wax in products implying wax combustion during the product use is known in Italy. In order to estimate CO_2 emissions for the whole time series it has been assumed that 65% of total amount of paraffin wax is destined to the manufacture of candles on account of information provided by the industrial association (Assocandele, 2015). Total paraffin wax consumption is included in "Bollettino Petrolifero" provided by the MSE and publicly available on the MSE website at the following link: http://dgsaie.mise.gov.it/dgerm/bollettino.asp. Default values for carbon content of paraffin wax as well as

ODU factor and LHV have been assumed (2006 IPCC Guidelines) and applied to the activity data according to a Tier 1 approach as in Equation 5.4 of the 2006 IPCC Guidelines:

$$CO_2\ Emissions = PW \cdot CC_{Wax} \cdot ODU_{Wax} \bullet 44/12$$

where:

CO_2 Emissions = CO_2 emissions from waxes, tonne CO_2
PW = total wax consumption, TJ
CCWax = carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ)
ODUWax = ODU factor for paraffin wax, fraction
44/12 = mass ratio of CO_2/C

Use of urea

Emissions of CO_2 originated by the use of urea in SCR systems in engines and Power plants have been estimated and reported in this sub-sector.
Concerning vehicles, SCR systems were introduced in Italy in 2006 so CO_2 emissions related to SCR systems can be traced back in the time series up to 2006. The amount of urea and CO_2 emitted using urea can be estimated by COPERT, which is the model used by Italy to estimate emissions for road transport. For further details, see paragraph 3.5.3 in the energy chapter.
Concerning power plants, the amount of urea used in SCR systems has been reported by operators under the Italian ETS together with CO_2 emissions since 1997.

Asphalt roofing and road paving

NMVOC emissions from the manufacturing of asphalt roofing materials have been estimated based on the total surface of bitumen roofing membranes (Federchimica, several years; Siteb, several years) and default emission factors (EMEP/CORINAIR, 2007; EMEP/EEA, 2009).
NMVOC emissions from road paving operations have been estimated based on the amount of asphalt mix produced for each year (ISTAT, several years [a]; Siteb, several years) and the emission factors also derived from data supplied by Siteb (EPA, 2000; Siteb, several years).

Solvent use

Emissions of NMVOC from solvent use have been estimated according to the methodology reported in the EMEP/EEA guidebook, applying both national and international emission factors (Vetrella, 1994; EMEP/CORINAIR, 2007, EMEP/EEA, 2013). Country specific emission factors provided by several accredited sources have been used extensively, together with data from the national EPER/EPRTR Registry; in particular, for paint application (Offredi P., several years; FIAT, several years [b]), solvent use in dry cleaning (ENEA/USLRMA, 1995), solvent use in textile finishing and in the tanning industries (TECHNE, 1998; Regione Toscana, 2001; Regione Campania, 2005; GIADA 2006). Basic information from industry on percentage reduction of solvent content in paints and other products has been applied to EMEP/EEA emission factors in order to evaluate the reduction in emissions during the considered period.
Emissions from domestic solvent use have been calculated using a detailed methodology, based on VOC content per type of consumer product.
As regards household and car care products, information on VOC content and activity data has been supplied by the Sectoral Association of the Italian Federation of the Chemical Industry (Assocasa, several years) and by the Italian Association of Aerosol Producers (AIA, several years [a] and [b]). As regards cosmetics and toiletries, basic data have been supplied by the Italian Association of Aerosol Producers too (AIA, several years [a] and [b]) and by the national Institute of Statistics and industrial associations (ISTAT, several years [a], [b], [c] and [d]; UNIPRO, several years); emission factors time series have been reconstructed on the basis of the information provided by the European Commission (EC, 2002).
The conversion of NMVOC emissions into CO_2 emissions has been carried out considering the carbon content value. In the previous submission carbon content was set equal to 85% as indicated by the European Environmental Agency for the CORINAIR project (EEA, 1997); as a result of the technical review in the framework of Article 19(1) of the European Regulation No 525/2013 it was recommended to use a fossil carbon content equal to 65% as indicated in the 2006 IPCC Guidelines (chapter 5.5.4).

4.5.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from non energy products from fuels and solvent use is estimated equal to 58.3% due to an uncertainty of 30% and 50% in activity data and emission factors, respectively.
In 2020, CO_2 derive mainly from the subcategory 'Other', which accounts for 82% of the sectoral emissions; specifically, emissions from the use of solvent share 75.7%. The second source of sectoral emissions is the use of lubricants contributing to 17% of the total. Table 4.29 shows CO_2 emission trend from 1990 to 2020.

Table 4.29 Trend in CO_2 emissions from the non energy products from fuels and solvent use category (kt)

Gas/subcategory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2D. Non-energy products from fuels. Other	**1,712**	**1,554**	**1,421**	**1,359**	**1,128**	**975**	**986**	**1,058**	**1,093**	**1,095**	**1,091**
2D1. Lubricant use	351	303	308	287	215	212	230	231	230	218	187
2D2. Paraffin wax use	19	20	21	14	13	15	12	13	11	7	7
2D.3. Other	1, 343	1,231	1,092	1,058	900	748	744	814	852	870	897
2D3a. Urea (emissions abatement in engines)	-	-	-	-	24	45	50	50	62	67	61
2D3b. Urea (emissions abatement in power plants)	-	-	2.38	2.35	11.71	7.34	7.04	7.50	9.31	10.32	10.61
2D3c. Road paving	-	-	-	-	-	-	-	-	-		
2D3d. Asphalt roofing	-	-	-	-	-	-	-	-	-		
2D3e. Solvent	1,343	1,231	1,089	1,056	865	696	687	757	781	793	825
Paint application	595	555	497	471	345	286	288	337	334	340	297
Degreasing and dry cleaning	136	82	64	56	49	43	42	41	40	39	38
Chemical products	170	189	182	131	121	109	110	127	118	112	111
Other	441	404	347	397	350	258	247	252	289	302	380

The decrease observed in emission levels from 1990 to 2020, about 36.3%, is to be attributed to the reduction in emissions from solvent use, mainly for the reduction in paint application, application of glue and adhesives and domestic solvent use; specifically, the reduction of emissions from paint application for domestic use, which drop by about 50% from 1990, is due to the implementation of Italian Legislative Decree 161/2006. Other European directives applies to the solvent use category, which represents the main source of NMVOC emissions at national level (42% of the total NMVOC); for instance, the European Directives (EC, 1999; EC, 2004) regarding NMVOC emission reduction in paint application entered into force, in Italy, in January 2004 and in March 2006, establishing a reduction of the solvent content in products.

4.5.4 Source-specific QA/QC and verification

For the solvent use category, different QA/QC and verification activities are carried out. Data production and consumption time series for some activities (paint application in constructions and buildings, polyester processing, polyurethane processing, pharmaceutical products, paints manufacturing, glues manufacturing, textile finishing, leather tanning, fat edible and non edible oil extraction, application of glues and adhesives) are checked with data acquired by the National Statistics Institute (ISTAT, several years [a], [b] and [c]), the Sectoral Association of the Italian Federation of the Chemical Industry (AVISA, several years) and the Food and Agriculture Organization of the United Nations (FAO, several years). For specific categories, emission factors and emissions are also shared with the relevant industrial associations; this is particularly the case of paint application for wood, some chemical processes and anaesthesia and aerosol cans.
In the framework of the MeditAIRaneo project, ISPRA commissioned to Techne Consulting S.r.l. a survey to collect national information on emission factors in the solvent sector. The results, published in the report "*Rassegna dei fattori di emissione nazionali ed internazionali relativamente al settore solventi*" (TECHNE, 2004), have been used to verify and validate the emission estimates. ISPRA commissioned to Techne Consulting S.r.l. another survey to compare emission factors with the last update published in the EMEP/EEA guidebook (EMEP/EEA, 2009). The results are reported in "*Fattori di emissione per l'utilizzo di solventi*" (TECHNE, 2008) and have been used to update emission factors for polyurethane and polystyrene foam processing activities.
In addition, for paint application, data communicated from the industries in the framework of the EU Directive 2004/42, implemented by the Italian Legislative Decree 161/2006, on the limitation of emissions of volatile

organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products have been used as a verification of emission estimates. These data refer to the composition of the total amount of paints and varnishes (water and solvent contents) in different subcategories for interior and exterior use and the total amount of products used for vehicle refinishing and they are available from the year 2007.
Additional verifications of the emissions from the sector occurred in 2012, on account of the bilateral independent review between Italy and Spain and the revision of national estimates and projections in the context of the National emission ceilings Directive for the EU Member States and the Gothenburg Protocol of the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

4.5.5 Source-specific recalculations

Significant recalculation occurred along the whole timeseries for CO_2 emissions from Lubricant use (2.D.1) due to the use of updated activity data timeseries and also in 2.D.3.
As for CO_2 emissions from lubricants use, recalculations occurred along the whole timeseries due to the update of the data resulting from COPERT model, as shown in the table 4.30:

Table 4.30 recalculation of CO_2 emissions from lubricants use (%)

	2012	2013	2014	2015	2016	2017	2018	2019
2D1 - Lubricants CO_2	0.57	0.20	0.15	0.12	0.12	0.12	0.09	0.15

Significant recalculations for CO_2 emissions occurred from the use of urea in engines (years from 2006 to 2017), as shown in table 4.31, due to the update of the data resulting from COPERT model.

Table 4.31 recalculation of CO_2 emissions (%) from the use of UREA in SCR systems (vehicles)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2D.3.a UREA in SCR systems (vehicles) - CO_2	0.05	0.04	0.14	0.24	0.30	0.29	0.11	0.29	0.23	0.21	0.08	-0.01	-0.01	-0.12

Recalculations occurred also in CO_2 from Solvent use in 2019 due to the update of the activity data:

4.5.6 Source-specific planned improvements

No further improvements are planned.

4.6 Electronics Industry Emissions (2E)

4.6.1 Source category description

Fluorocarbons emissions from this sub-sector are from semiconductor manufacturing industry (2.E.1).
Actually in Italy, there are three national plants of semiconductor manufacturing, owned by two company, ST Microelectronics (in the past purchased for a couple of years by Numonyx) and LFoundry (ex Micron Technology): in particular, ST Microelectronic is active from 1995, while LFoundry from 1998.
The semiconductor manufacturing companies supply yearly consumption and emission data for each plant (ST Microelectronics, several years; Micron, several years; Numonyx, several years; LFoundry, several years).
F-gas emissions from semiconductor manufacturing are estimated using the Tier 2a methodology of the new 2006 IPCC Guidelines (IPCC, 2006).
Fluorinated compounds emissions from heat transfer fluids are also estimated. Since 2017 the industry has started to communicate the consumption of the substances used in service equipment and consequently emissions have been estimated equal to consumptions (ST Microelectronic, several years; LFoundry, several years). For the previous years, industry communicated that no data is available and explained that consumptions of these substances are of course linked to the production but not dependent on it (i.e. if production of semiconductor occur, the use of these service equipment occur, but the refrigerant consumption is random). Because of previous considerations, emissions have been estimated constant for the whole time series.
As concern photovoltaic (PV) manufacturing, actually in Italy there is no production of PV cells, but only assembly. Before 2011, PV cells production occurred but no fluorinated compounds have been used for the

process (Lux, 2015; Solsonica, 2015). Finally, no thin-film-transistor flat panel display (TFT-FPD) production occurs in Italy (Linde Gas, 2015). The share of F-gas emissions from the electronics industry in the national total of F-gases accounts for 1.30% in 2020.

4.6.2 Methodological issues

F-gas emissions from semiconductor manufacturing are estimated using the Tier 2a methodology of the 2006 IPCC Guidelines (IPCC, 2006). As reported in the Guidelines, total emissions are equal to the sum of emissions from the gas FCi used in the production process plus the emissions of by-product calculated with equation 6.3/6.4/6.5/6.6.

Companies involved in the semiconductor manufacturing provide yearly data on consumption and emissions (ST Microelectronics, several years; Micron, several years; Numonyx, several years; LFoundry, several years), calculated on the basis of the following equation, accepted by the World Semiconductor Council (WSC). The formula gathers the IPCC Guidelines equations (combining equations 6.2/6.3/6.4/6.5/6.6 of the Guidelines) and includes both direct and by-product emissions):

$$\text{Emissions for } PFC_i = PFC_i*(1\text{-}h)[(1\text{-}C_i)(1\text{-}A_i)*GWP_i + B_i*GWP_{(byproduct)}*(1\text{-}A_{(byproduct)})]$$

where:

h = fraction of gas_i remaining in container (heel)

PFC_i = purchases of gas_i = kgs_i

kgs_i = mass of gas_i purchased

GWP_i = 100 yr global warming potential of gas_i

C_i = average utilization factor of gas_i (average for all etch and CVD processes) =1-EF_i

EF_i = average emission factor of gas_i (average for all etch and CVD processes)

B_i = mass of CF_4 created per unit mass of PFC_i transformed

A_i = fraction of PFC_i destroyed by abatement = $a_{i,j}*V_a$

By product formation

A_{CF4} = fraction of PFC_i converted to CF_4 and destroyed by abatement = $a_{CF4}*V_a$

$a_{i,j}$ = average destruction efficiency of abatement $tool_j$ for gas_i

a_{CF4} = average destruction efficiency of abatement $tool_j$ for CF_4

V_a = fraction of gas_i that is fed into the abatement tools

A_{CF4} = fraction of PFC_i converted to CF_4 and destroyed by abatement = $a_{CF4}*V_a$

$a_{i,j}$ = average destruction efficiency of abatement $tool_j$ for gas_i

a_{CF4} = average destruction efficiency of abatement $tool_j$ for CF_4

A_{C2F6} = fraction of PFC_i that is converted to C_2F_6 and destroyed by abatement = $a_{C2F6}*Va$

a_{C2F6} = average destruction efficiency of abatement $tool_j$ for C_2F_6

A_{C3F8} = fraction of PFC_i that is converted to C_3F_8 and destroyed by abatement = $a_{C3F8}*Va$

a_{C3F8} = average destruction efficiency of abatement $tool_j$ for C_3F_8

V_a = fraction of gas_i that is fed into the abatement tools

Emissions are calculated for the following fluorinated gases: HFC 23, HFC 32, HFC 134a, C_2F_6, CF_4, C_3F_8, C_4F_8, SF_6 and NF_3. From 2012, according with World Semiconductor Council (WSC), data on CH_2F_2, C_4F_6, C_5F_8 are gathered.

Since 2000, emissions are calculated considering the contribution of abatement systems.

ST Microelectronics provided emissions for each gas (CF_4, C_2F_6, HFC 23, C_2F_6, C_3F_8, C_4F_8, SF_6 and NF_3) for the year 1995 and from 2001 onwards. For the years 1996-2000 the company was not able to provide detailed data but only aggregated total emissions confirming that they occurred for all the gases and emissions of each gas have been estimated proportionally taking in account their distribution in 1995 and 2001. Moreover, on the basis of the 2001 emission factors (emission gas_i/consumption gas_i), consumption data have been extrapolated for the missing years.

For what concern Heat Transfer Fluids, during the manufacture of semiconductor devices, HTFs serve as coolants in chillers, removing excess heat during many manufacturing processes. During semiconductor device testing, containers of HTFs are cooled or heated to a desired temperature into which the devices are immersed to test their integrity. In addition, when testing the function of devices, HTFs are used to remove the heat the devices generate while being tested. HTFs are also used to attach semiconductor devices to circuit boards via solder, which may be melted by the vapour of an HTF heated to its boiling point. HTFs may also serve to cool semiconductor devices and other devices or systems that generate high heat during operation (EPA, 2006). Semiconductor industry started to collect data and communicated from the year 2017 the annual recharge of these coolants. Emissions have been estimated in terms of tonnes of CO_2 equivalent of unspecified mix of HFCs and PFCs (ST Microelectronic, several years; LFoundry, several years).

4.6.3 Uncertainty and time-series consistency

The combined uncertainty in F-gas emissions for PFC, HFC, SF_6 and NF_3 emissions from semiconductor manufacturing, included Heat Transfer Fluids, is estimated to be about 20.6% in annual emissions, 5% and 20% concerning respectively activity data and emission factors.
In table 4.32 emissions from semiconductor manufacturing are reported.

Table 4.32 Fluorocarbon emissions from semiconductor industry, 1990 –2020 (kt CO_2 eq.)

GAS	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
HFC 23	NO	6.07	8.65	7.19	10.73	9.36	8.60	8.94	6.82	9.62	8.56
HFC 32	NO	0.00	0.00	0.00	0.00	0.11	0.06	0.08	0.08	0.03	0.03
HFC 134a	NO	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF_4	NO	65.27	131.86	84.89	66.52	94.97	82.62	82.60	102.61	114.17	110.06
C_2F_6	NO	17.08	121.08	81.22	27.48	21.44	23.33	20.97	28.20	25.87	21.69
C_3F_8	NO	8.62	11.75	4.29	0.03	0.21	0.27	0.36	0.20	1.30	1.30
C_4F_8	NO	10.01	1.51	10.02	26.54	19.81	14.73	17.37	15.00	16.41	9.72
C_5F_8	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	NO	14.90	61.90	57.16	30.58	47.31	52.71	65.95	50.05	60.03	42.78
NF_3	NO	76.57	13.26	33.38	20.17	28.42	33.98	23.50	22.13	17.84	15.76
Unspecified mix of HFCs and PFCs from Heat Transfer Fluids	NO	24.97	24.97	24.97	24.97	24.97	24.97	24.97	23.15	23.54	22.86
F-gas emissions (kt CO_2 eq.)	**NO**	**223.49**	**375.04**	**303.12**	**207.01**	**246.60**	**241.26**	**244.73**	**248.25**	**268.81**	**232.75**

4.6.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures. Where information is available, emissions from production and consumption of fluorinated gases have been checked with data reported to the national EPER/E-PRTR registry.

4.6.5 Source-specific recalculations

No recalculation occurred.

4.6.6 Source-specific planned improvements

No further improvements are planned.

4.7 Emissions of fluorinated substitutes for ozone depleting substances (2F)

4.7.1 Source category description

The sub-sector Emissions of fluorinated substitutes for ozone depleting substances consists of the following sub-applications:

2.F.1 – Emissions from Refrigeration and Air Conditioning
2.F.2 – Emissions from Foam blowing Agents
2.F.3 – Emissions from Fire Protection

2.F.4 – Emissions from Aerosols

For category 2.F.5 Solvents, at the moment there is no evidence that these emissions occur in Italy although further work is on going to verify it.

Collected data, according to Article 19 of Regulation EU 517/2014, have been analysed. Only one company has declared for the past years a small quantity of HFC preparation placed on Community market for the first time for the years 2008, 2009, 2010, 2011 and 2013 for solvents applications. The Company sent us detailed data on sales in Italy but they explained that these sales are towards 'Chemistry' sector as the substances declared are HFC-134a, R-507 and R-410A, not usually used as solvents, Italy is checking for the correctness of these data with the company. The Company is not able to explain if those data referred effectively to 'Solvent' or it was more probable a mistake and referred to RAC systems in Chemistry industry. By the way, a preliminary emissions estimation has been done and results in less of 10,000 tons of CO_2 equivalent, much more below 0.05% of the national total GHG emissions, so they have been reported as NO.

HFC emissions from Refrigeration and Air Conditioning and from Fire extinguishers are key categories at level and trend assessment, both using Tier 1 and Tier 2, with and without LULUCF, in 2020. HFC emissions from Foam blowing agents is a key category at trend assessment using Tier 2 with and without LULUCF.

The share of F-gas emissions of fluorinated substitutes for ozone depleting substances in the national total of F-gases is 95% in 2020.

4.7.2 Methodological issues

The methods used to calculate F-gas emissions of fluorinated substitutes for ozone depleting substances are presented in the table 4.33.

Table 4.33 Sub-sources of F-gas emissions and calculation methods

Source category	Sub-application	Calculation method
Fluorinated Substitutes for ODS (2F)	Refrigeration and air conditioning equipment (2F1)	IPCC Tier 2a
	Foam blowing (2F2)	IPCC Tier 2a
	Fire extinguishers (2F3)	IPCC Tier 2a
	Aerosols/metered dose inhalers (2F4)	IPCC Tier 2a

Total emissions have been calculated as the sum of Manufacturing emissions, Use emissions, Containers emissions (only for Stationary Air Conditioning) and Disposal emissions. For the reporting of "Recovery" simple approach "Recovery" = "amount remaining in products at decommissioning" minus "Disposal emissions" has been assumed.

The Legislative Decree n. 151/05 has implemented in Italy the EU Directive on Waste from Electric and Electronic Equipment. According to this Decree when equipment are disposed of it is by law required to recover the remaining F-gas and either reuse or destruct it, but F-gases data are not available at the moment; although the number of authorized centers for the treatment of WEEE is known, there are many small authorized centers which do not have to report about their activities.

Because of lack of data, for the sub-categories Foam blowing and Fire extinguishers, emissions from disposal are included into the emissions during the product's life for the whole time series. The assumption implies that the F-gas charged into the equipment is emitted completely during the lifetime of the equipment. So at decommissioning there is not F-gas charge left and no emissions or recovery occur.

IPCC Tier 2a implies the availability of either number of applications/equipment using the individual gas or the amounts of the gas used in the different sectors. Based on the availability of the amount of individual gas produced in Italy and the sectoral uses of the gas we carry out the estimation of emissions according to IPCC Tier 2a. The estimates are based on single gas consumptions data supplied by the only national refrigerants producer (Solvay, several years) and by industry, except for Domestic Refrigeration and Stationary Air Conditioning sub-sector, where emissions have been calculated on the basis of appliances produced and placed on the market. The applied methodology, although is not a balance of chemical sales, uses specific emission factors for each consumption type.

Due to the methodology used to estimate emissions, based on the consumption of the F-gases in the different categories, where relevant, the estimated consumption includes also the amount of fluid contained in the imported products. As an example, the amount of F-gases used in the air conditioning devices mounted on vehicles manufactured abroad and imported in Italy is part of the information we use in the estimation process.

UNRAE, which is the Association of foreign car makers, provide us with the amount of F-gases used in the imported vehicles every year.
In 2016 and 2017, ISPRA signed two agreements with the Ministry of *Ecological Transition* for a survey, at a national level, about HFCs alternative substances with low GWP, natural refrigerants and alternative technologies made in Italy (ISPRA [a], 2018). In the meanwhile, an historic global climate deal was reached in Kigali, Rwanda, at the Twenty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (MOP28). The so called Kigali Amendment, which amends the 1987 Montreal Protocol, aims to phase out Hydrofluorocarbons (HFCs), by the late 2040s.
In this framework ISPRA is in contact with air conditioning and refrigeration national associations, major import/export F-gas companies, and the major experts of the sector, as well as companies, in order to better understand the market evolution in terms of HFCs substitutes. Data are being collected, both regarding HFCs and substitutes, but at present they are not enough to make a balance of chemical sales and use a top down approach to cross check emission estimates.

4.7.3 Emissions from Stationary Air Conditioning sector

Since the National Inventory Submissions 2019, the estimates of emissions from the Stationary air conditioning sector are no longer based on the refrigerants consumption data supplied by Solvay (Solvay, several years) but on data of air conditioning equipment production and sales, provided by Assoclima. ASSOCLIMA, the Italian Association of Air Conditioning Systems Manufacturers, collects an annual statistical survey of the Italian companies in the sector, taking into account the production and sales data by type of equipment and capacity. The Association supplied data on production and sales from 1995 to 2019 (Assoclima [a], several years) together with data on the average refrigerant charge of each type of appliances (Assoclima [b], several years). Data interpolation has been done in those cases where data was not available for confidential reasons (this affected some cases for which the companies that declare their production and/or sales were less than 3). Data on production include the appliances manufactured and sold in Italy plus the appliances manufactured in Italy and sold in the foreign market (EU and external EU); data on sales include appliances manufactured and sold in Italy plus appliances imported from abroad and sold in Italy. As Assoclima represents most of the industry but, for some kind of appliances, not the 100%, multiplicative factors have been provided by the Association in order to cover the total of the air conditioning companies, including those that are not associated. The multiplicative factors have been used for each type of equipment and are constant for all the years of the time series (Assoclima [b], several years).
Production data have been used to estimate emissions from manufacturing while sales data have been used for estimating operating emissions.
Unlike the previous submission, this year hybrid machines were included in the estimates. These machines, with an integrated boiler and heat pump system, are similar to chillers with capacities up to 50 kW, so the parameters used for chillers were assigned to hybrid machines with the same capacity. This approach was shared with the experts of the sector.
Another change concerns the charge of equipment using R-32; in fact, as this refrigerant has higher capacity in terms of cooling and heating compare with R410A, R32's equipments use up to 20% less refrigerant than R410A for the same performance. Therefore the charge of equipment with R-32 was reduced by 20% compared to the same equipments using 410A[4].
In Table 4.34 the type of appliance, the capacity, the average charge and the multiplicative factor used for the estimation are reported.

Table 4.34 Type of air conditioning equipment, average refrigerant charge and multiplicative factor

Type* of *condensation	**Type of equipment**		**Capacity (kW)**	**Average charge (kg)**	**Multiplicative factor**
Air cooled	Room air conditioner	Monoblock air conditioner without outdoor unit (double duct)	-	0.6	1
		Monoblock portable air conditioner up to 3 kW (single duct)	< = 3	0.5	1
		Portable air conditioner with remote condenser up to 4 kW (split type)	< = 4	0.8	1

[4] https://www.mitsubishi-termal.it/wp-content/uploads/2018/07/KIREIA_2019_CATALOGO_EN.pdf

Type of *condensation*	Type of equipment		Capacity (kW)	Average charge (kg)	Multiplicative factor
Air cooled	MONO-SPLIT air conditioning units	Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	< = 7	1.1 R-410A 0.87 R-32	1.13
			> 7	3.9 R-410A 3,14 R-32	1.13
Air cooled	MULTI-SPLIT air conditioning units	Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)		1.6 R-410A 1.27 R-32	1.13
Air cooled	VRF	Mini VRF (only external condensing units)	<16	4.1	1
		VRF (only external condensing units)	>=16	8.9	1
Air or water Cooled	Packaged, roof top ductable or not)	Vertical or horizontal Indoor Packaged	-	3.4	1.2
		Roof top	-	20.7	1.2
Air or water Cooled	Precision air conditioning		< = 17	3.6	1
			> 17	9.2	1
Air Cooled	Chiller	Only cooling or heat pump	Up to 17	2.2 R-410A 0.89 R-32	1.15
			from 18 to 50	5.7 R-410A 4.56 R-32	1.1
			from 51 to 100	14.3	1.08
			from 101 to 200	29.5	1.05
			from 201 to 350	46.7	105
			from 351 to 500	61.9	1.05
			from 501 to 700	89.5	1.05
			from 701 to 900	137.1	1.05
			from 901	154.3	1
Water Cooled	Chiller	Only cooling or heat pump	Up to 17	0.9	1.2
			from 18 to 50	1.7	1.1
			from 51 to 100	4.5	1.08
			from 101 to 200	9.8	1.05
			from 201 to 350	17.5	1.05
			from 351 to 500	40.4	1.05
			from 501 to 700	70.1	1.05
			from 701 to 900	88.9	1.02
			from 901	127.3	1
Air Cooled	Hybrid machines	Heat pump + boiler	Up to 17	2.2 R-410A 1.8 R-32	1.15
			from 18 to 50	5.7 R-410A 4.56 R-32	1.1
Water Cooled	Hybrid machines	Heat pump + boiler	Up to 17	0.9	1.2
			from 18 to 50	1.7	1.1

Regarding the general trend of products and components for air conditioning systems, the 2015 has been the year in which a recovery of the sector occurred after a period of economic crisis. While the time serie of the equipments production data shows a general decrease from 1996 to 2020 due to an increment to the import sector, a different trend is registered for sales data. Referring to the last Assoclima survey, in 2020 the positive sign in the air conditioning sector is registered for the room air conditioners due to the increase in the portable equipments sells, while the monoblock systems are decreased. (Assoclima, 2020). The number of VRF systems

sold, after a constant growth from 2014 to 2019, decreased in 2020 compare to 2019 due to lack of investment in the sectors most affected by the crisis due to the COVID 19 (restaurants, hotels, gyms, etc). Roof top sales also decreased by about 20% (the 40% of rooftop sales relate to large capacity machines, over 120 kW, typical of medium and large shopping centers or logistics areas). Lastly, the hydronic sector also felt the effects of the pandemic with the exception of heat pump chillers. Heat pump systems have been performing well for a number of years and currently the Italian market for residential air conditioning systems is dominated by this category. The non-residential (roof top and chiller market, especially for low power machines up to 50 kW), is also moving towards this technology and heat pump systems are also growing in higher power classes (Assoclima, 2020). In 2020 despite the lockdown crisis, heat pump machines continued to record positive trends. (Assoclima, 2021).

Among the measures adopted in the last years for promoting energy efficiency at national level, with a positive effect on the heat pumps market, there are the Conto Termico (Thermal energy account in the form of an economic contribution) and the Ecobonus, that is fiscal deductions for energy saving. Heat pumps have been indicated as a key technology within the PNIEC (Integrated National Plan for Energy and Climate published in January 2020) for achieving the Country's decarbonization target. Significant interventions in the civil consumption sector (residential and tertiary buildings) are needed to achieve this goal. In this regard, an important measure for support the carbon-neutral heating in residential homes has been introduced with Decree no. 34/2020 (Relaunch Decree, art. 119) then converted into Law no. 77/2020. This measure is called "Superbonus 110%" and allows to realize interventions for the energy efficiency improvement of existing buildings (Ecobonus) and for the reduction of seismic risk (Sismabonus) by obtaining a 110% deduction of the costs. The heat pump in hybrid system is one of the interventions that can access the Superbonus. The deduction concerns only the interventions of replacement of existing winter air conditioning system in condominiums or individual houses.

The air conditioning sector has been involved for years in the design of air conditioning systems with ever better energy performance in order to achieve the minimum environmental and energy performance requirements required by the Ecodesign regulation. Regarding the portable air conditioners with remote condenser, the production stopped in 2013, because they don't respect the minimum efficiency limits required by the ErPD regulations (Assoclima [b], several years). In the following Table 4.35, data on manufactured and sold equipment in the Stationary air conditioning sector are reported. The use of HFC in the air conditioning sector started in 1996.

Table 4.35 Number of manufactured and sold equipment in the Stationary air conditioning sector, 1996-2020

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Production (units)									
Room air conditioner	309,318	244,769	165,152	34,938	10,566	12,234	26,015	18,998	17,614
Monosplit	229,900	575,242	65,286	25,141	35	35	35	35	35
Multisplit	22,718	46,680	18,576	4,464	0	0	0	0	0
VRF (only external condensing units)	0	0	0	51	0	0	0	0	0
Packaged, roof top (ductable or not)	7,090	2,384	3,376	1,990	1,929	1,920	1,739	1,910	1,507
Precision air conditioning	9,927	24,635	13,619	2,237	5,387	5,614	5,203	5,025	4,209
Air cooled chiller	28,852	46,286	55,856	66,829	36,253	37,817	38,125	35,260	34,225
Water cooled chiller	2,740	4,902	5,727	5,530	5,689	4,929	4,186	4,327	4,266
Hybrid machines	0	0	0	0	0	0	0	0	0
Sales (units)									
Room air conditioner	112,212	101,860	111,540	143,632	72,552	92,984	128,564	113,560	140,577
Monosplit	358,756	875,558	1,082,572	910,491	741,229	1,083,282	1,184,119	1,205,609	1,725,133
Multisplit	22,879	129,860	326,525	281,118	222,176	308,995	342,079	376,556	516,558
VRF (only external condensing units)	0	0	8,292	18,116	15,131	19,812	23,303	25,343	22,436

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Packaged, roof top (ductable or not)	2,429	3,907	4,141	1,744	1,199	1,638	1,370	1,582	1,258
Precision air conditioning	4,233	11,458	3,515	791	1,247	1,083	765	525	309
Air cooled chiller	21,707	31,530	34,258	27,127	33,105	44,653	51,106	56,579	52,482
Water cooled chiller	1,631	2,993	2,730	2,565	1,921	1,608	1,440	1,511	1,486
Hybrid machines	0	0	0	0	3,767	7,713	8,055	8,699	15,706

HFC refrigerants used in the Stationary air conditioning sector

Air conditioning appliances started to use HFC, as substitutes of HCFC, in the second half of the 1990s (Assoclima [b], several years), and the replacement process was completed by 2005, with the elimination of HCFCs in new equipment.

In the last years, with the introduction of new refrigerants (natural refrigerants, HFO or HFC with a lower GWP) in substitution of the HFC, due to the F-gas Regulation and market dynamics, the percentage of sales and production of HFC equipments has changed. For portable air conditioners, the replacement of HFCs with HCs started earlier than the other machines thanks to the low charge involved that allow the use of flammable refrigerants. According to expert judgment, propane has started to be used after 2005, and in 2010 the 50% of the portable room air conditioner are with HC-290; this percentage growths to 90% in 2017 (Assoclima [b], several years) and becomes equal to zero in 2020 because, according to the F-Gas regulation as of January 2020, portable room air conditioners that contain a refrigerant with a GWP of 150 or more are banned from the market.

In the following Table 4.36 the percentage share of HFC equipment on the total of sales and production per year (1996-2019) is reported.

Table 4.36 Percentage share of HFC equipment manufactured and sold over the years in the Stationary air conditioning sector

Type of equipment	1996	2000	2005	2010	2015	2017	2018	2019	2020
All equipment except monobloc portable room air conditioner <= 3kW and portable room air conditioner with remote condenser <= 4 kW	0.01	0.05	0.95	1	1	1	1	1	1
Monobloc portable room air conditioner <= 3kW	0.1	0.5	1	0.5	0.3	0.1	0.1	0.1	0
Portable room air conditioner with remote condenser <= 4 kW	0.1	0.5	1	0.5	0.3	0.1	0.1	0.1	0

R-410A, HFC-134a, and R-407C have long been the main refrigerants used in the air conditioning sector with R-410A the dominant HFC followed by HFC-134a. R-410A has been used mainly for small air conditioning systems, while HFC-134a is a good replacement for larger equipment; for intermediate power machines both R-410A and HFC-134a can be used. R-407C was used for different years in the past as a substitute for R-22, instead of R-410A because this refrigerant allows to use the same components of a R-22 system but, due to thermodynamic problems, it has been progressively substituted by R-410A. For this reason, the use of R-407C started to decrease since 2010.

The percentage of HFC conditioning equipments, by type of refrigerant has been supplied by Assoclima and show a deep changing in the mix of refrigerants used over the years (Tables 4.36, 4.37, 4.38, 4.39). Initially the portable air conditioners used mainly R-134a due to the lower operating pressures but then they mainly passed to R-410A. Regarding the R-407C, chillers with rotary compressors also initially used this gas, while those with screw compressors (and centrifugal) switched directly to R-134A. Some indoor "packages" (air-to-air ducted and also water-air ducted) still use R-407C because it is not convenient to redesign the appliances. High capacity water chillers (from 351 kW) mainly use HFC-134a; they are losing market share.

Among the new refrigerants with lower GWP, the R-32 is receiving the most interest. Because of its flammable nature (A2L class), at present it is mainly used for split equipment in the residential sector. In fact, as the sectoral experts communicated (Assoclima [b], several years), in the last 4 years, R-32 mono e multi splits have entered the Italian market, with a growing percentage and this percentage will increase in the next years In detail, mono e multisplit have started using this refrigerant, as a replacement for the R-410A, in 2016. Compare to the submission 2020 on the base of the communication of Assoclima in June 2020, in the

Submission 2021 this percentage was changed as the market penetration of R-32 was faster than initially established. The percentage reached 80% in 2019 (Assoclima [b], several years), 60% in 2018 instead of 40%, of last Submission, 40% in 2017 instead of 20% and 20% in 2016 instead of 10%. Consequently, in the submission 2021 the percentage of mono and multisplit that use R-410A, of which R-32 is the replacement, has been changed starting from 2016 compared to the previous Submission (Assoclima [b], several years).
In 2020 R-32 air cooled chiller with a capacity up to 50 kW appeared in the Italian market. According to the experts of Assoclima we met in 2021, the percentage of this equipment is about 22%, consequently the percentage of the similar chillers that use R-410A is decreased from 100% in 2019 to 78% in 2020..
In the following Tables 4.37, 4.38, 4.39, 4.40 the percentage of HFC conditioning equipment, by type of refrigerant is reported.
Regarding the possibility of using flammable refrigerants, it is noted the decree of the Ministry of the Interior of 10 March 2020 on *"Fire prevention provisions for air conditioning systems included in activities subject to fire prevention controls*[5]*"*entered in force on 18 June 2020 (DM 73/2020). This decree allows the possibility of using, in air conditioning systems, machines equipped with refrigerants classified as Al or A2L, according to ISO 817 «Refrigerants - Designations and safety classification» or equivalent standard, thus overcoming the limitation of using only non-toxic or non-flammable fluids; it also reiterates that the design, installation, management and maintenance of the plants must be done in compliance with the safety requirements set by the rule of the art (for example: series of technical standards UNI EN 378), that is respecting the applicable rules and standards.
For the estimation, the percentage composition by type of refrigerant of the sales data is equal to the percentage distribution of the production data.

Table 4.37 Percentage of R-410A equipment by type of air conditioners, 1996-2020

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
ROOM AIR CONDITIONER										
Monoblock air conditioner without outdoor unit (ductable duct)		0.84	0.20	0.40	1.00	1.00	1.00	1.00	1.00	1.00
Monoblock portable air conditioner up to 3 kW (single duct)	<= 3	0.00	0.00	0.20	0.80	1.00	1.00	1.00	1.00	1.00
Portable air conditioner with remote condenser up to 4 kW (split type)	<= 4	0.00	0.00	0.20	1.00	-	-	-	-	-
MONOSPLIT										
Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	<= 7	0.82	0.10	0.60	1.00	1.00	0.60	0.40	0.20	0.05
	> 7	0.82	0.10	0.60	0.99	1.00	0.60	0.40	0.20	0.05
MULTISPLIT										
Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)		0.00	0.10	0.60	1.00	1.00	0.60	0.40	0.20	0.05
VRF (only external condensing units)										
Mini VRF	<=16	-	-	0.80	1.00	1.00	1.00	1.00	1.00	1.00
VRF	>16	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PACKAGED, ROOF TOP (ductable or not)										
Vertical or horizontal indoor packaged	-	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50	0.50
Roof top	-	-	-	0.20	0.80	0.90	0.90	0.90	0.90	0.90
PRECISION AIR CONDITIONING										
Precision air conditioning	< = 17	0.50	0.50	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Precision air conditioning	>17	0.50	0.50	0.80	1.00	1.00	1.00	1.00	1.00	1.00
AIR COOLED CHILLER										

5 Air conditioning systems for activities open to the public, such as schools, hotels, sport centers ecc.

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Only cooling	<= 17	0.90	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.78
Heat pump		0.90	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.78
Only cooling	18 -50	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.78
Heat pump		0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.78
Only cooling	51 -100	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	101 -200	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	201 - 350	0.00	0.00	0.00	0.86	0.86	0.86	0.86	0.86	0.86
Heat pump		0.00	0.00	0.00	0.90	0.90	0.90	0.90	0.90	0.90
Only cooling	351 - 500	0.00	0.00	0.00	0.80	0.80	0.80	0.80	0.80	0.80
Heat pump		0.00	0.00	0.00	0.95	0.70	0.70	0.70	0.70	0.70
Only cooling	501 - 700	0.00	0.00	0.00	0.10	0.30	0.30	0.30	0.30	0.30
Heat pump		0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10
Only cooling	701 - 900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER COOLED CHILLER										
Only cooling	<= 17	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	18 - 50	0.00	0.00	0.50	0.50	1.00	1.00	1.00	1.00	1.00
Heat pump		0.00	0.00	0.50	0.50	1.00	1.00	1.00	1.00	1.00
Only cooling	51 - 100	0.00	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00
Heat pump		0.00	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00
Only cooling	101 - 200	0.00	0.00	0.00	0.50	0.90	0.90	0.90	0.90	0.90
Heat pump		0.00	0.00	0.00	0.50	0.90	0.90	0.90	0.90	0.90
Only cooling	201 - 350	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	351 - 500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	501 - 700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	701 - 900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.90	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.78
	18 - 50	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.78
WATER COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00
	18 - 50	0.00	0.00	0.50	0.50	1.00	1.00	1.00	1.00	1.00

Table 4.38 Percentage of HFC-134a equipment by type of air conditioners, 1996-2020

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
ROOM AIR CONDITIONER										
Monoblock air conditioner without outdoor unit (ductable duct)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monoblock portable air conditioner up to 3 kW (single duct)	<= 3	0.98	0.90	0.60	0.20	0.00	0.00	0.00	0.00	0.00

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Portable air conditioner with remote condenser up to 4 kW (split type)	<= 4	0.98	0.90	0.60	0.00	-	-	-	-	-
MONOSPLIT										
Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	<= 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	> 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MULTISPLIT										
Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VRF (only external condensing units)										
Mini VRF	<=16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VRF	>16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PACKAGED, ROOF TOP (ductable or not)										
Vertical or horizontal indoor packaged	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Roof top	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PRECISION AIR CONDITIONING										
Precision air conditioning	< = 17	0	0.50	0.50	0.20	0.00	0.00	0.00	0.00	0.00
Precision air conditioning	>17	0	0.50	0.50	0.20	0.00	0.00	0.00	0.00	0.00
AIR COOLED CHILLER										
Only cooling	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	18 -50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	51 -100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	101 -200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	201 - 350	0.50	0.50	0.50	0.14	0.14	0.14	0.14	0.14	0.14
Heat pump		0.50	0.50	0.50	0.10	0.10	0.10	0.10	0.10	0.10
Only cooling	351 - 500	0.60	0.60	0.60	0.20	0.20	0.20	0.20	0.20	0.20
Heat pump		0.60	0.60	0.60	0.05	0.30	0.30	0.30	0.30	0.30
Only cooling	501 - 700	0.70	0.70	0.70	0.90	0.70	0.70	0.70	0.70	0.70
Heat pump		0.70	0.70	0.70	0.90	0.90	0.90	0.90	0.90	0.90
Only cooling	701 - 900	0.95	0.95	0.95	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		0.95	0.95	0.95	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	>= 901	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WATER COOLED CHILLER										
Only cooling	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	18 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	51 - 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	101 - 200	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10
Heat pump		0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10
Only cooling	201 - 350	0.40	0.40	0.40	0.90	0.95	0.95	0.95	0.95	0.95
Heat pump		0.40	0.40	0.40	0.90	0.95	0.95	0.95	0.95	0.95
Only cooling	351 - 500	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	501 - 700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Heat pump		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	701 - 900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Only cooling	>= 901	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heat pump		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AIR COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	18 -50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	18 -50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.39 Percentage of R-407C equipment by type of air conditioners, 1996-2020

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
ROOM AIR CONDITIONER										
Monoblock air conditioner without outdoor unit (ductable duct)		0.16	0.80	0.60	0.00	0.00	0.00	0.00	0.00	0.00
Monoblock portable air conditioner up to 3 kW (single duct)	<= 3	0.02	0.10	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Portable air conditioner with remote condenser up to 4 kW (split type)	<= 4	0.02	0.10	0.20	0.00	-	-	-	-	-
MONOSPLIT										
Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	<= 7	0.18	0.90	0.40	0.00	0.00	0.00	0.00	0.00	0.00
	> 7	0.18	0.90	0.40	0.01	0.00	0.00	0.00	0.00	0.00
MULTISPLIT										
Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)		0.00	0.90	0.40	0.00	0.00	0.00	0.00	0.00	0.00
VRF (only external condensing units)										
Mini VRF	<=16	-	-	0.20	0.00	0.00	0.00	0.00	0.00	0.00
VRF	>16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PACKAGED, ROOF TOP (ductable or not)										
Vertical or horizontal indoor packaged	-	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
Roof top	-	-	-	0.80	0.20	0.10	0.10	0.10	0.10	0.10
PRECISION AIR CONDITIONING										
Precision air conditioning	< = 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Precision air conditioning	>17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR COOLED CHILLER										
Only cooling	<= 17	0.10	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.10	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	18 -50	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	51 -100	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	101 -200	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	201 - 350	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Only cooling	351 - 500	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	501 - 700	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	701 - 900	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER COOLED CHILLER										
Only cooling	<= 17	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	18 - 50	1.00	1.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
Only cooling	51 - 100	1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00
Only cooling	101 - 200	1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00
Heat pump		1.00	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00
Only cooling	201 - 350	0.60	0.60	0.60	0.10	0.05	0.05	0.05	0.05	0.05
Heat pump		0.60	0.60	0.60	0.10	0.05	0.05	0.05	0.05	0.05
Only cooling	351 - 500	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	501 - 700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	701 - 900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.10	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	18 - 50	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	1.00	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
	18 - 50	1.00	1.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00

Table 4.40 Percentage of R-32 equipment by type of air conditioners, 1996-2020

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
ROOM AIR CONDITIONER										
Monoblock air conditioner without outdoor unit (ductable duct)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monoblock portable air conditioner up to 3 kW (single duct)	<= 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portable air conditioner with remote condenser up to 4 kW (split type)	<= 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MONOSPLIT										
Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	<= 7	0.00	0.00	0.00	0.00	0.00	0.40	0.60	0.80	0.95
	> 7	0.00	0.00	0.00	0.00	0.00	0.40	0.60	0.80	0.95
MULTISPLIT										

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)		0.00	0.00	0.00	0.00	0.00	0.40	0.60	0.80	0.95
VRF (only external condensing units)										
Mini VRF	<=16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VRF	>16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PACKAGED, ROOF TOP (ductable or not)										
Vertical or horizontal indoor packaged		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Roof top		-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PRECISION AIR CONDITIONING										
Precision air conditioning	< = 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Precision air conditioning	>17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR COOLED CHILLER										
Only cooling	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Only cooling	18 -50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Only cooling	51 -100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	101 -200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	201 - 350	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	351 - 500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	501 - 700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	701 - 900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER COOLED CHILLER										
Only cooling	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	18 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	51 - 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	101 - 200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	201 - 350	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	351 - 500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	501 - 700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	701 - 900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Only cooling	>= 901	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat pump		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR COOLED HYBRID MACHINE										

Type of equipment	Capacity (kW)	1996	2000	2005	2010	2015	2017	2018	2019	2020
Heath pump and boiler	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
	18 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
WATER COOLED HYBRID MACHINE										
Heath pump and boiler	<= 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	18 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

On the basis of the number of equipment manufactured and sold in the Italian market, of the average refrigerant charge and of the percentage of equipment by type of HFC, the quantities of HFC contained in the equipment manufactured and sold have been calculated (table 4.41).

Table 4.41 Quantities of HFCs contained in the air conditioning equipment manufactured and sold in the Italian market, 1996-2020 (t)

AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
HFC in manufactured equipment (t)									
HFC-134a	19.54	78.58	336.67	327.56	252.01	225.42	219.93	222.99	166.55
R-410A	3.39	8.60	238.39	623.31	544.11	540.86	532.29	529.31	447.68
R-407C	3.21	64.63	523.70	15.93	4.58	4.52	4.12	4.47	3.55
R-32	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.09	13.11
HFC in sold equipment (t)									
HFC-134a	7.20	33.55	169.76	93.95	78.78	66.22	74.12	85.43	62.33
R-410A	4.26	8.54	1,189.29	1,954.84	1,639.51	1,535.76	1,296.99	963.78	601.92
R-407C	2.34	71.63	981.82	10.61	2.60	3.48	2.94	3.37	2.68
R-32	0.00	0.00	0.00	0.00	0.00	568.87	942.36	1,303.40	2,222.40

Emission factors for the Stationary air conditioning sector

Appropriate losses rates have been applied for each gas used in the stationary air conditioning sector, taking into account the equipment where refrigerants are generally used, as suggested by a pool of experts during a specific meeting held at the Ministry of the Environment, Land and Sea (ISPRA-MATTM, 2013), in order to assess F-gas emissions from refrigeration and air conditioning. These experts represent the following national association of air conditioning sector:

- ASSOCLIMA-ANIMA (Air Conditioning) - Association of Manufacturers of aerodynamic equipment and systems under the Federation of National Associations of Mechanical and Engineering similar (ANIMA), which is the sectoral industrial association within Confindustria (Confederation of Italian Industry) representing companies in this sector.
- AICARR – Italian Association of Air Conditioning, Heating and Refrigeration.

For the years 1990-1999 leakage rates were supplied by the industrial associations of manufacturers as the best available country specific information for the years concerned. Industrial associations have revised the leakage rates for the years from 2000 to take into consideration the changes in technology which have been occurring in the manufacturing of the equipment concerned. The year 2000 has been taken as a turning point in terms of changes of technologies and good practice in the refrigerants handling, because of the transition from the use of CFCs and HCFCs towards the use of HFCs. The Regulation (EC) n. 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer (EC, 2000) entered into force in 2000, introducing the phase out of CFC and the phase down of HCFC and restriction in handling these substances. As a consequence of the legislation, the relevant operational procedures in manufacturing, during installation and in exercise, e.g. for split charging or appliances maintenance, changed resulting in a turning point of leakage rates. The manufacturing and operating emission factors of the stationary air conditioning sector have not changed compared to last year's estimates.

For the operating emission factors two different period have been considered: from 1996 to 2006 and from 2007. The emission factors for the period 1996-2006 has been assumed to be higher than those of the following period, because with the entry into force of Regulation 842/2006 on certain fluorinated greenhouse gases, improvements on the prevention of leaks from equipment containing F-gases were introduced.

Measures include in example containment of gases and proper recovery of equipment, training and certification of personnel and of companies handling these gases and labelling of equipment containing F-gases. Consequently, starting from that year, more attention has been paid by the technicians to install, service and maintain, repair or decommission AC systems and the year 2007 has been taken as another turning point in terms of changes of good practice in the refrigerants handling aimed at containing and preventing losses of HFCs from equipment. According to the sectoral experts, the emission factors of the period 1996-2006 are 50% higher than those from 2007 (Assoclima [b], several years).
Similarly, also the emission factors since 2007 have been estimated by expert judgment and the values of losses presented are an average of the risk relating to the entire fleet, by including machines that work correctly and those that may have problems.
For split system the leakages are directly proportional to the number of connections according to the following equations:

$$Leakrate_{split\,;\,multisplit} = 3\% \times \left(\frac{nr_of_connections}{4}\right)$$

For monosplit, the number of connections is equal to 4; for multisplit it has been considered a weighted average of the connections equals to 10, that means a loss rate of 7.5%. Chillers and rooftop (being packaged systems) are factory sealed products, therefore leak rate is estimated equals to 1%, while VRF system, being similar to multisplit, have leak rate depending on the number of connections. The emission factor value for this equipment is 12%. More information on the assumptions is reported also in the document *"Comments on Appendix A&B of the "Preparatory study for the Review of Regulation 842/2006 /Working group 1"* (WG1, 2013).
The appropriate manufacturing and operating emission factors for stationary air conditioning sector are reported in the following Table 4.42, distinguished in two different periods of the time series.
As some procedures used in manufacturing or during the installation of the RAC systems has changed in 2000, also F-gases market price has influenced losses control. In fact, since the F-gases are also expensive material in the manufacturing process it was a matter of concern of the manufacturers to succeed in limiting losses in that stage and that was achieved by setting higher levels in the acceptance testing procedures.

Table 4.42 Manufacturing and operating emission factors of Stationary air conditioning equipment

MANUFACTURING AND OPERATING LEAKAGE RATE IN THE STATIONARY AIR CONDITIONING SECTOR				
Type of equipment	**Manufacturing (%)**		**Operating (%)**	
	1996-1999	**From 2000**	**1996-2006**	**From 2007**
ROOM AIR CONDITIONER (Monoblock without outdoor unit (ductable duct) Portable air conditioner up to 3 kW (single duct) Portable air conditioner with remote condenser up to 4 kW (split type)	3.0%	0.5%	1.5%	1.0%
MONOSPLIT Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	3.0%	0.5%	4.5%	3.0%
MULTISPLIT Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)	3.0%	0.5%	11.3%	7.5%
VRF (only external condensing units)	3.0%	0.5%	18%	12.0%
PACKAGED, ROOF TOP (ductable or not)	3.0%	0.5%	1.5%	1.0%
PRECISION AIR CONDITIONING	3.0%	0.5%	1.5%	1.0%
CHILLER (Air/water cooled chiller, only cooling or heat pump)	3.0%	0.5%	1.5%	1.0%
HYBRID MACHINES (heath pump + boiler)	3.0%	0.5%	1.5%	1.0%

Since the National Inventory Submissions 2020, the emissions related to the refrigerant container management are also estimated. Without country specific data and information, we have assumed a containers emission factor equals to 5% (table 4.43) that is a value included in the LG IPCC 2006 range (2-10%).

Table 4.43 Management containers emission factors of Stationary air conditioning sector

REFRIGERANT CONTAINER MANAGEMENT LEAKAGE RATE IN THE STATIONARY AIR CONDITIONING SECTOR	
Emission Factors	**Emission Factors References**
5.0%	2006 IPCC Guideline

In the following box, the sources of activity data and emissions factors are summarized.

CRF Category	Category	Substance	Activity Data References	Emission Factors References
2.F.1.f	Stationary Air Conditioning	HFC-32 HFC-125 HFC-134a	ASSOCLIMA	Expert judgement 2006 IPCC Guidelines

The average lifetime for each type of air conditioning systems is from expert judgement and from IPCC Guidelines (IPCC, 2006; Assoclima [b], several years; ISPRA-MATTM, 2013; WG1, 2013).
Regarding the average lifetimes, a distinction must be made between air-conditioning units used for human comfort and those used with other purposes (in example to ensure an appropriate temperature level for flower foodstuffs shops or process plants). The formers are more susceptible to fashions and are often replaced before the end of their natural life cycle, also because these units are usually not subjected to constant maintenance that is often required by industrial machines. The machines aiming at human comfort are mainly with heat pump configuration while for the other uses only cooling machines are used.
For this reason, only cooling chillers have a lifetime higher than heat pump chillers.
Regarding the HFC recovery at the end of life of equipment, the national experts we contacted communicated that almost all the gases of larger size machines are currently recovered, while in the smaller equipment the recovery quotas can be lower. For this reason, a 90% of recovery for chiller and 50% for all the other types has been adopted, in a conservative approach; experts confirmed these assumptions.
Future improvements could come from the National Register of fluorinated greenhouse gases and equipment containing fluorinated gases (DPR 146/2018). From a first check of data of the Register, it emerges that, for the 2020, the only 'complete' year, on the total of F-gases sold the 90% is virgin gas, near the 10% is regenerated and the 0.03% is recycled.
Finally, the percentage of recovered gas at decommissioning have been applied, based on default values from 2006 IPCC Guidelines and expert judgment. Data are reported in the following table 4.44.

Table 4.44 Average lifetimes and recovery at decommissioning for the Stationary air conditioning equipment

Type of equipment	Average Lifetimes years)	Recovery at decommissioning (%)
ROOM AIR CONDITIONER (Monoblock without outdoor unit (ductable duct); portable air conditioner up to 3 kW (single duct); Portable air conditioner with remote condenser up to 4 kW (split type)	12	50
MONOSPLIT Outdoor condensing units connected to an indoor unit (wall floor installation, cassette, ducted false ceiling)	15	50
MULTISPLIT Outdoor condensing units connected to indoor units (wall floor installation, cassette, ducted false ceiling)	15	50
VRF (only external condensing units)	15	50
PACKAGED, ROOF TOP (ductable or not)	18	50
PRECISION AIR CONDITIONING	22	50
ONLY COOLING CHILLER (Air/water cooled chiller,)	25	90
HEAT PUMP CHILLER (Air/water cooled chiller)	20	90
HYBRID MACHINES (heath pump + boiler)	25	90

Since the National Inventory Submissions 2020, some changes have been made regarding the calculation of the remaining initial charge and the topping up of gases.
The quantity of gas remaining in the equipment at the end of its life depends on the value of the operating emission factor and on the gas topping up. The air conditioning equipment will lose more or less depend on the year in which it has been placed on the market, because of the change of the emission factor for the period after 2007 with respect to the previous period.
Without a gas topping up, the charge of gas will gradually decrease over time to reach the minimum value at the end of equipment's life. This value can be very low if the operating emission factor is high. For multisplit and VRF equipment this situation occurs after a few years the entering the market because of the major emission factors and a lifetime equals to 15 years. By considering the major attention to prevent the leakages of refrigerant through checks on the equipment, as an effect of the F-gas Regulation, and by considering the sectoral expert judgment since the last submission the topping up of gases has been considered. A periodic gas refilling frequency based on the type of equipment has been adopted. Therefore, the total amount of refrigerant placed on the market every year is equal to the amount contained in the new equipment sold in that year plus the amount used for the maintenance in the same year.
In the following Table 4.45, the amounts of HFC placed on the market, by type of refrigerant are reported.

Table 4.45 Amounts of HFC placed on the market of Stationary air conditioning sector (amount in the sold equipment plus amount used for topping up), 1996-2020 (t)

AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
HFC placed on the market (t)									
HFC-134a	7.20	33.55	169.76	98.48	97.46	81.58	87.08	95.24	72.36
R-410A	4.26	8.79	1,205.66	2,348.91	2,223.90	2,336.30	2,111.82	1,933.13	1,456.21
R-407C	2.34	71.77	1,012.89	295.02	211.82	174.87	130.25	110.77	58.76
R-32	0.00	0.00	0.00	0.00	0.00	568.87	942.36	1,323.72	2,257.84

HFC emissions estimation from Stationary air conditioning sector
On the basis of the amounts of refrigerant placed on the market, the HFC average annual stock for each year was calculated. This stock is given by the sum of the amount of refrigerant in the machines placed on the market in the considered year, plus the amount of the remainder refrigerant in the machines from the previous year and less the quantity of refrigerant in the machines that left the market in that year because at the end of their life. For each refrigerant the average annual stocks are calculated by the following equation:

$$Q_t = Q_{(t-1)}*(1 - \text{product life leakage rate}) + Qsold_t - Q_{(t-X)}* \text{ end of life charge (\%)}$$

Where:

Q_t = amount of refrigerant in operating systems year t

$Q_{(t-1)}$ = amount of refrigerant in operating systems year t-1

$Qsold_t$ = amount of refrigerant sold year t

$Q_{(t-x)}$ = amount of refrigerant in operating systems X years before

$Q_{(t-X)}$* end of life charge (%) is the amount of refrigerant in the machines that left the market at the end of its life.

In the table 4.46 the HFC average annual stocks are reported.

Table 4.46 HFC average annual stock for the Stationary air conditioning sector, 1996-2020 (t)

AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
HFC average annual stock (t)									

HFC-134a	7.20	97.70	712.13	1,254.55	1,441.44	1,502.55	1,544.59	1,600.54	1,646.80
R-410A	4.26	35.45	3,024.27	11,204.89	18,793.84	22,047.30	22,769.95	22,733.95	22,218.64
R-407C	2.34	127.60	3,824.71	5,783.75	5,732.87	5,212.81	4,550.66	3,564.94	2,872.21
R-32	0.00	0.00	0.00	0.00	0.00	869.03	1,774.47	3,023.15	5,144.34

Since the 2020 Submission, we also estimate the amount of refrigerants stocked in the containers. In the absence of specific information, we assumed this quantity as the sum of the HFC used to fill new equipment and the HFC use for servicing. The amount of HFC stocked in the containers are reported in the table 4.47.

Table 4.47 HFC stocked in the containers for the air conditioning sector, 1996-2020 (t)

AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
HFC in the containers (t)									
HFC-134a	19.54	78.58	336.67	332.09	270.68	240.78	232.89	232.80	176.58
R-410A	3.39	8.85	254.77	1,017.39	1,128.50	1,341.40	1,347.12	1,498.66	1,080.51
R-407C	3.21	64.77	554.77	300.34	213.80	175.91	131.43	111.87	59.63
R-32	0.00	0.00	0.00	0.00	0.00	0.04	0.07	20.41	225.72

The HFC emissions from the Stationary air conditioning sector have been estimated according to IPCC's Tier 2a methodology. The F-gas total emission is the sum of charge emission, lifetime emissions, disposal emissions and containers emissions, calculated separately, according to the following IPCC 2006 equation:

EQUATION 7.10
SUMMARY OF SOURCES OF EMISSIONS

$$E_{total,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t} + E_{end-of-life,t}$$

The containers emissions have been calculated by using the IPPC's formula:

$$E_{containers,t} = RM_t \bullet \frac{c}{100}$$

where RM_t is the sum of HFC used to fill new equipment and HFC used for servicing in year t, and c is the emission factor from containers management. Without specific information regarding refrigerant management of containers an emission factor equals to 5% was adopted.
As all the air conditioning units are factory charged with refrigerants, all the emissions due to the charging process of new equipment occur in the factory and thus, the charge emissions correspond to the manufacturing emissions. In this Report we use manufacturing emissions to indicate charge emissions.
The disposal emissions (end of life emissions) have been calculated as the difference between the remaining HFC in products at decommissioning and the quantity of HFC recovered. On the basis of product life leakage rate and the average lifetimes, the charge remaining at decommissioning is calculated as (1- product life leakage rate) * average lifetimes.
While in this report the HFC emissions from containers management are reported separately from the other quantities estimated according to the IPCC tier2a equation, in the "*CRF reporting table"* emission from containers are included in the voice *"Emissions from stocks",* together with the operating emissions.
In the following tables (tables 4.48, 4.49, 4.50, 4.51) the manufacturing, lifetime, containers and disposal emissions are reported.

Table 4.48 HFC manufacturing emissions of the Stationary air conditioning sector, 1996-2020 (t)

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Mnaufacturing emissions (t)									
HFC 134a	0.64	0.56	3.04	1.68	1.27	1.14	1.11	1.13	0.84
HFC-125	0.07	0.10	1.25	1.58	1.37	1.36	1.34	1.33	1.12

HFC-32	0.07	0.10	1.20	1.58	1.37	1.36	1.34	1.33	1.12

Table 4.49 HFC lifetime emissions (including containers emissions) of the Stationary air conditioning sector, 1996-2020 (t)

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Lifetime emissions (t)									
HFC-134a	1.20	10.02	139.43	136.85	132.02	120.23	106.07	86.12	67.67
HFC-125	0.24	3.30	152.20	314.71	481.09	546.48	562.26	558.47	529.05
HFC-32	0.24	3.12	147.90	310.57	477.09	579.82	634.26	686.29	757.89

Table 4.50 HFC disposal emissions of the Stationary air conditioning sector, 1996-2020 (t)

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Disposal emissions (t)									
HFC-134a	NO	NO	NO	8.05	49.77	107.49	176.47	258.47	168.43
HFC-125	NO	NO	NO	0.16	12.83	86.41	187.83	365.51	324.95
HFC-32	NO	NO	NO	0.15	12.15	82.81	181.62	356.02	318.65

Table 4.51 HFC containers emissions of the Stationary air conditioning sector, 1996-2020 (t)

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Containers emissions (t)									
HFC-134a	1.06	5.61	31.26	24.41	19.07	16.62	15.07	14.55	10.38
HFC-125	0.12	1.03	13.30	29.19	30.89	35.73	35.32	38.86	27.76
HFC-32	0.12	0.97	12.75	28.89	30.67	35.56	35.19	39.77	38.98

The HFC total emissions from the Stationary air conditioning sector are reported on the table 4.52.

Table 4.52 HFC total emissions of the Stationary air conditioning sector, 1996-2020 (t)

STATIONARY AIR CONDITIONING	1996	2000	2005	2010	2015	2017	2018	2019	2020
Total emissions (t)									
HFC-134a	1.84	10.58	142.47	146.57	183.06	228.85	283.65	345.72	236.94
HFC-125	0.32	3.40	153.45	316.45	495.28	634.25	751.43	925.31	855.12
HFC-32	0.31	3.22	149.10	312.30	490.61	663.98	817.22	1,043.63	1,077.66
Total HFC emissions	**2.46**	**17.19**	**445.03**	**775.32**	**1,168.95**	**1,527.09**	**1,852.30**	**2,314.67**	**2,169.72**

Total HFC emissions from the stationary air conditioning equipment increased from 1996 driven by the increase of their consumptions. HFC total consumptions continued to increase until 2019 because the HFC substitution process with the alternatives with a lower or null GWP, some of which flammable, started in delay in respect the other sectors. In fact the Italian regulation has been highly restrictive for flammable refrigerants in public buildings. A number of Ministerial Decrees affecting various public access buildings restricted the use of flammable refrigerants (A2L and A3) such as hydrocarbons, HFO, R-32 in air-conditioning equipment. Recently, the entry into force of the Ministerial Decree n.73/2020, in June 2020, by allowing the use of

flammable refrigerants in air conditioning systems for activities open to the public, will probably provide a new impetus to the process of HFC replacing with other alternatives. Besides, the standards on flammability is another critical factor that affects the choice of refrigerants in the sector: in Italy there is no a classification that distinguishes highly flammable, *mildly* flammable and not flammable substances (as for European and international standards) but at the legislative level it is distinguished only between flammable and non-flammable substances and thus, all the *mildly* flammable refrigerants (such as R-32) are classified as high flammable, by limiting their use. Because of the methodology approach followed, emissions reduction will occur in the following years.

4.7.4 Emissions from Refrigeration sector: commercial, domestic and industrial

Regarding the estimations from the refrigeration sector, no changes occurred in the methodology compared to the previous submission.

Both emissions from commercial and industrial refrigeration have been estimated on the basis of Solvay data consumptions but the commercial sub-sector was supplemented by data and information provided by industry experts contacted in recent months. Transport Refrigeration and professional refrigeration such as blast chiller estimations are included in Commercial Refrigeration because no detailed information is available to split consumptions and emissions in the different sectors. Domestic refrigeration estimations are based on data of manufactured and sold fridges and freezers provided by APPLiA Italia.

Refrigeration market: activity data and HFC used in the Refrigeration sector

Domestic refrigeration appliances started to use HFC-134a from 1994 (RAEE, 2017), as a consequence of the ban of CFC forced by the Law n. 549/1993, reporting the measures to protect the stratospheric ozone and the environment (Law 28th of December 1993). APPLiA Italia represents the manufacturers of the Domestic and Professional Appliance sector in Italy and supplied production data of fridges and freezers from 1987 to 2018 (APPLiA Italia, several years); at moment data for 2019 and 2020 are not available. Data for the other years (1992, 1994, 1995, 1996, 1998, 2000) have been interpolated. Production data have been used to estimate emissions from manufacturing.

Emissions from stocks have been estimated starting from the number of appliances placed on the market each year. Data have been supplied by APPLiA Italia for the year 1993 and from 2001 to 2019 (APPLiA Italia, several years), even if for the year 1993 the appliances placed on the market still used CFCs. Data for the other years have been interpolated (1994-2000). Data are reported in table 4.36.

APPLiA Italia supplied also data on HFCs coverage on the total of sales, the average charge of appliances and the lifetime (APPLiA Italia, several years), as reported in table 4.53 and 4.54.

Table 4.53 Number of manufactured and sold equipments for domestic refrigeration, 1994-2020

DOMESTIC REFRIGERATION	1994	1995	2000	2005	2010	2015	2017	2018	2019*	2020*
Production (units*1000)										
Fridges	5,461	5,746	7,169	5,496	2,400	1,804	1,467	1,459	-	-
Freezers	1,693	1,782	2,229	1,890	1,200	522	339	347	-	-
Sales (units*1000)										
Fridges	1,701	1,783	2,190	2,232	2,294	1,832	1,724	1,519	-	-
Freezers	420	455	630	593	647	425	340	339	-	-

*At moment, data for 2019 and 2020 are not available.

Table 4.54 Average lifetimes, average charge and percentage of appliances containing HFC in domestic refrigeration equipment, 1994-2020

DOMESTIC REFRIGERATION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
Average lifetime (years)	14	14	14	14	14	14	14	14	14	14
Average charge (g)	137.5	137.5	137.5	110	110	110	110	110	110	110
% of appliances containing HFC 134a	35	70	60	20	7	0	0	0	0	0

The quantities of HFC contained in the domestic refrigeration equipment manufactured and sold in the Italian market are reported in the following Table 4.55.

Table 4.55 Quantities of HFC contained in the manufactured domestic refrigeration equipment and quantities of HFC in operating systems, 1994-2020 (t)

DOMESTIC REFRIGERATION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
HFC in manufactured equipment (t)										
HFC-134a	344.26	724.53	775.33	162.51	27.72	0.00	0.00	0.00	0.00	0.00
HFC in operating systems (t)										
HFC-134a	314.55	1,358.69	2,105.11	1,973.25	797.57	620.80	355.74	258.91	201.04	152.49

For the commercial and industrial refrigeration sub-sectors, national HFC consumption data were communicated by Solvay, the only manufacturer of fluorinated substances in Italy until 2012 (Solvay, several years).
These data were subjected to a review process with the involvement of the refrigeration national association, import/export F-gas companies, and experts of the sector that validated them. At present, these data represent the only and the best available information of the refrigeration sector.
Refrigeration data provided by Solvay included the following refrigerants: HFC-23, HFC-134a, R-404A and R-507a.
As reported in the last submission, HFC emissions from industrial refrigeration have been calculated by assuming the consumption of HFC-23 from the industrial and no from commercial refrigeration. In fact, HFC-23 is used for very low temperature, typical for the industrial sector, and not in commercial refrigeration. For the commercial refrigeration sub-sector, HFC-134a is mainly used in small commercial appliances while R-404A and R-507a are mainly used in medium /large commercial applications with low/medium temperature; in particular R-404A is the dominant refrigerant in supermarkets/other commercial applications.
Thanks to the support of sectoral experts we contacted in the last year, the commercial refrigeration sub-sector has been updated in order to include the changing of the market occurred during the last years as a consequence of the introduction of the F-gas Regulation and more in general, the policies against the climate change. In particular way, new HFC refrigerants with a lower GWP have appeared in the market as substitutions of the traditional HFCs. R-448A, R-449A and R-452A are the main alternative gases that have entered the Italian market since 2015 with increasing quota.
In table 4.56, HFC consumption data for the Refrigeration sector are reported. As all the domestic equipment are factory charged and are hermetically sealed units (and no gas refilling is necessary during their lifetime), the quantities of refrigerants used to fill new manufactured products coincides with the annual HFC domestic refrigeration consumption.

Table 4.56 HFC consumptions in commercial, industrial and domestic refrigeration sub-sectors, 1994-2020 (t)

REFRIGERATION CONSUMPTION (t)	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
Commercial Refrigeration										
HFC-32	0.00	0.00	0.00	0.00	0.00	18.79	180.24	262.13	266.74	270.65
HFC-125	0.00	8.40	341.20	899.20	1042.42	1082.23	926.40	743.55	632.87	523.91
HFC-134a	0.00	0.40	2,620.32	2,955.05	3,312.30	3,385.47	2,654.52	2,090.95	1,890.00	1,687.80
HFC-143a	0.00	9.20	391.03	1,033.60	1,198.23	1,216.73	803.78	476.00	350.09	224.18
Total HFC consumption	*0.00*	*18.00*	*3,352.54*	*4,887.85*	*5,552.94*	*5,703.22*	*4,564.94*	*3,572.63*	*3,139.70*	*2,706.54*
Industrial Refrigeration										
HFC-23	0.00	15.00	26.44	50.00	40.00	40.00	31.20	25.20	22.80	20.40
Total HFC consumption	*0.00*	*15.00*	*26.44*	*50.00*	*40.00*	*40.00*	*31.20*	*25.20*	*22.80*	*20.40*
Domestic Refrigeration										
HFC-134a	344.26	724.53	775.33	162.51	27.72	0.00	0.00	0.00	0.00	0.00
0Total HFC consumption	*344.26*	*724.53*	*775.33*	*162.51*	*27.72*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total HFC consumption Refrigeration sector	***344.26***	***757.53***	***4,154.31***	***5,100.36***	***5,620.66***	***5,743.22***	***4,596.14***	***3,597.83***	***3,162.50***	***2,726.94***

R-404A and R-507a have a very high GWP, greater than 2,500. As the use of HFCs with a GWP above 2,500 is banned in all new commercial refrigeration equipment placed on the EU market after January 1st 2020, R-404A and R-507A use is not longer permit in new equipment starting from this year. They can only be used for maintenance as a recycled or regenerated gas.
As consequence of HFC bans and phase down, and of the market dynamic of the last years, with the increasing of the cost of HFC with higher GWP and a reduction of their availability, new HFC and alternative substances with lower or null GWP have been entering the market. The refrigeration national association, F-gas import/export companies and sectoral experts were contacted in order to gather information and data on these other gases, but at present no information are available.
As the experts of the sector communicated, the refrigerants market is moving towards a model characterized by a presence of many different gases, each one with a specific different application.

Emission factors for the refrigeration sector
Appropriate losses rates have been applied for each gas and subsector (commercial, industrial and domestic) taking into account the equipment where refrigerants are generally used, as suggested by a pool of experts during a specific meeting held at the Ministry of the Environment, Land and Sea (ISPRA-MATTM, 2013), in order to assess F-gas emissions from refrigeration and air conditioning, with a focus on commercial refrigeration. These experts represent the following national association of refrigeration sector:

- ASSOFOODTEC-ANIMA (Commercial Refrigeration) - Association of Italian manufacturers of machinery, plant, equipment for the production, processing and preservation of food, under the ANIMA Federation.
- AICARR – Italian Association of Air Conditioning, Heating and Refrigeration.
- APPLiA Italia (Domestic Refrigeration) - It represents the manufacturers of the Domestic and Professional Appliance sector in Italy; APPLIA is a member of ANIE Federation (The National Federation of Italian Electrotechnical, Electronics and ICT Companies) and Confindustria.

For the years 1990-1999 leakage rates were supplied by the industrial associations of manufacturers as the best available country specific information for the years concerned. Industrial associations have revised the leakage rates for the years from 2000 to take into consideration the changes in technology which have been occurring in the manufacturing of the equipment concerned.
The year 2000 has been taken as a turning point in terms of changes of technologies and good practice in the refrigerants handling, because of the transition from the use of CFCs and HCFCs towards the use of HFCs.
The Regulation (EC) n. 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer (EC, 2000) entered into force in 2000, introducing the phase out of CFC and the phase down of HCFC and restriction in handling these substances. As a consequence of the legislation, the relevant operational procedures in manufacturing, during installation and in exercise, e.g for split charging or appliances maintenance, changed resulting in a turning point of leakage rates.
The manufacturing and operating (product life) emission factors for commercial, industrial and domestic refrigeration equipment are reported in the following table (table 4.57).

Table 4.57 Manufacturing and operating emission factors for refrigeration equipment

Refrigeration sector	1990-1999 Leakage rate (%)		2000-2019 Leakage rate (%)	
	Manufacturing	Product life	Manufacturing	Product life
Small Commercial Refrigeration	0.5%	5.0%	0.5%	5.0%
Large Commercial Refrigeration	3.0%	15.0%	0.5%	12.0%
Domestic Refrigeration	3.0%	0.7%	3.0%	0.7%
Industrial Refrigeration	1.8%	15.0%	1.8%	15.0%

As some procedures used in manufacturing or during the installation of the RAC systems has changed in 2000, also F-gases market price has influenced losses control. In fact, since the F-gases are also expensive material in the manufacturing process it was a matter of concern of the manufacturers to succeed in limiting losses in that stage and that was achieved by setting higher levels in the acceptance testing procedures.
According to the information supplied by the industry reported above, year 2000 is considered a turning point for the sector market together with 2006, when the Regulation 842/2006 entered into force.
In the following box, the sources of activity data and emissions factors are summarized.

CRF Category	Category	Substance	Activity Data References	Emission Factors References
2.F.1.a	Commercial Refrigeration	HFC 32 HFC 125 HFC 134a HFC 143a	Solvay, expert judgement	Expert Judgement
2.F.1.b	Domestic Refrigeration	HFC 134a	APPLiA Italia	Expert Judgement
2.F.1.c	Industrial Refrigeration	HFC 23	Solvay	2006 IPCC Guideline

The average lifetimes for each type of refrigeration systems, in table 4.58, are from expert judgement and from IPCC Guidelines (IPCC, 2006; Assoclima [b], several years; ISPRA-MATTM, 2013; WG1, 2013).

Table 4.58 Average lifetime, initial charge remaining and recovery at decommissioning for refrigeration equipment

Refrigeration sector	Average Lifetimes (years)	Initial Charge Remaining (%)	Recovery at decommissioning (%)
Small Commercial Refrigeration	12	40%	85%
Large Commercial Refrigeration	12	-	90%
Domestic Refrigeration	14	90.2%	85%
Industrial refrigeration	20	-	90%

HFC emissions estimation from refrigeration sector

On the basis of the HFC consumption data, the average annual stock for commercial, industrial and domestic sub-sectors was calculated. This stock is given by the sum of the amount of refrigerant in the machines placed on the market in the considered year, plus the amount of the remainder refrigerant in the machines from the previous year and less the quantity of refrigerant in the machines that left the market in that year because at the end of their life. For each refrigerant the average annual stocks are calculated by the following equation:

$$Q_t = Q_{(t-1)}*(1 - \text{product life leakage rate}) + Qsold_t - Q_{(t-X)}* \text{ end of life charge (\%)}$$

where:

Q_t = amount of refrigerant in operating systems year t

$Q_{(t-1)}$ = amount of refrigerant in operating systems year t-1

$Qsold_t$ = amount of refrigerant sold year t

$Q_{(t-x)}$ = amount of refrigerant in operating systems X years before

$Q_{(t-X)}$* end of life charge (%) is the amount of refrigerant in the machines that left the market at the end of its life.

In the following table 4.59 the HFC average annual stocks for refrigeration sector are reported.

Table 4.59 HFC average annual stocks from the Refrigeration sector, 1994-2020

Refrigeration HFC average annual stock (t)	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a Commercial Refrigeration										
HFC-32	0.00	0.00	0.00	0.00	0.00	18.70	280.61	507.76	712.23	896.06
HFC-125	0.00	8.15	690.07	3,122.26	5,527.68	7,289.48	7,537.20	7,372.57	7,117.57	6,784.75
HFC -134a	0.00	0.39	2,945.12	7,438.91	11,572.11	13,418.65	13,647.17	13,429.13	13,118.07	12,720.08
HFC-143a	0.00	8.92	789.97	3,585.62	6,352.14	8,350.98	8,257.55	7,740.26	7,159.77	6,523.66

Refrigeration HFC average annual stock (t)	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
HFC average annual stock	*0.00*	*17.46*	*4,425.16*	*14,146.79*	*23,451.93*	*29,077.81*	*29,722.54*	*29,049.72*	*28,107.64*	*26,924.55*
2.F.1.b Domestic Refrigeration										
HFC-134a	101.38	314.55	1,580.21	2,152.09	1,762.92	620.80	355.74	258.91	201.04	152.49
HFC average annual stock	*101.38*	*314.55*	*1,580.21*	*2,152.09*	*1,762.92*	*620.80*	*355.74*	*258.91*	*201.04*	*152.49*
2.F.1.c Industrial Refrigeration										
HFC-23	0.00	5.90	34.86	73.64	97.32	97.18	94.90	90.57	85.95	81.07
HFC average annual stock	*0.00*	*5.90*	*34.86*	*73.64*	*97.32*	*97.18*	*94.90*	*90.57*	*85.95*	*81.07*
Total HFC average annual stock Refrigeration sector	***101.38***	***337.91***	***6,040.24***	***16,372.52***	***25,312.17***	***29,795.80***	***30,173.18***	***29,399.20***	***28,394.62***	***27,158.11***

Regarding the estimations from the refrigeration sector, no changes in the methodology was made compared to the last submission.
Commercial and industrial refrigeration emissions have been estimated on the base of Solvay data consumption (Solvay, several years) while domestic refrigeration emissions have been calculated on the basis of appliances produced and placed on the market (APPLiA Italia, several years).
Transport refrigeration and professional refrigeration such as blast chiller estimations are included in Commercial refrigeration, because no detailed information is available to split consumptions and emissions in the different sectors.
The emissions have been estimated according to IPCC's tier 2a methodologies. The F-gas total emission is the sum of charge emission, lifetime emissions, disposal emissions and containers emissions, calculated separately, according to the following LG IPCC 2006 equation:

EQUATION 7.10
SUMMARY OF SOURCES OF EMISSIONS

$$E_{total,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t} + E_{end-of-life,t}$$

Commercial and industrial refrigeration estimates are based on single gas consumptions data that include also the quantity of gases used for the maintenance. The combination of the emission factors and the lifetime of the equipment implies that the appliance can lose its charge completely during its lifetime and consequently, the charge remaining at decommissioning is zero. In these particular cases, it can be assumed that emissions are included in "operating systems" emissions and no emissions from disposal and emissions from recovery are present.
On the basis of information reported above, HFC emissions of the refrigeration equipment, from manufacturing, lifetime and disposal have been estimated and reported in tables 4.60, 4.61, 4.62. The disposal emissions have been calculated as the difference between the remaining HFC in products at decommissioning and the quantity of HFC recovered. In table 4.63 totals are reported.

Table 4.60 HFC manufacturing emissions from the refrigeration sector (t), 1994-2020

Refrigeration MANUFACTURING EMISSION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a - Commercial Refrigeration										
HFC-32 (t)	NO	NO	NO	NO	NO	0.09	0.90	1.31	1.33	1.35
HFC-125 (t)	NO	0.25	1.71	4.50	5.21	5.41	4.63	3.72	3.16	2.62
HFC-134a (t)	NO	0.01	13.10	14.78	16.56	16.93	13.27	10.45	9.45	8.44
HFC-143a (t)	NO	0.28	1.96	5.17	5.99	6.08	4.02	2.38	1.75	1.12
Total HFC manufacturing emissions (t)	*NO*	*0.54*	*16.76*	*24.44*	*27.76*	*28.52*	*22.82*	*17.86*	*15.70*	*13.53*
2.F.1.b - Domestic Refrigeration										

Refrigeration MANUFACTURING EMISSION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
HFC-134a (t)	10.33	21.74	23.26	4.88	0.83	0.00	0.00	0.00	0.00	*0.00*
Total HFC manufacturing emissions (t)	*10.33*	*21.74*	*23.26*	*4.88*	*0.83*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
2.F.1.c - Industrial Refrigeration										
HFC-23 (t)	NO	0.26	0.46	0.88	0.70	0.70	0.55	0.44	0.40	0.36
Total HFC manufacturing emissions (t)	*NO*	*0.26*	*0.46*	*0.88*	*0.70*	*0.70*	*0.55*	*0.44*	*0.40*	*0.36*
Total HFC manufacturing emissions - Refrigeration sector (t)	***10.33***	***22.54***	***40.49***	***30.19***	***29.30***	***29.22***	***23.37***	***18.30***	***16.10***	***13.89***

Table 4.61 HFC lifetime emissions from the refrigeration sector (t), 1994-2020

Refrigeration LIFETIME EMISSION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a - Commercial Refrigeration										
HFC-32 (t)	NO	NO	NO	NO	NO	2.24	33.67	60.93	85.47	107.53
HFC-125 (t)	NO	1.22	82.81	374.67	663.32	874.74	904.46	884.71	854.11	814.17
HFC-134a (t)	NO	0.06	150.75	388.16	607.46	710.03	736.49	736.39	730.10	718.02
HFC -143a (t)	NO	1.34	94.80	430.27	762.26	1,002.12	990.91	928.83	859.17	782.84
Total HFC lifetime emissions (t)	*NO*	*2.62*	*328.36*	*1,193.11*	*2,033.04*	*2,589.13*	*2,665.53*	*2,610.86*	*2,528.85*	*2,422.56*
2.F.1.b - Domestic Refrigeration										
HFC-134a (t)	0.71	2.20	11.06	15.06	12.34	4.35	2.49	1.81	1.41	1.07
Total HFC lifetime emissions (t)	*0.71*	*2.20*	*11.06*	*15.06*	*12.34*	*4.35*	*2.49*	*1.81*	*1.41*	*1.07*
2.F.1.c - Industrial Refrigeration										
HFC-23 (t)	NO	0.88	5.23	11.05	14.60	14.58	14.24	13.59	12.89	12.16
Total HFC lifetime emissions (t)	*NO*	*0.88*	*5.23*	*11.05*	*14.60*	*14.58*	*14.24*	*13.59*	*12.89*	*12.16*
Total HFC lifetime emissions Refrigeration sector (t)	***0.71***	***5.71***	***344.65***	***1,219.22***	***2,059.98***	***2,608.05***	***2,682.26***	***2,626.26***	***2,543.15***	***2,435.79***

Table 4.62 HFC disposal emissions from the refrigeration sector (t), 1994-2020

Refrigeration DISPOSAL EMISSION	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a - Commercial Refrigeration										
HFC-32 (t)	NO	NO	NO	NO	NO	0	0	0	0	0
HFC-125 (t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HFC-134a (t)	0.00	0.00	0.00	0.00	0.00	160.70	166.83	173.27	177.40	181.11
HFC -143a (t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total HFC disposal emissions (t)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*160.70*	*166.83*	*173.27*	*177.40*	*181.11*
2.F.1.b - Domestic Refrigeration										
HFC-134a (t)	0.00	0.00	0.00	0.00	32.85	25.68	14.53	14.15	8.41	7.07
Total HFC disposal emissions (t)	0.00	0.00	0.00	0.00	*32.85*	*25.68*	*14.53*	*14.15*	*8.41*	*7.07*
2.F.1.c - Industrial Refrigeration										
HFC-23 (t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total HFC disposal emissions (t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total HFC disposal emissions (t) Refrigeration sector	***0.00***	***0.00***	***0.00***	***0.00***	***32.85***	***186.38***	***181.36***	***187.42***	***185.81***	***188.18***

Table 4.63 HFC total emissions from refrigeration sector (t) (manufacturing emissions plus lifetime emissions and disposal emissions), 1994-2020

Refrigeration Total emissions	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a - Commercial Refrigeration										
HFC-32 (t)	0.00	0.00	0.00	0.00	0.00	2.34	34.57	62.24	86.80	108.88
HFC-125 (t)	0.00	1.47	84.51	379.17	668.53	880.15	909.10	888.43	857.27	816.79
HFC-134a (t)	0.00	0.07	163.85	402.94	624.02	887.66	916.59	920.12	916.96	907.57
HFC-143a (t)	0.00	1.61	96.75	435.44	768.25	1,008.20	994.92	931.21	860.92	783.96
Total HFC emissions (t)	*0.00*	*3.16*	*345.12*	*1,217.55*	*2,060.80*	*2,778.35*	*2,855.18*	*2,802.00*	*2,721.95*	*2,617.20*
2.F.1.b - Domestic Refrigeration										
HFC-134a (t)	11.04	23.94	34.32	19.94	46.02	30.02	17.02	15.96	9.82	8.14
Total HFC emissions (t)	*11.04*	*23.94*	*34.32*	*19.94*	*46.02*	*30.02*	*17.02*	*15.96*	*9.82*	*8.14*
2.F.1.c - Industrial Refrigeration										
HFC-23 (t)	0.00	1.15	5.69	11.92	15.30	15.28	14.78	14.03	13.29	12.52
Total HFC emissions (t)	*0.00*	*1.15*	*5.69*	*11.92*	*15.30*	*15.28*	*14.78*	*14.03*	*13.29*	*12.52*
Total HFC emissions (t) Refrigeration sector	***11.04***	***28.24***	***385.13***	***1,249.41***	***2,122.12***	***2,823.65***	***2,886.99***	***2,831.99***	***2,745.06***	***2,637.86***

Professional refrigeration

In 2019 a first investigation on the professional refrigeration subsector has been carry out by Applia Italia, the Italian Association of the manufactures of the Domestic and Professional sector.
The professional refrigeration sector includes the equipment used for storage, preservation and treatment for food, in use in the professional kitchens of public sector (such as restaurants, pizzerias, pubs, hotels) of collective catering (canteens) and commercial catering (restaurant and fast food chains). These appliances are mainly hermetically sealed stand-alone units (plug –in o self contained). Professional refrigeration equipment encompassesis refrigerators, freezers, blast chillers and ice-making machines. All these types of equipment differ in terms of capacity, refrigerant charge, temperature levels and process techniques, factors that together with the climatic characteristics of the professional kitchen affect the feasibility of replacing hydrofluorocarbons with gas with low GWP (APPLiA Italia, 2019). In fact, according to the EU Regulation n. 517/2014, the placing on the market of professional refrigeration products is prohibited:

- From 1 January 2020: for refrigerators and freezers for commercial use (hermetically sealed equipment) that contain HFCs with GWP of 2,500 or more
- From 1 January 2022: for refrigerators and freezers for commercial use (hermetically sealed equipment) that contain HFCs with GWP of 150 or more
- From 1 January 2020: for stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2,500 or more except equipment intended for application designed to cool products to temperatures below -50°C

The main HFCs used in the professional refrigeration sector are: R-404A, R-452A and HFC-134a. As these refrigerants have a very high global warming potential, they will need to be replaced by alternatives with no or very low GWP. At present, according to the experts of the sector, the hydrocarbons (mainly propane R-290) represent the only feasible alternatives to HFC: in fact the professional refrigeration sector is facing many difficulties in switching to alternatives to HFCs because of the safety standards regarding flammable products. The EN 60335-2-89 safety standard sets a charge limit of 150 g for flammables, limit that is often exceeded in this type of equipment.
In 2019, at the international IEC standard, with the contribution of EFCEM Italia, a new edition of the standard was approved. The new standard allows an increase in the propane charge up to 500 g.
European manufacturers are waiting the implementation of this standard at European level of CENELEC before they can implement an increase in the charge of natural refrigerant (APPLiA Italia, 2019).
The professional refrigeration equipment placed on the Italian market (excluding operators of collective and commercial catering) include 1,250,000 refrigerators (vertical and/or horizontal), 225,000 ice-making machines and 199,000 blast chillers. The number of equipment purchased in 2018 is estimated by considering a range of values relating to a prudential estimate and to an enlarged estimate. For the refrigerators the range of values is from 58,000 to 72,000 units, for ice making machines it is from 21,000 to 26,000 and for blust chillers the range is from 16,000 to 19,000.
More than the 23% of refrigerators stocked on the market are more than 10 years old. Ice making machines with more than 10 years old are more than 21% while the blust chillers are more than 15% of the corresponding stock on the market (APPLiA Italia, 2019).
Activity data on the professional refrigeration machines were collected for the year 2018 and are reported in the following box.

PROFESSIONAL REFRIGERATION IN ITALY

	VERTICAL AND/OR HORIZONTAL REFRIGERATORS	ICE MAKING MACHINES	BLAST CHILLER
Total professional refrigeration systems placed on the market	1,250,000	225,000	199,000
Number of equipment purchased in 2018	from 58,000 to 72,000	from 21,000 to 26,000	from 16,000 to 19,000
Number of units older than 10 years:	>23%	>21%	>15%
of which more than 15 years old	>12%	>9%	>6%

The use of HFC as alternative refrigerants to HCFC for the professional refrigerators started in 1995. R-404A was the main refrigerant initially utilized and subsequently it was replaced by R-452A and HFC-134a. In particular, R-452A is used in refrigerators with positive temperature and with charge equals to 300 g and in the refrigerators with negative temperature with charge equals to 450 g (APPLiA Italia, 2019). According to the APPLiA Italia report, propane is the main alternative to HFCs for the professional refrigerators, followed by isobuthane and HFO. Professional refrigerators manufacturers expect HFC to be completely replaced by 2021. Regarding the blast chillers, HCFCs were used until the mid-90s and then replaced by HFCs, R-404A initially and then R-452A and HFC-134a (this one in less amount). The use of HFCs for the ice-making machines started at the end of 90s. At present the main refrigerant used are R-452A, HFC-134a e R-290 and for the future they forecast their complete replacement with HCs and HFOs by 2030. For all these products, the factory loss rate is estimated to be less than 1% (APPLiA Italia, 2019*).* There is no updated information on this sector available.

4.7.5 Emissions from Mobile Air Conditioning, Foam blowing Agents, Fire Protection and Aerosols

The estimates of emissions are based on single gas consumption data supplied by the only national refrigerants producer (Solvay, several years) for foam blowing and by industry for the other sub-sectors.

For the mobile air conditioning equipment, the national motor company and the agent's union of foreign motor-cars vehicles have provided HFC-134a yearly consumptions (FIAT, several years [a]; IVECO, several years; UNRAE, several years; CNH, several years). Because of scarce availability of data regarding trucks from the industry, HFCs emissions from commercial vehicles air conditioning systems have been revised. Data from national statistics on vehicles from the Automobile Club of Italy (ACI, several years) have been used together with the assumption of a nominal refrigerant charge of 1.2 kg according to IPCC Guidelines (IPCC, 2006) and a lifetime of 14 years (ACI, several years).

Pharmaceutical industry has provided aerosols/metered dose inhaler data (Sanofi Aventis, several years; Boehringer Ingelheim, several years; Chiesi Farmaceutici, several years; GSK, several years; Lusofarmaco, several years; Menarini, several years; Istituto De Angeli, several years).

For the fire extinguishers sector the European Association for Responsible Use of HFCs in Fire Fighting was contacted (ASSURE, 2005), as well as the Consortium of fire protection systems (Clean Gas, 2001). More in details HFC-227ea partial consumptions for fire extinguishers along the whole time series has been provided by Clean Gas Consortium. Because other Consortia of fire protection systems are present in the country, consumption data provided by Clean Gas have been multiplied for a factor equal to five according to expert judgment and a comparison with the stock of gas estimated in 2005 (Gastec Vesta, 2017). HFC-227ea consumption levels have been supplied for the years 1990-2000 together with projections of consumptions for the years 2005 and 2010, for which Clean Gas estimated the same value (130 t). Data from 2000 to 2004 have been extrapolated, data from 2005 to 2010 has been assumed constant (130 t) and data from 2011 onwards have been estimated on the basis of the following assumptions. From 2010, according to information supplied by industry (Gastec Vesta, 2017) the amount of HFC-227ea started to decrease, replaced by the new chemical NOVEC concurrently with the entering in force of the Regulation n. 517/2014 (EU, 2014): in 2016 the consumption of HFC-227ea can be assumed the 80% of the 2010 consumption. In 2020 the value has been estimated on the basis of the percentage set by the phase down reported in the Annex V of the F-gases Regulation. On the basis of expert judgment and ASSURE, because of HFC-227ea covers the 90% of the fire extinguishers market, consumption data of HFC-125 and HFC-23 have been estimated, considering that HFC-125 is 2/3 of the remaining quota. In addition to the Novec, among the best alternative solutions to HFCs on the market are inert gases but at the moment we don't have information about the quotas placed in the market. ANIMA, the Federation of National Associations of Mechanical and Engineering similar which include fire protection industry, has been contacted in order to verify the presence of Consortia of fire protection systems. At present also the Federation did not provide update information. The main national fire protection industries (Gielle and Gastec Vesta), which were involved also for the Survey about HFCs alternative substances with low GWP, natural refrigerants and alternative technologies made in Italy (ISPRA[a], 2018) in the framework of the agreements with the Ministry of Ecological Transition, have been contacted and approved the estimation approach.

Investigation in order to collect information on the HFC recovery, recycling, regeneration or disposal activities used in fire extinguishers sector was carried out from Ispra in these years but at moment without results. A difficulty lies on the fact that in Italy, when the Authorized Halon Gas Collection Centers collect end of life F-gases, they use to mix all gases together in the containers, as confirmed also by the Ministry of Ecological Transition and it is no more possible to determine the types and quantities of gases collected in the consortium. To obtain other information, we have also contacted one of the major fire protection Company, Gielle, that collects, throughout the national territory, exhausted refrigerant gases, CFCs, HCFCs and HFCs, to be sent for recovery, recycling, regeneration or disposal. At the moment no information has been provided. According to Gielle, at the end of life no emissions occur if the equipment are delivered to an authorized and expert company. Improvements should be obtained by consulting the new Database of fluorinated greenhouse gases and equipment containing fluorinated gases (DPR 146/2018), the analysis of the national equipment register is ongoing, but there is no certainty of the actually stock of firefighting equipment, because many operators are in delay with the compliance of the legislation.
For the foam blowing agents, Solvay provided consumption data of HFC-245fa and HFC-134a; no information about other HFCs eventually used are available. Furthermore, no information is available on the type of foam, if open or closed cells, on which a different emission factor depends. In order to gather these information and data, we contacted the main national associations of foam blowing and the experts of the sector who reported that closed cell are more widespread than open cell foams and by reporting that other information at present are not available. For this reason, the HFC consumptions provided by Solvay have been entirely attributed to closed cells.
In the following table 4.64, the sources of activity data and emissions factors are summarized.

Table 4.64 Activity data and emission factors references for MAC, Foam blowing, Aerosols and Fire extinguishers

CRF Category	Category	Substance	Activity Data References	Emission Factors References
2.F.1.e	Mobile Air Conditioning	HFC-134a	FIAT, IVECO, UNRAE, CNH, ACI	IPCC, ACI
2.F.2.a	Foam blowing	HFC-245fa HFC-134a	Solvay	IPCC
2.F.4	Metered Dose Inhalers	HFC-134a	Menarini, Chiesi, Sanofi Aventis, GSK, Lusofarmaco, Istituto De Angeli, Boehringer	Chiesi
2.F.3	Fire Extinguishers	HFC-227ea	Clean Gas, Gastec Vesta, Expert judgment	ASSURE

Due to the methodology used to estimate emissions, based on the consumption of the F-gases in the different categories, where relevant, the estimated consumption include also the amount of fluid contained in the imported products. As an example, the amount of F-gases used in the air conditioning devices mounted on vehicles manufactured abroad and imported in Italy is part of the information we use in the estimation process. UNRAE, which is the Association of foreign car makers, provide us every year with the amount of F-gases used in the imported vehicles.
As for aerosols (i.e. MDI), every year the relevant operators at national level provide us with the consumption of F-gases used in the national production process. Some of the reporting operators manufacture the MDI at Italian facilities as well as export the products, while some others just market in Italy imported MDI.
Emissions estimation from MAC systems is based on gas consumption provided by the relevant national operators. These data have been used to estimate the quantity accumulated every year. Emissions from equipment disposal are already included into the emission during the product's life for the whole time series. According to the IPCC default values for MAC systems, leakage rates product's life are equal to 10-20%. The lower bounds of the ranges are usually to be used for new vehicles, the upper bound values for retrofit vehicles. From early 2000s all the new vehicles are equipped with AC and no more vehicles needed to be retrofitted. Emission factor for the first fill have been provided by manufacturers and are in line with the default value in the IPCC Guidelines (4-5%).
Emissions from MDI are estimated on the basis of HFC consumptions and losses rates provided by the relevant operators in Italy, using the Equation 7.6 of the 2006 IPCC Guidelines. Specifically, losses rate during manufacturing is set at 1.95% while it is assumed that 50% of the chemical charge escapes within the first year and the remaining charge escapes during the second year, according to 2006 IPCC Guidelines.
Concerning fire extinguishers, ASSURE, the European association for responsible use of HFCs in fire fighting, provided us with the information concerning losses rates in manufacturing of fire fighting systems (0%) and during the average lifetime of the fire extinguishers (less than 5%) (ASSURE, 2005). About the lifetime

emission national fire protection industries explained that an alarm safety system installed in the fire protection equipment starts when losses are over 5%. The whole gas is considered emitted and not recovered as required by the latest European and National legislation.
Emissions from the foam blowing are estimated using the leakage rates reported in the 2006 IPCC Guidelines emission factors for the closed cells. Specifically, losses rate during manufacturing is equals to 10% while the operating rate is 4.5%. The emission factors reported in table 4.65 have been used, for the whole time series.

Table 4.65 Manufacturing and product life leakage rate for MAC, Foam blowing, Fire extinguishers and Aerosols

Subsector	Leakage rate (%)	
	Manufacturing	Operating
Mobile Air Conditioning – new vehicles	4%	10%
Mobile Air Conditioning – retrofit vehicles	8%	20%
Metered Dose Inhalers	1.95%	50%
Foam blowing (closed cells)	10%	4.5%
Fire Protection	0%	5%

Finally, the following average lifetimes and the percentage of recovered gas at decommissioning have been applied, based on default values from 2006 IPCC Guidelines and expert judgment.

	Average Lifetimes (years)	Recovery at decommissioning (%)
MAC	14	0%
Metered Dose Inhalers (MDI)	2	0%

In table 4.66, an overview of the total emissions (manufacturing, lifetime and disposal) from the sub-sectors is given for the 1990-20120 period, per compound.

Table 4.66 HFC emissions from MAC, Foam blowing, Fire extinguishers and Aerosols sub-sectors, 1990-2020 (t)

COMPOUND (t)	1990	1995	2000	2005	2010	2015	2016	2018	2019	2020
2.F.1.e - Mobile Air Conditioning										
HFC-134a (t)	0.00	204.59	685.04	928.82	1,063.88	1,072.73	1,091.70	1,081.59	1,069.38	1,040.89
Total HFC emissions (t)	*0.00*	*204.59*	*685.04*	*928.82*	*1,063.88*	*1,072.73*	*1,091.70*	*1,081.59*	*1,069.38*	*1,040.89*
2.F.2.a - Foam blowing (closed cell)										
HFC-245fa (t)	0.00	0.00	0.00	140.56	229.14	302.03	297.96	288.28	275.77	260.55
HFC-134a (t)	0.00	0.00	49.37	180.07	213.81	234.74	229.62	221.87	212.20	200.71
Total HFC emissions (t)	*0.00*	*0.00*	*49.37*	*320.63*	*442.95*	*536.77*	*527.58*	*510.14*	*487.97*	*461.27*
2.F.3 - Fire Extinguishers										
HFC-227ea (t)	0.00	3.88	40.21	158.63	299.20	389.71	408.94	412.44	414.07	413.90
HFC-23 (t)	0.00	0.14	1.49	5.88	11.08	13.98	12.62	11.99	11.39	10.82
HFC-125	0.00	0.29	2.98	11.75	22.16	28.87	30.29	30.55	30.67	30.66
Total HFC emissions (t)	*0.00*	*4.31*	*44.68*	*176.26*	*332.44*	*432.56*	*451.84*	*454.98*	*456.13*	*455.37*
2.F.4 - Aerosol										
HFC-134a (t)	0.00	0.00	81.54	225.32	200.69	129.37	144.97	179.74	182.87	158.49
Total HFC emissions (t)	*0.00*	*0.00*	*81.54*	*225.32*	*200.69*	*129.37*	*144.97*	*179.74*	*182.87*	*158.49*

4.7.6 Uncertainty and time-series consistency

The combined uncertainty in F-gas emissions for HFC emissions from HFC emissions used as substitutes for ODS is estimated to be about 58% in annual emissions, 30% and 50%, concerning activity data and emission factors, respectively.

HFC emissions from the stationary air conditioning equipment, table 4.67, increased from1996 driven by the increase of their consumptions. HFC total consumptions continued to increase over the years because the HFC substitution process with the alternatives with a lower or null GWP, some of which flammable, started in delay in respect the other sectors. In fact the Italian regulation remains highly restrictive for flammable refrigerants in public buildings. A number of Ministerial Decrees affecting various public access buildings restricts the use of flammable refrigerants (A2L and A3) such as hydrocarbons, HFO, R-32 in air-conditioning equipment. Besides, the standards on flammability is another critical factor that affects the choice of refrigerants in the sector: in Italy there is no a classification that distinguishes highly flammable, mildly flammable and not flammable substances (as for European and international standards) but at the legislative level it is distinguished only between flammable and non-flammable substances and thus, all the mildly flammable refrigerants (such as R-32) are classified as high flammable, by limiting their use. In June 2020 the decree of the Ministry of the Interior on *"Fire prevention provisions for air conditioning systems included in activities subject to fire prevention controls*[6]*"*entered in force (DM 73/2020). This decree allows the possibility of using, in air conditioning systems for public activities (hotels, schools, etc..), machines equipped with refrigerants classified as Al or A2L, according to ISO 817 «Refrigerants - designations and safety classification 'or equivalent standard. Thus a major use of alternatives, some also flammable such as R-32 is expected for coming years.

Table 4.67 Total HFC emissions from Stationary Air Conditioning sector, 1996 - 2020 (t)

2.F.1.f - Stationary Air Conditioning TOTAL EMISSIONS	1996	2000	2005	2010	2015	2017	2018	2019	2020
COMPOUND (t)									
HFC-134a	1.84	10.58	142.47	146.57	183.06	228.85	283.65	345.72	236.94
HFC-125	0.32	3.40	153.45	316.45	495.28	634.25	751.43	925.31	855.12
HFC-32	0.31	3.22	149.10	312.30	490.61	663.98	817.22	1,043.63	1,077.66
Total HFC emissions - Stationary Air Conditioning	*2.46*	*17.19*	*445.03*	*775.32*	*1,168.95*	*1,527.09*	*1,852.30*	*2,314.67*	*2,169.72*

HFC emissions from refrigeration equipment increased from 1994 driven by the increase of their consumptions. HFC total consumptions started to decrease from 2015 due to the reduction of the quantity of hydrofluorocarbons placed on the market as well as the restrictions for some products and equipment derived from the entering in force of the European F-gases Regulation (UE, 2014).
Over the entire series, the maximum value of gases consumptions was registered in 2014 with 6,135.06 t. Due to the reduction of HFC consumptions, in 2020 total refrigeration emissions registered a decrease in comparison with the 2019 (2,637.86 t emitted in 2020 compared to 2,745.06 t emitted in 2019), table 4.68. With the methodology approach followed, emissions reduction will occur in the following years.

Table 4.68 Total HFC emissions from Refrigeration sector (t) (manufacturing emissions plus lifetime emissions and disposal emissions), 1994-2020

Refrigeration Total emissions	1994	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.a - Commercial Refrigeration										
HFC-32 (t)	0.00	0.00	0.00	0.00	0.00	2.34	34.57	62.24	86.80	108.88
HFC-125 (t)	0.00	1.47	84.51	379.17	668.53	880.15	909.10	888.43	857.27	816.79
HFC-134a (t)	0.00	0.07	163.85	402.94	624.02	887.66	916.59	920.12	916.96	907.57
HFC-143a (t)	0.00	1.61	96.75	435.44	768.25	1,008.20	994.92	931.21	860.92	783.96
Total HFC emissions (t)	*0.00*	*3.16*	*345.12*	*1,217.55*	*2,060.80*	*2,778.35*	*2,855.18*	*2,802.00*	*2,721.95*	*2,617.20*
2.F.1.b - Domestic Refrigeration										
HFC-134a (t)	11.04	23.94	34.32	19.94	46.02	30.02	17.02	15.96	9.82	8.14
Total HFC emissions (t)	*11.04*	*23.94*	*34.32*	*19.94*	*46.02*	*30.02*	*17.02*	*15.96*	*9.82*	*8.14*

6Air conditioning systems for activities open to the public, such as schools, hotels, sport centers etc.

2.F.1.c - Industrial Refrigeration										
HFC-23 (t)	0.00	1.15	5.69	11.92	15.30	15.28	14.78	14.03	13.29	12.52
Total HFC emissions (t)	*0.00*	*1.15*	*5.69*	*11.92*	*15.30*	*15.28*	*14.78*	*14.03*	*13.29*	*12.52*
Total HFC emissions (t) Refrigeration sector	***11.04***	***28.24***	***385.13***	***1,249.41***	***2,122.12***	***2,823.65***	***2,886.99***	***2,831.99***	***2,745.06***	***2,637.86***

HFC emissions from MAC, Foam blowing, Fire extinguishers and Aerosols sub-sectors increased from 1994 driven by the increase of their consumptions (table 4.69). HFC consumptions from MAC and Foam blowing started to decrease from 2016 due to the reduction of the quantity of hydrofluorocarbons placed on the market as well as the restrictions for some products and equipment derived from the entering in force of the European F-gases Regulation (EU, 2014). Because of the methodology approach followed, emissions reduction will occur in the following years.

Table 4.69 HFC emissions from MAC, Foam blowing, Fire extinguishers and Aerosols sectors, 1990-2020 (t)

COMPOUND (t)	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.F.1.e - Mobile Air Conditioning										
HFC-134a (t)	0.00	204.59	685.04	928.82	1,063.88	1,072.73	1,091.70	1,081.59	1,069.38	1,040.89
Total HFC emissions (t)	*0.00*	*204.59*	*685.04*	*928.82*	*1,063.88*	*1,072.73*	*1,091.70*	*1,081.59*	*1,069.38*	*1,040.89*
2.F.2.a - Foam blowing (closed cell)										
HFC-245fa (t)	0.00	0.00	0.00	140.56	229.14	302.03	297.96	288.28	275.77	260.55
HFC-134a (t)	0.00	0.00	49.37	180.07	213.81	234.74	229.62	221.87	212.20	200.71
Total HFC emissions (t)	*0.00*	*0.00*	*49.37*	*320.63*	*442.95*	*536.77*	*527.58*	*510.14*	*487.97*	*461.27*
2.F.3 - Fire Extinguishers										
HFC-227ea (t)	0.00	3.88	40.21	158.63	299.20	389.71	408.94	412.44	414.07	413.90
HFC-23 (t)	0.00	0.14	1.49	5.88	11.08	13.98	12.62	11.99	11.39	10.82
HFC-125	0.00	0.29	2.98	11.75	22.16	28.87	30.29	30.55	30.67	30.66
Total HFC emissions (t)	*0.00*	*4.31*	*44.68*	*176.26*	*332.44*	*432.56*	*451.84*	*454.98*	*456.13*	*455.37*
2.F.4 - Aerosol										
HFC-134a (t)	0.00	0.00	81.54	225.32	200.69	129.37	144.97	179.74	182.87	158.49
Total HFC emissions (t)	*0.00*	*0.00*	*81.54*	*225.32*	*200.69*	*129.37*	*144.97*	*179.74*	*182.87*	*158.49*

4.7.7 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures.

Air conditioning category, as well as refrigeration, foam blowing, fire extinguishers and aerosols has been analysed with experts of the national associations, in the framework of the study planned by the agreements with the Ministry of Ecological Transition for a survey, about HFCs alternative substances with low GWP, natural refrigerants and alternative technologies. A continuous sharing of information between the experts of national association and the Inventory team is ongoing.

The Regulation n. 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases (EC, 2006), has been transposed into a national decree in 2012, by the Decree of the President of the Republic 27 January 2012, n. 43 (DPR 43/2012), now replaced by the new Decree of the President of the Republic 16 November 2018, n. 146 (DPR 146/2018). In particular, the article 3(6) of the Regulation n. 842/2006 has been transposed in the art. 16 of the national Decree 43/2012, where was stated that every year by the 31 May, the operator of the refrigeration, air conditioning and heat pump equipment, as well as fire protection systems, which contain more than 3 kg of fluorinated greenhouse gases, submitted to ISPRA data on emissions referred to those application. With the new Decree ISPRA is not involved in the data collection anymore.

ISPRA has developed a specific website, where each operator requests username and password and compiles the Declaration, available from 2012 up to 2017.
Data are still of course not complete, and consequently not comparable with inventory data, but a preliminary analysis has been done, on data collected for 2013, resulting in product life factor for the commercial appliances much far lower compare to product life factors reported in the IPCC GPG and Guidelines, as enhanced in the following box.

Categories	Product Life Factor			
	2013 Declaration data	2014 Declaration data	IPCC Guidelines 2006	Inventory 2020
			%	
Air Conditioning	5.4	3.2	1-10	1-18
Commercial Refrigeration	9.8	11.3	1–35 1-35 (1-15 for Stand alone and 10-35 for large and medium)	5 (small appliances) 15-12 (large and medium)
Fire Protection	1.6	0.4	5	5.0%

A report concerning 2013-2014 F-gas data has been published by ISPRA (ISPRA, 2018 [b]).
Information from the reporting (EC, several years) under article 6 of the Regulation n. 842/2006 (EC, 2006) and article 19 Regulation n. 517/2014 (EU, 2014), as well information from the National Database of the refrigeration, air conditioning and fire protection systems, established by the article 16 of DPR 43/2012, has been analysed.
Information from the reporting above is checking with import and export data directly from the companies: in fact, from the beginning of 2017 ISPRA has contacted the companies involved in the reporting system, asking to provide data on import/export both from/to European countries and not European countries, and, where available, sales data distinguished for application, at a country level. Collected data is incomplete and an evaluation process by ISPRA is ongoing.

4.7.8 Source-specific recalculations

Recalculation affected the emission estimates of Commercial Refrigeration and Stationary Air conditioning sectors. Regarding the commercial refrigeration the recalculation is due to the introduction in 2015 of three new refrigerants, R-448A, R-449A and R-452A, as substitutes of R-404A and R-507A. The quota of these gases increased from 2015 to 2020, as a result of the F-gas Regulation. Consequently, the R-404A and R-507 consumptions for the last years were updated with data obtained by consulting the new National Telematic Registry of fluorinated greenhouse gases and equipment containing fluorinated gases.
For the Stationary air conditioning sector the recalculation is due to the revision of the charge of R-32 machines sold and manufactured. In detail, as this refrigerant is more efficient, the charge was reduced by 20% compared to the charge of the same machines using 410A.
Besides, unlike the previous submission, this year hybrid machines were included in the estimates. These machines are similar to chillers with capacity up to 50 kW, so the parameters used for chillers were assigned to hybrid machines with the same capacity. Data for the hybrid machines are available from 2014 and are provided by Assoclima.
A review of the activity data was also carried out which resulted in the correction of some values. The following table 4.70 shows the differences between the current submission and last year submission for what concern the Commercial refrigeration and the Stationary Air Conditioning sectors.

Table 4.70 Differences between 2021 and 2022 submission

COMPOUND (t)	1996	2000	2005	2010	2015	2016	2017	2018	2019
2.F.1.a – Commercial Refrigeration									
Submission 2021									
HFC-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HFC-125	8.09	84.51	379.17	668.53	877.20	889.74	899.79	848.10	804.32
HFC-134a	0.61	163.85	402.94	624.02	885.66	897.18	889.98	870.90	848.61
HFC-143a	9.32	96.75	435.44	768.25	1,008.20	1,022.63	1,034.19	974.79	924.47

COMPOUND (t)	1996	2000	2005	2010	2015	2016	2017	2018	2019
Total HFC emissions Commercial Refrigeration	***18.02***	***345.12***	***1,217.55***	***2,060..80***	***2,771.06***	***2,809.55***	***2,823.95***	***2,693.78***	***2,577.40***
Submission 2022									
HFC-32	0.00	0.00	0.00	0.00	2.34	14.31	34.57	62.24	86.80
HFC-125	8.09	84.51	379.17	668.53	880.15	907.65	909.10	888.43	857.27
HFC-134a	0.61	163.85	402.94	624.02	887.66	909.39	916.59	920.12	916.96
HFC-143a	9.32	96.75	435.44	768.25	1,008.20	1,022.63	994.92	931.21	860.92
Total HFC emissions Commercial Refrigeration	***18.02***	***345.12***	***1,217.55***	***2,060.80***	***2,778.35***	***2,853.97***	***2,855.18***	***2,802.00***	***2,721.95***
2.F.1.f - Stationary Air Conditioning									
Submission 2021									
HFC-134a	1.84	10.59	142.34	146.43	183.03	215,79	228.71	283.33	344,62
HFC-125	0.32	3.40	152.98	316.14	495.03	575.41	633.73	750.52	918,82
HFC-32	0.31	3.22	148.63	312.00	490.36	586.09	672.70	835.10	1,061.01
Total HFC emissions Stationary Air Conditioning	***2.47***	***17.20***	***443.95***	***774.58***	***1,168.42***	***1,377.30***	***1,535.14***	***1,868.95***	***2,324.44***
Submission 2022									
HFC-134a	1.84	10.58	142.47	146.57	183.06	215.75	228.85	283.65	345.72
HFC-125	0.32	3.40	153.45	316.45	495.28	575.75	634.25	751.43	925.31
HFC-32	0.31	3.22	149.10	312.30	490.61	583.06	663.98	817.22	1,043.63
Total HFC emissions Stationary Air Conditioning	***2.46***	***17.19***	***445.03***	***775.32***	***1,168.95***	***1,374.56***	***1,527.09***	***1,852.30***	***2,314.67***

No recalculation has occurred for, MAC, Foam blowing, Fire extinguishers and Aerosols sub-sectors.

4.7.9 Source-specific planned improvements

To improve our estimation in all the sectors above described we are constantly in contact with the national experts and Associations in order to collect any new information that gradually become available. For the stationary air conditioning sector the focus is on emissions from disposal, recovered and containers management, on the HFCs topping up, the use of alternatives refrigerants, in substitution of the traditional HFC and on the changes in the percentage distribution of equipments by refrigerant type and by average charges, over the years. For the Refrigeration sector also disposal and recovered emissions and the HFC topping up are topics to be investigated, as the information about the refrigerants market, the presence and use of new HFCs with lower GWP or natural refrigerants, such as CO_2. This gas is entering the market especially with the transcritical configuration adopted in supermarket and hypermarket. The effects of the growing prices of the traditional gases and the reduction of their availability, together with the bans of F-gas regulation, is causing the switch to alternative substances and thus the reduction of HFC emissions. A further fact-finding survey on organized large-scale distribution, and trade retail for the commercial refrigeration subsector is also planned in order to use this information for integrating and/or checking the estimation method used at present. For the Foam blowing the investigation focuses on the consumption of other F-gases eventually used in the sectors (for example HFC-365mfc and HFC-227ea) and on the different contribution of closed cell and open cell foams to the emissions. At moment, no information and data on this topics are available.

Improvements should be obtained by consulting the new National Telematic Registry of fluorinated greenhouse gases and equipment containing fluorinated gases that has been instituted by the DPR 146/2018, entered in force in January 2019. We have already started to check data of the Register and, from a first analysis, it emerged that the information contained is not always in the form and at the level of detail useful for estimating of the Inventory. In recent months, in order to overcome these problems, we contacted the Responsables of the Registry. After waiting for the our required changes to be implemented, we downloaded data and we are currently processing and evaluating them. We expect to report the results of these elaborations in the next year submission.

Finally, we have started to investigate the dryers and washer-dryers heat pump machines sector. According to Applia Italia, that we contacted, these machines have been starting to use HFC (R-134a, R-450A, R-407C) since recent times and R-290 is indicated as the main alternative to HFC. For all these machines the

manufacturing loss rate is estimated less than 1% (Applia Italia, 2019). To date, no further specific data is available to allow an estimate of emissions but we remain in constant contact with the Association, to check the availability of new information over time.

4.8 Other product manufacture and use (2G)

4.8.1 Source category description

The sub-sector "Other product manufacture and use" consists of the following sub-applications:
2.G.1 – SF_6 Emissions from electrical equipment
2.G.2 – SF_6 used in equipment in university and research particle accelerators
2.G.3 – N_2O from product uses
The share of SF_6 emissions from the sector in the national total of SF_6 was 72% in the base-year 1990, and 82.5% in 2020, whereas in the national total of F-gases, the share of SF_6 emissions from the sector was 7.8% in 1990 and 1.32% in 2020. N_2O accounts for only 2.6% of the national total N_2O emissions in 2020.

4.8.2 Methodological issues

Electrical Equipment (SF6)

As regard SF_6 emissions from electrical equipment, these have been estimated according to the IPCC Tier 2 approach. Concerning manufacturing and installation emissions, since 1995 the methodology used is largely in accordance with the IPCC Tier 3 methodology. In 1997, the ANIE Federation has begun a statistical survey within their associated companies, in accordance with ISPRA, in order to monitor yearly SF_6 used in electrical equipment > 1kV, and thus SF_6 manufacturing emissions (ANIE, 2001). ANIE Federation is the Confindustria member representing the electrotechnical and electronic companies operating in Italy. ANIE has developed data sheets for their associated companies in accordance with the methodology drawn up by CAPIEL, the Coordinating Committee for the Associations of Manufacturers of Switchgear and Controlgear equipment in the European Union: the CAPIEL inventory methodology covers all sorts of use of SF_6 in the electrical sector, from the SF_6 purchase till the end of life of the equipment and covers all aspects of the required data (CAPIEL, 2002). It is based on a Mass Balance Methodology, as given by IPCC Tier 3b, comparing the input and output on a yearly basis.
In the following box the summary sheet used for manufacturing inventory is reported (ANIE, several years).

SF_6 inventory at manufacturing level (ANIE, reporting year 2020)

<table>
<tr><th colspan="3">INVENTORY'S CATEGORIES</th><th></th><th></th><th>Year 2020 (kg)</th></tr>
<tr><td rowspan="2">1. Purchased amount</td><td colspan="2">1.1 In Italy</td><td>Weight of SF_6 contained in the tanks</td><td rowspan="2"></td><td>19,699</td></tr>
<tr><td colspan="2">1.2 Abroad</td><td>Weight of SF_6 contained in the tanks</td><td>50,348</td></tr>
<tr><td colspan="4"></td><td>TOTAL 1.</td><td>70,047</td></tr>
<tr><td rowspan="4">2. Amount contained in the equipment at the terms of sale</td><td rowspan="3">2.1 In Italy</td><td>2.1.1 ENEL</td><td>Weight of SF_6 contained in the equipment and in the tanks</td><td rowspan="4"></td><td>14,994</td></tr>
<tr><td>2.1.2 Energy industry and railways</td><td>Weight of SF_6 contained in the equipment and in the tanks</td><td>18,030</td></tr>
<tr><td>2.1.3 Others (Industry, Tertiary, Private, ecc.)</td><td>Weight of SF_6 contained in the equipment and in the tanks</td><td>10,293</td></tr>
<tr><td>2.2 Abroad</td><td></td><td>Weight of SF_6 contained in the equipment and in the tanks</td><td>14,906</td></tr>
<tr><td colspan="4"></td><td>TOTAL 2.</td><td>58,223</td></tr>
<tr><td colspan="3">3. Amount contained in the equipment returned to the manufacturer</td><td>Weight of SF_6 contained in the equipment and in the tanks</td><td>TOTAL 3.</td><td>0,000</td></tr>
<tr><td colspan="3">4. a) Destroyed amount</td><td>Weight of SF_6 in the equipment sent to authorized disposal treatment</td><td></td><td>0</td></tr>
</table>

INVENTORY'S CATEGORIES			Year 2020 (kg)
4. b) Amount returned to the manufacturer	Weight of SF_6 returned to manufacturer for authorized recycling		2,415
		TOTAL 4.	**2,415**
5. Annual stock changes		**TOTAL 5.**	**8,921**
SF_6 emissions from manufacturing	**Balance input-output (1+3-5)-(2+4)**		**488**

From 1990 to 1994 emissions have been estimated on the basis of leakage rate during manufacturing and installation and the amount of SF_6 contained in the equipment sold to the end users, because, for this period, only data referred to point 1 and point 2 of the box, are available from ANIE.
The loss rates during manufacturing and installation of the equipment, used to estimate the SF_6 emissions, are reported in table 4.71. Leakage rates have been derived from ANIE Federation expert judgement.

Table 4.71 Leakage rates used to estimate SF_6 emissions from manufacturing and installation from 1990 to 1994

	1990	1991	1992	1993	1994
Manufacturing	0.060	0.060	0.060	0.060	0.060
Installation	0.060	0.055	0.050	0.045	0.040

In Table 4.72, SF_6 emissions from manufacturing (which include installation), use and disposal are reported. Emissions from manufacturing were about 14 tons in 1995, whereas in 2019 are only 0.79 tons, due to the great increase of the SF_6 recycled.
Emissions trend from manufacturing is strongly decreasing thanks to the diligence of the companies involved, which have taken voluntary actions to reduce emissions as much as technically possible. Probable fluctuations within the time series in manufacturing emissions are basically due to yearly variation of the stocked quantity of SF_6.

Table 4.72 SF_6 emissions from manufacturing, use and disposal from 1990 to 2020

SF_6 EMISSIONS (Mg)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Manufacturing	8.470	14.657	5.637	3.562	3.185	1.259	1.684	1.255	1.558	0.795	0.488
Use	0.460	4.886	6.469	9.592	10.302	11.648	10.868	12.313	12.769	12.568	8.442
Disposal	0.000	0.623	0.464	0.199	0.059	0.037	0.054	0.044	0.089	0.088	0.000
Total	**8.930**	**20.165**	**12.571**	**13.353**	**13.546**	**12.945**	12.606	**13.612**	**14.415**	**13.452**	**8.930**

SF_6 use emissions are those from Closed Pressure Systems, including high voltage equipment that requires refilling with gas during its lifetime. Equipment use emissions are estimating by multiplying the quantity of SF_6 yearly accumulated by a use emission factor. The quantity of SF_6 accumulated is estimated using SF_6 annual sales activity data (ANIE, several years), multiplied for the factor 0.8, which take into account the percentage of the total sales referred to Closed Pressure Systems. Moreover, equipment use emissions are the sum of three components:

- emissions from ENEL (the former electricity monopoly);
- emissions from electricity utilities and the national railways company;
- emissions from industries and other private operators.

Since 1994, refilling data of SF_6 used in high voltage gas-insulated transmission lines have been supplied by the main energy distribution companies (in the past included in ENEL) checked with data reported under the national PRTR register (EDIPOWER, several years; EDISON, several years; ENDESA, 2004; ENDESA, several years [a] and [b]; ENEL, several years; TERNA, several years).
The leakage rate used to estimate the SF_6 use emissions is assumed equal to 0.01 from 1990 to 2009 and 0.005 from 2010, based on national expert judgment (AIET, 2007).
Finally, SF_6 disposal emissions from electrical equipment are estimating by multiplying the quantity of SF_6 contained in retired equipment by the fraction of SF_6 left in the equipment at the end of its life, assumed to be constant and equal to 0.15 from 1990 to 1995, and linearly decreasing until to 2010 value 0.03, as reported in table 4.73. Since 1995, activity data (point 3 of the SF_6 inventory at manufacturing level reported above) are

directly supplied by ANIE (ANIE, several years), whereas from 1990 to 1994 the total amount of SF_6 accumulated in the equipment is multiplied by a disposal rate which is equal to zero in that period. Leakage disposal rate and disposal rate derived from personal communication.

Table 4.73 Disposal rates and leakage rate at disposal used to estimate SF_6 emissions from disposal, 1990-2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Disposal rate	0	0	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Leakage rate at disposal	0.15	0.15	0.11	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03

As for fluctuation in emissions within the years, Figure 4.4 is reported for a better understanding.
As regard the years from 1995 to 2000, please consider that the total SF_6 emission values result by the sum of emissions from "manufacturing", "operating" and "retiring" and that concerning the trends of these contributions the following facts should be pointed out:
1) emissions from manufacturing reach a peak in 1997;
2) emissions from operating reach a peak in 1997;
3) emissions from retiring reach a peak in 1997 although the relevant contributions to total SF_6 emissions are those from manufacturing and operating.
Data between 1995 and 2000 are consistent and come from the SF_6 mass balance.
In Figure 4.5 the time series for SF_6 purchased amounts and of the three contributions to SF_6 emissions from electrical equipment are illustrated. It could be noted that the trend of the amounts of SF_6 estimated for "manufacturing" is driven by the trend of purchased SF_6.

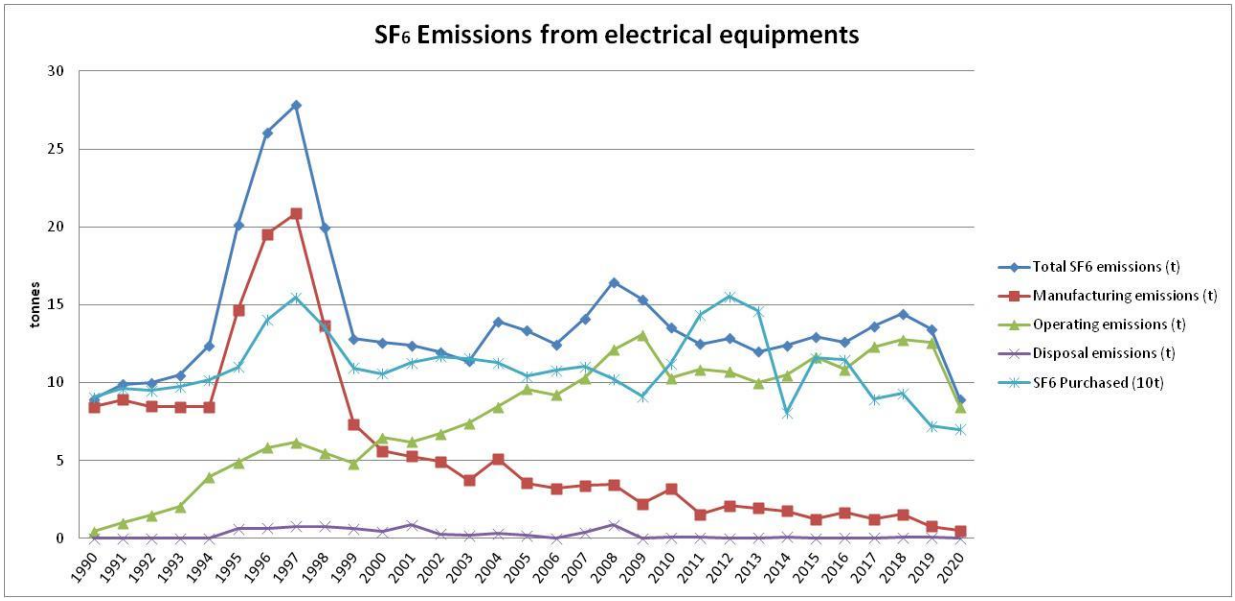


Figure 4.5 Time series for SF_6 purchased amounts and emissions from electrical equipment

SF6 used in equipment in university and research particle accelerators

SF_6 Emissions from research particle accelerators have been estimated from 1990. A survey on the particle accelerators used for research purpose has been carried on, asking directly information to the national research institutes: INFN, the National Institute for Nuclear Physics and INAF the National Institute of Astrophysics.
INFS has supplied refilling data of SF_6 for four particle accelerators located in three laboratories, Catania, Legnaro and Firenze (INFN, several years), for the entire time series 1990–2020. These particle accelerators use SF_6 from 1984, 1981, 1976 and 2004 respectively. INAF doesn't use SF_6 in their research activities.
SF_6 emissions from industrial and medical particle accelerators have been estimated from 1990 too. As for research particle accelerators, a survey on the accelerators used for medical purposes has been carried on.
In Italy particle accelerators for medical purposes are supplied by only three companies, Siemens Healthcare, Varian Medical System and Elekta. Data on the number of accelerators and the charge of SF_6 have been communicated from 1990 (Siemens, several years; Varian, several years).

N_2O from product use

N_2O emissions from the use of N_2O for anaesthesia, aerosol cans and explosives are estimated.

Emissions of N_2O have been estimated taking into account information available by industrial associations. Specifically, the manufacturers and distributors association of N_2O products has supplied data on the use of N_2O for anaesthesia from 1994 (Assogastecnici, several years). For previous years, data have been estimated by the number of surgical beds published by national statistics (ISTAT, several years [a]). It is assumed that all N_2O used will eventually be released to the atmosphere, therefore the emission factor for anaesthesia is equal to 1 Mg N_2O/Mg product use.

Moreover, the Italian Association of Aerosol Producers (AIA, several years [a] and [b]) has provided data on the annual production of aerosol cans used for whipped cream which contain N_2O as propellant. Emission factor used is 0.025 Mg N_2O/Mg product use, because the N_2O content is assumed to be 2.5% on average (Co.Da.P., 2005). The association provides also the number of aerosol cans for other uses (cosmetics, household and cleaning products, pharmaceutical products) and the propellants (LPG and HFC-134a for pharmaceutical products); relevant emissions are estimated in domestic solvent use category as NMVOC and in HFC-134a emissions from aerosols/metered dose inhalers category.

For the estimation of N_2O emissions from explosives, data on the annual consumption of explosives have been obtained by a specific study on the sector (Folchi and Zordan, 2004); as stated in the document, this figure is believed to be constant for all the time series with a variation within a range of 30%. As for the emission factor, the estimated N_2O emissions represent the theoretically maximum emittable amount; in fact, no figures are available on the amount of N_2O emissions actually emitted upon detonations and the value of 3,400 Mg N_2O/Mg explosive use is provided by a German reference (Benndford, 1999) which corresponds to the assumption of 68 g N_2O per kg ammonium nitrate.

N_2O emissions have been calculated multiplying activity data, total quantity of N_2O used for anaesthesia, total aerosol cans and explosives, by the related emission factors.

4.8.3 Uncertainty and time series consistency

The uncertainty in SF_6 emissions from electrical equipment and particle accelerators is estimated to be 20.6% in annual emissions, 5% and 20% concerning respectively activity data and emission factors.

In table 4.74 an overview of SF_6 emissions from electrical equipment and particle accelerators is given for the 1990-2020 period.

SF_6 emissions from electrical equipment increased from 1995 to 1997 and decreased in the following years; from 2004 emissions are enough stable: they are driven by emissions from manufacturing due to the amount of fluid filled in the new manufacturing products while emissions from stocks are slightly increasing.

Table 4.74 SF_6 emissions from other product manufacture and use, 1990-2020 (t)

COMPOUND (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2.G.1											
SF_6 emissions from electrical equipment	8.9	20.2	12.6	13.4	13.5	12.9	13.6	14.4	13.5	8.9	8.9
2.G.2.b											
SF_6 emissions from research particle accelerators	4.0	4.0	4.0	4.7	1.7	5.7	1.8	3.2	3.2	0.5	4.0
Total SF_6 emissions from 2G sector	**12.9**	**24.2**	**16.6**	**18.1**	**15.2**	**18.6**	**15.4**	**17.6**	**16.7**	**9.5**	**12.9**

The combined uncertainty in N_2O emissions is estimated equal to 11.2% due to an uncertainty in activity data of 5% and 10% in the emission factor. N_2O emissions remain almost at the same levels from 1990 onwards although, from 2000, a reduction is detected, due to a decrease in the anaesthetic use of N_2O that has been replaced by halogen gas. Table 4.75 shows the N_2O emission trend from 1990 to 2020.

Table 4.75 Trend in N_2O emissions from product uses, 1990 – 2020 (kt)

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2.G.3 Other product manufacture and use: N_2O (kt)											
N_2O from product uses (use of N_2O for anaesthesia, aerosol cans and explosives)	2.62	2.49	3.31	2.66	2.02	1.57	1.72	1.87	1.89	1.74	1.71

4.8.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures. Where information is available SF_6 data for refilling have been checked with data reported to the national EPER/E-PRTR registry.
For N_2O emissions from anaesthesia and aerosol cans, emission factors and emissions are also shared with the relevant industrial associations.
Other relevant uses of SF_6, as listed in the IPCC Guidelines, have been investigated to study the occurrence at national level. Some of these applications could be excluded, such as car tyres, sound proof windows and shoes soles also due to manufacturing additional costs. With regard to the other potential sources of emissions, such as SF_6 emissions from AWACs, in 2014 the Italian Air Force has been contacted in order to investigate the presence of such aircraft. The Italian Air Force answered that such kind of aircraft is a NATO aircraft and according to the Decision 3/CP.3 of the Kyoto Protocol, emissions resulting from multilateral operations pursuant to the Charter of the United Nations shall not be included in national total.

4.8.5 Source-specific recalculation

For 2.G sector minor recalculation occurred due to the update of SF6 topping up activity data.

4.8.6 Source-specific planned improvements

A revision of the article 16 of the Decree of the President of the Republic 27 January 2012, n. 43 has been adopted due to the enter into force of the F-Gases Regulation n. 517/2014 (EU, 2014), including in its scope also electrical equipment, which will improve the control and monitoring system of the appliances. Raw data from the National F-gases Register have been downloaded and a first picture of involved quantities of SF_6 sold and added in electrical switchgear for the year 2020 are reported in Table 4.76.

Table 4.76 – SF_6 data from National F-gases Register

Quantities of SF_6 (kg)	
Sales of gas	**Year 2020**
Total SF_6 sold	110,558.4
Reclaimed	12,084.0
Virgin	98,474.4
Installation of electrical switchgear	14,571.0
Added	14,440.0
Recycled	154.2
Reclaimed	672.7
Virgin	13,613.2
Recovered	131.0
Maintenance of electrical switchgear	35,417.4
Added	22,382.8
Recycled	943.7
Reclaimed	10,713.2
Virgin	10,726.0
Recovered	13,034.6
Repair of electrical switchgear	3,395.9
Added	1,670.3
Recycled	215.9
Reclaimed	210.4
Virgin	1,244.0
Recovered	1,725.6
Dismantling of electrical switchgear	15,416.1
Recovered	15,416.1

4.9 Other production (2H)

4.9.1 Source category description

Only indirect gases and SO_2 emissions occur from these sources.

In this sector, non-energy emissions from pulp and paper as well as food and drink production, especially wine and bread, are reported. CO_2 from food and drink production (e.g. CO_2 added to water or beverages) can be of biogenic or non-biogenic origin but only information on CO_2 emissions of non-biogenic origin should be reported in the CRF.

According to the information provided by industrial associations, CO_2 emissions do not occur, but only NMVOC emissions originate from these activities.

CO_2 emissions from food and beverages do not occur since they originated from sources of carbon that are part of a closed cycle.

As regards the pulp and paper production, NO_X and NMVOC emissions as well as SO_2 are estimated. NO_X and SO_2 emissions have been referred to the paper and pulp production from acid sulphite and neutral sulphite semichemical processes up to 2009, activity data and emissions were provided by the two Italian production plants: in 2008 the bleached sulphite pulp production has stopped while in 2009 the neutral sulphite semi-chemical pulp process has closed (reconversion of the plant is currently under negotiation). NMVOC emissions are related to chipboard production and have been estimated and reported.

5 AGRICULTURE [CRF sector 3]

5.1 Sector overview

In this chapter information on the estimation of greenhouse gas (GHG) emissions from the Agriculture sector, as reported under the IPCC Category 3 in the Common Reporting Format (CRF), is given. Emissions from enteric fermentation (3A), manure management (3B), rice cultivation (3C), agriculture soils (3D), field burning of agriculture residues (3F), liming (3G), urea application (3H) and other carbon-containing fertlizers (3I) are included in this sector. Methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions are estimated and reported. Savanna areas (3E) are not present in Italy. Emissions from other sources (3J) do not occur. Also, F-gas emissions do not occur.

To provide update information on the characteristics of the agriculture sector in Italy, figures from the latest available Agricultural Census (2010) are reported. According to ISTAT (ISTAT, 2008[a], 2012), in Italy there are 1.6 million of farms with a total Utilized Agricultural Area (UAA) of 12.9 million hectares, +0.9% more than the total a Utilized Agricultural Area (UAA) pointed out from Farm Structure Survey (FSS) 2007. Comparing the data from the last four censuses (see box below), it can be noted as the number of farms and the agricultural area have decreased; in particular, between 2000 and 2010, the reduction of farms is equal to 32% (775,390 units). At national level, the average size of farms varied from 5.5 hectares in 2000 to 7.9 hectares in 2010. This trend is in line with the average size of farms increment from 7.4 hectares (in 2005) to 7.6 hectares (in 2007) observed by FSS. However, more than 50% of farms have an area of less than 2 hectares of UAA. The distribution of farms by type confirms a typical family conduction system, which characterized the Italian agriculture system. About 1.5 million farms (95.4% of the total agricultural holdings with UAA) are under direct farmers conduction. These farms hold about 11 million hectares of UAA (82.8% of total)[7] (EUROSTAT, 2007[a], [b], 2012; ISTAT, 2008[a]).

CREA[8] annually update figures of the agriculture sector such as added value, employment, productivity, are available (CREA, 2020).

Farms characteristics from Agricultural Censuses

Farms characteristics	1982	1990	2000	2010
Number of farms	3,133,118	2,848,136	2,396,274	1,620,884
Utilized agricultural area - hectares	15,832,613	15,025,954	13,181,859	12,856,048
Total area of farms - hectares	22,397,833	21,628,355	18,766,895	17,081,099
Average size of farms	5.1	5.3	5.5	7.9

On the basis of the 2013 FSS (ISTAT, 2015), the number of farms and the UAA decreased by 9.5% and 3.3% respectively, compared to the figure recorded in the last agricultural census. A further decrement of 29.4% and 2.0% of number of farms and the UAA, respectively, with respect to 2010 values (see table above) are described in 2016 FSS (ISTAT, 2018). Therefore, the average size of farms increases from 7.9 to 8.5 hectares (according to the 2013 FSS) and 11.0 hectares (according to the 2016 FSS).

In 2013 the number of organic farms exceeded 47 thousand units (equivalent to 3.2% of the total farms and 5.8% of the total UAA), an increase of 4.7%, compared to the 2010 Census. In 2016 the number of organic farms become 132 thousand units and, therefore, it has almost tripled compared to the the 2010 Census. The utilized agricultural area, which corresponds to 1,555,522 hectares in 2016, has increased by 24% in the same period.

5.1.1 Emission trends

Emission trends per gas

In 2020, 8.6% of the Italian GHG emissions, excluding emissions and removals from LULUCF, (7.1% in 1990) are originated from the agriculture sector. Therefore, it is the second source of emissions, after the energy and followed by IPPU sector which accounts for 78.4% and 8.1%, respectively. For the agriculture sector, the trend of GHGs from 1990 to 2020 shows a decrease of 11.4% due to the reduction of the activity data, such as the number of animals, the cultivated surface/crop production, the amount of synthetic nitrogen fertilisers

[7] Agricultural Census data are available at the link http://dati-censimentoagricoltura.istat.it/

[8] Council for agricultural research and analysis of the agrarian economy https://www.crea.gov.it/en/about-crea

applied, and the changes in manure management systems (see Figure 5.1). In 2020, CH_4, N_2O and CO_2 emissions account for 59.0%, 39.5% and 1.5%, respectively. In the period 1990-2020, CH_4, N_2O and CO_2 emissions have decreased by 13.5%, 8.4% and 1.3%, respectively (see Table 5.1). In 2020, the agriculture sector has been the first source for CH_4 sharing 45.1% of national CH_4 levels and for N_2O accounting for 66.3% of national N_2O emissions. As for CO_2, the agriculture sector represents 0.2% of national CO_2 emissions.

Table 5.1 GHG emissions and trend from 1990 to 2020 for the agriculture sector (Gg CO_2 eq.)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CH_4	22,299	22,011	21,373	19,747	19,264	19,246	19,155	19,157	18,869	18,975	19,259	19,304	19,142	19,100	19,279
N_2O	14,091	15,071	14,739	13,882	11,910	12,382	12,587	11,877	11,955	11,774	12,288	11,923	11,875	11,824	12,902
CO_2	510	567	571	564	381	404	592	481	444	458	594	456	442	430	503
Total	**36,900**	**37,649**	**36,682**	**34,192**	**31,555**	**32,032**	**32,334**	**31,515**	**31,268**	**31,207**	**32,141**	**31,684**	**31,460**	**31,354**	**32,685**

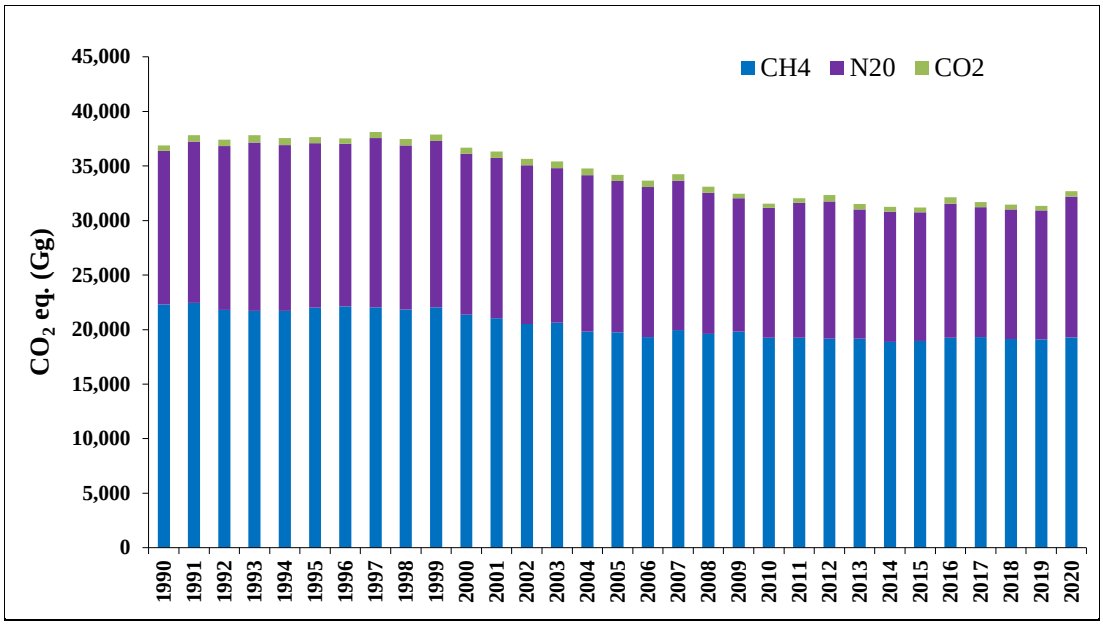


Figure 5.1 Trend of GHG emissions for the agriculture sector from 1990 to 2020 (Gg CO_2 eq.)

Emission trends per sector

Total GHG emissions and trends by subcategory from 1990 to 2020 are shown in Table 5.2 (expressed in Gg. CO_2 eq.). CH_4 emissions from enteric fermentation (3A) and N_2O emissions from direct managed soils (3D) are the most relevant categories. In 2020, their individual share in national GHG emissions excluding LULUCF was 3.6% and 2.8%, respectively.

Table 5.2 Total GHG emissions from 1990 to 2020 for the agriculture sector (Gg CO_2 eq.)

	GHG emissions (Gg CO_2 eq.) by sub category						
Year	**3A**	**3B**	**3C**	**3D**	**3F**	**3G-H-I**	**TOTAL**
1990	15,564	7,676	1,876	11,254	19	510	**36,899.5**
1995	15,399	7,314	1,989	12,361	18	567	**37,648.7**
2000	15,128	7,193	1,656	12,116	18	571	**36,682.4**
2005	13,293	7,095	1,752	11,468	20	564	**34,192.1**
2010	12,884	6,874	1,822	9,575	19	381	**31,555.2**
2011	12,885	6,824	1,805	10,095	19	404	**32,032.4**
2012	12,931	6,637	1,789	10,364	20	592	**32,333.7**
2013	13,085	6,533	1,661	9,736	19	481	**31,514.9**
2014	12,932	6,392	1,613	9,868	19	444	**31,267.9**
2015	13,035	6,353	1,668	9,672	20	458	**31,206.7**
2016	13,315	6,334	1,715	10,161	21	594	**32,140.8**
2017	13,429	6,335	1,646	9,799	19	456	**31,683.8**

	GHG emissions (Gg CO_2 eq.) by sub category						
Year	**3A**	**3B**	**3C**	**3D**	**3F**	**3G-H-I**	**TOTAL**
2018	13,381	6,233	1,601	9,784	19	442	**31,460.0**
2019	13,364	6,206	1,583	9,752	19	430	**31,353.6**
2020	13,535	6,225	1,582	10,820	19	503	**32,684.5**

5.1.2 Key categories

In 2020, CH_4 emissions from enteric fermentation and manure management, direct N_2O emissions from manure management, direct and indirect N_2O emissions from managed soils were ranked among the level key sources with the Approach 2, including the uncertainty (L2). CH_4 emissions from enteric fermentation, direct and indirect N_2O emissions from managed soils were ranked among the trend key sources with Approach 2, including the uncertainty (T2). Including LULUCF sector in the analysis, CH_4 emissions from enteric fermentation, direct and indirect N_2O emissions from managed soils are key sources at trend assessment with Approach 2 (T2). In Table 5.3, key and non-key categories from the agriculture sector are shown, with a level and/or trend assessment (*IPCC Approach 1 and Approach 2*), excluding and including the LULUCF sector in the analysis.

Table 5.3 Key-sources identification in the agriculture sector with the IPCC Approach 1 and Approach 2 for 2020

GHG source categories			***excluding LULUCF***	***including LULUCF***
3A	CH_4	Emissions from enteric fermentation	Key (L, T)	Key (L, T)
3B	CH_4	Emissions from manure management	Key (L)	Key (L, T1)
3Ba	N_2O	Direct emissions from manure management	Key (L)	Key (L)
3Bb	N_2O	Indirect emissions from manure management	Non-key	Non-key
3C	CH_4	Rice cultivation	Key (L1)	Key (L1)
3Da	N_2O	Direct emissions from managed soils	Key (L, T)	Key (L, T)
3Db	N_2O	Indirect emissions from managed soils	Key (L, T2)	Key (L, T)
3F	CH_4	Emissions from field burning of agriculture residues	Non-key	Non-key
3F	N_2O	Emissions from field burning of agriculture residues	Non-key	Non-key
3G	CO_2	Liming	Non-key	Non-key
3H	CO_2	Urea application	Non-key	Non-key
3I	CO_2	Other carbon-containing fertilizers	Non-key	Non-key

5.1.3 Activities

Emission factors used for the preparation of the national inventory reflect the characteristics of the Italian agriculture sector. Information from national research studies is considered. Activity data are mainly collected from the National Institute of Statistics (ISTAT, *Istituto Nazionale di Statistica*). Every year, national and international references, and personal communications used for the preparation of the agriculture inventory are archived in the *National References Database.*

Improvements for the Agriculture sector are described in the Italian Quality Assurance/Quality Control plan (ISPRA, several years [a]). Moreover, an internal report describes the procedure for preparing the agriculture UNFCCC/CLRTAP national emission inventory and projections (Di Cristofaro, several years).

Results from several research projects have improved the quality of the agriculture national inventory (MeditAIRaneo project and Convention signed between ISPRA and the Ministry for the Environment, Land and Sea; CRPA, 2006[a], CRPA, 2006[b], CRPA, 2018). Furthermore, recommendations and outcomes from the UNFCCC inventory review processes have been considered and implemented. Methodologies for the preparation of agriculture national inventory under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the United Nations Framework Convention on Climate Change (UNFCCC) are consistent. Synergies among international conventions and European directives while preparing the agriculture inventory are implemented.

The national agriculture UNFCCC/CLRTAP emission inventory is used, every 4 years (from 2021; previously it was every 5 years), to prepare a more disaggregated inventory by region and province as requested by CLRTAP (Cóndor *et al*., 2008[b]). A database with the time series for all sectors and pollutants is available (ISPRA, 2021; ISPRA, 2009; ISPRA, several years [b]). The methods and emission factors applied for GHG inventory are also used for emission scenarios and projections (MATTM, 2017).

5.1.4 Agricultural statistics

Every year, the Italian National Statistical System (SISTAN[9]) revises the National Statistical Plan that covers three years and includes, among others, the system of agricultural statistics. In this framework, the Agriculture, Forestry and Fishing Quality Panel has been established under the coordination of the Agriculture service of ISTAT where the producers and key users of agricultural statistics (mainly public institutions) meet each other every year to monitor and improve national statistics. ISTAT plays the major role in the agricultural sector collecting comprehensive data through different surveys (Greco and Martino, 2001):

- Structural surveys (Farm Structure Survey, survey on economic results of the farm, survey on the production inputs);
- Conjunctural surveys[10] (survey on the cultivation area and relative production, livestock number, milk production, slaughter, fertilizers, etc.);
- General Agricultural Census[11], carried out every 10 years (1990, 2000, 2010).

Detailed information on the agriculture sector is found every two/three years in the Farm Structure Survey, FSS[12] (ISTAT, 2018; ISTAT, 2015; ISTAT, 2008[a]; ISTAT, 2007[a]; ISTAT, 2006[a]). ISTAT has provided quality reports of the FSS 2005 and FSS 2007 (ISTAT, 2008[b]; ISTAT, 2007[d]) and a report on the assessment of the quality of the agricultural census data (ISTAT, 2013). The main agricultural statistics used for the agriculture emission inventory are available on-line. Detailed information is provided in Table 5.4.

Table 5.4 Main activity data sources used for the Agriculture emission inventory

Agricultural statistics	Time series	Web site
Livestock number	Table 5.7; 5.8; 5.12; 5.15	http://dati.istat.it/
Milk production	Table 5.7	http://dati.istat.it/
Fertilizers	Table 5.38; 5.45	http://dati.istat.it/
Crops production/surface	Table 5.48; Tables A.7.19-20-23	http://dati.istat.it/

Differences on some animal populations data are found comparing national statistics and FAOSTAT[13] data. FAO publishes figures of the *x-1* year on 1st January of the *x* year. Each year ISPRA verifies the official statistics directly contacting the experts responsible for each agricultural survey (number of animals, agricultural surface/production, fertilizers, etc). Agricultural statistics reported by ISTAT are also those published in the European statistics database[14] (EUROSTAT). A couple of anomalies were found in the EUROSTAT cattle statistics: the data for cattle subcategories also contain values for buffaloes, despite the fact that there are specific labels for buffaloes in the EUROSTAT database; between 2014 and 2015 for some subcategories there was a methodological change in the estimation of the number of animals, with obvious anomalous increases/decreases in the data. These anomalies have been reported to EUROSTAT.
Whenever outliers are identified, these are shown to ISTAT and category associations. Slight differences in the livestock number (cattle and other swine) are found comparing conjunctural surveys (used for emissions estimation) and the Agricultural census for the year 2010 (ISTAT, 2012), while differences are more relevant[15] for the other categories. The verification of statistics is part of the implemented QA/QC procedures. The livestock data represents the number of animals present on the farm at any given time of the year (conventionally June the 1st or December the 1st). Therefore, livestock figures do not represent the number of animals produced annually; for animal populations that are alive for only part of a complete year, the annual average population is estimated on the basis of "places" instead of the days of life and the number of cycles.

5.2 Enteric fermentation (3A)

5.2.1 Source category description

Methane is produced as a by-product of enteric fermentation, which is a digestive process where carbohydrates are degraded by microorganisms into simple molecules.

[9] SISTAN, *Sistema Statistico Nazionale* (http://www.sistan.it/)
[10] http://agri.istat.it/
[11] http://censagr.istat.it/; http://dati-censimentoagricoltura.istat.it/
[12] Indagine sulla struttura e produzione delle aziende agricole (SPA), survey carried out every two years in agricultural farms.
[13] FAOSTAT http://www.fao.org/faostat/en/#home
[14] http://ec.europa.eu/eurostat/data/database
[15] The number of heads of conjunctural surveys of the sows, sheep, goats, mules and asses, broilers, laying hens categories is on average 15% higher than the census, whereas for other poultry the difference is 30% and for horses and rabbits is more than double.

Methane emissions from enteric fermentation are a key category, in terms of level and trend assessment, for Approach 1 and Approach 2. All livestock categories have been estimated except camels and llamas, which are not present in Italy. Methane emissions from poultry and fur animals are not applicable. Emissions from rabbits, mules and asses, goats, buffalo and horses are estimated and included in "Other livestock" as shown in the CRF tables.
In 2020, CH_4 emissions from this category were 541.39 Gg which represents 70.2% of CH_4 emissions for the agriculture sector (69.8% in 1990) and 31.6% for national CH_4 emissions excluding LULUCF (31.5% in 1990). Methane emissions from this source consist mainly of cattle emissions: dairy cattle (222.29 Gg) and non-dairy cattle (208.92 Gg). These two sub-categories represented 41.1% (47.2% in 1990) and 38.6% (37.4% in 1990) of total enteric fermentation emissions, respectively.

5.2.2 Methodological issues

Methane emissions from enteric fermentation are estimated by defining an emission factor for each livestock category, which is multiplied by the population of the same category. Data for each livestock category are collected from ISTAT (several years [a], [b], [c], [f], [g]; ISTAT, 1991; 2007[a], [b]). Livestock categories, provided by ISTAT, are classified according to the type of production, slaughter or breeding, and the age of animals. In Table 5.5, livestock categories and source of information are provided. Parameters for the livestock categories are shown in Table 5.31. In order to have a consistent time series, it was necessary to estimate the number of animals for some categories. The estimation is based on information available from other official sources such as FAO and UNAITALIA (FAO, several years; UNAITALIA, several years).

Table 5.5 Activity data for the different livestock categories

Livestock category	Source
Cattle	ISTAT
Buffalo	ISTAT
Sheep	ISTAT
Goats	ISTAT
Horses	ISTAT/FAO(a)
Mules and asses	ISTAT/FAO(a)
Swine	ISTAT
Poultry	ISTAT/UNAITALIA(b)
Rabbits	ISTAT(c)

(a) Reconstruction of a consistent time series; (b) For 1990 data from the census and reconstruction for broilers, hens and other poultry based on meat production (UNAITALIA, several years); (c) For 1990 data from the census and reconstruction based on a production index (ISTAT, 2007[b]; ISTAT, several years [k])

Dairy cattle

Methane emissions from enteric fermentation for dairy cattle are estimated using a Tier 2 approach, following the 2006 IPCC Guidelines (IPCC, 2006). Feeding characteristics are described in a national publication (CRPA, 2004[a]) and have been discussed in a specific working group in the framework of the MeditAIRaneo project (CRPA, 2006[a]; CRPA, 2005). Parameters used for the calculation of the emission factor are shown in Table 5.6.

Table 5.6 Parameters for the calculation of dairy cattle emission factors from enteric fermentation

Parameter	Value	Reference	IPCC 2006(*)
Average weight (kg)	602.7	CRPA, 2006[a]	600
Coefficient NE_m (lactating cows)	0.386	NRC, 2001; IPCC, 2006	0.386
Pasture (%)	5	CRPA, 2006[a]; ISTAT, 2003	0(**)
Weight gain (kg day^{-1})	0.051	CRPA, 2006[a]; CRPA, 2004[b]	0
Milk fat content (%)	3.59-3.88	ISTAT, several years[a], [b], [d], [e], [h]	
Hours of work per day	0	CRPA, 2006[a]	0
Portion of cows giving birth	0.97-0.91	AIA, several years[a]	0.9
Milk production (kg $head^{-1}$ day^{-1})	11.5-23.7	CRPA, 2006[a]; OSSLATTE/ISMEA, 2003; ISTAT, several years[a], [b], [c], [d], [e], [f], [h]; OSSLATTE, 2001	16.4
Digestibility of feed (%)	68.77	CRPA, 2006[a]; CRPA, 2005; IPCC, 2006	65
Methane conversion factor (%)	5.98	CRPA, 2006[a]; IPCC, 2006	6.5
Energy content of methane (MJ/kg methane)	55.65	IPCC, 2006	55.65

(*) Data for estimating tier 1 enteric fermentation CH_4 emission factors for dairy cows (Western Europe); (**) Stall fed (feeding situation)

The coefficient for calculating net energy for maintenance (NE_m) for dairy cattle is the default value of the 2006 IPCC Gidelines.
The national statistics on milk production were analysed. Milk used for dairy production and milk used for calf feeding contributes to total milk production. The latter was estimated on national and ISTAT publications (ISTAT, several years[h]). For the calculation of milk production (kg $head^{-1}$ d^{-1}), total production is divided by the number of animals and by 365 days, as suggested by the IPCC (IPCC, 2006). Therefore, lactating and non-lactating periods are included in the estimation of the CH_4 dairy cattle EF (CRPA, 2006[a]).
Following a recommendation raised during 2018 UNFCCC review, additional information on the share of grazing animals is reported. The dairy cattle, reared in the mountain areas (above the 600 meters of altitude) were assigned to pasture for three months a year (MeditAIRaneo project - CRPA, 2006[a]); the percentage of abovementioned animals is equal to 5% of the national total, in line with 2010 General Agricultural Census data.
In Table 5.7, the time series of the dairy cattle population, fat content in milk, portion of cows giving birth and milk production are shown. Further information on parameters used for dairy cattle estimations is reported in Annex 7.1.
According to the 2019 IPCC Refinement (IPCC, 2019), DE e Ym parameters for dairy cows have been estimated considering average annual milk production per cow and per production level (low "<5000 kg/head/year", medium "5000-8500 kg/head/year" and high ">8500 kg/head/year") and information on animal diets. On the basis of data from the Italian Livestock Breeders' Association (AIA) on average annual milk production and the number of dairy cows in production, by region and breed, the distribution of animals was calculated according to the three productivity levels identified by the 2019 IPCC Refinement, for the years 2004-2019. The AIA carries out milk productivity checks on behalf of the Ministry of Agriculture and each year the sample of animals checked is about 50% of the number of animals reared. The difference in cow numbers between the AIA total and the ISTAT total (used for emission estimates) was attributed to the low production level. The DE values assigned to the three production levels (low, medium, high) are 62, 65 and 70.11% of gross energy intake respectively and were identified in collaboration with the CRPA (Research Centre on Animal Production) dairy cow feeding experts. The value 62 is the minimum value of the range indicated in Table 10.12 for low producing cows of the 2019 IPCC Refinement (Chapter 10 of the Volume 4). The value 65 is lower than the average value of the range indicated in Table 10.12 for medium producing cows. The value 70.11 for high-producing cows is a weighted average of two values: the first is 65 (corresponding to diets with DE≥70 and NDF≥35) and was attributed to 27% of the high-producing cows fed without silage fodder; the second is 72 (corresponding to diets with DE≥70 and NDF≤35) and was attributed to 73% (=100-27%) of the high-producing cows fed with silage fodder. With reference to the 27% of cows, this value includes cows whose milk is intended for the production of Parmigiano Reggiano (17% of total cows), and cows fed with good quality dry and green fodder (e.g. for the production of Trentingrana PDO (Protected Designation of Origin), Latte Fieno STG (Traditional Speciality Guaranteed) and other mountain cheeses) which correspond to the other 10% of total cows. In support of the choices made for high productivity values, mention is made of a study published in 2020 (Gislon et al, 2020) carried out on eight Italian Friesian cows in multiparous lactation, with high productivity, using a 4 × 4 replicated Latin square pattern. The experimental design of the square involves all cows receiving all diets (with adaptation periods between each), so 2 groups of 4 cows that rotated 4 times on 4 diets have been considered. The number of observations for each diet is 32. According to CRPA experts, the cow effect is nullified because all of them received all diets and, therefore, the results obtained are irrefutable and highly representative. Four diets, based on the following forages (expressed in % of dry matter of forages, DM, and in the neutral detergent fiber content, NDF, expressed as % of dry matter intake), were tested: corn silage (CS, 49.3; 32.8 NDF), alfalfa silage (AS, 26.8; 27.1 NDF), wheat silage (WS, 20.0; 33.7 NDF), and a typical hay-based Parmigiano Reggiano cheese production diet (PR, 25.3 of both alfalfa and Italian ryegrass hay; 36.7 NDF). The lowest DM digestibility was observed for the PR diet (64.5%) and the highest for the CS diet (73.3%); AS and WS diets showed intermediate values (71.4 and 70.3% respectively). PR diet is associated with diets with DE≥70 and NDF≥35 in Table 10.12 of the 2019 IPCC Refinement (Chapter 10 of the Volume 4) and the other three diets are associated with diets with DE≥70 and NDF≤35 in the same table. For the year 2020, the percentages of dairy cows according to the three productivity levels (low, medium e high milk production) are 78.9%, 12.3% and 8.8%, respectively. The digestibility values associated with these productivity levels are, as previously mentioned, 70.11%, 65% and 62%, respectively. With these data, the average digestibility value of the diets consumed by dairy cows was estimated in 68.77%. The weighted average value of Ym for the year 2020 is 5.98% of gross energy intake. This value was estimated from the percentage distribution of dairy cows according to the three productivity levels and using the default factors given in Table 10.12 of the 2019 IPCC Refinement (Chapter 10 of the Volume 4). These values are:

for lactating phase, 6.5 for low producing cows, 6.3 for medium producing cows, 6.0 and 5.7 for high producing cows; for dry phase, 7 for low producing cows, 6.3 for medium and high producing cows. From the two values for high producing cows in lactating phase, a weighted average value of 5.78 was estimated for the year 2020, with the distribution of cows according to diet type, shown above: 27% of high-productivity cows are associated with diets with DE≥70 and NDF≥35 (Ym 6.0); 73% of high-productivity cows are associated with diets with DE≥70 and NDF≤35 (Ym 5.7).
In Table 5.14, the dairy cattle emission factors (EF) are reported. In 2020, the CH_4 dairy cattle EF was 135.7 kg CH_4 head^{-1} year^{-1} with an average milk production of 8,665 kg head^{-1} year^{-1} (23.7 kg head^{-1} day^{-1}). The IPCC default EF is 117 kg CH_4 head^{-1} year^{-1} with a milk production of 6,000 kg head^{-1} year^{-1} (IPCC, 2006).

Table 5.7 Parameters used for the estimation of the CH_4 emission factor for dairy cattle

Year	Dairy cattle (head)	Fat content in milk (%)	Portion of cows giving birth	Milk production yield (kg head^{-1} d^{-1})
1990	2,641,755	3.59	0.97	11.5
1995	2,079,783	3.64	0.95	14.8
2000	2,065,000	3.65	0.93	15.1
2005	1,842,004	3.71	0.91	17.2
2010	1,746,140	3.72	0.90	18.8
2011	1,754,981	3.73	0.90	18.5
2012	1,857,004	3.75	0.89	17.7
2013	1,862,127	3.78	0.89	17.5
2014	1,830,990	3.77	0.90	18.7
2015	1,826,484	3.76	0.89	19.1
2016	1,821,764	3.79	0.90	19.7
2017	1,791,120	3.81	0.91	20.7
2018	1,693,332	3.71	0.91	22.2
2019	1,643,117	3.72	0.91	22.9
2020	1,638,382	3.88	0.91	23.7

Non-dairy cattle
For non-dairy cattle, CH_4 emissions from enteric fermentation are estimated with a Tier 2 approach of the 2006 IPCC Guidelines. The estimation of the EF uses country-specific data, disaggregated livestock categories (see Table 5.8), and it is based on dry matter intake (kg head^{-1} day^{-1}) calculated as percentage of live weight (CRPA, 2000; INRA, 1988; NRC, 1984; NRC, 1988; Borgioli, 1981; Holter and Young, 1992; Sauvant, 1995). Dry matter intake is converted into gross energy (MJ head^{-1} day^{-1}) using 18.45 MJ/kg dry matter conversion factor (IPCC, 2006). Emission factors for each category are calculated with equation 10.21 from 2006 IPCC guidelines (Chapter 10 of the Volume 4).
In Table 5.9, parameters used for the estimation of non-dairy cattle EF are shown. Average weights have been assessed with information from the Nitrogen Balance Inter-regional Project (CRPA, 2006[a]; Regione Emilia Romagna, 2004). For reporting purposes, some animal categories are aggregated, such as the non-dairy cattle and the swine categories.
The non-dairy cattle category includes different sub-categories as shown in Table 5.8; consequently, the gross energy intake, CH_4 conversion factor and EFs for this category are calculated as a weighted average.

Table 5.8 Non-dairy cattle population (heads) classified by type of production and age

Year	<1 year		1-2 years males		1-2 years females		>2 years males	>2 years females			
	for slaughter	others	breeding	for slaughter	breeding	for slaughter	all	breeding	for slaughter	others	**Total**
1990	300,000	2,127,959	72,461	708,329	749,111	186,060	128,958	467,216	57,654	312,649	**5,110,397**
1995	458,936	1,796,034	27,871	783,300	684,881	154,548	155,116	430,564	40,198	657,856	**5,189,304**
2000	408,000	1,783,000	27,521	641,479	736,000	160,000	93,000	500,000	51,000	588,000	**4,988,000**
2005	500,049	1,418,545	26,424	615,921	588,660	181,971	102,081	466,566	37,971	471,733	**4,409,921**
2010	507,452	1,228,696	23,913	557,386	597,733	212,983	70,284	445,370	70,411	372,089	**4,086,317**
2011	509,904	1,272,903	23,461	546,847	600,769	222,859	70,018	433,336	72,430	390,017	**4,142,544**
2012	441,975	1,081,177	21,231	494,860	671,688	177,308	76,035	485,930	54,694	380,708	**3,885,606**
2013	483,556	1,125,354	21,385	498,456	674,431	180,269	88,765	508,504	72,514	331,311	**3,984,545**

Year	<1 year		1-2 years males		1-2 years females		>2 years males	>2 years females			
	for slaughter	others	breeding	for slaughter	breeding	for slaughter	all	breeding	for slaughter	others	**Total**
2014	495,477	1,122,919	19,647	457,950	637,686	200,131	75,649	531,358	62,128	322,135	**3,925,080**
2015	492,126	1,141,545	19,966	465,391	638,566	205,966	82,304	524,745	64,570	319,685	**3,954,864**
2016	492,461	1,200,405	20,786	484,504	680,427	212,205	83,543	566,277	67,064	300,331	**4,108,003**
2017	485,250	1,206,116	21,294	496,344	704,296	231,499	100,101	543,379	79,508	290,486	**4,158,273**
2018	468,628	1,197,152	22,385	521,772	707,316	238,496	102,171	565,573	91,878	314,501	**4,229,872**
2019	461,877	1,241,787	22,615	527,137	723,737	256,341	99,095	546,867	99,932	352,442	**4,331,830**
2020	463,597	1,253,974	22,574	526,175	726,873	260,935	101,006	536,547	101,810	361,142	**4,354,633**

Table 5.9 Main parameters used for non-dairy cattle CH_4 emission factor estimations

	<1 year	1-2 years males		1-2 years females		>2 years males	>2 years females		
Parameters	Others (*)	breeding	for slaughter	breeding	for slaughter	all	breeding	for slaughter	Others
Average weight (kg)	236	557	557	405	444	700	540	540	557
Percentage weight ingested	2.1	1.9	2.1	2.1	2.1	2.4	2.1	2.1	1.9
Dry matter intake (kg head $^{-1}$ day^{-1})	4.8	10.7	11.6	8.5	9.3	17.1	11.5	11.5	10.6
Gross Energy (MJ head^{-1}day^{-1})	89.4	197.3	214.8	156.9	171.2	315.5	212.2	212.2	195.3
CH_4 conversion (%)	4	4.5	4	6	4	6	6	6	6

(*) It has been considered that calves for slaughter of <1 year do not emit CH_4 emissions, as they are milk fed. Therefore, the average weight for the category "others" of <1 year considers fattening male cattle, fattening heifer and heifer for replacement.

EFs reflect the national characteristics of Italian breeding as well as the age classification of animals and dry matter intake.

The Nitrogen Balance Inter-regional Project (CRPA, 2006[a]) provided data to estimate the CH_4 conversion factors. The project was carried out in cooperation with the Italian regions having the highest concentration of livestock; data on breeding performance, on feed consumption, on the characteristics and composition of rations were analyzed. The production of methane per head was estimated on the basis of the estimate of dry matter intake, calculated as weight percentage, by applying a conversion factor of energy intake into methane. Methane conversion factors were estimated from IPCC defaults and on the basis of ration digestibility; the ration of fattening animals is considered more digestible than the ration of replacement animals rich in fibre (CRPA, 2006[a]). As requested by the 2019 and 2021 UNFCCC review, detailed information is reported in Annex 7, addressing the request of provision of additional information on the CH_4 conversion factors for non-dairy cattle category (Annex 7.1) raised by previous review processes.

In Table 5.14, Implied Emission Factors (IEF) for non-dairy cattle are shown. In 2020, the non-dairy cattle EF was 48.0 kg CH_4 head^{-1} year^{-1}, while the 2006 IPCC Guidelines default EF is 57 kg CH_4 head^{-1} year^{-1} (Chapter 10 of Volume 4). The inter-annual decrease 2005/2006 of the IEF for non-dairy cattle is related to the reduction in the number of animals for some sub-categories and an increase in the number of the '*less than 1 year for the slaughter*' category (no emissions) (see Table 5.8). This last category (calves) has not been considered when estimating methane emissions as they are milk fed. The relevant parameters, for estimating N_2O emissions from manure management, for this category, are the following:

- Average body weight: 157 kg;
- Nitrogen excretion: 14.6 kg N/head/year;
- Average milk period: 4-6 months;
- Average weight at slaughter: less than 300 kg.

As regards the share of grazing animals, the same value used for dairy cattle was assumed for the other females in the category non-dairy cattle and no grazing is assumed for the males (see paragraph *Dairy cattle*).

Buffalo

Data collected in the framework of the MeditAIRaneo project allowed for the implementation of the 2006 IPCC Tier 2 approach for the buffalo category. Two different country-specific CH_4 EFs, for cow buffalo and other buffaloes, were estimated. Detailed description of the methodology is reported in Cóndor *et al*. (Cóndor *et al*., 2008[a]). In 2020, the CH_4 EFs were 87.6 and 61.8 kg CH_4 head^{-1} year^{-1} for cow buffaloes and other buffaloes respectively. The CRF IEF is an average value for the two categories (76.6 kg CH_4 head^{-1} year^{-1}). Parameters used for the Tier 2 approach are shown in Table 5.10 and 5.11.

Table 5.10 Parameters to estimate emission factors from enteric fermentation of cow buffalo

Parameters	Value	Reference
Average body weight (kg)	630	Infascelli, 2003; Consorzio per la tutela del formaggio mozzarella di bufala campana, 2002
Coefficient NE_m (lactating cows)	0.386	IPCC, 2006
Pasture (%)	2.90	ISTAT, 2003; Zicarelli, 2001; De Rosa and Di Francia, 2006
Weight gain (kg day^{-1})	0.055	Infascelli, 2003; Consorzio per la tutela del formaggio mozzarella di bufala campana, 2002
Milk fat content (%)	7.73-6.98	ISTAT, several years [a], [b], [d], [e], [h]
Hours of work per day	0	De Rosa and Di Francia, 2006
Proportion of calving cows	0.89-0.84	Barile, 2005; De Rosa and Trabalzi, 2004
Milk production (kg head^{-1} day^{-1})	1.91-3.28	OSSLATTE/ISMEA, 2003; OSSLATTE, 2001; ISTAT, several years [a], [b], [c] [d], [e], [f], [h]
Digestibility of feed (%)	65	Infascelli, 2003; Masucci *et al*., 1997, 1999
Methane conversion factor (%)	6.5	CRPA, 2006[a]; IPCC, 2006
Energy content of methane (MJ/kg methane)	55.65	IPCC, 2006

The buffalo grazing is very infrequent, equal to 5%, in the provinces of Caserta and Frosinone, where according to the University of Naples experts (MeditAIRaneo project (CRPA, 2006[a]), 58% of national livestock are rised.

Table 5.11 Parameters to estimate emission factors from enteric fermentation of other buffaloes

Parameter	Calves (3 months-1 year)	Sub-adult buffaloes (1-3 years)
Average body weight (kg)	150	405
Dry matter intake (% of body weight head^{-1} day^{-1})	3.0	2.5
Dry matter intake (kg head^{-1} day^{-1})	4.5	10.1
Gross Energy (MJ head^{-1} day^{-1})	82.75	186.58
CH_4 conversion (%)	6.5	6.5
CH_4 emission factor (kg head^{-1} year^{-1})	26.46 (*)	79.54

(*) original CH_4 emission factor was 35.28 kg CH_4 head^{-1} year^{-1}; a correction factor of 9/12 has been applied in order to consider the time between 3 months and 1 year, therefore the final emission factor was 26.46 kg CH_4 head^{-1} year^{-1}.

The coefficient for calculating net energy for maintenance (NE_m) and the methane conversion factor (Ym) for buffalo are the default values of the 2006 IPCC Gidelines.

Sheep

Methane emissions from enteric fermentation for sheep are estimated using a Tier 2 approach, following the 2006 IPCC Guidelines (IPCC, 2006). Gross energy intake was estimated separately for three sub-categories: mature ewes, growing lambs, other mature sheep. Data of mature ewes and other sheep (which includes growing lambs and other mature sheep) are provided by ISTAT (as reported in the 5.1.4 *Agricultural statistics*). Growing lambs and other mature sheep were estimated by applying the percentages of 85% and 15% respectively to the total number of other sheep (CRPA, 2006[a]). In Table 5.12, time series of sheep population are shown.

Table 5.12 Sheep population (heads) classified by sub-categories

Year	Mature ewes (head)	Growing lambs (head)	Other mature sheep (head)
1990	7,492,089	1,060,089	187,075
1995	8,518,496	1,827,054	322,421
2000	8,334,000	2,341,750	413,250
2005	7,007,217	804,908	142,043
2010	7,089,123	689,259	121,634
2011	7,123,014	696,683	122,944
2012	6,296,701	611,174	107,854
2013	6,322,871	730,113	128,844
2014	6,203,164	818,428	144,428
2015	6,196,466	809,258	142,810
2016	6,315,172	824,247	145,455
2017	6,271,593	802,264	141,576
2018	6,187,969	842,511	148,678
2019	6,086,538	777,191	137,151
2020	6,110,114	785,443	138,608

The sharp decline between 2000 and 2005 is mainly due to the spreading of Bluetongue infectious desease in 2001. In addition, the sheep number reduction along the whole time-series has been cause by the gradual erosion of profit margins in the production system of Sardinia, the Italian administrative region which holds the largest number of farms rearing sheep.
Parameters used for the calculation of the emission factor are shown in Table 5.13.

Table 5.13 Parameters for the calculation of sheep emission factors from enteric fermentation

Parameter	Mature ewes	Growing lambs	Other mature sheep	Reference
Average weight (kg)	51	14	59	CRPA, 2006[a]
Coefficient NE_m	0.217	0.236	0.217-0.250 (1)	IPCC, 2006
Pasture (%) (2)	29	31	33	Estimated data
Weight gain (kg day^{-1}) (3)		0.019		ARA, 2017; Agraria, 2009; AIA, several years[b]
Milk production (kg $head^{-1}$ day^{-1})	0.30-0.38			ISTAT, several years[h], [l], [b]; ISTAT, 2006[a]
Wool production (kg $head^{-1}$ y^{-1})	1.88-1.31			ISTAT, several years[l]
Portion of ewes giving birth	0.93			AIA, several years[c]
Single birth fraction (%)	70.8-74.8			AIA, several years[b]
Double birth fraction (%)	29.2-25.2			AIA, several years[b]
Digestibility of feed (%)	65	75 (4)	65	IPCC, 2006 (5)
Methane conversion factor (%)	6.5	4.5 (4)	6.5	IPCC, 2006 (5)

(1) The value increased by 15% for intact males; (2) Values estimated assuming an average of 11 month on pasture for 8 hours per day; (3) Assumptions made: sex ratio 40% males and 60% females; weight at weaning (30 days) 10 kg; weight at slaughter (90 days) 18 kg for males and 17 kg for females; (4) diets based on forage and concentrates (LAORE, 2014); (5) see Table 10.2 and 10.13 of the 2006 IPCC Guidelines.

In the CRF tables, the weighted average values of parameters reported in Table 5.13 were considered for sheep category.
Considering DE parameter, Italy uses the average default value of Table 10.2 of the 2006 IPCC Guidelines, relating to the ruminant categories and class 'pasture fed animals'. DE parameter is accompanied by a general description of the type of diets corresponding to the default values indicated. A literature review on dairy sheep feeding (Molle et al., 2008) and an available database on fresh forages and supplement composition commonly used for feeding sheep (Molle and Cannas, 2015) show that sheep diet digestibility (on dry matter basis) averages 70% in adult ewes during lactation (6-4 months) when they are usually fed at pasture and receive concentrate and hay as supplements. In contrast, diet digestibility as low as 60% (FU[16] 0.5-0.7/ kg dry matter)

[16] Feed unit is the net energy contained in one kg of barley = 1760 kcal

is common in mature ewes fed standing-hay or hay with a low amount of concentrate during dry period (8-6 months). These data support the use of the median level of diet digestibility (65%) shown in Table 10.2 and 10.13 of the 2006 IPCC Guidelines.

Rabbits

Methane emissions from rabbits have been estimated using a country-specific EF suggested by the CRPA. Daily dry matter intake for brood-rabbits and other rabbits are 0.13 kg day^{-1} and 0.11 kg day^{-1}, respectively. Besides, a value of 0.6% has been assumed as CH_4 conversion rate (CRPA, 2004[c]).

Other livestock categories

A Tier 1 approach, with IPCC default EFs, is used to estimate CH_4 emissions from swine, goats, horses, mules and asses (IPCC, 2006).

In Table 5.14, EFs for all livestock categories (dairy cattle, non-dairy cattle, buffalo, swine, sheep, goats, horses, mules and asses and rabbits) are presented. In Table 5.15, time series of the number of animals are shown.

Table 5.14 Average CH_4 emission factors from enteric fermentation (kg CH_4 $head^{-1}$ $year^{-1}$)

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sheep	Goats	Horses	Mules and asses	Sows	Other swine	Rabbits
	average CH_4 EF (kg CH_4 $head^{-1}$ $year^{-1}$)									
1990	111.1	45.6	74.4	7.2	5.0	18.0	10.0	1.5	1.5	0.08
1995	123.6	47.4	75.8	7.0	5.0	18.0	10.0	1.5	1.5	0.08
2000	124.6	47.0	78.2	6.5	5.0	18.0	10.0	1.5	1.5	0.08
2005	122.5	46.4	84.6	7.4	5.0	18.0	10.0	1.5	1.5	0.08
2010	122.6	45.9	76.7	7.4	5.0	18.0	10.0	1.5	1.5	0.08
2011	121.6	45.6	77.8	7.3	5.0	18.0	10.0	1.5	1.5	0.08
2012	121.0	48.0	77.6	7.5	5.0	18.0	10.0	1.5	1.5	0.08
2013	120.2	47.5	76.3	7.3	5.0	18.0	10.0	1.5	1.5	0.08
2014	123.5	46.9	77.4	7.2	5.0	18.0	10.0	1.5	1.5	0.08
2015	124.8	46.9	77.2	7.3	5.0	18.0	10.0	1.5	1.5	0.08
2016	125.9	47.1	76.7	7.4	5.0	18.0	10.0	1.5	1.5	0.08
2017	128.3	47.3	77.3	7.4	5.0	18.0	10.0	1.5	1.5	0.08
2018	130.8	48.1	76.5	7.5	5.0	18.0	10.0	1.5	1.5	0.08
2019	131.9	48.1	76.2	7.5	5.0	18.0	10.0	1.5	1.5	0.08
2020	135.7	48.0	76.6	7.5	5.0	18.0	10.0	1.5	1.5	0.08

Table 5.15 Time series of number of animals from 1990 to 2020 (heads)

Year	Buffalo	Sheep	Goats	Horses	Mules and asses	Sows	Other swine	Rabbits	Poultry
					(heads)				
1990	94,500	8,739,253	1,258,962	287,847	83,853	650,919	7,755,602	14,893,771	173,341,562
1995	148,404	10,667,971	1,372,937	314,778	37,844	689,846	7,370,830	17,110,587	184,202,416
2000	192,000	11,089,000	1,375,000	280,000	33,000	708,000	7,599,000	17,873,993	176,722,211
2005	205,093	7,954,167	945,895	278,471	30,254	721,843	8,478,427	20,504,282	174,667,361
2010	365,086	7,900,016	982,918	373,324	46,475	717,366	8,603,753	17,957,421	175,912,339
2011	354,402	7,942,641	959,915	373,327	50,966	708,770	8,642,011	17,549,225	174,787,108
2012	348,861	7,015,729	891,604	395,913	59,865	621,446	8,040,080	17,465,477	174,647,830
2013	402,659	7,181,828	975,858	393,915	63,166	590,278	7,971,405	16,548,690	176,919,056
2014	369,349	7,166,020	937,029	390,886	67,016	585,714	8,090,378	16,435,598	175,563,904
2015	374,458	7,148,534	961,676	384,767	70,872	582,447	8,092,346	15,760,502	177,391,671
2016	385,121	7,284,874	1,026,263	388,324	74,215	558,065	7,919,865	15,207,274	178,690,367
2017	400,792	7,215,433	992,177	367,561	72,455	561,654	8,009,153	14,000,931	178,635,180
2018	401,337	7,179,158	986,255	367,561	72,455	556,807	7,935,425	12,089,836	175,021,627
2019	402,286	7,000,880	1,058,720	367,561	72,455	556,009	7,954,259	11,755,922	175,520,313

Year	Buffalo	Sheep	Goats	Horses	Mules and asses	Sows	Other swine	Rabbits	Poultry
					(heads)				
2020	407,027	7,034,164	1,065,712	367,561	72,455	568,550	7,974,479	11,010,203	178,906,532

5.2.3 Uncertainty and time-series consistency

Uncertainty related to CH_4 emissions from enteric fermentation was 20.2% for annual emissions, resulting from the combination of 3% of uncertainty for activity data and 20% for emission factors.

In the 2011 submission, Montecarlo analysis was also applied to estimate uncertainty of this category for 2009; an asymmetrical probability density distribution resulted from the analysis, showing uncertainties values equal to -21.8% and 31.7%. Different distributions have been assumed for the parameters; assumptions or constraints on variables have been appropriately reflected on the choice of type and shape of distributions. A summary of the results is reported in Annex 1.

In 2020, CH_4 emissions from enteric fermentation were 541.39 Gg, i.e. 13.0% lower than in 1990 (622.58 Gg). Between 1990 and 2020 cattle livestock has decreased by 22.7% (from 7,752,152 to 5,993,015 heads). Dairy cattle and non-dairy cattle have decreased by 38.0% (from 2,641,755 to 1,638,382) and 14.8% (from 5,110,397 to 4,354,633), respectively. The reduction in number of cattle is the main driver for the reduction in CH_4 emissions, particularly as emissions per head from cattle are more than 10 times greater than those of sheep or goat. In 2020, cattle contribute with 79.6% to total CH_4 emissions from enteric fermentation.

In Table 5.16, emission trends from the enteric fermentation category are shown. Emissions from swine (12.81 Gg), as reported in the CRF tables, are disaggregated in 'other swine' and 'sow'.

Table 5.16 Trend of CH_4 emissions from enteric fermentation (Gg)

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sheep	Goats	Horses	Mules and asses	Sows	Other swine	Rabbits	Total
1990	293.57	233.00	7.03	62.89	6.29	5.18	0.84	0.98	11.63	1.16	**622.58**
1995	256.99	246.22	11.25	75.17	6.86	5.67	0.38	1.03	11.06	1.33	**615.95**
2000	257.36	234.48	15.02	72.18	6.88	5.04	0.33	1.06	11.40	1.39	**605.14**
2005	225.58	204.65	17.36	58.69	4.73	5.01	0.30	1.08	12.72	1.59	**531.72**
2010	214.02	187.46	28.02	58.39	4.91	6.72	0.46	1.08	12.91	1.39	**515.36**
2011	213.32	188.81	27.58	58.28	4.80	6.72	0.51	1.06	12.96	1.36	**515.41**
2012	224.72	186.43	27.06	52.50	4.46	7.13	0.60	0.93	12.06	1.36	**517.24**
2013	223.91	189.39	30.70	52.67	4.88	7.09	0.63	0.89	11.96	1.29	**523.40**
2014	226.09	184.07	28.58	51.85	4.69	7.04	0.67	0.88	12.14	1.28	**517.28**
2015	227.92	185.57	28.90	52.34	4.81	6.93	0.71	0.87	12.14	1.22	**521.40**
2016	229.29	193.31	29.55	53.69	5.13	6.99	0.74	0.84	11.88	1.18	**532.60**
2017	229.75	196.84	30.98	53.36	4.96	6.62	0.72	0.84	12.01	1.09	**537.17**
2018	221.49	203.61	30.69	53.52	4.93	6.62	0.72	0.84	11.90	0.94	**535.25**
2019	216.67	208.15	30.67	52.75	5.29	6.62	0.72	0.83	11.93	0.91	**534.56**
2020	222.29	208.92	31.16	52.68	5.33	6.62	0.72	0.85	11.96	0.86	**541.39**

5.2.4 Source-specific QA/QC and verification

Data on cow's milk collection from farms for dairy industry provided by the AGEA were compared to official statistics provided by ISTAT, for the years 2004-2015. AGEA data were higher than the ISTAT ones, on average by 6% and 3% for the 2004-2007 and 2011-2013 period, respectively. In other years, the differences are negligible, in particular for the years 2014 and 2015.

Differences on sheep's milk collection data are found between FAOSTAT and national statistics (ISTAT). On average, FAO data are more than 40% higher than the ISTAT ones for the 1990-1995 period; then the difference decreases. After 2003, FAO data becomes lower than official ISTAT statistics. In the period 2005-2008, FAO data are equal to the total of the milk collected at the farms including the amount used on farms (of the ISTAT data). The milk directly suckled by calves is not considered. In the period 2009-2013, FAO data is only equal to the total of milk collected at the farms without the amount used on farms (of the ISTAT data). Information related to the 2010 Agricultural census has been analysed and verified, as mentioned in the paragraph 5.1.4.

5.2.5 Source-specific recalculations

As regards for CH_4 emissions from enteric fermentation, the changes were: emissions of dairy cattle since 2004 have been updated, considering weighted average of Ym for lactating and dry cows, as indicated in the 2019 IPCC Refinement; emissions of sheep have been updated for the whole time series, considering weighted average of Ca parameter for time spent on pasture and housing; number of rabbit heads have been updated for 2019.

5.2.6 Source-specific planned improvements

Considering the evolution of Italian beef sector in the last 5 years, a revision of the current feeding plan, diets and slaughtering categories is foreseen. The breeding of beef cattle in Italy has evolved in the last five years towards types of animals that are following the consumer's demand: leaner meat, hence also younger animals. Animals consume less dry matter and have higher energy and protein requirements. Therefore, they use less dry matter in relation to live weight, hence more concentrated diets. Based on the collected information, which will be provided by the CRPA, the updating of values relating to dry matter intake currently in use will be evaluated. In addition, the Ym values in use will be recalculated with the Ellis formula based on the updated results of the composition of the diets, and then compared with the values reported in the 2019 IPCC Refinements.

Additional data and information will be collected to improve the estimation of methane emissions from sheep, in particular for the DE parameter for mature ewes and other mature sheep, as recommended during the 2019 UNFCCC review. Actually, Italy uses the average default value of Table 10.2 of the 2006 IPCC Guidelines, relating to the ruminant categories and class 'pasture fed animals' and which is accompanied by a general description of the type of diets corresponding to the default values indicated. In the 2006 IPCC Gudelines (Chaper 10 of Volume 4), the data reported in Table 10A-9 (where there is no description of the data reported) do not fit with those of Table 10.2 probably because the Table 10A-9 was affected by a typo error (0.6% insead of 60%). This table has been removed from the 2019 IPCC Refinement. The data used have been confirmed by experts in the sheep sector of AGRIS Sardegna, the agency of the Region of Sardinia for scientific research, experimentation and technological innovation in the agricultural, agro-industrial and forestry sectors.

Information and administrative data related to number of heads, average weight by livestock category, feed rations of livestock for cattle and swine, milk production data will be collected by the Ministry of Agriculture as part of the 2016 December the 9th Decree of Ministry for the Environment, Land and Sea enteteled "*Attuazione della legge 3 maggio n. 79 in materia di ratifica ed esecuzione dell'Emendamento di Doha al Protocollo di Kyoto"* (GU, 2016[b]) and comparisons and verifications with the data used to estimate emissions will be carried out.

5.3 Manure management (3B)

5.3.1 Source category description

In 2020, CH_4 emissions from manure management were 165.89 Gg, which represents 21.5% of CH_4 emissions for the agriculture sector (21.7% in 1990) and 9.7% of national CH_4 emissions (9.8% in 1990). CH_4 emissions from cattle were 80.70 Gg and from swine were 70.07 Gg. These two sub-categories represented 48.6% and 42.2% of total CH_4 manure management emissions, respectively. CH_4 emissions from manure management also include emissions from ostriches and emissions from pasture of cattle and buffalo categories, as recommended during 2019 UNFCCC review.

N_2O direct and indirect emissions, produced during the storage and treatment of manure before it is applied to soils, are reported separately. In 2020, N_2O emissions from manure management were 6.97 Gg (of which 4.38 Gg are direct emissions and 2.60 Gg are indirect emissions), which represents 16.1% of total N_2O emissions for the agriculture sector (20.1% in 1990) and 10.7% of national N_2O emissions (10.4% in 1990). In 2020, direct N_2O emissions from manure management consist of the solid storage system (2.20 Gg), which includes also the chicken-dung drying process system, and of liquid system (2.18 Gg). N_2O emissions of the anaerobic digesters, another management system used in the country, are reported equal to zero in line with the 2006 IPCC Guidelines (IPCC, 2006).

In the framework of the Nitrogen Balance Inter-regional Project, parameters related to the estimation of CH_4 and N_2O emissions, such as average weight, production of slurry and solid manure and the nitrogen excretion rates, have been set.
CH_4 emissions and direct N_2O emissions from manure management are key sources at level, following Approach 1 and Approach 2, excluding and including the LULUCF sector in the analysis.

5.3.2 Methodological issues

The IPCC Tier 2 approach is used for estimating methane EFs for manure management of cattle, buffalo and swine. For estimating slurry and solid manure EFs and the specific conversion factors, a detailed methodology (*Method 1*) was applied at a regional level for cattle and buffalo categories. Then, a simplified methodology, for estimating EF time series, was followed (*Method 2*). Livestock population activity data is collected from ISTAT (see Table 5.7; Table 5.8; Table 5.15).

Methane emissions (cattle and buffalo)

Method 1: Regional basis

Methane emission estimations for manure management are drawn up on a regional basis and depend on specific manure management practices and environmental conditions (Safley *et al*., 1992; Steed and Hashimoto, 1995; Husted, 1993; Husted, 1994). The following factors are used: average monthly temperatures (ISPRA, 2020), amount of slurry and solid manure produced per livestock category (CRPA, 2018; CRPA, 2006[a]; Regione Emilia Romagna, 2004), storage temperatures and timescale for emptying manure storages for the application of slurry and solid manure to soils for agricultural purposes in Italy (CRPA, 1993).
For cattle and buffalo, the estimation of the EF starts with the calculation of the *methane emission rate* (g CH_4 m^{-3} day^{-1}), which is obtained from equations 5.1 and 5.2 reported below for slurry and solid manure respectively.
For the quantification of emissions from storage of cattle manure, the methodology adopted is based on the studies conducted by Husted. The Husted methodology allows estimating methane on the basis of the parameters defining the manure storage in Italy. These parameters, which are mentioned in the introduction of this section, are average monthly temperatures, amount of slurry and solid manure produced per livestock category, storage temperatures and timescale for emptying manure storages. This method was adopted as it is based on experimental surveys carried out in the field, in environmental and breeding conditions that are transferable to the Italian reality with appropriate adaptations. This methodology allows to modulate the mass of methane emitted in relation to changes in temperature on a monthly basis. The average annual temperature represents an approximate datum for the elaboration of the methane emission estimates, since the same average annual value can correspond to more or less wide temperature excursions between the months (Steed and Hashimoto, 1995). This is followed by different methane emissions from manure storage depending on the number of months for which the 10°C threshold is exceeded, below which emissions are considered negligible. According to the methodology adopted, the mass of methane is calculated on the basis of two parameters, one of which is measured experimentally in field conditions (emission per unit volume of manure in relation to temperature) and the other estimated (the amount of slurry and solid manure produced and stored).
Average monthly temperature data were updated based on SCIA[17] data. SCIA made available the climatic normal temperature values for the 30-year climatological periods 1961-1990, 1971-2000, 1981-2010 in raster format. Using GIS software, the raster data were converted into points and intersected with the shape of the municipal boundaries to which altitude and LU data (i.e. data on the number of animals reared at municipal level, expressed in units of adult cattle) were also associated. Average data of 1971-2000 climatological period were considered to etimate the emissions in the first decade of the time series (1990-2000), while average data of 1981-2010 climatological period were considered to etimate the emissions from 2001 onward. Temperature data above 1000 m were not considered. National average monthly temperature data (obtained by weighing provincial average monthly temperature data with LUs) were used to update methane emissions from storage, according to the country-specific methodology. This update resulted in a revision of the CH_4 estimate from manure management for cattle and buffalo categories. Temperature data, aggregated per province by weighting with LU, were used to recalculate MCF.
Equations are presented below (CRPA, 2006[a]; Husted, 1994).

[17] SCIA is the national system for the collection, elaboration and dissemination of climatological data, by ISPRA, in the framework of the national environmental information system, in collaboration with the relevant institutions: http://www.scia.isprambiente.it/wwwrootscia/Home_new_eng.html

For slurry:
CH_4 (g m^{-3} day^{-1}) = $e^{(0.68+0.12) * t (°C) (average monthly temperature)}$ *Eq. 5.1*

For solid manure:
CH_4 (g m^{-3} day^{-1}) = $e^{(-2.3+0.1) * t (°C) (average monthly storage temperature)}$ *Eq. 5.2*

The monthly storage temperature from the solid manure is estimated with the following equation (Husted, 1994):
T solid manure storage = $6,7086e^{0.1014t (°C) (average monthly temperature)}$

For temperatures below 10°C emissions are considered negligible.
The volume of slurry and solid manure produced per livestock category (m^3 $head^{-1}$) was obtained by multiplying the average production of slurry and solid manure per livestock category per day (m^3 $head^{-1}$ day^{-1}) by the days of storage of slurry and solid manure. The volume of slurry and solid stored manure is based on regional regulations concerning the spreading of manure on agricultural land. Information about days of storage takes into account the retention time in storage facilities and temporal dynamics of storage and application on soils of slurry and manure (CRPA, 1997[a]). The production of solid manure and slurry were estimated assuming a distribution of housing systems in Italy. The distribution of housing for dairy cattle has been assessed on the basis of a 1998 CRPA survey carried out in Lombardy, Emilia Romagna and center of Italy, and on the basis of ISTAT statistics of 2003 (CRPA, 2006[a]; Bonazzi *et al*., 2005; APAT, 2004[a]; APAT, 2004[b]) for the period 1990-2005; from 2010 onward, the housing systems distribution has been deduced by the results of the 2010 Agricultural Census. Between 2005 and 2010 a gradual transition to the updated distribution of housing systems has been assumed for the intermediate years, taking in account the gradual penetration of systems to ensure animal welfare. For non-dairy cattle and buffalo categories data on distribution of housing systems derive from national studies and expert judgment (CRPA, 2006[a]).
By multiplying the *methane emission rates* (obtained from equations 5.1 and 5.2) with the volume of slurry and solid stored manure, the methane emissions were calculated.
The next step is to estimate the volatile solid (VS) production, calculated by multiplying the average production of slurry and solid manure (previously converted from volume to weight: slurry and solid manure values expressed in volume were multiplied by 1 t/m^3 and 0.75 t/m^3, respectively, to obtain the values in mass unit) by the factors proposed by Husted: 47.5 g VS/kg (slurry) and 142.7 g VS/kg (solid manure) (Husted, 1994; CRPA, 2006[a]). These values are very close to those obtained from a survey carried out by the CRPA on the characteristics of zootechnical manure in different types of breeding, equal to 48.21 g VS/kg (slurry) and 128.31 g VS/kg (solid manure). This survey allowed a collection of national data relating to solid and liquid manure of dairy cows for different types of housing. This collection of samples made it possible to quantify the production of manure, the total solids and the volatile solids (APAT, 2004[a]).
Finally, the *specific conversion factors* for slurry and solid manure is calculated as the ratio between methane emissions and VS production. These *specific conversion factors* are used for the simplified methodology (*Method 2*). The *specific conversion factor* values for slurry are 17.25 and 18.12 g CH_4/kg VS for the period 1990-2000 and from 2001 onward, respectively; and for solid manure are 8.11 and 9.28 g CH_4/kg VS for the period 1990-2000 and from 2001 onward, respectively.

Method 2: National basis
A simplified methodology (*Method 2*) for estimating methane EFs from manure management was used for the whole time series. Slurry and solid manure EFs (kg CH_4 $head^{-1}$ $year^{-1}$) were calculated with Equations 5.3 and 5.4, respectively. These equations include the *specific conversion factors* and the production of VS (kg $head^{-1}day^{-1}$), estimated with the slurry and solid manure production and the Husted factors (Husted, 1994; CRPA, 2006[a]): 47.5 g VS/kg (slurry) and 142.7 g VS/kg (solid manure).
The daily VS excreted, estimated for slurry and solid manure, are summed and used for calculating the methane producing potential (Bo).
EF slurry (for the period 1990-2000) = 17.25 g CH_4/kg VS • VS production slurry (kg VS $head^{-1}$ day^{-1}) • 365 days *Eq. 5.3(a)*
EF slurry (for the period since 2001) = 18.12 g CH_4/kg VS • VS production slurry (kg VS $head^{-1}$ day^{-1}) • 365 days *Eq. 5.3(b)*

EF solid manure (for the period 1990-2000) = 8.11 g CH_4/kg VS • VS production solid manure (kg VS head^{-1} day^{-1}) • 365 days *Eq. 5.4(a)*

EF solid manure (for the period since 2001) = 9.28 g CH_4/kg VS • VS production solid manure (kg VS head^{-1} day^{-1}) • 365 days *Eq. 5.4(b)*

In Table 5.17, EF estimations are shown.

Table 5.17 Methane manure management EFs for cattle and buffalo in 2020 (kg CH_4 head^{-1} yr^{-1})

Livestock category	Slurry (kg CH_4 head^{-1} yr^{-1})	Solid manure (kg CH_4 head^{-1} yr^{-1})	CH_4 manure management EF (kg CH_4 head^{-1} yr^{-1})
Calf	7.43	0.00	**7.43**
Male cattle	6.23	5.54	**11.77**
Female cattle	3.03	6.24	**9.27**
Other non-dairy cattle (*)	3.66	10.15	**13.80**
Dairy cattle	9.58	12.78	**22.36**
Cow buffalo	5.92	12.16	**18.08**
Other buffaloes	3.22	5.52	**8.74**

(*) Suckling cows and cows in late career (average weight 557 kg)

The sub-category 'Other non-dairy cattle' includes suckling cows (cows farmed for feeding of calves, whose milk is not normally intended for human consumption) and cows in late career defined as cows after the last lactation, no longer productive that will be slaughtered. Dairy cows in late career but still productive are included in dairy cattle category.

The average production of slurry and solid manure per livestock category per day (m^3 head^{-1} day^{-1}) has been set with results from the Nitrogen Balance Inter-regional Project (Regione Emilia Romagna, 2004). The updating on manure production for cattle and buffalo, based on Ministerial Decree of 25 February 2016 on criteria and general technical standards for the regional regulation of the agronomic use of farmed effluents and wastewater, as well as for the production and agronomic use of digestate (GU, 2016[a]), has been done. Based on the type and housing systems distribution for the different animal categories, and on the average weight of animals, a time series of slurry and solid manure production was obtained. The manure production data (liquid/slurry and solid) from the 2016 Ministerial Decree were used for the cattle and buffalo categories from 2016 onward and a gradual change from 2006 to 2016 production factors was calculated over the period from 2007 to 2015.

In Table 5.18 the disaggregated manure management EFs for cattle and buffalo are shown. In Table 5.24 the average EFs of main categories (dairy, non-dairy, buffalo and swine) are reported.

Table 5.18 Methane manure management EFs for cattle and buffalo (kg CH_4 head^{-1} yr^{-1})

Year	Calf	Male cattle	Female cattle	Other non dairy cattle (*)	Dairy cattle	Cow buffalo	Other buffaloes
	(kg CH_4 head^{-1} yr^{-1})						
1990	7.07	11.08	9.81	15.85	22.38	23.61	9.32
1995	7.07	11.70	9.82	15.85	22.38	23.45	9.26
2000	7.07	11.29	9.95	15.85	22.38	23.29	9.19
2005	7.43	12.92	11.31	17.71	25.01	25.94	10.11
2010	7.43	12.48	10.51	16.15	25.09	22.80	9.56
2011	7.43	12.29	10.16	15.76	24.64	22.01	9.42
2012	7.43	12.50	10.20	15.37	24.18	21.23	9.29
2013	7.43	12.14	10.07	14.97	23.72	20.44	9.15
2014	7.43	11.88	9.80	14.58	23.27	19.65	9.01
2015	7.43	11.71	9.55	14.19	22.81	18.87	8.88
2016	7.43	11.44	9.35	13.80	22.36	18.08	8.74
2017	7.43	11.60	9.34	13.80	22.36	18.08	8.74
2018	7.43	11.70	9.41	13.80	22.36	18.08	8.74

Year	Calf	Male cattle	Female cattle	Other non dairy cattle (*)	Dairy cattle	Cow buffalo	Other buffaloes
	(kg CH_4 head^{-1} yr^{-1})						
2019	7.43	11.75	9.31	13.80	22.36	18.08	8.74
2020	7.43	11.77	9.27	13.80	22.36	18.08	8.74

(*) Suckling cows and cows in late career (average weight 557 kg)

As recommended during the 2019 UNFCCC review, in Table A.7.14-16 in Annex 7, all data, parameters and equations used to estimate CH_4 emission from manure management for cattle and buffalo are reported. These data are: the average monthly temperature; storage temperatures and timescale for emptying manure storages; the amount of manure generated by each subcategory of cattle and buffalo (m^3/head day^{-1}); the *methane emission rates* (g CH_4/m^3 day^{-1}) calculated on the basis of the equations 5.1 and 5.2; the specific conversion factors (g CH_4/kg VS); the content of VS in manure (g VS/head day^{-1}) produced by different subcategories of cattle (dairy and non-dairy cattle) and buffalo (cow buffaloes and other buffaloes); the slurry and solid manure EFs (kg CH_4/head year^{-1}) calculated with Equations 5.3 and 5.4 respectively; the total (slurry and solid manure) amount of VS handled in slurry/liquid and solid manure management systems for the entire reporting period; the total (slurry and solid manure) CH_4 emission factors.

CH_4 emissions from manure management category (3B) also include emissions from the biogas production.

A national census on biogas production/technology/installed power/organic matrix used is available in CRPA and CRPA/AIEL (CRPA, 2013; CRPA, 2011; ENAMA, 2011; CRPA, 2008[a]; CRPA/AIEL 2008). Biogas production data are collected annually by the National Electric Network (TERNA, several years). Emissions of methane, from biogas produced by anaerobic digesters fed with animal manure, to be deducted to the total amount of methane from manure management, were calculated using the information and data provided by TERNA and CRPA. For further information on the country-specific methodology used see Annex 7.2.

On the basis of the recent study for the evaluation of the effects on emissions of livestock management practices carried out by CRPA (CRPA, 2018), the percentages of the different substrates feeding the anaerobic digesters and data on the average content of volatile solids by type of substrates have been changed resulting in a decrease of the estimated amount of manure feeding anaerobic digesters. For the year 2020 this amount is equal to about 15 million of tons and that is 46% of the total amount of feed treated in anaerobic digesters. Emissions from plant biogas losses, fueled by manure, energy crops and agro-industrial by-products, are greater than avoided emissions due to biogas recovery (for cattle until 2016). This is due to the estimated amount of manure that feeds the digesters, which is probably low compared to other substrates. Therefore increases in CH_4 emissions related to biogas recovery are assumed for cattle until 2016 according to the methodology described in Annex 7.2 (see paragraph *CH_4 emissions to be subtracted*).

In 2020, the CRF IEFs, for dairy cattle and non-dairy cattle, were 22.47 kg CH_4 head^{-1} year^{-1} and 10.08 kg CH_4 head^{-1} year^{-1}, respectively. IPCC default EFs of cool temperature are 29 kg CH_4 head^{-1}year^{-1} and 8 kg CH_4 head^{-1}year^{-1} for dairy cattle and non-dairy cattle, respectively (IPCC, 2006). The IPCC default EFs of cool temperate are considered as the estimate of the national average temperature is 14 °C calculated from SCIA data of 1981-2010 climatological period.

The IEF for non-dairy cattle and buffalo represent a weighted average. The non-dairy cattle IEF includes: calves, male cattle, female cattle and other non dairy cattle. The buffalo category includes: cow buffalo and other buffaloes categories. In Table 5.19, EFs and IEFs are shown. Differences, as mentioned before, are related to the amount of CH_4 reductions from biogas recovery and IEFs include also CH_4 emissions from pasture. In Table 5.19, the default EFs of the IPCC 2006 Guidelines are also reported.

Table 5.19 CH_4 EFs, IEF and default EF for cattle and buffalo (kg CH_4 head^{-1} yr^{-1})

Livestock category	EF (*) (kg CH_4 head^{-1} yr^{-1})	IEF (**) (kg CH_4 head^{-1} yr^{-1})	IPCC 2006 default EF (kg CH_4 head^{-1} yr^{-1})
Dairy cattle	22.36	22.47	29
Non-dairy cattle	10.05	10.08	8
Buffalo	14.09	14.14	5

(*) Data not include EFs for pasture; (**) IEF as reported in the CRF submission 2022

Emissions from the biogas combustion for energy production are estimated and reported in the energy sector in the 1.A.4.c category, agriculture, forestry and fisheries, biomass fuel.

Following previous UNFCCC review's remark, detailed information on the estimate of weighted average values of CH_4 producing potential (Bo) and methane conversion factor (MCF) is provided below.
The methodology used, based on Husted studies, do not require the estimate of Bo. Therefore, the factor is estimated with 2006 IPCC Gudelines Equation 10.23 (Chapter 10 of Volume 4) and using country specific EFs and VS by livestock category described above and the average value of MCF by livestock category.
The 2006 IPCC MCF values by temperature for manure management systems (solid storage, pasture, liquid/slurry system) are used. In particular for liquid/slurry system, at first, the values of MCF at the provincial level were calculated based on the 2006 IPCC MCFs, by temperature, on the basis of the average provincial temperatures (i.e. the average temperature at provincial level was calculated by weighing the temperature at municipal level data with the percentage of animals at provincial level). Subsequently, the MCF national average values by livestock category for climate zone (considering cool (<15°C) and temperate (≥ 15°C) climate zone) were calculated as the average of the provincial MCF values weighed with the animals distributed by province for climatic zone. In relation to the climatic zones of the country and the average temperatures, see also the paragraph *Other livestock categories* below. The numer of animals at provincial level come from the Agriculture Census from 1990, 2000 and 2010, and from the FSS for 2005 (ISTAT, 2007[a]), 2007 (ISTAT, 2008[a]), 2013 and 2016[18].
Information on the estimation process of the weighted average values of MCF for animal manure digested in anaerobic digesters are reported in Annex 7.2. Average MCFs were not used for estimating manure management EF, but they are useful to verify the EF accuracy.
In Table 5.20, estimated country-specific VS and Bo parameters, and IPCC default values are shown (IPCC, 2006). Differences are mainly attributed to country-specific characteristics.

Table 5.20 VS and Bo parameters for cattle, buffalo and swine

Livestock category	VS country-specific (*) (kg dm head^{-1} day^{-1})	VS IPCC default (kg dm head^{-1} day^{-1})	Bo country-specific (*) (CH_4 m^3/kg VS)	Bo IPCC default (CH_4 m^3/kg VS)
Dairy cattle	5.22	5.10	0.22	0.24
Non-dairy cattle	2.34	2.60	0.25	0.18
Buffalo	3.47	3.90	0.17	0.10
Swine	0.34	0.31(**)	0.42	0.45

(*) as reported in the CRF submission 2022; (**) weighted average with the number of heads of sows and other swine categories

As recommended during 2019 UNFCCC review, the VS for cattle and buffalo are calculated also using equation 10.24 of the 2006 IPCC Guidelines (Chapter 10 of Volume 4). The results are: for dairy cattle 5.07 kg dm/head/day in 1990 and 6.07 kg dm/head/day in 2020; for non-dairy cattle 2.74 kg dm/head/day in 1990 and 2.80 kg dm/head/day in 2020; for buffalo 3.44 kg dm/head/day in 1990 and 3.55 kg dm/head/day in 2020. For dairy cows, VS from manure are affected by the variation over the years of the housing systems, which affect the production of manure; the equation 10.24 of the 2006 IPCC Guidelines does not allow for this important parameter to be considered when estimating methane emissions from storage. For non-dairy cattle category, the enteric VS was calculating assuming DE equal to 65%, but this value should be lower, given that the average value of VS of this category is equal to 2.80 for 2019 (2.74 in 1990).
As regard the contribution of straw, the methodology used, based on Husted studies, does not require a control on the straw used. As reported in the MeditAIRaneo project, the VS produced in slurry/liquid and solid animal manure were elaborated using Husted data, i.e. 47.5 gVS/kg of slurry and 142.7 gVS/kg of solid manure (Husted, 1994; CRPA, 2006[a]). As reported in Husted (Husted, 1994), cattle slurry does not contain bedding material and cattle solid manure consisted mainly of faeces and a minor fraction of bedding material. Finally, as reported in the 2006 IPCC Guidelines, since the bedding materials typically are associated with solid storage systems, their contribution would not add significantly to overall methane production. However, the amount of straw used as bedding was estimated and the cross-check of amounts of bedding material contained in the manure used to estimate CH_4 emissions and N_2O emissions from animal manure applied to agricultural soils has been done, as recommended by the 2019 UNFCCC review. The amount of straw used as bedding that ends up on agricultural land during the spreading of manure was estimated considering the amount of straw per day (per tonnes of live weight, per type of housing, for cattle and buffalo), contained in the Ministerial Decree of 25 February 2016 on the use of zootechnical effluents, combined with the manure production coefficients used in the estimation of CH_4 emissions from storage. The nitrogen content was considered and was added to the

[18] http://dati.istat.it/?lang=en&SubSessionId=cead0f83-139d-4121-9178-e7de3f81675f

nitrogen input from manure applied to soils for N_2O emissions estimate. Data for cattle were updated, while data for buffaloes, previously missing, were included. Data have been updated since 1990. Further information and data can be found in paragraph 5.5.2 (Direct N_2O emissions from F_{AM}) and in the Annex 7.3.
As recommended during 2019 UNFCCC review, CH_4 emissions from pasture of cattle and buffalo categories have been estimated (using the equation 10.23 of the 2006 IPCC Guidelines) and reported in manure management emission category. As recommended during 2021 UNFCCC review, the revision of CH_4 EFs used to estimate emissions from pasture, paddock and range for cattle (dairy and non-dairy) and buffalo by correcting the allocation of MCF and manure handled by climate zone, in line with equation 10.23 of the 2006 IPCC Guidelines (Chapter 10 of Volume 4), has been made and CH_4 emissions for this subcategory has been recalculated. In the calculation of CH_4 EFs, the MCF value for both cool and temperate climate conditions was considered in the estimate. In Table 5.21 the disaggregated manure management EFs from pasture of cattle and buffalo are shown.

Table 5.21 CH_4 EFs from pasture for cattle and buffalo (kg CH_4 head^{-1} yr^{-1})

Year	Calf	Male cattle	Female cattle	Other non dairy cattle (*)	Dairy cattle	Cow buffalo	Other buffaloes
	(kg CH_4 head^{-1} yr^{-1})						
1990	0.019	0.026	0.029	0.042	0.164	0.128	0.050
1995	0.020	0.028	0.033	0.045	0.164	0.123	0.048
2000	0.023	0.032	0.036	0.050	0.164	0.118	0.047
2005	0.022	0.034	0.038	0.053	0.182	0.128	0.050
2010	0.023	0.033	0.039	0.050	0.145	0.106	0.045
2011	0.023	0.032	0.038	0.049	0.143	0.101	0.043
2012	0.025	0.035	0.043	0.052	0.140	0.096	0.042
2013	0.029	0.040	0.048	0.059	0.156	0.090	0.040
2014	0.029	0.039	0.047	0.058	0.153	0.086	0.039
2015	0.029	0.037	0.046	0.055	0.150	0.081	0.038
2016	0.030	0.037	0.046	0.055	0.149	0.077	0.037
2017	0.029	0.037	0.046	0.054	0.149	0.077	0.037
2018	0.029	0.037	0.046	0.055	0.149	0.077	0.037
2019	0.029	0.037	0.046	0.055	0.149	0.077	0.037
2020	0.030	0.037	0.048	0.056	0.152	0.077	0.037

(*) Suckling cows and cows in late career (average weight 557 kg)

Methane emissions (swine)
For the estimation of CH_4 emissions for swine, a country-specific *methane emission rate* was experimentally determined by the Research Centre on Animal Production (CRPA, 1996). The estimation of the EF considers: the storage systems for slurry (tank and lagoons), type of breeding and production of biogas.
Different parameters were considered, such as the livestock population, average weight for fattening swine and sows, and *methane emission rate*. Methane emission rates used are 41 normal litres CH_4/100 kg live weight/day for fattening swine, and 47 normal litres CH_4/100 kg live weight/day for sows including piglets (CRPA, 2006[a]). These data were based on experimental measurements on covered storage systems.
The shares of covered/uncovered storage systems are equal to 4% and 96% (CRPA, 2006[b]), respectively; the CH_4 emission rates used for uncovered storage systems were: 37.6 normal litre CH_4/100 kg live weight/day for fattening swine and 43.1 normal litre CH_4/100 kg live weight/day for sows, including piglets. These figures have been estimated on the basis of data provided by CRPA on methane emission rates from covered and total storages (CRPA, 1997 [a]; CRPA, 2006[a]; CRPA, 2006[b]).
The uncovered systems are emitting less than the covered ones since the temperatures are lower. According to the information on the storage systems collected by the 2010 Agriculture Census, the shares of covered/uncovered storage systems are equal to 11% and 89%, respectively; the shares of covered/uncovered storage systems are equal to 25% and 75%, respectively, taking into account the outcomes of the 2013 FSS ISTAT survey.
Characteristics of swine breeding and EFs are shown in Table 5.22; the emission factors reflect the share of covered/uncovered storage systems. The slurry production considered the different swine categories (classified by weight and housing characteristics); the average weight of sows, the production of slurry (t year^{-1} per t live

weight) and the volatile solid content in the slurry (g SV/kg slurry w.b.) have been set on the basis of 598 measurements carried out by CRPA (CRPA, 1996; CRPA, 2006[a]).
In 2020, the EF from sow was 22.88 kg CH_4 head^{-1}year^{-1}, and for the other swine category was 8.92 kg CH_4 head^{-1} year^{-1} (average swine EF is 8.36 kg CH_4 head^{-1}year^{-1}). In Table 5.24 the time series of EFs for the swine category (sow and other swine) are shown. The CRF IEF reported is 8.20 kg CH_4 head^{-1} year^{-1}. IPCC 2006 Guidelines default EF is 8 kg CH_4 head^{-1}year^{-1} for market swine and 12 kg CH_4 head^{-1}year^{-1} for breeding swine respectively, for cool temperature and 14°C as average annual temperature (IPCC, 2006). The difference between the EF and the IEF is due to the reduction in CH_4 because of biogas recovery (see Annex 7.2).
For reporting purposes, the VS daily excretion and Bo is estimated and is useful to verify the EF accuracy. The VS daily excretion was estimated for each sub-category with the following parameters: animal number, production of slurry (t/y/t live weight) and the volatile solids content in the slurry (g VS/kg slurry). Methane producing potential (Bo) used 2006 IPCC Guidelines Equation 10.23 (Chapter 10 of Volume 4). See paraghaph *Methane emissions (cattle and buffalo)* for more details on the estimation process.

Table 5.22 Methane manure management parameters and emission factors for swine in 2020

Livestock category	Average weight (kg)	Breed live weight (t)	Methane emission rate reduction (Nl CH_4/100 kg live weight)	Emission factor (kg CH_4 head^{-1} yr^{-1})
Other swine	**88**	**576,934**	**14,036**	**8.92**
20-50 kg	35	56,693	14,036	3.54
50-80 kg	65	82,984	14,036	6.58
80-110 kg	95	136,445	14,036	9.62
110 kg and more	135	296,320	14,036	13.67
Boar	200	4,492	14,036	20.25
Sows	**172**	**112,091**	**16,090**	**22.88**
Piglets	10	14,243	16,090	1.16
Sows	172.1	97,847	16,090	19.98
			Total	**8.36**

The fundamental characteristic of Italian swine production is the high live weight of the animals slaughtered as related to age; the optimum weight for slaughtering to obtain meat suitable for producing the typical cured meats is between 155 and 170 kg of live weight. Such a high live weight must be reached in no less than nine months of age.
Other characteristics are the feeding situation, to obtain high quality meat, and the concentration of Italian pig production, limited to a small area (*Lombardia, Emilia-Romagna, Piemonte* and *Veneto*), representing 75% of national swine resources (Mordenti *et al*., 1997).
These peculiarities of swine production influence the methane EF for manure management as well as nitrogen excretion factors used for the estimation of N_2O emissions.

Other livestock categories
Methane EFs used for calculating the other livestock categories are those included in the 2006 IPCC Guidelines. CH_4 emissions from pasture of other livestock categories (i.e., sheep, goats, horses, mules and asses) were not calculated as the manure management emissions for these animal categories were calculated using Tier1 emission factors, which include all management systems, including grazing.
Data on the number of broilers and laying hens in the period 2001-2009 and since 2011 have been updated. The estimation methodology involved successive steps. Firstly, ISTAT data from the Census and FSS surveys (available for the years 2000, 2005, 2007, 2010, 2013 and 2016) were considered; on the basis of these data the number of heads has been estimated for the missing years from 2001, assuming a linear trend. Secondly, the number of animals since 2001 on the basis of production data provided by UNAITALIA. The annual variation in production was multiplied by the number of animals in the 2000 Census. Thirdly, the average of the two time series, which were recreated in the previous steps, was calculated.
Based on the number of heads at provincial level (NUTS2) and the average temperature of each province, CH_4 emissions were calculated using the 2006 IPCC default emission factors by average annual temperature (considering cool (<15°C) and temperate (≥ 15°C) climate zone) at the provincial level. For the national estimate an IEF was calculated based on the sum of the provincial emissions.

In Table 5.23 the distribution of animals from the FSS 2005 (ISTAT) and number of heads in temperate and cool zones is summarised. Detailed data on the animal's distribution and average temperature at provincial level are included in Table A.7.13 of the Annex.

Table 5.23 Distribution of animals from the FSS 2005 (ISTAT) and number of heads in temperate and cool zones

Livestock categories based on data from the FSS 2005	Heads	Animals in temperate zone (≥ 15°C)		Animals in cool zone (< 15°C)	
		N animals	% animals	N animals	% animals
Non-dairy cattle	4,409,921	794,593	18.02	3,615,328	81.98
Dairy cattle	1,842,004	240,996	13.08	1,601,008	86.92
Buffalo	205,093	184,001	89.72	21091.8285	10.28
Other swine	8,478,427	354,560	4.18	8,123,867	95.82
Sows	721,843	56,455	7.82	665,388	92.18
Sheep	7,954,167	4,055,304	50.98	3,898,863	49.02
Goats	945,895	574,903	60.78	370,992	39.22
Horses	278,471	55,655	19.99	222,816	80.01
Mules and asses	30,254	10,226	33.80	20,028	66.20
Broilers (*)	93,124,306	3,484,340	3.74	89,639,966	96.26
Layer hens (*)	43,172,643	4,561,721	10.57	38,610,922	89.43
Other poultry	38,370,412	1,218,114	3.17	37,152,299	96.83
Rabbits	20,504,282	1,732,221	8.45	18,772,061	91.55

(*) The 2005 FSS data were recalculated on the basis of the updated estimate of laying hens and broilers described above.

In order to verify the used animal distribution, the 2010 Agriculture Census (ISTAT, 2012) has been used to infer the percentages of animals in temperate zone. Comparing the assessed percentage with the used distribution, slight differences have registered for all the categories, except for other swine (-30%), other equines (-30%) and laying hens categories (+27%); a high difference is present for the other poultry and broilers categories.

As recommended during the 2019 UNFCCC review, CH_4 emissions for ostriches are estimated and reported in the IPCC category other livestock. Activity data are provided by ISTAT for some years and for the other years the number of animals has been estimated. The default 2006 IPCC CH_4 EF has been used.

In Table 5.24, the average methane EFs for cattle, buffalo and swine categories are shown for the whole time series.

For the other categories, the EFs are as follows:

- rabbits, 0.080 kg CH_4 $head^{-1}$ $year^{-1}$
- sheep, 0.244 kg CH_4 $head^{-1}$ $year^{-1}$
- goats, 0.169 kg CH_4 $head^{-1}$ $year^{-1}$
- horses, 1.794 kg CH_4 $head^{-1}$ $year^{-1}$
- mules and asses, 0.840 kg CH_4 $head^{-1}$ $year^{-1}$
- laying hens, 0.030 kg CH_4 $head^{-1}$ $year^{-1}$
- broilers, 0.020 kg CH_4 $head^{-1}$ $year^{-1}$
- other poultry, 0.090 kg CH_4 $head^{-1}$ $year^{-1}$
- fur animals, 0.680 kg CH_4 $head^{-1}$ $year^{-1}$
- ostriches, 5.67 kg CH_4 $head^{-1}$ $year^{-1}$

The difference between the EF and the IEF for poultry is due to the reduction in CH_4 because of biogas recovery (see Annex 7.2).

Table 5.24 Average methane EFs for manure management (*) (kg CH^4 $head^{-1}$ $year^{-1}$)

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sows	Other swine
	(kg CH_4 $head^{-1}$ $year^{-1}$)				
1990	22.54	10.63	18.84	22.12	8.53
1995	22.54	11.13	18.37	21.94	8.51
2000	22.54	10.97	17.87	21.95	8.42
2005	25.19	12.20	20.88	22.28	8.34
2010	25.24	11.33	18.58	22.48	8.41
2011	24.78	11.06	17.97	22.54	8.46
2012	24.32	11.11	16.68	22.31	9.00
2013	23.88	10.86	16.04	22.83	9.03
2014	23.42	10.56	16.01	22.76	8.94
2015	22.96	10.35	15.14	22.78	8.94
2016	22.51	10.13	14.64	22.84	9.01
2017	22.51	10.16	14.66	22.84	8.98
2018	22.51	10.26	14.58	22.91	8.92
2019	22.51	10.23	14.26	22.92	8.91
2020	22.51	10.22	14.20	22.88	8.92

(*) These are the EFs used for estimating CH_4 emissions from manure management (for cattle and buffalo data include EFs for pasture). CH_4 reductions are not included.

Nitrous oxide emissions from manure management

Direct and indirect N_2O emissions, produced during the storage and treatment of manure before it is applied to soils, are reported separately, as indicated in the 2006 IPCC Guidelines.

Direct N_2O emissions from manure management

N_2O emissions were estimated with equation 10.25 (IPCC, 2006, Chapter 10 of Volume 4). Different parameters were used for the estimation: number of livestock species, country-specific nitrogen excretion rates per livestock category, fraction of total annual nitrogen excretion for each livestock category managed in each manure management systems and EFs for manure management systems (IPCC, 2006).

Liquid system and solid storage are considered according to their significance and major distribution in Italy. For these management systems, the same EF is used: 0.005 kg N_2O-N/kg N excreted (IPCC, 2006). Solid storage includes the chicken-dung drying process system. This system has been considered since 1995, since it has become increasingly common (CRPA, 2000; CRPA, 1997[b]). As regards the anaerobic digesters, another management system used in the country, the nitrogen quantities in livestock manure sent to anaerobic digestion were updated. On the basis of CRPA data on measurements of nitrogen quantities in livestock manure (downstream of releases to housing and storage) per animal category and type of manure, the nitrogen quantities in livestock manure sent to anaerobic digestion were estimated. The coefficients, expressed in g N/kg manure, were calculated gross of losses and then the losses to housing were deducted. Then, the resulting coefficients were then multiplied by the quantities of manure sent for anaerobic digestion. The whole time series was updated. N_2O emissions of the anaerobic digesters are reported as zero in line with the 2006 IPCC Guidelines (IPCC, 2006).

When estimating emissions from manure management, the amount related to manure excreted while grazing is subtracted and reported in 'Agricultural soils' under soil emissions - urine and dung deposited by grazing animals (see Table 5.25). As recommended during the 2021 UNFCCC review, N_2O direct and indirect emissions for ostriches are estimated and reported in the IPCC 'Agricultural soils'category because the manure management system for this category is pasture, range and paddock. The estimate of nitrogen excretion per manure management system is reported in CRF Table 3.B(b) (consistently with CRF Table 3.B(a)s2), in pasture range and paddock in other livestock. Further details on the estimate are given in 5.5.2 *Methodological issues* paragraph, in Direct N_2O emissions from managed soils, in *Urine and dung from grazing animals* (F_{PRP}).

Different parameters such as the nitrogen excretion rates (CRPA, 2006[a]; GU, 2006; Xiccato *et al*., 2005), the slurry and solid manure production, and the average weight (CRPA, 2006[a]; GU, 2006; Regione Emilia Romagna, 2004) were updated.

In Table 5.25, nitrogen excretion rates used for the estimation of N_2O are shown. In 2020, the nitrogen excretion rate for swine is 14.58 kg $head^{-1}$ yr^{-1}. This last parameter is a weighted average of sow (27.66 kg $head^{-1}$ yr^{-1}) and other swine (13.45 kg $head^{-1}$ yr^{-1}). The value for sows also includes the excreted nitrogen from

pigliets. The average nitrogen excretion rate for swine reported in the CRF is equal to 12.15 kg head^{-1} yr^{-1}. The figure is lower than the average rate for swine reported here since the value reported in the CRF is calculated by comparing the excreted nitrogen to the total pigs, including piglets.

Table 5.25 Average weight and nitrogen excretion rates in 2020

Livestock category	Average weight (kg)	N excreted housing (kg N head^{-1} yr^{-1})	N excreted grazing (kg N head^{-1} yr^{-1})	Total nitrogen excreted (kg N head^{-1} yr^{-1})
Non-dairy cattle	386.9	50.62	1.42	**52.04**
Dairy cattle	602.7	103.61	5.45	**109.06**
Buffalo	497.2	57.49	1.72	**59.21**
Other swine	88.1	13.45		**13.45**
Sows	172.1	27.66		**27.66**
Sheep	47.1	1.62	14.58	**16.20**
Goats	45.1	1.62	14.58	**16.20**
Horses	550.0	20.00	30.00	**50.00**
Mules and asses	300.0	20.00	30.00	**50.00**
Poultry	1.9	0.49		**0.49**
Rabbits	1.6	1.02		**1.02**
Fur animals	1.0	4.10		**4.10**

Country-specific annual nitrogen excretion rates have been set, based on the Nitrogen Balance Inter-regional Project results (nitrogen balance in animal farms); this project involved *Emilia Romagna*, *Lombardia*, *Piemonte* and *Veneto* regions, where animal breeding is concentrated. The N-balance methodology has been applied in real case farms, monitoring their normal feeding practice, without specific diet adaptation. In the project, the most relevant dairy cattle production systems in Italy have been considered. Contrary to what is normally found in European milk production systems, poor correlation between the N excretion and milk production has been found. The two possible reasons are: a) an extreme heterogeneity in the protein content of the forage and in the use of the feed; b) the non-optimisation of the protein diet of less productive cattle (De Roest and Speroni, 2005; CRPA, 2010). The N-balance methodology was followed, as suggested by the IPCC. As a result, estimations of nitrogen excretion rates[19] and net nitrogen arriving to the field[20] were obtained. In order to get reliable information on feed consumption and characteristics, and composition of the feed ratio, the project considered territorial and dimensional representativeness of Italian breeding. The final annual nitrogen excretion rates used for the UNFCCC/CLRTAP agriculture national inventory are included in a CRPA report (CRPA, 2006[a]).
In Table 5.26, nitrogen excretion rates for the main livestock categories are shown for the whole time series. For the other livestock categories, nitrogen excretion is the same for the whole time series, as shown in Table 5.25.
For the dairy cattle category, following a recommendation raised during the 2019 UNFCCC review, the annual average values of nitrogen excretion rates are estimated using equations 10.31-33 of the 2006 IPCC Guidelines, and therefore are calculated with the data used to estimate the enteric fermetation emissions. Following the update of the gross energy intake (GE), based on the estimation of the parameters digestibility (DE) of diet and methane conversion factor (Ym), the excreted nitrogen value of dairy cows was updated from the year 2004 onward. Excreted nitrogen is in fact calculated from GE using equations 10.31-10.33 of the 2006 IPCC Guidelines. In addition, the percentage for protein in diet has been updated since 2000 with respect to the previous submission. This parameter is used with GE in the estimation of excreted nitrogen. As regards the percentage for protein in diet, the crude protein of the ration was updated on the basis of data from around 500 samples of rations (unifeed) of lactating and dry dairy cows, analysed by the CRPA's zootechnical feed service for the three-year period 2017-2019, from all over Italy. The data were obtained by weighing the values expressed as % of the dry matter of the ration with the average annual lactation period (equal to 305 days) and the dry period (equal to 60 days). The value obtained is 14.22% and it was used for the time series from 2010 onwards, as indicated by the CRPA experts. For the previous years, the previous figure of 15.32% (Bittante *et al.*, 2004) was left until 2000, and an average value of 14.5% was used for the intermediate years between

[19] Nitrogen excretion = N consumed – N retained
[20] Net nitrogen to field = (N consumed – N retained) – N volatilized

2000 and 2010. This change results in a change in the nitrogen excreted by dairy cows (which is down from the previous submission).
For non-dairy cattle, buffalo and swine categories, the average values of nitrogen excretion rates are calculated on the basis of the weight of the annual number of animal subcategories and fluctuate over the years. For the 'Less than 1 year' subcategory of the non-dairy cattle category, an average value of nitrogen excreted was calculated based on the weight of the number of animals of the subcategories calf, fattening male cattle, fattening heifer and heifer for replacement subcategories. For the sows' category, an average weighted nitrogen excretion rate is calculated taking in account the nitrogen excretion from piglets (swine less than 20 kg).

Table 5.26 Nitrogen excretion rates for main livestock categories (kg N head^{-1} yr^{-1})

Year	Dairy cattle	Non-dairy cattle	Buffalo	Other swine	Sows
	(kg N head^{-1} yr^{-1})				
1990	104.85	50.00	94.32	13.13	28.10
1995	112.58	49.86	92.84	13.10	27.86
2000	105.65	50.08	91.20	12.96	27.87
2005	105.70	49.76	95.28	12.84	28.30
2010	102.02	50.01	81.99	12.85	28.36
2011	101.37	49.68	78.53	12.92	28.44
2012	101.45	51.87	72.69	13.74	28.13
2013	100.94	51.67	69.24	13.62	28.42
2014	102.63	51.35	67.78	13.48	28.34
2015	103.48	51.37	63.57	13.48	28.36
2016	103.81	51.76	60.55	13.59	28.43
2017	105.15	51.88	60.60	13.54	28.44
2018	105.95	52.45	60.37	13.45	28.53
2019	106.57	52.18	59.38	13.44	28.55
2020	109.06	52.04	59.21	13.45	27.66

For verification purpose, a time series reported by ISTAT in the yearbooks (animal weight before slaughter) was collected (CRPA, 2006[a]). For the specific case of sheep and goats, a detailed analysis was applied with information coming from the National Association for Sheep Farming (ASSONAPA, 2006). In order to estimate the average weight for sheep and goats, breed distribution in Italy and consistency for each breed were considered (CRPA, 2006[a]; PROINCARNE, 2005).
Slurry and solid manure production parameters are set on the basis of Italian breeding characteristics, taking into account the slurry and solid manure effluents, housing systems and the distribution for the different animal categories (CRPA, 2006[a]; Bonazzi *et al*., 2005; APAT, 2004[a]; APAT, 2004[b]).
Fractions of total annual nitrogen excretion for dairy cattle category managed in solid manure and liquid/slurry systems have been updated taking into account the distribution of housing systems resulting from the 2010 Agricultural Census.

Indirect N_2O emissions from manure management
N_2O emissions result from volatile nitrogen losses occurring primarily in the forms of ammonia and NO_x and from nitrogen leaching and run-off.
N_2O emissions due to atmospheric deposition of NH_3 and NO_x have been estimated following the IPCC Tier 2 approach (Equation 10.26 and 10.27 of the 2006 IPCC Guidelines, Volume 4, Chapter 10). The following parameters are used: total N excreted by livestock (kg head^{-1}yr^{-1}), the fraction of total annual nitrogen excretion for each livestock category managed in each manure management systems, $Frac_{GasMS}$ emission factor, which is the percentage of managed manure nitrogen that volatilises as NH_3 and NO_x in the manure management systems (see Table 5.27) and emission factor 0.01 kg N_2O-N per kg NH_3-N and NO_x-N emitted (IPCC, 2006). The $Frac_{GasMS}$ emission factor is equal to the ratio between the amount of NH_3-N and NO_x-N emissions at housing and storage system and the total nitrogen excreted.
NH_3 and NO_x emissions are estimated on the basis of the methodology indicated in the EMEP/EEA Guidebook for transboundary air pollutants. The estimation procedure for NH_3 and NO_x emissions of the manure management category consists in successive subtractions from the quantification of nitrogen excreted annually for each livestock category. This quantity can be divided in two different fluxes, depending on whether animals

are inside (housing, storage and manure application) or outside the stable (grazing). More in detail, part of the nitrogen excreted in housing volatilizes during the settle of manure in the stable and it is calculated with the relevant emission factor in housing for the different livestock; this amount is therefore subtracted from the total nitrogen excreted to derive the amount of nitrogen for storage. During storage another fraction of nitrogen is lost (calculated with the relevant emission factor for storage), and, therefore, it is subtracted to obtain the amount of nitrogen available for the agronomic spreading. Losses occurring during the spreading are finally calculated with the related emission factor for spreading. For the nitrogen excreted in the pasture, losses due to volatilization, calculated with the relevant emission factor for grazing by livestock, only occur at this stage. Ammonia and NO_x emissions coming from housing and storage by each livestock category are then summed and divided by the total nitrogen excreted for each year (CRPA, 2006[a]). Ammonia emissions related to the housing and storage by cattle, swine and laying hens categories have been updated based on the basis of ISTAT statistics such as 2010 Agricultural Census and 2013 Farm Structure Survey, on the distribution of housing and storage systems. In relation to the ammonia emissions from storage, NH_3 emissions from digesters biogas facilities (in particular due to different phases of the process: during storage of feedstock on the premises of the biogas facility; during open storage of the digestate) have been estimated taking into account the amount of excreted nitrogen feeding anaerobic digesters and the Tier 1 emission factor derived by the EMEP/EEA Guidebook (EMEP/EEA, 2019). NH_3 emissions from digesters biogas facilities have been subtracted from manure management category (only for cattle, swine and poultry categories) and allocated in the anaerobic digestion at biogas facilities (5B2 of the waste sector in the NFR classification under UNECE/LRTAP Convention). The percentage of nitrogen lost through N-NH_3 emissions from anaerobic digesters was subtracted from the percentage of nitrogen left after emissions during housing and storage, reducing the amount of nitrogen used at the spreading. The amount of nitrogen used at the spreading also includes the digestate.
N_2O emissions due to nitrogen leaching and run-off have been estimated and reported.
For estimating of N_2O emissions due to nitrogen leaching and run-off the IPCC Tier 2 approach was followed (Equation 10.28 of the 2006 IPCC Guidelines, Volume 4, Chapter 10). The following parameters are used: total N excreted by livestock (kg $head^{-1}yr^{-1}$), the fraction of total annual nitrogen excretion for each livestock category managed in each manure management systems, $Frac_{leachMS}$ emission factor, which is the percent of managed manure nitrogen losses due to leaching and runoff during solid and liquid storage of manure (see Table 5.27) and emission factor 0.0075 kg N_2O-N per kg N leaching/runoff (IPCC, 2006).
The national legislation (as well as the regional ones) requires that the storage of liquid manure is in containers with waterproof bottom. The solid storage should have the concrete or similar materials on the bottom and the leachate collection system. Nevertheless, manure heaps near the field are permitted for limited time after storage aimed at spreading (CRPA, 2016[b]). Leaching of N during manure management is thus restricted to these manure heaps after storage. On the basis of this information, $Frac_{leachMS}$ emission factor is assumed equal to 1% (the lower bound of the typical range, reported in 2006 IPCC Guidelines) and $Frac_{leachMS}$ is applied on the amount of N after the N volatilized from manure management is subtracted, because most N will already be volatilized before installing the manure heaps near the field.

Table 5.27 Parameters used for the estimation of N_2O indirect emissions

Year	N excreted (t N)	$Frac_{GasMS}$ (%)	N volatilised as NH_3 and NO_x (t N)	N excreted housing minus N volatilised (t N)	$Frac_{LeachMS}$ (%)	N leached from manure management (t N)
1990	929,662	24.16	224,623	528,333	1.0	5,283
1995	931,900	22.63	210,862	516,629	1.0	5,166
2000	914,896	22.19	203,048	502,816	1.0	5,028
2005	812,842	22.72	184,709	473,313	1.0	4,733
2010	791,821	22.91	181,370	453,305	1.0	4,533
2011	790,618	22.45	177,480	455,633	1.0	4,556
2012	778,051	22.17	172,490	460,775	1.0	4,608
2013	787,614	21.29	167,662	471,388	1.0	4,714
2014	779,610	20.99	163,658	468,326	1.0	4,683
2015	781,226	21.02	164,230	469,339	1.0	4,693
2016	791,885	20.97	166,043	474,773	1.0	4,748
2017	791,472	20.92	165,544	477,065	1.0	4,771
2018	782,018	20.82	162,796	471,205	1.0	4,712
2019	779,799	20.71	161,480	471,971	1.0	4,720
2020	785,226	20.58	161,637	476,476	1.0	4,765

5.3.3 Uncertainty and time-series consistency

Uncertainty of CH_4 and N_2O emissions from manure management has been estimated equal to 20.6%, as a combination of 5% and 20% for activity data and emission factors, respectively. Uncertainty of indirect N_2O emissions from manure management has been estimated equal to 50.2%, as a combination of 5% and 50% for activity data and emission factors, respectively.

In the 2012 submission, Montecarlo analysis was also applied to estimate uncertainty of these two categories. The resulting figures were 22.96% and 10.19% for CH_4 and N_2O emissions from manure management, respectively. Normal and lognormal distributions have been assumed for the parameters; at the same time, whenever assumptions or constraints on variables were known this information has been appropriately reflected on the range of distribution values. A summary of the results is reported in Annex 1.

In 2020, CH_4 emissions from manure management were 14.4% (165.89 Gg CH_4) lower than in 1990 (193.71 Gg CH_4). From 1990 to 2020, dairy and non-dairy cattle livestock population decreased by 38.0% and 14.8%, respectively, while swine increased by 2.4% (in particular, sows decrease by 12.7% and other swine increase by 4.0%).

The reduction of manure management emissions has mainly driven down by the number of cattle. For cattle category until 2016, CH_4 emissions from biogas produced by anaerobic digesters fed with animal manure must be added to the emissions from manure management and not deducted because of the plant biogas losses are greater than avoided emissions due to biogas recovery. Cattle CH_4 emissions contribute for 48.6% (in 1990 for 58.6%) to total CH_4 manure management emissions and swine for 42.2% (35.2% in 1990). For cattle, swine and poultry, the reduction of manure management emissions is also due to the reduction in CH_4 because of biogas recovery.

In Table 5.28, CH_4 emission trends from manure management (including emissions from pasture) are shown. These emissions considered the reduction of CH_4 because of biogas recovery.

Table 5.28 Trend in CH_4 emissions from manure management (Gg)

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sows	Other swine	Sheep	Goats	Horses	Mules and asses	Poultry	Rabbits	Fur animals	Ostriches	Total
1990	59.56	53.88	1.77	14.40	53.73	2.07	0.21	0.50	0.08	6.10	1.19	0.22	0.00	**193.71**
1995	46.94	57.33	2.72	15.12	50.48	2.52	0.23	0.55	0.03	6.84	1.37	0.15	0.03	**184.32**
2000	46.59	54.25	3.42	15.53	51.52	2.60	0.23	0.49	0.03	6.48	1.43	0.16	0.22	**182.93**
2005	46.55	53.52	4.27	15.96	56.04	1.88	0.16	0.48	0.03	6.61	1.64	0.14	0.16	**187.43**
2010	44.47	46.27	6.76	15.98	57.37	1.90	0.17	0.65	0.04	6.54	1.44	0.09	0.03	**181.70**
2011	44.54	46.50	6.35	15.78	57.70	1.91	0.16	0.65	0.04	6.46	1.40	0.11	0.03	**181.63**
2012	45.41	42.95	5.80	13.59	58.56	1.69	0.15	0.69	0.05	6.34	1.40	0.11	0.03	**176.76**
2013	44.81	43.13	6.44	13.21	57.79	1.73	0.17	0.68	0.05	6.34	1.32	0.12	0.03	**175.81**
2014	43.17	41.27	5.89	13.07	58.61	1.72	0.16	0.68	0.06	6.26	1.31	0.12	0.03	**172.36**
2015	42.09	40.62	5.65	13.00	58.62	1.70	0.16	0.67	0.06	6.25	1.26	0.12	0.02	**170.23**
2016	41.05	41.17	5.62	12.49	57.85	1.73	0.17	0.68	0.06	6.30	1.22	0.11	0.02	**168.48**
2017	40.24	41.65	5.85	12.57	58.35	1.72	0.17	0.64	0.06	6.06	1.12	0.12	0.02	**168.58**
2018	38.04	42.78	5.83	12.50	57.11	1.71	0.16	0.64	0.06	5.87	0.97	0.10	0.02	**165.80**
2019	36.93	43.71	5.71	12.49	57.23	1.71	0.18	0.66	0.06	5.79	0.94	0.10	0.02	**165.53**
2020	36.82	43.88	5.76	12.75	57.32	1.72	0.18	0.66	0.06	5.75	0.88	0.10	0.02	**165.89**

In Table 5.29, N_2O emissions from liquid systems, solid storage and 'other' sources are shown.

Table 5.29 Trend in N_2O emissions from manure management (Gg)

Year	Direct emissions			Indirect emissions	Total
	Liquid system	Solid storage	Other		
	Gg				
1990	2.89	3.03	0.00	3.59	**9.51**
1995	2.71	3.00	0.00	3.37	**9.08**
2000	2.53	3.01	0.00	3.25	**8.79**
2005	2.34	2.79	0.00	2.96	**8.09**
2010	2.43	2.49	0.00	2.90	**7.82**
2011	2.39	2.43	0.00	2.84	**7.66**
2012	2.32	2.35	0.00	2.76	**7.44**
2013	2.21	2.27	0.00	2.69	**7.17**
2014	2.16	2.20	0.00	2.63	**6.99**
2015	2.18	2.22	0.00	2.64	**7.04**
2016	2.19	2.26	0.00	2.67	**7.12**
2017	2.21	2.25	0.00	2.66	**7.12**
2018	2.18	2.21	0.00	2.61	**7.01**
2019	2.16	2.19	0.00	2.59	**6.94**
2020	2.18	2.20	0.00	2.60	**6.97**

In 2020, N_2O emissions from manure management were 26.7% (6.97 Gg N_2O) lower than in 1990 (9.51 Gg N_2O). The major contribution of direct emissions is given by the 'solid system' with 50.3% (in 1990 with 51.2%). In 2020, indirect N_2O emissions from manure management account for 37.2% of total N_2O emissions from manure management and were 27.7% (2.60 Gg N_2O) lower than in 1990 (3.59 Gg N_2O).

5.3.4 Source-specific QA/QC and verification

A study carried out by the CRPA in 2018 (CRPA, 2018) mentioned before also includes a survey on the digesters and the outcomes of the survey have been used to update the estimates as described in the paragraph 5.3.2.

A check was carried out on the VS values. An average of the time series of VS values was calculated for cattle. Three weighted mean values were calculated. The first was obtained using Husted values of 142.7 g VS/kg for solid manure and 47.5 g VS/kg for slurry. The second was obtained from the VS kg/head/day values calculated using Equation 10.24 of the 2006 IPCC Guidelines, which uses the data to estimate enteric emissions. The third was calculated as an average of the VS values measured by CRPA. Specifically, a crude average of VS values for manure and slurry was calculated from approximately 400 samples analysed in the period 2001-2019; from the average VS values for manure and slurry, a weighted average was calculated. The values obtained were 98.2, 93.5 and 117.4 g VS/kg manure, respectively. This verification supports the estimates made, based on the Husted factors, but further investigations will be carried out.

For verification purposes, the $Frac_{GasMS}$ parameter have been also estimated as a fraction of nitrogen recovered and stored that is emitted as N_NH_3-NO_x-N_2O-N_2. This value is equal to 0.329, for 1990, and to 0.282 in 2020.

As recommended by the 2019 UNFCCC review, starting from the data on amount of solid and slurry manure produced, used in the estimate of CH_4 emissions from manure management, the amount of straw added to the manure during housing was calculated. The estimated amount of straw for cattle and buffalo bedding was compared with the annual amount of wheat and barley straw used for various purposes. It was found that cattle and buffalo bedding is equal to 83% of the amount of wheat and barley straw.

5.3.5 Source-specific recalculations

As regards for CH_4 emissions from manure management, the changes were: recalculated EF CH_4 for grazing for cattle and buffalo since 1990 with average MCF value for cool and temperate zones, based on the distribution of livestock between these zones (as required by 2021 UNFCCC review); EF CH_4 update from equine and sheep/goat manure management since 1990 (EFs are weighted averages of the 2006 IPCC cool and temperate EFs, with updated values assigned to provinces consistent with the update of provincial mean temperatures based on SCIA data); corrected the provincial distribution of methane emissions from manure management with data from the 2010 census, this resulted in a slight change in the EFs from manure management of sheep, goats and horses; updated 2019 rabbit data; corrected the formula for calculating the

biogas produced, which affects the estimate of N at digesters the whole time series for dairy cattle and non-dairy cattle and, to a small extent, from 1991 to 2004 also for pigs.
As regards for N_2O emissions from manure management, the changes were: corrected EFs NH_3 housing for 2019 for non-dairy cattle and buffaloes categories; updated equine and sheep and goat housing NH_3 emission factors for the whole time series; modified the formula for estimating NH_3 emissions from storage for cattle, pigs and poultry by subtracting from N at housing also the amount of N at digesters before multiplying by the emission factor; included in storage estimates NH_3 emission factors for equine and sheep and goat for the whole time series; updated N excreted dairy cattle for 2019 based on updated protein percentage in milk; updated 2019 rabbit data; corrected the formula for calculating the biogas produced, which affects the estimate of N at digesters the whole time series for dairy cattle and non-dairy cattle and, to a small extent, from 1991 to 2004 also for pigs.

5.3.6 Source-specific planned improvements

In Table 5.30, future improvements in agreement with the QA/QC plan are presented.

Table 5.30 Improvements for manure management category according to the QA/QC plan

Category/sub category	Parameter	Year of submission 2022	Year of submission 2023	Activities
Livestock categories	CH_4 EFs		√	Further assessments will be made on the estimation of methane emissions from storage, considering estimating emissions according to both temperate and cool climate zones, updating temperatures and 2021 Census livestock data

For what concerns the methodology to estimate methane emissions from storage, developed by Husted, as recommended by the 2019 UNFCCC review, the possibility of using the IPCC equations 10.23-24 with the country specific values of the parameters to carry out the estimate of the emissions will be assessed. The data of the CRPA, which carried out around 400 analyzes on zootechnical waste in the period 2001-2019, collecting data on solids total and volatile solids, will also be considered. However, it should be emphasised that the methodology adopted allows methane emissions to be estimated taking into account national characteristics that influence emissions from manure storage and that would be lost if the IPCC equations were used to estimate methane emissions from manure storage.
Parameters used for this submission are shown in Table 5.31.

Table 5.31 Parameters used for the different livestock categories (2020)

Livestock category			Average weight (kg)	N excretion (kg N head^{-1} yr^{-1})
DAIRY CATTLE			602.7	109.06
NON- DAIRY CATTLE			386.9 (**)	52.04 (**)
Less than 1 year (*)			205.2 (**)	25.54 (**)
From 1 year - less than 2 years				
	Male	for reproduction	557.0	66.8
		for slaughter	557.0	66.8
	Female	for breeding	405.0	67.6
		for slaughter	444.0	53.3
From 2 years and more				
	Male	for reproduction	700.0	84.0
		for slaughter and work	700.0	84.0
	Female	Breeding heifer	540.0	90.2
		Slaughter heifer	540.0	64.8
		Other non dairy cattle (***)	557.0	54.1
BUFFALO			497.2 (**)	59.21 (**)
	Cow buffalo		630.0	71.31
	Other buffaloes		319.5	43.0
OTHER SWINE			88.1 (**)	13.45 (**)
Weight less than 20 kg			10.0	
From 20 kg weight and under 50 kg			35.0	5.3

Livestock category		Average weight (kg)	N excretion (kg N head^{-1} yr^{-1})
From 50 kg and more			
	Boar	200.0	30.5
	For slaughter		
	from 50 to 80 kg	65.0	9.9
	from 80 to 110 kg	95.0	14.5
	from 110 kg and more	135.0	20.6
SOWS		172.1	27.66 (**)
SHEEP	Sheep	51.1	16.2
	Other sheep	20.8	16.2
GOATS	Goats	53.8	16.2
	Other goats	14.9	16.2
EQUINE	Horses	550.0	50.0
	Mules and asses	300.0	50.0
POULTRY	Broilers	1.2	0.36
	Layer hens	1.8	0.66
	Other poultry	4.0	0.68
RABBITS	Female rabbits	4.0	2.5
	Other rabbits	1.3	0.8
FUR ANIMALS		1.0	4.1

(*) Categories included in less than 1 year are: calf, fattening male cattle, fattening heifer and heifer for replacement;
(**) values are variable for the time series.
(***) Suckling cows and cows in late career.

5.4 Rice cultivation (3C)

5.4.1 Source category description

For the rice cultivation category, only CH_4 emissions are estimated, other GHGs do not occur; N_2O from fertilisation during cultivation was estimated and reported in "Agricultural soils" under direct soil emissions - synthetic fertilizers. Methane emissions from rice cultivation have been identified as a key source at level assessment with Approach 1. In 2020, CH_4 emissions from rice cultivation were 63.3 Gg, which represent 8.2% of CH_4 emissions for the agriculture sector (8.4% in 1990) and 3.7% for national CH_4 emissions (3.8% in 1990).

In Italy, CH_4 emissions from rice cultivation are estimated only for an irrigated regime, other categories suggested by IPCC (rainfed, deep water and "other") are not present. Methane emissions, reported in the CRF tables, represent two water regimes: single aeration (32.8 Gg) and multiple aeration (30.5 Gg).

A detailed methodology was developed, in consultation with an expert in CH_4 emissions and rice cultivation (Wassmann, 2005) and following outcomes of previous UNFCCC review processes. For this purpose, an expert group on rice cultivation together with the C.R.A. – Experimental Institute of Cereal Research – Rice Research Section of Vercelli was established. Different national experts from the rice cultivation sector were also contacted[21].

5.4.2 Methodological issues

For the estimation of CH_4 emissions from rice cultivation a detailed methodology was implemented following the IPCC guidelines (IPCC, 2006, volume 4, chapter 5). Country-specific circumstances have been considered. Parameters such as an adjusted integrated emission factor (kg CH_4 $m^{-2}day^{-1}$), cultivation period of rice (days) and annual harvested area (ha) cultivated under specific conditions are considered. Information of the cultivated surface is collected 100% from rice farmers. Every year, timely data collection is ensured by the National Rice Institute (ENR, several years [b]). Activity data information is shown in Table 5.32.

[21] Stefano Bocchi, Crop Science Department (University of Milan); Aldo Ferrero, Department of Agronomy, Forestry and Land Management (University of Turin); Antonino Spanu, Department of agronomic science and agriculture genetics (University of Sassari).

Table 5.32 Parameters used for the calculation of CH_4 emissions from rice cultivation

Parameters	Reference
Cultivated surface with "dry-seeded" technique (%)	ENR, several years [a]
Cultivated surface – national (ha)	ISTAT, several years [a],[b],[j]; ENR, several years [b]
Cultivated surface by rice varieties (ha)	ENR, several years [b]
Cultivation period of rice varieties (days)	ENR, 2011; ENR, 2014 [a],[b]; ENSE, 1999; ENSE, 2004; ENR, 2013
Methane emission factor (kg CH_4 m^{-2} d^{-1})	Leip *et al*., 2002; Schutz *et al*., 1989[a], [b]; Meijide *et al*., 2011
Crop production (t yr^{-1})	ISTAT, several years [a],[b],[j]
Yield (t ha^{-1})	Estimations based on cultivated surface and crop production data
Straw incorporation (%)	Expert judgement (Tinarelli, 2005; Lupotto *et al*., 2005)
Agronomic practices (%)	ISTAT, 2006[b]; Tinarelli, 2005; Lupotto *et al*., 2005; Zavattaro et. al, 2004; Baldoni & Giardini, 1989; Tinarelli, 1973; 1986
Scaling factors (SFw, SFp, SFo)	IPCC, 2006; Yan *et al*., 2005

Rice cultivation practice

In Italy, rice is sown from mid-April to the end of May and harvested from mid-September to the end of October; the only practised system is the controlled flooding system, with variations in water regimes (Regione Emilia Romagna, 2005; Mannini, 2004; Tossato and Regis, 2002). In Table 5.33, water regimes descriptions for the most common agronomic practices in Italy are presented. Water regime trends have been estimated in collaboration with expert judgement expertise (Tinarelli, 2005; Lupotto *et al*., 2005) and available statistics (ENR, several years [b]).

Normally, the aeration periods are very variable in number and time, depending on different circumstances, as for example, the type of herbicide, which is used (Baldoni and Giardini, 1989). Another water regime system, present in southern Italy, is the sprinkler irrigation, which exists only on experimental plots and could contribute to the diffusion of rice cultivation in areas where water availability is a limiting factor (Spanu et al., 2004; Spanu and Pruneddu, 1996).

Table 5.33 Water regimes in Italy and classification according to IPCC guidelines

Type of seeding	April	May	June	July	August	September -October	Description
Wet-seeded "classic"	15-30 April Flooding and wet-seeded (*)	10 may	Herbicide treatment	Fertilizer application (1/3), soil is saturated but not flooded. Panicle formation	Final aeration	Harvest	2 aeration periods during rice cultivation, as minimum, not including the final aeration IPCC classification: Intermittently flooded – multiple aeration
		1ºaeration-AR	2º aeration-AA		3º final aeration		
Wet-seeded "red rice control"	15 April Flooding and wet-seeded (*)	First application of herbicides, the soil is dry. Approximately, on 15 may flooding and after some days seeding	At the end of June, fertilization treatment	Fertilizer application (1/3), soil is saturated but not flooded. Panicle formation	Final aeration	Harvest	2 aeration periods during rice cultivation, as minimum, not including the final aeration. In some cases, between April and May, even 3 aeration periods are practised. IPCC classification: Intermittently flooded – multiple aeration
		1° aeration – AC Approx. after 10 days 2° aeration - AR	3ºaeration - AA		Final aeration		
Dry-seeded with delay flooding	15 April Dry-seeded	Approximately, on 15 may flooding	Herbicide treatment	Fertilizer application (1/3), soil is saturated but not flooded. Panicle formation		Harvest	1 aeration period during rice cultivation, as minimum, not including the final aeration. IPCC classification: Intermittently flooded – single aeration

	1º aeration-AA	2º final aeration

(*) the first fertilization (2/3) during the initial part of the rice cultivation, generally on July there is a second period for the fertilization (1/3), normally there is no aeration during the second fertilization period. Aeration periods have mostly have last between 5-15 days and are classified as follows: AC=aeration to control red rice; AR=drained, aeration in order to promote rice rooting; AA=drained, tillering aeration.

In general, rice seeds are mechanically broadcasted in flooded fields. However, in Italy for the last 15 years, the seeds are also drilled to dry soil in rows. The rice which has been planted in dry soil is generally managed as a dry crop until it reaches the 3-4 leaf stage. After this period, the rice is flooded and grows in continuous submersion, as in the conventional system (Ferrero and Nguyen, 2004; Russo, 1994).
During the cultivation period, water is commonly kept at a depth of 4-8 cm, and drained away 2-3 times during the season to improve crop rooting, to reduce algae growth and to allow application of herbicides. Rice fields are drained at the end of August to allow harvesting, once in a year (Ferrero and Nguyen, 2004; Baldoni and Giardini, 1989; Tinarelli, 1973; Tinarelli, 1986).
Nitrogen is generally the most limiting plant nutrient in rice production and is subject to losses because of the reduction processes (denitrification) and leaching. Sufficient nitrogen should be applied pre-plant or pre-flood to assure that rice plant needs no additional nitrogen until panicle initiation or panicle differentiation stage. When additional nitrogen is required, it should be top-dressed at either of these plant stages or whenever nitrogen deficiency symptoms appear. The above-mentioned applications are usually used in two or three periods; the first period is always before sowing, that is on dry soil, while the others occur during the growing season (Russo, 2001; Russo, 1993; Russo *et al*., 1990; Baldoni and Giardini, 1989).
In Italy, another type of fertilization practise is the incorporation of straw. The incorporation period can vary according to weather conditions, but probably mainly incorporated approximately one month before flooding (Russo, 1988; Russo 1976). Rice straw is often burned in the field, otherwise incorporated into the soil or buried. For other agronomic practice, a national publication has been considered for understanding fertilizer and crop residues management (Zavattaro *et al*., 2004).

Methane emission factor
An analysis on recent and past literature, for the CH_4 daily EF (kg CH_4 m^{-2} d^{-1}) was done. Different scientific publications related to the CH_4 daily EF measurements in Italian rice fields were revised (Marik *et al*., 2002; Leip *et al*., 2002; Dan *et al*., 2001; Butterbach-Bahl *et al*., 1997; Schutz et al., 1989[a], [b]; Holzapfel-Pschorn & Seiler, 1986). Other publications indirectly related with CH_4 production were also considered (Kruger *et al*., 2005; Weber *et al*., 2001; Dannenberg & Conrad, 1999; Roy *et al*., 1997). Butterbach-Bahl *et al*. have presented interesting results associated to the difference in EFs of two cultivation periods (1990 and 1991). In these consecutive years, fields planted with rice cultivar Lido showed a level of CH_4 emissions 24-31% lower than fields planted with cultivar Roma. Marik *et al*. have published detailed information on agronomic practices (fertilized fields) related to measurements of CH_4 emission factor for years 1998 and 1999; values are similar to those presented in previous publications (Schutz et al., 1989[a], [b]; Holzapfel-Pschorn & Seiler, 1986). Leip *et al*. have published specific CH_4 EF for the so called dry-seeded with delay flooding, as shown in Table 5.34. The dry–seeded technique could bring interesting benefits in emission reduction, since lower emission rates compared with normal agronomic practices, were determined experimentally.
The estimation of CH_4 emissions for the rice cultivation category considers an irrigated regime, which includes intermittently flooded with single aeration and multiple aeration regimes. The CH_4 emission factor is adjusted with the following parameters: a daily integrated emission factor for continuously flooded fields without organic fertilizers, a scaling factor to account for the differences in water regime in the rice growing season (*SFw*), a scaling factor to account for the differences in water regime in the preseason status (*SFp*) and a scaling factor which varies for both types and amount of amendment applied (*SFo*). Scaling factor parameters have been updated according to literature (Yan *et al*., 2005) and the IPCC 2006 Guidelines (IPCC, 2006, volume 4, chapter 5).
In 2014, the cultivation period (days) for some rice varieties (ENR, 2014 [a], [b]; ENSE, 1999; ENSE, 2004; ENR, 2013) has been revised. Despite the upload of the vegetation period of some varieties, the estimate of the average value for water regime does not change the previous values. The Joint Research Centre Institute for Environment and Sustainability - Climate Change Unit, in charge of measuring rice paddy fields in Italy, has been contacted to obtain data related to measurements carried out in the latest years. On the basis of the documentation received, the daily emission factor for continuously flooded fields without organic amendments from 2009 (Meijide et al., 2011) has been assessed. The emission factor is based on experimental measurements carried out in 2009 in an area in the Po Valley, in Northern Italy, where rice cultivation is most widespread. The value is slightly lower than the previous one. Assumptions of agronomic practices and

parameters used for CH_4 emission estimations are shown in Table 5.33 and Table 5.34, respectively. Total CH_4 emissions for rice cultivation in 2020 were 63.28 Gg.

Table 5.34 Parameters used for estimating CH_4 emissions from rice cultivation in 2020

Rice cultivation water regimes: Intermittently flooded	**Single aeration**	**Multiple aeration**	**Multiple aeration**
Type of seeding	Dry-seeded	Wet-seeded (*classic*)	Wet-seeded (*red rice control*)
Surface (ha)	133,130	42,385	51,804
Daily EF (g CH_4 m^{-2} d^{-1})	0.20	0.27	0.27
SF_w	0.60	0.52	0.52
SF_p	0.68	0.68	0.68
SF_o	2.2	2.2	2.2
Adjusted daily EF (g CH_4 m^{-2} d^{-1})	0.18	0.21	0.21
Days of cultivation (days)	138	156	156
Seasonal EF (g CH_4 m^{-2} yr^{-1})	24.66	32.34	32.34
Methane emissions (Gg)	**32.83**	**13.71**	**16.75**

5.4.3 Uncertainty and time-series consistency

Uncertainty of emissions from rice cultivation has been estimated equal to 11.2% as a combination of 5% and 10% for activity data and emissions factor, respectively.

Lack of experimental data and knowledge about the occurrence and duration of drainage periods in Italy is the major cause of uncertainty. Moreover, it is not easy to quantify the surface where the traditional or the different number of aerations is practiced, which depends on the degree and the type of infestation, and the positive or negative results of the herbicide treatment application (Spanu, 2006).

In 2020, CH_4 emissions from rice cultivation were 15.7% (63.28 Gg CH_4) lower than in 1990 (75.06 Gg CH_4). In Italy, the driving force of CH_4 emissions from rice cultivation is the harvest area and the percentage of single aerated surface (lower CH_4 emission factor). From 1990-2020, the harvest area has increased by 5.5%, from 215,442 ha $year^{-1}$ (1990) to 227,319 ha $year^{-1}$ (2020). The percentage of single aerated surface has increased from 1.0% (1990) to 58.6% (2020). The dry seeded sowing (single aeration) has been widespread since the beginning of the 1990s owing to the simplification of cultivation operations and water management in particular. Moreover, dry seeded sowing allows better production performance than sowing in water in areas with very loose soils. Data on rice cultivation including harvest area with single aeration are provided by the National Rice Institute. In Table 5.35, CH_4 emissions from rice cultivation and harvested area are shown.

Table 5.35 Harvest area and CH_4 emissions from the rice cultivation sector

Year	**Harvested area ($10^9 m^2$ yr^{-1})**	**CH_4 emissions (Gg)**
1990	2.15	75.06
1995	2.39	79.56
2000	2.20	66.26
2005	2.24	70.09
2010	2.48	72.89
2011	2.47	72.22
2012	2.35	71.57
2013	2.16	66.45
2014	2.20	64.54
2015	2.27	66.73
2016	2.34	68.60
2017	2.30	65.83
2018	2.17	64.05
2019	2.20	63.33
2020	2.27	63.28

5.4.4 Source-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the sum of sub-categories. Data entries have been checked several times during the compilation of the inventory. Several QA activities are carried out in the different phases of the inventory process. The quality of the Italian rice emission inventory was verified with the Denitrification Decomposition model (DNDC). Initial results have found a high correspondence between the EFs used for the Italian inventory and those simulated with DNDC model (Leip and Bocchi, 2007).

In particular, the applied methodology has been presented and discussed during several national workshop and expert meeting, collecting findings and comments to be incorporated in the estimation process. All the agriculture categories have been embedded in the overall QA/QC-system of the Italian GHG inventory. In November 2014, the CH_4 emission factors used for the rice cultivation category in the Italian emissions inventory were presented at the 9th Expert Meeting on Data for the IPCC Emission Factor Database (EFDB) and the values were entered into the database.

5.4.5 Source-specific recalculations

No specific recalculations are observed.

5.4.6 Source-specific planned improvements

Provincial estimations on the basis of the relation between emissions and temperature would result in further possible improvements, even if enhancement would be limited since the largest Italian rice production is in the Po valley, where monthly temperatures of the rice paddies are similar. In 1990, *Piemonte* and *Lombardia* regions represented 95% of the national surface area of rice cultivation, while in 2016 they represented 93% (ENR, several years [b]; Confalonieri and Bocchi, 2005).

5.5 Agriculture soils (3D)

5.5.1 Source category description

In 2020, N_2O emissions from managed soils were 36.31 Gg, representing 83.9% of N_2O emissions for the agriculture sector (79.9% in 1990) and 55.6% for national N_2O emissions (41.4% in 1990). N_2O emissions from this source consist of direct emissions from managed soils (28.38 Gg) and indirect emissions from managed soils (7.93 Gg).

Direct and indirect N_2O emissions from managed soils are key sources at level assessment, both with Approach 1 and Approach 2. Direct and indirect N_2O emissions from managed soils are key sources at trend assessment, with Approach 1 and Approach 2, except indirect N_2O emissions that are key sources at trend assessment, with Approach 2 excluding the LULUCF sector.

For direct emissions from managed soils the following sources are estimated: inorganic nitrogen fertilizers; organic nitrogen fertilizers, which include animal manure applied to soils, sewage sludge applied to soils, other organic fertilizers applied to soils (as compost and other organic amendments used as fertiliser); urine and dung deposited by grazing animals; crop residues; cultivation of organic soils (i.e. histosols). Mineralised nitrogen resulting from loss of soil organic C stocks in mineral soils through land-use change or management practices (F_{SOM}) has been assumed as not applicable; agricultural practices result in no losses of carbon in cropland remaining cropland and therefore these do not generate N_2O emissions, as reported in the 2006 IPCC Guidelines.

For indirect emissions from managed soils, atmospheric deposition and nitrogen leaching and run-off are estimated. Nitrous oxide emissions from grazing animals are calculated together with the manure management category on the basis of nitrogen excretion, and reported in agricultural soils under "Urine and dung deposited by grazing animals" (see Table 5.36).

CH_4 emissions from managed soils have not been estimated as in the IPCC Guidelines the methodology is not available.

Table 5.36 N_2O emissions from managed soils (Gg)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Direct N_2O emissions from managed soils	**29.25**	**32.37**	**31.76**	**30.10**	**25.11**	**25.37**	**26.61**	**25.67**	**25.69**	**25.59**	**28.38**
Inorganic N fertilizers	11.63	12.23	11.99	11.94	7.95	7.82	8.64	7.90	7.48	7.03	8.76
Organic N fertilizers	8.57	8.44	8.33	7.82	7.83	8.30	8.35	8.86	8.51	8.76	9.41
a. Animal manure applied to soils	*8.23*	*8.03*	*7.81*	*7.33*	*7.03*	*7.25*	*7.33*	*7.37*	*7.29*	*7.30*	*7.37*
b. Sewage sludge applied to soils	*0.08*	*0.13*	*0.17*	*0.14*	*0.16*	*0.13*	*0.12*	*0.11*	*0.11*	*0.11*	*0.11*
c. Other organic fertilizers applied to soils	*0.26*	*0.28*	*0.35*	*0.35*	*0.65*	*0.92*	*0.89*	*1.38*	*1.11*	*1.34*	*1.93*
Urine and dung deposited by grazing animals	3.09	3.50	3.60	2.71	2.71	2.57	2.63	2.59	2.58	2.55	2.56
Crop residues	5.67	7.90	7.54	7.34	6.32	6.38	6.70	6.03	6.84	6.96	7.36
Cultivation of organic soils	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Indirect N_2O emissions from managed soils	**8.52**	**9.11**	**8.89**	**8.38**	**7.02**	**7.09**	**7.49**	**7.21**	**7.14**	**7.14**	**7.93**
Atmospheric deposition	2.57	2.54	2.45	2.25	1.91	1.96	2.10	2.01	1.93	1.94	2.16
Nitrogen leaching and run-off	5.94	6.57	6.45	6.13	5.11	5.13	5.39	5.20	5.22	5.20	5.77

ISPRA is in charge of collecting, elaborating and reporting the UNFCCC/CLRTAP agriculture national emission inventory, thus, consistency among methodologies and parameters is ensured. The nitrogen balance, from the CLRTAP emission inventory, feeds the UNFCCC inventory, specifically for the estimation of: $Frac_{GasMS}$ parameter, used for calculating managed manure nitrogen available for application to managed soils (Equation 10.34 of 2006 IPCC Guidelines, volume 4, chapter 10) and to assess F_{AM}; $Frac_{GASM}$ and $Frac_{GASF}$ parameters, used for calculating indirect N_2O emissions from atmospheric deposition of nitrogen volatilised from managed soils (Equation 11.9 of 2006 IPCC Guidelines). Direct and indirect N_2O emissions from the use of sewage sludge in agricultural soils have been estimated and reported.

5.5.2 Methodological issues

Methodologies used for estimating N_2O emissions from "Agricultural soils" follow the IPCC approach (Tier1). IPCC emission factors (IPCC, 2006, volume 4, chapter 11) and assessed by the Research Centre on Animal Production (CRPA, 2000; CRPA, 1997[b]) are used. Activity data used for estimations are shown in Table 5.37.

Table 5.37 Data used for estimating agricultural soil emissions

Data	Reference
Fertilizer distributed (t/yr)	ISTAT, several years [a], [b], [i]
Nitrogen content (%)	ISTAT, several years [a], [b], [i]
N excretion rates (kg head^{-1} yr^{-1})	CRPA, 2006[a]; GU, 2006; Xiccato *et al*., 2005
Cultivated surface (ha yr^{-1})	ISTAT, several years [a], [b], [j]
Annual crop production (t yr^{-1})	ISTAT, several years [a], [b], [j]
Residue/crop product ratio by crop type	CESTAAT, 1988
Crop residue production (t dry matter ha^{-1}yr^{-1})	CRPA/CNR, 1992
Dry matter content by crop type	CRPA/CNR, 1992
Protein content in dry matter by crop type	CESTAAT, 1988
Livestock data	ISTAT, several years [a], [b], [g]

The estimation of direct N_2O emissions from managed soils has been carried out in line with the IPCC guidelines (IPCC, 2006), taking into account country-specific peculiarities; N_2O-N emissions are estimated from the amount of: inorganic nitrogen fertilizers (F_{SN}); organic nitrogen fertilizers (F_{ON}), which include animal manure applied to soils (F_{AM}), sewage sludge applied to soils (F_{SEW}), other organic fertilizers applied to soils (as compost and other organic amendments used as fertiliser, F_{COMP} and F_{OOA} respectively); urine and dung deposited by grazing animals (F_{PRP}); crop residues (F_{CR}); cultivation of histosols (F_{OS}). Then default IPCC emission factors (IPCC, 2006, volume 4, chapter 11) are applied. Afterwards, N_2O-N emissions are converted to N_2O emissions, multiplying by the ratio of molecular weights (44/28). Urine and dung deposited

by grazing animals emissions are estimated according to the methodology described in section 5.3.2 for manure management.
Direct N_2O emissions from N inputs to managed soils include also emissions related to the application of fertilizers to the short rotation forest crops, according the 2006 IPCC Guidelines (IPCC, 2006, par. 11.2.1.3, vol. 4, chapter 11) and consistenly with the KP Supplement (IPCC, 2014, par. 2.4.4.2).
Indirect emissions are estimated as suggested by the IPCC (IPCC, 2006).

Direct N_2O emissions from managed soils

Applied synthetic fertilizers (F_{SN})
The total use of synthetic fertilizers (expressed in t N year^{-1}) is estimated for each type of fertilizer (see Table 5.38). Data on synthetic fertilizers are from ISTAT as reported in paragraph 5.1.3, 5.1.4 and 5.5.2. N-N_2O emissions from synthetic fertilizers are obtained multiplying F_{SN} by the emission factor, 0.01 kg N-N_2O/kg N (IPCC, 2006). The subcategory "Other nitrogenous fertilizers" was introduced since 1998, because activity data is available from that year (ENEA, 2006).
The amount of nitrogen from synthetic fertilizers applied to areas planted with rice was also estimated. The figure used for the estimate of 127 kg N/hectare (Zavattaro *et al*., 2004) was confirmed by the experts of the National Rice Institute (ENR). This value was multiplied by the area cultivated with rice and the result was subtracted from the quantity of N reported by ISTAT. The emission factor of 0.003 kg N-N_2O/kg N (IPCC, 2006) was used to estimate N_2O due to rice fertilization.
The time series of nitrogen content of fertilizers is shown in Table 5.45. In 2020, the total use of synthetic fertilizers was 577,451 t N (see Table 5.38).

Table 5.38 Total use of synthetic fertilizer in 2020 (t N yr^{-1})

Type of fertilizers	Fertilizers distributed (t yr^{-1})	Nitrogen content (%)	Nitrogen content of synthetic fertilizers (t N yr^{-1})
Ammonium sulphate	85,636	20.8%	17,830
Calcium cyanamide	14,410	19.7%	2,845
Nitrates (*)	123,490	22.8%	28,097
CAN	204,958	27.0%	55,339
Urea	643,562	45.9%	295,134
Other nitric nitrogen	119,711(**)	33.9%	2,155
Other ammoniacal nitrogen			9,036
Other amidic nitrogen			29,366
Phosphate nitrogen	262,219	17.0%	44,533
Potassium nitrogen	58,824	19.3%	11,353
NPK nitrogen	359,754	12.7%	45,730
Organic mineral	379,796	9.5%	36,033
Total	**2,252,360**		**577,451**

(*) includes ammonium nitrate < 27% and ammonium nitrate > 27% and calcium nitrate; (**) this amount refers to the total of other nitrogenous fertilizers, which includes other nitric, ammoniacal and amidic N fertilizers distributed. Total amount of N in these fertilizers is 40,557 t N/year, which is the sum of values reported in the column Nitrogen content of synthetic fertilizers for these three fertilizers considered. The nitrogen content (%) is calculated by dividing the total amount of N contained to the total amount of other nitrogenous fertilisers distributed.

The information on amount fertilizers distributed (tonnes/year) and nitrogen contained in the fertilizers (tonnes N/year) are collected by the ISTAT based on annual questionnaires sent to Italian companies that distribute fertilizers to wholesale and/or retail commercial structures, to farmers, cooperatives, etc. Data on nitrogen content (%) reported in table 5.38 are calculated values based on two above-mentioned amounts and are not directly used in the estimations of N_2O emissions from inorganic fertilizers applied to soils.
The methodology for estimating the amount of CAN used and the nitrogen content is given in section 5.9.2.
The time series of applied synthetic fertilisers is shown in Table 5.39. A strong decrease is observed in the year from 2009 to 2011 as result from the official statistics provided by the National Institute of Statistics (ISTAT), due to the economic crisis in particular for the amount of urea applied to soils. In 2012, a recovery from the sharp decline was recorded.

Table 5.39 Trend of annual amount of synthetic fertiliser N applied to soils (t N yr^{-1})

Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
F_{SN} (t N)	759,510	799,614	782,701	779,846	528,029	517,854	570,786	522,840	495,005	466,842	577,451

Applied organic N fertilisers (F_{ON})

The amount of organic N inputs applied to soils other than by grazing animals is calculated using Equation 11.3 of the 2006 IPCC Guidelines. This includes applied animal manure (F_{AM}), sewage sludge applied to soil (F_{SEW}) and other organic amendments (F_{OOA}), which also includes compost applied to soils (F_{COMP}).

Table 5.40 Trend of applied organic N fertilisers (t N yr^{-1})

Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
F_{AM} (t N)	523,712	511,033	496,765	466,575	447,212	461,284	466,743	469,267	463,888	464,804	469,164
F_{SEW} (t N)	5,071	8,137	10,954	8,874	10,040	8,303	7,410	7,116	7,247	6,977	6,759
F_{OOA} (t N)	16,518	18,116	22,571	22,308	41,125	58,488	56,906	87,706	70,450	85,554	122,688

Animal manure N applied to soil (F_{AM})

The annual amount of animal manure N applied to soils is calculated using Equation 11.4 of the 2006 IPCC Guidelines (IPCC 2006, vol. 4, chapter 11). The amount of managed manure nitrogen available for soil application is calculated using Equation 10.34 (IPCC 2006, vol. 4, chapter 10). The amount of managed manure nitrogen in manure management systems is estimated as reported in paragraph 5.3.2 "Direct N_2O emissions from manure management" and country-specific nitrogen excretion rates (CRPA, 2006[a]; GU, 2006; Xiccato *et al*., 2005) are used. $Frac_{LossMS}$ parameter of the Equation 10.34 is equal to:

- the managed manure nitrogen that volatilises as NH_3 and NO_x in the manure management systems (i.e. the $Frac_{GasMS}$ emission factor);
- the nitrogen losses from leaching and run-off at housing and storage sistems;
- the losses of N_2, that are considered in response to the 2018 ESD review process[22];
- the nitrogen lost through N-NH_3 emissions from digesters biogas facilities (during storage of feedstock on the premises of the biogas facility; during open storage of the digestate);
- the losses of N-N_2O in the manure management systems.

A description of the country-specific $Frac_{GasMS}$ parameter and the nitrogen leaching and run-off is reported in paragraph 5.3.2 "Indirect N_2O emissions from manure management". On the basis of the data on the quantity of straw per day (per tonnes of live weight, per type of housing, for cattle and buffalo), contained in the Ministerial Decree of 25 February 2016 on the use of zootechnical effluents, combined with the manure production coefficients used in the estimation of methane emissions from storage, the quantity of straw used as bedding that ends up on agricultural land during the spreading of manure was estimated, as recommended by the 2019 UNFCCC review. The nitrogen content was considered and was added to the nitrogen input from manure applied to soils for N_2O emissions estimate. Data for cattle were updated, while data for buffalo, previously missing, were included. Data have been updated since 1990. Further information and data can be found in the Annex 7.3. The description of the agricultural residues used for bedding material considered in the animal manure applied to soils (3Da2a) category, which also involves the crop residues (3Da4) and field burning of agricultural residues (3F) categories, is reported in the Annex 7.3. As recommended during the 2019 UNFCCC review, to enhance transparency on the total amount of crop residues generated and shares of the crop residue amounts used for different purposes (such as bedding material (3.D.a.2.a), left on fields (3.D.a.4), burnt on-site (3.F) and off-site (1.A, 5.C.2)), a flow-chart is reported in Annex 7, in Figure A.7.1.
$Frac_{FEED}$, $Frac_{FUEL}$ and $Frac_{CNST}$ parameters of the Equation 11.4 are assumed equal to zero.
The F_{AM} (t N yr^{-1}) value is estimated by summing the F_{AM} for each livestock category; then emissions are calculated with emission factor 0.01 kg N-N_2O/kg N (IPCC, 2006). In 2020, F_{AM} parameter was 469,164 t N.

Sewage sludge applied to soils (F_{SEW})

Direct and indirect N_2O emissions from the application of sewage sludge to agricultural soils were calculated using the Tier 1 methodology described in the IPCC (IPCC, 2006). Direct emissions were estimated by

[22] The 2018 annual review of the GHG emission inventory of Italy, pursuant to Article 19(2) of Regulation (EU) No 525/2013, with a view to monitoring Italy's achievement of its greenhouse gas emission reduction or limitation target pursuant to Article 3 of Decision No 406/2009/EC (the 'Effort Sharing Decision', ESD).

applying the relevant default IPCC equations, EFs and parameters (see Annex A7.3). From 1995 activity data (amount of sewage sludge) and parameters (N content) were collected from the Ministry for the Environment, Land and Sea, which is in charge of collecting and reporting data under the EU Sewage Sludge Directive 86/278/EEC (MATTM, 2014). From 1990 to 1994 AD and parameters were reconstructed, description is available in the Waste Chapter. The amount of sewage N applied was calculated using the amount of sewage sludge (expressed in t dry matter) and the N content of sludge. Emission factor used was 0.01 kg N-N_2O/kg N (IPCC, 2006).

Other organic amendments applied to soils (F_{OOA}) (*including compost N applied to soils* (F_{COMP}))
For the other organic fertilisers applied to soil category, the used amount, including compost and organic amendments, and N content are provided by ISTAT (as reported in the paragraph 5.1.3, 5.1.4 and 5.5.2). Data are available from 1998; for the previous years, data were reconstructed based on the trend of the available data. A peak of the amount of compost applied to soil is observed for 2011. A verification was requested to ISTAT which confirmed the value.

Urine and dung from grazing animals (F_{PRP})
The annual amount of N deposited on pasture is calculated using Equation 11.5 (IPCC 2006, vol. 4, chapter 11). As mentioned in section 5.3.2, when estimating N_2O emissions from manure management, the amount related to manure excreted while grazing is subtracted and reported in "Agricultural soils" under urine and dung from grazing animals. In Table 5.25, nitrogen excretion rates (kg head^{-1} yr^{-1}) used for estimations are shown. N_2O emissions are estimated with the total nitrogen excreted from grazing (include all livestock categories), number of animals, an EF for cattle (dairy, non-dairy and buffalo) of 0.02 kg N_2O-N/kg N excreted and an EF for sheep and other animals (goats, horses and mules and asses) of 0.01 kg N_2O-N/kg N excreted (IPCC, 2006). As recommended during the 2021 UNFCCC review, N_2O direct emissions for ostriches are estimated and reported in the IPCC category urine and dung deposited by grazing animals because the common rearing system for ostriches is free-range outdoor housing. Activity data are provided by ISTAT for some years and for the other years the number of animals has been estimated. The default value for nitrogen excretion rate for broilers (Table 10.19 of chapter 10, volume 4 of the 2006 IPCC Guidelines) has been used. The 2006 IPCC N_2O EF for direct emissions has been used (Table 11.1 of chapter 11, volume 4 of the 2006 IPCC Guidelines).

Table 5.41 Trend of annual amount of urine and dung N deposited by grazing animals on pasture (t N yr^{-1})

Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
F_{PRP} (t N)	176,718	204,710	211,343	156,521	157,462	147,895	151,259	149,054	148,206	146,538	147,304

Crop residue N, including N-fixing crops and forage, returned to soils (F_{CR})
For the estimation of nitrogen input from crop residues, the IPCC methodology is used with country specific data on aboveground residue/crop product ratio, percentage of the residue fixed and dry matter content. The total amount of crop aboveground residues is estimated (t dry matter yr^{-1}) by using the following parameters: annual crop production (t yr^{-1}), aboveground residue/crop product ratio, percentage of the residue fixed and dry matter content of residue by type of crop (%), while, when cultivated surface (ha) is the available activity data, only the crop residue production (t dry matter ha^{-1} yr^{-1}) parameter is used to assess total amount of crop aboveground residues (CESTAAT, 1988; CRPA/CNR, 1992; ENEA, 1994). Data on annual crop production and cultivated surface are from ISTAT as reported in paragraph 5.1.3, 5.1.4 and 5.5.2. The description of the agricultural residues used for bedding material considered in animal manure applied to soils (3Da2a), which also involves the categories crop residues (3Da4) and field burning of agricultural residues (3F), is reported in the Annex 7.3. The description of the type of agricultural residues is also included. As recommended during the 2019 UNFCCC review, to enhance transparency on the total amount of crop residues generated and shares of the crop residue amounts used for different purposes (such as bedding material (3.D.a.2.a), left on fields (3.D.a.4), burnt on-site (3.F) and off-site (1.A, 5.C.2)), a flow-chart is reported in Annex 7, in Figure A.7.1.
The nitrogen content of crop aboveground residues from cereals, legumes, tubers and roots, legumes forages and other forages (t N yr^{-1}) is estimated by multiplying the total amount of crop aboveground residue as dry matter with the reincorporated fraction (1- $Frac_{BURN}$, where $Frac_{BURN}$ is the fraction of crop residue that is burned rather than left on field equal to 0.1 kg N/kg crop-N (IPCC, 1997; CRPA, 1997[b])), and the nitrogen content for each crop type, in line with the Equation 11.6 (IPCC 2006, vol. 4, chapter 11). The nitrogen content is obtained converting protein content in dry matter (CESTAAT, 1988; Borgioli, 1981), dividing by factor 6.25 (100 g of protein/16 g of nitrogen). The contribution of the below-ground nitrogen to the total input of

nitrogen from crop residues has been considered and calculated by using the Equation 11.7A (IPCC 2006, vol. 4, chapter 11) and the IPCC default values of ratio of belowground residues to above-ground biomass and N content of below-ground residues. The amount of nitrogen of crop residues from perennial grasses is calculated by using the Equation 11.7A (IPCC 2006, vol. 4, chapter 11). The values related to N content of aboveground residues, ratio of belowground residues to aboveground biomass and N content of belowground residues used for other temporary forages are weighted averages of the IPCC values in Table 11.2, weighted with the productions of the various crops included in the category other temporary forages. The values used for the $Frac_{renew}$ parameter for other temporary forages (not renewed annually) are derived from Baldoni and Giardini (Baldoni and Giardini, 2002) and the value for perennial grasses is from ISTAT (ISTAT, 2010).
The F_{CR} parameter is obtained by adding the nitrogen content of cultivars crop residues. In 2020, F_{CR} parameter was 468,534 t N (see Table 5.42). Emissions are calculated with emission factor 0.01 kg N-N_2O/kg N (IPCC, 2006).
Detailed information related to the cultivated surfaces, crops production, residues production and parameters used for emissions estimates, for each type of crop, are shown in the Annex 7 (Tables A.7.19-24).

Table 5.42 Trend of annual amount of N in crop residues (t N yr^{-1})

Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
F_{CR} (t N)	360,563	502,989	480,045	466,910	402,447	406,289	426,556	383,425	435,051	442,924	468,534

Area of drained/managed organic soils (F_{OS})
In Italy, the area of organic soils cultivated annually (histosols) is estimated to be 23,195 hectares for the year 2019, a substantially constant value for the whole time series (FAOSTAT database[23]). This value is multiplied by 8 kg N-N_2O ha^{-1} yr^{-1}, following IPCC 2006 Guidelines (IPCC, 2006).
The data are consistent with figures used for estimation in the LULUCF sector. Additional information may be found in paragraph *6.3.4 Methodological issues* of the LULUCF sector.

Indirect N_2O emissions from managed soils
For indirect emissions from agricultural soils the following parameters are estimated:

- Atmospheric deposition
- Nitrogen leaching and run-off

For estimating of N_2O emissions due to atmospheric deposition of NH_3 and NO_x the IPCC tier 1 approach was followed (Equation 11.9 of the 2006 IPCC Guidelines). Parameters used are: total use of synthetic fertilizer F_{SN} (t N yr^{-1}), $Frac_{GASF}$ emission factor, total amount of organic N inputs applied to soils F_{ON} (t N yr^{-1}), total amount of urine and dung N deposited by grazing animals F_{PRP} (t N yr^{-1}), $Frac_{GASM}$ emission factor and the emission factor 0.01 kg N_2O-N per kg NH_3-N and NO_x-N emitted (IPCC, 2006).
$Frac_{GASF}$ parameter is estimated for the whole time series, following the IPCC definition, where the total N-NH_3 and N-NO_x emissions from fertilizers are divided by the total nitrogen content of fertilizers (see table 5.43). NH_3 EFs from the use of synthetic fertilizers for temperate climate and normal pH factors (reported in the EMEP/EEA Guidebook (EMEP/EEA, 2019)) according to the IPCC climate zones classification and the definition available in the 2002 EMEP/CORINAIR Guidebook for which Italy is defined with large areas of acidic soils (soil pH below 7.0) and with some calcareous soils (or managed with soil pH above 7.0), have been updated. NO_x emission factor for synthetic N-fertilizer (reported in the EMEP/EEA Guidebook (EMEP/EEA, 2019)) was also updated. $Frac_{GASM}$ is the fraction of applied organic N fertiliser materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilises as NH_3 and NO_x.
$Frac_{GASM}$ is then composed of the following fractions:

- Fraction of livestock N excretion that volatilizes as NH_3 and NO_x during spreading and grazing animals - $Frac_{GASM}$ indirect (as reported in the CRF). This fraction is equal to the ratio between the amount of NH_3-N and NO_x-N emissions and the total nitrogen excreted (see table 5.43);
- Fraction of N from other organic N fertilizers applied (sewage sludge, other organic amendments applied to soils including compost) that volatilizes as NH_3 and NO_x. The volatilization factor for N-NH_3 and NO_x-N emissions is 7.8% for other organic N fertilizers and 11.9% for sewage sludge applied, as reported in table 5.43.

[23] http://www.fao.org/faostat/en/#data/GV

For $Frac_{GASM}$ indirect, the ammonia emission factors from land spreading for cattle, swine, laying hens and broilers categories have been assessed, on the basis of ISTAT statistics on spreading systems (i.e. 2010 Agricultural Census, 2013 and 2016 Farm Structure Survey). NO_x emission factors (during spreading) were also assessed on the basis of the nitrogen mass-flow approach (Tier 2 method of the EMEP/EEA Guidebook (EMEP/EEA, 2019)). NH_3 and NO_x emission factors from other organic N fertilizers applied (sewage sludge, other organic amendments applied to soils including compost) were also updated based on the EMEP/EEA Guidebook (EMEP/EEA, 2019).
The estimation of N_2O emissions due to nitrogen leaching and run-off has followed the IPCC Tier 1 approach (Equation 11.10 of the 2006 IPCC Guidelines). Parameters used are: total use of synthetic fertilizer F_{SN} (t N yr^{-1}), total amount of organic N inputs applied to soils F_{ON} (t N yr^{-1}), total amount of urine and dung N deposited by grazing animals F_{PRP} (t N yr^{-1}), total amount of N in crop residues (above- and below-ground), including N-fixing crops and from forage F_{CR} (t N yr^{-1}), $Frac_{LEACH-(H)}$ emission factor 0.27 kg N/kg nitrogen of fertilizer or manure (see table 5.43) and the emission factor 0.0075 kg N_2O-N per kg nitrogen leaching/run-off (IPCC, 2006). As mentioned before, the $Frac_{LEACH-(H)}$ IPCC default value was compared with the country-specific $Frac_{LEACH-(H)}$ parameter (ADBPO, 2001; ADBPO, 1994).
The estimate of N lost through leaching and run-off includes the losses of N due to leaching from managed soils. As regards the $Frac_{LEACH-(H)}$, according to the 2006 IPCC Guidelines, the leached nitrogen has to be estimated only in those areas where there is a water surplus or where irrigation is employed. For the agricultural areas affected by the water surplus, the $Frac_{LEACH-(H)}$ is assumed equal to 0.3 kg N/kg N applied to soils or deposited by grazing animals, while a value equal to zero is assumed for the agricultural areas affected by the water deficit. To calculate the agricultural area affected by hydrological surplus, the following procedure was followed. The methodology involves estimating the annual hydrologic surplus of areas below 1,000 meters, which are assumed to be agricultural areas. Monthly surplus values are derived from the Big Bang model elaborated by ISPRA (https://groupware.sinanet.isprambiente.it/bigbang-data/library/bigbang40/grids), whose data are in Ascii format and the coordinate system is ETRS_1989_LAEA. The calculation is made in Qgis environment with the help of the raster of the altimetry and land use categories (Corine Land Cover). The surplus in each cell (which has a size of 1 km x 1 km) was calculated by summing the values of only the rainy months (October November and December) of each year (the range of values obtained varies from 0.0001 to over 1500 millimeters) from 1990 to 2019. The sum of the three months of each year was then multiplied by a boolean raster of the elevations (values 0 if above 1000 meters, 1 if below). In this way, areas above 1000 meters were excluded from the calculation. The agricultural land is identified thanks to the Corine Land Cover, the selected categories are: 211, 212, 213,221, 222, 223, 231, 241, 242, 243, 244, 321, 333 corresponding to the categories "grassland" and "cropland" defined according to the IPCC. Again, a boolean raster was created (values 0 for unselected categories, 1 for selected categories). Finally, cells where a surplus occurs were considered and the total area of these cells was calculated for each year. The result was related to the total area of land below 1000 meters of altitude. The weighted average value of $Frac_{LEACH-(H)}$ relative to the entire national agricultural area will be equal 27.3% of nitrogen applied to soils or deposited by grazing animals.

Table 5.43 Parameters used for the estimation of indirect N_2O emissions from managed soils

	Atmospheric deposition					N leaching and run-off	
Year	**$Frac_{GASF}$ (1) (%)**	**$Frac_{GASM}$ indirect (2) (%)**	**Fraction of N from other organic N fertilizers applied (%) (3)**	**Fraction of N from from sewage sludge applied (%)(4)**	**N volatilised from managed soils (t N)**	**$Frac_{LEACH-(H)}$ (5) (kg N/kg N)**	**N lost through leaching and run-off (t N)**
1990	8.76	10.24	7.8	11.9	163,678	0.27	504,290
1995	8.69	9.62	7.8	11.9	161,502	0.27	557,375
2000	8.83	9.09	7.8	11.9	155,767	0.27	546,935
2005	8.68	8.93	7.8	11.9	143,410	0.27	519,949
2010	8.75	8.95	7.8	11.9	121,491	0.27	433,683
2011	8.80	8.92	7.8	11.9	127,479	0.27	455,820
2012	9.86	8.96	7.8	11.9	142,550	0.27	465,683
2013	9.94	8.96	7.8	11.9	130,465	0.27	438,516
2014	9.64	8.90	7.8	11.9	124,948	0.27	446,284
2015	9.69	8.82	7.8	11.9	124,716	0.27	435,291
2016	10.30	8.76	7.8	11.9	133,506	0.27	457,279
2017	9.74	8.79	7.8	11.9	128,225	0.27	440,893
2018	9.53	8.81	7.8	11.9	122,521	0.27	442,487
2019	10.11	8.84	7.8	11.9	123,686	0.27	440,827
2020	9.95	8.86	7.8	11.9	137,444	0.27	489,526

Note: (1) the fraction is multiplied by F_{SN} (see Table 5.39); (2) the fraction is multiplied by total N excreted (see Table 5.27); (3) the fraction is multiplied by F_{OOA} (see Table 5.40); (4) the fraction is multiplied by F_{SEW} (see Table 5.40); (5) the fraction is multiplied by F_{SN}, F_{SEW}, F_{OOA}, F_{AM} and by F_{CR} (see Table 5.42).

As recommended during the 2021 UNFCCC review, N_2O indirect emissions for ostriches are estimated and reported in indirect N_2O emissions from managed soils, in atmospheric deposition and nitrogen leaching and run-off. Further details on the estimate are given in 5.5.2 *Methodological issues* paragraph, in Direct N_2O emissions from managed soils, in *Urine and dung from grazing animals* (F_{PRP}). The 2006 IPCC N_2O EFs, $Frac_{GASM}$ and $Frac_{LEACH-(H)}$ for indirect emissions have been used (Table 11.3 of chapter 11, volume 4 of the 2006 IPCC Guidelines).

5.5.3 Uncertainty and time-series consistency

Uncertainty for N_2O direct and indirect emissions from managed soils has been estimated to be 53.9%, as combination of 20% and 50% for activity data and emission factor, respectively.

In the 2012 submission, Montecarlo analysis was also applied to estimate uncertainty of the two key categories *Direct N_2O emissions from agricultural soils* and *Indirect N_2O emissions from nitrogen used in agriculture*. The resulting figures were 21.34% and 21.67% for *Direct and Indirect* N_2O emissions, respectively. Normal and lognormal distributions have been assumed for the parameters; at the same time, whenever assumptions or constraints on variables were known this information has been appropriately reflected on the range of distribution values. A summary of the results is reported in Annex 1.

In Table 5.44, time series of N_2O emissions from managed soils are reported.

Table 5.44 Nitrous oxide emission trends from managed soils (Gg)

Year	Direct emissions from managed soils	Indirect emissions from managed soils	Total
		Gg	
1990	29.25	8.52	37.76
1995	32.38	9.11	41.49
2000	31.80	8.89	40.69
2005	30.13	8.38	38.51
2010	25.12	7.02	32.14
2011	26.51	7.38	33.88
2012	27.06	7.73	34.78
2013	25.46	7.22	32.68
2014	25.90	7.22	33.12

Year	Direct emissions from managed soils	Indirect emissions from managed soils	Total
	Gg		
2015	25.37	7.09	32.46
2016	26.61	7.49	34.10
2017	25.67	7.21	32.88
2018	25.69	7.14	32.83
2019	25.59	7.14	32.73
2020	28.38	7.93	36.31

In 2020, N_2O emissions from managed soils were 3.9% (36.31 Gg N_2O) lower than in 1990 (37.76 Gg N_2O). Major contributions were given by direct emissions (28.38 Gg), that come mainly (56.8%) from inorganic N fertilizers (8.76 Gg) and animal manure applied to soils (7.37 Gg) (see Table 5.36). Indirect emissions (7.93 Gg) are mainly (42.5%) due to N_2O emissions from nitrogen leaching and run-off from inorganic N fertilizers (1.86 Gg) and animal manure applied to soils (1.51 Gg) (see Table 5.36). N_2O emissions from leaching and run-off are related to the nitrogen content in fertilizers and animal wastes, therefore, emissions are mainly linked to the use of N fertilizers and the animal number trends. Between 1996 and 1997 there was a high increase in the use of nitrogen fertilizers in Italy, thus, emissions could be identified as outlier. Between 2007/2008 (-14%) and 2008/2009 (-21%) N fertiliser distribution has decreased. In 2010 the same trend was observed. According to the Italian Fertilizer Association (AIF) the use of fertilisers is determined by their cost and particularly by the price of agricultural products. In the last years, prices have decreased and, as a result, farmers need to save costs, consequently, less fertilisers is being used (Perelli, 2007; De Corso 2008).

5.5.4 Source-specific QA/QC and verification

Synthetic fertilizers and nitrogen content are compared with the international FAO agriculture database statistics (FAO, several years). In Table 5.45, national and FAO time series of total nitrogen applied are reported. Differences between national data and FAO database are related to the difference in data elaboration (ISTAT, 2004) and could be attributed to different factors. First, national data are more disaggregated by substance than FAO data and the national nitrogen content is considered for each substance, while FAO utilises default values. Besides, differences could also derive from different products classification. A join meeting, held in July 2011 with the FAO experts in charge of the fertiliser database, ISPRA verified that there are two FAO databases for fertilisers. In Table 5.45 the two databases are presented.

Table 5.45 Total annual N content in fertilizer applied from 1990 to 2020

Year	National data (t N)	FAO database (Nitrous fertilizer consumption, t N)	FAO new database (Nitrous fertilizer consumption, t N)
1990	759,510	878,960	-
1995	799,614	875,000	-
2000	782,701	828,000	-
2005	779,846		800,697
2010	528,029		498,605
2011	541,325		516,543
2012	683,566		591,000(*)
2013	546,542		600,600(*)
2014	505,126		574,016(*)
2015	517,854		605,236(*)
2016	570,786		602,730(*)
2017	522,840		599,242(*)
2018	495,005		594,767(*)
2019	466,842		598,544(*)
2020	577,451		data not available

(*) Unofficial figure or international reliable sources

In 2021, a technical report (CREA, 2021) produced by CREA (Council for Agricultural Research and Economics), in collaboration with ISPRA, on the assessment of emissions related to the use of nitrogen fertilizers was published, which contains several analyses of nitrogen fertilizer consumption data from different

data sources: IFASTAT/Fertilizer Europe, FAO, EUROSTAT, Assofertilizzanti, National Integrated Production Specifications, Farm Accountancy Data Network (FADN). These analyses suggest further investigation to better understand the differences found between these data sources and the ISTAT data used for the estimates.
Data on national sales of synthetic nitrogen fertilizers (by type of fertilizers) as provided by *Assofertilizzanti – Federchimica*[24] for the period 2012-2016 have been compared to official statistics provided by ISTAT. Differences were mainly found for the amount of simple mineral nitrogen fertilizers, where data from *Assofertilizzanti* are higher by 20%, on average, for the years 2013-2016. This could be due to a possible double counting of some product which could be considered as a single product and as a compound with other fertilizers. Further investigations will be conducted.
In 2015, data on crop residues and, in particular, on the relationship between crop residues and product were compared with studies and research provided by the Agricultural Research Council (CRA)[25]. However, these studies were conducted in different countries from Italy, so despite the differences, the values used in the inventory, based on national studies, have not been changed.
Following the suggestion of the CRA experts, in the estimation of N_2O emissions from crop residues, the total amount of residues has been considered, without deducting the fraction removed for purposes such as feed, bedding and construction. Therefore, the data were revised using the fixed residues/removable residues ratio for each crop considered (ENEA, 1994), also used to estimate the emissions from category 3F (see paragraph 5.6.2).
Concerning compost data, from waste sector only data on compost production are available. Official statistics provided by ISTAT on compost used in agriculture sector (considered as the green and mixed amendments) are compared to data on compost from waste sector. For the year 2015, the amount of compost used is 58.1% of the compost production only from plants that treat a selected waste.
As regards $Frac_{LEACH-(H)}$, Italy verified that the IPCC default is similar to the country-specific reference value reported from the main regional basin authority - Po Valley (ADBPO, 2001; ADBPO, 1994).
At the end of 2016, in response to the UNFCCC review process, experts on land use and wheater climate were contacted to investigate on the $Frac_{LEACH-(H)}$ fulfilment to criteria set out in the 2006 IPCC Guidelines.
As recommended during the 2019 UNFCCC review, the investigation of the driving forces for the significant inter-annual changes has been done. As regards the other organic fertilizers, ISTAT was asked to verify the quantities of amendments for 2011, which determine the anomalous trend between 2010 and 2011: the anomalous figure is for the amount of compost, which accounts for about 60% of the amendments. The figure was confirmed by contacting the companies that provided the data. In any case, further ISTAT checks are under way.
As regards the sewage sludge applied, the values used are official data provided by the Ministry of the Environment which collects them at the Italian Regions under the EU Sewage Sludge Directive. The annual variations depend on the fact that some Regions prohibit the practice of spreading in certain years, on the basis of weather-climatic, soil and water conditions, and also over the years other types of sludge treatment, such as the anaerobic digestion, have been implemented, to the detriment of the spreading.
In 2020 a working group was set up with *Assofertilizzanti* and ISTAT to compare the statistics produced by these two bodies. Initial results have led to a revision of the data on nitrate consumption in the period 2009-2011 and the estimation of CAN fertiliser consumption. Verification work will continue during 2021.

5.5.5 Source-specific recalculations

As regards for N_2O emissions from agricultural soils, the changes were: correction of estimated amount of nitrogen from crop residues (Fcr) as requested during the 2022 review in January/February; correction of estimated runoff and leached nitrogen (Fracleach) with new data based on the hydrological balance of the national territory; change in estimate of emissions from N synthetic fertilisers, because estimate of N_2O from rice cultivation for the whole time series has been included; corrected amendments data for the years 2015-2019, based on an update by ISTAT; updated N excreted dairy cattle for 2019 based on updated protein percentage in milk; updated 2019 rabbit data; modification of N at spreading as a result of the changes described in reference to N_2O emissions from manure management, related to NH_3 emissions in housing and storage; corrected 2016 fertiliser data, based on an ISTAT update; for the estimation of N at spreading, the

[24] Federchimica is the National Association of the Chemical Industry and Assofertilizzanti represents the production companies of the fertilizer industry.
[25] CRA is a national research organization which operates under the supervision of the Ministry of Agriculture, with general scientific competence within the fields of agriculture, agro-industry, food, fishery and forestry.

percentages of N remaining after emissions in the housing, storage and after other losses during storage (NO_2, N_2O, N_2, N leached in manure management, NH_3 from digesters) were recalculated and N bedding was added; updated the estimate of straw use for dairy cattle, non-dairy cattle and buffaloes to take into account sheltered animals only (removing grazing animals); included estimate of direct and indirect N_2O emissions for ostriches, where manure management system is grazing (as required by UNFCCC 2021 review); corrected value of N from other staff for year 2019; updated data on areas and production of vetch, lupin and other temporary fodder in different years, which imply changes in N_2O emissions of the Fcr category.

5.5.6 Source-specific planned improvements

In Table 5.46, planned improvements for this category are presented.

Table 5.46 Improvements for the agricultural soils category

Category/sub category	Parameter	Year of submission 2022	Activities
Activity data	Urea	√	Further checks will be made between apparent consumption and end uses, based on production data, import, export and final uses.

In the coming years, the Permanent census of agriculture will provide valuable information on animal and agronomic production methods. The focus of the Permanent census is to provide a comprehensive information framework on the structure of the agricultural system and the livestock at national, regional and local level by integrating archive data and carrying out statistical support surveys. Statistical registers will be created with the aim of increasing the quantity and quality of information in order to reduce the response burden and the overall production cost of official statistics[26].

5.6 Field burning of agriculture residues (3F)

5.6.1 Source category description

Methane and nitrous oxide emissions from field burning agriculture residues have not been identified as a key source.

In 2020, CH_4 emissions from this source were 0.60 Gg, representing 0.08% of emissions for the agriculture sector. N_2O emissions were 0.013 Gg, representing 0.03% of emissions for the agriculture sector.

5.6.2 Methodological issues

The estimation of emissions from field burning of agriculture residues has been carried out on the basis of the IPCC methodology, using different parameters, such as the amount of residues produced, the amount of dry residues, the total biomass burned, and the total carbon and nitrogen released as reported in Table 5.47.

Table 5.47 Data used for estimating field burning of agriculture residues emission

Data	Reference
Annual crop production	ISTAT, several years [a], [b], [j]
Removable residues/product ratio	CESTAAT, 1988
Fixed residues/removable residues ratio	ENEA, 1994
Fraction of dry matter in residues	IPCC, 1997; CRPA/CNR, 1992; CESTAAT, 1988; Borgioli, 1981
Fraction of the field where “fixed” residues are burned	IPCC, 1997; CRPA, 1997[b]; ANPA-ONR, 2001; CESTAAT, 1988
Fraction of residues oxidized during burning	IPCC, 2006
Fraction of carbon of dry matter of residues	IPCC, 1997
Raw protein in residues (dry matter fraction)	CESTAAT, 1988; Borgioli, 1981
IPCC default emission rates (CH_4, N_2O)	IPCC, 1997

[26] https://www.istat.it/en/permanent-censuses/agriculture

Activity data (annual crop production of cereals) used for estimating burning of agriculture residues are reported in the Table 5.48.
The same methodology is used to estimate emissions from open burning of agriculture residues (burnt off-site). Emissions from fixed residues (stubble), burnt on open fields, are reported in this category (3F) while emissions from removable residues burnt off-site, are reported under the waste sector (open burning of waste - 5C2 category). In response to the 2018 UNFCCC review process, the description of the agricultural residues used for bedding material considered in animal manure applied to soils (3Da2a), which also involves the categories crop residues (3Da4) and field burning of agricultural residues (3F), is reported in the Annex 7.3. The description of the type of agricultural residues is also included in the Annex 7.3. As recommended during the 2019 UNFCCC review, to enhance transparency on the total amount of crop residues generated and shares of the crop residue amounts used for different purposes (such as bedding material (3.D.a.2.a), left on fields (3.D.a.4), burnt on-site (3.F) and off-site (1.A, 5.C.2)), a flow-chart is reported in Annex 7, in Figure A.7.1.

Table 5.48 Time series of activity data (tons) used for 3F estimations

Year	Wheat	Barley	Maize	Oats	Rye	Rice	Sorghum
			Agricultural production (tons)				
1990	8,108,500	1,702,500	5,863,900	298,400	20,800	1,290,700	114,200
1995	7,946,081	1,387,069	8,454,164	301,322	19,780	1,320,851	214,802
2000	7,427,660	1,261,560	10,139,639	317,926	10,292	1,245,555	215,200
2005	7,717,129	1,214,054	10,427,930	429,153	7,876	1,444,818	184,915
2010	6,849,858	944,257	8,495,946	288,880	13,926	1,574,320	275,572
2011	6,641,807	950,934	9,752,373	297,079	14,381	1,560,128	299,862
2012	7,654,248	940,234	7,888,668	292,357	16,083	1,601,478	157,808
2013	7,312,025	875,553	7,899,617	246,916	14,306	1,433,111	316,919
2014	7,141,926	848,681	9,250,045	241,138	11,529	1,415,906	368,782
2015	7,394,495	955,131	7,073,897	261,366	13,183	1,505,804	294,218
2016	8,037,872	988,285	6,839,499	260,798	13,170	1,598,027	313,788
2017	6,966,465	984,281	6,048,499	229,041	11,097	1,516,033	240,694
2018	6,932,943	1,010,328	6,179,035	243,366	10,639	1,480,887	293,865
2019	6,576,584	1,072,447	6,258,747	238,107	12,509	1,498,133	312,384
2020	6,553,861	1,090,630	6,771,089	242,709	11,475	1,513,057	361,694

The methodology for estimating emissions refers to fixed residues burnt. The same steps are followed to calculate emissions from removable residues burnt off-site reported in 5C. Parameters taken into consideration are the following:

a) Amount of "fixed" residues (t), estimated with annual crop production, removable residues/product ratio, and "fixed" residue/removable residues ratio. This last value is equal to 0.25 for all type of cereals and represents the part of the fixed residue (compared to the removable residue) that remains on the ground.
b) Amount of dry residues in "fixed" residue (t dry matter), calculated with amount of fixed residues and fraction of dry matter.
c) Amount of "fixed" dry residues oxidized (t dry matter), assessed with amount of dry residues in the "fixed" residues, fraction of the field where "fixed" residues are burned, and fraction of residues oxidized during burning.
d) Amount of carbon from stubble burning release in air (t C), calculated with the amount of "fixed" dry residue oxidized and the fraction of carbon from the dry matter of residues.
e) C-CH_4 from stubble burning (t C-CH_4), calculated with the amount of carbon from stubble burning release in air and default emissions rate for C-CH_4, equal to 0.005 (IPCC, 1997).

Data related to the removable residues/product ratio, the "fixed" residue/removable residues ratio, the fraction of dry matter, the fraction of carbon of dry matter of residues are available for each type of cereals.
Fraction of the field where "fixed" residues are burned is 10% (IPCC, 1997; CRPA, 1997[b]) for all crops except for rice, for which the fraction varies as a function of the change in annual percentage of the reincorporated rice straw into the soil (see *straw incorporation* in the methodological issues in rice cultivation (3C) paragraph). CH_4 emissions from on field burning of agriculture residues (0.60 Gg CH_4 in 2020) have been estimated multiplying the C-CH_4 value (0.449 Gg C-CH_4) by the ratio of molecular weights (16/12). In Table 5.49, parameters used for estimating of CH_4 emissions from on field burning of agriculture residues are shown.

Table 5.49 Parameters used for the estimation of CH_4 emissions from agriculture residues in 2020

Crops	Annual crop harvest production (t 1000)	Amount of "fixed" burnable residues (t 1000)	Amount of dry residue in the "fixed" residues (t 1000 dry matter)	Amount of "fixed" dry residues burnt (t 1000 dry matter)	Amount of carbon C-CH_4 from stubble burning (t 1000 C)	C-CH_4 from stubble burning (t C-CH_4)
Wheat	6,554	1,131	964	94	41	205
Rye	11	2	2	0	0	0
Barley	1,091	218	187	19	6	31
Oats	243	42	37	4	1	7
Rice	1,513	253	190	114	38	189
Maize	6,771	677	282	0	0	0
Sorghum	362	127	105	11	3	17
Total	**16,545**	**2,450**	**1,767**	**241**	**90**	**449**

For estimating N_2O emissions, the same amount of "fixed" dry residue oxidized described above were used; further parameters are:

a) Amount of nitrogen from stubble burning release in air (t N), calculated with the amount of "fixed" dry residue oxidized and the fraction of nitrogen from the dry matter of residues. The fraction of nitrogen has been calculated considering raw protein content from residues (dry matter fraction) divided by 6.25.
b) N-N_2O from stubble burning (t N-N_2O), calculated with the amount of nitrogen from stubble burning release in air and the default emissions rate for N- N_2O, equal to 0.007 (IPCC, 1997).

Data related to the raw protein content from residues (dry matter fraction) is available for each type of cereals. N_2O emissions from on field burning of agriculture residues (0.013 Gg N_2O in 2020) are estimated by multiplying the N-N_2O value (0.008 Gg N) by the ratio of molecular weights (44/28).
In Table 5.50 the parameters for the estimation of N_2O emissions from field burning of agriculture residues are shown.

Table 5.50 Parameters used for the estimation of N_2O emissions from agriculture residues in 2020

Crops	Amount of "fixed" dry residues burnt (t 1000 dry matter)	Raw protein content from residues (dry matter fraction)	Fraction of nitrogen from the dry matter of residues	Amount of nitrogen from stubble burning (t 1000 N)	N-N_2O from stubble burning (t N-N_2O)
Wheat	94	0.030	0.005	0.405	2.84
Rye	0	0.036	0.006	0.001	0.01
Barley	19	0.037	0.006	0.100	0.70
Oats	4	0.040	0.006	0.021	0.15
Rice	114	0.041	0.007	0.599	4.19
Maize	0	0.000	0.007	0.000	0.00
Sorghum	11	0.037	0.006	0.056	0.39
Total	**241**			**1.181**	**8.27**

5.6.3 Uncertainty and time-series consistency

Uncertainties for CH_4 and N_2O emissions from field burning of agriculture residues are estimated to be 58.3% as a result of 30% and 50% for activity data and emission factor, respectively.
In 2020, emissions from field burning of agriculture residues were 0.60 Gg CH_4 emissions and 0.013 Gg N_2O emissions (see Table 5.51). Variation in emissions trend is related to cereal production trends. In particular, in the period 1998-2003, the biomass available from wheat and barley decreases compared to the first half of the ninety years due to the sharp drop in production as a consequence of unfavourable weather conditions.

Table 5.51 CH_4 and N_2O emission trends from field burning of agriculture residues (Gg)

Year	CH_4 (Gg)	N_2O (Gg)
1990	0.601	0.012
1995	0.593	0.012
2000	0.591	0.012
2005	0.636	0.013
2010	0.612	0.013
2011	0.604	0.013
2012	0.643	0.014

Year	CH_4 (Gg)	N_2O (Gg)
2013	0.607	0.013
2014	0.599	0.013
2015	0.624	0.013
2016	0.669	0.014
2017	0.602	0.013
2018	0.602	0.013
2019	0.594	0.013
2020	0.599	0.013

5.6.4 Source-specific QA/QC and verification

Activity data of this category were calculated on the basis of various parameters, and in particular the fraction of carbon and nitrogen of dry matter of residues, whose values are differentiated by crops. IPCC emission factors used (IPCC, 1997) are the ratios for carbon compounds (i.e. C-CH_4), that are mass of carbon compound released (in units of C) relative to mass of total carbon released from burning (in units of C); those for the nitrogen compounds (i.e. N-N_2O) are expressed as the ratios of mass of nitrogen compounds relative to the total mass of nitrogen released from the fuel (IPCC, 1997). The comparison with the 2006 IPCC emission factors has been done; the implied emission factors are consistent with those of the 2006 IPCC Guidelines.
In response to the 2007 review process (UNFCCC, several years) and in order to verify the national assumption, which considered that 10% of the cultivated surface (cereals) is burned in Italy, a specific elaboration of data has been carried out by ISTAT, in the framework of FSS in 2003. The information, provided by ISTAT, related to the regional practises of field burning (cereals) has confirmed the abovementioned assumption (ISTAT, 2007[c]).

5.6.5 Source-specific recalculations

No specific recalculations are observed.

5.6.6 Source-specific planned improvements

No specific improvements are planned.

5.7 Liming (3G)

5.7.1 Source category description

CO_2 emissions from application of carbonate containing lime and dolomite to agricultural soils have been estimated. In 2017 submission, in response to the UNFCCC review process, CO_2 emissions from application of carbonate containing lime and dolomite are estimated separately. In 2020, CO_2 emissions from liming were 10.0 Gg, which represents 2.0% of CO_2 emissions of the agriculture sector (0.3% in 1990) and 0.0033% of national CO_2 emissions (0.0003% in 1990). CO_2 emissions from liming have not been identified as a key source.

5.7.2 Methodological issues

Tier 1 approach, assuming that the total amount of carbonate containing lime and dolomite is applied annually to soil, has been followed. The 2006 IPCC Guidelines equation 11.12 has been used to estimate CO_2 emissions.
National statistics report an aggregate annual amount of lime and dolomite, without disaggregation between calcic limestone and dolomite (ISTAT, several years [i]; ISTAT, several years [f]). Data on the disaggregation between limestone and dolomite used in agriculture are provided by the largest lime producer in the country (UNICALCE, 2016). These values are equal to 55% and 45%, respectively. Therefore, the average emission factor weighed is equal to 0.1245 t C/t limestone-dolomite (=0.12*0.55+0.13*0.45).
Data on agricultural lime application have been estimated for the period 1990-1997, since these data have not been made available for that period. Data were estimated on the basis of the ratio of the amount of limestone or dolomite applied for the year 1998 and the area planted to crops, woody and permanent forage.

5.7.3 Uncertainty and time-series consistency

Uncertainty for CO_2 emissions from additions of carbonate limes to soils has been estimated to be 22.4%, as combination of 10% and 20% for activity data and emission factor, respectively.

In 2020, CO_2 emissions from liming (10.0 Gg CO_2) were more than ten times higher than in 1990 (1.36 Gg CO_2). An increasing trend is observed from 2002, both for limestone and dolomite application, as resulting from the official statistics published by the National Institute of Statistics (ISTAT).
In Table 5.52 activity data, emission factor and CO_2 emission trend from liming are shown.

Table 5.52 CO_2 emissions from lime application

Year	Amount of limestone and dolomite (Mg)	EF (t C (t limestone and dolomite)$^{-1}$)	C emissions (Gg)	CO_2 emissions (Gg)
1990	2,969	0.1245	0.3696	1.36
1995	3,045	0.1245	0.3791	1.39
2000	4,050	0.1245	0.5042	1.85
2005	31,451	0.1245	3.9156	14.36
2010	40,115	0.1245	4.9943	18.31
2011	55,675	0.1245	6.9315	25.42
2012	34,792	0.1245	4.3316	15.88
2013	30,934	0.1245	3.8513	14.12
2014	26,222	0.1245	3.2646	11.97
2015	29,583	0.1245	3.6831	13.50
2016	26,182	0.1245	3.2597	11.95
2017	38,280	0.1245	4.7659	17.47
2018	33,851	0.1245	4.2144	15.45
2019	35,584	0.1245	4.4302	16.24
2020	21,860	0.1245	2.7216	9.98

5.7.4 Source-specific QA/QC and verification
Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the estimation of emissions.

5.7.5 Source-specific recalculations
As regards for CO_2 emissions from liming, the changes were: corrected 2016 soil correctives data, based on an ISTAT update.

5.7.6 Source-specific planned improvements
No specific improvements are planned.

5.8 Urea application (3H)

5.8.1 Source category description
CO_2 emissions from application of urea to agricultural soils have been estimated. In 2020, CO_2 emissions from urea application were 471.9 Gg, which represents 93.8% of CO_2 emissions of the agriculture sector (91.2% in 1990) and 0.16% of national CO_2 emissions (0.11% in 1990). CO_2 emissions from urea application have not been identified as a key source.

5.8.2 Methodological issues
Tier 1 approach, assuming that the total amount of urea is applied annually to soil, has been followed; an overall emission factor of 0.20 t C (t urea)$^{-1}$ has been used to estimate CO_2 emissions. The 2006 IPCC Guidelines equation 11.13 has been used to estimate CO_2 emissions. The source of the activity data are national statistics (ISTAT, several years [i]).

5.8.3 Uncertainty and time-series consistency
Uncertainty for CO_2 emissions from urea application to soils has been estimated to be 22.4%, as combination of 10% and 20% for activity data and emission factor, respectively.
In 2020, CO_2 emissions from urea application were 1.5% (471.9 Gg CO_2) higher than in 1990 (464.8 Gg CO_2).

In Table 5.53 activity data, emission factor and CO_2 emission trend from urea application are shown. A strong decrease is observed in the years from 2009 to 2011 due to the economic crisis in particular for the amount of urea applied to soils. In 2012, a recovery from the sharp decline was recorded as result from the official statistics provided by the National Institute of Statistics (ISTAT).

Table 5.53 CO_2 emissions from urea application

Year	Amount of urea (Mg)	EF (t C (tonnes of urea)$^{-1}$)	C emissions (Gg)	CO_2 emissions (Gg)
1990	633,873	0.20	126.8	464.8
1995	698,251	0.20	139.7	512.1
2000	716,412	0.20	143.3	525.4
2005	691,255	0.20	138.3	506.9
2010	456,951	0.20	91.4	335.1
2011	478,306	0.20	95.7	350.8
2012	751,235	0.20	150.2	550.9
2013	614,208	0.20	122.8	450.4
2014	560,449	0.20	112.1	411.0
2015	579,444	0.20	115.9	424.9
2016	765,097	0.20	153.0	561.1
2017	570,608	0.20	114.1	418.4
2018	552,621	0.20	110.5	405.3
2019	540,618	0.20	108.1	396.5
2020	643,562	0.20	128.7	471.9

5.8.4 Source-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the estimation of emissions. Activity data are the same used in the agriculture soils (3D) category.

5.8.5 Source-specific recalculations

As regards for CO_2 emissions from urea application, the changes were: corrected 2016 fertiliser, based on an ISTAT update.

5.8.6 Source-specific planned improvements

Further checks on urea data will be made between apparent consumption and end uses, based on production data, import, export and final uses.

5.9 Other carbon-containing fertilizers (3I)

5.9.1 Source category description

CO_2 emissions from application of Calcium Ammonium Nitrate (CAN) to agricultural soils have been estimated. In 2020, CO_2 emissions from CAN application were 21.5 Gg, which represents 4.3% of CO_2 emissions of the agriculture sector (8.6% in 1990) and 0.007% of national CO_2 emissions (0.010% in 1990). CO_2 emissions from CAN application have not been identified as a key source.

5.9.2 Methodological issues

Tier 1 approach, assuming that the total amount of CAN is applied annually to soil, has been followed. Based on the data provided by *Assofertilizzanti* (personal communication) concerning the annual estimates of ammonium nitrate and CAN distributed over the country from 2011 to 2019, an annual ratio of CAN to nitrate was calculated. An overall average of these ratios was calculated for the period 2011-2019. This value was multiplied by the total amount of ammonium nitrate (<28% and >28%) distributed annually and provided by ISTAT since 1990. The carbonate content was estimated by multiplying the previously estimated series by the

value 23%, which represents the average carbonate content in CAN (77% is the share of ammonium nitrate). An overall emission factor of 0.125 t C (t carbonates)$^{-1}$ has been used to estimate CO_2 emissions. The 2006 IPCC Guidelines equation 11.12 has been used to estimate CO_2 emissions. The source of the activity data are national statistics (ISTAT, several years [i]).

5.9.3 Uncertainty and time-series consistency

Uncertainty for CO_2 emissions from CAN application to soils has been estimated to be 22.4%, as combination of 10% and 20% for activity data and emission factor, respectively. In 2020, CO_2 emissions from CAN application were 50.8% (21.5 Gg CO_2) lower than in 1990 (43.7 Gg CO_2).
In Table 5.54 activity data, emission factor and CO_2 emission trend from CAN application are shown.

Table 5.54 CO_2 emissions from CAN application

Year	Amount of CAN (t)	Amount of carbonates content (t)	EF (t C (tonnes of carbonates)$^{-1}$)	C emissions (Gg)	CO_2 emissions (Gg)
1990	416,907	95,293	0.125	11.9	43.7
1995	515,751	117,886	0.125	14.7	54.0
2000	416,818	95,273	0.125	11.9	43.7
2005	405,351	92,652	0.125	11.6	42.5
2010	263,930	60,327	0.125	7.5	27.6
2011	263,719	60,279	0.125	7.5	27.6
2012	241,758	55,259	0.125	6.9	25.3
2013	160,046	36,582	0.125	4.6	16.8
2014	197,192	45,072	0.125	5.6	20.7
2015	189,628	43,344	0.125	5.4	19.9
2016	200,300	45,783	0.125	5.7	21.0
2017	192,028	43,892	0.125	5.5	20.1
2018	206,681	47,241	0.125	5.9	21.7
2019	161,164	36,838	0.125	4.6	16.9
2020	204,958	46,847	0.125	5.9	21.5

5.9.4 Source-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the estimation of emissions. Activity data are the same used in the agriculture soils (3D) category. As recommended during the 2020 ESD review, CO_2 emissions from CAN application to soils has been estimated and reported in the category 3I Other carbon-containing fertilizers.

5.9.5 Source-specific recalculations

As regards for CO_2 emissions from CAN application, the changes were: corrected 2016 fertiliser, based on an ISTAT update; updated 2019 nitrate data, as per ISTAT data update.

5.9.6 Source-specific planned improvements

A working group was set up with *Assofertilizzanti* and ISTAT to compare the statistics produced by these two bodies. The aim is also to revise the data collection questionnaire in order to detect the amount of CAN distributed throughout the country.

6 Land Use, Land Use Change and Forestry [CRF sector 4]

6.1 Sector overview

CO_2 emissions and removals occur as a result of changes in land-use and management activities as well as because of forestry activities and disturbances. The sector is responsible for 32.4 Mt of CO_2 eq. net removal from the atmosphere in 2020.

Methods applied to estimate the GHG emissions and removals from the sector are derived from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) and from 2013 IPCC KP Supplement (IPCC, 2014) for HWP estimation; similarly, all factors for which national data are not available have been taken from the 2006 IPCC Guidelines and from the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement). For category 4A (Forest Land) estimates were supplied by a growth model, applied to national forest inventory (NFI) data, consistently with the TACCC principles implemented by IPCC methods, and with mostly country specific factors and parameters.

CO_2 emissions from forest fires are included in the net carbon stock changes reported in CRF table 4A, instead of in CRF table 4(V).

Greenhouse gas removals and emissions in the main categories of the LULUCF sector in 2020 are shown in Figure 6.1.

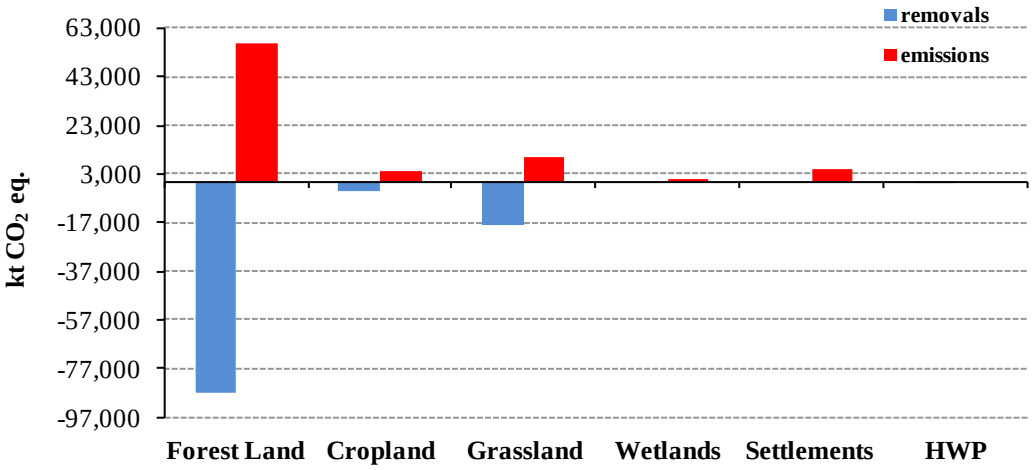


Figure 6.1 Greenhouse gas removals and emissions in LULUCF sector in 2020 [kt CO_2 eq.] by LULUCF sector categories

In Table 6.1 emissions and removals time series is reported.

Table 6.1 Trend in greenhouse gas net emissions/removals (kt GHG) from the LULUCF sector in the period 1990-2020

GHG Source and Sink Categories	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO_2	**-5,790**	**-25,137**	**-22,522**	**-36,171**	**-42,316**	**-34,545**	**-26,236**	**-40,116**	**-41,170**	**-43,684**	**-40,973**	**-21,951**	**-36,135**	**-41,377**	**-33,089**
A. Forest Land	-17,852	-31,122	-26,004	-34,667	-36,257	-32,252	-28,082	-36,946	-38,073	-39,385	-36,311	-21,543	-31,980	-36,367	-30,261
B. Cropland	1,631	570	-586	-1,937	-909	748	2,000	1,723	1,404	572	-1,331	-1,057	-640	-607	-33
C. Grassland	4,179	-2,155	-1,977	-6,364	-9,537	-7,697	-4,896	-9,708	-9,245	-9,535	-8,540	-4,628	-9,003	-8,166	-7,364
D. Wetlands	NE,NO	5	8	8	130	130	130	130	130	130	32	32	32	32	32
E. Settlements	6,640	8,272	6,491	7,291	4,400	4,406	4,411	4,420	4,428	4,446	5,183	5,186	5,193	5,201	5,207
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWP	-388	-706	-454	-503	-142	120	202	265	186	89	-6	59	264	-1,469	-669
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
CH_4	**51.44**	**12.11**	**28.57**	**11.97**	**14.01**	**22.68**	**48.00**	**6.26**	**10.98**	**10.57**	**12.26**	**60.44**	**6.46**	**8.11**	**10.50**
A. Forest Land	23.77	4.82	12.38	4.99	4.42	9.00	24.51	3.46	4.42	6.54	7.55	45.41	4.90	4.47	5.80
B. Cropland	0.22	0.06	0.13	0.06	0.05	0.10	0.19	0.31	0.03	0.10	0.08	0.32	0.09	0.13	0.14
C. Grassland	27.45	7.22	16.07	6.93	9.54	13.58	23.30	2.49	6.52	3.94	4.62	14.71	1.47	3.51	4.56
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWP	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	**2.88**	**2.95**	**2.33**	**2.11**	**1.44**	**1.53**	**1.82**	**1.12**	**1.21**	**1.10**	**1.44**	**1.87**	**1.52**	**1.66**	**1.43**
A. Forest Land	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
B. Cropland	0.25	0.39	0.14	0.14	0.14	0.11	0.09	0.06	0.03	0.00	0.07	0.15	0.20	0.27	0.05
C. Grassland	0.86	0.23	0.50	0.22	0.30	0.43	0.73	0.08	0.21	0.12	0.15	0.46	0.05	0.11	0.14
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	1.70	2.25	1.65	1.72	0.97	0.97	0.97	0.97	0.97	0.97	1.22	1.22	1.22	1.22	1.22
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWP	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
LULUCF (kt *CO_2 equivalent*)	**-3,646**	**-23,955**	**-21,114**	**-35,242**	**-41,536**	**-33,521**	**-24,494**	**-39,626**	**-40,534**	**-43,093**	**-40,236**	**-19,882**	**-35,521**	**-40,680**	**-32,401**

CO_2 emissions and removals in LULUCF sector, in the period 1990-2020, are shown in Figure 6.2.

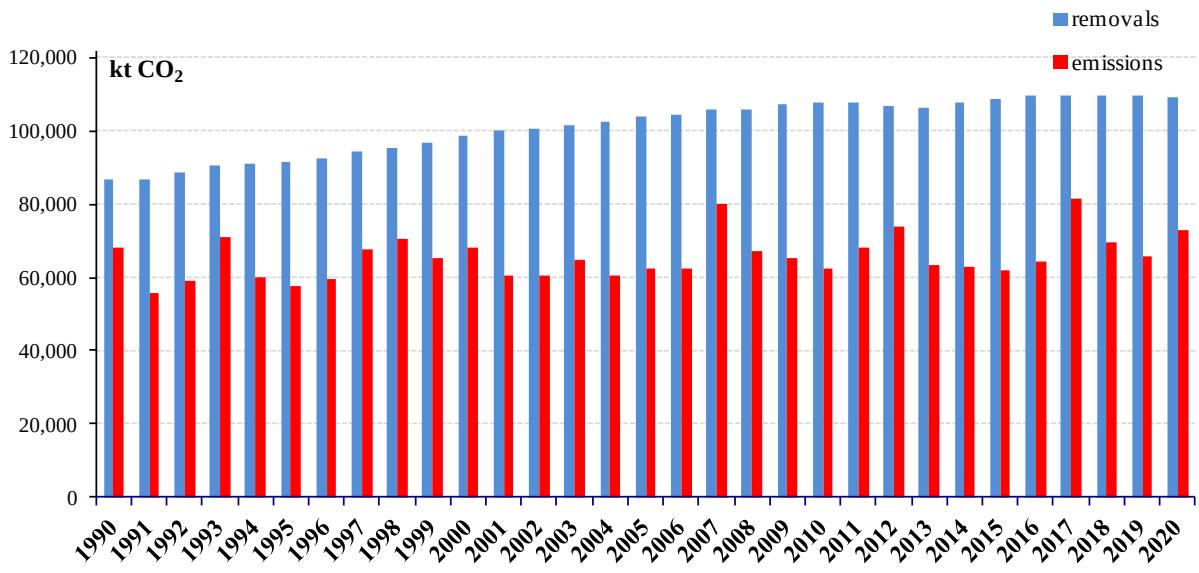


Figure 6.2 CO_2 removals and emissions in LULUCF sector in the period 1990-2020 [kt CO_2]

The outcomes of the key category analysis for 2020, for both level and/or trend assessment with IPCC Approach 1 and Approach 2, are listed in Table 6.2.

Table 6.2 Key* categories identified in the LULUCF sector

	gas	*Categories*	2020
4.A.1	CO_2	Forest land remaining forest land	key (L, T)
4.A.2	CO_2	Land converted to forest land	key (L, T)
4.B.1	CO_2	Cropland remaining cropland	key (T)
4.B.2	CO_2	Land converted to Cropland	key (T2)
4.C.1	CO_2	Grassland remaining Grassland	key (L, T)
4.C.2	CO_2	Land converted to Grassland	key (L, T)
4.E.2	CO_2	Land converted to Settlements	key (L, T)

** L = key category in level assessment under both Approach 1 and 2*
T = key category in trend assessment under both Approach 1 and 2
L2 = key category in level assessment under Approach 2 only
T2 = key category in trend assessment under Approach 2 only

Background data for the land representation originates from the NFIs[27] (1985, 2005, 2012) and from the National Land-Use Inventory IUTI[28] referring to years 1990, 2000 and 2008. Additional data on non-forest categories were collected for the year 2012, through the first phase survey in the framework of the III NFI that was carried out on an IUTI's subgrid (i.e., 301,300 points, across the entire country territory).
Due to the technical characteristics of the IUTI assessment (i.e., classification of orthophotos), it was not possible to clearly distinguish among some subcategories included in *cropland* and *grassland* categories (e.g., annual pastures vs grazing land), and between them (e.g., annual crops and grazing land). Therefore, although the total aggregated area of the 2 categories *cropland* and *grassland* together is derived from the IUTI data, the area of each of their subcategories is disaggregated using as proxies the national statistics (ISTAT, [b], [c]) on annual crops, perennial woody crops, grazing land, and grassland. The data from the NFI have a higher hierarchical order than that of IUTI, so that differences among the two datasets have been reconciled by adjusting[29] the grassland category (subcategory natural grassland).

[27] National Forest Service, Ministry of Agricultural, Food and Forestry Policies (MIPAAF), Forest Monitoring and Planning Research Unit (CRA-MPF)
[28] Detailed information on IUTI is reported in Annex 10
[29] Where the NFI area of forest land was larger than that of IUTI an equivalent portion of grassland area, as classified by IUTI, was reclassified as forest land while if the NFI area was smaller an equivalent area of forest land in IUTI was reclassified as grassland. Such adjustments were implemented at regional level.

Annual figures for areas in transition between different land uses have been derived applying a rule-based method, informed by expert judgement, based on known patterns of land-use changes in Italy, while ensuring that the total national area remains constant.
Rules applied are the following:

- when the forest land area increases, an equivalent area is transferred from grassland;
- when the cropland area increases, an equivalent area is transferred from grassland;
- when the grassland area increases, an equivalent area is transferred from cropland;
- when the forest land decreases, an equivalent area is transferred to settlements; indeed, in Italy land use changes from forest to other uses are allowed in very limited circumstances (railways, highways constructions or other public utility projects) and only upon formal authorization, as stated in art. 4.2 of the Law Decree n. 227 of 2001. Further, land use changes of burnt forest areas are forbidden by national legislation (Law Decree 21 November 2000, n. 353, art.10.1).
- when the settlements area increases more than the deforested area, an equivalent area is transferred from grassland, and if the grassland decreases is not larger enough, the remaining portion is transferred from cropland and, where needed, from other land (see Table 6.22, 6.31, 6.40, 6.41).

On the basis of the land use and land-use change data derived from NFIs and IUTIs classifications after the application of the rule-based approach for land representation, a time series of land use matrices, one for each year of the period 1990–2020, have been compiled. Furthermore, land use changes have been derived, by the way of land use change matrices, smoothing their area over a 5-year period, harmonizing the whole time series (i.e. the 2015–2010 difference in area for each subdivision is divided by five, and the resulting value is added, year by year, to the previous year area to deduce the current area). The smoothing period affects the assessment of the area, depending on the amount of the difference between the two reference years (i.e. 2015–2010), as well as on the number of years included in the smoothing period. The smoothing process also affects the annual land-use change data.
In addition, it has to be noted that the smoothing process is implemented at the most disaggregated level (i.e. for annual and woody crops in cropland category, grazing land and shrublands in grassland category), and that it has been implemented starting from 1970 to the last reported year (i.e. 2020).
In the tables 6.3a and 6.3b land use data with and without the smoothing are provided.

Table 6.3a Land use areas before smoothing

kha	FL	CL	GL	WL	SL	OL	Total
1990	7,590	10,841	8,891	510	1,644	658	30,134
1991	7,668	10,857	8,768	511	1,672	658	30,134
1992	7,746	10,874	8,646	511	1,699	658	30,134
1993	7,824	10,891	8,523	511	1,727	658	30,134
1994	7,902	10,908	8,400	512	1,754	658	30,134
1995	7,980	10,924	8,278	512	1,782	657	30,134
1996	8,058	10,929	8,167	513	1,810	657	30,134
1997	8,136	10,919	8,071	513	1,837	657	30,134
1998	8,213	10,805	8,079	514	1,865	657	30,134
1999	8,291	10,697	8,082	514	1,892	657	30,134
2000	8,369	10,487	8,186	515	1,920	656	30,134
2001	8,447	10,351	8,216	515	1,948	656	30,134
2002	8,525	10,293	8,168	516	1,975	656	30,134
2003	8,603	10,031	8,324	516	2,003	656	30,134
2004	8,681	10,059	8,191	517	2,030	656	30,134
2005	8,759	9,879	8,265	517	2,058	656	30,134
2006	8,814	9,534	8,527	518	2,086	655	30,134
2007	8,868	9,555	8,424	518	2,113	655	30,134
2008	8,923	9,551	8,345	519	2,141	655	30,134
2009	8,978	9,069	8,751	526	2,156	655	30,134
2010	9,032	9,159	8,584	534	2,170	655	30,134
2011	9,087	8,947	8,718	541	2,185	655	30,134
2012	9,142	8,641	8,948	549	2,200	655	30,134
2013	9,196	8,977	8,535	556	2,214	655	30,134
2014	9,251	8,952	8,483	564	2,229	655	30,134
2015	9,305	8,845	8,513	571	2,244	655	30,134
2016	9,360	8,929	8,352	579	2,258	655	30,134
2017	9,415	8,889	8,316	586	2,273	655	30,134
2018	9,469	8,990	8,145	586	2,288	655	30,134
2019	9,524	9,001	8,065	586	2,302	655	30,134
2020	9,578	9,044	7,953	586	2,317	655	30,134

Table 6.3b Land use areas after smoothing

kha	FL	CL	GL	WL	SL	OL	Total
1990	7,590	10,841	8,891	510	1,644	658	30,134
1991	7,668	10,857	8,768	511	1,672	658	30,134
1992	7,746	10,874	8,646	511	1,699	658	30,134
1993	7,824	10,891	8,523	511	1,727	658	30,134
1994	7,902	10,908	8,400	512	1,754	658	30,134
1995	7,980	10,924	8,278	512	1,782	657	30,134
1996	8,058	10,837	8,259	513	1,810	657	30,134
1997	8,136	10,749	8,241	513	1,837	657	30,134
1998	8,213	10,662	8,223	514	1,865	657	30,134
1999	8,291	10,574	8,204	514	1,892	657	30,134
2000	8,369	10,487	8,186	515	1,920	656	30,134
2001	8,447	10,365	8,202	515	1,948	656	30,134
2002	8,525	10,244	8,218	516	1,975	656	30,134
2003	8,603	10,122	8,233	516	2,003	656	30,134
2004	8,681	10,000	8,249	517	2,030	656	30,134
2005	8,759	9,879	8,265	517	2,058	656	30,134
2006	8,814	9,769	8,292	518	2,086	655	30,134
2007	8,868	9,660	8,318	518	2,113	655	30,134
2008	8,923	9,551	8,345	519	2,141	655	30,134
2009	8,978	9,355	8,464	526	2,156	655	30,134
2010	9,032	9,159	8,584	534	2,170	655	30,134
2011	9,087	9,096	8,570	541	2,185	655	30,134
2012	9,142	9,033	8,555	549	2,200	655	30,134
2013	9,196	8,971	8,541	556	2,214	655	30,134
2014	9,251	8,908	8,527	564	2,229	655	30,134
2015	9,305	8,845	8,513	571	2,244	655	30,134
2016	9,360	8,885	8,401	574	2,258	655	30,134
2017	9,415	8,925	8,289	577	2,273	655	30,134
2018	9,469	8,964	8,177	580	2,288	655	30,134
2019	9,524	9,004	8,065	583	2,302	655	30,134
2020	9,578	9,044	7,953	586	2,317	655	30,134

Italy uses the IPCC default land use transition period of 20 years for each land-use change category. Consequently, to determine the area of lands converted to other land use categories for the inventory years 1990-2020, land use change matrices have also been prepared for the period 1971-1989.
The relevant equations of 2006 IPCC Guidelines (vol. 4, chapter 2, eq. 2.15, 2.16, 2.24, 2.25) have been applied; once a land has converted to a land use category, the annual changes in carbon stocks in mineral soils have been reported for 20 years subsequent the conversion.
In the following Table 6.4, the land use matrices are reported in two columns. The annual matrices starting from the 1989-1990 period to 2019-2020 in the left column, while the 20-year matrices starting from the 1971-1990 period to the 2001-2020 one are in the right column. Annual matrices for the years 1990-2020 are also reported in CRF tables 4.1.

Table 6.4 Land use change matrices for the years 1990-2020 [kha]

		1990						*total 1989*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1989	Forest	**7,511**				0.72		*7,512*
	Grassland	78.68	**8,891**	0.00	0.00	1.73	-	*8,971*
	Cropland		0	**10,841**	0.00	25	-	*10,866*
	Wetland				**510**			*510*
	Settlements					**1,616**		*1,616*
	Other Land					0.00	**658**	*658*
	total 1990	*7,590*	*8,891*	*10,841*	*510*	*1,644*	*658*	30,134
	Land converted to:	78.7	0.0	0.0	0.0	27.6	0.0	

		1991						*total 1990*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1990	Forest	**7,589**				0.72		*7,590*
	Grassland	78.68	**8,768**	16.77	0.47	26.70	-	*8,891*
	Cropland		0	**10,841**	0.00	0	-	*10,841*
	Wetland				**510**			*510*
	Settlements					**1,644**		*1,644*
	Other Land					0.18	**658**	*658*
	total 1991	*7,668*	*8,768*	*10,857*	*511*	*1,672*	*658*	30,134
	Land converted to:	78.7	0.0	16.8	0.5	27.6	0.0	

		1992						*total 1991*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1991	Forest	**7,667**				0.72		*7,668*
	Grassland	78.68	**8,646**	16.77	0.47	26.70	-	*8,768*
	Cropland		0	**10,857**	0.00	0	-	*10,857*
	Wetland				**511**			*511*
	Settlements					**1,672**		*1,672*
	Other Land					0.18	**658**	*658*
	total 1992	*7,746*	*8,646*	*10,874*	*511*	*1,699*	*658*	30,134
	Land converted to:	78.7	0.0	16.8	0.5	27.6	0.0	

20 years matrix		1990						*total 1971*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1971	Forest	**6,901**				14.4		*6,916*
	Grassland	689	**8,566**	136	0.00	33	0	*9,423*
	Cropland		325	**10,704**	0.00	174	0	*11,203*
	Wetland				**510**			*510*
	Settlements					**1,423**		*1,423*
	Other Land					0.00	**658**	*658*
	Total 1990	*7,589.8*	*8,890.9*	*10,840.5*	*510.1*	*1,644.0*	*658.3*	30,134
	Land converted to:	688.5	325.0	136.1	0.0	220.8	0.0	

20 years matrix		1991						*total 1972*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1972	Forest	**6,932**				14.4		*6,947*
	Grassland	736	**8,450**	153	0.47	59	0	*9,398*
	Cropland		318	**10,704**	0.00	169	0	*11,192*
	Wetland				**510**			*510*
	Settlements					**1,429**		*1,429*
	Other Land					0.18	**658**	*658*
	Total 1991	*7,668*	*8,768*	*10,857*	*511*	*1,672*	*658*	30,134
	Land converted to:	736	318	153	0	243	0	

20 years matrix		1992						*total 1973*
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
1973	Forest	**6,963**				14.4		*6,978*
	Grassland	782	**8,334**	170	0.95	86	0	*9,373*
	Cropland		312	**10,704**	0.00	164	0	*11,181*
	Wetland				**510**			*510*
	Settlements					**1,434**		*1,434*
	Other Land					0.36	**658**	*658*
	Total 1992	*7,746*	*8,646*	*10,874*	*511*	*1,699*	*658*	30,134
	Land converted to:	782	312	170	1	265	0	

1992	1993						total 1992
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,745**				0.72		*7,746*
Grassland	78.68	**8,523**	16.77	0.47	26.70	-	*8,646*
Cropland		0	**10,874**	0.00	0	-	*10,874*
Wetland				**511**			*511*
Settlements					**1,699**		*1,699*
Other Land					0.18	**658**	*658*
total 1993	*7,824*	*8,523*	*10,891*	*511*	*1,727*	*658*	30,134
Land converted to:	78.7	0.0	16.8	0.5	27.6	0.0	

1974	20 years matrix	1993						total 1974
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**6,994**				14.4		*7,009*
	Grassland	829	**8,218**	186	1.42	113	0	*9,348*
	Cropland		305	**10,704**	0.00	159	0	*11,169*
	Wetland				**510**			*510*
	Settlements					**1,440**		*1,440*
	Other Land					0.54	**658**	*658*
	Total 1993	*7,824*	*8,523*	*10,891*	*511*	*1,727*	*658*	30,134
	Land converted to:	829	305	186	1	287	0	

1993	1994						total 1993
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,823**				0.72		*7,824*
Grassland	78.68	**8,400**	16.77	0.47	26.70	-	*8,523*
Cropland		0	**10,891**	0.00	0	-	*10,891*
Wetland				**511**			*511*
Settlements					**1,727**		*1,727*
Other Land					0.18	**658**	*658*
total 1994	*7,902*	*8,400*	*10,908*	*512*	*1,754*	*658*	30,134
Land converted to:	78.7	0.0	16.8	0.5	27.6	0.0	

1975	20 years matrix	1994						total 1975
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,025**				14.4		*7,040*
	Grassland	876	**8,101**	203	1.89	139	0	*9,322*
	Cropland		299	**10,704**	0.00	155	0	*11,158*
	Wetland				**510**			*510*
	Settlements					**1,445**		*1,445*
	Other Land					0.72	**658**	*658*
	Total 1994	*7,902*	*8,400*	*10,908*	*512*	*1,754*	*658*	30,134
	Land converted to:	876	299	203	2	309	0	

1994	1995						total 1994
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,901**				0.72		*7,902*
Grassland	78.68	**8,278**	16.77	0.47	26.70	-	*8,400*
Cropland		0	**10,908**	0.00	0	-	*10,908*
Wetland				**512**			*512*
Settlements					**1,754**		*1,754*
Other Land					0.18	**657**	*658*
total 1995	*7,980*	*8,278*	*10,924*	*512*	*1,782*	*657*	30,134
Land converted to:	78.7	0.0	16.8	0.5	27.6	0.0	

1976	20 years matrix	1995						total 1976
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,056**				14.4		*7,071*
	Grassland	923	**7,985**	220	2.37	166	0	*9,297*
	Cropland		292	**10,704**	0.00	150	0	*11,147*
	Wetland				**510**			*510*
	Settlements					**1,451**		*1,451*
	Other Land					0.90	**657**	*658*
	Total 1995	*7,980*	*8,278*	*10,924*	*512*	*1,782*	*657*	30,134
	Land converted to:	923	292	220	2	331	0	

1995	1996						total 1995
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,979**				0.72		*7,980*
Grassland	78.68	**8,199**	0	0.00	0.00	-	*8,278*
Cropland		60.32	**10,837**	0.47	26.70	-	*10,924*
Wetland				**512**			*512*
Settlements					**1,782**		*1,782*
Other Land					0.18	**657**	*657*
total 1996	*8,058*	*8,259*	*10,837*	*513*	*1,810*	*657*	30,134
Land converted to:	78.7	60.3	0.0	0.5	27.6	0.0	

1977	20 years matrix	1996						total 1977
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,068**				14.4		*7,083*
	Grassland	989	**7,907**	193	2.37	161	0	*9,252*
	Cropland		353	**10,644**	0.47	176	0	*11,174*
	Wetland				**510**			*510*
	Settlements					**1,456**		*1,456*
	Other Land					1.08	**657**	*658*
	Total 1996	*8,058*	*8,259*	*10,837*	*513*	*1,810*	*657*	30,134
	Land converted to:	989	353	193	3	353	0	

1996	1997						total 1996
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,057**				0.72		*8,058*
Grassland	78.68	**8,181**	0	0.00	0.00	-	*8,259*
Cropland		60.32	**10,749**	0.47	26.70	-	*10,837*
Wetland				**513**			*513*
Settlements					**1,810**		*1,810*
Other Land					0.18	**657**	*657*
total 1996	*8,136*	*8,241*	*10,749*	*513*	*1,837*	*657*	30,134
Land converted to:	78.7	60.3	0.0	0.5	27.6	0.0	

1978	20 years matrix	1997						total 1978
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,080**				14.4		*7,095*
	Grassland	1,055	**7,828**	166	2.37	157	0	*9,207*
	Cropland		413	**10,584**	0.95	203	0	*11,201*
	Wetland				**510**			*510*
	Settlements					**1,462**		*1,462*
	Other Land					1.26	**657**	*658*
	Total 1997	*8,136*	*8,241*	*10,749*	*513*	*1,837*	*657*	30,134
	Land converted to:	1,055	413	166	3	375	0	

1997	1998						total 1997
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,135**				0.72		*8,136*
Grassland	78.68	**8,162**	0	0.00	0.00	-	*8,241*
Cropland		60.32	**10,662**	0.47	26.70	-	*10,749*
Wetland				**513**			*513*
Settlements					**1,837**		*1,837*
Other Land					0.18	**657**	*657*
total 1998	*8,213*	*8,223*	*10,662*	*514*	*1,865*	*657*	30,134
Land converted to:	78.7	60.3	0.0	0.5	27.6	0.0	

1979	20 years matrix	1998						total 1979
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,093**				14.4		*7,107*
	Grassland	1,121	**7,749**	138	2.37	152	0	*9,163*
	Cropland		473	**10,524**	1	230	0	*11,228*
	Wetland				**510**			*510*
	Settlements					**1,467**		*1,467*
	Other Land					1.44	**657**	*658*
	Total 1998	*8,213*	*8,223*	*10,662*	*514*	*1,865*	*657*	30,134
	Land converted to:	1,121	473	138	4	398	0	

1998	1999						total 1998
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,213**				0.72		*8,213*
Grassland	78.68	**8,144**	0	0.00	0.00	-	*8,223*
Cropland		60.32	**10,574**	0.47	26.70	-	*10,662*
Wetland				**514**			*514*
Settlements					**1,865**		*1,865*
Other Land					0.18	**657**	*657*
total 1999	*8,291*	*8,204*	*10,574*	*514*	*1,892*	*657*	30,134
Land converted to:	78.7	60.3	0.0	0.5	27.6	0.0	

1980	20 years matrix	1999						total 1980
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,105**				14.4		*7,119*
	Grassland	1,187	**7,671**	111	2.37	147	0	*9,118*
	Cropland		534	**10,463**	1.89	257	0	*11,256*
	Wetland				**510**			*510*
	Settlements					**1,473**		*1,473*
	Other Land					1.62	**657**	*658*
	Total 1999	*8,291*	*8,204*	*10,574*	*514*	*1,892*	*657*	30,134
	Land converted to:	1,187	534	111	4	420	0	

1999	2000						total 1999
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,291**				0.72		*8,291*
Grassland	78.68	**8,126**	0	0.00	0.00	-	*8,204*
Cropland		60.32	**10,487**	0.47	26.70	-	*10,574*
Wetland				**514**			*514*
Settlements					**1,892**		*1,892*
Other Land					0.18	**656**	*657*
total 2000	*8,369*	*8,186*	*10,487*	*515*	*1,920*	*656*	30,134
Land converted to:	78.7	60.3	0.0	0.5	27.6	0.0	

1981	20 years matrix	2000						total 1981
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,117**				14.4		*7,131*
	Grassland	1,252	**7,592**	84	2.37	142	0	*9,073*
	Cropland		594	**10,403**	2.37	283	0	*11,283*
	Wetland				**510**			*510*
	Settlements					**1,478**		*1,478*
	Other Land					1.80	**656**	*658*
	Total 2000	*8,369*	*8,186*	*10,487*	*515*	*1,920*	*656*	30,134
	Land converted to:	1,252	594	84	5	442	0	

2000	2001						total 2000
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,369**				0.72		*8,369*
Grassland	78.68	**8,107**	-	-	-	-	*8,186*
Cropland		94.48	**10,365**	0.47	26.70	-	*10,487*
Wetland				**515**			*515*
Settlements					**1,920**		*1,920*
Other Land					0.18	**656**	*656*
total 2001	*8,447*	*8,202*	*10,365*	*515*	*1,948*	*656*	30,134
Land converted to:	78.7	94.5	0.0	0.5	27.6	0.0	

1983	20 years matrix	2002						total 1983
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,144**				14.4		*7,159*
	Grassland	1,381	**7,552**	84	2.37	142	0	*9,161*
	Cropland		666	**10,160**	3.32	327	0	*11,156*
	Wetland				**510**			*510*
	Settlements					**1,489**		*1,489*
	Other Land					2.17	**656**	*658*
	Total 2002	*8,525*	*8,218*	*10,244*	*516*	*1,975*	*656*	30,134
	Land converted to:	1,381	666	84	6	486	0	

2002	2003						total 2002
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,525**				0.72		*8,525*
Grassland	78.68	**8,139**	-	-	-	-	*8,218*
Cropland		94.48	**10,122**	0.47	26.70	-	*10,244*
Wetland				**516**			*516*
Settlements					**1,975**		*1,975*
Other Land					0.18	**656**	*656*
total 2003	*8,603*	*8,233*	*10,122*	*516*	*2,003*	*656*	30,134
Land converted to:	78.7	94.5	0.0	0.5	27.6	0.0	

20 years matrix	2003						total 1984
1984	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,158**				14.4		*7,173*
Grassland	1,445	**7,531**	84	2.37	142	0	*9,205*
Cropland		702	**10,038**	3.79	349	0	*11,093*
Wetland				**510**			*510*
Settlements					**1,495**		*1,495*
Other Land					2.35	**656**	*658*
Total 2003	*8,603*	*8,233*	*10,122*	*516*	*2,003*	*656*	30,134
Land converted to:	1,445	702	84	6	508	0	

2003	2004						total 2003
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,603**				0.72		*8,603*
Grassland	78.68	**8,155**	-	-	-	-	*8,233*
Cropland		94.48	**10,000**	0.47	26.70	-	*10,122*
Wetland				**516**			*516*
Settlements					**2,003**		*2,003*
Other Land					0.18	**656**	*656*
total 2004	*8,681*	*8,249*	*10,000*	*517*	*2,030*	*656*	30,134
Land converted to:	78.7	94.5	0.0	0.5	27.6	0.0	

20 years matrix	2004						total 1985
1985	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,172**				14.4		*7,186*
Grassland	1,509	**7,511**	84	2.37	142	0	*9,249*
Cropland		738	**9,916**	4.26	371	0	*11,030*
Wetland				**510**			*510*
Settlements					**1,500**		*1,500*
Other Land					2.53	**656**	*658*
Total 2004	*8,681*	*8,249*	*10,000*	*517*	*2,030*	*656*	30,134
Land converted to:	1,509	738	84	7	530	0	

2004	2005						total 2004
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,678**				3.69		*8,681*
Grassland	81.65	**8,168**	-	-	-	-	*8,249*
Cropland		97.46	**9,879**	0.47	23.73	-	*10,000*
Wetland				**517**			*517*
Settlements					**2,030**		*2,030*
Other Land					0.18	**656**	*656*
total 2005	*8,759*	*8,265*	*9,879*	*517*	*2,058*	*656*	30,134
Land converted to:	81.7	97.5	0.0	0.5	27.6	0.0	

20 years matrix	2005						total 1986
1986	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,183**				17.4		*7,200*
Grassland	1,577	**7,488**	84	2.37	142	0	*9,293*
Cropland		777	**9,795**	4.74	390	0	*10,966*
Wetland				**510**			*510*
Settlements					**1,506**		*1,506*
Other Land					2.71	**656**	*658*
Total 2005	*8,759*	*8,265*	*9,879*	*517*	*2,058*	*656*	30,134
Land converted to:	1,577	777	84	7	552	0	

2005	2006						total 2005
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,756**				3.69		*8,759*
Grassland	58.31	**8,207**	-	-	-	-	*8,265*
Cropland		84.89	**9,769**	0.47	23.73	-	*9,879*
Wetland				**517**			*517*
Settlements					**2,058**		*2,058*
Other Land					0.18	**655**	*656*
total 2006	*8,814*	*8,292*	*9,769*	*518*	*2,086*	*655*	30,134
Land converted to:	58.3	84.9	0.0	0.5	27.6	0.0	

20 years matrix	2006						total 1987
1987	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,258**				20.4		*7,278*
Grassland	1,556	**7,430**	84	2.37	140	0	*9,213*
Cropland		862	**9,686**	5.21	388	0	*10,941*
Wetland				**510**			*510*
Settlements					**1,534**		*1,534*
Other Land					2.89	**655**	*658*
Total 2006	*8,814*	*8,292*	*9,769*	*518*	*2,086*	*655*	30,134
Land converted to:	1,556	862	84	8	552	0	

2006	2007						total 2006
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,810**				3.69		*8,814*
Grassland	58.31	**8,233**	-	-	-	-	*8,292*
Cropland		84.89	**9,660**	0.47	23.73	-	*9,769*
Wetland				**518**			*518*
Settlements					**2,086**		*2,086*
Other Land					0.18	**655**	*655*
total 2007	*8,868*	*8,318*	*9,660*	*518*	*2,113*	*655*	30,134
Land converted to:	58.3	84.9	0.0	0.5	27.6	0.0	

20 years matrix	2007						total 1988
1988	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,333**				23.4		*7,356*
Grassland	1,536	**7,371**	84	2.37	139	0	*9,132*
Cropland		947	**9,577**	5.68	387	0	*10,916*
Wetland				**510**			*510*
Settlements					**1,561**		*1,561*
Other Land					3.07	**655**	*658*
Total 2007	*8,868*	*8,318*	*9,660*	*518*	*2,113*	*655*	30,134
Land converted to:	1,536	947	84	8	552	0	

2007	2008						total 2007
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,865**				3.69		*8,868*
Grassland	58.31	**8,260**	-	-	-	-	*8,318*
Cropland		84.89	**9,551**	0.47	23.73	-	*9,660*
Wetland				**518**			*518*
Settlements					**2,113**		*2,113*
Other Land					0.18	**655**	*655*
total 2008	*8,923*	*8,345*	*9,551*	*519*	*2,141*	*655*	30,134
Land converted to:	58.3	84.9	0.0	0.5	27.6	0.0	

20 years matrix	2007						total 1988
1988	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,333**				23.4		*7,356*
Grassland	1,536	**7,371**	84	2.37	139	0	*9,132*
Cropland		947	**9,577**	5.68	387	0	*10,916*
Wetland				**510**			*510*
Settlements					**1,561**		*1,561*
Other Land					3.07	**655**	*658*
Total 2007	*8,868*	*8,318*	*9,660*	*518*	*2,113*	*655*	30,134
Land converted to:	1,536	947	84	8	552	0	

2007	2008						total 2007
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,865**				3.69		*8,868*
Grassland	58.31	**8,260**	-	-	-	-	*8,318*
Cropland		84.89	**9,551**	0.47	23.73	-	*9,660*
Wetland				**518**			*518*
Settlements					**2,113**		*2,113*
Other Land					0.18	**655**	*655*
total 2008	*8,923*	*8,345*	*9,551*	*519*	*2,141*	*655*	30,134
Land converted to:	58.3	84.9	0.0	0.5	27.6	0.0	

20 years matrix	2008						total 1989
1989	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,408**				26.3		*7,434*
Grassland	1,516	**7,313**	84	2.37	137	0	*9,052*
Cropland		1,032	**9,467**	6.16	386	0	*10,891*
Wetland				**510**			*510*
Settlements					**1,589**		*1,589*
Other Land					3.25	**655**	*658*
Total 2008	*8,923*	*8,345*	*9,551*	*519*	*2,141*	*655*	30,134
Land converted to:	1,516	1,032	84	9	552	0	

2008	2009						total 2008
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,919**				3.69		*8,923*
Grassland	58.31	**8,286**	-	-	-	-	*8,345*
Cropland		177.88	**9,355**	7.52	10.98	-	*9,551*
Wetland				**519**			*519*
Settlements					**2,141**		*2,141*
Other Land					0.00	**655**	*655*
total 2009	*8,978*	*8,464*	*9,355*	*526*	*2,156*	*655*	30,134
Land converted to:	58.3	177.9	0.0	7.5	14.7	0.0	

20 years matrix	2009						total 1990
1990	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,483**				29.3		*7,512*
Grassland	1,495	**7,255**	84	2.37	135	0	*8,971*
Cropland		1,210	**9,271**	13.68	371	0	*10,866*
Wetland				**510**			*510*
Settlements					**1,616**		*1,616*
Other Land					3.25	**655**	*658*
Total 2009	*8,978*	*8,464*	*9,355*	*526*	*2,156*	*655*	30,134
Land converted to:	1,495	1,210	84	16	539	0	

2009	2010						total 2009
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**8,974**				3.69		*8,978*
Grassland	58.31	**8,406**	-	-	-	-	*8,464*
Cropland		177.88	**9,159**	7.52	10.98	-	*9,355*
Wetland				**526**			*526*
Settlements					**2,156**		*2,156*
Other Land					0.00	**655**	*655*
total 2010	*9,032*	*8,584*	*9,159*	*534*	*2,170*	*655*	30,134
Land converted to:	58.3	177.9	0.0	7.5	14.7	0.0	

20 years matrix	2010						total 1991
1991	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**7,558**				32.3		*7,590*
Grassland	1,475	**7,196**	84	2.37	134	0	*8,891*
Cropland		1,387	**9,075**	21.19	357	0	*10,841*
Wetland				**510**			*510*
Settlements					**1,644**		*1,644*
Other Land					3.25	**655**	*658*
Total 2010	*9,032*	*8,584*	*9,159*	*534*	*2,170*	*655*	30,134
Land converted to:	1,475	1,387	84	24	526	0	

2010	2011						total 2010
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,029**				3.69		9,032
Grassland	58.31	**8,526**	-	-	-	-	8,584
Cropland		44	**9,096**	7.52	10.98	0.00	9,159
Wetland				**534**			534
Settlements					**2,170**		2,170
Other Land					0.00	**655**	655
total 2011	9,087	8,570	9,096	541	2,185	655	30,134
Land converted to:	58.3	44.1	0.0	7.5	14.7	0.0	

1992	20 years matrix	2011						total 1992
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,633**				35.3		7,668
	Grassland	1,454	**7,138**	67	1.89	107	0	8,768
	Cropland		1,432	**9,029**	28.7	368	0	10,857
	Wetland				**511**			511
	Settlements					**1,672**		1,672
	Other Land					3.07	**655**	658
	Total 2011	9,087	8,570	9,096	541	2,185	655	30,134
	Land converted to:	1,454	1,432	67	31	513	0	

2011	2012						total 2011
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,083**				3.69		9,087
Grassland	58.31	**8,511**	-	-	-	-	8,570
Cropland		44	**9,033**	7.52	10.98	0.00	9,096
Wetland				**541**			541
Settlements					**2,185**		2,185
Other Land					0.00	**655**	655
total 2012	9,142	8,555	9,033	549	2,200	655	30,134
Land converted to:	58.3	44.1	0.0	7.5	14.7	0.0	

1993	20 years matrix	2012						total 1993
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,707**				38.2		7,746
	Grassland	1,434	**7,080**	50	1.42	80	0	8,646
	Cropland		1,476	**8,983**	36.23	379	0	10,874
	Wetland				**511**			511
	Settlements					**1,699**		1,699
	Other Land					2.89	**655**	658
	Total 2012	9,142	8,555	9,033	549	2,200	655	30,134
	Land converted to:	1,434	1,476	50	38	500	0	

2012	2013						total 2012
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,138**				3.69		9,142
Grassland	58.31	**8,497**	-	-	-	-	8,555
Cropland		44	**8,971**	7.52	10.98	0.00	9,033
Wetland				**549**			549
Settlements					**2,200**		2,200
Other Land					0.00	**655**	655
total 2013	9,196	8,541	8,971	556	2,214	655	30,134
Land converted to:	58.3	44.1	0.0	7.5	14.7	0.0	

1994	20 years matrix	2013						total 1994
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,782**				41.2		7,824
	Grassland	1,414	**7,021**	34	0.95	53	0	8,523
	Cropland		1,520	**8,937**	43.75	390	0	10,891
	Wetland				**511**			511
	Settlements					**1,727**		1,727
	Other Land					2.71	**655**	658
	Total 2013	9,196	8,541	8,971	556	2,214	655	30,134
	Land converted to:	1,414	1,520	34	45	487	0	

2013	2014						total 2013
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,192**				3.69		9,196
Grassland	58.31	**8,483**	-	-	-	-	8,541
Cropland		44	**8,908**	7.52	10.98	-	8,971
Wetland				**556**			556
Settlements					**2,214**		2,214
Other Land					0.00	**655**	655
total 2014	9,251	8,527	8,908	564	2,229	655	30,134
Land converted to:	58.3	44.1	0.0	7.5	14.7	0.0	

1995	20 years matrix	2014						total 1995
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,857**				44.2		7,902
	Grassland	1,393	**6,963**	17	0.47	27	0	8,400
	Cropland		1,564	**8,891**	51.27	401	0	10,908
	Wetland				**512**			512
	Settlements					**1,754**		1,754
	Other Land					2.53	**655**	658
	Total 2014	9,251	8,527	8,908	564	2,229	655	30,134
	Land converted to:	1,393	1,564	17	52	475	0	

2014	2015						total 2014
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,247**				3.69		9,251
Grassland	58.31	**8,469**	-	-	-	-	8,527
Cropland		44	**8,845**	7.52	10.98	0.00	8,908
Wetland				**564**			564
Settlements					**2,229**		2,229
Other Land					0.00	**655**	655
total 2015	9,305	8,513	8,845	571	2,244	655	30,134
Land converted to:	58.3	44.1	0.0	7.5	14.7	0.0	

1996	20 years matrix	2015						total 1996
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**7,932**				47.1		7,980
	Grassland	1,373	**6,905**	0	0.00	0	0	8,278
	Cropland		1,608	**8,845**	58.79	412	0	10,924
	Wetland				**512**			512
	Settlements					**1,782**		1,782
	Other Land					2.35	**655**	657
	Total 2015	9,305	8,513	8,845	571	2,244	655	30,134
	Land converted to:	1,373	1,608	0	59	462	0	

2015	2016						total 2015
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,302**				3.69		9,305
Grassland	58.31	**8,401**	39.66	3.01	10.98	-	8,513
Cropland		0	**8,845**	0.00	-	-	8,845
Wetland				**571**			571
Settlements					**2,244**		2,244
Other Land					0.00	**655**	655
total 2016	9,360	8,401	8,885	574	2,258	655	30,134
Land converted to:	58.3	0.0	39.7	3.0	14.7	0.0	

1997	20 years matrix	2016						total 1997
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**8,007**				50.1		8,058
	Grassland	1,353	**6,853**	40	3.01	11	0	8,259
	Cropland		1,548	**8,845**	58.31	385	0	10,837
	Wetland				**513**			513
	Settlements					**1,810**		1,810
	Other Land					2.17	**655**	657
	Total 2016	9,360	8,401	8,885	574	2,258	655	30,134
	Land converted to:	1,353	1,548	40	61	449	0	

2016	2017						total 2016
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,356**				3.69		9,360
Grassland	58.31	**8,289**	39.66	3.01	10.98	-	8,401
Cropland		0	**8,885**	-	-	-	8,885
Wetland				**574**			574
Settlements					**2,258**		2,258
Other Land					0.00	**655**	655
total 2017	9,415	8,289	8,925	577	2,273	655	30,134
Land converted to:	58.3	0.0	39.7	3.0	14.7	0.0	

1998	20 years matrix	2017						total 1998
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**8,082**				53.1		8,136
	Grassland	1,332	**6,802**	79	6.01	22	0	8,241
	Cropland		1,487	**8,845**	57.84	359	0	10,749
	Wetland				**513**			513
	Settlements					**1,837**		1,837
	Other Land					1.98	**655**	657
	Total 2017	9,415	8,289	8,925	577	2,273	655	30,134
	Land converted to:	1,332	1,487	79	64	436	0	

2017	2018						total 2017
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,411**				3.69		9,415
Grassland	58.31	**8,177**	39.66	3.01	10.98	-	8,289
Cropland		0	**8,925**	-	-	-	8,925
Wetland				**577**			577
Settlements					**2,273**		2,273
Other Land					0.00	**655**	655
total 2018	9,469	8,177	8,964	580	2,288	655	30,134
Land converted to:	58.3	0.0	39.7	3.0	14.7	0.0	

1999	20 years matrix	2018						total 1999
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**8,157**				56.1		8,213
	Grassland	1,312	**6,750**	119	9.02	33	0	8,223
	Cropland		1,427	**8,845**	57.37	332	0	10,662
	Wetland				**514**			514
	Settlements					**1,865**		1,865
	Other Land					1.80	**655**	657
	Total 2018	9,469	8,177	8,964	580	2,288	655	30,134
	Land converted to:	1,312	1,427	119	66	423	0	

2018	2019						total 2018
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,466**				3.69		9,469
Grassland	58.31	**8,065**	39.66	3.01	10.98	-	8,177
Cropland		0	**8,964**	-	-	-	8,964
Wetland				**580**			580
Settlements					**2,288**		2,288
Other Land					0.00	**655**	655
total 2019	9,524	8,065	9,004	583	2,302	655	30,134
Land converted to:	58.3	0.0	39.7	3.0	14.7	0.0	

2000	20 years matrix	2019						total 2000
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**8,232**				59.0		8,291
	Grassland	1,291	**6,698**	159	12.03	44	0	8,204
	Cropland		1,367	**8,845**	56.89	305	0	10,574
	Wetland				**514**			514
	Settlements					**1,892**		1,892
	Other Land					1.62	**655**	657
	Total 2019	9,524	8,065	9,004	583	2,302	655	30,134
	Land converted to:	1,291	1,367	159	69	410	0	

2019	2020						total 2019
	Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
Forest	**9,520**				3.69		9,524
Grassland	58.31	**7,953**	39.66	3.01	10.98	-	8,065
Cropland		0	**9,004**	-	-	-	9,004
Wetland				**583**			583
Settlements					**2,302**		2,302
Other Land					0.00	**655**	655
total 2020	9,578	7,953	9,044	586	2,317	655	30,134
Land converted to:	58.3	0.0	39.7	3.0	14.7	0.0	

2001	20 years matrix	2020						total 2001
		Forest	Grassland	Cropland	Wetlands	Settlements	Other Land	
	Forest	**8,307**				62.0		8,369
	Grassland	1,271	**6,647**	198	15.04	55	0	8,186
	Cropland		1,306	**8,845**	56.42	279	0	10,487
	Wetland				**515**			515
	Settlements					**1,920**		1,920
	Other Land					1.44	**655**	656
	Total 2020	9,578	7,953	9,044	586	2,317	655	30,134
	Land converted to:	1,271	1,306	198	71	397	0	

6.1 Forest Land (4A)

6.1.1 Description

Under this category, CO_2 emissions and removals from living biomass and dead organic matter, in forest land remaining forest land and from living biomass, dead organic matter (DOM) and soil organic matter (SOM) in land converted to forest land have been reported.
Forest land removals share, in 2020, 69.5% of total CO_2 eq. LULUCF net removals. CO_2 removals are mainly due to the living biomass, i.e., 95.2%, while DOM and SOM contribute only to 1.8% and 2.3%.
CO_2 emissions and removals from forest land remaining forest land and CO_2 removals from land converted to forest land have been identified as key categories in level and in trend assessment either with Approach 1 and Approach 2.
Management practices in the Italian forests are guided by the Legislative Decree n. 227 of 18 May 2001, although the design and implementation of specific guidelines has been carried out at regional level since, according to the Italian Constitutional Law, the forest management is a regional competence. The Legislative Decree n. 227/2001 provides 5 general guidance on forest management:

- → protect forest ecosystem functions, genetic resources, water basins and landscape;
- → avoid conversion of forest land to other land uses, and where occurring apply compensative reforestations with endemic species;
- → avoid conversion from forest stands to coppices;
- → avoid clear-cut;
- → conserve biodiversity, including true conservation of old trees and dead wood.

6.1.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The forest definition adopted by Italy in the framework of application of KP-LULUCF activities is also applied to the LULUCF sector of the inventory under the Convention, in order to maintain coherence and congruity between the two forest-related reporting.
The forest definition adopted under the Convention and under the Kyoto Protocol is the same used for the NFIs[30]. The forest definition includes areas where trees 1) fulfil the required threshold or 2) "have the potential to reach *in situ*" such required thresholds. For instance, *abandoned land with regenerating forest* is classified forest in consideration of the potential that vegetation has to reach the forest thresholds while that are not expected to evolve in forests do not and will never meet the forest definition; for this reason, this kind of shrublands are included in the *grassland* category and are defined as other wooded land. The assessment of vegetation potential to meet thresholds is carried out in the field (phase 2 of the NFI), and it is mainly based on the time needed to reach the forest thresholds, which should not exceed the 20 years. This means that also shrublands that are expected to evolve to forest vegetation within such time frame are classified as forests.
Forest land area is that of the NFIs. For any forest area growth, it is assumed that new forest land area can only come from grassland.
The Italian Ministry of Agriculture and Forests (MAF) and the Experimental Institute for Forest Management (ISAFA) carried out the National Forest Inventories. The first NFI was based on a regular sampling grid of 3 km by 3 km, (MAF/ISAFA, 1988), the second NFI (INFC2005) used a grid of 1 km by 1 km, so as the third NFI (NFI2015). The NFI2015 has completed its second phase, delivering on-field measurements on the plots of the sampling grid; 2015 area data of “Forest” and of “Other Wooded Land” have been therefore modified accordingly, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated). Complete NFI2015 results will be available in the late 2022, supplying data related to current increment and stocks.

[30] The detailed definition is reported on the website of the NFIs http://www.sian.it/inventarioforestale/jsp/q_features.jsp *(forest definition:* http://www.sian.it/inventarioforestale/jsp/linkmetodo/definizionilink1.jsp*)*

6.1.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The forest definition adopted by Italy in the framework of the Kyoto Protocol has been used. This definition is in line with the definition of the Food and Agriculture Organization of the United Nations, therefore the following threshold values for tree crown cover, land area and tree height have been applied:

a. a minimum area of land of 0.5 hectares;
b. a minimum tree crown cover of 10 per cent;
c. minimum tree height of 5 meters.

6.1.4 Methodological issues

Forest Land remaining Forest Land

To model C stock changes in forest land Italy uses the *For-est* model together with data from NFIs.

Table 6.5 Carbon pools, ecosystem components in the NFI surveys[31]

Forest carbon pools	Ordinary survey	Supplementary survey (Third phase)	Thresholds
Aboveground biomass	Biomass of trees with DBH≥4.5 cm (trees-AGB) Number or subjects of regeneration and shrubs	Ratio dry matter to wet & allometric Ratio dry matter to wet	All woody AGB included
Belowground biomass		Ratio root to shoot	⌀ > 2 mm
Deadwood	Volume of coarse woody debris (CWD)	Basic densities	⌀ ≥ 9.5 cm
	Volume of stumps	Basic densities	⌀ ≥ 9.5 cm
	Volume of standing dead trees (STD)	Basic densities	As for living trees
	Fine woody debris: not measured (FWD)	Wet weight per unit area; dry matter to wet ratio	2.5 ≤ ⌀ < 9.5 cm
Litter	not measured	Wet weight per unit area; dry matter to wet ratio	Fine woody debris ⌀ ≤ 2.5 cm, plus all other non-living biomass ⌀ ≤ 2 mm
Soil	not measured	Organic carbon per unit area	all organic carbon for an increment of 30 cm, plus all other biomass and dead mass ⌀ < 2 mm

The model applies the IPCC classification and definitions for C pools: living biomass, both aboveground and belowground; dead organic matter, including dead wood and litter; and soil organic matter. Information on the model is reported in Annex 14; additional information on methodological aspects can be found in Federici et al. (2008).

As described in step 3.b of Annex 14, biomass in burnt areas is assumed to have been completely lost, although not all the biomass stock is oxidised during the fire event (see also Annex 15 for the methodology used for forest fire emission estimates). In Figure 6.3, aboveground biomass losses due to harvest and forest fires, expressed as percentage on total aboveground carbon stock in forest land, are shown. In the late 2018, North-Eastern regions of Italy (i.e., Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Lombardia and, only marginally, Piemonte and Valle d'Aosta) were hit by Vaia storm, recording severe forest damages. Destroyed or intensely damaged forest stands amounted to about 42.500 ha; the growing stock volume of fallen trees was about 8.5 million m^3 (Chirici et al., 2019). The Vaia effects are noticeable in 2018 losses of aboveground carbon by harvest in figure 6.3.

[31] Specific documentation and information on the definitions of the NFI pools (e.g. the diameter threshold for deadwood and how this pool is differentiated from litter, which soil horizons are included in the soil pool and which pool contains the humus layer) are available at the NFI website: https://www.inventarioforestale.org/it/node/72 (i.e., https://www.inventarioforestale.org/sites/default/files/datiinventario/manuale_fase3%2B_v4_definitiva_REGp.pdf; https://www.inventarioforestale.org/sites/default/files/datiinventario/pubb/INFC2015_Guida_per_i_rilievi_in_campo_2016-12.pdf)

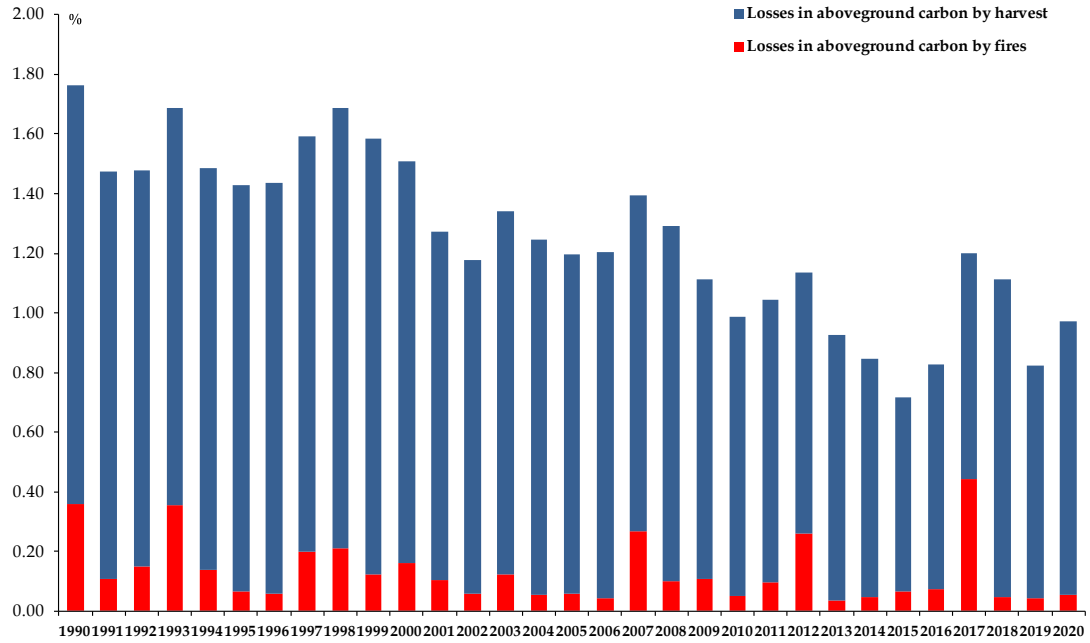


Figure 6.3 Losses by harvest and fires in relation to aboveground carbon

CO_2 emissions due to wildfires in forest land remaining forest land are included in CRF Table 4.A.1, carbon stocks change in living biomass - losses. Non-CO_2 gases are estimated separately from the aboveground biomass loss calculated by the *For-est* model; from the aboveground biomass loss the amount of C oxidized during the fire event is estimated using oxidation factors specific of the for each fire event, accordingly to the amount of C oxidized. CH_4 and N_2O emissions are inferred (see also paragraph 6.12.2 and Annex 15). Non-CO_2 emissions from fires have been estimated and reported in CRF table 4(V).
Organic soils in forest land remaining forest land do not occur (NO).
CO_2 emissions due to wildfires in land converted to forest land are included in CRF Table 4.A.2, carbon stocks change in living biomass - losses.
Non-CO_2 emissions from fires have been estimated and reported in CRF table 4(V); details on the methodology used to estimate emissions are reported in paragraph 6.12.2.

Land converted to Forest Land
The area of land converted to forest land always comes from grassland not subject to any specific management practice (i.e., under natural conditions). It is assumed that other conversions do not occur, and there is no evidence that those do occur. Accordingly, methods and factors for grassland converted to forest land are applied to estimate C stock changes and associated GHG emissions and removals.
Italy applies a 20-year conversion period and an approach 2 for land representation, so that, in any inventory year, the area reported under this category is the cumulated area of all conversions occurred in that year plus the area converted in the 19 previous years.
As for forest land remaining forest land, carbon stock changes in living biomass are calculated using the same *For-est* model.
The DOM pools have been estimated using coefficient values for each forest inventory typology and assuming a constant, linear, accumulation rate of both dead wood and litter across the conversion time till the coefficient value is achieved when the land transfers to the category forest land remaining forest land. In practice, in each conversion year, 1/20 of the dead wood mass coefficient and of the litter mass coefficient are reported as net CO_2 removals.
The dead wood dry mass coefficients for each forest inventory typology, see table 6.6, have been estimated using data taken for the Italian national forest inventory, in 2008 and 2009 across the country from the plots of the national forest inventory network (http://www.sian.it/inventarioforestale/jsp/necromassa.jsp). The mass (wet matter) collected on the ground in those plots has been converted in dry matter using basic densities appositely calculated in a specific study (Di Cosmo et al., 2013). The data collected, aggregated at regional level, are accessible at the NFI website: http://www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp.
The definition of the deadwood pool, coherent with the definition adopted by the NFI, is "*All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes*

wood lying on the surface, stumps larger than or equal to 10 cm in diameter and standing trees with DBH > 4,5 cm".

Table 6.6 Dead-wood coefficients for dry mass (d.m.)

	Inventory typology	d.m. *t ha^{-1}*
stands	norway spruce	6.360
	silver fir	7.770
	larches	3.830
	mountain pines	4.385
	mediterranean pines	2.670
	other conifers	4.290
	european beech	3.350
	turkey oak	1.770
	other oaks	1.690
	other broadleaves	3.990
coppices	european beech	3.350
	sweet chestnut	12.990
	hornbeams	2.730
	other oaks	1.690
	turkey oak	1.770
	evergreen oaks	1.370
	other broadleaves	2.690
	Conifers	4.290
plantations	eucalyptuses coppices	0.670
	other broadleaves coppices	0.670
	poplars stands	0.480
	other broadleaves stands	0.670
	conifers stands	3.040
protective	rupicolous forest	2.730
	riparian forest	4.790

Litter mass coefficients per hectare has been estimated at regional level from data available from the national forest inventory (http://www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp).
To estimate carbon stock changes in mineral soils, the IPCC default method has been applied. A country-specific SOC stock for natural grassland has been set at 78.9 t C ha^{-1}, based on a review of the literature on soil carbon in mountain meadows, pastures, set-aside lands as well as undisturbed abandoned land, in Italy (Masciandaro and Ceccanti, 1999; Del Gardo *et al*., 2003; Benedetti *et al*., 2004; Viaroli and Gardi, 2004; La Mantia *et al*., 2007; Xiloyannis, 2007; IPLA, 2007; ERSAF, 2008; CRPA, 2009). For forest soils, the time series of SOC stocks has reported in Table 6.7. A detailed description of the methodology used in the estimation process of soils pool, and consequently of the SOC stocks, is provided in par. 9.3.1.2, related to the KP-LULUCF.

Table 6.7 Soil Organic Carbon (SOC) stocks for *forest land remaining forest land*

Years	SOC stock *t C ha^{-1}*
1985-1994	79.809
1995-1999	80.172
2000-2004	80.575
2005-2009	81.083
2010-2014	81.601
2015-2019	82.213

In Figure 6.4, the C stock changes in land converted to forest land are shown.

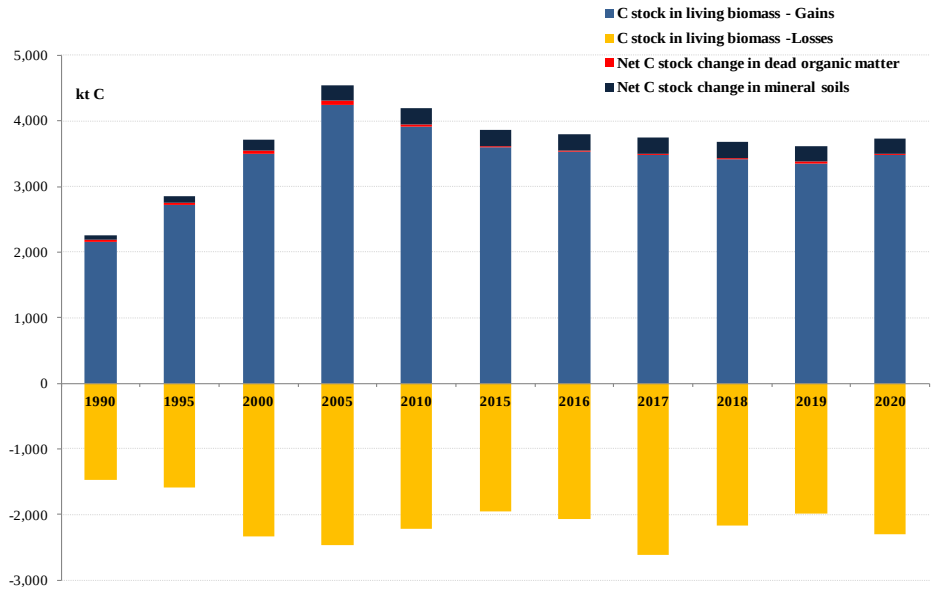


Figure 6.4 C stock changes in land converted to forest land (kt C)

Land converted to forest land do not occur (NO) on organic soils.

CO_2 emissions due to wildfires in land converted to forest land are included in CRF Table 4.A.2, carbon stocks change in living biomass - losses.

Non-CO_2 emissions from fires have been estimated and reported in CRF table 4(V); details on the methodology used to estimate emissions are reported in paragraph 6.12.2.

6.1.5 Uncertainty and time series consistency

To assess the overall uncertainty of the time series 1990–2020, Approach 1 of 2006 IPCC Guidelines (IPCC, 2006) has been applied. Input uncertainties for activity data and emission factors are derived from the country specific information and from the defaults provided in the 2006 IPCC Guidelines (IPCC, 2006).

In Table 6.8, the values of carbon stock of each pool, for the year 1985, and the associated uncertainties are reported for the entire forest land area.

Table 6.8 Carbon stocks and uncertainties for year 1985 and current increment related uncertainty

Carbon stocks *t CO_2 eq. ha^{-1}*	*Aboveground biomass*	V_{AG}	139.92
	Belowground biomass	V_{BG}	31.6
	Dead wood	V_D	3.3
	Litter	V_L	2.7
Uncertainty	*Growing stock*	E_{NFI}	3.2%
	Current increment (Richards)[32]	E_{NFI}	51.6%
	Harvest	E_H	30%
	Fires	E_F	30%
	Drain and grazing	E_D	30%
	Mortality	E_M	30%
	BEF	E_{BEF1}	30%
	R	E_R	30%
	Deadwood	E_{DEF}	4.6%
	Litter	E_L	10%
	Wood Basic Density (WDB)	E_{BD}	30%
	C Conversion Factor	E_{CF}	2%

[32] The current increment is estimated by the Richards function (first derivative); uncertainty has been assessed considering the standard error of the linear regression between the estimated values and the corresponding current increment values reported in the National Forest Inventory

The uncertainties of each carbon pool and the overall uncertainty for 1985 has been computed and shown in Table 6.9.

Table 6.9 C stock uncertainties for the year 1985

Aboveground biomass	E_{AG}	42.59%
Belowground biomass	E_{BG}	52.10%
Dead wood	E_{D}	42.84%
Litter	E_{L}	43.75%
Overall uncertainty	$\mathbf{E_{1985}}$	**34.85%**

The overall uncertainty related to 1985 (the year of the first National Forest Inventory) has been propagated through the years, till 2020, following Approach 1.
The uncertainties related to the carbon pools and the overall uncertainty for 2020 are shown in Table 6.10.

Table 6.10 Uncertainties for the year 2020

Aboveground biomass	E_{AG}	42.64%
Belowground biomass	E_{BG}	52.14%
Dead wood	E_{D}	42.89%
Litter	E_{L}	43.80%
Overall uncertainty	**E**	**35.41%**

Following Approach 1 and the abovementioned methodology, the overall uncertainty in the estimates produced by the described model has been quantified; in Table 6.11 the uncertainties of the 1985-2020 period are reported.

Table 6.11 Overall uncertainties 1985 – 2020 (%)

1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
34.9	35.0	35.1	35.2	35.2	35.3	35.3	35.3	35.3	35.3	35.4	35.4	35.4	35.4	35.4	35.4

The overall uncertainty in the model estimates between 1990 and 2020 has been assessed subtracting uncertainties with Approach 1 (IPCC 2006, Vol.1, Ch. 3, Equation 3.2, resulting in overall uncertainty equal to 25.1%.
A Monte Carlo analysis has been carried out to assess uncertainty for Forest Land category (considering both Forest Land remaining Forest Land and Land converted to Forest Land), considering the different reporting pools (*aboveground, belowground, litter, deadwood and soils*), and the subcategories stands, coppices and rupicolous and riparian forests for the reporting year 2009, resulting equal to 49%. As for Land converted to Forest Land, an asymmetrical probability density distribution resulted from the analysis, showing uncertainties values equal to -147.6% and 192.3%. Normal distributions have been assumed for most of the parameters. A more detailed description and results are reported in Annex 1.

6.1.6 Category-specific QA/QC and verification

Systematic quality control activities have been carried out to ensure completeness and consistency in time series and correctness in the sum of sub-categories; where possible, activity data comparison among different sources (FAO database[33], ISTAT data[34]) has been made. Data entries have been checked several times during the compilation of the inventory; attention has been focussed on the categories showing significant changes between two years in succession. Land use matrices have been accurately checked and cross-checked to ensure that data were properly reported. An independent verification of the living biomass net change with data from the second NFI, for the year 2005 (Tabacchi et al., 2010) was performed. In Figure 6.5 outcome of the comparison is shown.

[33] FAO, 2015. FAOSTAT, http://faostat3.fao.org/home/E
[34] ISTAT, several years [a], [b], [c]

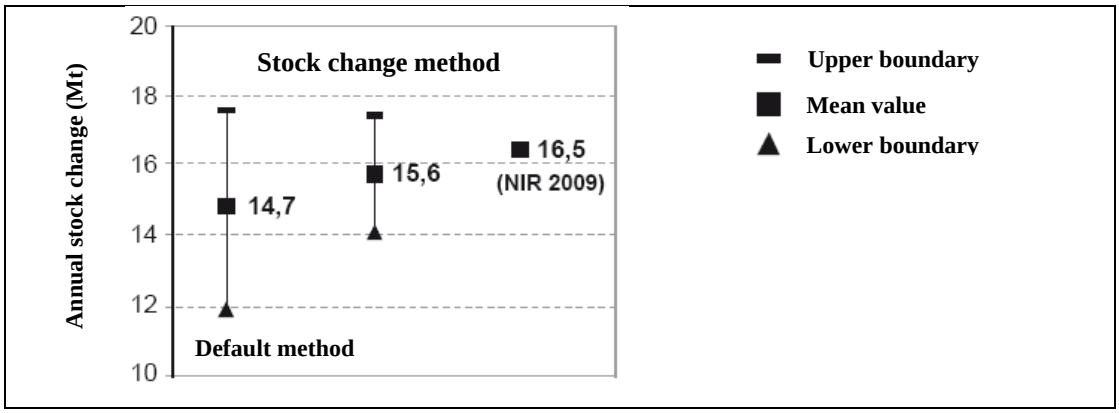


Figure 6.5 Comparison between carbon stock changes, for living biomass pool, by the National GHG Inventory (ISPRA) and estimated data of NFI2005 (II NFI) measurements (modified from Tabacchi *et al.*, 2010)

The NFI2005 forest typologies are different from those elaborated for the first forest inventory. A confusion matrix, between forest typologies of the NFI2005 and those of the first forest inventory classification systems is under finalization. In the meanwhile, a comparison among NFI2005 current increment data and *For-est* model current increment data is possible only for a not exhaustive number of inventory typologies. In the following Figure 6.6 the comparison has been reported.

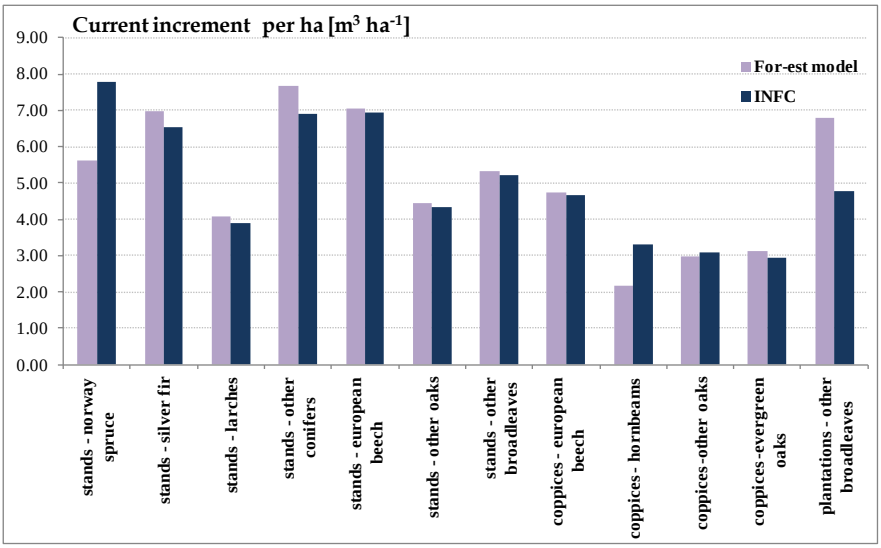


Figure 6.6 Average national current increment: comparison among NFI2005 (INFC) data and For-est model estimates

An interregional project, named INEMAR[35], developed to carry out atmospheric emissions inventories at local scale, includes a module to estimate forest land emissions and removals, following the methodology described in the par. 6.2.4. The module has been applied, at local scale with local data in Lombardia region, for the different pools and for the years 1990, 2000, 2005, 2008.
In Figure 6.7 carbon stocks, in the different pools, estimated by the National GHG Inventory (ISPRA) and the corresponding values obtained in the INEMAR framework for the Lombardia region, are shown (ARPA Lombardia - Regione Lombardia, 2011 [a, b]).

[35] INEMAR: INventario EMissioni Aria: http://www.ambiente.regione.lombardia.it/inemar/e_inemarhome.htm

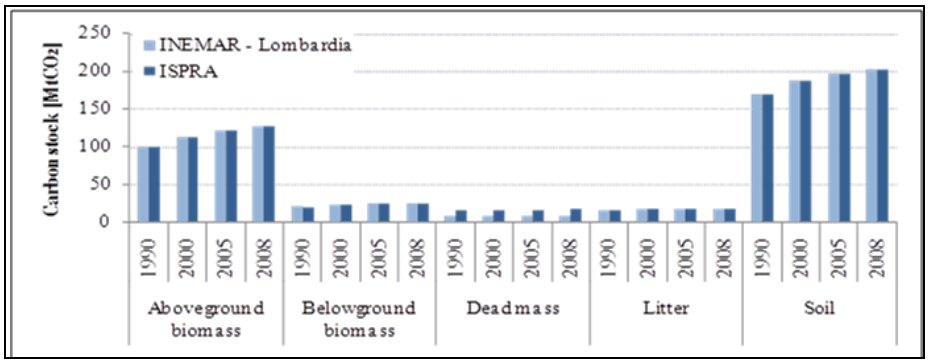


Figure 6.7 CO_2 removals estimates by the National GHG Inventory (ISPRA) and the INEMAR project for Lombardia

In Table 6.12 carbon stocks, in the different pools, estimated by the National GHG Inventory (ISPRA) and the corresponding values obtained in the INEMAR framework for the Lombardia region, are shown.

Table 6.12 CO_2 removals by the National GHG Inventory (ISPRA) and the INEMAR project for Lombardia

	INEMAR - Lombardia	ISPRA	Differences
	kt CO_2	*kt CO_2*	*%*
1990	311,370	319,203	-2.45
2000	345,886	353,326	-2.11
2005	367,537	375,275	-2.06
2008	379,742	387,673	-2.05

An additional verification activity has been carried out, comparing the implied carbon stock change per area (IEF), related to the living biomass, with the IEFs reported by other Parties. The 2021 submission[36] has been considered to deduce the different IEFs; in Figure 6.8 the comparison is showed, taking into account the IEFs for both the forest land remaining forest land (FL-FL) and land converting to forest land (L-FL) subcategories, for the living biomass.

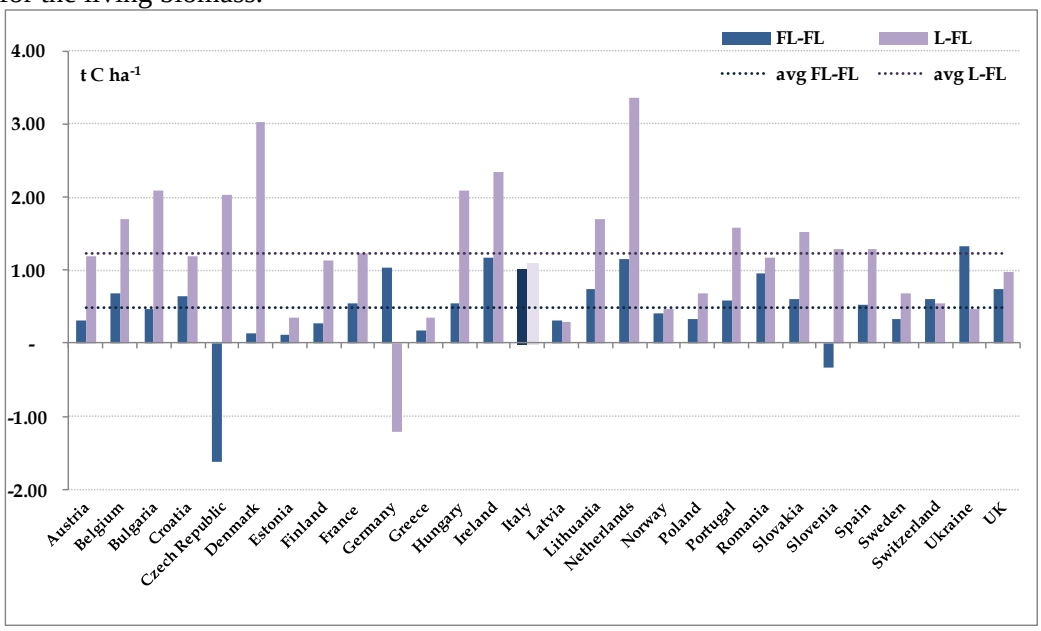


Figure 6.8 Implied carbon stock change per area for the living biomass

[36] GHG Review Tools (unfccc.int)

6.1.7 Category-specific recalculations

The recalculation, as shown in tables 6.13 and 6.14, occurs in the 2022 submission, comparing to the 2021 submission, for the forest land remaining forest land (-17.7% for the 2019 reporting year) and land converted to forest land (-10.9% for the 2019 reporting year). The recalculation is due to the update of the activity data as resulting from the NFI outcomes (NFI2015): 2015 area data of "Forest" and of "other wooded land" (reported under grassland category), have been therefore modified accordingly, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated).
Complete NFI2015 results will be available in the late 2022, supplying data related to current increment and stocks.

Table 6.13 Recalculation in forest land category, for carbon pool

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission					CO_2 eq. - kt					
Forest land	**-17,852**	**-31,122**	**-26,004**	**-34,667**	**-36,257**	**-39,385**	**-36,311**	**-21,549**	**-31,980**	**-36,367**
- *living biomass*	*-16,444*	*-29,579*	*-24,243*	*-32,607*	*-34,658*	*-37,846*	*-34,777*	*-20,014*	*-30,458*	*-34,851*
- *dom*	*-1,191*	*-1,191*	*-1,191*	*-1,191*	*-639*	*-639*	*-639*	*-639*	*-639*	*-639*
- *soils*	*-217*	*-352*	*-570*	*-869*	*-960*	*-901*	*-895*	*-895*	*-883*	*-877*
2021 submission					CO_2 eq. - kt					
Forest land	**-17,852**	**-31,122**	**-26,004**	**-34,662**	**-36,658**	**-40,114**	**-37,074**	**-22,508**	**-32,822**	**-37,267**
- *living biomass*	*-16,444*	*-29,579*	*-24,243*	*-32,607*	*-34,942*	*-38,457*	*-35,424*	*-20,858*	*-31,185*	*-35,637*
- *dom*	*-1,191*	*-1,191*	*-1,191*	*-1,191*	*-767*	*-767*	*-767*	*-767*	*-767*	*-767*
- *soils*	*-217*	*-352*	*-570*	*-865*	*-949*	*-890*	*-883*	*-883*	*-870*	*-864*
recalculation					*%*					
Forest land	**0.0**	**0.0**	**0.0**	**0.0**	**-1.1**	**-1.9**	**-2.1**	**-4.5**	**-2.6**	**-2.5**
- *living biomass*	*0.0*	*0.0*	*0.0*	*0.0*	*-0.8*	*-1.6*	*-1.9*	*-4.2*	*-2.4*	*-2.3*
- *dom*	*0.0*	*0.0*	*0.0*	*0.0*	*-20.0*	*-20.0*	*-20.0*	*-20.0*	*-20.0*	*-20.0*
- *soils*	*0.0*	*0.0*	*0.0*	*0.5*	*1.2*	*1.2*	*1.3*	*1.3*	*1.5*	*1.6*

Table 6.14 Recalculation in forest land category, for subcategories FL-FL e L-FL

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission					CO_2 eq. - kt					
Forest land	**-17,852**	**-31,122**	**-26,004**	**-34,667**	**-36,257**	**-39,385**	**-36,311**	**-21,543**	**-31,980**	**-36,367**
FL-FL	-15,002	-26,485	-20,983	-27,099	-29,016	-32,379	-29,966	-17,442	-26,476	-30,374
L-FL	-2,849	-4,636	-5,022	-7,567	-7,241	-7,007	-6,345	-4,101	-5,504	-5,993
2021 submission					CO_2 eq. - kt					
Forest land	**-17,852**	**-31,122**	**-26,004**	**-34,662**	**-36,658**	**-40,114**	**-37,074**	**-22,502**	**-32,822**	**-37,267**
FL-FL	-15,002	-26,485	-20,983	-27,099	-29,361	-33,009	-30,629	-18,276	-27,212	-31,164
L-FL	-2,849	-4,636	-5,022	-7,563	-7,297	-7,105	-6,445	-4,226	-5,610	-6,103
recalculation					*%*					
Forest land	**0.0**	**0.0**	**0.0**	**0.0**	**-1.1**	**-1.9**	**-2.1**	**-4.5**	**-2.6**	**-2.5**
FL-FL	0.0	0.0	0.0	0.0	-1.2	-1.9	-2.2	-4.8	-2.8	-2.6
L-FL	0.0	0.0	0.0	0.1	-0.8	-1.4	-1.6	-3.1	-1.9	-1.8

6.1.8 Category-specific planned improvements

The complete set of third NFI (NFI2015) data, expected in 2022, will allow calibrating the increment curve and verifying the *For-est* estimates through a comparison with estimates prepared with the stock-difference method. Currently, the *For-est* model does not remove year by year the impact of deforestation from the calculation of the forest biomass density and consequently from the calculation of the annual increment. This improvement is planned for the 2023 submission. The *For-est* model currently does not calculate annual

biomass increment in the areas converted to forest in the year. The inclusion of such areas is deemed necessary to address the identified underestimate of the biomass C stock (see Annex 14 on the *For-est* model). This improvement is planned for the 2023 submission. The *For-est* model does not discriminate among forest remaining forest and land converted to forest, once data from the third NFI will be available an update of the model could be planned to allow for disaggregated estimates of C stock changes in land converted to forest land.

6.2 Cropland (4B)

6.2.1 Description

Under this category, CO_2 emissions from living biomass, and soils have been reported, for cropland remaining cropland and for land converted to cropland.
Cropland net emissions share 0.1% of total 2019 LULUCF CO_2 net emissions; in particular, the soil pools represent 50.6% of the whole cropland emissions and removals while the remaining 49.4% originate from living biomass pool.
CO_2 emissions and removals from cropland remaining cropland and land converted to cropland have been identified as key category in trend assessment with Approach 1 and 2 (cropland remaining cropland) and with Approach 2 only (land converted to cropland).

6.2.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Information on the land representation is reported in section 6.1. For the cropland category, as already discussed, it is assumed that the only conversion occurring is from grassland to cropland. The IPCC default land use transition period of 20 years has been applied.

6.2.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

Cropland includes all annual and perennial crops.
Due to the technical characteristics of the IUTI assessment (i.e., classification of orthophotos), it was not possible clearly distinguish among some subcategories in *cropland* and non-woody *grassland* categories (e.g., grazing lands and unmanaged/natural grasslands). Therefore, although the total aggregated area of the 2 categories *cropland* and *grassland* together is derived from the IUTI data, the area of each of their subcategories is disaggregated using as proxies the national statistics (ISTAT, [b], [c]) on annual crops and perennial woody crops.

6.2.4 Methodological issues

Activity data for cropland remaining cropland have been subdivided into annual and perennial crops. Changes in the biomass C stock has been estimated for perennial crops in both cropland remaining cropland and land converted to cropland, while for annual crops in land converted to cropland only.
Soil carbon stock changes have been estimated and reported for annual and perennial crops in both cropland remaining cropland and land converted to cropland subcategories.

Living biomass – perennial crops
For perennial crops, biomass carbon stock changes have been estimated on the basis of the annual rates of biomass gain and loss (IPCC 2006, Vol. 4, Chapter 2, Equation 2.7).
The annual carbon stock in living biomass and the woody crops area annually undergoing to a woody biomass removal (e.g., biomass cleared and replanted with a different crop) have been estimated; in addition, the total woody crops area has subdivided into age classes, taking into account three main woody crops types (i.e., olives, vineyards and other fruit). The estimation process has been carried out at NUTS2 (regional) level, based

on the available data from national statistics (ISTAT, [b], [c]) for the different woody crops species[37] and harvest/maturity cycles.
The carbon stock change in living biomass during the plantation cycle is estimated on the basis of an annual constant net gain (accumulation rate), per perennial crop type and age class. Table 6.15 summarises the aboveground and belowground biomass carbon stock at the end of the maturity cycle for each group of perennial crops. These values correspond to the total biomass carbon stocks removed during the harvesting. All values have been assessed based on the database collected in the framework of the LIFE project MEDINET[38].

Table 6.15 Harvest/maturity cycle, aboveground and belowground biomass carbon stock at harvest

Crops	Harvest/maturity cycle	Aboveground C stock		Belowground C stock	
	yr	*t C ha^{-1}*	*std dev (t C ha^{-1})*	*t C ha^{-1}*	*std dev (t C ha^{-1})*
olive	50	9.13	1.07	2.60	0.09
vineyards (wine grapes)	20	5.60	0.50	4.46	0.34
vineyards (for other)	30	5.62	0.50	4.48	0.35
orchards, pear, apple, cherry	25	8.91	1.32	5.75	0.32
peach, apricot	15	8.94	1.29	5.72	0.65
kiwifruit	20	8.90	1.31	5.73	0.68
other fruits	20	8.90	1.31	5.73	0.68

Net biomass carbon stock changes are equal to -316.5 kt C for 1990, and -350.5 kt C for 2020, a complete time series is summarised in Table 6.16.

Table 6.16 Change in carbon stock in living biomass

	Area	aboveground biomass			belowground biomass			net change in C stock
		Gains	Losses	Net change	Gains	Losses	Net change	
	kha	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*
1990	2,698	486	-693	-207	316	-425	-110	-317
1991	2,701	481	-448	33	312	-311	1	33
1992	2,704	472	-569	-97	305	-391	-86	-183
1993	2,707	464	-538	-74	300	-371	-71	-145
1994	2,710	453	-433	21	292	-303	-10	10
1995	2,712	443	-534	-91	285	-367	-82	-173
1996	2,691	431	-671	-241	277	-447	-170	-411
1997	2,670	417	-630	-212	268	-428	-160	-372
1998	2,648	403	-646	-243	259	-426	-167	-410
1999	2,627	388	-616	-228	249	-424	-175	-403
2000	2,606	376	-693	-316	240	-533	-293	-609
2001	2,600	369	-382	-12	237	-267	-30	-43
2002	2,594	365	-440	-75	235	-308	-73	-148
2003	2,589	363	-466	-102	234	-321	-87	-189
2004	2,583	361	-382	-20	234	-268	-34	-54
2005	2,577	360	-467	-107	234	-305	-71	-178
2006	2,578	359	-369	-10	234	-263	-29	-39
2007	2,579	359	-389	-29	235	-265	-30	-59
2008	2,579	360	-431	-71	235	-303	-67	-138
2009	2,577	360	-447	-87	236	-294	-58	-145
2010	2,574	360	-441	-81	236	-320	-84	-165
2011	2,540	358	-680	-321	235	-404	-169	-490

[37] Olive, vineyard (for wine grapes and other), orchards (orange, mandarine, clementine, lemon, grapefruit, bergamot, cedar, chinotto), apple, peach, pear, apricot, cherry, kiwifruit, other fruits (carob, fig, plum, hazelnut, almond, raspberry)
[38] MEDINET (Mediterranean Network for Reporting Emissions and Removals in Cropland and Grassland): https://www.lifemedinet.com/

	Area	aboveground biomass			belowground biomass			net change in C stock
		Gains	Losses	Net change	Gains	Losses	Net change	
	kha	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*	*kt C*
2012	2,507	351	-796	-445	231	-483	-251	-696
2013	2,473	336	-589	-254	223	-428	-205	-459
2014	2,439	327	-658	-331	218	-451	-232	-563
2015	2,405	319	-665	-346	214	-451	-237	-582
2016	2,412	317	-399	-82	215	-280	-65	-148
2017	2,419	316	-408	-92	217	-275	-58	-150
2018	2,426	316	-440	-123	219	-290	-71	-194
2019	2,433	314	-376	-62	220	-240	-21	-83
2020	2,440	329	-546	-217	232	-365	-134	-350

Soils – annual and perennial crops

For mineral soils, the estimation method is based on changes in SOC stocks over a finite period due to changes in management practices. According to the 2006 IPCC Guidelines (IPCC, 2006), the change in mineral SOC stocks (vol. 4, chapter 2, eq. 2.25) is the result of a change in management practices in a unit of land across time. The SOC stock changes in annual and perennial crops have been estimated considering the following cropland management practices reported in table 6.17.

Table 6.17 Cropland management practices

cropland subcategory	management practices	definition	CAP regulations
annual crops	Arable land (Ordinary)	A kind of agriculture that does not evidence any kind of soil carbon stock technical maintenance	
	Organic arable land	Management of waste crop; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009
	Sustainable arable land	Crop rotation; Grassing; Specific erosion prevention; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009
	Set aside	Natural grassing; At least one mowing	Reg. (EEC) N. 1765/1992; National decree on cross compliance implementation n. 30125/2009 and subsequent revisions
	Conservative practices	Zero tillage; Organic manure; Grassing; Cover crops; Minimum tillage; Crop rotation	RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009
perennial crops	Woody crops (Ordinary)	A kind of agriculture that does not evidence any kind of soil carbon stock technical maintenance	
	Organic woody crops	Management of waste crop; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009
	woody crops - Sustainable management	Crop rotation; Grassing; Specific erosion prevention; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009

In the following Table 6.18 the data source for each management practice is listed.

Table 6.18 Cropland management practices and relative data sources

cropland subcategory	management practice	data source
annual crops	Ordinary	ISTAT
	Organic	National Information system on organic agriculture (SINAB)
	Sustainable	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2018
	Set aside	Eurostat: 1990-2016
	Conservative practices	Annual Implementation Reports (RAE): 2008-2018
perennial crops	Ordinary	ISTAT
	Organic	National Information system on organic agriculture (SINAB)
	Sustainable	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2018

The annual areas subject to the abovementioned management practices, at regional level, have been estimated, also considering the transition to and from different management practices (e.g. ordinary annual crops to organic annual crops, ordinary annual crops to sustainable annual crops, etc.). Changes in carbon stocks in mineral soils has been calculated by applying the equation 2.25 of the IPCC, 2006 (vol. 4, chapter 2). The IPCC default transition period, i.e. 20 years, has been considered.
The SOC_{ref} classification of the soils is based on the default reference SOC stocks for mineral soils (tC/ha in 0-30 cm) provided in table 2.3 of IPCC 2006. The identification of country specific SOC_{ref} have been performed using a combination of the following map layers:

- IPCC climate zones (JRC) - http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/
- Corine Land cover 2006 (grassland: legend codes: 2.3 ad 3.2) - http://sia.eionet.europa.eu/CLC2006
- Soil map of Italy - (reclassified according to the main groups of soil types as in table 2.3) - Costantini E.A.C., L'Abate G., Barbetti R., Fantappiè M., Lorenzetti R., Magini S. (2013) Carta dei suoli d'Italia, scala 1:1.000.000 - http://www.soilmaps.it/
- Map of Italy with administrative boundaries.

Overlapping the abovementioned layers, the Italian soils have been classified according to the IPCC soil classes (table 2.3, vol. 4, chapter 2 of the 2006 IPCC Guidelines), and their related climate zones as percentage in each region. According to the thereby defined distribution of the soil types and climate zones in each Italian region, it was possible to define the SOC_{ref}. The stock change factors (F_{LU}, F_{MG}, F_I) adapted to the national circumstances, have been derived by the default values provided in table 5.5 of the 2006 IPCC Guidelines (vol.4, chapter 5) and have been applied considering the percentage of moist and dry climates in each administrative region. The F factors considered, and are reported in the following Table 6.19.

Table 6.19 Stock change factors

	Management practice	F_{LU}		F_{MG}		F_I	
		Moist	*Dry*	*Moist*	*Dry*	*Moist*	*Dry*
annual crops	Ordinary	0.69	0.8	1	1	0.92	0.95
	Organic	0.69	0.8	1	1	1.44	1.37
	Sustainable	0.69	0.8	1.08	1.02	1	1
	Set aside	0.82	0.93	1.15	1.1	0.92	0.95
	Conservative	0.69	0.8	1.15	1.1	1.11	1.04
perennial crops	Ordinary	1	1	1	1	1	1
	Organic	1	1	1.08	1.02	1.44	1.37
	Sustainable	1	1	1.08	1.02	0.92	0.95

The SOC stocks per hectare in the mineral soil, calculated on the basis of the previously described procedure, are shown in the table 6.20, per region and per management practices, for annual and perennial crops. Estimates of SOC stock changes in annual and perennial crops are reported in Table 6.21.

Table 6.20 SOC stocks per region and management practice

Region	annual crops					perennial crops		
	Ordinary	Organic	Sustainable	Set aside	Conservative	Ordinary	Organic	Sustainable
	SOC stock (t C ha^{-})[1]					*SOC stock (t C ha^{-})[1]*		
Piemonte	49.04	74.86	56.02	65.64	65.18	72.91	109.79	71.92
Valle D'Aosta	57.29	89.45	67.07	78.13	79.15	89.72	139.09	89.08
Liguria	51.15	78.64	58.89	68.87	68.82	77.29	117.47	76.40
Lombardia	52.32	80.88	60.59	70.76	71.06	80.06	122.53	79.26
Trentino – Alto Adige	56.84	88.97	66.73	77.68	78.87	89.54	139.26	88.97
Veneto	46.88	71.05	53.14	62.38	61.55	68.60	102.36	67.53
Friuli - Venezia Giulia	55.94	87.56	65.67	76.45	77.62	88.12	137.05	87.56
Emilia - Romagna	40.13	59.60	44.50	52.53	50.87	56.17	81.60	54.94
Toscana	38.18	56.43	42.11	49.78	47.98	52.88	76.32	51.64
Umbria	46.72	70.81	52.96	62.17	61.34	68.37	102.01	67.30
Marche	39.05	57.86	43.18	51.02	49.29	54.36	78.72	53.14
Lazio	39.33	58.52	43.69	51.55	50.01	55.26	80.48	54.09
Abruzzo	40.97	60.98	45.54	53.72	52.13	57.61	83.93	56.39
Molise	32.74	47.67	35.52	42.18	40.09	43.94	62.20	42.72
Campania	31.64	45.99	34.26	40.71	38.63	42.31	59.75	41.11
Puglia	29.21	42.21	31.43	37.42	35.30	38.60	54.07	37.42
Basilicata	30.64	44.37	33.05	39.31	37.17	40.67	57.16	39.46
Calabria	34.42	50.34	37.53	44.51	42.48	46.63	66.39	45.39
Sicilia	28.70	41.38	30.81	36.69	34.56	37.76	52.77	36.59
Sardegna	30.11	43.56	32.44	38.60	36.47	39.89	55.99	38.69

Table 6.21 SOC stock changes in in the mineral soil for annual and perennial crops

	area		SOC stock change		
	annual crops	perennial crops	annual crops	perennial crops	**total**
	kha	*kha*	*kt C*	*kt C*	*kt C*
1990	8,005.9	2,698.5	325.4	2.4	327.8
1991	8,003.1	2,701.2	486.5	3.1	489.6
1992	8,000.4	2,704.0	652.3	5.6	657.9
1993	7,997.6	2,706.7	842.1	16.3	858.4
1994	7,994.9	2,709.5	712.7	28.5	741.2
1995	7,992.1	2,712.3	574.8	37.8	612.5
1996	7,953.1	2,691.0	536.6	61.8	598.4
1997	7,914.1	2,669.8	592.7	118.7	711.3
1998	7,875.1	2,648.5	691.1	145.5	836.6
1999	7,836.1	2,627.2	777.3	169.1	946.4
2000	7,797.2	2,605.9	933.6	186.5	1,120.1
2001	7,681.2	2,600.2	922.0	247.4	1,169.4
2002	7,565.2	2,594.5	868.5	204.3	1,072.8
2003	7,449.3	2,588.8	811.1	185.5	996.5
2004	7,333.3	2,583.1	749.5	173.9	923.4
2005	7,217.4	2,577.4	850.4	204.7	1,055.1
2006	7,107.6	2,578.0	867.0	225.8	1,092.7
2007	6,997.8	2,578.7	901.7	224.3	1,126.0
2008	6,888.1	2,579.3	755.2	232.8	988.0
2009	6,694.2	2,576.9	778.6	297.9	1,076.6
2010	6,500.3	2,574.4	451.4	309.3	760.7
2011	6,488.4	2,540.5	345.9	262.6	608.5
2012	6,476.5	2,506.6	165.5	286.7	452.2
2013	6,464.5	2,472.6	-46.2	313.7	267.5
2014	6,452.6	2,438.8	137.9	281.4	419.3
2015	6,440.6	2,404.9	336.9	306.1	643.0
2016	6,433.6	2,411.9	474.6	345.3	820.0
2017	6,426.5	2,419.0	504.1	323.1	827.1

	area		SOC stock change		
	annual crops	perennial crops	annual crops	perennial crops	**total**
	kha	*kha*	*kt C*	*kt C*	*kt C*
2018	6,419.5	2,426.0	497.0	310.0	807.0
2019	6,412.5	2,433.0	450.0	301.1	751.1
2020	6,405.6	2,439.9	353.7	301.4	655.2

CO_2 emissions from cultivated organic soils in cropland remaining cropland have been estimated, using default emission factor for warm temperate climate zone from Table 5.6 of the 2006 IPCC Guidelines (vol.4, chapter 5): 10 t C ha^{-1} y^{-1}. The area of organic soils is taken from the FAOSTAT[39] database that overlaps:
- the map of Histosols classes in the *Harmonized World Soil Database*[40] and
- the three "cropland" classes in the global land cover dataset, GLC2000[41].

Land converted to Cropland
In accordance with the IPCC methodology, estimates of carbon stock change in living biomass and in SOM in mineral soils have been provided.
Italy applies a 20-year conversion period and an approach 2 land representation, so that in any inventory year the area reported under this category is the cumulated area of all conversions occurred in that year plus the area converted in the 19 previous years.
Direct and indirect N_2O emissions arising from nitrogen mineralization associated with loss of soil organic matter have also been estimated, and these are reported in CRF tables 4(III) and in tables (IV), respectively.
The biomass carbon stock change, for land converted to cropland, is estimated at Tier 1 (equation 2.16, vol. 4, chapter 2 of the 2006 IPCC Guidelines) and it is equal to the removal of biomass from the initial land use plus the carbon stocks of one year of growth in perennial crops or the average biomass stock in annual crops following the conversion. Since only conversion from grassland to cropland has occurred, the biomass removal is that of grassland (natural grassland), and the value applied, as dry matter, is the default reported in Table 6.4 of the 2006 IPCC Guidelines (vol. 4, chapter 6) for warm temperate – dry climate, i.e. 6.1 t d.m. ha^{-1}. In accordance with national expert judgement, it has been assumed that the final crop type in all land converted to cropland is annual crop; consequently, for annual crop, the carbon stock gain of one year of growth has been taken from Table 5.9 of the 2006 IPCC Guidelines (vol. 4, chapter 5), for temperate region i.e. 5.0 t C ha^{-1}.
Conversion to cropland is a quite rare event in the time series of land matrices (table 6.4 and CRF tables 4.1).
Changes in carbon stocks in mineral soils in land converted to cropland have been estimated applying IPCC equation 2.25 (vol. 4, chapter 2). SOC values for cropland are reported in the table 6.20, according to the different management practices considered and disaggregated by region.
C emissions [kt C] due to change in carbon stocks in living biomass and soils in land converted to cropland are reported in Table 6.22.

[39] FAOSTAT database: http://faostat3.fao.org/faostat-gateway/go/to/download/G1/GV/E
[40] FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.
[41] EC-JRC. 2003. Global Land Cover 2000 database. Available at http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

Table 6.22 Change in carbon stock in living biomass and soil in land converted to cropland

	Conversion Area		Carbon stock	
	annual change	*20 years change*	*Living biomass*	*Soils*
year	*kha*	*kha*	*kt C*	*kt C*
1990	0	136.1	0	-233.7
1991	16.8	152.9	-12.9	-261.3
1992	16.8	169.7	-12.9	-286.7
1993	16.8	186.5	-12.9	-315.8
1994	16.8	203.2	-12.9	-341.5
1995	16.8	220.0	-12.9	-367.0
1996	0	192.8	0	-319.8
1997	0	165.5	0	-273.0
1998	0	138.3	0	-224.9
1999	0	111.1	0	-177.7
2000	0	83.8	0	-133.2
2001	0	83.8	0	-133.2
2002	0	83.8	0	-133.2
2003	0	83.8	0	-133.2
2004	0	83.8	0	-133.2
2005	0	83.8	0	-133.2
2006	0	83.8	0	-133.2
2007	0	83.8	0	-133.2
2008	0	83.8	0	-133.2
2009	0	83.8	0	-133.2
2010	0	83.8	0	-133.2
2011	0	67.1	0	-105.7
2012	0	50.3	0	-80.3
2013	0	33.5	0	-51.2
2014	0	16.8	0	-25.5
2015	0	0	0	0
2016	39.7	39.7	-30.4	-63.3
2017	39.7	79.3	-30.4	-130.0
2018	39.7	119.0	-30.4	-191.9
2019	39.7	158.6	-30.4	-254.2
2020	39.7	198.3	-30.4	-46.9

6.2.5 Uncertainty and time series consistency

Uncertainty estimates for the period 1990–2020 have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). Input uncertainties dealing with activity data and emission factors have been assessed on the basis of the information provided in the 2006 IPCC Guidelines (IPCC, 2006). For 2020, the uncertainty related to the living biomass and soils pools have been estimated equal to 15.6% and 8.4%, respectively. The uncertainty related to the cropland category is equal to 34.9%, for 2020.

A Monte Carlo analysis has been carried out to assess uncertainty for cropland category (considering both cropland remaining cropland and land converted to cropland). For cropland remaining cropland, an asymmetrical probability density distribution resulted from the analysis, showing uncertainties values equal to -108.5% and 210.2%, taking into account all the carbon pools estimated. As for land converted to cropland, an asymmetrical probability density distribution resulted from the analysis, showing uncertainties values equal to -408.2% and 178.5%. Normal distributions have been assumed for most of the parameters. A more detailed description of the results is reported in Annex 1.

6.2.6 Category-specific QA/QC and verification

Category-specific quality control activities includes comparison with alternative data sources (FAO database[42], ISTAT data[43]). Land use matrices have been accurately checked and cross-checked to ensure that data were properly reported. Several QA activities are carried out in the different phases of the inventory process. All the LULUCF categories have been embedded in the overall QA/QC-system of the Italian GHG inventory.

6.2.7 Category-specific recalculations

Recalculations occur in the 2022 submission, comparing to the 2021 submission, as shown in tables 6.23 and 6.24, for living biomass and mineral soils, affecting both cropland remaining cropland and land converted to cropland. For living biomass, the recalculation is due to an update of the activity data and the consequent smoothing process affecting the 2016-2019 period. Additional information on the smoothing process is reported in the section 6.1. For mineral soils, an error, related to the soil carbon stock estimation for the whole time series, was detected in previous submission and fixed.

Table 6.23 Recalculation in cropland category, for carbon pool

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission					*kt C*					
- living biomass	-317	-186	-609	-178	-165	-582	-178	-181	-225	-113
- mineral soils	94	246	987	922	627	643	757	697	615	497
2021 submission					*kt C*					
- living biomass	-317	-186	-609	-178	-165	-582	-261	-303	-345	-233
- mineral soils	-86	112	880	849	627	643	752	688	602	486
recalculation					*%*					
- living biomass	0.0	0.0	0.0	0.0	0.0	0.0	-46.4	-67.8	-53.7	-106.0
- mineral soils	191.8	54.2	10.8	7.9	0.0	0.0	0.6	1.2	2.1	2.1

Table 6.24 Recalculation in cropland category, for CL-CL and L-CL

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission					*CO_2 eq. - kt*					
Cropland	**1,631**	**570**	**-586**	**-1,937**	**-909**	**572**	**-1,331**	**-1,057**	**-640**	**-607**
CL-CL	774	-823	-1,075	-2,426	-1,398	572	-1,674	-1,645	-1,456	-1,651
L-CL	857	1,393	489	489	489	NO	344	588	815	1,044
2021 submission										
Cropland	**2,293**	**1,058**	**-196**	**-1,668**	**-909**	**572**	**-1,010**	**-576**	**-158**	**-140**
CL-CL	774	-823	-1,075	-2,426	-1,398	572	-1,369	-1,194	-1,019	-1,247
L-CL	1,519	1,881	879	757	489	NO	359	618	861	1,107
recalculation					*%*					
Cropland	**-40.6**	**-85.7**	**66.6**	**13.9**	**0.0**	**0.0**	**24.1**	**45.5**	**75.3**	**77.0**
CL-CL	0.0	0.0	0.0	0.0	0.0	0.0	18.2	27.5	30.0	24.5
L-CL	-77.2	-35.0	-80.0	-55.0	0.0	-	-4.5	-5.0	-5.6	-6.1

6.2.8 Category-specific planned improvements

No improvements are planned for the next annual submission.

[42] FAO, 2005. FAOSTAT, http://faostat3.fao.org/home/E
[43] ISTAT, several years [a], [b], [c]

6.3 Grassland (4C)

6.3.1 Description

Under this category, CO_2 emissions from living biomass, and soil organic matter, in grassland remaining grassland and land converted to grassland have been reported.
Grassland category is responsible for 7.207 kt of CO_2 net removals in 2020 sharing 16.9% of total CO_2 eq. LULUCF net removals; in particular, the living biomass emissions represent 10.2% of the grassland CO_2 fluxes and the removals from soil organic matter 88.6%, while the remaining 1.2% is represented by the dead organic matter pool.
CO_2 emissions and removals from grassland remaining grassland and land converted to grassland are key categories in level and trend assessment both with Approach 1 and Approach 2.

6.3.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Information on the land representation is reported in section 6.1. For the grassland category, as already discussed, it is assumed that the only conversion occurring is from cropland to grassland. The IPCC default land use transition period of 20 years is applied.

6.3.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

Grassland includes all grazing land, natural grassland and other wooded land that do not fulfil the forest definition (as shrublands).
Due to the technical characteristics of the IUTI assessment (i.e. classification of orthophotos), it was not possible clearly distinguish among some subcategories in *cropland* and non-woody *grassland* categories (e.g. annual crops, annual pastures versus grazing land). Therefore, although the total aggregated area of the 2 categories *cropland* and *grassland* together is derived from the IUTI data, the area of each of their subcategories is disaggregated using as proxies the national statistics (ISTAT, [b], [c]) on grazing lands, forage crops, permanent pastures, natural grassland and lands once used for agriculture purposes, but in fact set-aside since 1970. However, the area of the subcategory other wooded land, i.e., shrublands, has been derived from the NFIs (CRA-MPF, NFI1985, NFI2005 and the NFI2015), on the basis of IUTI data (par. 6.1), through linear interpolations for the periods 1985-2005, 2005-2012 and linear extrapolation for the period 2012-2020. The NFI2015 has completed its second phase, delivering on-field measurements on the plots of the sampling grid; 2015 area data of "Forest" and of "other wooded land" have been therefore modified accordingly, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated).

6.3.4 Methodological issues

Grassland remaining Grassland

Grazing land
This land mostly includes annual biomass so that according to IPCC Tier 1 methodological approach gain and losses in the biomass and DOM and pools are assumed at long term equilibrium, so no net C stock changes are estimated.
For mineral soils, the estimation method is based on changes in SOC stocks over a finite period following changes in management that impact soil organic C. According to the 2006 IPCC Guidelines (IPCC, 2006), the change in mineral SOC stocks (vol. 4, chapter 2, eq. 2.25) is the result of a change in management practices in a unit of land across time. The SOC stock changes have been estimated taking into account natural (unmanaged) grazing land and managed grazing land subcategories. The latter are reported in the table 6.25.

Table 6.25 Grazing land management practices and data sources

Management practices	Definition	CAP regulations	Data source
Managed grazing land (ordinary)	Renewal and/or thickening of crops; connection to zootechnics	National decree on cross compliance implementation n. 30125/2009 and subsequent revisions	ISTAT
organic grazing land	Renewal and/or thickening of crops; connection to zootechnics	RDPs 2000-2006: Reg. (EC) n. 1257/1999; RDPs 2007 - 2013: Reg. (EC) n. 1998/2005 and Reg. (EC) n. 74/2009; Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008; Reg. (EC) n. 1804/2007	National Information system on organic agriculture (SINAB)

The annual areas subject to the abovementioned management practices, at regional level, have been estimated, considering the transition to and from different management practices (i.e., grazing land to organic grazing land and vice versa). Changes in organic carbon stocks in mineral soils has been calculated by applying the equation 2.25 of the IPCC, 2006 (vol. 4, chapter 2). The IPCC default transition period, i.e., 20 years, has been considered.

The SOC_{ref} classification of the soils is based on the default reference SOC stocks for mineral soils (tC/ha in 0-30 cm) provided in table 2.3 of IPCC 2006. The identification of country specific SOC_{ref} have been performed using a combination of the following map layers:

- IPCC climate zones (JRC) - http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/
- Corine Land cover 2006 (Grassland: legend codes: 2.3 ad 3.2) - http://sia.eionet.europa.eu/CLC2006
- Soil map of Italy- (reclassified according to the main groups of soil types as in table 2.3) -Costantini E.A.C., L'Abate G., Barbetti R., Fantappiè M., Lorenzetti R., Magini S. (2013) Carta dei suoli d'Italia, scala 1:1.000.000 - http://www.soilmaps.it/
- Map of Italy with administrative boundaries.

Overlapping the abovementioned layers, the Italian soils have been classified according to the IPCC soil classes (table 2.3, vol. 4, chapter 2 of the 2006 IPCC Guidelines), and their related climate zones as percentage in each region. According to the thereby defined distribution of the soil types and climate zones in each Italian region, it was possible to define the SOC_{ref}. The stock change factors (F_{LU}, F_{MG}, F_I) adapted to the national circumstances, have been derived by the default values provided in table 6.2 of the 2006 IPCC Guidelines (vol.4, chapter 6). The F factors considered are reported in the following table 6.26.

Table 6.26 Stock change factors for grazing land subcategories

Grazing land subcategory	F_{LU}		F_{MG}		F_I	
	Moist	*Dry*	*Moist*	*Dry*	*Moist*	*Dry*
Ordinary management	1	1	1	1	1.11	1.11
Organic management	1	1	1.14	1.14	1.11	1.11
Natural (unmanaged)*	1	1	0.95	0.95	1.11	1.11

*** The same factors of natural (unmanaged) grazing land subcategory are also used to estimate other wooded land SOC stock (see next section)**

The SOC stocks per hectare in mineral soil, calculated on the basis of the previously described procedure, are shown in the table 6.27, per region and per management practices. Estimates of SOC stock changes in grazing land are reported in the table 6.28.

Table 6.27 SOC stocks on hectares basis per region and management practice

Region	grazing land		
	Ordinary management *SOC stock (t C ha^{-1})*	Organic management *SOC stock (t C ha^{-1})*	Natural (unmanaged)* *SOC stock (t C ha^{-1})*
Piemonte	91.78	104.62	78.55
Valle D'Aosta	77.1	87.9	65.99
Liguria	92.7	105.68	79.34
Lombardia	79.93	91.13	68.41
Trentino – Alto Adige	78.51	89.5	67.19
Veneto	101.54	115.76	86.91
Friuli - Venezia Giulia	99.93	113.92	85.52
Emilia - Romagna	91.11	103.87	77.98
Toscana	62.24	70.95	53.27

Region	grazing land		
	Ordinary management *SOC stock (t C ha^{-1})*	Organic management *SOC stock (t C ha^{-1})*	Natural (unmanaged)* *SOC stock (t C ha^{-1})*
Umbria	91.28	104.06	78.12
Marche	91	103.74	77.88
Lazio	88.98	101.43	76.15
Abruzzo	99.01	112.87	84.74
Molise	75.28	85.82	64.43
Campania	64.66	73.72	55.34
Puglia	42.03	47.91	35.97
Basilicata	60.13	68.55	51.46
Calabria	65.84	75.05	56.35
Sicilia	46.5	53.01	39.80
Sardegna	56.91	64.88	48.71

*** The same SOC stocks on hectares basis of natural (unmanaged) grazing land subcategory are estimated for other wooded land (see next section)**

Table 6.28 SOC stock changes in in mineral soil for grazing land

	area	net change in C stock
	kha	*kt C*
1990	7,033	-31.6
1991	6,905	36.2
1992	6,777	116.7
1993	6,649	177.1
1994	6,521	236.2
1995	6,394	278.4
1996	6,303	296.5
1997	6,213	344.7
1998	6,123	351.8
1999	6,032	336.1
2000	5,942	345.7
2001	5,910	389.5
2002	5,878	398.8
2003	5,846	396.2
2004	5,814	415.6
2005	5,780	428.6
2006	5,711	424.0
2007	5,642	406.7
2008	5,573	357.1
2009	5,505	428.3
2010	5,436	493.8
2011	5,367	394.4
2012	5,299	272.9
2013	5,230	209.8
2014	5,161	322.8
2015	5,092	230.5
2016	5,030	254.5
2017	4,968	147.9
2018	4,906	156.5
2019	4,844	174.5
2020	4,782	167.2

CO_2 emissions from drainage of organic soils in grassland remaining grassland have been estimated, using default emission factor for warm temperate climate zone from Table 6.3 of the 2006 IPCC Guidelines (vol.4, chapter 6): 2.5 t C ha^{-1} y^{-1}. The area of organic soils is taken from the FAOSTAT[44] database that overlaps:

- the map of Histosols classes in the *Harmonized World Soil Database*[45], and
- the grassland area in the global land cover dataset, GLC2000[46].

Other wooded land

Other wooded land includes all woody vegetation types that do not fit the forest definition. as, for example the "macchia mediterranea" (Italian translation for "Mediterranean maquis"). Other wooded lands are considered in the NFIs although they do not meet the forest minimum height threshold; this subcategory is here defined as "shrublands". In this land, the total biomass changes (aboveground and belowground) are estimated by the *For-est* model at regional scale (NUTS2). A detailed description of the model is reported in Annex 14.
In table 6.29, the biomass expansion factor (BEF) to expand growing stock volume to aboveground shrub volume, the wood basic density (WBD) conversion factor to convert volume in mass of dry matter, the root/shoot ratio (R) to estimate the belowground biomass and the carbon fraction (CF) to convert dry matter are reported.

Table 6.29 Expansion and Conversion Factors for shrublands

Inventory typology	BEF *aboveground biomass / growing stock*	WBD *dry weight t d.m./ fresh volume m^3*	R *root to shoot ratio*	CF *carbon stock t C/ biomass t d.m.*
shrublands	1.49	0.63	0.62	0.47

The DOM pools have been estimated using coefficient values and assuming a constant, linear, accumulation rate of both dead wood and litter across the conversion time till the coefficient value is achieved when the land transfers to the category grassland remaining grassland. In practice, in each conversion year 1/20 of the dead wood mass coefficient and of the litter mass coefficient t are reported as net CO_2 removals.
Both, the dead wood and the litter mass coefficient, see table 6.30, have been estimated from data taken for the Italian national forest inventory, in 2008 and 2009 across the country from the plots of the national forest inventory network (http://www.sian.it/inventarioforestale/jsp/necromassa.jsp). The mass (wet matter) collected on the ground in those plots has been converted in dry matter using basic densities appositely calculated in a specific study (Di Cosmo et al., 2013). The data collected, aggregated at regional level, are accessible at the NFI website: http://www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp.
The definition of the deadwood pool, coherent with the definition adopted by the NFI, is "*All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, stumps larger than or equal to 10 cm in diameter and standing trees with DBH > 4,5 cm*". In Table 6.30 dead wood and litter coefficients are reported.

Table 6.30 Dead wood and litter coefficients [live/dead ratio]

Inventory typology	dead wood *t C ha^{-1}*	litter *t C ha^{-1}*
Shrublands	1.510	1.990

As for soils pool, following the ERT recommendation, Italy has decided to apply the IPCC Tier1, assuming that, the carbon stock in soil organic matter, for other wooded land, does not change. Land conversions from natural (unmanaged) grazing land to other wooded land are possible because of land abandonment and woody encroachment. However, for these two subcategories of grassland, the same SOC stocks are estimated on the basis of the factors of table 6.2 of the 2006 IPCC Guidelines (vol.4, chapter 6) as shown in table 6.26 and 6.27. Therefore, carbon stock changes in soils pool, for other wooded land in grassland remaining grassland, have been not reported.

[44] FAOSTAT database: http://faostat3.fao.org/faostat-gateway/go/to/download/G1/GV/E
[45] FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.
[46] EC-JRC. 2003. Global Land Cover 2000 database. Available at http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

In figure 6.9, other wooded land areas and net changes in carbon stock, for the different pools, are reported, for the period 1990-2020.

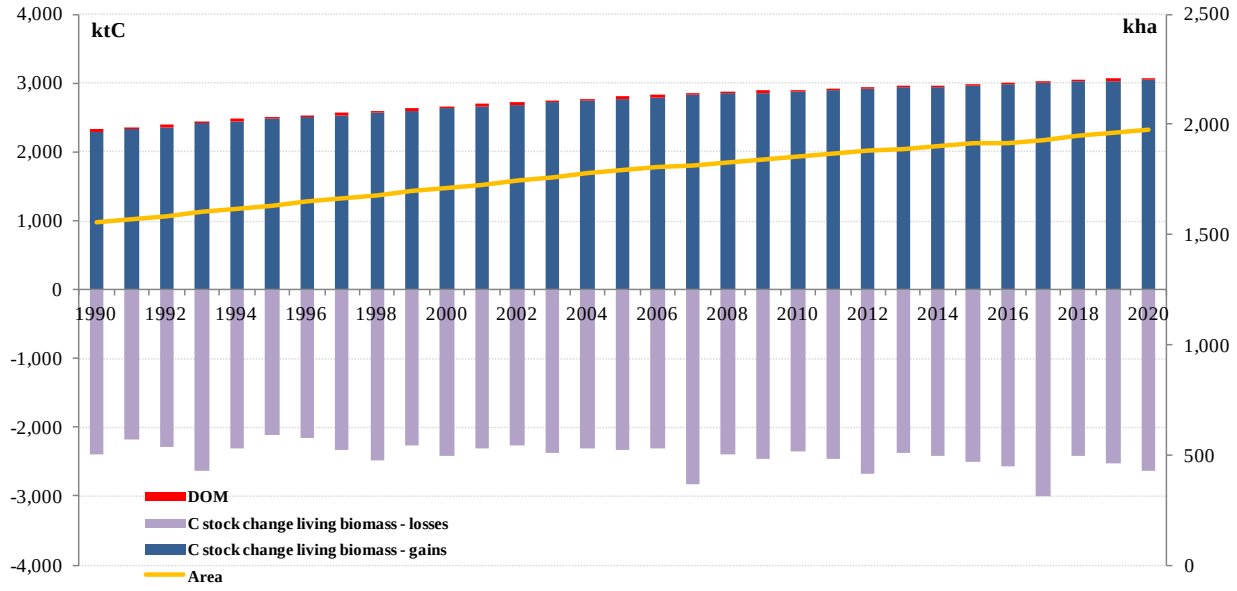


Figure 6.9 Other wooded land areas and net changes in carbon stock, for the different pools

Land converted to Grassland

In accordance with the IPCC methodology, estimates of carbon stock change in living biomass and in SOM in mineral soils have been provided. Italy applies a 20-year conversion period and an approach 2 for land representation, so that in any inventory year the area reported under this category is the cumulated area of all conversions occurred in that year plus the area converted in the 19 previous years. As a result of conversion to grassland, it is assumed that the dominant vegetation is removed entirely, after which some type of grass is planted or otherwise established; alternatively, grassland can result from the abandonment of the preceding land use, and the area is taken over by grassland. The Tier 1 has been followed, assuming that carbon stocks in biomass immediately after the conversion are equal to 0 t C ha^{-1}. The 2006 IPCC Guidelines equation 2.16 (vol. 4, chapter 2) has been used to estimate the change in carbon stocks, resulting from the land use change. Conversion from cropland to grassland has occurred, including annual crops converted to grazing land and woody crops converted to other wooded land. For the annual crops converted to natural (unmanaged) grazing land and for woody crops converted to other wooded land, it has been assumed that an abrupt transition has not occurred (i.e., change is not deliberate and therefore is not associated with land preparation operations like clearing and burning). For annual crops converted to managed grazing land, the default biomass carbon stock has been used, i.e. 4.7 t C ha^{-1}, as supplied by the 2006 IPCC Guidelines (vol. 4, chapter 6, par. 6.3.1.2). For other land uses converted to grassland, the used default biomass carbon stock is equal to 6.1 t d.m. ha^{-1}, as supplied by Table 6.4 of the 2006 IPCC Guidelines (vol. 4, chapter 6) for warm temperate – dry. The total C emissions [kt C] due to change in carbon stocks in living biomass in land converted to grassland are reported in Table 6.31.

Table 6.31 Change in carbon stock in living biomass in land converted to grassland

	Conversion Area		**ΔC**
	annual change	*20 years change*	
year	*kha*	*kha*	*kt C*
1990	0	325.0	0
1991	0	318.5	0
1992	0	312.0	0
1993	0	305.5	0
1994	0	299.0	0
1995	0	292.5	0
1996	60	352.8	134.8
1997	60	413.1	154.5
1998	60	473.5	166.6

	Conversion Area		ΔC
	annual change	*20 years change*	
year	*kha*	*kha*	*kt C*
1999	60	533.8	116.7
2000	60	594.1	135.8
2001	94	630.1	224.2
2002	94	666.1	160.5
2003	94	702.1	177.4
2004	94	738.0	216.5
2005	97	777.0	188.0
2006	85	861.9	92.0
2007	85	946.8	119.0
2008	85	1,031.7	203.7
2009	178	1,209.6	328.6
2010	178	1,387.4	263.2
2011	44	1,431.5	120.7
2012	44	1,475.7	123.0
2013	44	1,519.8	115.6
2014	44	1,563.9	61.7
2015	44	1,608.0	124.6
2016	0	1,547.7	0
2017	0	1,487.3	0
2018	0	1,427.0	0
2019	0	1,366.7	0
2020	0	1,306.4	0

Changes in SOC stocks in mineral soils in land converted to grassland have been estimated applying IPCC equation 2.25 (vol. 4, chapter 2). SOC stocks for the different subcategories of grassland are reported in the table 6.27, according to the different management practices considered and broken down by region. C emissions [kt C] due to SOC change in mineral in land converted to grassland, are summarised in table 6.32.

Table 6.32 Change in carbon stock in soils

	Conversion Area		Carbon stock
year	*annual change*	*20 years change*	
	kha	*kha*	*kt C*
1990	0	325.0	321.7
1991	0	318.5	313.0
1992	0	312.0	304.2
1993	0	305.5	295.4
1994	0	299.0	286.7
1995	0	292.5	277.9
1996	60.3	352.8	347.1
1997	60.3	413.1	409.9
1998	60.3	473.5	476.1
1999	60.3	533.8	544.8
2000	60.3	594.1	611.3
2001	94.5	630.1	679.4
2002	94.5	666.1	754.6
2003	94.5	702.1	831.5
2004	94.5	738.0	898.9
2005	97.5	777.0	978.7
2006	84.9	861.9	1,090.8
2007	84.9	946.8	1,194.2
2008	84.9	1,031.7	1,295.3
2009	177.9	1,209.6	1,521.7
2010	177.9	1,387.4	1,765.0
2011	44.1	1,431.5	1,799.2
2012	44.1	1,475.7	1,825.3

	Conversion Area		Carbon stock
year	*annual change*	*20 years change*	
	kha	*kha*	*kt C*
2013	44.1	1,519.8	1,860.7
2014	44.1	1,563.9	1,907.1
2015	44.1	1,608.0	1,941.3
2016	0	1,547.7	1,872.1
2017	0	1,487.3	1,809.4
2018	0	1,427.0	1,743.2
2019	0	1,366.7	1,674.5
2020	0	1,306.4	1,608.0

6.3.5 Uncertainty and time series consistency

For the period 1990–2020, the uncertainty estimates have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). Input uncertainties dealing with activity data and emission factors have been assessed based on the information provided in the 2006 IPCC Guidelines (IPCC, 2006). In 2020, the uncertainty related to the living biomass and soils pools have been estimated equal to 42.6% and 71.0%, respectively. The uncertainty related to the grassland category is equal to 57.7%, for 2020.
A Monte Carlo analysis has been carried out to assess uncertainty for grassland category (considering both Grassland remaining grassland and land converted to grassland). For grassland remaining grassland, an asymmetrical probability density distribution resulted from the analysis, showing uncertainties values equal to -67.7% and 75.0%. An asymmetrical probability density distribution resulted from the analysis for the subcategory land converted to grassland too. Its values are equal to -119.3% and 194.5%. Normal distributions have been assumed for most of the parameters; whenever assumptions or constraints on variables were known this information has been appropriately reflected on the choice of type and shape of distributions. A more detailed description of the results is reported in Annex 1.

6.3.6 Category-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the sum of sub-categories. Where possible, activity data comparison among different sources (FAO database[47], ISTAT data[48]) has been made. Data entries have been checked several times during the compilation of the inventory; attention has been focussed on the categories showing significant changes between two years in succession. Land use matrices have been accurately checked and cross-checked to ensure that data were properly reported. Several QA activities are carried out in the different phases of the inventory process. The applied methodologies have been presented and discussed during several national workshop and expert meetings, collecting findings and comments to be incorporated in the estimation process. All the LULUCF categories have been embedded in the overall QA/QC-system of the Italian GHG inventory.

6.3.7 Category-specific recalculations

The recalculation, as shown in table 6.33, occurs in the 2022 submission, comparing to the 2021 submission, for the grassland remaining grassland (+18.6% for the 2020 reporting year) and land converted to grassland 3.9% for the 2020 reporting year). The recalculation is due to the update of the activity data as resulting from the NFI outcomes (NFI2015): 2015 area data “other wooded land”, reported under grassland category, have been therefore modified accordingly, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated). In addition, an error, related to the soil carbon stock estimation for the land converted to grassland, for the whole time series, was detected in previous submission and fixed.

[47] FAO, 2005. FAOSTAT, http://faostat3.fao.org/home/E
[48] ISTAT, several years [a], [b], [c]

Table 6.33 Recalculation in grassland category

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission					*CO_2 eq. - kt*					
Grassland	**4,179**	**-2,155**	**-1,977**	**-6,364**	**-9,537**	**-9,535**	**-8,540**	**-4,628**	**-9,003**	**-8,166**
GL-GL	5,358	-1,136	762	-2,086	-2,101	-1,960	-1,676	2,007	-2,611	-2,026
L-GL	-1,180	-1,019	-2,739	-4,278	-7,437	-7,575	-6,864	-6,634	-6,392	-6,140
2021 submission					*CO_2 eq. - kt*					
Grassland	**3,605**	**-2,411**	**-2,212**	**-6,460**	**-9,521**	**-9,498**	**-8,497**	**-4,589**	**-9,010**	**-8,264**
GL-GL	5,358	-1,136	762	-2,086	-2,084	-1,923	-1,633	2,046	-2,619	-2,124
L-GL	-1,754	-1,275	-2,974	-4,375	-7,437	-7,575	-6,864	-6,634	-6,392	-6,140
recalculation					*%*					
Grassland	**13.7**	**-11.9**	**-11.9**	**-1.5**	**0.2**	**0.4**	**0.5**	**0.8**	**-0.1**	**-1.2**
GL-GL	0.0	0.0	0.0	0.0	0.8	1.9	2.6	-1.9	-0.3	-4.8
L-GL	-48.7	-25.1	-8.6	-2.3	0.0	0.0	0.0	0.0	0.0	0.0

6.3.8 Category-specific planned improvements

No improvements are planned for the next annual submission.

6.4 Wetlands (4D)

6.4.1 Description

Under this category, activity data from wetlands remaining wetlands are reported. Neither wetlands remaining wetlands nor land converted to wetlands are as a key category.

6.4.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Wetlands area have been estimated within the national land representation applying the methodology described in section 6.1. During the period 1990-2020 conversions of annual cropland and natural grassland to wetlands have occurred.

6.4.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

Wetlands includes lands covered or saturated by water, for all or part of the year (MAMB, 1992). Reservoirs or water bodies regulated by human activities have not been considered.

6.4.4 Methodological issues

Italy applies a 20-year conversion period and an approach 2 for land representation, so that in any inventory year the area reported under this category is the cumulated area of all conversions occurred in that year plus the area converted in the 19 previous years.

Only CO_2 emissions from flooded lands have been estimated. In wetlands remaining wetlands no activities are implemented. According to the equation 7.10 of the 2006 IPCC guidelines (vol. 4, chapter 7) the biomass stock after flooding is assumed to be zero, while for the biomass immediately before flooding default values reported in the 2006 IPCC guidelines have been used. In particular, for grassland (B_{before}) the value reported in table 6.4 (vol. 4, chapter 6) for warm temperate dry climate, 6.1 t d.m. ha^{-1}, has been used; while for cropland (B_{before}) the value equal to 10 t C ha^{-1} has been used (vol. 4, chapter 6) for cropland containing annual crops. The carbon fraction of 4.7 t of carbon ha^{-1} has been used.

C stocks [kt C] in living biomass are reported in table 6.34 and 6.35, for cropland converted to wetlands and grassland converted to wetlands, respectively.

Table 6.34 Change in carbon stocks in living biomass in cropland converted to wetlands

	annual change	20 years change	B after	B before	ΔC *converted*
	kha	*kha*	*t d.m. ha^{-1}*	*t d.m. ha^{-1}*	*kt C*
1990	0.00	0.00	0	10.0	0.00
1991	0.00	0.00	0	10.0	0.00
1992	0.00	0.00	0	10.0	0.00
1993	0.00	0.00	0	10.0	0.00
1994	0.00	0.00	0	10.0	0.00
1995	0.00	0.00	0	10.0	0.00
1996	0.47	0.47	0	10.0	-2.23
1997	0.47	0.95	0	10.0	-2.23
1998	0.47	1.42	0	10.0	-2.23
1999	0.47	1.89	0	10.0	-2.23
2000	0.47	2.37	0	10.0	-2.23
2001	0.47	2.84	0	10.0	-2.23
2002	0.47	3.32	0	10.0	-2.23
2003	0.47	3.79	0	10.0	-2.23
2004	0.47	4.26	0	10.0	-2.23
2005	0.47	4.74	0	10.0	-2.23
2006	0.47	5.21	0	10.0	-2.23
2007	0.47	5.68	0	10.0	-2.23
2008	0.47	6.16	0	10.0	-2.23
2009	7.52	13.68	0	10.0	-35.34
2010	7.52	21.19	0	10.0	-35.34
2011	7.52	28.71	0	10.0	-35.34
2012	7.52	36.23	0	10.0	-35.34
2013	7.52	43.75	0	10.0	-35.34
2014	7.52	51.27	0	10.0	-35.34
2015	7.52	58.79	0	10.0	-35.34
2016	0.00	58.31	0	10.0	0.00
2017	0.00	57.84	0	10.0	0.00
2018	0.00	57.37	0	10.0	0.00
2019	0.00	56.89	0	10.0	0.00
2020	0.00	56.42	0	10.0	0.00

In table 6.35 C stocks [kt C] related to change in carbon stocks in living biomass in grassland converted to wetlands are reported.

Table 6.35 Change in carbon stocks in living biomass in grassland converted to wetlands

	annual change	20 years change	B after	B before	ΔC *converted*
	kha	*kha*	*t d.m. ha-1*	*t d.m. ha-1*	*kt C*
1990	0.00	0.00	0	6.1	0.00
1991	0.47	0.47	0	6.1	-1.36
1992	0.47	0.95	0	6.1	-1.36
1993	0.47	1.42	0	6.1	-1.36
1994	0.47	1.89	0	6.1	-1.36
1995	0.47	2.37	0	6.1	-1.36
1996	0.00	2.37	0	6.1	0.00
1997	0.00	2.37	0	6.1	0.00

	annual change	20 years change	B after	B before	ΔC *converted*
	kha	*kha*	*t d.m. ha-1*	*t d.m. ha-1*	*kt C*
1998	0.00	2.37	0	6.1	0.00
1999	0.00	2.37	0	6.1	0.00
2000	0.00	2.37	0	6.1	0.00
2001	0.00	2.37	0	6.1	0.00
2002	0.00	2.37	0	6.1	0.00
2003	0.00	2.37	0	6.1	0.00
2004	0.00	2.37	0	6.1	0.00
2005	0.00	2.37	0	6.1	0.00
2006	0.00	2.37	0	6.1	0.00
2007	0.00	2.37	0	6.1	0.00
2008	0.00	2.37	0	6.1	0.00
2009	0.00	2.37	0	6.1	0.00
2010	0.00	2.37	0	6.1	0.00
2011	0.00	1.89	0	6.1	0.00
2012	0.00	1.42	0	6.1	0.00
2013	0.00	0.95	0	6.1	0.00
2014	0.00	0.47	0	6.1	0.00
2015	0.00	0.00	0	6.1	0.00
2016	3.01	3.01	0	6.1	-8.62
2017	3.01	6.01	0	6.1	-8.62
2018	3.01	9.02	0	6.1	-8.62
2019	3.01	12.03	0	6.1	-8.62
2020	3.01	15.04	0	6.1	-8.62

6.4.5 Uncertainty and time series consistency

Uncertainty estimates for the period 1990–2020 have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). Input uncertainties for activity data and emission factors have been assessed on the basis of the information provided in the 2006 IPCC Guidelines (IPCC, 2006).

6.4.6 Category-specific recalculations

A recalculation of 25% occurs in the 2022 submission, comparing to the 2021 submission, for the years 2016-2019. The recalculation is due to an update of the activity data and the consequent smoothing process affecting the 2016-2019 period. Additional information on the smoothing process is reported in the section 6.1.

Table 6.36 Recalculation in Wetlands category

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	*CO_2 eq. - kt*									
Wetlands	NE,NO	5.0	8.2	8.2	129.6	129.6	31.6	31.6	31.6	31.6
2021 submission	*CO_2 eq. - kt*									
Wetlands	NE,NO	5.0	8.2	8.2	129.6	129.6	39.5	39.5	39.5	39.5
recalculation	*%*									
Wetlands	-	-	-	-	-	-	-25.0	-25.0	-25.0	-25.0

6.4.7 Category-specific planned improvements

No improvements are planned for the next submission.

6.5 Settlements (4E)

6.5.1 Description

Under this category, CO_2 emissions, from living biomass and soil, from land converted to settlements only have been reported. In 2020, settlements emissions share 11.9% of absolute CO_2 eq. LULUCF emissions and removals. CO_2 emissions and removals from land converted to settlements is a key category, in the level and trend assessment, with Approach 1 and Approach 2.

6.5.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Information on the land representation is reported in section 6.1.

6.5.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

All artificial surfaces, transportation infrastructures (urban and rural), power lines and human settlements of any size, including parks, have been included in this category.

6.5.4 Methodological issues

Settlements remaining Settlements

Following the 2006 IPCC Tier 1 approach no C stock changes have been estimated for any of the C pools.

Land converted to Settlements

The 2006 IPCC Guidelines equations 2.15 and 2.16 (Vol. 4, chapter 2) have been used to estimate changes in biomass and DOM carbon stocks. According to IPCC Tier 1, biomass and DOM stocks in the settlement category are assumed to be 0, which means that a complete loss of biomass and DOM stocks due to the land use change.

For the land converted to settlements, the 20-years transition period has been applied to determine the area in conversion. However, due to the characteristics of the final land use category (settlements), it is assumed that, for each carbon pool, all C stocks of the area subjected to an annual conversion are completely lost in the same conversion year, while the related CO_2 emissions are assigned to the first year the conversion has occurred.

As reported in table 6.4, in the period 1990-2020 conversions to settlements have occurred from the following categories: forest land, grassland, cropland and other land.

Carbon stock changes in forest land converted to settlements have been estimated for living biomass, dead organic matter and mineral soils, using forest land carbon stocks estimated, at regional level, by the *For-est* model described in paragraph 6.2.4, 9.3.1.2 and in Annex 14.

Concerning forest soils, the SOC stocks reported in the table 6.37 have been considered; the time range reported in the first column of the abovementioned table provides the time references for the SOC stocks' use. A detailed description of the methodology used in the estimation process of soils pool, and consequently of the SOC stocks, is provided in par. 9.3.1.2, related to the KP-LULUCF.

Table 6.37 Soil organic carbon (SOC) stocks for *forest land*

	SOC stock
years	*t C ha^{-1}*
1985-1994	79.81
1995-1999	80.17
2000-2004	80.57
2005-2009	81.10
2010-2014	81.64
2015-2020	82.33

In Table 6.38, C stocks changes [kt C] in living biomass, dead organic matter and soils in forest land converted to settlements are reported.

Table 6.38 Change in carbon stocks in forest land converted to settlements

	Forest land to settlements				***Total Carbon stock***
Year	*conversion Area*	*living biomass*	*dead organic matter*	*soils*	
	kha	*kt C*	*kt C*	*kt C*	*kt C*
1990	0.72	-32.09	-3.06	-57.64	-92.79
1991	0.72	-32.38	-3.06	-57.64	-93.08
1992	0.72	-32.64	-3.06	-57.64	-93.34
1993	0.72	-32.66	-3.06	-57.64	-93.36
1994	0.72	-32.91	-3.05	-57.64	-93.61
1995	0.72	-33.24	-3.05	-57.90	-94.19
1996	0.72	-33.55	-3.05	-57.90	-94.51
1997	0.72	-33.70	-3.05	-57.90	-94.65
1998	0.72	-33.81	-3.05	-57.90	-94.76
1999	0.72	-34.02	-3.05	-57.90	-94.97
2000	0.72	-34.21	-3.04	-58.19	-95.45
2001	0.72	-34.51	-3.04	-58.19	-95.75
2002	0.72	-34.89	-3.04	-58.19	-96.12
2003	0.72	-35.13	-3.04	-58.19	-96.36
2004	0.72	-35.46	-3.04	-58.19	-96.69
2005	3.69	-183.12	-15.53	-299.62	-498.28
2006	3.69	-185.39	-15.52	-299.62	-500.53
2007	3.69	-186.00	-15.50	-299.62	-501.12
2008	3.69	-187.87	-15.48	-299.62	-502.97
2009	3.69	-189.95	-15.47	-299.62	-505.04
2010	3.69	-192.33	-15.45	-301.63	-509.41
2011	3.69	-194.28	-15.43	-301.63	-511.35
2012	3.69	-195.76	-15.42	-301.63	-512.81
2013	3.69	-198.15	-15.40	-301.63	-515.19
2014	3.69	-200.61	-15.39	-301.63	-517.63
2015	3.69	-203.14	-15.37	-304.17	-522.68
2016	3.69	-205.34	-15.36	-304.17	-524.87
2017	3.69	-206.06	-15.34	-304.17	-525.58
2018	3.69	-207.90	-15.32	-304.17	-527.40
2019	3.69	-210.09	-15.31	-304.17	-529.58
2020	3.69	-211.69	-15.30	-304.17	-531.16

For cropland converted to settlements, carbon stocks changes have been estimated, for annual or perennial crops biomass, using default factors shown in the following table 6.39 (IPCC, 2006, table 8.4, vol. 4, chapter 8). SOC value for cropland has been set to 56.7 tC/ha on the basis of reviewed references (par. 6.3.4).

Table 6.39 Stock change factors for cropland

	Biomass carbon stock
	t C ha^{-1}
Annual cropland	4.7
Perennial woody cropland	10

For grassland converted to settlements, changes in carbon stocks have been estimated for living biomass and for the soil pool. In table 6.40 C stocks changes [kt C] in living biomass in cropland and grassland converted to settlements are reported.

Table 6.40 Change in carbon stocks in living biomass in cropland and grassland converted to settlements

	cropland to settlements		**grassland to settlements**	
Year	*conversion area*	*carbon stock*	*conversion area*	*carbon stock*
	kha	*kt C*	*kha*	*kt C*
1990	25.2	-151.8	1.7	-5.0
1991	0	0	26.7	-76.6
1992	0	0	26.7	-76.6

	cropland to settlements		grassland to settlements	
Year	*conversion area*	*carbon stock*	*conversion area*	*carbon stock*
	kha	*kt C*	*kha*	*kt C*
1993	0	0	26.7	-76.6
1994	0	0	26.7	-76.6
1995	0	0	26.7	-76.6
1996	26.7	-161.3	0	0
1997	26.7	-161.2	0	0
1998	26.7	-161.1	0	0
1999	26.7	-161.0	0	0
2000	26.7	-161.0	0	0
2001	26.7	-161.3	0	0
2002	26.7	-161.6	0	0
2003	26.7	-162.0	0	0
2004	26.7	-162.4	0	0
2005	23.7	-144.6	0	0
2006	23.7	-145.0	0	0
2007	23.7	-145.4	0	0
2008	23.7	-145.8	0	0
2009	11.0	-67.8	0	0
2010	11.0	-68.1	0	0
2011	11.0	-68.0	0	0
2012	11.0	-67.8	0	0
2013	11.0	-67.7	0	0
2014	11.0	-67.6	0	0
2015	11.0	-67.4	0	0
2016	0	0	11.0	-31.5
2017	0	0	11.0	-31.5
2018	0	0	11.0	-31.5
2019	0	0	11.0	-31.5
2020	0	0	11.0	-31.5

In Table 6.41 SOC changes [kt C] in mineral soils in cropland and grassland converted to settlements are reported.

Table 6.41 Change in carbon stocks in soil in cropland and grassland converted to settlements

	cropland to settlements		grassland to settlements	
Year	*conversion area*	*carbon stock*	*conversion area*	*carbon stock*
	kha	*kt C*	*kha*	*kt C*
1990	25.2	-1426.1	1.7	-135.1
1991	0	0	26.7	-2085.2
1992	0	0	26.7	-2085.2
1993	0	0	26.7	-2085.2
1994	0	0	26.7	-2085.2
1995	0	0	26.7	-2085.2
1996	26.7	-1514.0	0	0
1997	26.7	-1514.0	0	0
1998	26.7	-1514.0	0	0
1999	26.7	-1514.0	0	0
2000	26.7	-1514.0	0	0
2001	26.7	-1514.0	0	0
2002	26.7	-1514.0	0	0
2003	26.7	-1514.0	0	0
2004	26.7	-1514.0	0	0
2005	23.7	-1345.5	0	0
2006	23.7	-1345.5	0	0
2007	23.7	-1345.5	0	0
2008	23.7	-1353.8	0	0
2009	11.0	-1156.2	0	0

Year	cropland to settlements		grassland to settlements	
	conversion area	*carbon stock*	*conversion area*	*carbon stock*
	kha	*kt C*	*kha*	*kt C*
2010	11.0	-622.5	0	0
2011	11.0	-622.5	0	0
2012	11.0	-622.5	0	0
2013	11.0	-622.5	0	0
2014	11.0	-622.5	0	0
2015	11.0	-622.5	0	0
2016	0	0	11.0	-857.3
2017	0	0	11.0	-857.3
2018	0	0	11.0	-857.3
2019	0	0	11.0	-857.3
2020	0	0	11.0	-857.3

Concerning other land converted to settlements, change in carbon stocks has been not estimated, in line with the 2006 IPCC Guidelines (IPCC, 2006) as other land does not contain any significant carbon stocks.

6.5.5 Uncertainty and time series consistency

Uncertainty estimates for the period 1990–2020 have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). Input uncertainties dealing with activity data and emission factors have been assessed on the basis of the information provided in the 2006 IPCC Guidelines (IPCC, 2006).
A Monte Carlo analysis has been carried out to assess uncertainty for settlements category, resulting in an asymmetrical probability density distribution, with uncertainties values equal to -100.3% and 49.2%. Normal distributions have been assumed for most of the parameters; whenever assumptions or constraints on variables were known this information has been appropriately reflected on the choice of type and shape of distributions. A more detailed description of the results is reported in Annex 1.

6.5.6 Category-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness in the sum of sub-categories; where possible, activity data comparison among different sources (FAO database[49], ISTAT data[50]) has been made. Data entries have been checked several times during the compilation of the inventory; particular attention has been focussed on the categories showing significant changes between two years in succession. Land use matrices have been accurately checked and cross-checked to ensure that data were properly reported. Several QA activities are carried out in the different phases of the inventory process. All the LULUCF categories have been embedded in the overall QA/QC-system of the Italian GHG inventory.

6.5.7 Category-specific recalculations

Slight recalculation (0.03% in 2019) occurs in 2022 submission compared to the 2021 one, due to the updated activity data.

6.5.8 Category -specific planned improvements

Urban tree formations will be probed for information, in order to estimate carbon stocks.

6.6 Other Land (4F)

Under this category, CO_2 emissions, from living biomass, dead organic matter and soils, from land converted in other land should be accounted for; no data is reported since the conversion to other land is not occurring.

[49] FAO, 2015. FAOSTAT, http://faostat3.fao.org/home/E
[50] ISTAT, several years [a], [b], [c]

6.7 Direct N_2O emissions from N inputs to managed soils (4(I))

N_2O emissions from N inputs to managed soils of cropland and grassland are reported in the agriculture sector; therefore, only N inputs to managed soils in forest land should be included in this section. All the related emissions are reported in the Agriculture sector, following the 2006 IPCC Guidelines (IPCC, 2006, par. 11.2.1.3, vol. 4, chapter 11) and coherently with the KP Supplement (IPCC, 2014, par. 2.4.4.2).

6.8 Emissions and removals from drainage and rewetting and other management of organic and mineral soils (4(II))

As regards N_2O emissions from N drainage of forest or wetlands soils no data have been reported, since no drainage is applied to forest or wetlands soils.

6.9 N_2O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils

6.9.1 Description

Under this category, direct N_2O emissions from N mineralization associated with loss of soil organic matter in mineral soils in land converted to cropland and to settlements are reported.

6.9.2 Methodological issues

N_2O emissions from mineralization of soil organic matter in mineral soils occur in land converted to cropland and land converted to settlements. The 2006 IPCC Guidelines eq. 11.1 and 11.8 (vol. 4, chapter 11) have been used to estimate the direct N_2O emissions. IPCC default values, from 2006 Guidelines have been used, namely 15 for the C/N ratio and 0.01 kg N_2O-N/kg N as EF.

In table 6.42 and table 6.43 N_2O emissions from land-use conversion to cropland and from land-use conversion to settlements are reported, respectively.

Table 6.42 N_2O emissions from land-use conversion to cropland

	Conversion area		Carbon stock change	F_{SOM}	$N_2O_{net\text{-}min}$ -N	N_2O emissions
	annual change	*20 yrs change*				
year	*kha*	*kha*	*kt C*	*kt N*	*kt N_2O-N*	*kt N_2O*
1990	0	136.1	233.7	15.6	0.16	0.24
1991	16.8	152.9	261.3	17.4	0.17	0.27
1992	16.8	169.7	286.7	19.1	0.19	0.30
1993	16.8	186.5	315.8	21.1	0.21	0.33
1994	16.8	203.2	341.5	22.8	0.23	0.36
1995	16.8	220.0	367.0	24.5	0.24	0.38
1996	0	192.8	319.8	21.3	0.21	0.34
1997	0	165.5	273.0	18.2	0.18	0.29
1998	0	138.3	224.9	15.0	0.15	0.24
1999	0	111.1	177.7	11.8	0.12	0.19
2000	0	83.8	133.2	8.9	0.09	0.14
2001	0	83.8	133.2	8.9	0.09	0.14
2002	0	83.8	133.2	8.9	0.09	0.14
2003	0	83.8	133.2	8.9	0.09	0.14
2004	0	83.8	133.2	8.9	0.09	0.14
2005	0	83.8	133.2	8.9	0.09	0.14
2006	0	83.8	133.2	8.9	0.09	0.14
2007	0	83.8	133.2	8.9	0.09	0.14
2008	0	83.8	133.2	8.9	0.09	0.14
2009	0	83.8	133.2	8.9	0.09	0.14
2010	0	83.8	133.2	8.9	0.09	0.14
2011	0	67.1	105.7	7.0	0.07	0.11
2012	0	50.3	80.3	5.4	0.05	0.08
2013	0	33.5	51.2	3.4	0.03	0.05
2014	0	16.8	25.5	1.7	0.02	0.03
2015	0	0.0	0.0	0.0	0.00	0.00
2016	38.9	39.7	63.3	4.2	0.04	0.07
2017	38.9	79.3	130.0	8.7	0.09	0.14
2018	38.9	119.0	191.9	12.8	0.13	0.20
2019	38.9	158.6	254.2	16.9	0.17	0.27
2020	38.9	198.3	46.9	3.1	0.03	0.05

Table 6.43 N_2O emissions from land-use conversion to settlements

	Conversion area		Carbon stock change	F_{SOM}	$N_2O_{net\text{-}min}$ -N	N_2O emissions
	annual change	*20 yrs change*				
year	*kha*	*kha*	*kt C*	*kt N*	*kt N_2O-N*	*kt N_2O*
1990	27.6	220.8	1,618.9	107.9	1.08	1.70
1991	27.6	242.9	2,142.9	142.9	1.43	2.24
1992	27.6	265.0	2,142.9	142.9	1.43	2.24
1993	27.6	287.1	2,142.9	142.9	1.43	2.24
1994	27.6	309.2	2,142.9	142.9	1.43	2.24
1995	27.6	331.3	2,143.1	142.9	1.43	2.25
1996	27.6	353.3	1,571.9	104.8	1.05	1.65
1997	27.6	375.4	1,571.9	104.8	1.05	1.65
1998	27.6	397.5	1,571.9	104.8	1.05	1.65
1999	27.6	419.6	1,571.9	104.8	1.05	1.65
2000	27.6	441.7	1,572.2	104.8	1.05	1.65
2001	27.6	463.8	1,572.2	104.8	1.05	1.65

	Conversion area		Carbon stock change	F_{SOM}	$N_2O_{net-min}$ -N	N_2O emissions
	annual change	*20 yrs change*				
year	*kha*	*kha*	*kt C*	*kt N*	*kt N_2O-N*	*kt N_2O*
2002	27.6	485.9	1,572.2	104.8	1.05	1.65
2003	27.6	507.9	1,572.2	104.8	1.05	1.65
2004	27.6	530.0	1,572.2	104.8	1.05	1.65
2005	27.6	552.1	1,645.1	109.7	1.10	1.72
2006	27.6	552.1	1,645.1	109.7	1.10	1.72
2007	27.6	552.1	1,645.1	109.7	1.10	1.72
2008	27.6	552.1	1,653.4	110.2	1.10	1.73
2009	14.7	539.2	1,455.9	97.1	0.97	1.53
2010	14.7	526.2	924.1	61.6	0.62	0.97
2011	14.7	513.3	924.1	61.6	0.62	0.97
2012	14.7	500.4	924.1	61.6	0.62	0.97
2013	14.7	487.4	924.1	61.6	0.62	0.97
2014	14.7	474.5	924.1	61.6	0.62	0.97
2015	14.7	461.6	926.6	61.8	0.62	0.97
2016	14.7	448.6	1,161.5	77.4	0.77	1.22
2017	14.7	435.7	1,161.5	77.4	0.77	1.22
2018	14.7	422.8	1,161.5	77.4	0.77	1.22
2019	14.7	409.9	1,161.5	77.4	0.77	1.22
2020	14.7	396.9	1,161.5	77.4	0.77	1.22

6.9.3 Category-specific recalculations

The recalculation occurred in the 2022 submission, comparing to the 2021 submission, for the N_2O emissions from land-use conversion to cropland and settlements is shown in table 6.44. The recalculation is due to an change in the soil carbon stock changes for the abovementioned subcategories, driving an update of the F_{SOM} values used in the estimation process.

Table 6.44 Recalculation in N_2O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	*CO_2 eq. - kt*									
L-CL	0.2	0.4	0.1	0.1	0.1	NO	0.1	0.1	0.2	0.3
L-SL	1.7	2.2	1.6	1.7	1.0	1.0	1.2	1.2	1.2	1.2
2021 submission	*CO_2 eq. - kt*									
L-CL	0.4	0.5	0.3	0.2	0.1	NO	0.1	0.1	0.2	0.3
L-SL	1.7	2.2	1.6	1.7	1.0	1.0	1.2	1.2	1.2	1.2
recalculation	*%*									
L-CL	-77.2	-36.3	-80.0	-55.0	0.0	-	-7.6	-6.6	-6.8	-7.0
L-SL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

6.10 Indirect N_2O emissions from managed soils (4(IV))

6.10.1 Description

Direct N_2O emissions from N inputs of synthetic and organic fertilizer to managed soils in any land use categories are reported in the agriculture sector; accordingly, the indirect N_2O emissions are reported in the

agriculture sector too. In this category, only the indirect N_2O emissions from N mineralization associated with loss of soil organic matter are reported.

6.10.2 Methodological issues

Indirect N_2O emissions from nitrogen leaching and runoff have been estimated with method (equation 11.10) and default values (Table 11.3) from the 2006 IPCC Guidelines (vol. 4, ch. 11). In particular, 0.3 for the $Frac_{LEACH-(H)}$ and 0.0075 kg N_2O-N/kg N default values have been adopted for the EF_5. Indirect N_2O emissions are shown in table 6.45.

Table 6.45 Indirect N_2O emissions from managed soils - Nitrogen leaching and run-off

	F_{SOM}	$Frac_{LEACH-(H)}$	EF_5	N_2Onet-min -N	N_2O emissions
year	*kt N*		*kg N_2O-N/kg N*	*kt N_2O-N*	*kt N_2O*
1990	15.58	0.3	0.0075	0.035	0.055
1991	17.42	0.3	0.0075	0.039	0.062
1992	19.11	0.3	0.0075	0.043	0.068
1993	21.05	0.3	0.0075	0.047	0.074
1994	22.76	0.3	0.0075	0.051	0.080
1995	24.47	0.3	0.0075	0.055	0.087
1996	21.32	0.3	0.0075	0.048	0.075
1997	18.20	0.3	0.0075	0.041	0.064
1998	15.00	0.3	0.0075	0.034	0.053
1999	11.85	0.3	0.0075	0.027	0.042
2000	8.88	0.3	0.0075	0.020	0.031
2001	8.88	0.3	0.0075	0.020	0.031
2002	8.88	0.3	0.0075	0.020	0.031
2003	8.88	0.3	0.0075	0.020	0.031
2004	8.88	0.3	0.0075	0.020	0.031
2005	8.88	0.3	0.0075	0.020	0.031
2006	8.88	0.3	0.0075	0.020	0.031
2007	8.88	0.3	0.0075	0.020	0.031
2008	8.88	0.3	0.0075	0.020	0.031
2009	8.88	0.3	0.0075	0.020	0.031
2010	8.88	0.3	0.0075	0.020	0.031
2011	7.05	0.3	0.0075	0.016	0.025
2012	5.35	0.3	0.0075	0.012	0.019
2013	3.41	0.3	0.0075	0.008	0.012
2014	1.70	0.3	0.0075	0.004	0.006
2015	-	0.3	0.0075	0.000	-
2016	4.22	0.3	0.0075	0.009	0.015
2017	8.67	0.3	0.0075	0.020	0.031
2018	12.79	0.3	0.0075	0.029	0.045
2019	16.95	0.3	0.0075	0.038	0.060
2020	3.13	0.3	0.0075	0.007	0.011

6.10.3 Category-specific recalculations

A recalculation of -1.3% occur in the 2022 submission, comparing to the 2021 submission, for the 2019 reporting year. The recalculation is due to an error fixing, related to the soil carbon stock estimation for the land converted to cropland, for the whole time series.

6.11 Biomass Burning (4(V))

6.11.1 Description

Under this source category, CH_4 and N_2O emissions from wildfires occurring in forest land and CO_2, CH_4 and N_2O emissions from wildfires occurring in cropland and grassland categories are estimated. Areas affected by fires encompassed in settlements category have been reported, but no emissions are estimated, since the emissions have been assumed to be insignificant. An approximate estimate of GHG emissions from settlements has been carried out on the basis of the 2006 IPCC (i.e., value for shrublands, table 2.4, vol. 4, chap. 2, namely 26.7 t dm/ha). This resulted in a maximum of 7.96 kt CO_2 eq. in 2017 (0.47 kt CO_2 eq. in 2019), which is less than 500 kt CO_2 eq. and represents about 0.002 per cent of the national totals without LULUCF in 2020, which is less than 0.05 per cent of the national totals without LULUCF in 2020.

CH_4 and N_2O emissions from wildfires occurring in forest land and other wooded land under grassland have been estimated on a specific model (For-Fires) which is described in Annex 15.

Statistics related to fires occurring in other land use categories (i.e., cropland, grassland, and settlements) have been collected in the framework of *ad hoc* expert panel on fires has been set up, formed by experts from different institutions from ISPRA and the Carabinieri Force (the Armed Forces and Police Authority where the State Forestry Service is embedded, following the legislative decree 19/08/2016, n. 177), currently in charge for the data collection related to burned area.

CO_2 emissions due to forest fires in forest land remaining forest land and land converting to forest land are included in CRF table 4.A.1, under carbon stock change in living biomass - losses.

Non-CO_2 emissions from fires have been estimated and reported in CRF table 4(V), while NO_x, CO and NMVOC emissions from fires have been reported in CRF table 4. SO_2 emissions from fires are reported in 4H (Other - SO_2 from fires).

6.11.2 Methodological issues

CO_2 emissions due to forest fires in forest land remaining forest land and land converting to forest land are included in carbon stock change in living biomass – decrease, in CFR table 4.A.1. The total biomass loss due to forest fires has been estimated following the methodology reported in section 6.2.4.

Detailed information on the estimation process for the non-CO_2 emissions from forest fires is reported in Annex 15.

C released from forest cropland and grassland fires have been estimated following the 2006 IPCC methodology (vol. 4, chapter 4, eq. 2.27); these estimates have been, then, multipled by the emission ratios elaborated for EMEP/EEA 2009 (table 3.3, Ch. 11.B) to estimate CH_4, N_2O, CO and NO_x fire emissions.

In table 6.46 CH_4 and N_2O emissions resulting from biomass burning in forest land category are reported.

Table 6.46 CH_4 and N_2O emissions from biomass burning in forest land category

	Forest land remaining forest land		*Land converted to forest land*	
	CH_4	**N_2O**	**CH_4**	**N_2O**
year	*kt*	*kt*	*kt*	*kt*
1990	21.618	0.007	2.157	0.001
1991	6.551	0.002	0.695	0.000
1992	9.177	0.003	1.031	0.000
1993	22.020	0.007	2.611	0.001
1994	8.535	0.003	1.065	0.000
1995	4.266	0.001	0.558	0.000
1996	3.754	0.001	0.525	0.000
1997	12.809	0.004	1.909	0.001
1998	13.612	0.004	2.151	0.001
1999	7.948	0.002	1.327	0.000
2000	10.526	0.003	1.852	0.001
2001	6.983	0.002	1.289	0.000
2002	3.851	0.001	0.744	0.000
2003	8.425	0.003	1.701	0.001
2004	3.735	0.001	0.786	0.000

	Forest land remaining forest land		*Land converted to forest land*	
	CH_4	**N_2O**	**CH_4**	**N_2O**
year	*kt*	*kt*	*kt*	*kt*
2005	4.088	0.001	0.897	0.000
2006	2.915	0.001	0.625	0.000
2007	19.284	0.006	4.039	0.001
2008	7.256	0.002	1.484	0.000
2009	8.037	0.003	1.606	0.001
2010	3.702	0.001	0.722	0.000
2011	7.559	0.002	1.440	0.000
2012	20.669	0.006	3.846	0.001
2013	2.925	0.001	0.531	0.000
2014	3.753	0.001	0.665	0.000
2015	5.573	0.002	0.965	0.000
2016	6.460	0.002	1.091	0.000
2017	38.987	0.012	6.426	0.002
2018	4.220	0.001	0.679	0.000
2019	3.864	0.001	0.606	0.000
2020	5.031	0.002	0.770	0.000

In Table 6.47 CO_2, CH_4 and N_2O emissions resulting from biomass burning in cropland and grassland categories are reported.

Table 6.47 CO_2, CH_4 and N_2O emissions from biomass burning in cropland and grassland categories

	Cropland			*Grassland*		
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**
year	*kt*	*kt*	*kt*	*kt*	*kt*	*kt*
1990	39.821	0.217	0.007	5,032.029	27.447	0.863
1991	28.636	0.156	0.005	2,932.016	15.993	0.503
1992	25.136	0.137	0.004	2,878.694	15.702	0.493
1993	35.902	0.196	0.006	5,004.449	27.297	0.858
1994	36.668	0.200	0.006	3,897.569	21.259	0.668
1995	11.460	0.063	0.002	1,324.247	7.223	0.227
1996	15.475	0.084	0.003	1,652.503	9.014	0.283
1997	19.911	0.109	0.003	2,745.529	14.976	0.471
1998	33.915	0.185	0.006	4,103.100	22.381	0.703
1999	13.049	0.071	0.002	1,769.220	9.650	0.303
2000	23.181	0.126	0.004	2,945.316	16.065	0.505
2001	15.714	0.086	0.003	1,974.728	10.771	0.339
2002	8.454	0.046	0.001	1,056.866	5.765	0.181
2003	19.618	0.107	0.003	2,404.274	13.114	0.412
2004	16.153	0.088	0.003	1,718.959	9.376	0.295
2005	10.727	0.059	0.002	1,270.284	6.929	0.218
2006	9.666	0.053	0.002	1,095.213	5.974	0.188
2007	45.664	0.249	0.008	5,833.787	31.821	1.000
2008	14.816	0.081	0.003	2,089.793	11.399	0.358
2009	16.027	0.087	0.003	2,640.929	14.405	0.453
2010	8.552	0.047	0.001	1,748.790	9.539	0.300
2011	18.059	0.099	0.003	2,489.590	13.580	0.427
2012	33.948	0.185	0.006	4,272.534	23.305	0.732
2013	56.285	0.307	0.010	456.722	2.491	0.078
2014	5.964	0.033	0.001	1,196.236	6.525	0.205
2015	17.625	0.096	0.003	721.490	3.935	0.124
2016	15.068	0.082	0.003	847.602	4.623	0.145
2017	59.529	0.325	0.010	2,695.996	14.705	0.462
2018	16.129	0.088	0.003	269.515	14.705	0.462
2019	24.669	0.135	0.004	643.508	3.510	0.110
2020	25.687	0.140	0.004	835.858	4.559	0.143

6.11.3 Uncertainty and time series consistency

Uncertainty estimates for the period 1990–2020 have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). Input uncertainties dealing with activity data and emission factors have been assessed on the basis of the information provided in the 2006 IPCC Guidelines (IPCC, 2006).

6.11.4 Category-specific QA/QC and verification

Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness. Data entries have been checked several times during the compilation of the inventory. Several QA activities are carried out in the different phases of the inventory process. In particular, the applied methodologies have been presented and discussed during several national workshop and expert meeting, collecting findings and comments to be incorporated in the estimation process. Additional methodological information and a comparison of approaches for reporting forest fire-related biomass loss and greenhouse gas emissions in southern Europe may be found in Chiriacò et al., (2013). All the LULUCF categories have been embedded in the overall QA/QC-system of the Italian GHG inventory.

6.11.5 Category-specific recalculations

No deviation occurs for emissions from wildfires occurring in forest land. The recalculation occurring for GHG emissions from wildfires occurred in cropland and grassland are due to a revision of the activity data (i.e., burned area for 2018 and 2019).

Table 6.48 Recalculation of emissions from biomass burning occurring in forest land, cropland and grassland

2022 submission	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Biomass burning - Forest land										
CH4	23.77	4.82	12.38	4.99	4.42	6.54	7.55	45.41	4.90	4.47
N2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Biomass burning - Cropland										
CO2	39.82	11.46	23.18	10.73	8.55	17.63	15.07	59.53	16.13	24.67
CH4	0.22	0.06	0.13	0.06	0.05	0.10	0.08	0.32	0.09	0.13
N2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Biomass burning - Grassland										
CO2	5,032.03	1,324.25	2,945.32	1,270.28	1,748.79	721.49	847.60	2,696.00	269.51	643.51
CH4	27.45	7.22	16.07	6.93	9.54	3.94	4.62	14.71	1.47	3.51
N2O	0.86	0.23	0.50	0.22	0.30	0.12	0.15	0.46	0.05	0.11

2021 submission	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Biomass burning - Forest land										
CH4	23.77	4.82	12.38	4.99	4.42	6.54	7.55	45.41	4.90	4.47
N2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Biomass burning - Cropland										
CO2	39.82	11.46	23.18	10.73	8.55	17.63	15.07	59.53	8.06	13.02
CH4	0.22	0.06	0.13	0.06	0.05	0.10	0.08	0.32	0.04	0.07
N2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Biomass burning - Grassland										
CO2	5,032.03	1,324.25	2,945.32	1,270.28	1,748.79	721.49	847.60	2,696.00	214.10	495.52
CH4	27.45	7.22	16.07	6.93	9.54	3.94	4.62	14.71	1.17	2.70
N2O	0.86	0.23	0.50	0.22	0.30	0.12	0.15	0.46	0.04	0.08

recalculation	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019

Biomass burning - Forest land										
CH4	-	-	-	-	-	-	-	-	-	-
N2O	-	-	-	-	-	-	-	-	-	-
Biomass burning - Cropland										
CO2	-	-	-	-	-	-	-	-	50.00	47.22
CH4	-	-	-	-	-	-	-	-	50.00	47.22
N2O	-	-	-	-	-	-	-	-	50.00	47.22
Biomass burning - Grassland										
CO2	-	-	-	-	-	-	-	-	20.56	23.00
CH4	-	-	-	-	-	-	-	-	20.56	23.00
N2O	-	-	-	-	-	-	-	-	20.56	23.00

6.11.6 Category-specific planned improvements

No improvements are planned for the next submission.

6.12 Harvested wood products (HWP) (4G)

6.12.1 Description

Under this source category, annual changes in carbon stocks and associated CO_2 emissions and removals from the Harvested Wood Products (HWP) pool are estimated, following the production approach as outlined in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement, IPCC, 2019), that actually revise and correct errors included in the HWP chapter in the 2006 IPCC Guidelines); the HWP methods included in the 2019 Refinement are totally consistent with the method for HWP estimation outlined in the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement, IPCC 2014), currently used for the HWP reporting under the Kyoto Protocol. Data, parameters, emission factors used to estimate HWP under the Convention and under the Kyoto Protocol are the same.

6.12.2 Methodological issues

Emissions from this source are mainly influenced by the trend in forest harvest rates: in 2020, the net emissions from harvested wood products were -662.5 kt CO_2. The figure 6.10 shows the trend of HWP in use for the period 1961-2020, disaggregated into sawnwood, wood-based panels and paper & paperboard.

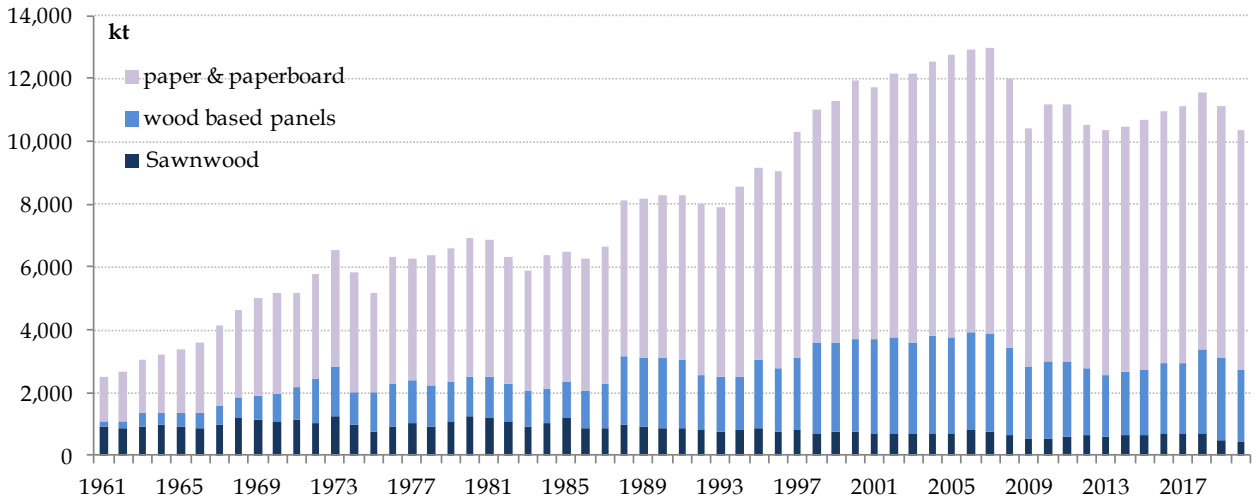


Figure 6.10 HWP in use for the period 1961-2020

The activity data (production of sawnwood, wood-based panels and paper and paperboard) are derived from FAO forest product statistics (Food and Agriculture Organization of the United Nations: forest product statistics, http://faostat3.fao.org/download/F/FO/E).
Italy uses the same methodology to estimate emissions annual changes in carbon stocks and associated CO_2 emissions and removals from the HWP pools under UNFCCC and KP, following the Decision 2/CMP.7, paragraph 29, namely, that "*transparent and verifiable activity data for harvested wood products categories are available, and accounting is based on the change in the harvested wood products pool of the second commitment period, estimated using the first-order decay function*".
The estimates have been carried out on the basis of the 2019 Refinement methodology. The Tier 1 approach, first order decay, was applied to the HWP categories (sawnwood, wood-based panels and paper and paperboard) according to equation 12.2 of the 2019 Refinement (IPCC, 2019, vol. 4, ch. 12), corresponding to the equation 12.1 of the 2006 IPCC Guidelines (IPCC, 2006, vol. 4, ch. 12) and to the equation 2.8.5 in the KP Supplement (IPCC, 2014, ch. 2).
Equation 12.8 of the 2019 Refinement (IPCC, 2019, vol. 4, ch. 12) has been applied to estimate the annual fraction of the feedstock coming from domestic harvest for the HWP categories sawnwood and wood-based panels.
The change in carbon stocks was estimated separately for each product category; the default values (table 12.2 in IPCC, 2019, equivalent to the table 2.8.1, in IPCC, 2014) have been applied. Emission factors for specific product categories were calculated with default half-lives of 35 years for sawnwood, 25 years for wood panels and 2 years for paper (table 12.3, IPCC 2019, equivalent to table 2.8.2, IPCC 2014).
The annual change in stock for the period 1961-2020, disaggregated into sawnwood, wood-based panels and paper & paperboard, is reported in figure 6.11.

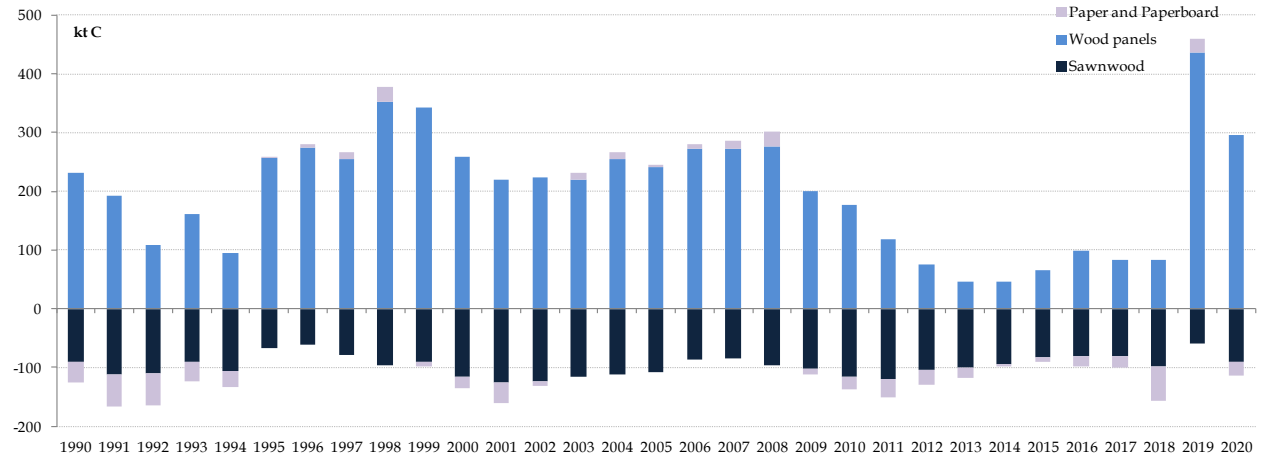


Figure 6.11 Annual change in stock (kt C) for the period 1990-2020

6.12.3 Uncertainty and time series consistency
Uncertainty estimates for the period 1990–2020 have been assessed following Approach 1 of 2006 IPCC Guidelines (IPCC, 2006). The uncertainties of activity data and emission factors used in the estimation process have assessed based on the uncertainties of the default factors provided in the 2019 Refinement (IPCC, 2019) and the uncertainties of used statistical data.

6.12.4 Category-specific QA/QC and verification
Systematic quality control activities have been carried out in order to ensure completeness and consistency in time series and correctness. Data entries have been checked several times during the compilation of the inventory. Several QA activities are carried out in the different phases of the inventory process. All the LULUCF categories have been embedded in the overall QA/QC-system of the Italian GHG inventory.

6.12.5 Category-specific recalculations
Deviations result from the comparison with 2021 submission (+18.3% in 2019), due to the revision of FAOSTAT time series for wood-based panels (for 2018-2019), industrial roundwood (for the years 2011-2019), sawnwood for 2019, paper and paperboard for 2019.

Table 6.49 Recalculation of emissions and removals from HWP category

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	*CO_2 eq. - kt*									
HWP	-388	-706	-454	-503	-142	89	-6	59	264	-1,469
2021 submission	*CO_2 eq. - kt*									
HWP	-388	-706	-454	-503	-142	196	-37	35	156	-1,799
recalculation	*%*									
HWP	0.0	0.0	0.0	0.0	0.0	54.7	83.3	-67.3	-69.1	18.3

6.12.6 Category-specific planned improvements

No improvements are planned for the next submission.

7 WASTE [CRF sector 5]

7.1 Sector overview

The waste sector comprises four source categories:

1 solid waste disposal (5A);
2 biological treatment of solid waste (5B);
3 incineration and open burning of waste (5C);
4 wastewater treatment and discharge (5D).

The waste sector share of GHG emissions in the national greenhouse gas total is presently 4.88% (and was 3.33% in 1990).

The trend in greenhouse gas emissions from the waste sector is summarised in Table 7.1. It clearly shows that methane emissions from solid waste disposal sites (landfills) are by far the largest source category within this sector.

Emissions from waste incineration facilities without energy recovery are reported under category 5C, whereas emissions from waste incineration facilities, which produce electricity or heat for energetic purposes, are reported under category 1A4a (according to the IPCC reporting guidelines).

Under 5B, CH_4, N_2O and NMVOC emissions from compost production and CH_4 emissions from anaerobic digestion of solid waste are reported.

Emissions from methane recovered, used for energy purposes, in landfills and wastewater treatment plants are estimated and reported under category 1A4a.

Table 7.1 Trend in greenhouse gas emissions from the waste sector 1990 – 2020 (Gg)

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 (Gg)											
5C. Waste incineration	512.01	458.23	208.26	230.15	177.21	98.72	103.10	92.08	91.03	95.62	92.74
CH_4 (Gg)											
5A. Solid waste disposal on land	488.25	604.93	687.98	680.10	622.46	561.35	547.59	545.80	545.14	537.77	570.12
5B. Biological treatment of waste	0.19	0.43	1.86	3.66	4.65	4.83	4.91	4.84	4.77	4.70	4.52
5C. Waste incineration	2.00	2.32	2.23	2.46	2.33	2.32	2.41	2.26	2.19	2.18	2.24
5D. Wastewater treatment	127.99	120.79	112.98	109.71	104.56	97.25	99.08	97.73	98.06	97.60	94.99
N_2O (Gg)											
5B. Biological treatment of waste	0.07	0.16	0.68	1.33	1.69	1.75	1.78	1.75	1.73	1.70	1.64
5C. Waste incineration	0.12	0.12	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.06	0.07
5D. Wastewater treatment	4.22	4.10	4.33	4.41	4.46	4.23	4.20	4.23	4.25	4.21	4.08

In the following box, key and non-key sources of the waste sector are presented based on level, trend or both. Methane emissions from landfills result as a key category at level and trend assessment calculated with Approach 1 and Approach 2; N_2O emission from biological treatment of waste is a key category at level for 2020 and at trend assessment only considering the uncertainty; methane emission from wastewater treatment is a key source at level assessment with Approach 1 and Approach 2; N_2O emissions from wastewater treatment result as a key category at level assessment calculated with Approach 1 and Approach 2 and at trend assessment only with the Approach 2, taking into account the uncertainty. When including the LULUCF sector in the key source analysis, methane emissions from landfills is a key category at level and at trend assessment both with the Approach1 and the Approach 2, whereas N_2O emission from biological treatment of waste is a key category at trend and level assessment with the Approach 2, N_2O and CH_4 from wastewater treatment are key categories at level assessment both with the Approach 1 and Approach 2 and at trend assessment only with the Approach 2.

Key-source identification in the waste sector with the IPCC Approach 1 and Approach 2 (without LULUCF) for 2020

5A	CH_4	Emissions from solid waste disposal sites	Key (L, T)
5B	N_2O	Emissions from biological treatment of waste	Key (L2, T2)
5D	CH_4	Emissions from wastewater treatment	Key (L)
5D	N_2O	Emissions from wastewater treatment	Key (L, T2)
5B	CH_4	Emissions from biological treatment of waste	Non-key
5C	CO_2	Emissions from waste incineration	Non-key
5C	CH_4	Emissions from waste incineration	Non-key
5C	N_2O	Emissions from waste incineration	Non-key

7.2 Solid waste disposal on land (5A)

7.2.1 Source category description

The source category solid waste disposal on land is a key category for CH_4, both in terms of level and trend. The share of CH_4 emissions is presently 33.3% (and was about 24.7% in the base year 1990) of the CH_4 national total. For this source category, also NMVOC emissions are estimated; it has been assumed that non-methane volatile organic compounds are 1.3 weight per cent of VOC (Gaudioso et al., 1993): this assumption refers to US EPA data (US EPA, 1990).

Methane is emitted from the degradation of waste disposed of in municipal landfills, both managed and unmanaged. The main parameters that influence the estimation of emissions from landfills are, apart from the amount of waste disposed into managed landfills, the waste composition, the fraction of methane in the landfill gas and the amount of landfill gas collected and treated. These parameters are strictly dependent on the waste management policies throughout the waste streams which start from waste generation, flow through collection and transportation, separation for resource recovery, treatment for volume reduction, stabilisation, recycling and energy recovery and terminate at landfill sites.

Urban waste disposal in landfill sites is still one of the main disposal practices but the percentage of waste disposed in landfills dropped from 91.1% in 1990 to 30.1% in 2020. This trend is strictly dependent on policies that have been taken in the last 20 years in waste management. In fact, at the same time, waste incineration as well as composting and mechanical and biological treatment have shown a remarkable rise due to the enforcement of legislation. Also recyclable waste collection, which at the beginning of nineties was a scarce practice and waste were mainly disposed in bulk in landfills or incineration plants, has been increasing: in 2020, the percentage of municipal solid waste separate collection is about 63.0% (the legislative targets fixed 50% in 2009), characterized by a strong growth in recent years.

In particular, in Italy the first legal provision concerning waste management was issued in 1982 (Decree of President of the Republic 10 September 1982, n.915), as a consequence of the transposition of some European Directives on waste (EC, 1975; EC, 1976; EC, 1978). In this decree, uncontrolled waste dumping as well as unmanaged landfills are forbidden, but the enforcement of these measures has been concluded only in 2000. Thus, from 2000 municipal solid wastes are disposed only into managed landfills.

For the year 2020, the non hazardous landfills in Italy disposed 5,817 kt of MSW and 2,910 kt of industrial wastes, as well as 162 kt of sludge from urban wastewater treatment plants.

Since 1999, the number of MSW landfills has decreased by more than 500 plants up to 127 in 2020, despite the decrease of the amount of wastes disposed of is less pronounced. This because both uncontrolled landfills and small controlled landfills have been progressively closed, especially in the south of the country, where the use of modern and larger plants was opted in order to serve large territorial areas.

Concerning the composition of waste which is disposed in municipal landfills, this has been changed over the years, because of the modification of waste production due to changes in the life-style and not to a forceful policy on waste management.

The Landfill European Directive (EC, 1999) has been transposed into national decree only in 2003 by the Legislative Decree 13 January 2003 n. 36 and applied to the Italian landfills since July 2005, but the effectiveness of the policies will be significant in the future. Moreover, a following law decree (Law Decree 30 December 2008, n.208) moved to December 2009 the end of the temporary condition regarding waste acceptance criteria, thus the composition of waste accepted in landfills is expected to change slowly.

Finally, methane emissions are expected especially from non hazardous waste landfills due to biodegradability rate of the wastes disposed of; in the past, provisions by law forced only non hazardous waste landfills to have a collecting gas system.

7.2.2 Methodological issues

Emission estimates from solid waste disposal on land have been carried out using the IPCC Tier 2 methodology, through the application of the First Order Decay Model (FOD) with the start of the decay reaction on 1 january in the year after disposal.
Parameter values used in the landfill emissions model are:

1) total amount of waste disposed;
2) fraction of Degradable Organic Carbon (DOC);
3) fraction of DOC dissimilated (DOC_F);
4) fraction of methane in landfill gas (F);
5) oxidation factor (O_X);
6) methane correction factor (MCF);
7) methane generation rate constant (k);
8) landfill gas recovered (R).

It has been assumed that all the landfills, both managed and unmanaged, started operations in the same year, and have the same parameters, although characteristics of individual landfill sites can vary substantially.
Moreover, the share of waste disposed of into uncontrolled landfills has gradually decreased, as specified previously, and in the year 2000 it has been assumed equal to 0; nevertheless, emissions still have been occurring due to the waste disposed in the past years. The unmanaged sites have been considered "shallow" according to the IPCC classification.

Municipal solid waste

Basic data on waste production and landfills system are those provided by the national Waste Cadastre. The Waste Cadastre is formed by a national branch, hosted by ISPRA, and by regional and provincial branches. The basic information for the Cadastre is mainly represented by the data reported through the Uniform Statement Format (MUD), complemented by information provided by regional permits, provincial communications and by registrations in the national register of companies involved in waste management activities.
These figures have been elaborated and published by ISPRA yearly since 1999: the yearbooks report waste production data, as well as data concerning landfilling, incineration, composting and generally waste life-cycle data (APAT-ONR, several years; ISPRA, several years).
For inventory purposes, a database of waste production, waste disposal in managed and unmanaged landfills and sludge disposal in landfills was created and it has been assumed that in Italy waste landfilling started in 1950.
The complete database from 1975 of waste production, waste disposal in managed and unmanaged landfills and sludge disposal in landfills is reconstructed on the basis of different sources (MATTM, several years [a]; FEDERAMBIENTE, 1992; AUSITRA-Assoambiente, 1995; ANPA-ONR, 1999 [a], [b]; APAT, 2002; APAT-ONR, several years; ISPRA, several years), national legislation (Legislative Decree 5 February 1997, n.22), and regression models (Colombari et al, 1998).
Since waste production data are not available before 1975, they have been reconstructed on the basis of proxy variables. Gross Domestic Product data have been collected from 1950 (ISTAT, several years [a]) and a correlation function between GDP and waste production has been derived from 1975; thus, the exponential equation has been applied from 1975 back to 1950.
Consequently, the amount of waste disposed into landfills has been estimated, assuming that from 1975 backwards the percentage of waste landfilled is constant and equal to 80%; this percentage has been derived from the analysis of available data. As reported in the Figure 7.1, in the period 1973 – 1991 data are available for specific years (available data are reported in dark blue, whereas estimated data are reported in light blue). From 1973 to 1991 waste disposal has increased, because the most common practice in waste management; from early nineties, thanks to a change in national policies, waste disposal in landfill has started to decrease, in favour of other waste treatments.

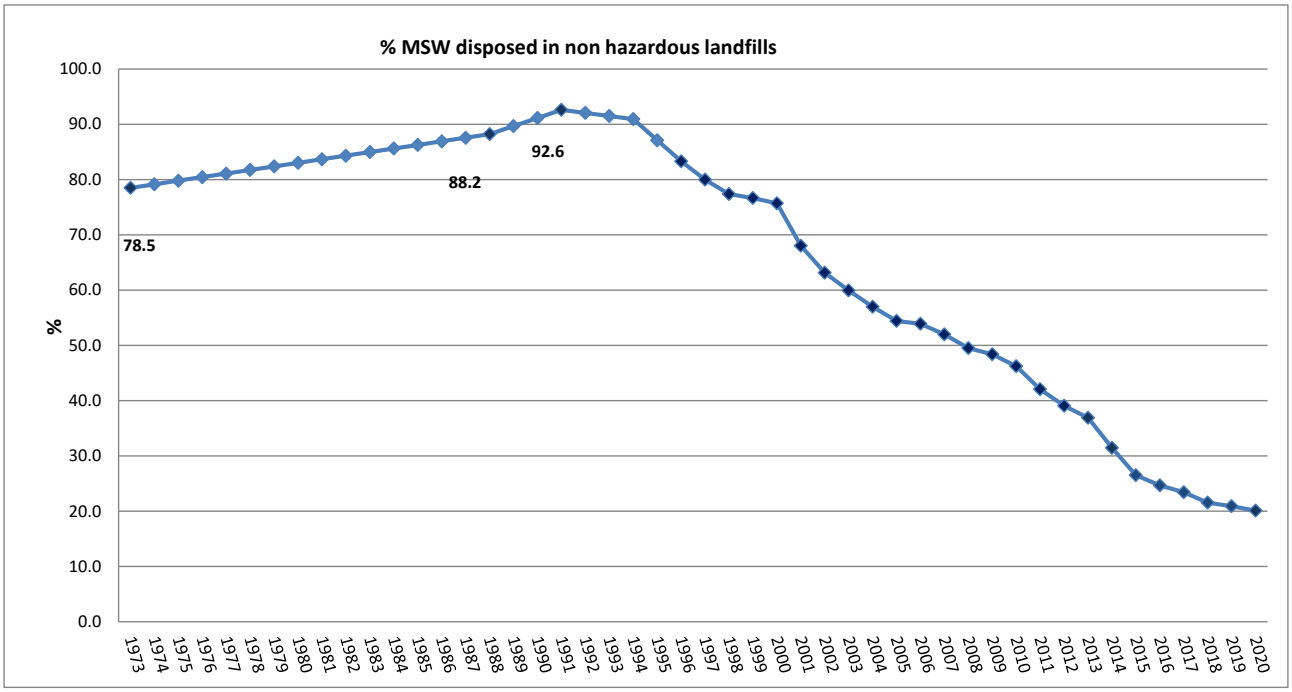


Figure 7.1 Percentage of MSW disposal on land (%)

In the following Table 7.2, the time series of MSW production and MSW disposed of into non hazardous landfills from 1990 is reported. The amount of waste disposed in managed landfills is yearly provided by the national Waste Cadastre since 1995. The time series has been reconstructed backwards on the basis of several studies reporting data available for 1973, 1988, 1991, 1994 (Tecneco, 1972; MATTM, several years [a]).
The amount of waste disposed in unmanaged landfills has been estimated as a percentage of the waste disposed in managed landfills. Different studies provided information about the percentage of waste in unmanaged sites for 1973, 1979, 1991 (Tecneco, 1972; ISTAT, 1984, MATTM, several years [a]) and data in other years are extrapolated. These studies show that the share of waste disposed of into uncontrolled landfills has gradually decreased, from 72.8%, in 1973, to 53.4% in 1979 and 26.6% in 1991, which is a consequence of the progressive implementation of the national legislation. Since 2000 the percentage of waste in unmanaged landfills is equal to zero because of legal enforcement described in 7.2.1.
Uncontrolled landfills have been monitored since 1982 when the D.P.R. 915/82 (Decree of the President of the Republic 915/82) introduced this requirement but the effective reduction of uncontrolled landfills occurred only following the D. Lgs. 22/97 with the implementation of European Directives. From 1997 the amount of waste disposed in uncontrolled landfills (landfills not fullfilling the technological standard but allowed with special permits) strongly reduced till 2000 when they were not allowed anymore. Since 2000 police forces as Corpo Forestale dello Stato and Carabinieri (NOE - Environmental Care Command) protect and supervise the compliance with the law; if an illegal disposal of waste is revealed they proceed to the seizure and site remediation. Recently, the Law 68/2015 introduced in the Italian Penal Code a new Title entirely dedicated to crimes against the environment (Law 22 maggio 2015, n. 68).

Industrial waste

Industrial waste assimilated to municipal solid waste (AMSW) could be disposed of in non hazardous landfills. Composition of AMSW must be comparable to municipal solid waste composition.
From 2001, data on industrial waste disposed of in municipal landfills are available from Waste Cadastre.
For previous years, assimilated municipal solid waste production has been reconstructed, and the same percentage of MSW disposed in landfill has been applied also to AMSW.
The complete database of AMSW production from 1975 to 2000 has been reconstructed starting from data available for the years 1988 (ISTAT, 1991) and 1991 (MATTM, several years [a]) with a linear interpolation, and with a regression model based on Gross Domestic Product (Colombari et al, 1998). From 1975 back to 1950 AMSW production has been derived as a percentage of MSW production; this percentage has been set equal to 15%, which is approximately the value obtained from the only data available (MSW and AMSW production for the years 1988 and 1991).

The time series of AMSW and domestic sludge disposed of into non hazardous landfills from 1990 is reported is also reported in Table 7.2.

Table 7.2 Trend of MSW production and MSW, AMSW and domestic sludge disposed in landfills, 1990 – 2020

ACTIVITY DATA	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
MSW production (Gg)	22,231	25,780	28,959	31,664	32,479	29,524	30,112	29,572	30,158	30,079	28,945
MSW disposed in landfills for non hazardous waste (Gg)	17,432	22,459	21,917	17,226	15,015	7,819	7,432	6,927	6,496	6,283	5,817
Assimilated MSW disposed in landfills for non hazardous waste (Gg)	2,828	2,978	2,825	2,914	3,508	3,222	2,513	3,899	3,512	3,256	2,910
Sludge disposed in managed landfills for non hazardous waste (Gg)	2,454	1,531	1,326	544	346	387	378	342	261	232	162
Total Waste to managed landfills for non hazardous waste (Gg)	16,363	21,897	26,069	20,684	18,870	11,428	10,322	11,167	10,269	9,771	8,889
Total Waste to unmanaged landfills for non hazardous waste (Gg)	6,351	5,071	0	0	0	0	0	0	0	0	0
Total Waste to landfills for non hazardous waste (Gg)	22,714	26,968	26,069	20,684	18,870	11,428	10,322	11,167	10,269	9,771	8,889

Sludge from urban wastewater plants

Sludge from urban wastewater treatment plants has also been considered, because it can be disposed of at the same landfills as municipal solid waste and assimilated, once it meets specific requirements. The fraction of sludge disposed in landfill sites has been estimated to be 75% in 1990, decreasing to 5% in 2020.

On the basis of their characteristics, sludge from urban wastewater treatment plants is also used in agriculture, sludge spreading on land, and in compost production, or treated in incineration plants.

The percentage of each treatment (landfilling, soil spreading, composting, incinerating and stocking) has been reconstructed within the years starting from 1990: for that year, percentages have been set based on data on tonnes of sludge treated in a given way available from a survey conducted by the National Institute of Statistics on urban wastewater plants for the year 1993 (ISTAT, 1998 [a] and [b]; De Stefanis P. et al., 1998).

From 1990 onwards each percentage has been varied on the basis of data available for specific years: in particular, data on sludge use in agriculture have been communicated by the Ministry for the Environment, Land and Sea concerning the reference time period from 1995 (MATTM, 2005; MATTM, several years [a]); data on sludge used in compost production are published from 1999, while data on sludge disposed into landfills are published from 2001 (APAT-ONR, several years; ISPRA, several years).

The total production of sludge from urban wastewater plants is communicated, every three years, by the Ministry for the Environment, Land and Sea from 1995 (MATTM, 2005; MATTM several years [b]) in the framework of the reporting commitments established by the European Sewage Sludge Directive (EC, 1986) transposed into the national Legislative Decree 27 January 1992, n. 99.

Moreover, sewage sludge production is available from different sources also for the years 1987, 1991 (MATTM, several years [a]) and 1993 (ISTAT, 1998 [a] and [b]). Thus, for the missing years data have been extrapolated.

As for the waste production, also sludge production time series has been reconstructed from 1950. Starting from the number of wastewater treatment plants in Italy in 1950, 1960, 1970 and 1980 (ISTAT, 1987), the equivalent inhabitants have been derived.

To summarize, from 1987 both data on equivalent inhabitants and sludge production are available (published or estimated), thus it is possible to calculate a *per capita* sludge production: the parameter results equal on

average to 80 kg inhab.$^{-1}$ yr^{-1}. Consequently, this value has been multiplied to equivalent inhabitants from 1987 back to 1950.
In Table 7.3, time series of sewage sludge production and landfilling is reported.

Table 7.3 Trend of total sewage sludge production and landfilling, 1990 – 2020

ACTIVITY DATA	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Total sewage sludge production (Gg)	3,272	2,437	3,402	4,299	3,698	3,069	3,184	3,184	3,137	3,268	3,248
Sewage sludge landfilled (Gg)	2,454	1,531	1,326	544	346	387	378	342	261	232	162
Percentage (%)	75.0	62.8	39.0	12.7	9.4	12.6	11.9	10.7	8.3	7.1	5.0

Waste composition
One of the most important parameters that influences the estimation of emissions from landfills is the waste composition. An in-depth survey has been carried out, in order to diversify waste composition over the years. On the basis of data available on waste composition (Tecneco, 1972; CNR, 1980; Ferrari, 1996), three slots (1950-1970; 1971-1990; 1991- 2005) have been individuated to which different waste composition has been assigned.
Waste composition used from 2005 back to 1971 (CNR, 1980; Ferrari, 1996) has been better specified, on the basis of data available from those publications. In particular, screened waste (< 20mm) has been included in emissions estimation, because the 50% of it has been assumed as organic and thus rapidly biodegradable. This assumption has been strengthened by expert judgments and sectoral studies (Regione Piemonte, 2007; Regione Umbria, 2007).
In more recent years, taking advantage of the collaboration of the branch of ISPRA that deals with waste, it has been possible to carry out characterizations of the waste based on the data collected at national level from the relevant land registry. This operation is obviously very expensive from a computational point of view, so today it is possible to carry out an in-depth analysis every 10 years, also making use of the regional studies periodically carried out at local level.
So, a fourth slot (2006- 2015) has been individuated on the basis of the analysis of several regional waste composition and the analysis of waste disposed of into non hazardous landfills specified by the European Waste Catalogue (EWC) code for the year 2007, available from Waste Cadastre database (ISPRA, 2010). Data on waste composition refer to recent years and they are representative of the national territory, deriving from the North of Italy (Regione Piemonte, 2007; Regione Veneto, 2006; Regione Emilia Romagna, 2009), the Centre (Regione Umbria, 2007; Provincia di Roma, 2008) and the South (Regione Calabria, 2002; Regione Sicilia 2004). This last waste composition, adopted from 2006, includes compost residues which are disposed into landfills because their parameters are not in compliance with those set by the law: compost residues are reported under garden and park waste component, as they are considered moderately biodegradable. The complete AD time series has been reconstructed by filling gaps with the combination of the methods provided in the 2006 IPCC guidelines (mainly overlap and interpolation). Furthermore, the consistency between the last two classifications is ensured by the high detail of the most recent data which has made it possible to univocally associate the waste deposited in landfills in the last period with those of the previous period. This also ensure the consistency in the application of the k values.
The moisture content and the organic carbon content are from national studies (Andreottola and Cossu, 1988; Muntoni and Polettini, 2002).
Finally, starting from the settings of the previous work carried out on the 2007 data, the municipal waste sent to landfill was classified into the different classes considered in the 2006 IPCC Guidelines in order to obtain the three categories mentioned above. (slowly, moderately and rapidly biodegradable). These values were compared with various regional studies conducted over the last 10 years on the characterization of waste in landfills. The studies taken into consideration were drawn from the PRGRs of Piemonte (Regione Piemonte, 2016), Emilia Romagna (Regione Emilia Romagna, 2016), Toscana (Regione Toscana, 2014), Lazio (Regione Lazio, 2020), Calabria (Regione Calabria, 2016), Campania (Regione Campania, 2016) and Sardinia (Regione Sardegna, 2016). Compared to the previous processing (based on 2007 data), the fractions of food residues (-6%) and cellulosic materials (-8%) decrease, related to the better penetration and effectiveness of separate waste collection, which are able to better intercept these fractions and subtract them from landfill disposal. On the other hand, the fraction defined here as underscreen (*sottovaglio*) and linked to the increase in TMB

(Biological Mechanical Treatments) treatments of waste which has led to an increase in treatment residues. Furthermore, from various studies and hypotheses reported in the PRGRs (Regional Waste Mmanagement Plan), an increase in the organic fraction in the underscreen was noted, which was assumed to be equal to 70%. In Tables 7.4, 7.5, 7.6, 7.7 and 7.8 waste composition of each national survey mentioned above and waste composition derived from the analysis of EWC code is reported, together with moisture content, organic carbon content and consequently degradable organic carbon both in waste type *i* and in bulk waste, DOC calculation is described in following paragraphs. Waste types containing most of the DOC and thus involved in methane emissions are highlighted in bold type.
Since sludge is not included in waste composition, because it usually refers to waste production and not to waste landfilled, it has been added to each waste composition, recalculating the percentage of waste type.

Table 7.4 Waste composition and Degradable Organic Carbon calculation, 1950 - 1970

WASTE COMPONENT	Composition by weight (wet waste)	Moisture content	Organic carbon content (dry matter)	DOC content in % of wet waste	DOC_i (kgC/tMSW)
Organic	**32.7%**	**60%**	**48%**	**19%**	**62.73**
Garden and park	**3.6%**	**50%**	**48%**	**24%**	**8.71**
Paper, paperboard	**29.7%**	**9%**	**50%**	**46%**	**135.11**
Plastic	2.9%	2%	70%		
Inert	26.9%				
Sludge	**4.2%**	**75%**	**48%**	**12%**	**5.05**
DOC					**211.61**

Table 7.5 Waste composition and Degradable Organic Carbon calculation, 1971 – 1990

WASTE COMPONENT	Composition by weight (wet waste)	Moisture content	Organic carbon content (dry matter)	DOC content in % of wet waste	DOC_i (kgC/tMSW)
Organic	**33.3%**	**60%**	**48%**	**19%**	**64.02**
Garden and park	**3.7%**	**50%**	**48%**	**24%**	**8.89**
Paper, paperboard, textile and wood	**19.6%**	**9%**	**50%**	**46%**	**89.29**
Plastic	6.3%	2%	70%		
Inert	6.2%				
Metal	2.6%				
Screened waste (< 2 cm)					
- organic	8.1%	**60%**	**48%**	**19%**	**15.46**
- non organic	8.1%				
Sludge	**12.0%**	**75%**	**48%**	**12%**	**14.40**
DOC					**192.06**

Table 7.6 Waste composition and Degradable Organic Carbon calculation, 1991 - 2005

WASTE COMPONENT	Composition by weight (wet waste)	Moisture content	Organic carbon content (dry matter)	DOC content in % of wet waste	DOC_i (kgC/tMSW)
Organic	**24.7%**	**60%**	**48%**	**19%**	**47.36**
Garden and park	**4.2%**	**50%**	**48%**	**24%**	**10.09**
Paper, paperboard	**25.5%**	**8%**	**44%**	**40%**	**103.36**
Nappies	**2.7%**	**8%**	**44%**	**40%**	**10.98**
Textiles	**4.8%**	**10%**	**55%**	**50%**	**23.98**
Leather and rubbers	2.1%	2%	70%		
Light plastics	8.9%	2%	70%		
Rigid plastics	3.0%	2%	70%		

Inert and glasses	5.9%				
Metal	2.9%				
Bulky waste	0.5%				
Various	1.5%				
Screened waste (< 2 cm)					
- organic	**3.4%**	**60%**	**48%**	**19%**	**6.60**
- non organic	3.4%				
Sludge	**6.3%**	**75%**	**48%**	**12%**	**7.55**
DOC					**209.92**

Table 7.7 Waste composition and Degradable Organic Carbon calculation, 2006 – 2015

WASTE COMPONENT	Composition by weight (wet waste)	Moisture content	Organic carbon content (dry matter)	DOC content in % of wet waste	DOC_i (kgC/tMSW)
Organic	**21.9%**	**60%**	**48%**	**19%**	**42.07**
Garden and park	**5.6%**	**50%**	**48%**	**24%**	**13.53**
Wood	**1.6%**	**20%**	**50%**	**40%**	**6.47**
Paper, paperboard, nappies	**23.9%**	**8%**	**44%**	**40%**	**96.72**
Textiles and leather	**3.0%**	**10%**	**55%**	**50%**	**14.86**
Plastics	11.8%	2%	70%		
Metals and Aluminium	2.3%				
Inert and glasses	6.4%				
Bulky waste	2.2%				
Various	6.5%				
Screened waste (< 2 cm)					
- organic	**5.4%**	**60%**	**48%**	**19%**	**10.43**
- non organic	5.4%				
Sludge	**3.9%**	**75%**	**48%**	**12%**	**4.68**
DOC					**188.76**

Table 7.8 Waste composition and Degradable Organic Carbon calculation, 2016 – 2020

WASTE COMPONENT	Composition by weight (wet waste)	Moisture content	Organic carbon content (dry matter)	DOC content in % of wet waste	DOC_i (kgC/tMSW)
Organic	**15.9%**	**60%**	**48%**	**19%**	**30.61**
Garden and park	**4.3%**	**50%**	**48%**	**24%**	**10.36**
Wood	**2.1%**	**20%**	**50%**	**40%**	**8.54**
Paper, paperboard, nappies	**16.1%**	**8%**	**44%**	**40%**	**65.03**
Textiles and leather	**2.5%**	**10%**	**55%**	**50%**	**12.50**
Plastics	11.7%	2%	70%		
Metals and Aluminium	5.8%				
Inert and glasses	9.5%				
Bulky waste	0.0%				
Various	8.7%				
Screened waste (< 2 cm)					
- organic	**14.7%**	**60%**	**48%**	**19%**	**28.16**
- non organic	6.3%				
Sludge	**2.4%**	**75%**	**48%**	**12%**	**2.85**
DOC					**158.05**

On the basis of the waste composition, waste streams have been categorized in three main types: rapidly biodegradable waste, moderately biodegradable waste and slowly biodegradable waste, as reported in Table 7.9. Methane emissions have been estimated separately for each mentioned biodegradability class and the results have been consequently added up.

Table 7.9 Waste biodegradability

Waste biodegradability	Rapidly biodegradable	Moderately biodegradable	Slowly biodegradable
Food	X		
Sewage sludge	X		
Screened waste (organic)	X		
Garden and park		X	
Paper, paperboard			X
Nappies			X
Textiles, leather			X
Wood			X

Degradable organic carbon (DOC) and Methane generation potential (L_0)

Degradable organic carbon (DOC) is the organic carbon in waste that is accessible to biochemical decomposition, and should be expressed as Gg C per Gg of waste. The DOC in waste bulk is estimated based on the composition of waste and can be calculated from a weighted average of the degradable carbon content of various components of the waste stream. The following equation estimates DOC using default carbon content values.

$$DOC = \sum_i (DOC_i * W_i)$$

Where:
DOC = fraction of degradable organic carbon in bulk waste, kg C/kg of wet waste
DOC_i = fraction of degradable organic carbon in waste type *i*,
W_i = fraction of waste type *i* by waste category

Degradable organic carbon in waste type *i* can be calculated as following:

$$DOC_i = C_i * (1-u_i) * W_i$$

Where:
C_i = organic carbon content in dry waste type *i*, kg C/ kg of waste type *i*
u_i= moisture content in waste type *i*
W_i = fraction of waste type *i* by waste category

Once known the degradable organic carbon, the methane generation potential value (L_0) is calculated as:

$$L_0 = MCF * DOC * DOC_F * F * 16/12$$

Where:
MCF = methane correction factor
DOC_F = fraction of DOC dissimilated
F = fraction of methane in landfill gas

Fraction of degradable organic carbon (DOC_F) is an estimate of the fraction of carbon that is ultimately degraded and released from landfill, and reflects the fact that some degradable organic carbon does not degrade, or degrades very slowly, under anaerobic conditions in the landfill.
DOC_F value is dependent on many factors like temperature, moisture, pH, composition of waste: the default value 0.5 has been used.
The methane correction factor (MCF) accounts for that unmanaged SWDS (solid waste disposal sites) produce less CH_4 from a given amount of waste than managed SWDS, because a larger fraction of waste decomposes aerobically in the top layers of unmanaged SWDS. The MCF should be also interpreted as the 'waste management correction factor' because it reflects the management aspects.

The MCF value used for unmanaged landfill is the default IPCC value reported for uncategorised landfills: in fact, in Italy, before 2000 the existing unmanaged landfills were mostly shallow, because they resulted in uncontrolled waste dumping instead of real deep unmanaged landfills. On the basis of the qualitative information available regarding the national unmanaged landfills, the default IPCC value used has been considered the most appropriate to represent national circumstances also in consideration of the type of waste landfilled and the humidity degree of landfills. It is assumed that landfill gas is 50% VOC. On the basis of the recent inventory review in the framework of the ESD (Effort Sharing Directive) (EEA, 2017), Italy has distinguished wetlands from dry areas by associating each type of area with landfills in their respective territories, more information are available in the following paragraph. As it is estimated that sewage sludge has been disposed of only into landfills localized in the dry zone, the values of methane generation potential for the rapidly biodegradable fraction are slightly different. The following Table 7.10 summarizes the methane generation potential values (L_0) generated, distinguished for managed and unmanaged landfills.

Table 7.10 Methane generation potential values by waste composition, landfill typology and moisture conditions

L_0 (m3CH_4/tRSU)	1950 - 1970		1971 - 1990		1991 - 2005		2006 - 2015		2016-2020	
	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet
Rapidly biodegradable										
- Managed landfill	89.7	94.6	85.4	94.6	87.2	94.6	91.4	90.2	91.4	94.6
- Unmanaged landfill	53.8	56.7	51.3	56.7	52.3	56.7	54.8	54.1	54.8	56.7
Moderately biodegradable										
- Managed landfill	118.2	118.2	118.2	118.2	118.2	118.2	118.2	118.2	118.2	118.2
- Unmanaged landfill	70.9	70.9	70.9	70.9	70.9	70.9	70.9	70.9	70.9	70.9
Slowly biodegradable										
- Managed landfill	224.1	224.1	224.1	224.1	205.9	205.9	204.0	204.0	204.6	204.6
- Unmanaged landfill	134.5	134.5	134.5	134.5	123.5	123.5	122.4	122.4	122.7	122.7

Finally, oxidation factors have been assumed equal to 0.1 for managed landfills and 0 for unmanaged according to the IPCC 2006 Guidelines where 0.1 is suggested for well managed landfills.

Methane generation rate constant (k)

The methane generation rate constant *k* in the FOD method is related to the time necessary for DOC in waste to decay to half its initial mass (the 'half life' or t½).

The maximum value of *k* applicable to any single SWDS is determined by a large number of factors associated with the composition of the waste and the conditions at the site. The most rapid rates are associated with high moisture conditions and rapidly degradable material such as food waste. The slowest decay rates are associated with dry site conditions and slowly degradable waste such as wood or paper. Thus, for each rapidly, moderately and slowly biodegradable fraction, and for each site conditions a different maximum methane generation rate constant has been assigned, as reported in Table 7.11. Different *k* values for rapidly, moderately and slowly biodegradable waste splitted up into dry or wet zones are applied to the different parts of the model. As above reported, consistency has been ensured in the application of a weighted average k value for slowly degradable waste but, more, Italy - applying the FOD model ith the individual k values - noted that non underestimation occurred. Furthermore, Italian experts believe that the application of the weighted average, especially for slowly biodegradable waste, constitutes a more realistic representation of the phenomenon.

The methane generation rate constant *k* values derive from the 2006 IPCC Guidelines. Italy has investigated more deeply the country specific conditions and revised the k-values considering the subdivision of the national territory in dry or wet zones on the basis of georeferenced data (30 km grid) consisting of the monthly average climatic summaries (period 1986-2015) of precipitation and evapotranspiration referring to the rainy period (October-December) and to the entire national territory provided by the Research Centre for Agriculture and Environments CREA-AA (CREA, 2017). Subsequently the ratio between precipitation (MAP = Mean Annual Precipitation) and evapotranspiration (PET = Potential Evapotranspiration) has been calculated and dry and wet zones distinguished following the 2006 Guidelines. Results have been reported in Figure 7.2., more information in (ISPRA, 2018).

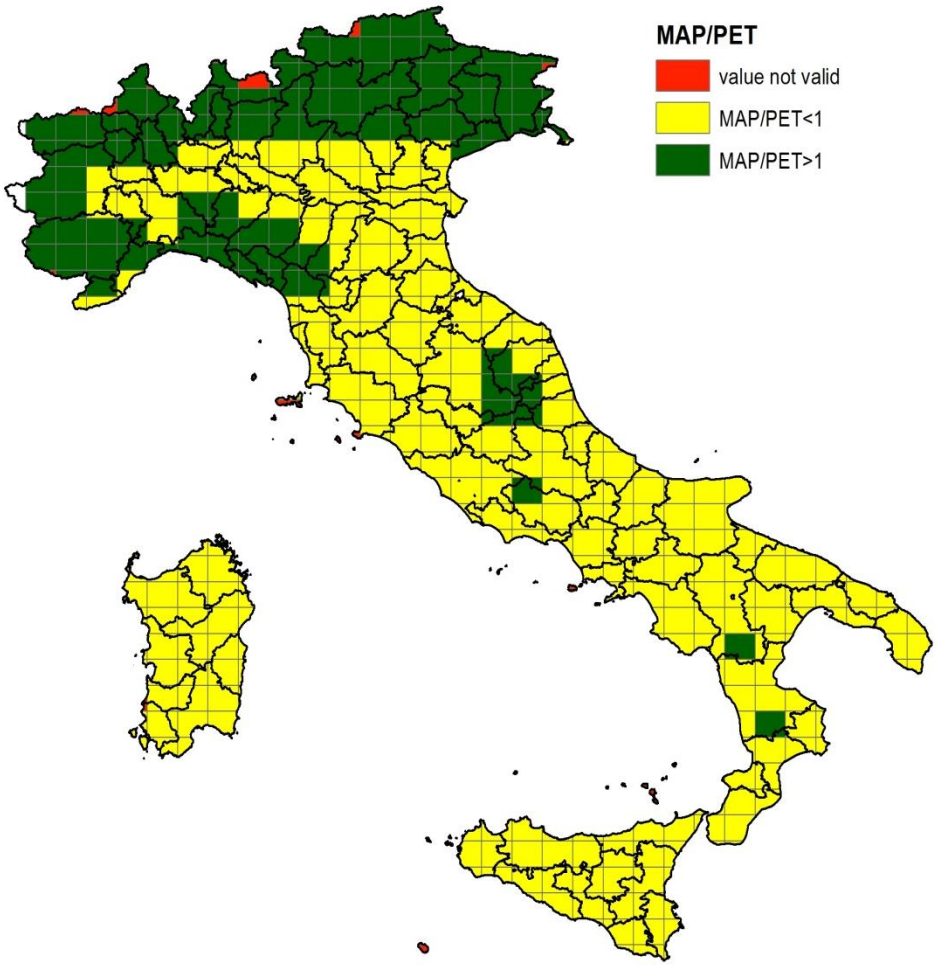


Figure 7.2 Distribution of moisture conditions as defined by the 2006 IPCC GL

On the basis of the location of the solid waste disposal sites and of the distribution of dry or wet zones, the appropriate k values have been set; in particular, as reported in Table 7.10: 1) dry zones, rapidly biodegradable waste half life=12 years and k=0.06, moderately biodegradable half life=14 years and k=0.05, slowly biodegradable half life=20 years and k=0.03; 2) wet zones, rapidly biodegradable waste half life=4 years and k=0.17, moderately biodegradable half life=7 years and k=0.10, slowly biodegradable half life=14 years and k=0.05. Information and data about the fraction of waste landfilled in dry or wet zones are reported in (ISPRA, 2018). In particular, in 1990 MSW have been landfilled for 81% in dry zones and 19% in wet zones and assimilated MSW for 84% in dry and 16% in wet zones. In 2020 MSW have been landfilled for 92% in dry zones and 8% in wet zones while assimilated MSW keep the same distribution.

Table 7.11 Half-life values and related methane generation rate constant

MOISTURE CONDITIONS	WASTE TYPE	Half life	Methane generation rate constant
DRY	Rapidly biodegradable	12 year	0.06
	Moderately biodegradable	14 years	0.05
	Slowly biodegradable	20 years	0.03
WET	Rapidly biodegradable	4 year	0.17
	Moderately biodegradable	7 years	0.10
	Slowly biodegradable	14 years	0.05

Landfill gas recovered (R)

Landfill gas recovered data have been reconstructed on the basis of information on extraction plants (De Poli and Pasqualini, 1991; Acaia et al., 2004; Asja, 2003) and electricity production (TERNA, several years).

Only managed landfills have a gas collection system, and the methane extracted can be used for energy production or can be flared.

The amount of methane recovery in landfills has increased as a result of the implementation of the European Directive on the landfill of waste (EC, 1999); the amounts of methane recovered and flared have been estimated taking into account the amount of energy produced, the energy efficiency of the methane recovered, the captation efficiency and the efficiency in recovering methane for energy purposes assuming that the rest of methane captured is flared. The emissions from biogas recovered from landfills and used for energy purposes are reported in the energy sector in "1A4a biomass" category together with wood, the biomass fraction of incinerated waste and biogas from wastewater plants. In Table 7.12 consumptions and low calorific values are reported for the year 2020.

Table 7.12 1A4a biomass detailed activity data. Year 2020

Fuels		Consumption (Gg)	LCV (TJ/Gg)
Wood and similar	Wood	292.51	10.47
	Steam Wood	0.00	30.80
Incinerated waste (biomass)		2140.03	11.39
Biogas from landfills		218.78	55.07
Biogas from wastewater plants		25.90	55.07

The total CH_4 recovered is the sum of methane flared and methane used for energy purposes (see figure 7.3). Until 2000, the methane used for energy production is estimated starting from the electricity produced annually (E=GWh*3.6=TJ) by landfills (TERNA, several years) assuming an energy conversion efficiency equal to 0.3, typical efficiency value for engines that produce electricity from biogas (Colombo, 2001), and a LCV (Lower Calorific Value) equal to 50.038 TJ/Gg:

$$((E/0.3)/50.038) *1000= CH_4 \text{ Mg/year}$$

The LCV used for biogas derives from national experts and it is verified with energy and quantitative data about biogas production from waste supplied by TERNA (National Independent System Operator).

Since 2001, TERNA provides directly the amounts of biogas recovered for energy purposes, in this case the LCV has been derived from the comparison with the supplied energy data.

For the years 1987, 1988, 1989 and 1990, the methane flared is supplied by the plants (De Poli and Pasqualini, 1991); from 1991 to 1997 the methane flared has been extrapolated from the previous years; finally, for the following years the methane flared has been estimated using information based on monitored data supplied by the main operators (Asja, 2003 and Acaia, 2004) regarding the efficiency in recovering methane for energy purposes with respect to the total methane collected. This efficiency value increased from 56% of the total, in 1998, to 65% since 2002. In particular, the flared quantity of methane in 1990, reported by (De Poli and Pasqualini, 1991), is equal to 1,170,000 m^3/day which result in 108,858 Mg/y and, in 1990, this amount corresponds to the total methane recovered. Since 1991 TERNA (National Independent System Operator) supplies the amount of biogas collected with energy recovery while (ASJA, 2003) and (Acaia, 2004) supply the percentage (flared / with energy recovered) equal to 35% in 2000 (survey on landfills in the Lombardy region, year 2000, 32 plants) and 30% in the following years (Asja landfills produced 35% of energy from landfill gas at the national level in 2001-2002). After 2020 this value, 30 % flared of total biogas collected, has been keep constant not considering further improving in efficiency in recovering methane for energy purposes with respect to the total methane collected. Since 2002 the efficiency is estimated on the basis of an interpolation over the period 2002-2020.

Furthermore, following the recommendation of 2016 ESD- review (EU, 2016), Italy has started to collect plant data derived from IPPC permits. The completion of this search takes time as there are no available data base but it is necessary to make a documentary study, plant by plant. The documents analyzed at the time (some of these are available on the website http://ippc-aia.arpa.emr.it/ippc-aia/CercaImpiantiTipo.aspx) seem to confirm current estimates (biogas flared = 30/35% of collected biogas).

Total methane collected is estimated, in 2020, equal to 33% of the total methane produced.

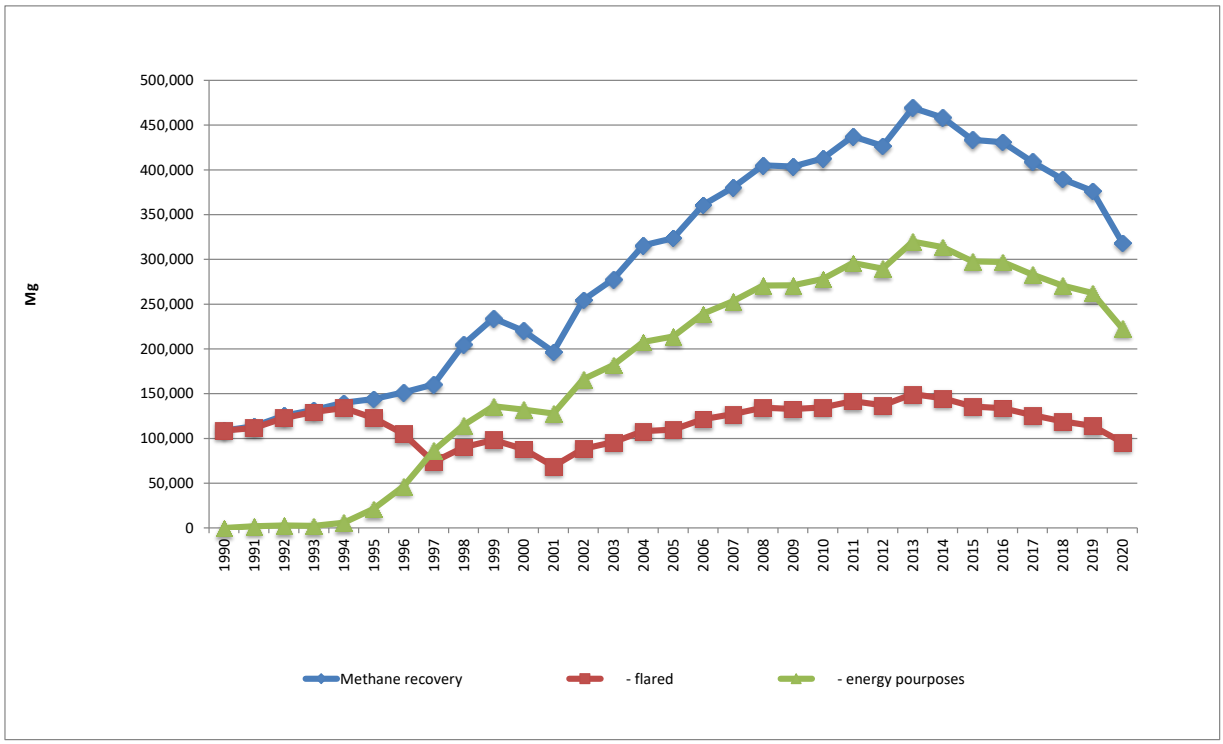


Figure 7.3 Methane recovery distinguished in flared amount and energy purposes (Mg)

CH_4 and NMVOC emission time series

The time series of CH_4 emissions is reported in Table 7.13; emissions from the amount used for energy purposes are estimated and reported under category 1A4a.

Whereas waste production continuously increases, from 2001 solid waste disposal on land has decreased as a consequence of waste management policies, although fluctuations in the amounts of industrial waste and sludge could influence this trend. At the same time, the increase in the methane-recovered percentage has led to a reduction in net emissions.

Further reduction is expected in the future because of the increasing in waste recycling.

Table 7.13 VOC produced, recovered and CH_4 and NMVOC net emissions, 1990 – 2020 (Gg)

EMISSIONS	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Managed Landfills											
VOC produced (Gg)	396.4	565.5	772.3	916.7	977.6	957.7	944.4	925.0	909.2	891.8	874.1
VOC recovered (Gg)	108.9	144.1	220.4	323.7	412.7	433.6	431.0	409.1	389.7	376.6	318.5
VOC recovered (%)	27.5	25.5	28.5	35.3	42.2	45.3	45.6	44.2	42.9	42.2	45.0
CH_4 net emissions (Gg)	255	374.3	490.3	526.7	501.8	465.5	456.0	458.3	461.4	457.7	493.5
NMVOC net emissions (Gg)	3.4	4.9	6.5	6.9	6.6	6.1	6.0	6.0	6.1	6.0	6.5
Unmanaged Landfills											
VOC produced (Gg)	235.9	233.6	200.3	155.4	122.3	97.1	92.8	88.7	84.8	81.1	77.6
VOC recovered (Gg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CH_4 net emissions (Gg)	232.8	230.6	197.7	153.4	120.7	95.8	91.6	87.5	83.7	80.1	76.6
NMVOC net emissions (Gg)	3.1	3.0	2.6	2.0	1.6	1.3	1.2	1.2	1.1	1.1	1.0

7.2.3 Uncertainty and time-series consistency

The uncertainty in CH_4 emissions from solid waste disposal sites has been estimated both by Approach 1 and Approach 2 of the IPCC guidelines.

Following Approach 1, the combined uncertainty is estimated to be 22.4%, 10% and 20% for activity data and emission factors, respectively, as suggested by the IPCC Guidelines (IPCC, 2006).

Applying Montecarlo analysis, the resulting uncertainty is estimated equal to 12.6% in 2009. Normal distributions have been assumed for most of the parameters; whenever assumptions or constraints on variables were known this information has been appropriately reflected on the choice of type and shape of distributions. A summary of the results is reported in Annex 1.
Emissions from landfills (Table 7.13) are influenced, apart from the amount of waste landfilled, also from waste composition and site conditions, as for each biodegradability class different parameters are used in the model.
The total amount of waste disposed of into managed landfills increased until 2000 (in 2000 the landfilling of waste in unmanaged landfills has stopped too), then it decreased from 2000 to 2003, while from 2003 to 2008 it is quite stable. Since 2009, due to the increasing in collection and recycling, but also to the economic crisis, the amount of waste disposed of in landfills is significantly decreased. It is important to remind that the total amount of waste disposed of is the sum of municipal solid wastes (which have decreased due to the enforcement of the legislation), sludge and industrial waste (only those similar to the municipal ones), which are subjected to fluctuation.
As previously reported, five waste compositions have been used, changing from 1950 to 2020 as well as the percentage of rapidly, moderately and slowly biodegradable fraction. The combination of the amount of waste landfilled and the waste composition has led to an increase of methane production from 1990 to the period 2005-2010 and a reduction in the last years.
At the same time, biogas recovery has increased up to 2013, but from 2000 the recovery rate is higher: in 2013 the methane recovered is about 42% of the methane produced. Methane emissions for 2013 result mainly from the amount of waste landfilled in the previous three years (2010-2012) and the observed decline is explained by the sharp decrease in the amount of solid waste disposed in landfills in these years.

7.2.4 Source-specific QA/QC and verification

The National Waste cadastre is managed by ISPRA and is formed by a national branch hosted by ISPRA and regional and provincial branches hosted by the Regional Agencies for the Protection of the Environment. So the system requires continuous and systematic knowledge exchange and QA/QC checks in order to ensure homogeneity of information concerning waste production and management throughout the entire Italian territory. At central level, ISPRA provides assessment criteria and procedures for data validation, through the definition of uniform standard procedures for all regional branches. The national branch, moreover, ensures spreading of the procedures and training of technicians in each regional branch. Data are validated by ISPRA detecting potential errors and data gaps, comparing among different data sources and asking for further explanation to the regional branches whenever needed. Moreover, ISPRA has started a number of sectoral studies with a view to define specific waste production coefficients related to each production process. So through the definition of such 'production factors' and the knowledge of statistical information on production, it is possible to estimate the amount of waste originated from each sector for the selected territorial grid cell and compare the results to the statistical data on waste production.
For general QC checks on emission estimates and related parameters, each inventory expert fills in, during the inventory compilation process, a format with a list of questions to be answered which helps the compiler avoid potential errors and is also useful to prove the appropriateness of the methodological choices.
Following a recommendation during the previous review process further verifications have been carried out to check the k values for slowly degrading waste; the FOD model has been applied using the k value calculated as a weighted average between paper and wood but also inputing the different and appropriate values for paper and for wood. On the basis of 2019 submission data, the methane produced in the first case is 632,294 Mg in 1990 and 1,013,714 Mg in 2017; in the second one the methane produced is equal to 616,283 Mg in 1990 and 1,013,062 Mg in 2017. More, the sum of methane produced with the first model from 1990 to 2017 is equal to 26,943,609 Mg while using two distinct k values the sum results in 26,697,478 demonstrating that there is not an underestimation.
As regards the choice in k values, an in depth survey has been conducted and results have been reported in a technical note (ISPRA, 2018).
On the basis of the last European Review (EEA, 2020) a comparison of the IPCC waste model (MS excel) with the model used by Italy for the simulation of biogas production was carried out. To adequately compare the two calculation models, 4 outputs were created corresponding to the categories used in the Italian model: wet-managed (SWDS in wet zone and well managed), wet unmanaged (SWDS in wet zone and not managed), dry managed (SWDS in dry zone and well managed) and dry unmanaged (SWDS in dry zone and not

managed). By using the same activity data and the same parameters in both models, almost identical results are obtained as can be seen from the following figures demonstrating the correct implementation of the physicochemical relationships in the Italian model. The differences shown in the table are largely within the uncertainty of the estimate.

Table 7.14 Comparison between the Italian (sub 2021) and the IPCC spreadsheet for biogas production

	IPCC model	Italian model	difference
	CH_4 Gg	CH_4Gg	%
1990			
wet managed 1990	80	84	4.4%
wet unmanaged 1990	50	53	5.8%
dry managed 1990	277	273	-1.3%
dry unmanaged 1990	183	183	0.4%
tot 1990	589	593	0.6%
2019			
wet managed 2019	113	113	0.4%
wet unmanaged 2019	9	10	8.8%
dry managed 2019	711	698	-1.8%
dry unmanaged 2019	70	71	2.0%
tot 2019	903	892	-1.1%

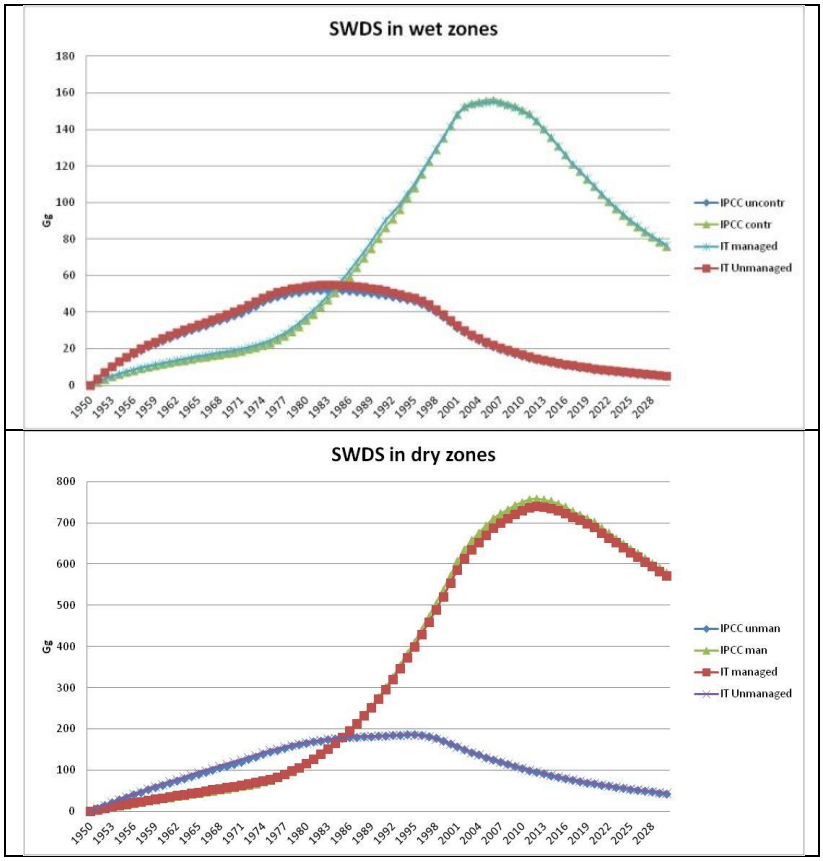


Figure 7.4 Comparison between the Italian (sub 2021) and the IPCC spreadsheet for biogas production

Following another recommendation deriving from the review process, Italy investigated the possibility to estimate the emissions from certain episodes of illegal dumping. There are no quantitative data about this issue but from a qualitative point of view it was known that waste was prevalently industrial waste rich in heavy metals and inorganic chemicals, generally no or slowly biodegradable. Anyhow, the waste has been collected and temporarily stored in "ecoballe", therefore officially registered and sent to appropriate treatments resulting in the data reported by the National database (for example in the case of events in the Naples region).
Moreover, an in depth analysis of EWC codes of waste disposed of in landfills has been done for the year 2007 and 2019, thanks to the complete database of Waste Cadastre kindly supplied by ISPRA Waste Office. This

accurate analysis has permitted to verify the correctness of waste typology assumptions used for the estimations.
Finally, an important improvement in waste data collection has been implemented by ISPRA and the Regional Agencies for the Protection of the Environment, consequently the waste statistical report includes the urban waste data referred to last years allowing a timely reporting.

7.2.5 Source-specific recalculations

In Table 7.15, municipal and industrial (assimilated to MSW) wastes disposed into non hazardous landfills are reported also for submission 2020.

Table 7.15 MSW disposed into landfills time series, 1990 – 2020 (t), AMSW disposed into landfills time series, 1990 – 2020 (t), and differences in percentage between Submission 2022 and Submission 2021.

Year	Submission 2022			Submission 2021			% MSW	% AMSW	% Total
	MSW to landfill (t)	AMSW to landfill (t)	Total waste (except sludge) to landfill (t)	MSW to landfill (t)	AMSW to landfill (t)	Total waste (except sludge) to landfill (t)			
1990	17,431,760	2,827,867	20,259,627	17,431,760	2,827,867	20,259,627	-	-	-
1995	22,458,880	2,977,672	25,436,552	22,458,880	2,977,672	25,436,552	-	-	-
2000	21,917,417	2,825,340	24,742,757	21,917,417	2,825,340	24,742,757	-	-	-
2005	17,225,728	2,913,697	20,139,425	17,225,728	2,913,697	20,139,425	-	-	-
2006	17,525,881	2,480,830	20,006,711	17,525,881	2,480,830	20,006,711	-	-	-
2007	16,911,545	2,776,637	19,688,182	16,911,545	2,776,637	19,688,182	-	-	-
2008	16,068,760	3,703,220	19,771,980	16,068,760	3,703,220	19,771,980	-	-	-
2009	15,537,822	3,180,904	18,718,726	15,537,822	3,180,904	18,718,726	-	-	-
2010	15,015,119	3,508,400	18,523,519	15,015,119	3,508,400	18,523,519	-	-	-
2011	13,205,749	2,882,686	16,088,435	13,205,749	2,882,686	16,088,435	-	-	-
2012	11,720,316	2,291,946	14,012,262	11,720,316	2,291,946	14,012,262	-	-	-
2013	10,914,353	2,511,711	13,426,064	10,914,353	2,511,711	13,426,064	-	-	-
2014	9,331,898	2,912,908	12,244,806	9,331,898	2,912,908	12,244,806	-	-	-
2015	7,818,795	3,221,646	11,040,441	7,818,795	3,221,646	11,040,441	-	-	-
2016	7,431,611	2,512,938	9,944,549	7,431,611	2,512,938	9,944,549	-	-	-
2017	6,926,548	3,899,413	10,825,961	6,926,548	3,899,413	10,825,961	-	-	-
2018	6,496,000	3,511,898	10,007,898	6,485,714	3,511,898	9,997,612	-	-	-
2019	6,283,307	3,256,299	9,539,606	6,283,307	3,256,299	9,539,606	-	-	-
2020	5,817,128	2,909,686	8,726,814						

In Table 7.16 differences in percentage between emissions from landfills reported in the updated time series and 2021 submission are presented. Some minor recalculations occurred because of the update of sludge activity data since 2007 while the main update, and the consequent recalculation, is due to the new waste characterization applied starting from 2016.

Table 7.16 Differences in percentage between emissions from landfills reported in the updated time series and 2021 submission

EMISSIONS	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Managed Landfills										
VOC produced (Gg)	0.00%	0.00%	0.00%	0.00%	0.01%	0.08%	0.10%	-0.28%	-0.69%	-1.07%
VOC recovered (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CH_4 net emissions (Gg)	0.00%	0.00%	0.00%	0.00%	0.03%	0.15%	0.18%	-0.50%	-1.21%	-1.84%
NMVOC net emissions (Gg)	0.00%	0.00%	0.00%	0.00%	0.03%	0.15%	0.18%	-0.50%	-1.21%	-1.84%
Unmanaged Landfills										
VOC produced (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
VOC recovered (Gg)	-	-	-	-	-	-	-	-	-	-
CH_4 net emissions (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NMVOC net emissions (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

7.2.6 Source-specific planned improvements

Currently, more recent data on the fraction of CH_4 in landfill gas and on the amount of landfill gas collected and treated are under investigation. Based on the last review process, CO_2 emissions from HWP in SWDS are under investigations. In the current submission, as discussed during the review process in an intersectoral way (LULUCF and waste team), a revision of the method used to estimate the HWP in Solid Waste Disposal Sites has been applied: the waste team has implemented the HWP sheet used in the IPCC FOD model to estimate the long-term storage of C in waste disposal sites and the annual change in total long-term C storage in HWP waste.

7.3 Biological treatment of solid waste (5B)

7.3.1 Source category description

Biological treatment of solid waste is a key category for N_2O emissions at level (for 2020) and trend assessment but only with the Approach 2. Under this source category CH_4 and N_2O emissions from compost production and CH_4 emissions from anaerobic digestion of waste have been reported. NMVOC emissions from compost production have been estimated too. The amount of waste treated in composting and digestion plants has shown a great increase from 1990 to 2020 (from 283,879 Mg to 6,818,914 Mg for composting and from 79,440 Mg to 2,309,097 Mg for anaerobic digestion).

Information on input waste to composting plants are published yearly by ISPRA since 1996, including data for 1993 and 1994 (ANPA, 1998; APAT-ONR, several years; ISPRA, several years), while for 1987 and 1995 only data on compost production are available (MATTM, several years [a]; AUSITRA-Assoambiente, 1995); on the basis of this information the whole time series has been reconstructed. Regarding anaerobic digestion, the same sources of information have been used to reconstruct the time series until 2004 while ISPRA publishes yearly more accurate data from 2005.

7.3.2 Methodological issues

Composting

The composting plants are classified in two different kinds: plants that treat a selected waste (food, market, garden waste, sewage sludge and other organic waste, mainly from the agro-food industry); and mechanical-biological treatment plants, where the unselected waste is treated to produce compost, refuse derived fuel (RDF), and a waste with selected characteristics suitable for landfilling or incinerating systems.

It is assumed that 100% of the input waste to the composting plants from selected waste is treated as compost, while in mechanical-biological treatment plants 30% of the input waste is treated as compost on the basis of national studies and references (Favoino and Cortellini, 2001; Favoino and Girò, 2001).

In previous submissions, literature data (Hogg, 2001) have been used for the emission factor, 0.029 g CH_4 kg^{-1} treated waste, corresponding to the minimum of the range proposed by 2006 IPCC Guidelines on a wet weight basis. This choice has been taken because in the 2006 IPCC Guidelines the default value (4 g CH_4/kg waste treated) is clearly shifted towards high values because most of world plants does not use advanced technologies.

The majority of references reported in Table 4.1 of 2006 IPCC Guidelines that have found high emission factors referred to composting time of 10-14 months, low turning frequency and no aeration system. In Italy, almost all of the plants are industrial plants (216/279 >1000 Mg/year in 2014), with enclosed areas for rotting and decomposition served by biofilters, turning when needed (to maintain the right porosity) and, above all, forced ventilation or suction system. Following the discussion started during the effort sharing decision review (EU, 2016) a specific survey on methane emission factor from composting and the relationship with technologies and management practices has been conducted (ISPRA, 2017) resulting in a new emission factor equal to 0.65 kg CH_4/Mg waste treated on a wet weight basis. As reported in the IPCC Guidelines, Table 4.1, the emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.

NMVOC emissions have also been estimated: emission factor (51 g NMVOC kg^{-1} treated waste) is from international scientific literature too (Finn and Spencer, 1997). In Table 7.17 and in Figure 7.5, activity data expressed in wet weight, CH_4, N_2O and NMVOC emissions are reported.

Anaerobic digestion

The anaerobic digestion plants too are subdivided in the same two different kinds: plants that treat a selected waste and mechanical-biological treatment plants.

It is assumed that 100% of the input waste to the plants from selected waste is treated as anaerobic digestion, while in mechanical-biological treatment plants 15% of the input waste is considered as anaerobically digested. The default IPCC 2006 emission factor has been used. Since the plants are closed systems, emissions are related to the possibility of gas leaks estimated in 5 % of potential emissions.

Table 7.17 CH_4, N_2O and NMVOC emissions from biological treatment of solid waste, 1990 – 2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Activity data											
Amount of waste to composting process (Gg ww)	283.88	657.22	2,834.31	5,550.89	7,030.81	7,288.30	7,414.86	7,302.93	7,192.29	7,085.97	6,818.91
Amount of waste to composting process (Gg dw)	113.55	262.89	1,133.72	2,220.36	2,812.32	2,915.32	2,965.94	2,921.17	2,876.91	2,834.39	2,727.57
Amount of waste to anaerobic digestion (Gg ww)	79.44	127.43	467.80	1,407.20	1,976.36	2,303.17	2,330.25	2,422.17	2,385.20	2,450.63	2,309.97
Amount of waste to anaerobic digestion (Gg dw)	31.78	50.97	187.12	562.88	790.54	921.27	932.10	968.87	954.08	980.25	923.99
CH_4											
Compost production (Gg)	0.185	0.427	1.842	3.608	4.570	4.737	4.820	4.747	4.675	4.606	4.432
Anaerobic digestion (Gg)	0.003	0.005	0.019	0.056	0.079	0.092	0.093	0.097	0.095	0.098	0.092
N_2O											
Compost production (Gg)	0.068	0.158	0.680	1.332	1.687	1.749	1.780	1.753	1.726	1.701	1.637
NMVOC											
Compost production (Gg)	0.014	0.033	0.144	0.282	0.357	0.370	0.377	0.371	0.365	0.360	0.346

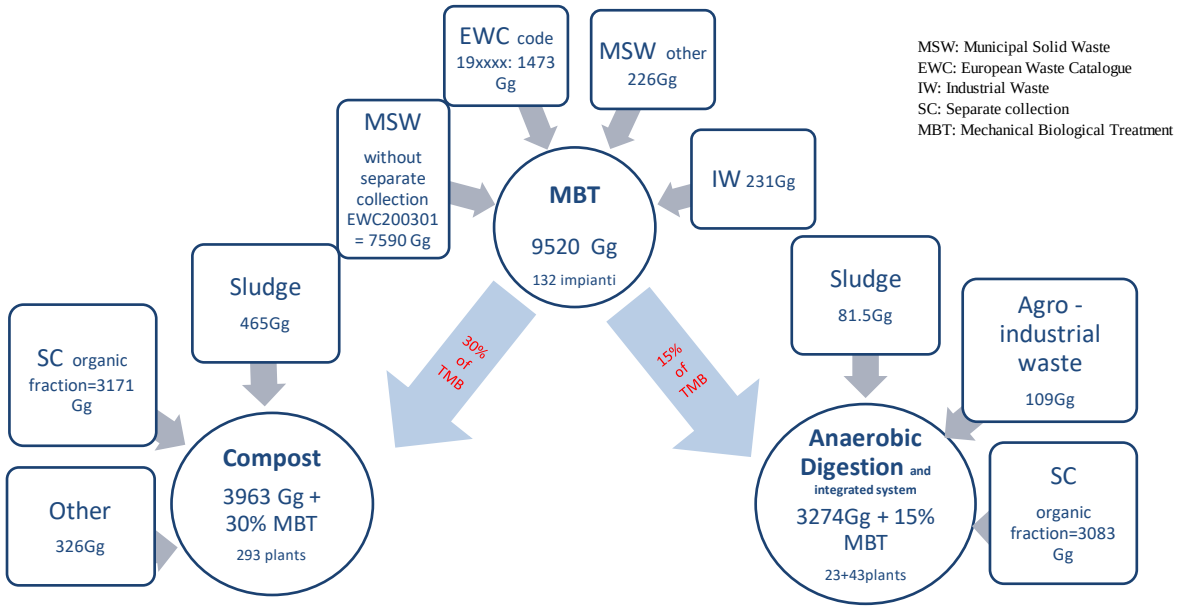


Figure 7.5 Waste treated in compost and anaerobic plants in 2020

7.3.3 Uncertainty and time-series consistency

The uncertainty in CH_4 emissions from biological treatment of waste is estimated to be about 100% in annual emissions, 20% and 100% concerning activity data and emission factors respectively. The uncertainty in N_2O emissions from biological treatment of waste is estimated to be about 100% in annual emissions, 20% and 100% concerning activity data and emission factors, respectively.

7.3.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures. Moreover, as concerns composting, an in depth survey has been conducted in 2017 investigating literature and plant data. Results are reported in (ISPRA, 2017).

7.3.5 Source-specific recalculations

Recalculations occur in 2019 because of the update of activity data for mechanical biological treatments.

Table 7.18 CH_4 and N_2O recalculations for biological treatment of solid waste, 1990 – 2019

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
CH_4										
Compost production (Gg)	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%
Anaerobic digestion (Gg)	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%
N_2O										
Compost production (Gg)	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%

7.3.6 Source-specific planned improvements

Anaerobic digestion of solid waste is under investigation to collect more information about technologies and emission factors.

7.4 Waste incineration (5C)

7.4.1 Source category description

Existing incinerators in Italy are used for the disposal of municipal waste, together with some industrial waste, sanitary waste and sewage sludge for which the incineration plant has been authorized by the competent authority. Other incineration plants are used exclusively for industrial and sanitary waste, both hazardous and not, and for the combustion of waste oils, whereas there are few plants where residual waste from waste treatments, as well as sewage sludge, are treated. Since 2007, the activity of co-incineration in industrial plants, especially to produce wooden furniture, has increased significantly, resulting in an increase of the relevant emissions related to the proportion of waste burned.

Emissions from incineration of human bodies in crematoria have been estimated too.

As mentioned above, emissions from waste incineration facilities with energy recovery are reported under category 1A4a (Combustion activity, commercial/institutional sector, see Table 7.12) in the “Other fuel” and “Biomass” subcategory for the fossil and biomass fraction of wastes, respectively, whereas emissions from other types of waste incineration facilities are reported under category 5C (Waste incineration). For 2020, about 99% of the total amount of waste incinerated is treated in plants with energy recovery system.

A complete database of the incineration plants is now available, updated with the information reported in the yearly report on waste production and management published by ISPRA (APAT-ONR, several years; ISPRA, several years).

Emissions from removable residues from agricultural production are included in the IPCC category 5C: the total residues amount and carbon content have been estimated by both IPCC and national factors. The detailed methodology is reported in Chapter 5 (5.6.2).

CH_4 and N_2O emissions from biogenic, plastic and other non-biogenic wastes have been calculated.

7.4.2 Methodological issues

Regarding GHG emissions from incinerators, the methodology reported in the IPCC Good Practice Guidance (IPCC, 2000) has been applied, combined with that reported in the CORINAIR Guidebook

(EMEP/CORINAIR, 2007; EMEP/EEA, 2009; EMEP/EEA, 2019). A single emission factor for each pollutant has been used combined with plant specific waste activity data. Since 2010, NO_x, SO_2 and CO emission factors for urban waste incinerators have been updated on the basis of data provided by plants (ENEA-federAmbiente, 2012; De Stefanis P., 2012).
As regard incineration plants, emissions have been calculated for each type of waste: municipal, industrial, hospital, sewage sludge and waste oils.
A complete database of these plants has been built, on the basis of various sources available for the period of the entire time series, extrapolating data for the years for which no information was available (MATTM, several years [a]; ANPA-ONR, 1999 [a] and [b]; APAT, 2002; APAT-ONR, several years; AUSITRA-Assoambiente, 1995; Morselli, 1998; FEDERAMBIENTE, 1998; FEDERAMBIENTE, 2001; AMA-Comune di Roma, 1996; ENI S.p.A., 2001; COOU, several years; Fondazione per lo sviluppo sostenibile e FISE UNIRE, 2016).
For each plant a lot of information is reported, among which the year of the construction and possible upgrade, the typology of combustion chamber and gas treatment section, if it is provided with energy recovery (thermal or electric), and the type and amount of waste incinerated (municipal, industrial, etc.).
Different procedures were used to estimate emission factors, according to the data available for each type of waste, except CH_4 and N_2O emission factor that is derived from EMEP Corinair (EMEP/CORINAIR, 2007).
Specifically:

1 for municipal waste, emission data from a large sample of Italian incinerators were used (FEDERAMBIENTE, 1998; ENEA-federAmbiente, 2012);
2 for industrial waste and waste oil, emission factors have been estimated on the basis of the allowed levels authorized by the Ministerial Decree 19 November 1997, n. 503 of the Ministry of Environment;
3 for hospital waste, which is usually disposed of alongside municipal waste, the emission factors used for industrial waste were also applied;
4 for sewage sludge, in absence of specific data, reference was made to the emission limits prescribed by the Guidelines for the authorisation of existing plants issued on the Ministerial Decree 12 July 1990.

In Table 7.19, emission factors are reported in kg per tons of waste treated, for municipal, industrial, hospital waste, waste oils and sewage sludge.

Table 7.19 Waste incineration emission factors

POLLUTANT/WASTE TYPOLOGY	NMVOC (kg/t)	CO (kg/t)	CO_2 fossil (kg/t)	N_2O (kg/t)	NO_x (kg/t)	SO_2 (kg/t)	CH_4 (kg/t)
Municipal waste 1990 - 2009	0.46	0.07	295.17	0.1	1.15	0.39	0.06
Municipal waste since 2010	0.46	0.07	467.50	0.1	0.62	0.02	0.06
Hospital waste	7.4	0.075	1200	0.1	0.604	0.026	0.06
Sewage sludge	0.25	0.6	0	0.227	3	1.8	0.06
Waste oils	7.4	0.075	3000.59	0.1	2	1.28	0.06
Industrial waste	7.4	0.56	1200	0.1	2	1.28	0.06

Here below (Tables 7.20, 7.21, 7.22, 7.23), details about data and calculation of specific emission factors are reported. Emission factors have been estimated on the basis of a study conducted by ENEA (De Stefanis, 1999), based on emission data from a large sample of Italian incinerators (FEDERAMBIENTE, 1998; AMA-Comune di Roma, 1996), legal thresholds (Ministerial Decree 19 November 1997, n. 503 of the Ministry of Environment; Ministerial Decree 12 July 1990), the last study conducted by ENEA and federAmbiente (ENEA-federAmbiente, 2012) and expert judgements.
The CO_2 implied emission factor for waste incineration varies annually and depends on the fossil carbon fraction in line with the variation of waste composition thath varies yearly on the basis of the amount of annual municipal, industrial and hospital waste and the quantity of sewage sludge to burn.
In details, from 1990 to 2009 CO_2 emission factor for municipal waste has been calculated considering a carbon content equal to 23%; moreover, on the basis of the IPCC Guidelines (IPCC, 2006) and referring to the average content analysis on a national scale (De Stefanis P., 2002), a distinction was made between CO_2 from fossil fuels (generally plastics) and CO_2 from renewable organic sources (paper, wood, other organic materials). Only emissions from fossil fuels, which are equivalent to 35% for municipal waste, were included in the inventory. In the last submissions, further improvement has been carried out; with the aim to upgrade the C content in municipal waste an analysis on waste composition in recent years has been conducted resulting in a

carbon content for municipal waste equal to 25.5% (ISPRA, 2010) and a subdivision between fossil and renewable fuels equal to 50-50%. These updates have been applied starting from 2010. Regarding the other waste components, C in sludge is considered completely organic, while C in industrial and hospital waste are considered completely fossil carbon according to the national definitions of these type of wastes. Mortal remains are not part of hospital waste but are included in the activity data used to estimate emissions from crematories; C in this case is considered completely organic.CO_2 emission factor for industrial, oils and hospital waste has been derived as the average of values of investigated industrial plants.
On the other hand, CO_2 emissions from the incineration of sewage sludge were not included at all, while all emissions relating to the incineration of hospital and industrial waste were considered.
In this way, the resulting CO_2 emission factor for waste incineration varies in line with the variations of waste composition as can be seen in table 5.C of the CRF tables.
In Table 7.24 activity data are reported by type of waste.

Table 7.20 Municipal waste emission factors

MUNICIPAL WASTE	Average concentration values (mg/Nm^3)		Standard specific flue gas volume (Nm^3/KgMSW)		E.F. (g/Mg)	
	1990-2009	2010-	1990-2009	2010-	1990-2009	2010-
SO_2	78.00	2.17	5	6.7	390	18
NO_x	230.00	97.08			1,150	621
CO	14.00	12.30			70	73
N_2O					100	100
CH_4					59.80	59.80
NMVOC					460.46	460.46
C content, % weight	23	25.5				
CO_2					843.3 (kg/Mg)	935.4(kg/Mg)

Table 7.21 Industrial waste and oils emission factors

INDUSTRIAL AND OIL WASTE	Average concentration values (mg/Nm^3)	Standard specific flue gas volume (Nm^3/KgMSW)	E.F. (g/t)
SO_2	160.00	8	1,280
NO_x	250.00		2,000
CO	70.00		560
N_2O			100
CH_4			59.80
NMVOC			7,400
CO_2			1,200 (kg/t)

Table 7.22 Hospital waste emission factors

HOSPITAL WASTE	Average concentration values (mg/Nm^3)	Standard specific flue gas volume (Nm^3/KgMSW)	E.F. (g/t)
SO_2	3.24	8	26
NO_x	75.45		604
CO	9.43		75
N_2O			100
CH_4			59.80
NMVOC			7,400
CO_2			1,200 (kg/t)

Table 7.23 Sewage sludge emission factors

SEWAGE SLUDGE	Average concentration values (mg/Nm^3)	Standard specific flue gas volume (Nm^3/KgMSW)	E.F. (g/t)
SO_2	300	6	1,800
NO_x	500		3,000
CO	100		600
N_2O			100
CH_4			59.80
NMVOC			251.16
CO_2			700 (kg/t)

Table 7.24 Amount of waste incinerated by type, 1990 – 2020 (Gg)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Total Waste incinerated	1,656	2,149	3,062	4,964	6,977	7,535	7,588	7,477	7,726	7,510	7,514
- with energy recovery	911	1,558	2,750	4,721	6,796	7,431	7,501	7,386	7,634	7,420	7,427
- without energy recovery	745	591	312	244	181	103	87	91	92	90	87
Total Waste incinerated - Carbon content (Gg)	439	560	773	1,309	1,970	2,123	2,161	2,132	2,195	2,141	2,149
MSW incinerated	1,026	1,437	2,325	3,220	4,337	4,698	4,454	4,325	4,577	4,359	4,280
- with energy recovery	626	1,185	2,161	3,168	4,284	4,698	4,454	4,325	4,577	4,359	4,280
- without energy recovery	399	251	164	52	53	0	0	0	0	0	0
MSW incinerated - Carbon content (Gg)	236	330	535	741	1,106	1,199	1,136	1,103	1,168	1,112	1,092
Industrial Waste incinerated											
Other waste	*473*	*536*	*604*	*1,602*	*2,499*	*2,709*	*3,024*	*3,033*	*3,020*	*3,058*	*3,145*
- with energy recovery	258	330	508	1,446	2,399	2,676	2,988	2,999	2,991	3,022	3,110
- without energy recovery	215	206	96	155	100	33	36	34	29	36	35
Other waste - Carbon content (Gg)	155	175	198	524	818	887	990	993	988	1,001	1,029
Hospital waste	*134*	*152*	*110*	*126*	*135*	*102*	*105*	*100*	*108*	*78*	*76*
- with energy recovery	25	41	77	106	113	57	59	62	65	39	37
- without energy recovery	109	111	34	21	23	45	46	38	43	39	38
Hospital waste- Carbon content (Gg)	44	50	36	41	44	33	34	33	35	25	25
Sludge	*20.72*	*23.18*	*21.50*	*15.60*	*5.98*	*25.10*	*4.97*	*18.39*	*20.49*	*14.06*	*13.64*
- with energy recovery	0.00	0.00	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- without energy recovery	20.72	23.18	18.11	15.60	5.98	25.10	4.97	18.39	20.49	14.06	13.64
Sludge - Carbon content (Gg)	3.96	4.43	4.10	2.98	1.14	4.79	0.95	3.51	3.91	2.68	2.60
Waste oil	*2.66*	*1.41*	*0.82*	*0.67*	*0.18*	*0.46*	*0.27*	*0.30*	*0.42*	*0.23*	*0.29*
- with energy recovery	1.77	0.94	0.55	0.54	0.18	0.46	0.27	0.30	0.42	0.23	0.29
- without energy recovery	0.89	0.47	0.27	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste oil - Carbon content (Gg)	0.87	0.46	0.27	0.22	0.06	0.15	0.09	0.10	0.14	0.07	0.10

CH_4 and N_2O emissions from agriculture residues removed, collected and burnt 'off-site', as a way to reduce the amount of waste residues, are reported in the waste incineration sub-sector.

Removable residues from agriculture production are estimated for each crop type (cereal, green crop, permanent cultivation) taking into account the amount of crop produced, the ratio of removable residue in the crop, the dry matter content of removable residue, the ratio of removable residue burned, the fraction of residues oxidised in burning, the carbon and nitrogen content of the residues. Most of these wastes refer especially to pruning of olives and wine, because of the typical national cultivation.

Emissions due to stubble burning, which are emissions only from the agriculture residues burned on field, are reported in the agriculture sector, under 3.F, more info is also rported in the Annex 7. Under the waste sector the burning of removable agriculture residues that are collected and could be managed in different ways (disposed in landfills, used to produce compost or used to produce energy) is reported.

Different percentages of the removable agriculture residue burnt for different residues are assumed, varying from 10% to 90%, according to national and international literature. Moreover, these removable wastes are

assumed to be all burned in open air (e.g. on field) taking in consideration the higher (without abatement) available CO, NMVOC, PM, PAH and dioxins emission factors. The amount of these wastes treated differently is not supplied, but they are included in the respective sectors (landfill, composting, biogas production for energy purposes, etc.).
The methodology is the same used to calculate emissions from residues burned on fields, in the category 3F, described in detail in Chapter 5.
On the basis of carbon and nitrogen content of the residues, CH_4 and N_2O emissions have been calculated, both accounting nearly for 100% of the whole emissions from waste incineration. CO_2 emissions have been calculated but not included in the inventory as biomass. All these parameters refer both to the IPCC Guidelines (IPCC, 2006) and country-specific values (CESTAAT, 1988; Borgioli, 1981).
The amount of biomass from pruning used for domestic heating is reported in the energy sector in the 1A4b category as biomass fuel.
As recommended during the 2019 UNFCCC review, to enhance transparency on the total amount of crop residues generated and shares of the crop residue amounts used for different purposes (such as bedding material (3.D.a.2.a), left on fields (3.D.a.4), burnt on-site (3.F) and off-site (1.A, 5.C.2)), a flow-chart is reported in Annex 7, in Figure A.7.1.
As regard incineration of corpses in crematoria, activity data have been supplied by a specific branch of Federutility, which is the federation of energy and water companies (SEFIT, several years).
In Table 7.25 time series of cremation as well as annual deaths and crematoria in Italy are reported.

Table 7.25 Cremation time series (activity data), 1990 – 2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Cremations (no. of corpses)	5,809	15,436	30,167	48,196	77,379	137,168	141,555	170,903	183,146	194,669	247,840
Deaths (no. of corpses)	543,700	555,203	560,241	567,304	587,488	653,000	615,261	649,061	633,133	634,432	746,146
Mortal remains (no.)	1,000	1,750	1,779	9,880	18,899	34,178	36,608	36,425	37,538	38,305	29,266
Cremation percentage	1.07	2.78	5.38	8.50	13.17	21.01	23.01	26.33	28.93	30.68	33.22
Crematoria (no.)	NA	31	35	43	53	70	75	79	83	85	87

The major emissions from crematoria are nitrogen oxides, carbon monoxide, sulphur dioxide, particulate matter, mercury, hydrogen fluoride (HF), hydrogen chloride (HCl), NMVOCs, other heavy metals, and some POPs.
In Table 7.26 emission factors for cremation are reported; all emission factors are from (SEFIT, 2015; SEFIT, 2019) except for CH_4 and N_2O, assumed equal to MSW emission factor because values were not available. CO_2 emissions have been not calculated for the inventory as human body is 'biomass'.

Table 7.26 Cremation emission factors

POLLUTANT/WASTE TYPOLOGY	NMVOC (kg/body)	CO (kg/body)	N_2O (kg/t)	NO_x (kg/body)	SO_2 (kg/body)	CH_4 (kg/t)
Cremation	0.009	0.005	0.1	0.474	0.009	0.06

Since the 2020 submission, CO_2 emissions from open burning of waste have been considered. Open burning of waste is forbidden in Italy but sometimes it illegally occurs. Estimates are based on 2006 IPCC Guidelines, in particular the paragraph 5.3.2 to define the amount of waste open burned using data about population, the fraction of "rural people", the per capita waste production and estimating the rate of the waste amount that is burned relative to the total amount of waste treated on the bases of recent national data (Bfrac=0.4%). In the following table activity data and CO_2 emissions have been reported.

Table 7.27 Open burning of waste time series, 1990 – 2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Pfrac	9.4%	9.4%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.4%	9.4%
Bfrac	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
MSW_B (Gg)	8.36	9.69	10.43	11.40	10.63	10.84	10.65	10.86	10.81	10.42	10.39
CO_2 (Gg) fossil	2.47	2.86	3.08	3.36	4.97	5.07	4.98	5.08	5.05	4.87	4.86
CO_2 (Gg) organic	4.58	5.31	5.71	6.25	4.97	5.07	4.98	5.08	5.05	4.87	4.86

CH_4 and N_2O emission factore are under investigations.

7.4.3 Uncertainty and time-series consistency

The combined uncertainty in emissions from waste incineration is estimated to be about 22.4%, 10% and 20% for activity data and emission factors respectively.

The time series of activity data, distinguished in Municipal Solid Waste and other (including cremation), is shown in Table 7.28; CO_2 emission trends for each type of waste category are reported in Table 7.29, both for plants without energy recovery, reported under 5C, and plants with energy recovery, reported under 1A4a. In Table 7.30 N_2O and CH_4 emissions are summarized, including those from open burning and cremation.

In the period 1990-2020, total CO_2 emissions have increased by 464%, but whereas emissions from plants with energy recovery have increased by nearly 991%%, emissions from plants without energy recovery decreased by 83% (Table 7.28). While CO_2 emission trend reported in 5C is influenced by the amount of waste incinerated in plant without energy recovery, CH_4 and N_2O emission trend are related to the open burning, as already reported above.

Table 7.28 Waste incineration activity data, 1990 – 2020 (Gg)

Activity Data	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
MSW Production (Gg)	22,231	25,780	28,959	31,664	32,479	29,524	30,112	29,572	30,158	30,079	28,945
MSW Incinerated (%)	4.6%	5.6%	8.0%	10.2%	13.4%	15.9%	14.8%	14.6%	15.2%	14.5%	14,8%
- in energy recovery plants	2.8%	4.6%	7.5%	10.0%	13.2%	15.9%	14.8%	14.6%	15.2%	14.5%	14,8%
MSW to incineration (Gg)	1,026	1,437	2,325	3,220	4,337	4,698	4,454	4,325	4,577	4,359	4,280
Industrial, Sanitary, Sewage Sludge and Waste Oil to incineration (Gg)	631	712	737	1,744	2,640	2,836	3,134	3,152	3,149	3,151	3,234
Cremation (no. of corpses)	5,809	15,436	30,167	48,196	77,379	137,168	141,555	170,903	183,146	194,669	247,840
Total Waste to incineration, excluding cremation (5C and 1A4a) (Gg)	**1,656**	**2,149**	**3,062**	**4,964**	**6,977**	**7,535**	**7,588**	**7,477**	**7,726**	**7,510**	**7514**

Table 7.29 CO_2 emissions from waste incineration (without and with energy recovery), 1990 – 2020 (Gg)

CO_2 Emissions	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Incineration of domestic or municipal wastes (Gg)	117.83	74.12	48.26	15.32	24.74	0.00	0.00	0.00	0.00	0.00	0.00
Incineration of industrial wastes (except flaring) (Gg)	257.99	247.11	115.74	186.50	119.88	40.19	43.39	41.32	34.75	43.40	42.11
Incineration of hospital wastes (Gg)	131.07	132.73	40.36	24.61	27.12	53.57	54.65	45.79	51.20	47.16	45.76
Incineration of waste oil (Gg)	2.66	1.41	0.82	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Incineration of corpses	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste incineration (5C) (Gg)	510	455	205	227	172	94	98	87	86	91	88

CO_2 Emissions	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Waste incineration reported under 1A4a (Gg) – not biomass	530	798	1,341	2,799	5,017	5,477	5,739	5,696	5,809	5,712	5,778
Waste incineration reported under 1A4a (Gg) - biomass	343	650	1,185	1,737	2,003	2,196	2,082	2,022	2,140	2,038	2,001
Total waste incineration – fossil (Gg)	1,039	1,254	1,546	3,026	5,189	5,571	5,837	5,783	5,894	5,802	5,866

Table 7.30 N_2O and CH_4 emissions from waste incineration (cremation and open burning included), 1990 – 2020 (Gg)

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
N_2O (Gg)											
Waste incineration (5C)	0.12	0.12	0.09	0.09	0.08	0.07	0.07	0.07	0.06	0.06	0.07
MSW incineration reported under 1A4a – not biomass	0.05	0.08	0.13	0.27	0.47	0.51	0.53	0.52	0.53	0.52	0.53
MSW incineration reported under 1A4a – biomass	0.04	0.08	0.14	0.21	0.21	0.23	0.22	0.22	0.23	0.22	0.21
CH_4 (Gg)											
Waste incineration (5C)	2.00	2.32	2.23	2.46	2.33	2.32	2.41	2.26	2.19	2.18	2.24
MSW incineration reported under 1A4a – not biomass	0.03	0.05	0.08	0.16	0.28	0.30	0.32	0.31	0.32	0.31	0.32
MSW incineration reported under 1A4a – biomass	0.02	0.05	0.08	0.12	0.13	0.14	0.13	0.13	0.14	0.13	0.13

7.4.4 Source-specific QA/QC and verification

Several verifications were carried out on the basis of the analysis of documentation supplied in the framework of IPPC permits and of environmental reports.

7.4.5 Source-specific recalculations

Recalculations occur since 2018 because of update of activity data.

Table 7.31 Differences in percentages between time series reported in the updated time series and 2021 submission

GAS/SUBSOURCE	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
CO_2 (Gg)										
Waste incineration (5C)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	76.23%	79.66%
MSW incineration reported under 1A4a - fossil	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.64%	-4.88%
N_2O (Gg)										
Waste incineration (5C)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.98%	0.98%
MSW incineration reported under 1A4a - fossil	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.58%	-4.51%
CH_4 (Gg)										
Waste incineration (5C)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.06%
MSW incineration reported under 1A4a - fossil	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.58%	-4.51%

7.4.6 Source-specific planned improvements

No further improvements are planned for the next submission.

7.5 Wastewater handling (5D)

7.5.1 Source category description

Under source category 5D, CH_4, N_2O and NMVOC are estimated both from domestic and industrial wastewater. The principal by-product of the anaerobic decomposition of the organic matter in wastewater is methane gas. Normally, CH_4 emissions are not encountered in untreated wastewater because even small amounts of oxygen tend to be toxic to the organisms responsible for the production of methane. Occasionally, however, as a result of anaerobic decay in accumulated bottom deposits, methane can be produced. Again, wastewater collected in closed underground sewers is not believed to be a significant source of CH_4 (IPCC, 2006).

In 2020, the 99.5% of population is served by sewer systems, whereas 88% of population is served by wastewater treatment plants (BLUE BOOK, several years; COVIRI, several years; ISTAT [d], [e], several years). In 1990, the percentage of population served by sewer system was 57%, whereas only 52% of population was served by wastewater treatment plants (BLUE BOOK, several years; COVIRI, several years; ISTAT [d], [e], several years).

In Italy, domestic wastewaters follow the treatment systems and discharge pathways reported in Figure 7.6, whereas in **brown** are enhanced CH_4 sources.

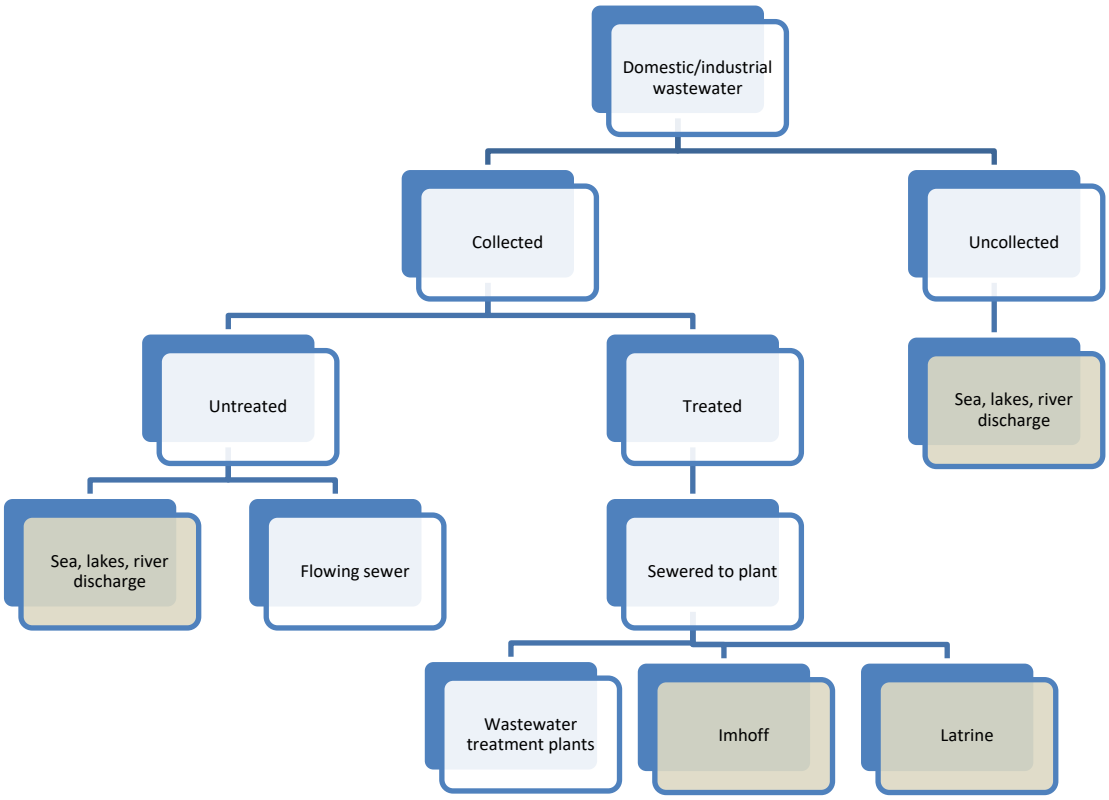


Figure 7.6 Domestic wastewater treatment system and discharge pathways

Methane is produced from the anaerobic treatment process used to stabilize wastewater sludge.

The plant typology is usually distinguished in ‘primary’ (only physical-chemical unit operations such as sedimentation), ‘secondary’ (biological unit process) or ‘advanced’ treatments, defined as those additional treatments needed to remove suspended and dissolved substances remaining after conventional secondary treatment.

In urban areas, wastewater handling is managed mainly using a secondary treatment, with aerobic biological units: a wastewater treatment plant standard design consists of bar racks, grit chamber, primary sedimentation, aeration tanks (with return sludge), settling tank, chlorine contact chamber. The stabilization of sludge occurs in aerobic or anaerobic reactors; where anaerobic digestion is used, the reactors are covered and provided of gas recovery.

On the contrary, in rural areas, wastewaters are treated in Imhoff tanks or in other on-site systems, such as latrines.

For high strength organic waste, such as some industrial wastewater, anaerobic process is recommended also for wastewater besides sludge treatment.
It is assumed that industrial wastewaters are treated 85% aerobically and 15% anaerobically (IRSA-CNR, 1998).
Emissions from methane recovered, used for energy purposes, in wastewater treatment plants are estimated and reported under category 1A4a, as reported in Table 7.12.

7.5.2 Methodological issues

Emissions from domestic wastewater – CH_4

CH_4 emissions from domestic wastewater are estimated using a Tier 2 approach, according to new 2006 IPCC Guidelines (IPCC, 2006).
The general equation used to estimate CH_4 emissions from domestic wastewater is:

$$CH_4 \text{ emissions} = [\ \Sigma_{i,j}\ (\ U_i * T_{i,j} * EF_j\ )] * (TOW - S) - R \text{ (kg } CH_4\text{/yr)}$$

where:

TOW = total organics in wastewater in inventory year (kg BOD/yr)
S = organic component removed as sludge in inventory year (kg BOD/yr)
U_i = fraction of population in income group i in inventory year
$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i in inventory year
i = income group: rural and urban high income (urban low income is not considered in national inventory, for the typical Italian urbanization)
j = each treatment/discharge pathway or system
EFj = emission factor (kg CH_4/kg BOD)
R = amount of CH_4 recovered in inventory year (kg CH_4/yr)

An in-depth analysis of national circumstances has been made, collecting many statistical data on population and on urban wastewater treatment plants (BLUE BOOK, several years; COVIRI, several years; ISTAT, 1984; ISTAT, 1987; ISTAT, 1991; ISTAT, 1993; ISTAT [a], [b], 1998; ISTAT [d], [e], several years).
Some data, such as the degree of collected or treated wastewater are available for specific year, so the entire time series has been reconstructed with interpolation of data.
In the following tables (7.32, 7.33, 7.34), domestic wastewater population data are reported.

Table 7.32 Population data for domestic wastewater, 1990 – 2020 (*1000)

Population Activity Data	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Total Population	56,778	56,844	56,961	58,289	59,948	60,164	60,067	59,938	59,817	59,641	59,236
Urban high-income Population	52,947	53,134	53,372	54,867	56,602	56,938	56,866	56,761	56,664	56,513	56,132
Rural Population	3,831	3,710	3,589	3,422	3,347	3,225	3,201	3,177	3,153	3,129	3,104
Population served by collected wastewater systems (%)	57.0	69.8	86.0	83.0	90.1	99.4	99.4	99.5	99.5	99.5	99.5
Population served by wastewater treatment plants (%)	51.9	58.0	60.0	69.0	76.1	82.2	83.4	84.6	85.8	87.0	88.2

Table 7.33 Urban high-income Population for domestic wastewater, 1990 – 2020 (*1000)

Urban high-income Population	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Population not served by collected wastewater systems	22,761	16,042	7,472	9,327	5,588	342	327	312	297	283	267
Population served by collected wastewater systems	30,186	37,092	45,900	45,540	51,013	56,597	56,539	56,449	56,366	56,230	55,865
Pop. collected and treated	15,678	21,507	27,540	31,422	38,830	46,501	47,136	47,744	48,356	48,919	49,277
Pop. collected untreated	14,508	15,585	18,360	14,117	12,183	10,096	9,402	8,705	8,011	7,311	6,589
sea/lake/river discharge	8,705	9,351	11,016	8,470	7,310	6,058	5,641	5,223	4,806	4,387	3,953
flowing sewer discharge	5,803	6,234	7,344	5,647	4,873	4,038	3,761	3,482	3,204	2,925	2,635

Table 7.34 Rural Population data for domestic wastewater, 1990 – 2020 (*1000)

Rural Population	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Population not served by collected wastewater systems	1,647	1,120	502	582	330	19	18	17	17	16	15
Population served by collected wastewater systems	2,184	2,590	3,087	2,840	3,016	3,206	3,183	3,160	3,136	3,113	3,090
Pop. treated in Imhoff tanks	421	647	845	468	635	967	1,102	1,120	1,138	1,156	1,174
Pop. treated in latrines	1,763	1,943	2,242	2,373	2,381	2,239	2,081	2,040	1,998	1,957	1,915

The emission factor for a wastewater treatment and discharge pathway and system is a function of the maximum CH_4 production potential B_0 and the methane correction factor (MCF) for the wastewater treatment and discharge system, as indicated as following:

$$EF_j = B_0 * MCF_j$$

The default B_0 value (0.6 kg CH_4/kg BOD) and default MCF values have been used.

Type of treatment and discharge pathway or system	MCF
Untreated system	
Sea, river and lake discharge	0.1
Flowing sewer	0
Treated system	
Centralized, aerobic treatment plants	0.05
Anaerobic digester for sludge	0.8
Imhoff tanks	0.5
Latrines	0.1

The total amount of organically degradable material in the wastewater is calculated from the human population and the BOD generation per person:

$$TOW = P * BOD * 0.001 * I * 365$$

where:
TOW = total organics in wastewater in inventory year (kg BOD/yr)
P = country population in inventory year (person)
BOD = country specific per capita BOD in inventory year (g/person/day)
0.001 = conversion from grams to kg BOD
I = correction factor for additional industrial BOD discharged into sewers (I = 1.25, IPCC 2006).
The parameter I, equal to 1.25 has been applied both for collected and uncollected wastewater, in order to consider illegal wastewater spills from industry or craft activities that are not taking into account in official statistics and other industries and establishments (e.g., restaurants, butchers or grocery stores) that can co-discharged with domestic wastewater.
The organic load in biochemical oxygen demand per person is equal to 60 g BOD_5 $capita^{-1}$ d^{-1}, as defined by national legislation and expert estimations (Legislative Decree 11 May 1999, no.152; Masotti, 1996; Metcalf and Eddy, 1991).

The total organics in sludge (TOW sludge) has been estimated half of total organics in wastewater, according to international literature (Metcalf and Eddy, 1991), that states that the typical reduction in volatile solids achieved in anaerobic digestion for mixed sludge (primary plus secondary) varies from 45 to 60 percent.
In the following table 7.35, the total amount of organically degradable material expressed in tons, calculated for each treatment/discharge pathway or system is reported.

Table 7.35 Total organically degradable material in domestic wastewater, 1990 – 2020 (t BOD)

TOW (t BOD)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Urban high-income Population											
TOW uncollected wastewater	623,069	439,148	204,547	255,337	152,984	9,352	8,951	8,546	8,144	7,735	7,299
TOW wastewater treatment plant	429,195	588,761	753,901	860,185	1,062,969	1,272,957	1,290,361	1,306,990	1,323,741	1,339,155	1,348,948
TOW sludge	214,598	294,381	376,951	430,093	531,485	636,478	645,181	653,495	661,871	669,578	674,474
TOW untreated (sea/lake/river)	238,289	255,979	301,560	231,876	200,113	165,825	154,429	142,974	131,574	120,091	108,219
TOW untreated (flowing sewer)	158,860	170,653	201,040	154,584	133,409	110,550	102,952	95,316	87,716	80,061	72,146
Rural Population											
TOW uncollected wastewater	45,088	30,665	13,755	15,925	9,045	530	504	478	453	428	404
TOW Imhoff	11,535	17,705	23,129	12,799	17,378	26,467	30,156	30,653	31,149	31,646	32,143
TOW latrines	48,263	53,197	61,366	64,955	65,192	61,300	56,974	55,839	54,704	53,569	52,433

As previously reported, in Italy wastewater handling is managed mainly using a secondary treatment, with aerobic biological units. The stabilization of sludge occurs in aerobic or anaerobic reactors covered and provided of gas recovery. All the anaerobic digestion systems are equipped with systems to collect the methane produced. The methane collected is partly flared and partly used for energy purposes. The total methane recovered is estimated on the basis of the methane production and the efficiency of captation. Where anaerobic digestion of sludge is used, the reactors are covered and provided of gas recovery and the efficiency of captation isequal to 100% In fact, in Italy, anaerobic digestion tanks for sludge stabilization in wastewater treatment plants are built with fixed covered: fix covered provide a free space between the roof of the digester and the liquid surface. Gas storage is provided so that when the liquid volum is changed, gas, not air, will be drawn into the digester, and gas will not be lost by displacement.
CH_4 emissions from sludge have been subtracted from the total amount of CH_4 produced, because emissions from sludge from wastewater treatment are considered in landfills, agricultural soils and incineration.
Moreover, CH_4 recovery has been distinguished between flaring and CH_4 recovery for energy generation, which has been reported in the Energy Sector.

Emissions from domestic wastewater –N_2O
Nitrous oxide (N_2O) emissions can occur as direct and indirect emissions. Direct emissions occur from nitrification and denitrification in wastewater treatment plants, whereas indirect emissions are those from wastewater after disposal of effluent into waterways, lakes or sea.
Emissions from advanced centralised wastewater treatment plants are typically much smaller than those from effluent and are estimated using the method reported in Box 6.1 of the Volume 5, Chapter 6 of new 2006 IPCC Guidelines (IPCC, 2006).

Direct emissions

$$N_2O_{PLANTS} = P * T_{PLANT} * F_{IND-COM} * EF_{PLANT}$$

where:
N_2O_{PLANTS} = total N_2O emissions from plants in inventory year (kg N_2O/yr)
P = human population

T_{PLANT} = degree of utilization of modern, centralised wastewater treatment plants (%)
$F_{IND-COM}$ = fraction of industrial and commercial co-discharged protein (default = 1.25)
EF_{PLANT} = emission factor, 3.2 g N_2O/person/year

Indirect emissions

$$N_2O_{EMISSIONS} = N_{EFFLUENT} * EF_{EFFLUENT} * 44/28$$

where:
$N_2O_{EMISSIONS}$ = N_2O emissions in inventory year (kg N_2O/yr)
$N_{EFFLUENT}$ = nitrogen in the effluent discharged to aquatic environments (kg N/yr)
$EF_{EFFLUENT}$ = emission factor for N_2O emissions from discharged to wastewater assumed equal to 0.005 (kg N_2O-N/kg N)

Moreover:

$$N_{EFFLUENT} = N_{EFFLUENT\,TOT} - N_{SLUDGE} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE}$$

where:
$N_{EFFLUENT}$ = nitrogen in the effluent discharged to aquatic environments (kg N/yr)
P = human population
Protein = annual per capita protein consumption (kg/person/yr)
F_{NPR} = fraction of nitrogen in protein (default = 0.16 kg N/kg protein)
$F_{NON-COM}$ = fraction of non consumed protein added to the wastewater
$F_{IND-COM}$ = fraction of industrial and commercial co-discharged protein (default = 1.25)
N_{SLUDGE} = nitrogen removed with sludge (kg N/yr)
The time series of the protein intake is from the yearly FAO Food Balance (FAO, several years) and refers to the Italian value. The estimation procedure checks for consistency with sludge produced and sludge applications, as sludge applied to agriculture soils, sludge incinerated, sludge composting and sludge deposited in solid waste disposal. Sludge spreading is subtracted from nitrogen in the effluent discharged to aquatic environments and is not accounted for twice.
For the parameter $F_{NON-COM}$ the value of 1.1 it is assumed, because, even if Italy is a developed country, garbage disposals of food that is not consumed and may be washed down the drain are not used.

Emissions from industrial wastewater – CH_4
The methane estimation concerning industrial wastewaters makes use of the IPCC method based on wastewater output and the respective degradable organic carbon for each major industrial wastewater source. Default emission factors of methane per Chemical Oxygen Demand (COD) equal to 0.25 kg CH_4 kg^{-1} COD, suggested in the 2006 IPCC Guidelines (IPCC, 2006), has been used for the whole time series.
It is assumed that industrial wastewaters are treated 85% aerobically and 15% anaerobically (IRSA-CNR, 1998).
Data have been collected for several industrial sectors (iron and steel, refineries, organic chemicals, food and beverage, paper and pulp, textiles and leather industry). The total amount of organic material, for each industry selected, has been calculated multiplying the annual production (t $year^{-1}$) by the amount of wastewater consumption per unit of product (m^3 t^{-1}) and by the degradable organic component (kg COD $(m^3)^{-1}$). Moreover, the fraction of industrial degradable organic component removed as sludge has been assumed equal to zero. The yearly industrial productions are reported in the national statistics (ISTAT, several years [a], [b] and [c]), whereas the wastewater consumption factors and the degradable organic component are either from 2006 IPCC Guidelines (IPCC, 2006) or from national references. National data have been used in the calculation of the total amount of both COD produced and wastewater output specified as follows: refineries (UP, several years), organic chemicals (FEDERCHIMICA, several years), beer (Assobirra, several years), wine, milk and sugar sectors (ANPA-ONR, 2001), pulp and paper sector (ANPA-FLORYS, 2001; Assocarta, several years), and leather sector (ANPA-FLORYS, 2000; UNIC, several years).
In Table 7.36 detailed references for 2020 are reported: for these national data, slightly differences within the years can occur.

Emissions from industrial wastewater – N_2O
N_2O emissions from industrial wastewater have been estimated on the basis of the emission factors equal to 0.25 g N_2O/m^3 of wastewater production (EMEP/CORINAIR, 2007). EMEP/EEA Guidelines, after 2007

version, does not report any N_2O E.F but, about the methodology to estimate N_2O emissions from industrial wastewater, they refer to 2006 IPCC Guidelines. In 2006 IPCC Guidelines it is written that industrial wastewater may be treated on site or released into domestic wastewater. In the national inventory, the fraction of industrial wastewater relased into domestic wastewater it is estimated because of the parameter $F_{IND-COM}$. For the fraction treated on site 0.25 g N_2O/m^3 has been applied to the volume of wastewater generated for type of industry.
The wastewater production is resulting from the model for the estimation of methane emissions from industrial wastewater.

Table 7.36 Wastewater generation and COD values, 2020.

	Wastewater generation (m^3/t)	References	COD (g/l)	References
Coke	1.5	IPCC, 2000	0.1	IPCC, 2000
Petroleum Refineries	UNIONE PETROLIFERA supplies Total COD generated per year			
Organic Chemicals	22.3	FEDERCHIMICA, several years	3	IPCC, 2000
Paints	5.5	IPCC, 2000	5.5	IPCC, 2000
Plastics and Resins	0.6	IPCC, 2000	3.7	IPCC, 2000
Soap and Detergents	3	IPCC, 2000	0.9	IPCC, 2000
Vegetables, Fruits and Juices	20	IPCC, 2000	5.2	IPCC, 2000
Sugar Refining	4	ANPA-ONR, 2001	2.5	ANPA-ONR, 2001
Vegetable Oils	3.1	IPCC, 2000	1.2	IPCC, 2000
Dairy Products	3.87	ANPA-ONR, 2001	2.7	ANPA-ONR, 2001
Wine and Vinegar	3.8	ANPA-ONR, 2001	0.2	ANPA-ONR, 2001
Beer and Malt	4.2	Assobirra, several years	2.9	IPCC, 2000
Alcohol Refining	24	IPCC, 2000	11.0	IPCC, 2000
Meat and Poultry	13	IPCC, 2000	4.1	IPCC, 2000
Fish Processing	13	same value of Meat and Poultry	2.5	IPCC, 2000
Paper	25	Assocarta, several years	0.1	ANPA-FLORYS, 2001; Assocarta, several years
Pulp	25	Assocarta, several years	0.1	ANPA-FLORYS, 2001; Assocarta, several years
Textiles (dyeing)	60	IPCC, 1995	1.0	IPCC, 2000
Textiles (bleaching)	350	IPCC, 1995	1.0	IPCC, 2000
Leather	0.10	UNIC, several years	4.71	UNIC, several years

In the Table 7.37, N_2O emissions from industrial wastewater are reported, together with the deriving nitrogen in effluent (kt N-N_2O), that is reported in the CRF table 5.D. In the CRF Reporter GHG inventory software the table related to the category 5.D.2 requests, among the others, the N in effluent (kt) as well as the IEF (kg N_2O-N/kg N); N in effluent is calculated with the following formula, assuming the default emission factor 0.25 kg N_2O-N/kg N (IPCC, 2006):
N in effluent (kt) = N_2O emissions (kt) / IEF (kg N_2O-N/kg N) *28/44

As N_2O emissions from industrial wastewater are estimated on the basis of the cubic meters of wastewater produced by a specific industry and the emission factor equal to 0.25 g N_2O/m^3 (EMEP/CORINAIR, 2007), it was not possible to report this value in the CRF Reporter: consequently, we were forced to derive the N in effluent from the N_2O emissions by multiplying for the conversion factor 28/44 and dividing for the IEF 0.25 kg N2O-N/kg N, the maximum for a cautelative reason.

Table 7.37 N_2O emissions from industrial wastewater, 1990 – 2020 (kt)

N_2O Emissions (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Industrial wastewater											
Industrial wastewater production (1000 m^3)	908,840	928,479	920,614	867,085	717,846	659,246	696,608	691,463	708,427	697,032	654,197
EF (g/m^3)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
N_2O Emissions (kt N_2O)	0.227	0.232	0.230	0.217	0.179	0.165	0.174	0.173	0.177	0.174	0.164
N in effluent (kt)	0.578	0.591	0.586	0.552	0.457	0.420	0.443	0.440	0.451	0.444	0.416

Emissions from domestic and industrial wastewater – NMVOC

Emissions from NMVOC has been also estimated, both from domestic and industrial wastewaters, using a default emission factor derived from Guidebook published by the European Environmental Agency with the CLRTAP Task Force on Emission Inventories and Projections (EMEP/EEA, 2016).

In Table 7.38 NMVOC emissions from domestic and industrial wastewater are reported for the whole time series.

Table 7.38 NMVOC emissions from domestic and industrial wastewater, 1990 – 2020 (kt)

NMVOC Emissions (t)	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
Domestic wastewater										
Equivalent inhabitants	46,435,617	60,015,346	65,600,590	73,426,011	76,847,364	75,238,909	85,490,844	86,899,080	88,307,315	89,715,550
Domestic wastewaters production (1000 m3)	4,237,250	5,476,400	5,986,054	6,700,124	7,012,322	6,865,550	7,801,040	7,929,541	8,058,042	8,186,544
Per capita water supply (lt./person*die)	250	250	250	250	250	250	250	250	250	250
EF (mg/m3)	15	15	15	15	15	15	15	15	15	15
NMVOC Emissions (t)	**63.6**	**82.1**	**89.8**	**100.5**	**105.2**	**103.0**	**117.0**	**118.9**	**120.9**	**122.8**
Industrial wastewater										
Industrial wastewaters production (1000 m3)	908,840	928,479	920,614	867,085	717,846	659,246	696,608	691,463	708,427	697,032
EF (mg/m3)	15	15	15	15	15	15	15	15	15	15
NMVOC Emissions (t)	**13.6**	**13.9**	**13.8**	**13.0**	**10.8**	**9.9**	**10.4**	**10.4**	**10.6**	**10.5**

7.5.3 Uncertainty and time-series consistency

The combined uncertainty in CH_4 and N_2O emissions from wastewater handling is estimated to be about 102% in annual emissions 100% and 20% for activity data and emission factor respectively, as derived by the IPCC Guidelines (IPCC, 2000; IPCC, 2006).

Concerning domestic wastewater, CH_4 emission trends are shown in Table 7.39, whereas the emission trend for N_2O emissions is shown in Table 7.40.

Table 7.39 CH_4 emissions from domestic wastewater, 1990 – 2020 (t)

CH_4 Emissions (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Urban high-income Population											
CH_4 uncollected wastewater	37,384	26,349	12,273	15,320	9,179	561	537	513	489	464	438
CH_4 wastewater treatment plant	6,478	8,913	11,496	13,012	16,136	19,263	19,533	19,793	20,046	20,302	20,303
CH_4 anaerobic digestion	103,007	141,303	180,936	206,444	255,113	305,510	309,687	313,677	317,698	321,397	323,748
CH_4 untreated (sea/lake/river)	14,297	15,359	18,094	13,913	12,007	9,950	9,266	8,578	7,894	7,205	6,493
CH_4 untreated (flowing sewer)	0	0	0	0	0	0	0	0	0	0	0
Rural Population											
CH_4 uncollected wastewater	2,705	1,840	825	956	543	32	30	29	27	26	24
CH_4 Imhoff	3,460	5,312	6,939	3,840	5,213	7,940	9,047	9,196	9,345	9,494	9,643
CH_4 latrines	2,896	3,192	3,682	3,897	3,912	3,678	3,418	3,350	3,282	3,214	3,146

CH_4 Emissions (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CH_4 total produced	170,227	202,266	234,244	257,381	302,101	346,933	351,518	355,137	358,782	362,102	363,794
CH_4 recovered	103,007	141,303	180,936	206,444	255,113	305,510	309,687	313,677	317,698	321,397	323,748
CH_4 flared	103,007	140,583	179,473	205,802	250,613	285,108	289,116	292,026	297,317	299,834	302,042
CH_4 energy recovery	0	719	1,463	643	4,500	20,401	20,570	21,652	20,381	21,563	21,706
CH_4 total emissions	**67,220**	**60,964**	**53,308**	**50,937**	**46,989**	**41,423**	**41,832**	**41,460**	**41,084**	**40,705**	**40,047**

Table 7.40 N_2O emissions from domestic wastewater, 1990 – 2020 (t)

N_2O Emissions (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
N_2O emissions from wastewater effluent (Indirect emissions)	3,911	3,787	4,010	4,037	4,129	3,900	3,865	3,898	3,911	3,876	3,762
N_2O emissions from wastewater treatment plants (Direct emissions)	86.9	84.2	91.1	155.2	151.9	160.6	160.3	160.0	159.6	159.2	158.1
N_2O total emissions	3,997	3,871	4,101	4,192	4,281	4,061	4,025	4,058	4,070	4,035	3,920

The amount of total industrial wastewater production is reported, for each sector, in Table 7.41.
CH_4 emission trend for industrial wastewater handling for different sectors is shown in Table 7.42, whereas the emission trend for N_2O emissions from industrial wastewater handling is shown again in Table 7.43.
Concerning CH_4 emissions from industrial wastewater, neither wastewater flow nor average COD value change much over time, therefore emissions are stable and mainly related to the production data.

Table 7.41 Total industrial wastewater production by sector, 1990 – 2020 (1000 m^3)

Wastewater production (1000 m^3)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Iron and steel	9.53	7.78	6.76	6.86	6.17	2.97	2.97	2.87	2.92	2.83	2.17
Oil refinery	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Organic chemicals	210.94	212.32	215.05	214.74	214.12	213.80	213.27	214.24	214.05	213.93	213.67
Food and beverage	179.12	177.38	182.74	185.66	186.26	177.91	187.88	179.05	183.75	186.54	181.45
Pulp and paper	377.17	402.95	387.28	366.02	232.69	202.64	232.67	235.06	246.67	238.78	216.88
Textile industry	108.46	103.05	101.57	75.49	64.36	48.90	47.13	46.82	47.75	42.85	29.92
Leather industry	23.62	25.00	27.22	18.32	14.25	13.03	12.69	13.40	13.29	12.10	10.12
Total	908.840	928.479	920.614	867.085	717.846	659.246	696.608	691.463	708.427	697.032	654.197

Table 7.42 CH_4 emissions from anaerobic industrial wastewater treatment, 1990 – 2020 (kt)

CH_4 Emissions (kt)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Iron and steel	0.036	0.029	0.025	0.026	0.023	0.011	0.011	0.011	0.011	0.011	0.008
Oil refinery	5.850	5.625	4.250	4.750	4.750	4.750	4.750	4.750	4.750	4.750	4.750
Organic chemicals	23.794	23.911	24.173	24.177	24.069	23.998	23.899	24.101	24.062	24.046	24.014
Food and beverage	22.946	22.112	22.871	23.197	23.447	22.575	24.125	22.830	23.531	23.905	22.736
Pulp and paper	0.923	0.986	1.055	0.997	0.544	0.552	0.634	0.640	0.672	0.650	0.591
Textile industry	4.067	3.864	3.809	2.831	2.414	1.834	1.768	1.756	1.791	1.607	1.122
Leather industry	3.192	3.378	3.677	2.901	2.517	2.272	2.242	2.368	2.348	2.138	1.788
Total	60.81	59.91	59.86	58.88	57.76	55.99	57.43	56.46	57.16	57.11	55.01

Table 7.43 N_2O emissions from industrial wastewater, 1990 – 2020 (kt)

N_2O Emissions (kt)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Industrial wastewater	0.227	0.232	0.230	0.217	0.179	0.165	0.174	0.173	0.177	0.174	0.164

7.5.4 Source-specific QA/QC and verification

Where information is available, wastewater flows and COD concentrations are checked with those reported yearly by the industrial sectoral reports or technical documentation developed in the framework of the Integrated Pollution and Prevention Control (IPPC) Directive of the European Union (http://eippcb.jrc.es).
Moreover, in the framework of EPER/E-PRTR registry the methodology used to estimate emissions from wastewater handling can be used by the operators of wastewater treatment plants to check if their emission data exceed the reporting threshold values.
Finally, a Ph.D. thesis on GHG emissions from wastewater handling has been carried out at Environmental, Hydraulic, Infrastructures and Surveying Engineering Department (DIIAR) of Politecnico di Milano (Solini, 2010), where national methodology has been compared with that reported in 2006 IPCC Guidelines (IPCC, 2006) and with a methodology developed in the framework of a previous thesis Ph.D. for the estimation of emissions from wastewater treatment plants located in Regione Lombardia.

7.5.5 Source-specific recalculations

Several recalcualtions have occurred in wastewater handling category. The main recalculation regards the population: the time series have been revised because of un update by the National Institute of Statistics (ISTAT, 2006; ISTAT, 2021). Minor recalculations regard the annual per capita protein consumption value from 2014 to 2019, because un update of FAO Food Balance (FAO, several years); sludge disposed into landfills and sludge incinerated for the year 2019; lastly, sludge production and sludge spread into soils for the Italian region Emilia Romagna for the year 2019. In Table 7.44, the time series for population and consequently for CH_4 emitted are reported for both the 2021 and the current submission.

Table 7.44 Differences between time series reported in the updated time series and 2021 submission

Differences Submission 2021/2022	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Total Population (submission 2021) - *1000	57,104	57,333	57,844	58,752	60,626	60,666	60,589	60,484	60,360	60,245
Total Population (submission 2022) - *1000	56,778	56,844	56,961	58,289	59,948	60,164	60,067	59,938	59,817	59,641
Urban high-income Population (submission 2021) - *1000	53,272	53,623	54,255	55,330	57,280	57,440	57,388	57,307	57,207	57,116
Urban high-income Population (submission 2022) - *1000	52,947	53,134	53,372	54,867	56,602	56,938	56,866	56,761	56,664	56,513
CH_4 total emitted (submission 2021) - tons	67,220	60,964	53,308	50,937	46,989	41,423	41,832	41,460	41,084	40,705
CH_4 total emitted (submission 2022) - tons	67,538	61,347	53,811	51,183	47,243	41,516	41,922	41,547	41,164	40,787

7.5.6 Source-specific planned improvements

According with the 2021 annual submission review process, where the ERT encouraged the Party to pursue investigation into a different methodology for estimating total biogas production and revise the amount of CH_4 flared, a draft methodology has been applied, with substantial differences in biogas production. Total gas production is estimated usually from the percentage of volatile solids reduction: typical values vary from 0.75 to 1.12 m^3/kg of volatile solids destroyed (Metcalf and Eddy, 1991): unfortunally data on volatile solids abatement are not available at present. Gas production can also be crudely estimated on a per capita basis: the normal yeld is 15 to 22 $m^3/10^3$person·day in primary plants treating normal domestic wastewater; in secondary treatment plants the gas production increase to about 28 $m^3/10^3$person·day. Applying this parameter, the total gas production and consequently the CH_4 production has been estimated as reported in the following Table 7.45. Differences are very important, thus further investigations, concerned also volatile solids destroyed, are planned.

Table 7.45 CH_4 production from anaerobic digestion of sludge, estimated with IPCC methodology and Metcalf and Eddy parameters

Total Gas Production in anaerobic digestion	1990	1995	2000	2005	2010	2015	2020
TOW sludge (kg BOD/year)	214,597,690	294,380,746	376,950,614	430,092,574	531,484,619	636,478,432	674,474,078
CH_4 anaerobic digestion - IPCC Guidelines (kg CH_4/year)	103,006,891	141,302,758	180,936,295	206,444,436	255,112,617	305,509,647	323,747,558
CH_4 anaerobic digestion - Metcalf and Eddy (kg CH_4/year)	54,211,645	74,366,432	95,225,223	108,649,939	134,263,586	160,787,112	170,385,568

Further improvements are welcome as soon as additional data will be available. We expect that environmental reports from industry will be improved each passing year. Moreover, specific survey on those industries that produce considerable amounts of wastewater with significant organic carbon levels are planned, in order to revise the methodology for estimating emissions from industrial wastewater, according to the revised 2019 IPPC Guidelines.

8 RECALCULATIONS AND IMPROVEMENTS

8.1 Explanations and justifications for recalculations

To meet the requirements of transparency, consistency, comparability, completeness and accuracy of the inventory, the entire time series from 1990 onwards is checked and revised every year during the annual compilation of the inventory. Measures to guarantee and improve these qualifications are undertaken and recalculations should be considered as a contribution to the overall improvement of the inventory.

Recalculations are elaborated on account of changes in the methodologies used to carry out emission estimates, changes due to different allocation of emissions as compared to previous submissions, changes due to error corrections and in consideration of new available information.

The complete revised CRFs from 1990 to 2019 have been submitted as well as the CRF for the year 2020. Explanatory information on the recalculations involving methodological changes between the 2021 and 2022 submissions are reported in Table 8.1.

The revisions that lead to relevant changes in GHG emissions are pointed out in the specific sectoral chapters and summarized in the following section 8.4.1.

8.2 Implications for emission levels

The time series reported in the 2022 submission is summarised in Table 8.2 by gas; differences in emission levels due to recalculations are also reported.

Improvements in the calculation of emission estimates have led to a recalculation of the entire time series of the national inventory. Considering total GHG emissions without LULUCF, estimates show a decrease in comparison with the last year submission, equal to 0.12% for 1990 and a decrease of 0.04% for 2019. Considering the national total with the LULUCF sector, the year 1990 has decreased by 0.17% and the 2019 emission levels increased by 2.86%.

Detailed explanations of these recalculations are provided in the sectoral chapters.

Table 8.1 Explanations of the main recalculations in the 2022 submission

Implementing Regulation Article 16: Reporting on major changes to methodological descriptions		
Please report the major changes to the methodological descriptions in the national inventory report since its submission due on 15 April of the previous year, in the table below:		

Member State:	ITALY		
Reporting year:	2022		

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please **mark the relevant cell** where the latest NIR includes major changes in methodological descriptions compared to the NIR of the previous year	Please **mark the relevant cell** where this is also reflected in recalculations compared to the previous years' CRF	If the cell is marked please provide a reference to the relevant section or pages in the NIR and if applicable some more detailed information such as the sub-category or gas concerned for which the description was changed.
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (sectoral approach)			
1. Energy industries			
2. Manufacturing industries and construction			
3. Transport			
4. Other sector			
5. Other			
B. Fugitive emissions from fuels			
1. Solid fuels			
2. Oil and natural gas and other emissions from energy production			
C. CO2 transport and storage			
2. Industrial processes and product use			
A. Mineral industry			
B. Chemical industry			
C. Metal industry			
D. Non-energy products from fuels and solvent use			
E. Electronic industry			
F. Product uses as substitutes for ODS	x	x	R-448A, R-449A, and R-452A gases have been added for Refrigeration since 2015 resulting in a change in consumption of R-404A and R-507A7
G. Other product manufacture and use			
H. Other			
3. Agriculture			

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please **mark the relevant cell** where the latest NIR includes major changes in methodological descriptions compared to the NIR of the previous year	Please **mark the relevant cell** where this is also reflected in recalculations compared to the previous years' CRF	If the cell is marked please provide a reference to the relevant section or pages in the NIR and if applicable some more detailed information such as the sub-category or gas concerned for which the description was changed.
A. Enteric fermentation	x	x	CH4 emissions from enteric fermentation of dairy cows since 2004 have been updated, considering weighted average of Ym for lactating and dry cows, as indicated in the 2019 IPCC Refinement. Application of the 2019 IPCC Refinement from submission 2021 for DE and Ym estimation of dairy cows
B. Manure management			
C. Rice cultivation			
D. Agricultural soils	x	x	Update of N2O emission estimate methodology for calculation of Fcr parameter and in particular estimate of N from belowground residues
E. Prescribed burning of savannahs			
F. Field burning of agricultural residues			
G. Liming			
H. Urea application			
I. Other carbon containing fertilisers			
J. Other			
4. Land use, land-use change and forestry			
A. Forest land			
B. Cropland			
C. Grassland			
D. Wetlands			
E. Settlements			
F. Other land			
G. Harvested wood products			
H. Other			
5. Waste			
A. Solid waste disposal			
B. Biological treatment of solid waste			
C. Incineration and open burning of waste			
D. Wastewater treatment and discharge			
E. Other			
6. Other (as specified in Summary 1.A)			
KP LULUCF			
Article 3.3 activities			

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please **mark the relevant cell** where the latest NIR includes major changes in methodological descriptions compared to the NIR of the previous year	Please **mark the relevant cell** where this is also reflected in recalculations compared to the previous years' CRF	If the cell is marked please provide a reference to the relevant section or pages in the NIR and if applicable some more detailed information such as the sub-category or gas concerned for which the description was changed.
Afforestation/reforestation			
Deforestation			
Article 3.4 activities			
Forest management			
Cropland management (if elected)			
Grazing land management (if elected)			
Revegetation (if elected)			
Wetland drainage and rewetting (if elected)			

NIR Chapter	**DESCRIPTION**		**REFERENCE**
	Please mark the cell where the latest NIR includes major changes in descriptions compared to the previous year NIR		**If the cell is marked please provide some more detailed information for example reference to pages in the NIR**

Table 8.2 Differences in time series between the 2022 and 2021 submissions due to recalculations

	subm	1990	1995	2000	2005	2010	2015	2017	2018	2019
CO_2 net emissions/removals (kt CO_2-eq.)	2021	434,050	428,341	452,453	465,108	390,908	315,558	328,643	328,643	328,643
	2022	434,595	429,231	453,502	466,752	393,234	319,310	319,245	319,245	319,245
Differences		*-0.13%*	*-0.21%*	*-0.23%*	*-0.35%*	*-0.59%*	*-1.17%*	*2.94%*	*2.94%*	*2.94%*
CO_2 emissions (without LULUCF) (kt CO_2-eq.)	2021	439,640	451,433	470,294	494,458	426,351	355,785	348,991	348,991	348,991
	2022	439,944	451,979	470,768	495,234	424,873	355,483	350,323	350,323	350,323
Differences		*-0.07%*	*-0.12%*	*-0.10%*	*-0.16%*	*0.35%*	*0.08%*	*-0.38%*	*-0.38%*	*-0.38%*
CH_4 emissions (kt CO_2-eq.)	2021	49,746	50,707	51,698	48,659	47,276	44,091	45,333	45,333	45,333
	2022	49,719	50,657	51,669	48,565	47,126	43,424	43,266	43,266	43,266
Differences		*0.05%*	*0.10%*	*0.06%*	*0.19%*	*0.32%*	*1.54%*	*4.78%*	*4.78%*	*4.78%*
CH_4 emissions (without LULUCF) (kt CO_2-eq.)	2021	48,263	50,361	50,765	48,299	46,919	43,801	43,852	43,852	43,852
	2022	48,236	50,311	50,737	48,206	46,769	43,133	42,870	42,870	42,870
Differences		*0.06%*	*0.10%*	*0.06%*	*0.19%*	*0.32%*	*1.55%*	*2.29%*	*2.29%*	*2.29%*
N_2O emissions (kt CO_2-eq.)	2021	26,907	28,258	29,123	28,401	19,238	17,875	18,285	18,285	18,285
	2022	27,246	28,059	29,053	28,413	19,699	18,192	18,710	18,710	18,710
Differences		*-1.24%*	*0.71%*	*0.24%*	*-0.04%*	*-2.34%*	*-1.74%*	*-2.27%*	*-2.27%*	*-2.27%*
N_2O emissions (without LULUCF) (kt CO_2-eq.)	2021	26,084	27,430	28,445	27,788	18,826	17,547	17,796	17,796	17,796
	2022	26,423	27,231	28,374	27,799	19,057	17,636	17,954	17,954	17,954
Differences		*-1.28%*	*0.73%*	*0.25%*	*-0.04%*	*-1.21%*	*-0.50%*	*-0.88%*	*-0.88%*	*-0.88%*
HFCs (kt CO_2-eq.)	2021	444	946	2,496	7,531	11,743	14,723	15,313	15,313	15,313
	2022	444	869	2,479	7,089	11,356	14,468	14,682	14,682	14,682
Differences		*0.00%*	*8.85%*	*0.71%*	*6.24%*	*3.41%*	*1.76%*	*4.30%*	*4.30%*	*4.30%*
PFCs (kt CO_2-eq.)	2021	2,907	1,492	1,488	1,940	1,520	1,688	1,314	1,314	1,314
	2022	2,907	1,492	1,488	1,940	1,520	1,688	1,629	1,629	1,629
Differences		*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-19.33%*	*-19.33%*	*-19.33%*
Unspecified mix (kt CO_2-eq.)	2021	408	680	604	550	394	472	417	417	417
	2022	410	681	605	550	394	441	377	377	377
Differences		*-0.34%*	*-0.17%*	*-0.10%*	*-0.02%*	*0.06%*	*7.04%*	*10.69%*	*10.69%*	*10.69%*
SF_6 (kt CO_2-eq.)	2021			13	33	22	28	26	28	28
	2022			13	33	20	28	28	28	28
Differences				*0.00%*	*0.00%*	*10.07%*	*-2.23%*	*-7.72%*	*1.19%*	*2.05%*
NF_3 (Gg CO_2-eq.)	2021	514,462	510,500	537,877	552,223	471,099	394,436	409,329	409,329	409,329
	2022	515,321	511,066	538,809	553,343	473,349	397,552	397,935	397,935	397,935
Differences		*-0.17%*	*-0.11%*	*-0.17%*	*-0.20%*	*-0.48%*	*-0.78%*	*2.86%*	*2.86%*	*2.86%*
Total (with LULUCF) (kt CO_2-eq.)	2021	517,746	532,419	554,106	580,600	505,773	434,044	427,708	427,708	427,708
	2022	518,363	532,640	554,464	580,851	503,989	432,878	427,862	427,862	427,862
Differences		*-0.12%*	*-0.04%*	*-0.06%*	*-0.04%*	*0.35%*	*0.27%*	*-0.04%*	*-0.04%*	*-0.04%*
Total (without LULUCF) (kt CO_2-eq.)	2021	434,050	428,341	452,453	465,108	390,908	315,558	328,643	328,643	328,643
	2022	434,595	429,231	453,502	466,752	393,234	319,310	319,245	319,245	319,245
Differences		*-0.13%*	*-0.21%*	*-0.23%*	*-0.35%*	*-0.59%*	*-1.17%*	*2.94%*	*2.94%*	*2.94%*

8.3 Implications for emission trends, including time series consistency

Recalculations account for an improvement in the overall emission trend and consistency in time series.

In comparison with the time series submitted in 2021, emission levels of the year 1990, as total emissions in CO_2 equivalent without LULUCF, slightly changed (-0.12%). If considering emission levels with LULUCF, a decrease by 0.17% is observed in total figures, in CO_2 equivalent, for 1990.

The trend 1990- 2019, without LULUCF, does not show a significant change from the previous to this year submission; the reduction in emissions, 1990-2019, is equal now to 17.4 % whereas it was 17.5% in the last year submission.

8.4 Recalculations, response to the review process and planned improvements

This chapter summarises the recalculations and improvements made to the Italian GHG inventory since the last year submission.
In addition to a new year, the inventory is updated annually by a revision of the existing activity data and emission factors in order to include new information available; the update could also reflect the revision of methodologies. Revisions always apply to the whole time series.
The inventory may also be expanded by including categories not previously estimated if sufficient information on activity data and suitable emission factors have been identified and collected.

8.4.1 Recalculations

The key differences in emission estimates occurred since the last year submission are reported in Table 8.1 and Table 8.2.
All sectors were involved in changes due to updates of activity data and some emission factor.
Specifically:

Energy. For the stationary combustion in industry and in transformation sector the CO_2 emission factors for natural gas have been slightly revised for 2017-2019 taking in account the biogas produced and feeded in the natural gas distribution network.
The whole time series of road transport emissions has been recalculated mainly as a result of of the upgrade of Copert model version used, applying the planned improvement regarding a general review of mileages and input circulation parameters.
Fugitive CH4 emissions from natural gas distribution have been recalculated because of new information provided by the relevant operators.

IPPU. Recalculations occurred for F-gases as a consequence of the revision of Commercial Refrigeration and Stationary Air Conditioning: Regarding the commercial refrigeration the recalculation is due to the introduction in 2015 of three new refrigerants, R-448A, R-449A and R-452A, as substitutes of R-404A and R-507A. The quota of these gases increased from 2015 to 2020, because of the F-gas Regulation. Besides, from this year hybrid machines were included in the estimates. These machines are similar to chillers with capacity up to 50 kW, so the parameters used for chillers were assigned to hybrid machines with the same capacity.

Agriculture. CH_4 emissions from enteric fermentation have been recalculated from 2004 considering weighted average of Ym for lactating and dry cows, according to 2019 IPCC Refinement while emissions of sheep have been updated for the whole time series, considering weighted average of Ca parameter for time spent on pasture and housing. For manure management CH_4 emissions have been recalculated because of the updating of CH_4 grazing emission factors for cattle and buffalo with average MCF value for cool and temperate zones and CH_4 emission factors for sheep, goats and horses based on the distribution of animals between cool and temperate climate zones. N_2O emissions have been recalculated mainly due to the update of indirect N2O emissions from volatilisation due to changes in NH_3 emissions, the update of NH_3 emission factors from housing for equine and sheep and goats for the whole time series, the change of the formula for estimating emissions from storage for cattle, pigs and poultry, removing the amount of N at digesters from N at housing before multiplying by the emission factor, the addition of NH_3 emissions from storage for equines and sheep and goats for the entire time series.The most relevant recalculation of the sector regarded N_2O from soils which have been recalculated because of the update of emission estimate methodology for calculation of Fcr parameter and in particular estimate of N from belowground residues increasing about 10% of N_2O emissions of the agriculture sector for the whole time series.

LULUCF. The recalculation occurred in the sector is due to the following elements reported in the table 8.3:

Table 8.3 Drivers for recalculation in the LULUCF sector

	CO_2	CH_4	N_2O
Forest land	Update of the activity data as resulting from the NFI outcomes		
Cropland	An error, related to the soil carbon stock estimation for the whole time series, was detected in previous submission and fixed.	Update of activity data (fires occuring in cropland)	An error, related to the soil carbon stock estimation for the whole time series, was detected in previous submission and fixed. The revision of soil carbon stocks led to a revision of the calculated Fsom and the related N_2O emissions
Grassland	Activity data (area of other wooded land subcategory) has been updated, based on the NFI outcomes (NFI2015). An error, related to the soil carbon stock estimation for the whole time series, was detected in previous submission and fixed.	Update of activity data (burned area)-	
Wetlands	Update of the activity data and the consequent smoothing process affecting the 2016-2019 period. Additional information on the smoothing process is reported in the section 6.1	-	-
Settlements	Update of the activity data for 2019	-	-
HWP	Update of the activity data (FAOSTAT)	-	-

Waste. Minor recalculations occurred in this sector for the update of some activity data as sludge production and sludge used for agricultural purposes time series, the population time series update by ISTAT and for waste incineration the update of few plants industrial waste activity data from 2018. Moreover, the new waste characterization has been applied starting from 2016 affecting emissions from landfills.

8.4.2 Response to the UNFCCC review process

A complete list of improvements following the UNFCCC review process is reported in Annex 12.
Improvements regarded the completeness and transparency of the information reported in the NIR.
Most of the recommendations has been addressed in this year submission. Additional information has been provided in all the sectors, more information on methodology used to estimate emissions for industrial processes (especially for F-gases estimations), estimates for the agriculture sector and LULUCF has been recalculated and the description of country specific methods and the rationale behind the choice of emission factors, activity data and other related parameters for different sector has been better detailed.

8.4.3 Planned improvements (e.g., institutional arrangements, inventory preparation)

Specific improvements are identified in the relevant chapters and specified in the 2022 QA/QC plan; they can be summarized in the following.
For the energy and industrial sectors, the database where information collected in the framework of different EU legislation, Large Combustion Plant, E-PRTR and Emissions Trading, is annually updated and improved. The database has helped highlighting the main discrepancies in information and detecting potential errors leading to a better use of these data in the national inventory. Energy data submitted to the international organizations in the framework of the Joint Questionnaire OECD/IEA/EUROSTAT will be compared with the national energy statistics with the aim to reduce the differences with the international statistics. A revision of biomass and waste fuel consumption time series is planned for the next submission on the basis of energy data communicated by the Ministry of Economic Development to the Joint Questionnaire

OECD/IEA/EUROSTAT, after a verification and comparison with data up to now used and available in the National Energy Balance reports.
Improvements for road transport sector will be connected to the availability of information regarding activity data, calculation factors and parameters, development of the methodology and update of the software.
For maritime activities further improvements will regard a verification of activity data on ship movements and emission estimates with regional environmental agencies, especially with those more affected by maritime pollution. In particular we plan to build an emission estimation database which calculate every year emissions at harbor level taking in account of the information officially provided by Italy to Eurostat per type of ship, class of tonnage and movement statistics.

For the Industrial processes sector, investigations concerning the replacement of natural raw material in clinker manufacture and in lime production are planned to better explain differences of the average emission factors in the time series. Further investigations about final market shares of urea in Italy are planned in order to check the amount of urea used in the inventory against the apparent consumption in Italy. Many improvements are planned for Fgases emissions estimates and in particular in the professional refrigeration sub-sector to try gathering more information and data on the equipment manufactured and sold over the years, the avarege charge, the operating emission factor in order to estimate the manufacturing and lifetime emissions.
For the agriculture and waste sectors, improvements will be related to the availability of new information on emission factors, activity data as well as parameters necessary to carry out the estimates. Specifically, for agriculture, further improvements are expected on information on the standard diets of cattle for fattening, for the updating of values relating to dry matter intake and Ym. Additional data and information will be collected to improve the estimation of methane emissions from sheep, in particular for the DE parameter for mature ewes and other mature sheep. Updated average temperature data will be collected to verify and update the average monthly temperatures for both the climate zones (cool and temperate) considered in the national inventory to increase accuracy of the estimates of CH_4 emissions from manure management for cattle and buffalo. A working group was set up with *Assofertilizzanti* and ISTAT to compare the statistics produced by these two bodies. The aim is also to revise the data collection questionnaire in order to detect the amount of CAN distributed throughout the country. The improvement of the waste production and management database, handled by another unit of ISPRA, is ongoing, facilitating the extrapolation and elaboration of the huge amount of information contained in the database. Analysis and elaboration e.g. on waste composition will be easier and will allow improvements in the emission estimates in the future submission.
For the LULUCF, the final result of the third NFI, hopefully available in 2022, will allow using of IPCC carbon stock change method to estimate emissions and removals for forest land remaining forest land category. Planned improvements are also related to the investigation on the end-use, the discard rates of HWP, as well as the final market use of wood in Italy. The main outcome of this investigation could be the set-up of country specific emission factors to be used in the estimation process.

Additional studies will regard the comparison between local inventories and national inventory and exchange of information with the 'local inventories' national expert group.
Further analyses will concern the collection of statistical data and information to estimate uncertainty in specific sectors by implementing Approach 2 of the IPCC guidelines. In this regards we plan to reassess the uncertainty for the same categories reported in the annex of the NIR because these are the main categories for which the analysis makes sense in consideration of the information available on parameters and underlying distributions. We will try to extend the analysis to some other key categories in the IPPU sector (chemical and mineral).

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

9 KP-LULUCF

9.1 General information

Under the Kyoto Protocol (KP), Italy reports emissions and removals from afforestation (A), reforestation (R) and deforestation (D), Article 3, paragraph 3, and emissions and removals from forest management (FM), cropland management (CM) and grazing land management (GM), Article 3, paragraph 4. The estimates for emissions and removals under Articles 3.3 and 3.4 are consistent with the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (2013 KP Supplement, IPCC, 2014) and the relevant UNFCCC Decisions (15/CMP.1, 16/CMP.1, 2/CMP.6, 2/CMP.7).

9.1.1 Definition of forest and any other criteria

The forest definition to be used in the second commitment period is the same definition adopted for the first commitment period. The forest definition adopted by Italy corresponds to the definition of the Food and Agriculture Organization of the United Nations for its Global Forest Resource Assessment (FAO FRA, 2000), which is consistent with the definition given in Decision 16/CMP.1. Forest is a land with the following threshold values for tree crown cover, land area and tree height:

a. a minimum area of land of 0.5 hectares;
b. tree crown cover of 10 per cent;
c. minimum tree height of 5 meters;

and with a minimum width of 10 meters.

Forest roads, cleared tracts, firebreaks and other open areas within the forest as well as protected forest areas are included in forest. Any plantation for wood production in former cropland is also included under forest land. Land where tree vegetation does not meet the previously listed thresholds, but it is expected to meet those within a 20-year period is also included in forest land.

9.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

Italy has elected cropland management (CM) and grazing land management (GM) as additional activities under Article 3.4. Following Decision 2/CMP.7 forest management (FM) is a mandatory activity to be accounted for under Article 3.4.

9.1.3 Description of how the definitions of each activity under Article 3.3 and FM and each elected activity under Article 3.4 have been implemented and applied consistently over time

Afforestation and *reforestation* areas have been derived from the three Italian National Forest Inventories (IFN1985, INFC2005 and the on-going INFC2015).

Deforestation data have been collected through surveys carried out in the framework of the NFIs for the years 2005 and 2012. Accordingly, deforested areas for the years 2006-2011 have been estimated through linear interpolation and for the years 2013-2020 have been estimated through linear extrapolation. Administrative records at NUT2 level collected by the National Institute of Statistics on deforested areas have been used for the period 1990-2005. In addition, it should be noted that land use changes due to wildfires are not allowed by national legislation (Law Decree 21 November 2000, n. 353, art.10.1).

The definition of *forest management* is implemented using the broader approach as described in the 2013 KP Supplement, consequently all forest land not reported under ARD activities are reported under forest management.

Concerning *deforestation* activities, in Italy land use changes from forest to other land use categories are allowed in very limited circumstances, as stated in art. 4.2 of the Law Decree n. 227 of 2001, and only upon authorization of authorities.

Lands subject to *cropland management* correspond to the cropland reported under the Convention in the year 1990 minus any land converted to forest or grassland, and plus settlement, wetlands and other land, converted to cropland, if any. Area under CM are derived from IUTI data for the years 1990, 2000, 2008 and 2012; thus, areas for the period 2013-2020 data have been estimated through linear extrapolation for the period 2012-2020.

In Italy, land subject to *grazing land management* is predominantly covered by herbaceous vegetation

(introduced or indigenous) for a period longer than five years, used for grazing or fodder harvesting and/or under practices to control the amount and type of vegetation. In the current submission, the land subject to *grazing land management* has been extended by the inclusion of all the managed grazing land of which the 'improved grazing land' or organic grazing land is a part. The organic grazing land corresponds to lands subject to inspections and certifications procedures on organic production, in accordance with the EU Regulations[51], as well as the Rural Development Regulations[52] on organic farming. Data of the area of total managed grazing land are derived from Eurostat and ISTAT, while data of grazing areas managed with organic practices are derived from the National System on Organic Farming (SINAB, http://www.sinab.it/) of the Ministry of Agriculture. Data of total managed grazing land from ISTAT are available at regional level for the period 1990-1993, for the year 1995, for the period 1998-2005, and for the period 2006-2020 under the definition of permanent fodder grassland, while data from Eurostat at regional level covers the years 1994, 1996, 1997. The time series of total managed grazing land at regional level from 1971 to 1998 were calculated by extrapolating and interpolating the available data. The area of managed grazing land not subjected to organic practices is estimated, year by year, by the difference between the area of the total managed grazing land and the area of organic (improved) grazing land.

9.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

In line with guidance provided by the 2013 KP Supplement (IPCC, 2014), a hierarchy has been established among the activities elected under Article 3.4.

In Italian context, the GM activity has a higher hierarchical order than CM activity. Furthermore, land converted from cropland to grassland is assumed to be converted into natural grassland, thus included in the CM activity. Moreover, it has been assumed that land converted to managed grazing lands comes from natural grassland; land converted to organic grazing land comes from managed grazing land not subject to inspections and certifications, in accordance with the EU Regulations on organic production.

9.2 Land-related information

Italy implements the Reporting Method 1 for lands subject to Article 3.3 and Article 3.4 activities. The area boundaries for land subject to Article 3.3 and to FM activities have been identified with the administrative boundaries of Italian regions (NUTS2). The area boundaries for land subject to GM and CM activities have been identified with the administrative boundaries of Italy (NUTS1). These areas include multiple units of land subject to *afforestation/reforestation*, *deforestation*, *forest management*, *cropland management* and *grazing land management*. Approach 2 has been used for representing land areas, together with ancillary information (see below).

Data for land use and land-use changes were obtained by the National Forest Inventories (IFN1985, IFNC2005 and the on-going INFC2015). IFN1985 was accomplished by means of systematic sampling with a single phase of information gathering on the ground. The sampling points were identified in correspondence to the nodes of a grid with a mesh of 3 km superimposed on the official Italian map on a scale of 1:25.000. Therefore, each point represents 900 ha, for a total of 33,500 points distributed within the national territory. IFNC2005 has a three-phases sampling design; the sampling units were 300,000 and were identified in correspondence to the nodes of a grid with a mesh of 1 km superimposed on the official Italian map. A first inventory phase, consisting in interpretation of 1m resolution orthophotos taken from 2002 to 2003, was followed by ground

[51] Commission Regulation (EC) n. 889/2008: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0889&from=EN; Council Regulation (EC) n. 834/2007: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:f86000&from=IT; Council Regulation (EEC) n. 2092/91: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991R2092:EN:HTML

[52] Regulation (EEC) n. 2078/92: http://ec.europa.eu/agriculture/envir/programs/evalrep/text_en.pdf;
Council Regulation (EC): n. 1257/1999 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999R1257&from=en;
Council Regulation (EC) n. 1698/2005: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005R1698&from=en;
Regulation (EU) n. 1305/2013: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:EN:PDF

surveys to assess the forest use and to detect the main qualitative attributes of Italian forests. The third phase has consisted in ground surveys to estimate the values of the main quantitative attributes of forest stands (i.e., volume of growing stock, tree density, annual growth, aboveground biomass, carbon stock, deadwood volume and biomass). A specific survey was dedicated to the soil pool, collecting soil organic carbon stock data in 1,500 sampling areas selected by the IFNC2005 original grid. The third national forest inventory, the IFNC2015, has the same three-phases sampling design of the previous one (INFC2005); the first phase of INFC2015 (orthophotos' interpretation) has been carried out in 2013, resulting in an assessment of forest land area; The NFI2015 has completed its second phase, delivering on-field measurements on the plots of the sampling grid; 2015 area data of "Forest" and of "Other Wooded Land" have been therefore modified accordingly, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated). Complete NFI2015 results will be available in the late 2022, supplying data related to current increment and stocks. Details on the management practices of area subject to CM and GM activities, their definitions and the data sources used in the estimation process are listed in the table 9.1.

Table 9.1 CM-GM: management practices, definitions and data sources

CM/GM activities	management practices	definition	CAP regulations	Data source
CM - annual crops	Arable land (Ordinary)	A kind of agriculture that does not evidence any kind of soil organic carbon stock technical maintenance		ISTAT
	Organic arable land	Management of crop wastes; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	National Information system on organic agriculture (SINAB)
	Sustainable arable land	Crop rotation; Grassing; Specific prevention for erosion; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2019
	Set aside	Natural grassing; At least one mowing	Reg. (EEC) N. 1765/1992; National decree on cross compliance implementation n. 30125/2009 and subsequent revisions	Eurostat: 1990-2016, linear extrapolation for the period 2017-2019
	Conservative practices	Zero tillage; Organic manure; Grassing; Cover crops; Minimum tillage; Crop rotation	RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE): 2008-2019
CM – perennial crops	Woody crops (Ordinary)	A kind of agriculture that does not evidence any kind of soil organic carbon stock technical maintenance		ISTAT
	Organic woody crops	Management of crop wastes; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	National Information system on organic agriculture (SINAB)
	Woody crops - Sustainable management	Crop rotation; Grassing; Specific prevention for erosion; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2019

CM/GM activities	management practices	definition	CAP regulations	Data source
	grazing land	Renewal and/or thickening of crops	National decree on cross compliance implementation n. 30125/2009 and subsequent revisions	ISTAT
GM	organic grazing land	Renewal and/or thickening of crops; Connection to zootechnics	RDPs 2000-2006: Reg. (EC) n. 1257/1999; RDPs 2007 - 2013: Reg. (EC) n. 1998/2005 and Reg. (EC) n. 74/2009; Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008; Reg. (EC) n. 1804/2007	National Information system on organic agriculture (SINAB)

9.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit to determine the land areas under Article 3.3 is 0.5 ha, which corresponds to the forest land minimum mapping unit.

9.2.2 Methodology used to develop the land transition matrix

The land transition matrix is shown in CRF Table NIR-2. The same data sources are used for the UNFCCC greenhouse gas inventory and for GHG emissions and removals estimates under Articles 3.3 and 3.4.
LUC matrices for each year of the period 1990–2020 have been assembled based on the IUTI[53] data.
Annual data for *afforestation/reforestation* areas were estimated on the basis of the forest area increase as detected by the National Forest Inventories.
Regarding *deforestation* it is assumed, on the basis of data collected so far from IUTI, that all deforestation corresponds to forest land converted to settlements. Consequently, deforested land cannot be subsequently converted to any other land use so avoiding any double counting of areas with other activities. Further, it is assumed that all deforestation occurs on FM areas. Such assumption will be verified on the basis of the results of the current IUTI survey.
For forest management, the area from NFI for the year 1990, same area reported as forest land at the beginning of the year 1990 (see CRF table 4.1 for the year 1990), has been adjusted across the time series by removing deforested areas.
Due to the technical characteristics of the IUTI assessment (i.e., classification of orthophotos), it was not possible to clearly distinguish among some subcategories in *cropland* and *grassland* categories (e.g., annual pastures vs grazing land), and between them (e.g., annual crops and grazing land). Therefore, it has been decided to aggregate the cropland and grassland categories, as detected by IUTI, and then disaggregate them into the different subcategories, using as proxies the national statistics (ISTAT, [b], [c]) related to annual crops and perennial woody crops. The cropland area has been identified as the area of land subject to *cropland management*. Data sources used to assess the area of lands to *cropland management* and to *grazing land management* are reported in table 9.1.

9.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The Italian administrative regions (NUTS2 level) have been used as the geographical units for reporting (Figure 9.1) land subject to Article 3.3 and to FM activities. The geographical boundaries for reporting GM and CM land have been identified with the administrative boundaries of Italy (NUTS1 level).

[53] Detailed information on IUTI is reported in Annex 10

Figure 9.1 Geographical boundaries of NUTS2 regions

9.3 Activity-specific information

9.3.1 Methods for carbon stock change and GHG emission and removal estimates

9.3.1.1 Description of the methodologies and the underlying assumptions used

Methods for estimating carbon stock changes and associated GHG emissions and removals for land subject to *afforestation/reforestation* and *forest management* are the same as those used for the UNFCCC greenhouse gas inventory for Forest land; details are given in par. 6.2.4 and in Annex 14. Further, following the 2011 ERT's recommendation on SOM in land under FM, Italy has decided to apply the IPCC Tier1; transparent and verifiable information that the pool is not a net source is provided in par. 9.3.1.2. Therefore, carbon stock changes in soils pool, for land subject to *forest Management*, have not been reported; IPCC Tier 1 has been also applied to dead wood and litter carbon pools of land subjected to cropland management and grazing land management; carbon stock changes from these pools under CM and GM are thus not estimated and transparent and verifiable information that the pool is not a net source is provided in par. 9.3.1.2.

Methods for estimating carbon stock changes and associated GHG emissions and removals for land subject to *cropland management* are the same used for the UNFCCC greenhouse gas inventory for cropland and for any land converted since 1990 from cropland to other land uses, except for forest. Detailed information is given in par. 6.3.4. Basically:

→ the C stock changes in the biomass pool have been estimated on the annual rate of biomass gain and loss according to equation 2.7 of the 2006 IPCC Guidelines (vol. 4, ch.2);

→ the organic C stock changes in the mineral soil have been estimated applying the equation 2.25 of the 2006 IPCC Guidelines (vol. 4, ch. 2). The IPCC default transition period (i.e., 20 years) has been considered. The country specific SOC_{ref} have been estimated as described in the par. 6.3.4. The stock change factors (FLU, FMG, FI) are reported in the table 6.19. The SOC stocks per hectare are shown in the table 9.2, per region and per management practices, for annual and perennial crops.

Table 9.2 SOC stocks per region and management practice

Region	annual crops					Perennial crops		
	Ordinary	Organic	Sustainable	Set aside	Conservative	Ordinary	Organic	Sustainable
	SOC stock (t C ha^{-1})					*SOC stock (t C ha^{-1})*		
Piemonte	49.04	74.86	56.02	65.64	65.18	72.91	109.79	71.92
Valle D'Aosta	57.29	89.45	67.07	78.13	79.15	89.72	139.09	89.08
Liguria	51.15	78.64	58.89	68.87	68.82	77.29	117.47	76.40
Lombardia	52.32	80.88	60.59	70.76	71.06	80.06	122.53	79.26
Trentino – Alto Adige	56.84	88.97	66.73	77.68	78.87	89.54	139.26	88.97

Region	annual crops					Perennial crops		
	Ordinary	Organic	Sustainable	Set aside	Conservative	Ordinary	Organic	Sustainable
	SOC stock (t C ha^{-1})					*SOC stock (t C ha^{-1})*		
Veneto	46.88	71.05	53.14	62.38	61.55	68.60	102.36	67.53
Friuli - Venezia Giulia	55.94	87.56	65.67	76.45	77.62	88.12	137.05	87.56
Emilia - Romagna	40.13	59.60	44.50	52.53	50.87	56.17	81.60	54.94
Toscana	38.18	56.43	42.11	49.78	47.98	52.88	76.32	51.64
Umbria	46.72	70.81	52.96	62.17	61.34	68.37	102.01	67.30
Marche	39.05	57.86	43.18	51.02	49.29	54.36	78.72	53.14
Lazio	39.33	58.52	43.69	51.55	50.01	55.26	80.48	54.09
Abruzzo	40.97	60.98	45.54	53.72	52.13	57.61	83.93	56.39
Molise	32.74	47.67	35.52	42.18	40.09	43.94	62.20	42.72
Campania	31.64	45.99	34.26	40.71	38.63	42.31	59.75	41.11
Puglia	29.21	42.21	31.43	37.42	35.30	38.60	54.07	37.42
Basilicata	30.64	44.37	33.05	39.31	37.17	40.67	57.16	39.46
Calabria	34.42	50.34	37.53	44.51	42.48	46.63	66.39	45.39
Sicilia	28.70	41.38	30.81	36.69	34.56	37.76	52.77	36.59
Sardegna	30.11	43.56	32.44	38.60	36.47	39.89	55.99	38.69

Methods for estimating carbon stock changes and associated GHG emissions and removals for land subject to *grazing land management* are the same used for the UNFCCC greenhouse gas inventory for grassland and for any land converted, since 1990 onward, from grassland to other land uses, except for forest. The grassland subdivision that is reported under GM includes only grassland pasture with no woody vegetation. Therefore, the application of Tier 1 approach is appropriate, since non no significant changes occur in the biomass pool and no significant stocks, and consequently no significant changes, occur in the DOM pools.
The soil carbon stock changes in the mineral soils have been estimated applying the equation 2.25 of the 2006 IPCC Guidelines (vol. 4, ch. 2). The IPCC default transition period (i.e. 20 years) has been considered. The country specific SOC_{ref} have been estimated as described in the par. 6.4.4. The stock change factors (F_{LU}, F_{MG}, F_I) are reported in the table 6.26. The SOC stocks per hectare are shown in the table 9.3, per region and per management practices described in table 9.1.

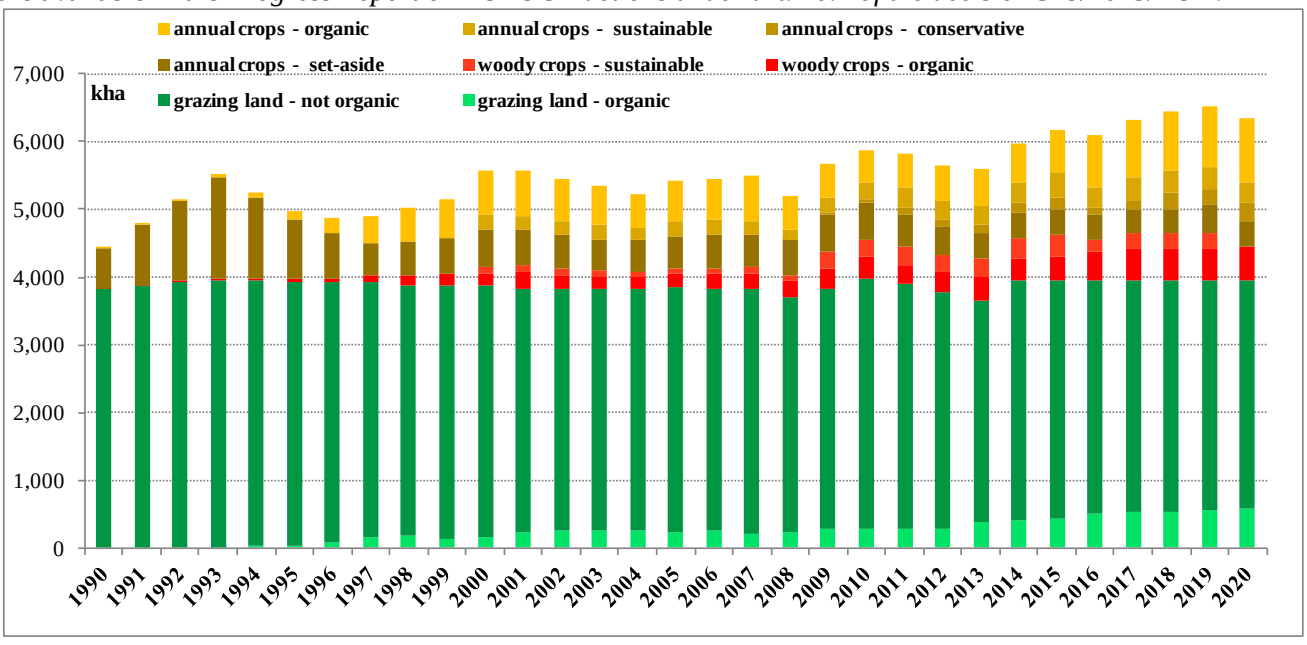
Table 9.3 SOC stocks per region and management practice

Region	grazing land	
	Ordinary	Organic
	SOC stock (t C ha^{-1})	
Piemonte	91.78	104.62
Valle D'Aosta	77.1	87.9
Liguria	92.7	105.68
Lombardia	79.93	91.13
Trentino – Alto Adige	78.51	89.5
Veneto	101.54	115.76
Friuli - Venezia Giulia	99.93	113.92
Emilia - Romagna	91.11	103.87
Toscana	62.24	70.95
Umbria	91.28	104.06
Marche	91	103.74
Lazio	88.98	101.43
Abruzzo	99.01	112.87
Molise	75.28	85.82
Campania	64.66	73.72
Puglia	42.03	47.91
Basilicata	60.13	68.55
Calabria	65.84	75.05
Sicilia	46.5	53.01
Sardegna	56.91	64.88

Methods to estimate carbon stock changes and associated GHG emissions for land subject to *deforestation* are those applied to forest land converted to settlements, as reported under the Convention. Activities planned in the framework of the registry for carbon sinks are expected to refine these estimates, providing detailed information on the final land use of the deforested area. In addition, it should be noted that land use changes due to wildfires are not allowed by national legislation (Law Decree 21 November 2000, n. 353, art.10, comma 1).
The 20-years transition period has been applied to determine the area in conversion; however, considering the nature of final land use category (settlements), and assuming that soil organic matter content of previous land use category is lost in the conversion year, the related CO_2 emissions are assumed to occur in the year following the conversion. Carbon stock changes due to deforestation have been estimated, for each year and for each pool (living biomass, dead organic matter and soils), on the basis of forest land carbon stocks present before deforestation as estimated by the *For-est* model described in par. 6.2.4 and in Annex 14. Soil organic carbon (SOC) reference value, for settlements category, has been assumed to be zero.
GHG emissions from biomass burning were estimated with the same method as described in par. 6.12.2 and Annex 15. CO_2 emissions due to forest fires in areas subject to art. 3.3 and *forest management* activities have been included in corresponding tables. In particular, CO_2 emissions from biomass burning in land subject to art 3.3 activities are included in CRF table 4(KP-I)A.1.1, Losses (Aboveground and belowground pools), while CO_2 emissions from burnt areas under *forest management* are included in CRF table 4(KP-I)B.1, Forest Management, Losses (Aboveground and belowground pools). GHG emissions from biomass burning from lands subject to CM and GM activities have been reported in the CRF table (KP-II)4.

9.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

Tier1 is applied for litter and deadwood pools in CM and GM. On one side, these pools are not estimated as dead organic matter (DOM) carbon stocks (and their changes) are insignificant in annual crops and GM. On the other side, DOM carbon stocks are assumed to be at equilibrium, with insignificant C stock changes, in perennial crops. Considering that agricultural practices within the European Union policies are increasingly sustainable and climate-friendly (see figure 9.2), and that the area of annual and perennial crops is progressively decreasing over time, any comparison among GHG fluxes in the base year and in the CP-years results in a net sink. Therefore, DOM pools cannot be considered a net C source under any circumstances. The key driver for the increasing trend of sustainable management practices in Europe (and consequently in Italy) is the *Common Agricultural Policy*[54] (CAP); additional information, detailed for management practices in Italy, are available in the *Progress Report on LULUCF actions under art. 10.2 of the decision 529/2013/EU*[55].



[54] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#title
[55] http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/italy-progress-report-on-lulucf-article-10-2-of-dec-529-update-2020/view

Figure 9.2 Area of management practices under cropland and grazing land in Italy in the period 1990-2020

Following the main finding of 2011 review process, Italy has decided not to account for the SOC changes in mineral soils from activities under *forest management*, providing transparent and verifiable information to demonstrate that SOM in mineral soils is not a source, as required by par. 21 of the annex to decision 16/CMP.1.

Art. 3.4 – Forest Management: demonstration that SOM in mineral soils is not a source
Carbon stock changes in minerals soils, for *Forest land remaining Forest land* and for land under art. 3.4 (*Forest Management*) activities, have been inferred from stock changes estimated in the aboveground biomass through linear regression i.e., SOC = f ($C_{Aboveground}$); consequently the carbon stock changes in mineral soils is calculated as:

$$\Delta_{SOC} = f\left(C_{Aboveground}\right)_{time\ 2} - f\left(C_{Aboveground}\right)_{time\ 1}$$

per forestry use – stands (conifers, broadleaves, mixed stands) and coppices. These equations have been calculated on data collected within the European project BioSoil[56], for SOM, and a Life+ project FutMon[57] (*Further Development and Implementation of an EU-level Forest Monitoring System*), for the aboveground biomass. SOC stock values in mineral soils were assessed down to 40 cm, standardized at 30 cm, with layer-based sampling (0-10, 10-20, 20-40 cm) on 227 forest plots on a 15x18 km grid. SOC stock values have been estimated in each layer using layer depths, soil carbon concentrations (704 values), bulk densities (543 measured data, 163 estimated data in the field or by means of pedotransfer functions) and volumes of coarse fragment (704 values estimated in the field). BioSoil assessed also OF and OH layers in which organic material is in various states of decomposition (down to humus) and included these in the SOC stock estimations.
In table 9.4 the regressions calculated to infer SOC stocks [t C ha^{-1}] from the aboveground biomass [t C ha^{-1}] are shown.

[56] BioSoil project – http://www3.corpoforestale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/487/UT/systemPrint; http://www.inbo.be/content/page.asp?pid=EN_MON_FSCC_condition_report
[57] FutMon: Life+ project for the "*Further Development and Implementation of an EU-level Forest Monitoring System*"; http://www.futmon.org;
http://www3.corpoforestale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/D.e54313ecaf7ae893e249/P/BLOB%3AID%3D397

Table 9.4 Regressions to estimate the SOC stocks (t C ha^{-1}) in the upper 30 cm as a function of aboveground biomass in the different Italian forest typologies

	Inventory typology	Regressions aboveground biomass – SOC (t C ha^{-1})	R^2	Standard error
stands	norway spruce	y = 0.2218x + 73.005	0.0713	40.14
	silver fir	y = 0.2218x + 73.005	0.0713	40.14
	larches	y = 0.2218x + 73.005	0.0713	40.14
	mountain pines	y = 0.2218x + 73.005	0.0713	40.14
	mediterranean pines	y = 0.2218x + 73.005	0.0713	40.14
	other conifers	y = 0.2218x + 73.005	0.0713	40.14
	european beech	y = 0.2502x + 79.115	0.0925	44.10
	turkey oak	y = 0.2502x + 79.115	0.0925	44.10
	other oaks	y = 0.2502x + 79.115	0.0925	44.10
	other broadleaves	y = 0.2502x + 79.115	0.0925	44.10
coppices	european beech	y = 0.2683x + 70.208	0.073	33.39
	sweet chestnut	y = 0.2683x + 70.208	0.073	33.39
	hornbeams	y = 0.2683x + 70.208	0.073	33.39
	other oaks	y = 0.2683x + 70.208	0.073	33.39
	turkey oak	y = 0.2683x + 70.208	0.073	33.39
	evergreen oaks	y = 0.2683x + 70.208	0.073	33.39
	other broadleaves	y = 0.2683x + 70.208	0.073	33.39
	conifers	y = 0.2218x + 73.005	0.0713	40.14
plantations	eucalyptuses coppices	y = 0.2683x + 70.208	0.073	33.39
	other broadleaves coppices	y = 0.2683x + 70.208	0.073	33.39
	poplars stands	y = 0.2502x + 79.115	0.0925	44.10
	other broadleaves stands	y = 0.2502x + 79.115	0.0925	44.10
	conifers stands	y = 0.2218x + 73.005	0.0713	40.14
protective	rupicolous forest	y = 0.3262x + 68.648	0.1338	38.96
	riparian forest	y = 0.3262x + 68.648	0.1338	38.96

Different trends in SOC stocks per hectare, for the different forest inventory typologies, have been inferred, as shown in table 9.5.

Table 9.5 SOC stocks per hectare in the upper 30 cm, for the different forest inventory typologies

	Inventory typology	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
		SOC stocks (t C ha^{-1})										
stands	norway spruce	85.42	84.86	84.32	83.99	83.87	83.78	83.76	83.74	83.55	83.51	83.46
	silver fir	87.17	86.23	85.34	85.07	85.13	85.29	85.33	85.33	85.20	85.22	85.21
	larches	83.77	83.14	82.56	82.40	82.57	82.73	82.76	82.77	82.71	82.72	82.73
	mountain pines	83.81	84.64	85.34	86.37	87.41	88.57	88.82	88.94	89.10	89.34	89.55
	mediterranean pines	83.23	84.88	86.27	87.86	89.04	90.42	90.72	90.86	91.15	91.44	91.68
	other conifers	80.05	80.79	81.39	82.22	83.13	84.10	84.31	84.46	84.59	84.79	84.96
	european beech	98.73	98.50	98.39	98.69	99.01	99.76	99.97	99.95	100.10	100.31	100.43
	turkey oak	94.76	95.04	95.30	95.91	96.30	96.95	97.12	97.15	97.34	97.53	97.65
	other oaks	89.21	89.55	89.89	90.63	91.14	91.77	91.91	91.92	92.09	92.26	92.36
	other broadleaves	89.88	89.97	89.99	90.53	91.03	91.67	91.83	91.84	91.99	92.15	92.28
coppices	european beech	83.23	82.80	82.45	82.43	82.78	83.36	83.49	83.53	83.63	83.76	83.86
	sweet chestnut	84.10	87.09	89.55	92.15	94.89	97.80	98.37	98.71	99.28	99.83	100.31
	hornbeams	76.40	76.08	75.82	75.73	75.81	76.00	76.05	76.05	76.08	76.12	76.14
	other oaks	75.53	75.95	76.18	76.41	76.68	77.11	77.20	77.23	77.32	77.41	77.45
	turkey oak	79.18	78.68	78.26	78.03	78.01	78.22	78.27	78.26	78.32	78.38	78.39
	evergreen oaks	79.62	79.44	79.28	79.29	79.38	79.71	79.77	79.75	79.86	79.95	80.00
	other broadleaves	78.61	80.22	81.51	82.76	83.95	85.05	85.25	85.34	85.49	85.66	85.78
	conifers	80.00	80.43	80.81	81.41	82.14	83.00	83.18	83.31	83.46	83.64	83.80
plantations	eucalyptuses coppices	83.72	87.06	88.15	88.83	88.99	88.93	88.84	88.53	88.72	88.87	88.83
	other broadleaves coppices	84.15	86.95	88.25	89.14	89.75	90.14	90.18	90.06	90.17	90.25	90.26

	Inventory typology	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
		SOC stocks (t C ha^{-1})										
	poplars stands	87.84	91.09	93.49	95.70	97.34	98.28	98.40	98.49	98.56	98.63	98.67
	other broadleaves stands	86.85	86.68	86.87	87.44	88.12	88.98	89.17	89.28	89.49	89.69	89.86
	conifers stands	82.30	84.01	86.25	89.31	92.44	96.00	96.67	97.25	98.03	98.75	99.45
protective	rupicolous forest	76.80	77.31	77.81	78.44	79.09	79.75	79.89	79.96	80.10	80.25	80.38
	riparian forest	83.66	83.16	82.77	82.54	82.71	82.86	82.89	82.88	82.91	82.93	82.96

From SOC stock values reported in table 9.5 the SOC stock change values have been calculated for each forest typology group and reported in table 9.6 and figure 9.3.

Table 9.6 SOC stock changes in the upper 30 cm of the mineral soils at national level

Inventory typology group	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
	SOC stock (kt C)										
stands	1,954	2,327	2,149	2,449	1,837	1,911	1,856	1,489	1,687	1,868	1,741
coppices	3,403	3,742	3,567	3,683	2,750	2,887	2,772	2,321	2,730	2,777	2,557
rupicolous and riparian forests	564	641	615	642	451	453	450	385	454	455	443
plantations	227	196	191	190	123	110	98	92	95	94	89
Total	**6,149**	**6,905**	**6,522**	**6,964**	**5,162**	**5,361**	**5,175**	**4,287**	**4,967**	**5,194**	**4,829**

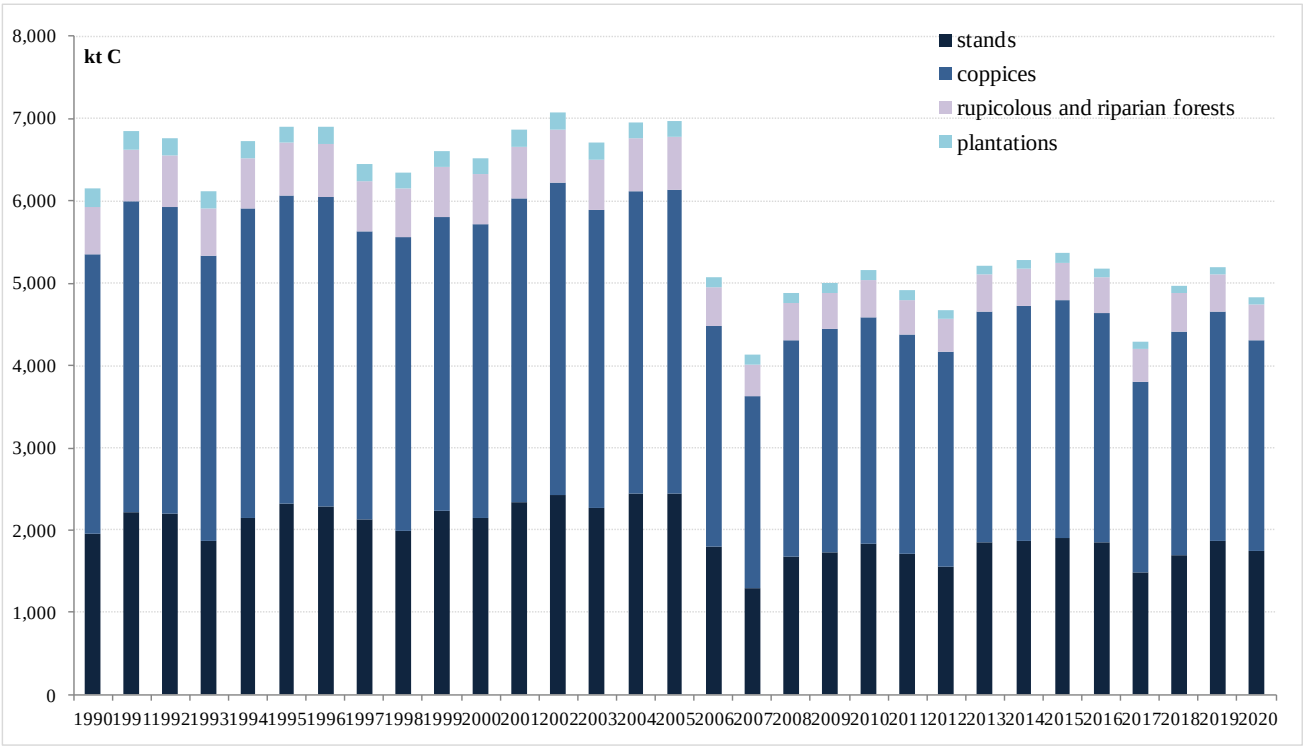


Figure 9.3 SOC stock changes in mineral soils of Italian forests

A comparison of the model results versus data measured in the framework of the II NFI (INFC2005) has been carried out and results are shown in the following table 9.7:

Table 9.7 Comparison between SOC stock estimates int the upper 30 cm depth for the entire national forest land territory derived from NFI 2005 and the *For-est* model

	NFI 2005	***For-est* model**	*differences*	
	t C= Mg	*t C= Mg*	*t C= Mg*	*%*
SOC stock	703,524,894	710,577,508	7,052,614	**+1.00**

Monte Carlo analysis has been carried out for the CO_2 emissions and removals from *Forest Land remaining Forest Land*, considering the different reporting pools (aboveground, belowground, litter, deadwood and soils), and the tipology groups (stands, coppices and protective) for the reporting year 2009, resulting equal to 49%. In the following table 9.8, the results of the uncertainty assessment for soils pool are reported.

Table 9.8 Monte Carlo uncertainty assessment for soils pool

Uncertainties for the different tipology groups, year 2009	
Inventory typology group	*%*
stands	44.65
coppices	67.35
protective	58.52
total	**49.33**

9.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

The net-net accounting factors out indirect and natural effects in all activities under Article 3.4 so far as these occur with a similar magnitude in both elements of the accounting, i.e., actual emissions and removals and those included in the reference value. For ARD activities, which a 0 value as reference, there are no methods agreed for factoring out removals; however, the gross-net accounting applied to those activities fully account for any subsequent reversal of removals associated with elevated atmospheric CO_2 concentration and nitrogen deposition so that such symmetry provides for factoring out from accounting those removals, although their factoring occurs across time. The projection of the FMRL factors out the impact of the pre-1990 activities as well as that of disturbances from FM while those impacts are negligible in CM and GM since biomass stocks have not asymmetries in the age class structure, if any, and are null in ARD activities since these occurred since 1990 only.

9.3.1.4 Changes in data and methods since the previous submission (recalculations)

A comprehensive comparison of 2022 and 2021 submissions has been carried out; in table 9.9 a summary related to the ARD and FM activities is reported, while in table 9.10 the recalculation are shown for each carbon pool, with reference to the 2019 reporting year.
The 2022 submission results, for AR and FM activities, in a deviation for the the reporting years 2013-2019; the recalculation is due to the update of the activity data as resulting from the NFI outcomes (NFI2015): 2015 area data of "Forest" and of "Other Wooded Land" (reported under grassland category), have been therefore modified, resulting in a consequent recalculation of the 2005-2015 period (annual areas have been interpolated) and 2015-2020 period (annual areas have been extrapolated).
A slight deviation (-0.1% in 2019) occurs for *deforestation* activities, respect the previous estimates.
A decrease of 22.5% results by the comparison of the last two submissions for HWP, for 2019, mainly due to the revision of FAOSTAT time series for wood-based panels (for 2018-2019), industrial roundwood (for the years 2011-2019), sawnwood for 2019 and paper and paperboard (for 2019).

Table 9.9 Summary of ARD recalculation from the comparison of the 2022 and 2021 submissions

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
				%			
AR	-27.6	-2.9	-3.4	6.8	35.8	-43.3	-12.9
D	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
FM	-0.7	-0.8	-1.0	-1.6	-4.5	-2.5	-2.8

Table 9.10 ARD recalculation for carbon pool from the comparison of the 2022 and 2021 submissions

2019	**AR**	**D**	**FM**
		%	
aboveground	-14.6	-0.1	-1.8
belowground	-14.9	-0.2	-1.8
litter	-16.3	0.0	-5.7
deadwood	-19.6	0.0	-7.6
soils	2.2	0.0	NA

2019	AR	D %	FM
HWP	NA	NA	-22.5
total	**-12.9**	**-0.1**	**-2.8**

The comparison of the 2022 and 2021 submissions resulted, for *cropland management* activities, in a recalculation, shown in table 9.11, due to the revision of woody crops acitivity data and related carbon stock changes from living biomass, for 2016-2019. A slight deviation occurs in mineral soils in 2019 (-0.4%); the recalculation in 1990 (-34.1%) is due to the fixing of an error included in the 2021 submission.

Table 9.11 CM recalculation from the comparison of the 2022 and 2021 submissions

CM		1990	2013	2014	2015	2016	2017	2018	2019
Area subject to the activity	*kha*	0	0	0	0	0	0	0	0
Carbon stock change in above-ground biomass									
Gains	*kt C*	0	0	0	0	0.4	0.9	1.3	1.8
Losses	*kt C*	0	0	0	0	-11.3	-16.5	-15.1	-16.9
Net change	*kt C*	0	0	0	0	-38.9	-47.6	-40.0	-56.7
Carbon stock change in below-ground biomass									
Gains	*kt C*	0	0	0	0	0.4	0.9	1.3	1.8
Losses	*kt C*	0	0	0	0	-11.3	-16.5	-15.1	-16.9
Net change	*kt C*	0	0	0	0	-38.9	-47.6	-40.0	-56.7
Net carbon stock change in soils									
Mineral soils	*kt C*	-34.1	0	0	0	0	0	0	-0.4
Organic soils	*kt C*	0	0	0	0	0	0	0	0
Net emissions/removals - CO_2	*kt*	83.5	0.0	0.0	0.0	5.6	8.6	9.0	8.1

No recalculation occurred for *grazing land management* activities, from the comparison of the 2022 and 2021 submissions.
The GHG emissions biomass burning have been recalculated in 2022 submission for updated burned area under *cropland management* in 2018 and 2019, resulting in an increase of reported emissions as shown in table 9.12.

Table 9.12 Biomass burning recalculation from the comparison of the 2021 and 2020 submissions

	2013	2014	2015	2016 %	2017	2018	2019
AR							
area	-	-	-	-	-	-	-
CO_2	-	-	-	-	-	-	-
CH_4	-	-	-	-	-	-	-
N_2O	-	-	-	-	-	-	-
FM							
area	-	-	-	-	-	-	-
CO_2	-	-	-	-	-	-	-
CH_4	-	-	-	-	-	-	-
N_2O	-	-	-	-	-	-	-
CM							
area	-	-	-	-	-	50.0	79.3
CO_2	-	-	-	-	-	50.0	47.2
CH_4	-	-	-	-	-	50.0	47.2
N_2O	-	-	-	-	-	50.0	47.2

The detailed list of the driver for the recalculation in the KP-activities is reported in table 9.13.

Table 9.13 Drivers for the recalculation in the KP-activities

	CO_2	CH_4	N_2O
Afforestation-Reforestation **Forest Management**	- update of the activity data as resulting from the NFI outcomes (NFI2015)		
Cropland Management	- revision of woody crops and related carbon stock changes from living biomass. Mineral soils: error fixing in 1990 and update of activity data in 2019		- update of F_{SOM}, recalculated on the basis of the updated soils C stock changes of land converted to cropland.
Grazing land management			
HWP	- revision of FAOSTAT time series for wood-based panels (for 2018-2019), industrial roundwood (for the years 2011-2019), sawnwood for 2019, paper and paperboard for 2019.		
Biomass Burning	- updated burned area under cropland management in 2018 and 2019		

9.3.1.5 Uncertainty estimates

It was assumed that uncertainty estimates for forest land (par. 6.2.5) also apply for lands under FM. The uncertainties related to the different pools are reported, for 2020, in Table 9.14.

Table 9.14 FM uncertainty for the year 2020

Aboveground biomass	E_{AG}	42.64%
Belowground biomass	E_{BG}	52.14%
Dead mass	E_D	42.89%
Litter	E_L	43.80%
Overall uncertainty	**E**	**35.41%**

The uncertainties for Article 3.3 activities estimates are expected to be higher. It can be assumed that the given uncertainty analysis in Table 9.14 covers the uncertainty of all gains and all losses in living tree biomass under FM and ARD.

Concerning *cropland management*, it was assumed that the uncertainty assessment carried out for cropland category also apply to land subject to CM. Additional details are reported in par. 6.3.5. Concerning *grazing land management*, the uncertainty assessment was carried out on the basis of information and values included in the 2013 KP Supplement (IPCC, 2014) and the 2006 IPCC Guidelines (IPCC, 2006). In the following table 9.15 the CM and GM uncertainties are shown.

Table 9.15 CM and GM uncertainties

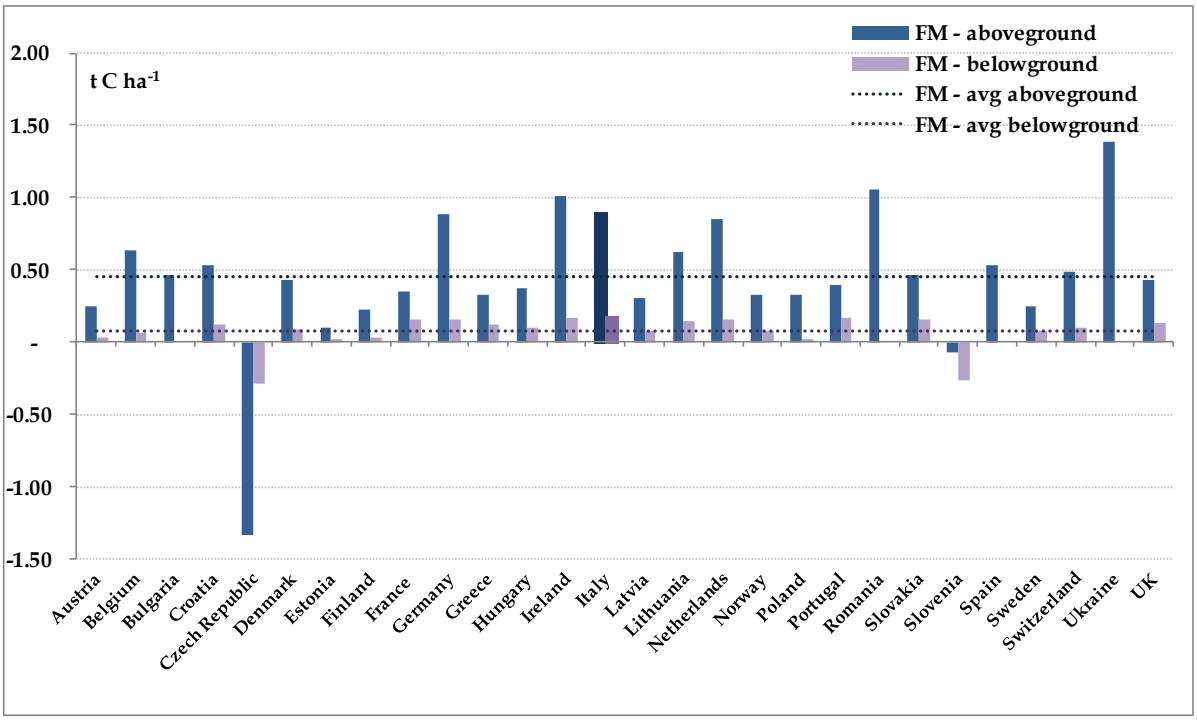
	1990	2013	2014	2015	2016	2017	2018	2019	2020
					%				
CM - *Living biomass*	18.7	28.2	19.9	20.4	30.7	25.3	19.2	40.2	15.9
CM - *Soils*	21.5	10.6	9.3	7.9	7.3	7.2	7.4	7.9	8.4
Total CM	28.1	54.2	69.5	213.9	13.5	13.2	16.1	15.7	34.9
GM - *Soils*	35.7	33.2	24.0	33.6	31.0	82.7	78.3	70.0	73.0

A Monte Carlo analysis has been carried out to assess uncertainty for the LULUCF sector, including forest land, cropland and grassland category (considering both land remaining land and land converted to other land uses). A detailed description of the results is reported in Annex 1.

9.3.1.6 Information on other methodological issues

Italy has decided to account for the emissions and removals under Article 3 paragraphs 3 and 4 at the end of the commitment period. The inventory of land use (IUTI, see Annex 10) has been completed, resulting in land use classification, for all national territory, for the years 1990, 2000 and 2008 (Corona et al., 2012, Marchetti et al., 2012). For 2012, land use and land use change data were assessed through the survey, carried out in the framework of the III NFI, on an IUTI's subgrid (i.e. 301,300 points, covering the entire country). Verification and validation activities have been undertaken and the resulting time series have been discussed with the institutions involved in the data providing (i.e. National Forest Service, Ministry of Agricultural, Food and Forestry Policies (MIPAAF), Forest Monitoring and Planning Research Unit (CRA-MPF)).

An in-depth verification process has been carried out to compare the implied carbon stock change per area (IEF), related to the aboveground and belowground pools, with the IEFs reported by other Parties. The 2021 submission[58] has been considered to deduce the different IEFs; in Figure 9.4 the comparison is showed, taking into account the IEFs for both the AR and FM activities, for the aboveground and belowground pools.



[58] GHG Review Tools (unfccc.int)

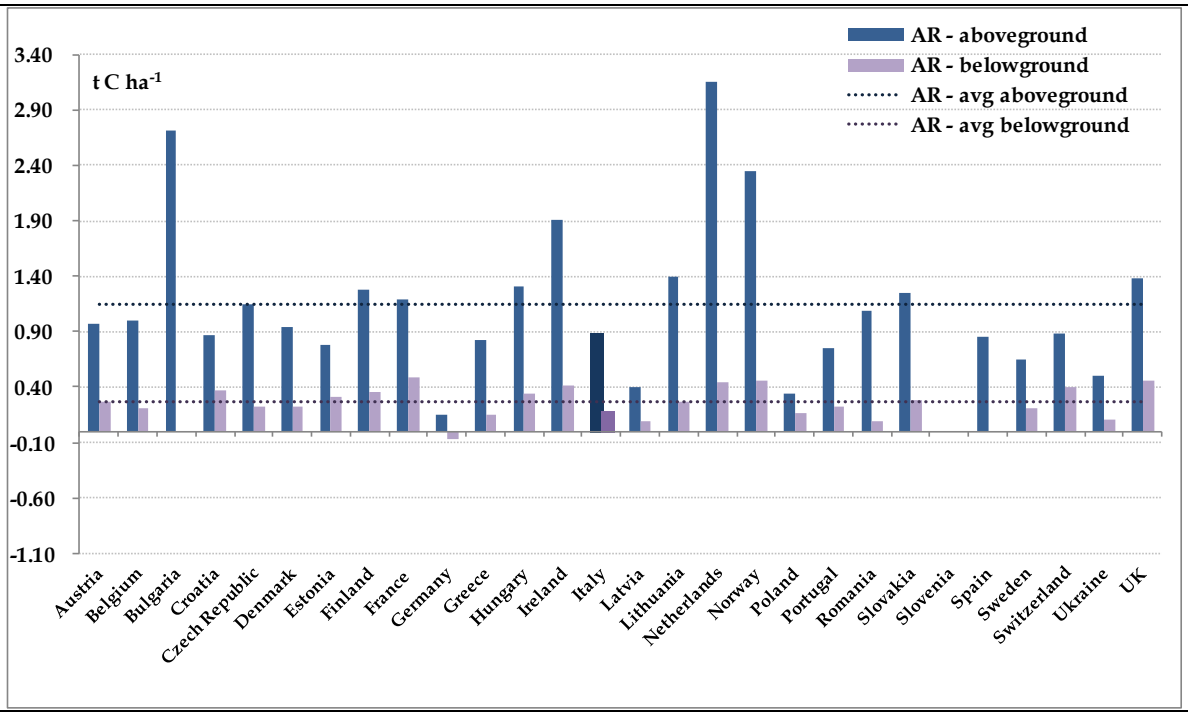


Figure 9.4 AR and FM biomass Implied carbon stock change factors

9.3.1.7 The year of the onset of an activity, if after 2008

For the ARD activities (Art. 3.3), Italy reports all the area subject to these activities since 1st January 1990. The entire Italian forest area is subject to sustainable FM practices since before 1990, so that the onset of the activity is 1990. Same consideration applies to CM and GM, which practices have been established before 1990, so that the onset of the activity is 1990.

9.4 Article 3.3

9.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Changes in forest area were detected on the basis of national forest inventories data (see section 9.2).
The following *afforestation/reforestation* activities that occurred or could have occurred on or after 1990 (table 9.16) are included in the reporting of these activities:

- Planted or seeded cropland and grassland;
- Abandoned arable lands, which are forested, through the human-induced promotion of natural seed sources.

In Italy, the entire area is considered as managed regardless of the land use category to which belong (cropland, grassland, forest land); therefore, any change in the management activities and consequently in the land use is direct human-induced.
Afforested/reforested areas are to be considered legally bound by national legislation[59]. Usually, these activities have resulted from a decision to change the land use by tree planting or seeding. In abandoned agricultural

[59] In particular: Law Decree n. 227/2001; Law n. 353/2000; Law 1497/1939; Law Decree n. 3267/1923; 985, Law n. 431

land forest vegetation regrows naturally, although the protection[60] activity to which each land with forest colonization is subject, including fire suppression[61], qualifies the land as subject to AR[62] activity.
In addition, *afforestation* and *reforestation* activities are essentially linked to political decisions under the EEC Regulations 2080/92 and 1257/99 (art.10.1 and 31.1), therefore induced by man. Articles 10.1 and 31.1 of the EEC Regulations 1257/99 (Council Regulation (EC) No 1257/1999 of 17 May 1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF)) refer directly to the provision of incomes for elderly farmers who decide to stop farming and to the support granted for the afforestation of agricultural land.

Table 9.16 Cumulative area estimates (kha) under Article 3.3 activities Afforestation/Reforestation for different years

Afforestation /Reforestation	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
					kha			
Abruzzo	72.1	74.7	77.3	80.0	82.6	85.3	88.0	90.7
Basilicata	56.0	58.2	60.3	62.5	64.6	66.8	69.0	71.2
Calabria	97.5	100.9	104.3	107.6	111.0	114.4	117.8	121.2
Campania	76.3	79.2	82.2	85.1	88.1	91.1	94.1	97.2
Emilia-Romagna	109.9	113.6	117.2	120.9	124.5	128.2	131.8	135.5
Friuli-Venezia Giulia	66.3	68.5	70.7	72.9	75.1	77.3	79.4	81.6
Lazio	106.7	110.4	114.2	118.0	121.8	125.6	129.4	133.2
Liguria	64.4	66.4	68.4	70.4	72.5	74.5	76.5	78.5
Lombardia	120.6	124.5	128.4	132.3	136.2	140.0	143.9	147.8
Marche	55.1	56.7	58.4	60.0	61.6	63.2	64.8	66.4
Molise	26.6	27.7	28.9	30.1	31.3	32.5	33.7	35.0
Piemonte	170.7	176.2	181.7	187.1	192.6	198.0	203.5	208.9
Puglia	29.2	30.2	31.2	32.3	33.3	34.4	35.4	36.5
Sardegna	102.4	106.0	109.7	113.3	117.0	120.7	124.4	128.1
Sicilia	58.2	60.7	63.1	65.6	68.1	70.7	73.2	75.8
Toscana	202.5	209.0	215.4	221.8	228.1	234.5	240.8	247.1
Trentino – Alto Adige	143.0	147.1	151.2	155.2	159.2	163.2	167.1	171.0
Bolzano-Bozen	68.3	70.3	72.3	74.3	76.2	78.1	80.1	82.0
Trento	74.7	76.8	78.9	81.0	83.0	85.1	87.1	89.1
Umbria	71.1	73.5	76.0	78.4	80.9	83.4	85.8	88.3
Valle d'Aosta	19.7	20.3	20.9	21.4	22.0	22.6	23.2	23.8
Veneto	80.2	82.9	85.6	88.3	91.0	93.6	96.3	99.0
Italia	**1,728**	**1,787**	**1,845**	**1,903**	**1,962**	**2,020**	**2,078**	**2,137**

Concerning *deforestation* activities, in Italy the land use changes from forest to other land use categories are allowed in very limited circumstances, as stated in art. 4.2 of the Law Decree n. 227 of 2001 and only where authorized through an administrative act. *Deforestation* areas have been collected for years 2005 and 2012 by the surveys carried out in the framework of the NFIs. Consequently, areas for the time series 2006-2011 have been inferred through linear interpolation and those for the years 2013-2020 have been inferred through linear extrapolation. Administrative records at NUT2 level collected by the National Institute of Statistics on deforested areas have been used for the period 1990-2005. Activities planned in the framework of the registry for carbon sinks are expected to refine these estimates.

[60] Law Decree n. 3267/1923 updated in 1999, (protection through AR, art.39 and art. 75, clear-cut ban in AR land, art. 51, subsidies for AR of bare land and grassland, art. 90 and 91).
[61] Law Decree 227/2001 Law 353/2000, Law 431/1985, even though focused on specific issues as forest fires and to the protection of nature and landscape are coherent with the previous decrees and complete the legislative framework on the issue; for example, for burnt areas no land use change is allowed and for forest areas, natural restoration of previous ecosystem occurs.
[62] "Afforestation" is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.
"Reforestation" is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

9.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Extensive forest disturbances have been rare in Italy, except for wildfires; however, land-use change after wildfires is forbidden by law (n. 353 of 2000, art.10.1). In addition, clear-cutting is a not allowed practice (Law Decree n. 227 of 2001, art. 6.2).

Data collected on deforested land through visual interpretation assessed whether a different use of the land was present in areas that have lost the tree cover; in absence of a new land use the area is still classified as forest, although under regeneration, while in case of a new land use the area is considered deforested. Data collected by the Italian Statistical office refer to administrative acts that authorized deforestation so that no confusion is possible.

9.4.3 Information on the size and geographical location of forest areas that have lost forest cover, but which are not yet classified as deforested

As reported in the previous section, only forest fires, and in exceptional cases windstorm, cause a total forest cover loss since clear-cut is forbidden by law. However, disturbed areas cannot be converted as it is an illegal practice. Considering that the cause of tree cover loss is always identified through photointerpretation of aerial photos (IUTI), there are not forest areas which have lost their tree cover and are not yet either confirmed in their forest classification (disturbed areas) or already classified under their new land use (deforested areas).

9.4.4 Information related to the natural disturbances provision under article 3.3

Italy did not apply the provision to exclude emissions and subsequent removals associated with natural disturbances from the accounting of afforestation and reforestation (AR) under art. 3.3 during the second commitment period in accordance with provision in paragraph 33 of the annex to decision 2/CMP.7.

For transparency purposes only, the AR background level of emissions associated with disturbances is included in the NIR, based on country-specific information, in accordance with paragraphs 33(a) and (b) of the Annex to Decision 2/CMP.7 and related guidance provided by the 2013 KP Supplement (IPCC, 2014).

In table 9.17 the total and the area specific emissions from disturbance for the calibration period for AR activities have been reported.

Table 9.17 Total and area specific emissions from disturbances for the calibration period for AR

Total and area specific emissions from disturbances for the calibration period for AR																																		
Disturbance type*	Inventory year during the calibration period																																	
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
	Total annual emission [kt CO_2 eq.]																																	
Wildfires	450	145	215	544	222	116	109	398	448	277	386	269	155	355	164	187	130	842	309	335	151	300	802	111	139	201	227	1339	141	126	160
Insect attacks and disease infestations																																		
extreme weather events																																		
geological disturbances																																		
other																																		
SUM	450	145	215	544	222	116	109	398	448	277	386	269	155	355	164	187	130	842	309	335	151	300	802	111	139	201	227	1,339	141	126	160			
For all land under AR	Total area [kha]																																	
	74	148	221	295	369	443	516	590	664	738	811	885	959	1033	1106	1177	1224	1270	1437	1495	1553	1612	1670	1728	1787	1845	1903	1962	1903	2020	2078			
	Area-specific emissions (Emissions per unit of land area under AR, kt CO_2 eq. ha^{-1})**																																	
	6.09	0.98	0.97	1.84	0.60	0.26	0.21	0.67	0.68	0.38	0.48	0.30	0.16	0.34	0.15	0.16	0.11	0.66	0.22	0.22	0.10	0.19	0.48	0.06	0.08	0.11	0.12	0.68	0.07	0.06	0.08			

** *In any year, emissions per unit of land area are calculated as the Sum divided by the total area under AR*

The main components related to background level and margin estimation process for AR activities have been reported in table 9.18.

Table 9.18 Components of background level and margin for AR activities

Calibration period	1990 - 2020
Method used	IPCC default
Background level	0.28 kt CO_2 eq.
Margin	0.43 kt CO_2 eq.

9.4.5 Information on Harvested Wood Products under article 3.3

Annual changes in carbon stocks and associated CO_2 emissions and removals from the Harvested Wood Products (HWP) pool under article 3.3 are estimated following the production approach described in the Annex

to Volume 4, Chapter 12, of the 2006 IPCC Guidelines (IPCC, 2006), in line with Decision 2/CMP.7 and the guidance provided by the 2013 KP Supplement (IPCC, 2014). All wood originated from deforestation is assigned to fuelwood, so that there are not HWP originating from *deforestation* activity. HWP originated from *afforestation/reforestation* activities have been included in the HWP contribution calculated for *forest management*.

9.5 Article 3.4

9.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

FM, CM and GM do not occur in absence of human actions, so these are human-induced, or better anthropogenic activities. FM, CM and GM have occurred since 1990, indeed, FM covers the area subject to sustainable forest management practices since 1990, not subject to subsequent conversions, and CM and GM have in 1990 their base year, counterfactual, values.

9.5.2 Information relating to Forest Management

The forest resource in Italy has progressively reached 12 million hectares (forest land plus other wooded land), mostly in mountain and hilly areas, covering today 39% of the national surface, with a progressive increase since the 70's with an expansion rate of about 78 kha y^{-1} in the year 2000, and 53.8 kha y^{-1} in the year 2010. Laws n. 3267 of 1923 and n. 431 of 1985 impose a restriction on the uses of all forest land. Forest harvesting occurs only according to prescriptions and plans, as approved by regional administrations. The land-use change from forest to any other land use is not allowed unless specifically authorized by the regional administration under specific circumstances with the obligation to afforest an area of equivalent surface. Any illegal harvest and forest clearing is pursued by the law, and the forest replantation is always imposed. Historical management practices in the Italian forests have been guided by the Legislative Decree n. 227 of 18 May 2001, although the design and implementation of specific guidelines has been carried out at regional level. Indeed, according to the Italian Constitutional Law, the forest management is a regional competence. The Legislative Decree n. 227/2001 provides 5 general guidance on forest management:

- → protect forest ecosystem functions, genetic resources, water basins and landscape;
- → avoid conversion of forest land to other land uses, and where occurring apply compensative reforestations with endemic species;
- → avoid conversion from forest stands to coppices;
- → avoid clear-cut;
- → conserve biodiversity, including true conservation of old trees and dead wood.

From 2008 onward, such guidance has been further elaborated in the Framework Program for the Forestry Sector (Programma Quadro per il Settore Forestale - PQSF) for the protection, enhancement and sustainable management of the national forest patrimony in compliance with the commitments undertaken at international and European level. Such goals have to be achieved within 4 area of action: bio-economy; conservation, including conservation and enhancement of the forest carbon stocks; rural and social development; socio-recreational and educational functions and public awareness. With the entry into force of the Testo Unico in materia di Foreste e Filiere forestali (TUFF), the National Forest Strategy (Strategia Forestale Nazionale - SFN) has been established by the 2022[63], in continuation of the above-mentioned PQSF (paragraph 1, Article 6, Legislative Decree 3 April 2018, n. 34).

9.5.2.1 Conversion of natural forest to planted forest

Conversion of natural forest to planted forest is not occurring.

[63] National Forest Strategy

9.5.2.2 Forest Management Reference Level (FMRL)

The forest management reference level (FMRL[64]) for Italy, inscribed in the appendix to the annex to decision 2/CMP.7, is equal to –21.182 Mt CO_2 eq. per year assuming instantaneous oxidation of the harvested wood products (HWP), and –22.166 Mt CO_2 eq. applying a first-order decay function for HWP. According to the decision 2/CMP.7, paragraph 29 of the annex, the accounting shall be on the basis of the changes in the HWP pool during the second and subsequent commitment periods, estimated using the first-order decay function. Consequently, applying a first-order decay function for HWP, the FMRL for Italy is equal is –22.166 Mt CO_2 eq., as inscribed in the appendix to the annex to decision 2/CMP.7.

Italy is one of the Member States of the EU for which the Joint Research Centre (JRC) of the European Commission developed projections in collaboration with two EU modeling groups. The FMRL[65] is the average value of the projected time series of emissions and removals associated with forest management (FM) for the period 2013-2020, on the basis of forest data and of policies implemented before 2010. Aboveground and belowground biomass, dead organic matter and HWP pools are included in the FMRL. Non-CO_2 emissions from forest wildfires are also included in the FMRL.

9.5.2.3 Technical Corrections of FMRL

According to Decision 2/CMP.7, methodological consistency between the FMRL and reporting for *forest management* during the second commitment period has to be ensured, applying technical correction if necessary. Following the guidance provided by the 2013 KP Supplement (IPCC, 2014), the methodological elements listed in paragraph 2.7.5.2 (IPCC, 2014) have been analysed, providing a description on the detected inconsistencies (table 9.19).

Table 9.19 Methodological elements triggering a methodological inconsistency between the FMRL and FM reporting

Criteria	Description
The method used for GHG reporting (for Forest land remaining forest land or Forest Management) changed after the adoption of FMRL	The FMRL has been calculated with the EU models G4M (IIASA) and EFISCEN (EFI). Estimates of emissions and removals under FM activities have been carried out with the *For-est* growth model, which is used to estimate the net change of carbon in the five reporting pools.
Forest characteristics and related management[66]	Availability of new data resulting from the ongoing NFI and consequent recalculations of the reported data under FM and *Forest Land Remaining Forest Land used* to establish the reference level
Harvested wood products	The estimates have been carried out on the basis of the 2013 KP Supplement (IPCC, 2014) methodology

The recommendation received in the technical assessment (UNFCCC, 2011, par. 3.7) of the FMRL highlighted the need to make a "technical adjustment to the FMRL when final agreement on the HWP estimation is reached". The changes related to the methodological elements listed in table 9.19 trigger a methodological inconsistency between the FMRL and FM reporting, to be addressed through a technical correction (TC). Therefore, to ensure methodological consistency between the FMRL and the reporting for Forest Management during the second commitment period, the FMRL has been recalculated ($FMRL_{corr}$) in order to deduce the technical correction to the FRML.

Basically, the rationale for the calculating the $FMRL_{corr}$ is to address the elements of methodological inconsistency as listed in the table 9.19. The key element is the use, in the elaboration of the $FMRL_{corr}$, of the same model used in the FM reporting (i.e. the *For-est* model, as described in paragraphs 6.2.4 and 9.3.1.1). In addition, the latest available activity data (i.e. forest areas, harvest statistics, fires occurrences) have been used and the HWP have been estimated following the 2013 KP Supplement (IPCC, 2014) methodology.

[64] Submission of information on forest management reference levels by Italy:
http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_italy_2011.pdf
Communication of 11 May 2011 regarding harvested wood products value by Italy:
http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_italy_corr.pdf

[65] When constructing the FMRL, the following elements were taken into account: (a) removals or emissions from forest management as shown in GHG inventories and relevant historical data, (b) age-class structure, (c) forest management activities already undertaken, (d) projected forest management activities under business as usual, (e) continuity with the treatment of forest management in the first commitment period.

[66] This includes, among others: age-class structure, increment, species composition, rotation lengths, management practices, etc.

The resulting $FMRL_{corr}$ and the related technical correction is provided in the following table 9.20.

Table 9.20 Technical correction and $FMRL_{corr}$

	Emissions and removals (*Gg yr^{-1}*)
FMRL	-22,166
$FMRL_{corr}$	-23,846
difference in %	8%
Technical Correction	-1,680
Accounting Parameter	23,846

9.5.2.4 Information related to the natural disturbances provision under article 3.4

Italy did not apply the provision to exclude emissions and subsequent removals associated with natural disturbances from the accounting of forest management (FM) under art. 3.3 during the second commitment period in accordance with provision in paragraph 33 of the annex to decision 2/CMP.7.

For transparency purposes only, the FM background level of emissions associated with disturbances has been developed, on the basis of country-specific information, in accordance with paragraphs 33(a) and (b) of the annex to Decision 2/CMP.7 and related guidance provided by the 2013 KP Supplement (IPCC, 2014).

In table 9.21 the total and the area specific emissions from disturbance for the calibration period for FM activities are reported.

Table 9.21 Total and area specific emissions from disturbances for the calibration period for FM

Total and area specific emissions from disturbances for the calibration period for FM																																
Disturbance type*	Inventory year during the calibration period																															
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Total annual emission [kt CO_2 eq.]																															
Wildfires	4,506	1,365	1,913	4,589	1,779	889	782	2,670	2,837	1,657	2,194	1,455	803	1,756	778	852	608	4,019	1,512	1,675	772	1,576	4,308	610	782	1,162	1,346	8,126	880	805	1,049
Insect attacks and disease infestations																															
extreme weather events																															
geological disturbances																															
other																															
SUM	4,506	1,365	1,913	4,589	1,779	889	782	2,670	2,837	1,657	2,194	1,455	803	1,756	778	852	608	4,019	1,512	1,675	772	1,576	4,308	610	782	1,162	1,346	8,126	880	805	1,049
For all land under FM	Total area [kha]																															
	7511	7510	7510	7509	7508	7508	7507	7506	7505	7505	7504	7503	7502	7502	7501	7497	7494	7490	7486	7483	7479	7475	7471	7468	7464	7460	7457	7453	7449	7446	7442
	Area-specific emissions (Emissions per unit of land area under FM, kt CO_2 eq. ha^{-1})**																															
	0.60	0.18	0.25	0.61	0.24	0.12	0.10	0.36	0.38	0.22	0.29	0.19	0.11	0.23	0.10	0.11	0.08	0.54	0.20	0.22	0.10	0.21	0.58	0.08	0.10	0.16	0.18	1.09	0.12	0.11	0.14

** *In any year, emissions per unit of land area are calculated as the Sum divided by the total area under FM*

The main components related to background level and margin estimation process for FM activities have been reported in table 9.22.

Table 9.22 Components of background level and margin for FM activities

Calibration period	1990 - 2020
Method used	IPCC default
Background level	1,165 kt CO_2 eq.
Margin	851 kt CO_2 eq.

9.5.2.5 Information on Harvested Wood Products under article 3.4

Annual changes in carbon stocks and associated CO_2 emissions and removals from the Harvested Wood Products (HWP) pool under article 3.4 are estimated, following the production approach described in the Annex to Volume 4, Chapter 12, of the 2006 IPCC Guidelines (IPCC, 2006), in line with Decision 2/CMP.7 and applying methodological guidance provided by the 2013 KP Supplement (IPCC, 2014).

Emissions from this source are mainly influenced by the trend in forest harvest rates; in 2020, the net emissions and removals from harvested wood products were -668.5 kt CO_2. Details on HWP in use from 1961 onwards are reported in Figure 6.10 (see section 6.13.2).

The activity data (production of sawnwood, wood-based panels and paper and paperboard) are derived from FAO[67] forest product statistics. Italy uses the same methodology to estimate annual changes in carbon stocks and associated CO_2 emissions and removals from the HWP pools under UNFCCC and KP, following the

[67] Food and Agriculture Organization of the United Nations: forest product statistics, http://faostat3.fao.org/download/F/FO/E

Decision 2/CMP.7, paragraph 29, namely "*transparent and verifiable activity data for harvested wood products categories are available, and accounting is based on the change in the harvested wood products pool of the second commitment period, estimated using the first-order decay function*". For more information on the methodology applied see section 6.13.
The annual change in stock for the period 1990-2020, disaggregated into sawnwood, wood-based panels and paper & paperboard, is reported in figure 9.5.

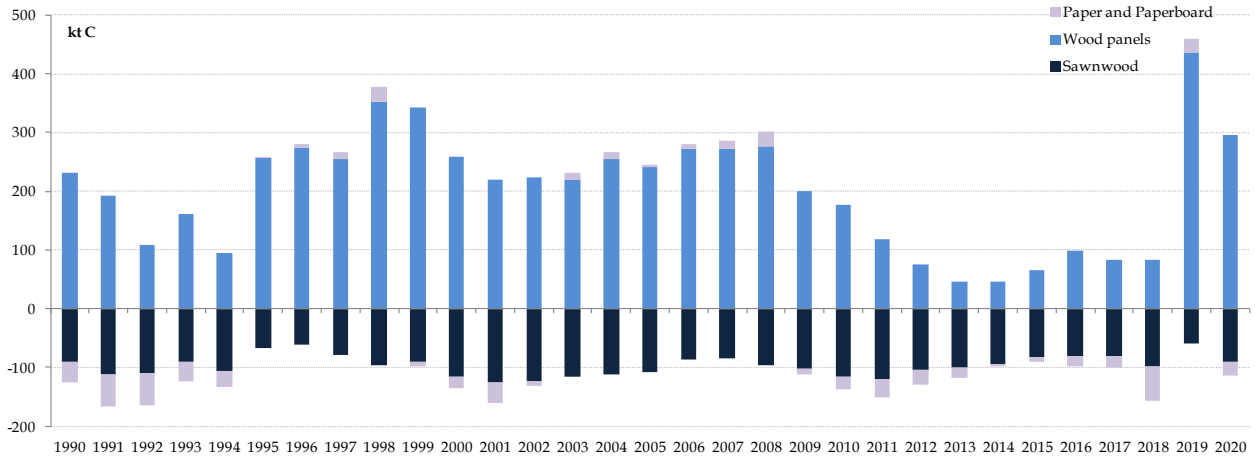


Figure 9.5 Annual change in stock (kt C) for the period 1990-2020

9.5.3 Information relating to Cropland Management, Grazing Land Management, Revegetation and Wetland Drainage and Rewetting if elected, for the base year

As shown in table 9.23, part of the area subject to *cropland management* activities in 1990 is no longer reported under CM or other art. 3.3 or art. 3.4 elected activity.
For CM and GM, the guidance provided in the 2013 KP Supplement (IPCC, 2014) acknowledges to account as zero any land that was under CM or GM in the base year and that, therefore, was never accounted in any of the commitment period years.

Table 9.23 Area subject to CM and GM activities in 1990 (base year), and 2013-2019

	1990 *kha*	**2013** *kha*	**2014** *kha*	**2015** *kha*	**2016** *kha*	**2017** *kha*	**2018** *kha*	**2019** *kha*	**2020** *kha*
Cropland management	10,730	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Grazing land management	3,826	3,654	3,949	3,949	3,949	3,949	3,949	3,949	3,949

Consequently, the GHG contribution of 1,730 kha (10,730 kha in 1990 minus 9,000 kha in 2013) in 1990 has been excluded from the base year GHG estimates of CM. Following the KP Supplement, to enhance the transparency in the reporting, the the consequences of this exclusion on reported emissions and removals are below described.
The area subject to CM activities in 1990 excluded in the following reporting years (i.e., 1,730kha) includes cropland converted to grassland (natural grassland subcategory, 1,350kha), cropland converted to wetlands (33kha) and cropland converted to settlements (347 kha). The total emissions and removals related to the abovementioned areas are equal to -69.095 kt CO_2, for the period 1990-2012; this amount is the sum of the removals from cropland converted to grassland (i.e., -72,940 kt CO_2) and the emissions from cropland converted to settlements (i.e., 3,844 kt CO_2).

9.6 Other information

9.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Key category analysis for KP-LULUCF activities was carried out according to section 2.3.6 of the 2013 KP Supplement (IPCC, 2014). In the following table 9.24 a summary overview for key categories for LULUCF activities under the Kyoto Protocol is reported.

Table 9.24 Summary overview for key categories for LULUCF activities under Kyoto Protocol

Key categories of emissions and removals	Gas	Criteria used for key category identification		Comments
		Associated category in UNFCCC inventory is key	Category contribution is greater than the smallest key category in the UNFCCC inventory (including LULUCF)	
Forest Management	CO_2	*Forest land remaining forest land*	Yes	key (L, T)
Afforestation and Reforestation	CO_2	*Land converted to forest land*	Yes	key (L, T)
Deforestation	CO_2	*Land converted to Settlements*	Yes	key (L, T)
Cropland management	CO_2	*Cropland remaining cropland*	Yes	key (L)
Grazing land management	CO_2	*Grassland remaining Grassland*	Yes	key (L, T)

The figures have been compared with table 1.6 Key categories for the latest reported year (2020) based on level of emissions (including LULUCF).

9.7 Information relating to Article 6

Italy is not participating in any project under Article 6 (Joint Implementation).

10 INFORMATION ON ACCOUNTING OF KYOTO UNITS

10.1 Background information

Annex I Parties are required to report information on accounting of Kyoto units in their national registries as specified in Decision 15/CMP.1. Such information is reported in the following chapters and is also submitted electronically using the Standard Electronic Format (SEF).
Since the Italian Registry operates within the Consolidated System of European Union Registries (CSEUR), the SEF reports are based on the data provided by the European Commission and have been produced using the report tool version 3.8.3 provided by the UNFCCC Secretariat.
Although there is no obligation to submit a SEF report for the first commitment period after the end of its true-up-period, a separate report was generated manually and included in the submission.

10.2 Summary of information reported in the SEF tables

Information under decision 15/CMP.1 annex I.E paragraph 11 for year 2021 has been reported:

- in RREG1_IT_2021_1_1 (submitted both in xls and xml format) with regards to units of the first commitment period;
- in RREG1_IT_2021_2_1 (submitted both in xls and xml format) with regards to units of the second commitment period.

The reports contain data on acquisition, holding, transfer, cancellation, retirement and carry-over of ERUs, CERs, tCERs, lCERs, AAUs and RMUs of the first and the second commitment period.
Full details for CP2 units are available in the SEF tables reported in Annex 8.

10.3 Discrepancies and notifications

Information under decision 15/CMP.1 annex I.E paragraphs 12 to 17 for year 2021 is provided below:

- paragraph 12 *List of discrepant transactions*: no discrepant transactions occurred in 2021;
- paragraph 13 and 14 *List of CDM notifications*: no CDM notifications occurred in 2021;
- paragraph 15 *List of non-replacements*: no non-replacements occurred in 2021;
- paragraph 16 *List of invalid units*: no invalid units exist as of 31 December 2021;
- paragraph 17 *Actions and changes to address discrepancies*: since no discrepant transactions occurred in 2021, there's been no need for actions to correct or changes to prevent discrepancies in the reported period.

Considering the information above, reports R2, R3, R4 and R5 have not been included in the submission.

10.4 Publicly accessible information

Non-confidential information required by Decision 13/CMP.1 annex II.E paragraphs 44-48, is publicly accessible via the Union Registry website at:
https://unionregistry.ec.europa.eu/euregistry/IT/public/reports/publicReports.xhtml
and it is also available on the informative website at :
https://www.isprambiente.gov.it/en/services/emission_trading_registry/public-reports
All required information is provided with the following exceptions:

- paragraph 45(d)(e): account number, representative identifier name and contact information is deemed as confidential according to Annex III and VIII (Table III-I and VIII-I) of Commission Delegated Regulation (EU) No 2019/1122;
- paragraph 46: no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project did not occur in the specified period;
- paragraph 47(a)(d)(f): holding and transaction information is provided on an account type level, due to more detailed information being declared confidential by article 80 of Commission Delegated Regulation (EU) No 2019/1122.

Public information available at the above-mentioned links is updated on a monthly basis.

10.5 Calculation of the commitment period reserve (CPR)

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and paragraph 18 of Decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. According to paragraph 6 of the Annex to decision 11/CMP.1, the commitment period reserve equals the lower of either 90% of a Party's assigned amount or 100% of its most recently reviewed inventory, multiplied by 8.

For the purposes of the joint fulfillment, the commitment period reserve applies to the EU, its Member States and Iceland individually.

The Italian commitment period reserve is calculated either as:

2,410,291,421 t CO_2 equivalent * 0.9 = 2,169,262,279 t CO_2 equivalent

or:

418,280,596 t CO_2 equivalent (emission level 2019) * 8 = 3,346,244,769 t CO_2 equivalent

The Italian commitment period reserve is therefore 2,169,262,279 t CO_2 equivalent.

10.6 KP-LULUCF accounting

Italy will account for Article 3.3 and 3.4 LULUCF activities at the end of the commitment period.

In Table 10.1, information on accounting for the KP-LULUCF activities based on the reporting for the years 2013-2020 are given. Accounting quantities for cropland management and grazing land management under art. 3.4 of the Kyoto Protocol have been assessed as the level of emissions and removals in the commitment period less the duration of the reporting period (2013-2020) in years times the level of emissions and removals from these elected activities in the base year (paragraph 10 of Decision 2/CMP.7).

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year[2]	NET EMISSIONS/REMOVALS									Accounting parameters	Accounting quantity [4]
		2013	2014	2015	2016	2017	2018	2019	2020	Total[3]		
	(kt CO_2 eq)											
A. Article 3.3 activities												
A.1. Afforestation/reforestation		-6,257	-8,166	-8,570	-9,036	-8,300	-5,485	-7,987	-9,142	-62,942		-62,942
Excluded emissions from natural disturbances[5]		NO	NO	NO	NO	NO	NO	NO	NO	NO		NO
A.2. Deforestation		1,942	1,953	1,964	1,973	1,975	1,983	1,993	2,000	15,785		15,785
B. Article 3.4 activities												
B.1. Forest management										-213,299		-22,531
Net emissions/removals		-30,100	-31,097	-32,248	-29,064	-13,117	-24,275	-30,218	-23,179	-213,299		
Excluded emissions from natural disturbances[6]		NO	NO	NO	NO	NO	NO	NO	NO	NO		NO
Forest management reference level (FMRL)[7]											-22,166.000	
Technical corrections to FMRL[7]											-1,680.06	
Forest management cap[8]											146,138	-22,531
B.2. Cropland management	1,381	-2,283	-2,578	-3,504	-5,674	-5,581	-5,318	-5,417	-4,011	-34,366		-45,418
B.3. Grazing land management	126	-769	-1,183	-845	-933	-542	-574	-640	-613	-6,100		-7,105

Table 10.1 Information table on accounting for activities under art. 3.3 and 3.4 of the Kyoto Protocol, for 2013-2020

(1) All values are reported in table 4(KP) and tables 4(KP-I).A.1.1, 4(KP-I).B.1.1, 4(KP-I).B.1.2 and 4(KP-I).B.1.3 of the CRF for the relevant inventory year as reported in the current submission and are automatically entered in this table.

(2) Net emissions and removals from cropland management, grazing land management, revegetation and/or wetland drainage and rewetting, if elected, in the Party's base year, as established by decision 9/CP.2.

(3) Cumulative net emissions and removals for all years of the commitment period reported in the current submission.

(4) The accounting quantity is the total quantity of units to be added to or subtracted from a Party's assigned amount for a particular activity in accordance with the provisions of Article 7.4 of the Kyoto Protocol.

(5) A Party that has indicated their intent to apply the natural disturbance provisions may choose to exclude emissions from natural disturbances either annually or at the end of the commitment period.

(6) Forest management reference level as inscribed in the appendix of the annex to decision 2/CMP.7, in kt CO2 eq per year.

(7) Technical corrections in accordance with paragraphs 14 and 15 of the annex to decision 2/CMP.7 and reported in table 4(KP-I)B.1.1 in kt CO2 eq per year.

(8) For the second commiment period, additions to the assigned amount of a Party resulting from forest management shall, in accordance with paragraph 13 of the annex to decision 2/CMP.7, not exceed 3.5 per cent of the national total emissions excluding LULUCF in the base year times eight.

11 INFORMATION ON CHANGES IN NATIONAL SYSTEM

No changes with respect to the last year submission occurred in the Italian National System.

12 INFORMATION ON CHANGES IN NATIONAL REGISTRY

12.1 Previous Review Recommendations

The SIAR Report for Italy from last year reported no recommendations.

12.2 Changes to National Registry

The following changes to the national registry of Italy have occurred in 2021.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	There was a change in the cooperation arrangement during the reported period as the United Kingdom of Great Britain and Northern Ireland no longer operate their registry in a consolidated manner within the Consolidated System of EU registries, CSEUR.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security were introduced.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.

13 INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

13.1 Overview

In the framework of the EU Burden Sharing Agreement, Italy has committed to reduce its GHG emissions by 6.5% below base-year levels (1990) over the first commitment period, 2008-2012. After the review of the initial report of Italy under the Kyoto Protocol (KP), the Kyoto objective was fixed in 483.255 $MtCO_2$ per year for each year of the "commitment period" (UNFCCC, 2007).

In this section Italy provides an overview of its commitments under Article 3.1, and specifically how it is striving to implement individually its commitment under Article 3 paragraph 14 of the KP. Under Article 3.14 of the KP:

"Each Party included in Annex I shall strive to implement the commitments mentioned in paragraph 1[68] above in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9[69], of the Convention. In line with relevant decisions of the Conference of the Parties on the implementation of those paragraphs, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, consider what actions are necessary to minimize the adverse effects of climate change and/or the impacts of response measures on Parties referred to in those paragraphs. Among the issues to be considered shall be the establishment of funding, insurance and transfer of technology.

For the preparation of this chapter ISPRA has collected information through the revision of peer review international articles on sustainable development (SD) of ex-ante/ex-post assessments related to activities on climate change mitigation, and through personal communication with people/institutions involved in project/programs/policy implementation of climate change activities. Moreover, experts from the Ministry for the Environment, Land and Sea (*Ministero dell'Ambiente e della Tutela del Territorio e del Mare*, MATTM) and the Directorate General for Development Co-operation (DGCS) from the Ministry of Foreign Affairs (*Ministero degli Affari Esteri*, MAE) were contacted.

This chapter has been updated with new information according to the on-going activities at national and international level and the relevant databases. In particular, the update of the distribution of global CDM projects by Host country and scope, as presented in Figure 14.1 and relevant tables (Tables 14.2 and 14.3). The amount of financial resources to developing countries has been assessed and preliminary data for 2020 has been reported in Table 14.5. The section of Annex 8 related to the information of the registered CDM projects where Italy is involved has been checked for the current submission but the information reported is the same as the previous year.

As the reporting obligation related to Article 3, paragraph 14 does not include an obligation to report on each specific mitigation policy. Italy briefly describes how EU is striving to minimize adverse impacts, because Italy is member of the European Union, thus incorporated into its European legal system to implement directives/policies; and individually how is striving to implement Article 3.14 with specific examples.

Two main parts are requested under Article 3.14 for reporting purposes: commitments to minimize adverse effects (section 14.2, 14.3) and priority actions (section 14.4, 14.5). Future improvements/research activities are expected for next submissions (section 14.6).

13.2 European Commitment under Art 3.14 of the Kyoto Protocol

The EU is well aware of the need to assess impacts, and has built up thorough procedures in line with obligations. This includes bilateral dialogues and different platforms that allow interacting with third countries,

[68] **Kyoto Protocol, Art. 3 Par. 1 "**The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012."

[69] **UNFCCC, Art 4. Par 8.** "In the implementation of the commitments in this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on: (a) Small island countries; (b) Countries with low-lying coastal areas; (c) Countries with arid and semi-arid areas, forested areas and areas liable to forest decay; (d) Countries with areas prone to natural disasters; (e) Countries with areas liable to drought and desertification; (f) Countries with areas of high urban atmospheric pollution; (g) Countries with areas with fragile ecosystems, including mountainous ecosystems; (h) Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products; and (i) Landlocked and transit countries. Further, the Conference of the Parties may take actions, as appropriate, with respect to this paragraph." **UNFCCC Art 4. Par. 9**. "The Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology."

explain new policy initiatives and receive comments from third countries. Impacts on third countries are mostly indirect and can frequently neither be directly attributed to a specific EU policy, nor directly measured by the EU in developing countries. A wide-ranging impact assessment (IA) system accompanying all new policy initiatives has been established. This approach ensures that potential adverse social, environmental and economic impacts on various stakeholders are identified and minimized within the legislative process (European Commission, 2010).
At European level, IA is required for most important Commission initiatives, policy and programs and those which will have the most far-reaching impacts. In 2009, IA was adopted, replacing the previous Guidelines 2005 and also the 2006 update. In general, the IA evidence advantages and disadvantages of possible policy options by assessing their potential impacts. Among different issues, it should be assessed which are the likely social, environmental and economic impacts of those options (European Commission, 2009[a]). Since 2003 all IA of EU policies are listed and published online by subject (European Commission, 2021).
Key questions on economic, social and environmental impacts in relation to third countries are listed in Table 14.1.

Table 14.1 Questions in relation to impacts on Third countries

Economic	Social	Environmental
• How does the policy initiative affect trade or investment flows between the EU and third countries? How does it affect EU trade policy and its international obligations, including in the WTO? • Does the option affect specific groups (foreign and domestic businesses and consumers) and if so in what way? • Does the policy initiative concern an area in which international standards, common regulatory approaches or international regulatory dialogues exist? • Does it affect EU foreign policy and EU development policy? • What are the impacts on third countries with which the EU has preferential trade arrangements? • Does it affect developing countries at different stages of development (least developed and other low-income and middle income countries) in a different manner? • Does the option impose adjustment costs on developing countries? • Does the option affect goods or services that are produced or consumed by developing countries?	• Does the option have a social impact on third countries that would be relevant for overarching EU policies, such as development policy? • Does it affect international obligations and commitments of the EU arising from e.g. the ACP-EU Partnership Agreement or the Millennium Development Goals? • Does it increase poverty in developing countries or have an impact on income of the poorest populations?	• Does the option affect the emission of greenhouse gases (e.g. carbon dioxide, methane etc) into the atmosphere? • Does the option affect the emission of ozone-depleting substances (CFCs, HCFCs etc)? • Does the option affect our ability to adapt to climate change? • Does the option have an impact on the environment in third countries that would be relevant for overarching EU policies, such as development policy?

Source: European Commission, 2009[a]

A review of European response measures for two EU policies were chosen for further description because the IA identified potential impacts on thirds countries. These measures are the Directive 2009/28/EC on the promotion of the use of renewable energy, and the EU emission trading scheme for the inclusion of the aviation (see European Commission, 2009[b]; European Commission, 2010).

Directive on the promotion of the use of renewable energy
EU will reach a 20% share of energy from renewable sources in the overall energy consumption by 2020 (with individual targets for each Member State) and a 10% share of renewable energy specifically in the transport sector, which includes biofuels, biogas, hydrogen and electricity from renewables. EU leaders agreed on 23 October 2014 the domestic 2030 targets of greenhouse gas reduction of at least 40% compared to 1990 and at least 27% for renewable energy and energy savings by 2030. IAs related to enhanced use in the EU showed that the cultivation of energy crops have positive (growing of EU demand for bioenergy generates new export revenues and employment opportunities for developing countries and boosts rural economies), and negative (biodiversity, soil and water resources and have positive/ negative effects on air pollutants) impacts. For this reason, Article 17 of the EU's Directive has created "sustainability criteria", applicable to all biofuels (biomass used in the transport sector) and bioliquids, which consider to establish a threshold for GHG emission reductions that have to be achieved from the use of biofuels; to exclude the use of biofuels from land with high biodiversity value (primary forest and wooded land, protected areas or highly biodiverse grasslands), and to exclude the use of biofuels from land with high C stocks, such as wetlands, peatlands or continuously forested

areas. In this context, developing country representatives as well as other stakeholder were extensively consulted during the development of the sustainability criteria and preparation of the directive and the extensive consultation process has been documented. The Commission also reports on biofuels' potential indirect land use change effect and the positive and negative impact on social sustainability in the Union and in third countries, including the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues. The first reports were submitted in 2012 (European Commission, 2010).

Inclusion of aviation in the EU emission trading scheme

In 2005 the Commission adopted a Communication entitled "Reducing the Climate Change Impact of Aviation", which evaluated the policy options available to this end and was accompanied by an IA. The assessment concluded that, in view of the likely strong future growth in air traffic emissions, further measures are urgently needed. Aircraft operators from developing countries will be affected to the extent they operate on routes covered by the scheme. As operators from third countries generally represent a limited share of emissions covered, the impact is also modest. On the other hand, to the extent that aviation's inclusion in the EU ETS creates additional demand for credits from JI and CDM projects, there will also be indirect positive effects as such projects imply additional investments in clean technologies in developing countries (European Commission, 2010).

Common Agricultural Policy

Furthermore, many developing countries and least developed countries (LDC) are based on the agricultural production, therefore, it will be important to understand how the *EU Common Agricultural Policy (CAP) Health Check*, together with the new targets on climate change and renewable energies will potentially influence developing countries. Some information on cereal intervention options on third parties have been identified (European Commission, 2008). Some studies on the impact of agricultural policies on developing countries are also available (Schmidhuber, 2009; Hallam, 2010). Brooks et al (2010) has recently presented DEVPEM[70] a companion to the OECD-country PEM[71] as a tool for policy evaluation in developing countries. Preliminary results for Malawi indicate that agricultural policies may have fundamentally different impacts on incomes in low income countries to those obtained in developed OECD countries.

13.3 Italian commitment under Art 3.14 of the Kyoto Protocol

Article 3, paragraph 14 of the KP is related to Annex I Parties' way of implementing commitments under Article 3.1 of the KP. Therefore, it addresses the implementation of the quantified emission limitation and reduction objectives (QELROs) under Article 3.1, the implementation of LULUCF activities under Article 3 paragraphs 3 and 4, the use of Emission Reduction Units (ERUs) and Certified Emission Reductions (CERs) under Article 3 paragraphs 10, 11, and 12.

Italy is aware of the potential direct and indirect impact of measures/policies and tries to ensure that the implementation of national mitigation policies under the KP does not impact other parties. Minimizing adverse effects of policies/measures are described in Chapter 4.8 in the Sixth National Communication (MATTM, 2014). Information of activities under Article 3 paragraphs 3 and 4 of the KP is described in 'Chapter 10' KP-LULUCF' of this report.

National and sectoral Italian policies are expected to have no direct impacts in developing countries. Policies and measures in the Italian energy sector aim to increase energy efficiency and develop a low-carbon energy system but in the context of a global energy scenarios that do not foresee a decline in income for fossil fuel exporting countries (IEA, World Energy Outlook 2008).

Efforts to tackle adverse social, economic, and environmental impacts of mitigation actions are directly expected in the framework of the Kyoto Mechanisms. Hence, this chapter has concentrated efforts to analyze the Clean Development Mechanism and Joint Implementation in order to provide response to reporting requirements under Article 3.14 of KP.

[70] DEVPEM, Development Policy Evaluation Model

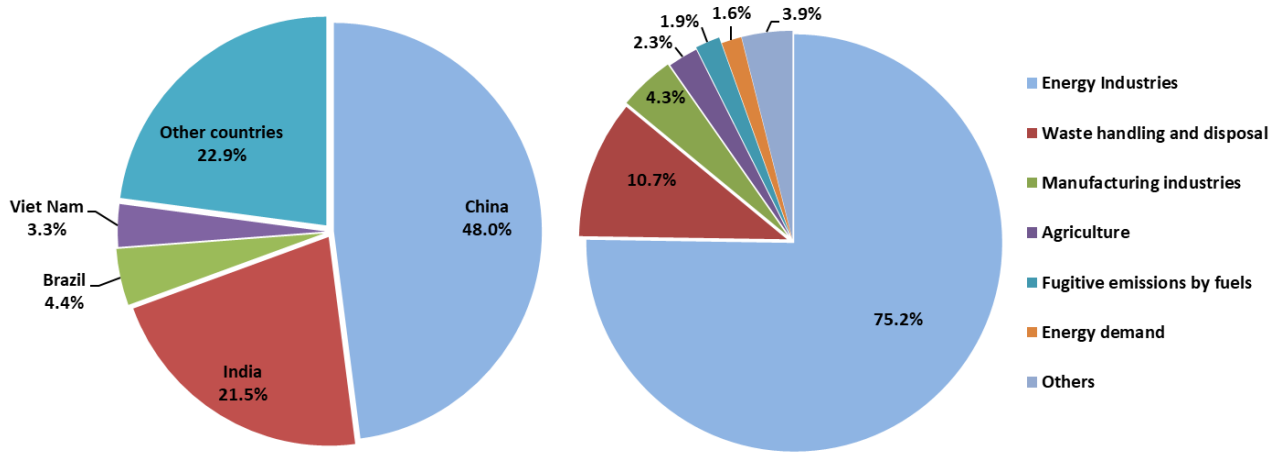
[71] PEM, Policy Evaluation Model examine the effects of agricultural policies in member countries

Procedure for assessing sustainability at local and national level for CDM and JI

The Clean Development Mechanism (CDM), defined in Article 12 of the KP, allows a country with an emission-limitation commitment (Annex B Party) to implement an emission-reduction project in developing countries.

For this section, information was collected from the UNFCCC CDM Project Search Database (UNFCCC, 2022[a]). On 24 February 2022, the UNFCCC CDM Database reported a total of 7,847 registered project activities out of 8,070 projects. With data as of 31 January 2022, 83.6% of CDM projects were registered in Asia and the Pacific Region, 12.9% in Latin America and Caribbean, 2.9% in Africa, and 0.6% in Countries with economies in transition. The distribution of registered projects by scope activity was mainly: energy industries (75.2%), waste handling and disposal (10.7%) and manufacturing industries (4.3%). Registered projects by Host Party were mainly in China (48%), India (21.4%), Brazil (4.4%) and Viet Nam (3.3%).

The distribution of global CDM projects by Host country and scope is presented in Figure 14.1.



Source: UNFCCC, 2022[b]

Figure 14.1 CDM projects by Host country and scope (as for 31/01/2022)

Italy as investor Party, contributes with 1.7% of world-wide registered CDM project portfolio. Up to 24 February 2022, Italy is involved in 129 CDM registered projects. One new project has been registered since the last year. Italy is involved directly, as government, in 52 registered CDM (MATTM, 2011). Projects by dimension are 60.5% large scale and 39.5% small scale. Italy is the only proposer for 39.5% of the CDM projects where Italy is involved.

In Annex A8.2.4 a complete list of CDM projects is available. Italian CDM projects by Host country and scope are illustrated in tables 14.2 and 14.3 respectively.

Table 14.2 Italian CDM projects by Host country

Country	**n°**	**%**
China	52	40.3
India	12	9.3
Brazil	6	4.7
Nepal	5	3.9
Uganda	5	3.9
Kenya	5	3.9
Republic of Moldova	4	3.1
Argentina	4	3.1
Tunisia	3	2.3
Other	33	25.6
Total	**129**	**100**

Table 14.3 Italian CDM projects by scope (there are project with multiple scopes)

Scope	**n°**	**%**
Energy industries (renewable/non renewable)	82	53.6
Waste handling and disposal	20	13.1

Scope	n°	%
Afforestation and reforestation	16	10.5
Manufacturing industries	16	10.5
Fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride	8	5.2
Energy demand	7	4.6
Other	4	2.6
Total	153	100

Parties should follow a project cycle to propose CDM projects (first designing phase and realization phase). During the first phase, among other activities, Parties participating in the CDM shall designate a national authority (DNA). Each Host Party has implemented a procedure for assessing CDM projects. The DNA evaluates project documentation against a set of pre-defined criteria, which tend to encompass social, environmental and economic aspects. For instance, India has SD criteria such as the social, economic, environmental and technological 'well-being'. Instead, China discriminated projects by priority area and by gas based-approach (Olsen and Fenhann, 2008; Boyd et al., 2009).

Most of the CDM projects (if large-scale) are subject to ex-ante assessments. For instance, environmental impact assessments (EIA) are required. In other cases, because of the size of the project, EIA are not necessary. Still some CDM projects have performed voluntary EIA. This is the case for the *Santa Rosa* Hydroelectric CDM project in Peru (Endesa Carbono, 2010). After, a second evaluation is performed by the DNA as described previously. For example, in the Peruvian DNA, the process follows the: submission of the project to the Ministry of competence on the activities, a site visit of the project done by the Ministry of Environment, and the conformation of an *ad hoc* committee that evaluate projects considering legal, social, environmental and economic criteria (MINAM, 2010). Thus, possible impacts of the CDM projects are mainly subject to local and national verification.

In some cases, an ex-post assessment could be also performed by the Designated Operational Entities (DOE), which validated CDM projects and certifies as appropriate and requests the Board to issue CERs. For some CDM projects, for instance, *Poechos I* Hydroelectric project (Peru), CERs are approve only if the project complies also with social and environmental conditions (Endesa Carbono, 2010). In addition, Italy agreed to accept in principle common guidelines for approval of large hydropower project activities. EU Member States have arrived at uniform guidelines on the application of Article 11b(6) of the Directive 2004/101/EC to ensure compliance (of such projects) with the international criteria and guidelines, including those contained in the World Commission on Dams 2000 Report. It aims to ensure that hydro projects are developed along the SD and the not damaging to the environment (exploring possible alternatives) and addressing such issues as gaining public acceptance, and fair and equitable treatment of stakeholders, including local and indigenous people (MATTM, 2010[a]).

Another feedback for participating to CDM project with SD characteristics comes from the carbon funds. For instance, Italy participates to the *BioCarbon Fund* (BCF), the *Community Development Carbon Fund* (CDCF) and the *Italian Carbon Fund* (ICF). The first two funds aim to finance projects with strong social impact at local level, that combine community development attributed with emission reductions and will significantly improve the life of the poor and their local environment (MATTM, 2010[a]). Italian CDM projects which are under the CDCF initiative are listed in Annex A8.2.4.

The Joint implementation (JI) is defined in Article 6 of the KP allowing a country with a limitation commitment (Annex B) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party. Two procedures could be followed. 'Track 1' procedures apply when the Host Party and investors meets all of the eligibility requirements to transfer and/or acquire ERUs, and the project is additional to any that would otherwise occur. 'Track 2' applies when the Host Party fulfils with a limited set of eligibility requirements or there is not an institutional authority able to follow up the project cycle. In this case the project should go through the verification procedure under the Joint Implementation Supervisory Committee (JISC). The development of the project is divided in a design and implementation phases (MATTM 2011[b]). Parties involved in JI activities should designated focal point for approving projects, and prepared Guidelines and Procedures for approving Art.6 Projects, including the consideration of stakeholders' (MATTM, 2010[b]). Up to 31 January 2022 the JI database from IGES source shows only one large scale

project (Track 1) with Italy involved. The task of the project is to reduce GHG emissions fuel switch (IGES, 2022).
Voluntary validation of sustainable development is taking place at international level for CDM and JI projects. The UNEP database (2022) highlights the Gold Standard (GS) and the Climate, Community and Biodiversity Alliance (CCB) for assessing SD on CDM project, and only GS for JI projects. In 2014 the CDM Board published a tool to report about the contribution of CDM projects to sustainable development (UNFCCC[c], 2022). The SD Tool is a voluntary tool for describing sustainable development co-benefits (SDC) of CDM project activities or programmes of activities enables CDM project developers to highlight the sustainable development benefits of their projects or PoAs by using a check list of predefined criteria and indicators. The GS operates a certification scheme for premium quality carbon credits and promotes sustainable development (GS label). Indicators include air/water quality, soil condition, biodiversity, quality of employment, livelihood of the poor, access to affordable and clean energy services, etc (Gold Standard, 2011). After labelling, these projects are tracked in the UNFCCC/CDM Registry. The CCBA is a voluntary standard, which support the design and identification of land management activities that simultaneously minimize climate change, support sustainable development, and conserve biodiversity. Project design standards include: climate, community, and biodiversity indicators (CCBA, 2011). Up to 01 January 2022 the UNEP database reports 7,174 registered CDM projects in the pipeline with 7,845 registered from which 6 projects are validated with CCB, 125 with GS, and 44 with SD tool (Sustainable Development tool).

Assessment of social, environmental, and economic effects of CDM and JI projects

The assessment of adverse social, environmental, and economic impacts contribution of CDM projects has been concentrated in the energy sector (or non-forestry CDM projects). Results from most relevant peer-review literature are available in this section.
Most common used methodologies for assessing sustainability are checklists and multicriteria assessments (Olsen 2007). For instance, Sirohi (2007) has qualitatively analyzed and discussed the Project Design Document (PDD) of 65 CDM projects covering all the types of CDM project activity in India. Results from this paper show that the benefits of the projects focusing on improving energy efficiency in industries, fossil fuel switching in industrial units and destruction of HFC-23 would remain largely "firm-specific" and are unlikely to have an impact on rural poverty. Boyd et al. (2009) have chosen randomly 10 CDM projects that capture diversity of project types and regions. Environment and development benefits (environment, economic, technology transfer, health, employment, education and other social) were assessed qualitatively. This review shows divergences and no causal relationship between project types and SD outcomes. Sutter and Parreño (2007) assessed CDM projects in terms of their contribution to employment generation, equal distribution of CDM returns, and improvement of local air quality. The multi-attribute assessment methodology (MATA-CDM) for non-forestry CDM projects was used for assessing 16 CDM projects registered at UNFCCC as of August 30, 2005. Results indicated that projects might contribute to one of the two CDM objectives (GHG emission reductions and SD in the Host country), but neither contributes strongly to both objectives. Uruguay's DNA has adopted this tool for approval of CDM projects. Nussbaumer (2009) has presented a SD assessment of 39 CDM projects. Label CDM projects ('Gold Standard' label and CDCF focuses) were compared to similar non-labelled CDM projects. Results show that labelled CDM activities tend to slightly outperform comparable projects, although not unequivocally. Nussbaumer selected criteria based on those from Sutter (2003) including social (stakeholder participation, improved service availability, equal distribution, capacity development), environmental (fossil energy resources, air quality, water quality, land resource) and economic (regional economy, microeconomic efficiency, employment generation, sustainable technology transfer) issues.
Some studies have also addressed the assessment of forestry CDM projects. Olsen and Fenhann (2008) have developed a taxonomy for sustainability assessment based on PDD text analysis. These authors concluded that the taxonomy can be supportive of DNAs to decide what the consequences should be, if a CDM project at the verification stage does not show signs of realizing its potential SD benefits. Palm et al (2009) developed a ranking process to assess sustainability of forest plantation projects in India. They concluded that successful implementation of forest-based project activities will require local participation and are likely to involve multiple forest products and environmental services demanded by the local community. For the first time a study has addressed the choice of an appropriate method for measuring strong sustainability. In a decision-aiding process, 10 UNFCCC/CDM afforestation/reforestation projects were evaluated through criteria that reflect global and local interests using a non-compensatory multicriteria method. Criteria for assessing SD included: social (land tenure, equitably share natural, skill development, ensure local participation), economic

(employment, financial resource to local entities, financial forestry incentives) and environmental (use of native species, conservation and maintenance of soil/water resources, biodiversity conservation) issues. The multicriteria assessment allows sorting forestry projects in three ordered categories: synergistic, reasonably synergistic, and not synergistic. This means that those projects, which are synergistic comply with a higher number of criteria (Cóndor et al., 2010).
A UNFCCC report concluded that most studies of hydrofluorocarbon and nitrous oxide related projects yield the fewest SD benefits, but the studies differ in their assessment of other project types. It also reports that other studies suggest a trade-off between the goals of the CDM in favour of producing low-cost emission reductions at the expense of achieving SD benefits (UNFCCC, 2011[a]).
For this section we have accessed project databases (UNFCCC, 2022[a]; Carbon Finance, 2019; UNEP, 2022) and peer-reviewed articles (see Annex A8.2.4 for detailed information on CDM research studies). For non-forestry CDM projects, Nussbaumer (2009) have published results of SD assessment from Honduras and Peru (Hydroelectric), Nepal (Biogas), Argentina (landfill), Moldova (Biomas), India (small hydroelectric and wind) and China (hydropower), and Sirohi (2007) for projects in India (biomass, F-gas, hydroelectric). For forestry CDM projects, Cóndor et al. (2010) has assessed 3 out from 13 CDM projects in which Italy is involved. 'The Moldova Soil Conservation' project was classified as a 'synergistic' project, while the 'Assisted Natural Regeneration of Degraded Lands' project in Albania and the 'Facilitating Reforestation for Guangxi Watershed Management' project in China were classified as 'reasonably synergistic'. The higher the assignment of the project, the better the performance respect to social, economic and environmental criteria including climate change, biodiversity and desertification issues.
Most articles found for JI are related with institutional arrangements (Evans et al., 2000; Streimikiene and Mikalauskiene, 2007; Firsova and Taplin, 2008) or the integration of JI with other mechanisms such as the white certificates (Oikonomou and van der Gaast, 2008). On peer-review article, no much information was found regarding JI and SD assessment. However, Cha et al. (2008) developed Environmental-Efficiency and Economic-Productivity indicators to choose an environmentally and economically-efficient CDM and JI project.

13.4 Funding, strengthening capacity and transfer of technology

According to Art 3.14 of the KP information on funding and transfer of technology need to be described, thus, brief information is provided in this section.
The flow of financial resources to developing countries and multilateral organisations from Italy is shown in Table 14.4 (OECD, 2022). Between 2006 and 2008 the Ministry of Foreign Affairs has contributed with around 30 million EUR in bilateral and multilateral cooperation with developing countries for climate change related activities. In order to contribute to the implementation of the commitment foreseen in the "Bonn Declaration", since 2002 the Ministry for the Environment, Land and Sea, has been authorized to finance bilateral and multilateral activities in developing countries for 55.1 million EUR/year as of 2008 (MATTM, 2009). A recent peer review report of the Development Assistance Committee (DAC) describes bilateral and multilateral cooperation funding activities in Italy. The Directorate General for Development Co-operation (DGCS) from the Ministry of Foreign Affairs in collaboration with other players in Italian Co-operation is in charge of implementing recommendations (OECD, 2009). The most important institutional actor is the Ministry for the Environment, Land and Sea, because of its contribution to implementing the Kyoto Protocol and other Rio conventions in developing countries.
The Ministry of Foreign Affairs defined the Programming Guidelines and Directions of Italian Development Co-operation 2011-2013, where priority areas are identified (MAE, 2010[a]): i) agriculture/food security; ii) human development, particularly referred to health and education/training; iii) governance and civil society; iv) support for endogenous development, inclusive and sustainable, the private sector, and v) environment, land and natural resources management, particularly referred to water and mitigation/adaptation to climate change. The aid effectiveness is a top priority for the Italian cooperation as described in the 'Aid Effectiveness Action Plan' (DGCS, 2009). The Ministry of Foreign Affairs has a database of environmental projects available online (DGCS, 2013). The ecosystem approach management is a strategy adopted by Italian cooperation. In the environment field, projects that have been monitored by the Central Technical Unit/DGCS - Ministry of Foreign Affairs, are subject to field visit and ex-post assessments in order to verify compliance in the framework of climate change activities (MAE, 2010[b]).

Table 14.4 Financial resources to developing countries and multilateral organisations from Italy, USD million.

	2001-02	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NET DISBURSEMENTS											
I. Official Development Assistance (ODA) (A + B)	**1980**	**3297**	**2996**	**4326**	**2737**	**3430**	**4009**	**4003**	**5087**	**5858**	**5098**
ODA as % of GNI	**0.18**	**0.16**	**0.15**	**0.20**	**0.14**	**0.17**	**0.19**	**0.22**	**0.27**	**0.30**	**0.25**
A. Bilateral Official Development Assistance	724	875	759	1703	624	867	1372	1829	2420	2977	2140
of which: General budget support	-1	9	5	1	6	7	8	6	1	0	1
Core support to national NGOs	64	-	15	-	1	99	93	118	137	37	38
Investment projects	-107	37	-34	310	-17	9	42	32	6	-9	48
Administrative costs	34	59	42	53	35	36	40	36	21	39	46
Other in-donor expenditures	10	5	5	526	272	406	843	985	1666	1808	1129
of which: Refugees in donor countries	8	-	3	525	247	404	840	983	1665	1804	1125
Imputed student costs							1	1	1	5	5
B. Contributions to Multilateral Institutions	1255	2423	2237	2623	2113	2563	2637	2174	2667	2881	2958
of which: UN	198	205	170	150	188	217	200	161	155	271	169
EU	691	1862	1557	1924	1516	1605	1662	1424	1773	1761	1920
IDA	183	214	386	179	166	329	377	198	214	216	323
Regional Development Banks	61	24	6	206	105	229	178	135	286	290	263
II. Other Official Flows (OOF) net (C + D)	-158	-72	-151	-214	196	161	96	43	51	110	37
C. Bilateral Other Official Flows (1 + 2)	-158	-72	-151	-214	196	161	96	43	51	110	37
1. Official export credits(1)	16	-28	-28	117	97	90	48	-	-	-	-
2. Equities and other bilateral assets(1)	-173	-44	-123	-330	100	71	48	-	-	-	-
D. Multilateral Institutions	-	-	-	-	-	-	-	-	-	-	-
III. Officially supported export credits(2)	1271	463	882	1234	725	2031	584	1414	802	1368	2121
IV. Private Flows at Market Terms (long-term) (1 to 3)	-2504	1719	5731	6456	7436	11024	3896	10033	13286	7390	98
1. Direct investment	930	129	4366	7530	8016	8643	3369	9715	8046	2	10
2. Bilateral portfolio investment	-3434	1590	1365	-1074	-580	2381	527	317	5239	7388	88
3. Securities of multilateral agencies	-	-	-	-	-	-	-	-	-	-	-
V. Grants by Private Voluntary Agencies(3)	16	162	150	111	91	58	121	128	83	64	23
VI. Total resource flows (long-term) (I to V)	**605**	**5569**	**9608**	**11912**	**11186**	**16703**	**8706**	**15621**	**19309**	**14791**	**7378**
Total resource flows as a % of GNI	**0.05**	**0.27**	**0.47**	**0.55**	**0.56**	**0.81**	**0.41**	**0.86**	**1.04**	**0.76**	**0.35**

Source: OECD (OECD, 2022) http://www.oecd.org/dac/financing-sustainable-development/development-finance-data/statisticsonresourceflowstodevelopingcountries.htm

(1) no more updated by OECD since 2018 submission.
(2) item reported as **"2. Private export credits"** under title IV up to 2017 submission.
(3) item reported as title "III. Grants by Private Voluntary Agencies " up to 2017 submission.

Preliminary data for 2020 are available in the report of the Italian Development co-operation profiles at the URL:
https://www.oecd-ilibrary.org/sites/37f92091-en/index.html?itemId=/content/component/5e331623-en&_csp_=b14d4f60505d057b456dd1730d8fcea3&itemIGO=oecd&itemContentType=chapter

Total Official Development Assistance (ODA) on a grant-equivalent basis stood at USD 4.2 billion in 2020 (preliminary data), 7.9% less than 2019 and representing 0.22% of Italy's gross national income (GNI). Italy ranked 20th among Development Assistance Committee member countries in relation to its ODA/GNI ratio in 2019. Italy is committed, at the European level, to collectively achieve a 0.7% ODA/GNI ratio by 2030. Under the cash-flow methodology used in the past, net ODA was USD 4.3 billion in 2020. Within Italy's gross ODA portfolio in 2019, 97.4% was provided in the form of grants and 2.6% in the form of non-grants (Table 14.5).

Table 14.5 Financial resources to developing countries and multilateral organisations from Italy, USD million in 2020 (preliminary data).

Official Development Assistance, grant equivalent measure	4,186
I. Bilateral ODA	1,115
Grants	952
Grant equivalents of bilateral loans	163
Debt relief	-
Other, net flows	-
Private sector instruments - institutional approach	-
Private sector instruments - instrument approach	-

II. Multilateral ODA	3,071
Grants and capital subscriptions	3,071
Grant equivalent of loans	-
GROSS NATIONAL INCOME AT MARKET PRICES	1,905,282
ODA grant equivalent as per cent of GNI	0
Population (million)	59
Official Development Assistance, net	4,348
I. Bilateral ODA, net	1,277
a. Budget support	9
b. Bilateral core support & pooled programmes & funds	350
c. Project-type interventions	620
d. Experts and other technical assistance	11
e. Debt relief	2
f. Administrative costs not included elsewhere	24
g. Other	262
In-donor refugee costs	229
a. Grants	1,006
of which: Recoveries on grants	-
b. Non grants, gross	368
c. Non grants, net	270
of which: Offsetting entry for debt forgiveness	- 52
II. Multilateral ODA, net	3,071
a. United Nations	206
b. EU	2,010
c. World Bank (AMCs, IDA, IBRD, IFC, MIGA)	432
d. Regional development banks and funds	152
e. Other	270

Italian multilateral cooperation on climate change has been performed with different United Nations organizations, funds, and institutions[72]. Cooperation has involved from the supply of financial resources, to the design and implementation of programmes and projects, the promotion of transfer of environmentally-sound technologies aiming at reducing the impacts of human activities on climate change, and support to adaptation measures. Italian bilateral cooperation continues activities described in the Fourth National Communication to the UNFCCC and has implemented new projects on climate change. Focus is given to different geographical regions world-wide[73]. Funding climate change and related topics in developing countries has different and ambitious objective: efficient use of energy, implementation of innovative financial mechanisms, efficient water management, carbon sequestration, professional training, and exchange of know-how, promotion of eco-efficient technologies. Further detailed description is given in 'Chapter 7 Financial assistance and Technology Transfer' of the Sixth National Communication from Italy (MATTM, 2014).

The DGCS of the Ministry of Foreign Affairs is contributing with bilateral projects in the energy sector, for example, in Albania, Bangladesh, Sierra Leone and Palestinian territories (improvement of electric system or hydroelectric power generation). An example is the hydroelectric project in Ethiopia that has been supported by the Ministry of Foreign Affairs. Next step of this project will be an ex-post assessment of adverse effects through the use of the OECD-DAC guidelines (MAE, 2010[c]). These guidelines include the assessment of the relevance, effectiveness, efficiency, impact (positive/negative) and sustainability of the activities (OECD, 2008). In June 2010 the guidelines for on-going and ex-post evaluation of official development assistance implemented by the DGCS-Ministry of Foreign Affairs were published (MAE, 2010[d]).

Evidence of technology transfer activities were found in the context of the Kyoto Mechanisms. A study analyzed comprehensively technology transfer in the CDM: 3296 registered and proposed projects (Seres et al., 2009). Results address that roughly 36% of the projects accounting for 59% of the annual emission reductions claim to involve technology transfer. These authors concluded that as the number of projects increases, technology transfer occurs beyond the individual projects. This is observed for several of the most common project types in China and Brazil with the result that the rate of technology transfer for new projects in those countries has fallen significantly.

[72] Italian multilateral cooperation with the United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Industrial Development Organization (UNIDO), Food and Agriculture Organization of the United Nations (FAO), the Regional Environmental Centre for Central and Eastern Europe (REC), the Global Environment Facility (GEF), the World Bank (WB), International Union for Conservation of Nature (IUCN), the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and the Mediterranean Action Plan (MAP).

[73] Italian bilateral cooperation with the Asian and Middle East countries (China, Iraq, Thailand and India), Mediterranean and African region (Algeria, Egypt, Israel, Tunisia, Morrocco), Central and Eastern European countries (Albania, Bosnia, Croatia, Bulgaria, Serbia, Montenegro, Macedonia, Poland, Romania, Turkey, Hungary, Kyrgyzstan and Tajikistan), and Latin America, the Caribean and the Pacific Islands (Belize, Argentina, Mexico, Cuba, Brazil, 14 countries of the South Pacific Small Islands Developing States).

13.5 Priority actions in implementing commitments under Article 3 paragraph 14

For the purposes of completeness in reporting, and according to the reporting guidelines for supplementary information (UNFCCC, 2002), a summary of how Italy gives priority to the actions specified in Decision 15/CMP.1, paragraph 24 is given below. More detailed information is found in the Sixth National Communication under the UNFCCC, Chapter 5 Projections and effects of policies and measures and Chapter 7 Financial resources and transfer of technology (MATTM, 2014). The preparation of this paragraph was discussed with energy experts from ISPRA (ISPRA, 2011[a], [b]).

Paragraph 24 (a)

The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

EU emissions trading scheme, promotion of biomass and biofuel, Common Agricultural Policy can potentially have impacts in developing countries (European Commission, 2009[b]). Italy is subject to the European legal system and it will implement the EU legislation. At national level, it is not planned to further increase biomass – biofuel objectives already established (ISPRA, 2011[a]).

Paragraph 24 (b)

Removing subsidies associated with the use of environmentally unsound and unsafe technologies.

Council regulation EC No 1407/2002 rules for granting state aid to contribute to restructure coal industry (European Commission, 2010). Anyway, Italy has a negligible domestic coal production.

Paragraph 24 (c)

Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end.

At European level and national level, 'non-energy uses of fossil fuels' is not a current research priority (European Commission, 2010).

Paragraph 24 (d)

Cooperating in the development, diffusion, and transfer of less greenhouse gas emitting advanced fossil-fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort.

The ongoing activities on multilateral and bilateral Italian cooperation are coordinated through the Ministry of Foreign Affairs and the Ministry for the Environment, Land and Sea, see MATTM (2009, 2014).

For example, Italy has signed with India a Memorandum of Understanding (MoU) on "Co-operation in the Area of Climate Change and Development and Implementation of Projects under the CDM/ Kyoto Protocol". In this framework, the MATTM supported a project on Carbon Sequestration Potential Assessment.

The Italian Government has already funded research on carbon capture and storage (CCS) technologies carried out by several organizations and institutions: total value 10-15 million euro for the period 2009-2011. A draft decree transposing EU directive 2009/31/CE in the Italian legislation has been presented to the Parliament by the MATTM and the Ministry for Economic Development. ENEL and ENI, the two major energy utilities in the country, have signed a general agreement for CCS development and will apply for EU funds to set up a pilot unit in Brindisi and a demonstration unit in Porto Tolle. At the international level, Enel is developing a project to build a CO_2 capture system in China and has signed agreements for the development of CCS with other countries like South Korea (ISPRA, 2011[b]).

Paragraph 24 (e)

Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities.

The ongoing activities on multilateral and bilateral Italian cooperation are coordinated through the Ministry of Foreign Affairs and the Ministry for the Environment, Land and Sea, see MATTM (2009, 2014).

For example, in Central Eastern Europe Italy has multilateral activities within the Regional Environmental Center for Central and Eastern Europe (REC CEE). More than 100 projects have been implemented for the region, specifically, to climate change and energy issues, several programs were carried out on training and capacity building, energy efficiency in small and medium-sized enterprises, public access to information and participation in climate decision-making processes, promotion of climate change mitigation and adaptation policies, development of solar passive and active systems and development of national GHG emission registries.

Paragraph 24 (f)

Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies.

The ongoing activities on multilateral and bilateral Italian cooperation are coordinated through the Ministry of Foreign Affairs and the Ministry for the Environment, Land and Sea, see MATTM (2009, 2014). For example, within the framework of the Mediterranean Renewable Energy Programme (MEDREP) Initiative, the MATTM has signed a MoU with UNEP-DTIE in order to carry out projects helping the establishment of a regional RET market in the Mediterranean region (Tunisia, Egypt, Montenegro and Albania). After, the Mediterranean Investment Facility was launched aiming to the development (2007–2011) of several projects having an important impact on CO_2 emissions by diversifying the use of small scale renewable energy and energy efficiency technologies by targeting different niche markets.

In 2007, the MATTM supported the "Observatory for Renewable Energy in Latin America and the Caribbean" through the signature of a Trust Fund Agreement with UNIDO. Activities are focused on biomass utilization in Uruguay and Brazil in order to reduce the methane emissions and the GHGs' climate change effects, promoting the utilization of bio-digester plants for the electricity production into the livestock farms, based on a local energy management distributed generation system.

13.6 Additional information and future activities related to the commitment of Article 3.14 of the Kyoto Protocol

Italy is aware of its commitments under Article 3.14 of KP, and it is also well aware of the need to assess social, environmental and economic impacts. Different national and international mechanisms and guidelines are guiding the prevention of adverse effects while implementing projects in developing countries. Different activities have been identified for future commitments under Art 3.14. For instance, priority actions need to be further classified into positive and negative, direct and indirect features.

Italian private companies are participating to flexible mechanisms. For instance, ENI an Italian world-wide energy company, projects to reduce gas flaring associated with oil production, with the goal of reducing by 70% emissions from gas flaring, compared to 2007. For some of these projects, ENI promotes the recognition flexible mechanisms within the CDM (ENI, 2010). ENEL is the Italian largest power company that is one of the main worldwide operators applying the CDM. Most of these initiatives were developed bilaterally between Enel-Endesa and the Host country. The group portfolio includes 105 direct participation projects, mostly located in China (79 projects) and other located in India, Africa and Latin America. As for the JI mechanism, the Group's portfolio includes 7 projects in Uzbekistan and Ukraine and 32 indirect-participation projects in the European Union, Russia, Moldova and Ukraine (ENEL, 2011).

Finally, projects from decentralized development cooperation are to be considered (OICS, 2011). Principles, actors, priority areas and instruments relating to programs conducted by DGCS with the regions and local authorities (provinces and municipalities) are defined in specific guidelines for decentralized cooperation (MAE, 2010[e]).

13.7 Review process of Article 3.14 of the Kyoto Protocol

In 2011 an in-country review process for the Fifth National Communication took place. During this process also the minimization of adverse impacts in accordance with Article 3, paragraph 14, of the Kyoto Protocol was reviewed. Additional information reported for submission 2010 and 2011 related with this theme was also provided. According to the UNFCCC review report, the Expert review team (ERT) considers the reported information to be transparent and complete. The ERT also commends Italy for its comprehensive, transparent and well-documented information on the minimization of adverse impacts and encourages it to continue exploring and reporting on the adverse impacts of the response measures (UNFCCC, 2011[b]).

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ANNEX 1: KEY CATEGORIES AND UNCERTAINTY

A1.1 Introduction

The 2006 IPCC Guidelines (IPCC, 2006) recommends as good practice the identification of *key categories* in national GHG inventories. A *key category* is defined as an emission source that has a significant influence on a country's GHG inventory in terms either of the absolute/relative level of emissions or the trend in emissions, or both. In this document whenever the term *category* is used, it includes both sources and sinks. Two different approaches are reported in the guidelines according to whether or not a country has performed an uncertainty analysis of the inventory: Approach 1 and Approach 2.

When using Approach 1, key categories are identified by means of a pre-determined cumulative emissions threshold, usually fixed at 95% of the total. If an uncertainty analysis is carried out at category level for the inventory, Approach 2 can be used to identify key categories. Approach 2 is a more detailed analysis that builds on Approach 1; in fact, the results of Approach 1 are multiplied by the relative uncertainty of each source/sink category. Key categories are those that represent 90% of the uncertainty contribution. So the factors which make a source or a sink a key category have a high contribution to the total, a high contribution to the trend and a high uncertainty. If both the approaches are applied, it is good practice to use the results of the Approach 2 analysis.

For the Italian inventory, a key category analysis has been carried out according to both the methods, excluding and including the LULUCF sector. National emissions have been disaggregated, as far as possible, into the categories proposed in the IPCC guidelines; other categories have been added to reflect specific national circumstances. Both level and trend analysis have been applied. For the base year, the level assessment has been carried out.

Summary of the results of the key category analysis, for the base year and 2020, is reported in Tables 1.3– 1.6 of chapter 1. The tables indicate whether a key category derives from the level assessment or the trend assessment, according to Approach 1, Approach 2 or both.

For the base year, 27 categories were individuated according to Approach 1, whereas 30 categories were carried out by Approach 2. Including the LULUCF sector in the analysis, 33 categories were selected according to Approach 1 and 35 with Approach 2.

For the year 2020, 27 categories were individuated by the Approach 1 accounting for 95% of the total emissions, without LULUCF; for the trend 26 key categories were selected. Repeating the key category analysis for the full inventory, including the LULUCF sector, 32 categories were individuated accounting for 95% of the total emissions and removals in 2020, and 33 key categories in trend assessment.

The application of the Approach 2 to the 2020 emission levels gives as a result 26 key categories accounting for the 90% of the total levels with uncertainty; when applying the trend analysis the number of the key categories is equal to 30. The application of the Approach 2 including the LULUCF categories results in 29 key categories, for the year 2020, accounting for the 90% of the total levels with uncertainty; for the trend analysis including LULUCF categories, the results were 34 key categories.

A1.2 Approach 1 key category assessment

As described in the 2006 IPCC Guidelines (IPCC, 2006), the Approach 1 for identifying key categories assesses the impact of various categories on the level and on the trend of the national emission inventory. Both level and trend assessments should be applied to an emission GHG inventory.

As regards the level assessment, the contribution of each source or sink category to the total national inventory level is calculated as follows:

$$\text{Category Level Assessment} = \frac{|\text{Source or Sink Category Estimate}|}{\text{Total Contribution}}$$

$$L_{x,t} = \frac{|E_{x,t}|}{\sum_y |E_{y,t}|}$$

where

$L_{x,t}$ = level assessment for source or sink x in year t;

$|E_{x,t}|$ = absolute value of emission and removal estimate of source or sink category *x* in year *t*;

$\sum_y |E_{y,t}|$ = total contribution, which is the sum of the absolute values of emissions and removals in year *t*.

The contribution of all categories (including the LULUCF sector) is entered as absolute values.
Therefore, key categories are those which, when summed in descending order of magnitude, add up to over 95% of the total emissions.
As far as the trend assessment is concerned, the contribution of each source and sink category's trend can be assessed by the following equation:

Category Trend Assessment =

$$\left(\text{Source or Sink Category Level Assessment}\right)\cdot\left|\text{Source or Sink Category Trend - Total Trend}\right|$$

$$T_{x,t} = \left|E_{x,0}\right| \Big/ \sum_y \left|E_{y,0}\right| \cdot \left| \left[\left(E_{x,t} - E_{x,0}\right) \Big/ \left|E_{x,0}\right| \right] - \left[\left(E_t - E_0\right) \Big/ \sum_y \left|E_{y,0}\right| \right] \right|$$

where

$T_{x,t}$ = trend assessment, which is the contribution of the category trend to the overall inventory trend;

$|E_{x,0}|$ = absolute value of emission and removal estimate of category *x* in the base year (year *0*);

$\sum_y |E_{y,0}|$ = total contribution, which is the sum of the absolute values of emissions and removals in year *0*;

$E_{x,t}$ *and* $E_{x,0}$ = real values of estimates of category *x* in years *t* and 0, respectively;

E_t *and* $E_0 = \sum_y E_{y,t}$ *and* $\sum_y E_{y,0}$ = total inventory estimates in years *t* and 0, respectively.

The source or sink category trend is the change in the category emissions over time, computed by subtracting the base year estimate for a generic category from the latest inventory year estimate and dividing by the absolute value of the latest inventory year estimate; the total trend is the change in the total inventory emissions over time, computed by subtracting the base year estimate for the total inventory from the current year estimate and dividing by the current year estimate.
In circumstances where the base year emissions for a given category are zero, the expression is reformulated to avoid zero in the denominator:

$$T_{x,t} = \left|E_{x,t} \Big/ \left|E_{x,0}\right|\right|$$

As differences in trend are more significant to the overall inventory level for larger categories, the results of the trend difference is multiplied by the results of the level assessment to provide appropriate weighting.
Thus, key categories will be those for which the category trend diverges significantly from the total trend, weighted by the emission level of the category.
Both level and trend assessments have been carried out for the Italian GHG inventory. For the base year, a level assessment is computed.
In this section, detailed results are reported for the last year inventory.
The results of Approach 1 are shown in Table A1.1 and Table A1.2, level and trend assessments without LULUCF categories. Results of the key category analysis with the LULUCF are reported in Table A1.3 and Table A1.4.

Table A1.1 Results of the key category analysis without LULUCF. Approach 1 Level assessment, year 2020

CATEGORIES	2020 *kt CO_2 eq*	Level assessment	Cumulative Percentage
Transport - CO2 Road transportation	77,832	0.204	0.20
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	55,195	0.145	0.35
Energy industries - CO2 gaseous fuels	51,148	0.134	0.48
Manufacturing industries and construction - CO2 gaseous fuels	30,744	0.081	0.56
Energy industries - CO2 solid fuels	15,613	0.041	0.60
Energy industries - CO2 liquid fuels	14,415	0.038	0.64
Solid waste disposal - CH4	14,253	0.037	0.68
Other sectors - CO2 commercial, residential, agriculture liquid fuels	13,610	0.036	0.72
Enteric Fermentation- CH4	13,535	0.036	0.75
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	13,479	0.035	0.79
Manufacturing industries and construction - CO2 liquid fuels	8,677	0.023	0.81
Direct N2O Emissions from Managed soils	8,458	0.022	0.83
Mineral industry - CO2 Cement production	7,059	0.019	0.85
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	5,778	0.015	0.87
Manufacturing industries and construction - CO2 solid fuels	4,985	0.013	0.88
Transport - CO2 Waterborne navigation	4,624	0.012	0.89
Manure Management - CH4	4,147	0.011	0.90
Fugitive - CH4 Oil and natural gas - Natural gas	3,073	0.008	0.91
Wastewater treatment and discharge - CH4	2,375	0.006	0.92
Indirect N2O Emissions from Managed soils	2,363	0.006	0.92
Other sectors - CH4 commercial, residential, agriculture biomass	2,153	0.006	0.93
Manure Management - N2O	2,076	0.005	0.93
Mineral industry - CO2 Lime production	1,611	0.004	0.94
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	1,600	0.004	0.94
Rice cultivations - CH4	1,582	0.004	0.945
Fugitive - CO2 Oil and natural gas - Oil	1,486	0.004	0.949
Wastewater treatment and discharge - N2O	1,217	0.003	0.952
Metal industry- CO2 Iron and steel production	1,215	0.003	0.96
Transport - CO2 Civil Aviation	1,195	0.003	0.96
Other sectors - N2O commercial, residential, agriculture biomass	1,156	0.003	0.96
Non-Energy products from Fuels and Solvent Use - CO2	1,091	0.003	0.96
Other sectors - N2O commercial, residential, agriculture liquid fuels	760	0.002	0.97
Transport - N2O Road transportation	737	0.002	0.97
Transport - CO2 Other transportation - pipelines	675	0.002	0.97
Chemical industry- CO2 Ammonia production	658	0.002	0.97
Other non specified - CO2 military mobile - liquid fuels	625	0.002	0.97

Table A1.2 Results of the key category analysis without LULUCF. Approach 1 Trend assessment base year-2020

CATEGORIES	Contribution to trend (%)	Cumulative Percentage
Energy industries - CO2 liquid fuels	0.182	0.18
Energy industries - CO2 gaseous fuels	0.156	0.34
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.115	0.45
Manufacturing industries and construction - CO2 liquid fuels	0.062	0.52
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.058	0.57
Manufacturing industries and construction - CO2 solid fuels	0.056	0.63
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.054	0.68
Energy industries - CO2 solid fuels	0.051	0.74
Transport - CO2 Road transportation	0.041	0.78
Manufacturing industries and construction - CO2 gaseous fuels	0.029	0.81
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.022	0.83
Solid waste disposal - CH4	0.021	0.85
Mineral industry- CO2 Cement production	0.018	0.87
Chemical industry- N2O Adipic acid production	0.013	0.88
Fugitive - CH4 Oil and natural gas - Natural gas	0.012	0.89
Enteric Fermentation- CH4	0.009	0.90
Direct N2O Emissions from Managed soils	0.008	0.91
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.006	0.92
Metal industry- PFCs Aluminium production	0.006	0.92
Chemical industry- N2O Nitric acid production	0.006	0.93
Other sectors - CH4 commercial, residential, agriculture biomass	0.006	0.93
Mineral industry- CO2 Other processes uses of carbonates	0.005	0.94
Metal industry- CO2 Iron and steel production	0.004	0.94
Other sectors - N2O commercial, residential, agriculture biomass	0.003	0.95
Chemical industry- CO2 Ammonia production	0.003	0.948
Other sectors - CO2 commercial, residential, agriculture solid fuels	0.003	0.951
Transport - CO2 Waterborne navigation	0.002	0.95
Manure Management - CH4	0.002	0.96
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.002	0.96
Indirect N2O Emissions from Managed soils	0.002	0.96

Table A1.3 Results of the key category analysis with LULUCF. Approach 1 Level assessment, year 2020

CATEGORIES	2020 *kt CO_2 eq*	Level assessment	Cumulative Percentage
Transport - CO2 Road transportation	77,832	0.183	0.18
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	55,195	0.130	0.31
Energy industries - CO2 gaseous fuels	51,148	0.120	0.43
Manufacturing industries and construction - CO2 gaseous fuels	30,744	0.072	0.50
Forest Land remaining Forest Land - CO2	-25,040	0.059	0.56
Energy industries - CO2 solid fuels	15,613	0.037	0.60
Energy industries - CO2 liquid fuels	14,415	0.034	0.63
Solid waste disposal - CH4	14,253	0.033	0.67
Other sectors - CO2 commercial, residential, agriculture liquid fuels	13,610	0.032	0.70
Enteric Fermentation- CH4	13,535	0.032	0.73
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	13,479	0.032	0.76
Manufacturing industries and construction - CO2 liquid fuels	8,677	0.020	0.78
Direct N2O Emissions from Managed soils	8,458	0.020	0.80
Mineral industry- CO2 Cement production	7,059	0.017	0.82
Land Converted to Grassland - CO2	-5,896	0.014	0.83
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	5,778	0.014	0.85
Land Converted to Forest Land - CO2	-5,221	0.012	0.86
Land Converted to Settlements - CO2	5,207	0.012	0.87
Manufacturing industries and construction - CO2 solid fuels	4,985	0.012	0.88
Transport - CO2 Waterborne navigation	4,624	0.011	0.89
Manure Management - CH4	4,147	0.010	0.90
Fugitive - CH4 Oil and natural gas - Natural gas	3,073	0.007	0.91
Wastewater treatment and discharge - CH4	2,375	0.006	0.92
Indirect N2O Emissions from Managed soils	2,363	0.006	0.92
Other sectors - CH4 commercial, residential, agriculture biomass	2,153	0.005	0.93
Manure Management - N2O	2,076	0.005	0.93
Mineral industry- CO2 Lime production	1,611	0.004	0.94
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	1,600	0.004	0.94
Rice cultivations - CH4	1,582	0.004	0.94
Fugitive - CO2 Oil and natural gas - Oil	1,486	0.003	0.95
Grassland Remaining Grassland - CO2	-1,468	0.003	0.950
Wastewater treatment and discharge - N2O	1,217	0.003	0.953
Other sectors - N2O commercial, residential, agriculture biomass	1,156	0.003	0.96
Non-Energy products from Fuels and Solvent Use - CO2	1,091	0.003	0.96
Other sectors - N2O commercial, residential, agriculture liquid fuels	760	0.002	0.97
Transport - N2O Road transportation	737	0.002	0.97
Other sectors - N2O commercial, residential, agriculture biomass	1,156	0.003	0.96

Table A1.4 Results of the key category analysis with LULUCF. Approach 1 Trend assessment, base year-2020

CATEGORIES	% Contribution to trend	Cumulative Percentage
Energy industries - CO2 liquid fuels	0.152	0.15
Energy industries - CO2 gaseous fuels	0.149	0.30
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.115	0.42
Transport - CO2 Road transportation	0.058	0.47
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.054	0.53
Manufacturing industries and construction - CO2 liquid fuels	0.051	0.58
Manufacturing industries and construction - CO2 solid fuels	0.047	0.63
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.046	0.67
Energy industries - CO2 solid fuels	0.039	0.71
Manufacturing industries and construction - CO2 gaseous fuels	0.034	0.74
Solid waste disposal - CH4	0.023	0.77
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.020	0.79
Forest Land remaining Forest Land - CO2	0.019	0.81
Grassland Remaining Grassland - CO2	0.019	0.83
Land Converted to Grassland - CO2	0.016	0.84
Mineral industry- CO2 Cement production	0.014	0.86
Enteric Fermentation- CH4	0.011	0.87
Chemical industry- N2O Adipic acid production	0.011	0.88
Direct N2O Emissions from Managed soils	0.010	0.89
Fugitive - CH4 Oil and natural gas - Natural gas	0.009	0.90
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.006	0.90
Other sectors - CH4 commercial, residential, agriculture biomass	0.006	0.91
Land Converted to Forest Land - CO2	0.005	0.91
Metal industry- PFCs Aluminium production	0.005	0.92
Chemical industry- N2O Nitric acid production	0.005	0.92
Mineral industry- CO2 Other processes uses of carbonates	0.004	0.93
Transport - CO2 Waterborne navigation	0.003	0.93
Metal industry- CO2 Iron and steel production	0.003	0.94
Manure Management - CH4	0.003	0.94
Cropland Remaining Cropland - CO2	0.003	0.94
Other sectors - N2O commercial, residential, agriculture biomass	0.003	0.95
Land Converted to Settlements - CO2	0.003	0.948
Indirect N2O Emissions from Managed soils	0.002	0.9505
Chemical industry- CO2 Ammonia production	0.002	0.95
Other sectors - CO2 commercial, residential, agriculture solid fuels	0.002	0.96
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.002	0.96
Manufacturing industries and construction - CO2 other fuels	0.002	0.96
Biological treatment of Solid waste - N2O	0.002	0.96

The application of Approach 1, excluding LULUCF categories, gives as a result 27 key categories accounting for the 95% of the total levels; when applying the trend analysis, excluding LULUCF categories, the number of key categories is equal to 26 (Tables A1.1, A1.2).
The Approach 1 level assessment repeated for the full inventory, including the LULUCF, results in 32 key categories (sources and sinks), and 33 key categories outcome from the trend analysis (Tables A1.3, A1.4).
For the base year, the results are reported in the following tables, including and excluding LULUCF.

Table A1.5 Results of the key category analysis without LULUCF. Approach 1 Level assessment, base year

CATEGORIES	Base year kt CO_2 eq	Level assessment	Cumulative Percentage
Transport - CO2 Road transportation	92,332	0.18	0.18
Energy industries - CO2 liquid fuels	81,197	0.16	0.33
Energy industries - CO2 solid fuels	38,647	0.07	0.41
Other sectors - CO2 commercial, residential, agriculture liquid fuels	38,274	0.07	0.48
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	36,338	0.07	0.55
Manufacturing industries and construction - CO2 liquid fuels	32,805	0.06	0.61
Manufacturing industries and construction - CO2 gaseous fuels	32,234	0.06	0.68
Manufacturing industries and construction - CO2 solid fuels	25,732	0.05	0.73
Energy industries - CO2 gaseous fuels	16,954	0.03	0.76
Mineral industry- CO2 Cement production	15,846	0.03	0.79
Enteric Fermentation - CH4	15,564	0.03	0.82
Solid waste disposal - CH4	12,206	0.02	0.84
Direct N2O Emissions from Managed soils	8,716	0.02	0.86
Fugitive - CH4 Oil and natural gas - Natural gas	8,236	0.02	0.88
Transport - CO2 Waterborne navigation	5,470	0.01	0.89
Manure Management - CH4	4,843	0.01	0.90
Chemical industry- N2O Adipic acid production	4,402	0.01	0.90
Wastewater treatment and discharge - CH4	3,200	0.01	0.91
Metal industry- CO2 Iron and steel production	3,124	0.01	0.92
Manure Management - N2O	2,830	0.01	0.92
Mineral industry - CO2 Other processes uses of carbonates	2,544	0.00	0.93
Indirect N2O Emissions from Managed soils	2,538	0.00	0.93
Fugitive - CO2 Oil and natural gas - Oil	2,402	0.00	0.94
Chemical industry - N2O Nitric acid production	2,005	0.00	0.94
Metal industry - PFCs Aluminium production	1,975	0.00	0.94
Chemical industry - CO2 Ammonia production	1,892	0.00	0.947
Mineral industry - CO2 Lime production	1,877	0.00	0.9504
Rice cultivations - CH4	1,876	0.00	0.954
Non-Energy products from Fuels and Solvent Use - CO2	1,712	0.00	0.957
Transport - CO2 Civil Aviation	1,493	0.00	0.96

Table A1.6 Results of the key category analysis with LULUCF. Approach 1 Level assessment, base year

CATEGORIES	Base year kt CO_2 eq	Level assessment	Cumulative Percentage
Transport - CO2 Road transportation	92,332	0.17	0.17
Energy industries - CO2 liquid fuels	81,197	0.15	0.31
Energy industries - CO2 solid fuels	38,647	0.07	0.38
Other sectors - CO2 commercial, residential, agriculture liquid fuels	38,274	0.07	0.45
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	36,338	0.07	0.52
Manufacturing industries and construction - CO2 liquid fuels	32,805	0.06	0.58
Manufacturing industries and construction - CO2 gaseous fuels	32,234	0.06	0.63
Manufacturing industries and construction - CO2 solid fuels	25,732	0.05	0.68
Energy industries - CO2 gaseous fuels	16,954	0.03	0.71
Mineral industry- CO2 Cement production	15,846	0.03	0.74
Enteric Fermentation- CH4	15,564	0.03	0.77
Forest Land remaining Forest Land - CO2	-15,002	0.03	0.79
Solid waste disposal - CH4	12,206	0.02	0.82
Direct N2O Emissions from Managed soils	8,716	0.02	0.83
Fugitive - CH4 Oil and natural gas - Natural gas	8,236	0.01	0.85
Land Converted to Settlements - CO2	6,640	0.01	0.86
Transport - CO2 Waterborne navigation	5,470	0.01	0.87
Grassland Remaining Grassland - CO2	5,358	0.01	0.88
Manure Management - CH4	4,843	0.01	0.89
Chemical industry- N2O Adipic acid production	4,402	0.01	0.89
Wastewater treatment and discharge - CH4	3,200	0.01	0.90
Metal industry- CO2 Iron and steel production	3,124	0.01	0.91
Land Converted to Forest Land - CO2	-2,849	0.01	0.91
Manure Management - N2O	2,830	0.01	0.92
Mineral industry- CO2 Other processes uses of carbonates	2,544	0.00	0.92
Indirect N2O Emissions from Managed soils	2,538	0.00	0.93
Fugitive - CO2 Oil and natural gas - Oil	2,402	0.00	0.93
Chemical industry- N2O Nitric acid production	2,005	0.00	0.93
Metal industry- PFCs Aluminium production	1,975	0.00	0.94
Chemical industry- CO2 Ammonia production	1,892	0.00	0.94
Mineral industry- CO2 Lime production	1,877	0.00	0.94
Rice cultivations - CH4	1,876	0.00	0.947
Non-Energy products from Fuels and Solvent Use - CO2	1,712	0.00	0.9504
Transport - CO2 Civil Aviation	1,493	0.00	0.95
Wastewater treatment and discharge - N2O	1,259	0.00	0.96
Land Converted to Grassland - CO2	-1,180	0.00	0.96
Other non specified - CO2 military mobile - liquid fuels	1,071	0.00	0.96

The application of Approach 1 to the base year, excluding LULUCF categories, gives as a result 27 key categories accounting for the 95% of the total levels; when applying the base year assessment, including the LULUCF, the number of key categories increases to 33 (Tables A1.5, A1.6).

A1.3 Uncertainty assessment (IPCC Approach 1)

Approach 2 for the identification of key categories implies the assessment of the uncertainty analysis to an emission inventory. As already mentioned, the IPCC Approach 1 has been applied to the Italian GHG inventory to estimate uncertainties for the base year and the last submitted year. In this section, detailed results are reported for the 2020 inventory. The uncertainty analysis has also been implemented both excluding and including the LULUCF sector in the national totals.

Results are reported in Table A1.7, for the year 2020, excluding the LULUCF sector and in Table A1.8 figures of inventory total uncertainty, including the LULUCF sector, are shown.

Details on the method used for LULUCF are described in chapter 6.

Table A1.7 Results of the uncertainty analysis excluding LULUCF (Approach 1). Year 2020

		Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
IPCC category	**Gas**	**Base year**	**2020**	**AD**	**EF**	**Combined**	**Contribution to variance**	**Type A**	**Type B**	**introduced by EF uncertainty**	**introduced by AD uncertainty**	**in total national emissions**
Energy industries - CO2 liquid fuels	CO2	81,197	14,415	3%	3%	0.042	0.000	0.087	0.028	0.003	0.001	0.0000081
Energy industries - CO2 solid fuels	CO2	38,647	15,613	3%	3%	0.042	0.000	0.024	0.030	0.001	0.001	0.0000022
Energy industries - CO2 gaseous fuels	CO2	16,954	51,148	3%	3%	0.042	0.000	0.074	0.098	0.002	0.004	0.0000224
Energy industries - CO2 other fuels	CO2	143	178	3%	3%	0.042	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - N2O liquid fuels	N2O	288	118	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - N2O solid fuels	N2O	163	68	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - N2O gaseous fuels	N2O	9	30	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - N2O other fuels	N2O	1	1	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - N2O biomass	N2O	16	108	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - CH4 liquid fuels	CH4	74	9	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - CH4 solid fuels	CH4	132	11	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - CH4 gaseous fuels	CH4	11	32	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - CH4 other fuels	CH4	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Energy industries - CH4 biomass	CH4	10	65	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - CO2 liquid fuels	CO2	32,805	8,677	3%	3%	0.042	0.000	0.030	0.017	0.001	0.001	0.0000013
Manufacturing industries and construction - CO2 solid fuels	CO2	25,732	4,985	3%	3%	0.042	0.000	0.027	0.010	0.001	0.000	0.0000008
Manufacturing industries and construction - CO2 gaseous fuels	CO2	32,234	30,744	3%	3%	0.042	0.000	0.014	0.059	0.000	0.003	0.0000065
Manufacturing industries and construction - CO2 other fuels	CO2	0	473	3%	3%	0.042	0.000	0.001	0.001	0.000	0.000	0.0000000
Manufacturing industries and construction - N2O liquid fuels	N2O	926	395	3%	50%	0.501	0.000	0.001	0.001	0.000	0.000	0.0000001
Manufacturing industries and construction - N2O solid fuels	N2O	243	49	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - N2O gaseous fuels	N2O	164	168	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - N2O other fuels	N2O	0	27	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - N2O biomass	N2O	6	63	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - CH4 liquid fuels	CH4	42	15	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - CH4 solid fuels	CH4	107	37	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - CH4 gaseous fuels	CH4	14	13	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000

IPCC category	Gas	Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Manufacturing industries and construction - CH4 other fuels	CH4	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Manufacturing industries and construction - CH4 biomass	CH4	4	209	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.0000001
Transport - CO2 Road transportation	CO2	92,332	77,832	3%	3%	0.042	0.000	0.019	0.150	0.001	0.006	0.0000407
Transport - N2O Road transportation	N2O	838	737	3%	40%	0.401	0.000	0.000	0.001	0.000	0.000	0.0000000
Transport - CH4 Road transportation	CH4	867	148	3%	40%	0.401	0.000	0.001	0.000	0.000	0.000	0.0000001
Transport - CO2 Waterborne navigation	CO2	5,470	4,624	3%	3%	0.042	0.000	0.001	0.009	0.000	0.000	0.0000001
Transport - N2O Waterborne navigation	N2O	38	34	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CH4 Waterborne navigation	CH4	35	17	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CO2 Civil Aviation	CO2	1,493	1,195	3%	3%	0.042	0.000	0.000	0.002	0.000	0.000	0.0000000
Transport - N2O Civil Aviation	N2O	12	10	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CH4 Civil Aviation	CH4	1	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CO2 Railways	CO2	613	136	3%	5%	0.058	0.000	0.001	0.000	0.000	0.000	0.0000000
Transport - N2O Railways	N2O	72	16	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CH4 Railways	CH4	1	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CO2 Other transportation - pipelines	CO2	411	675	3%	3%	0.042	0.000	0.001	0.001	0.000	0.000	0.0000000
Transport - N2O Other transportation - pipelines	N2O	7	10	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Transport - CH4 Other transportation - pipelines	CH4	0	1	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other sectors - CO2 commercial, residential, agriculture liquid fuels	CO2	38,274	13,610	3%	3%	0.042	0.000	0.028	0.026	0.001	0.001	0.0000019
Other sectors - CO2 commercial, residential, agriculture solid fuels	CO2	899	0	3%	3%	0.042	0.000	0.001	0.000	0.000	0.000	0.0000000
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	CO2	36,338	55,195	3%	3%	0.042	0.000	0.055	0.106	0.002	0.005	0.0000230
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	CO2	530	5,778	3%	3%	0.042	0.000	0.010	0.011	0.000	0.000	0.0000003
Other sectors - N2O commercial, residential, agriculture liquid fuels	N2O	996	760	3%	50%	0.501	0.000	0.000	0.001	0.000	0.000	0.0000000
Other sectors - N2O commercial, residential, agriculture solid fuels	N2O	4	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other sectors - N2O commercial, residential, agriculture gaseous fuels	N2O	194	284	3%	50%	0.501	0.000	0.000	0.001	0.000	0.000	0.0000000
Other sectors - N2O commercial, residential, agriculture other fossil fuels	N2O	15	158	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other sectors - N2O commercial, residential, agriculture biomass	N2O	531	1,156	3%	50%	0.501	0.000	0.001	0.002	0.001	0.000	0.0000006
Other sectors - CH4 commercial, residential, agriculture liquid fuels	CH4	94	17	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000

IPCC category	Gas	Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Other sectors - CH4 commercial, residential, agriculture gaseous fuels	CH4	41	60	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other sectors - CH4 commercial, residential, agriculture other fossil fuels	CH4	1	8	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other sectors - CH4 commercial, residential, agriculture biomass	CH4	996	2,153	3%	50%	0.501	0.000	0.003	0.004	0.001	0.000	0.0000019
Other non specified - CO2 military mobile - liquid fuels	CO2	1,071	625	3%	5%	0.058	0.000	0.000	0.001	0.000	0.000	0.0000000
Other non specified - N2O military mobile - liquid fuels	N2O	67	15	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Other non specified - CH4 military mobile - liquid fuels	CH4	4	2	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CO2 Solid fuels	CO2	0	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CH4 Solid fuels	CH4	132	26	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CO2 Oil and natural gas - Oil	CO2	2,402	1,486	3%	10%	0.104	0.000	0.001	0.003	0.000	0.000	0.0000000
Fugitive - CH4 Oil and natural gas - Oil	CH4	310	87	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - N2O Oil and natural gas - Oil	N2O	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CO2 Oil and natural gas - Natural gas	CO2	9	5	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CH4 Oil and natural gas - Natural gas	CH4	8,236	3,073	3%	50%	0.501	0.000	0.006	0.006	0.003	0.000	0.0000082
Fugitive - CO2 Oil and natural gas - venting and flaring	CO2	956	418	50%	10%	0.510	0.000	0.001	0.001	0.000	0.001	0.0000003
Fugitive - N2O Oil and natural gas - venting and flaring	N2O	1	1	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CH4 Oil and natural gas - venting and flaring	CH4	178	90	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	CO2	681	204	50%	10%	0.510	0.000	0.001	0.000	0.000	0.000	0.0000001
Fugitive - N2O Oil and natural gas - Other - flaring in refineries	N2O	11	7	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.0000000
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	CH4	202	595	50%	50%	0.707	0.000	0.001	0.001	0.000	0.001	0.0000008
Mineral industry- CO2 Cement production	CO2	15,846	7,059	3%	10%	0.104	0.000	0.009	0.014	0.001	0.001	0.0000011
Mineral industry- CO2 Lime production	CO2	1,877	1,611	3%	10%	0.104	0.000	0.000	0.003	0.000	0.000	0.0000000
Mineral industry- CO2 Glass production	CO2	453	569	3%	10%	0.104	0.000	0.000	0.001	0.000	0.000	0.0000000
Mineral industry- CO2 Other processes uses of carbonates	CO2	2,544	541	3%	10%	0.104	0.000	0.003	0.001	0.000	0.000	0.0000001
Chemical industry- CO2 Ammonia production	CO2	1,892	658	3%	10%	0.104	0.000	0.001	0.001	0.000	0.000	0.0000000
Chemical industry- N2O Nitric acid production	N2O	2,005	39	3%	10%	0.104	0.000	0.003	0.000	0.000	0.000	0.0000001
Chemical industry - CO2 Adipic acid production	CO2	1	2	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000

IPCC category	Gas	Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Chemical industry - N2O Adipic acid production	N2O	4,402	80	3%	10%	0.104	0.000	0.006	0.000	0.001	0.000	0.0000004
Chemical industry - Caprolactam, Glyoxal and Glyoxylic Acid production -N2O	N2O	11	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Chemical industry- CO2 Carbide production	CO2	26	4	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Chemical industry- CO2 Titanium dioxide production	CO2	0	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Chemical industry- CO2 Soda ash production	CO2	183	268	3%	10%	0.104	0.000	0.000	0.001	0.000	0.000	0.0000000
Chemical industry - CO2 Petrochemical and carbon black production	CO2	422	426	3%	10%	0.104	0.000	0.000	0.001	0.000	0.000	0.0000000
Chemical industry - CH4 Petrochemical and carbon black production	CH4	61	4	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Chemical industry- HFCs Fluorochemical production	HFCs	444	1	5%	50%	0.502	0.000	0.001	0.000	0.000	0.000	0.0000001
Chemical industry- PFCs Fluorochemical production	PFCs	932	418	5%	50%	0.502	0.000	0.001	0.001	0.000	0.000	0.0000001
Chemical industry- SF6 Fluorochemical production	SF6	114	0	5%	50%	0.502	0.000	0.000	0.000	0.000	0.000	0.0000000
Metal industry- CO2 Iron and steel production	CO2	3,124	1,215	3%	10%	0.104	0.000	0.002	0.002	0.000	0.000	0.0000001
Metal industry- CH4 Iron and steel production	CH4	68	30	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Metal industry- CO2 Ferroalloys production	CO2	395	0	3%	10%	0.104	0.000	0.001	0.000	0.000	0.000	0.0000000
Metal industry- CO2 Aluminium production	CO2	359	0	3%	20%	0.202	0.000	0.001	0.000	0.000	0.000	0.0000000
Metal industry- PFCs Aluminium production	PFCs	1,975	0	3%	20%	0.202	0.000	0.003	0.000	0.001	0.000	0.0000003
Metal industry- HFCs Magnesium production	HFCs	0	5	3%	20%	0.202	0.000	0.000	0.000	0.000	0.000	0.0000000
Metal industry- CO2 Zinc production	CO2	500	224	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.0000000
Non-Energy products from Fuels and Solvent Use - CO2	CO2	1,712	1,091	30%	50%	0.583	0.000	0.000	0.002	0.000	0.001	0.0000008
Electronics Industry - HFCs	HFCs	0	32	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.0000000
Electronics Industry - PFCs	PFCs	0	121	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.0000000
Electronics Industry - SF6	SF6	0	48	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.0000000
Electronics Industry - NF3	NF3	77	16	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.0000000
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	HFCs	0	13,479	30%	50%	0.583	0.000	0.026	0.026	0.013	0.011	0.0002889
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	HFCs	0	555	30%	50%	0.583	0.000	0.001	0.001	0.001	0.000	0.0000005
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	HFCs	0	1,600	30%	50%	0.583	0.000	0.003	0.003	0.002	0.001	0.0000041
Product uses as substitutes for ozone depleting substances - HFCs Aerosols	HFCs	0	227	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.0000001

IPCC category	Gas	Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Other Product Manufacture and Use - SF6	SF6	294	216	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.0000000
Other Product Manufacture and Use - N2O	N2O	781	509	5%	10%	0.112	0.000	0.000	0.001	0.000	0.000	0.0000000
Enteric Fermentation- CH4	CH4	15,564	13,535	3%	20%	0.202	0.000	0.004	0.026	0.001	0.001	0.0000019
Manure Management - CH4	CH4	4,843	4,147	5%	20%	0.206	0.000	0.001	0.008	0.000	0.001	0.0000004
Manure Management - N2O	N2O	2,830	2,076	5%	20%	0.206	0.000	0.000	0.004	0.000	0.000	0.0000001
Field burning of agricultural residues - CH4	CH4	15	15	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.0000000
Field burning of agricultural residues - N2O	N2O	4	4	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.0000000
Liming and other carbon containing fertilisers - CO2	CO2	45	31	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.0000000
Urea application - CO2	CO2	465	472	10%	20%	0.224	0.000	0.000	0.001	0.000	0.000	0.0000000
Direct N2O Emissions from Managed soils	N2O	8,716	8,458	20%	50%	0.539	0.000	0.004	0.016	0.002	0.005	0.0000251
Indirect N2O Emissions from Managed soils	N2O	2,538	2,363	20%	50%	0.539	0.000	0.001	0.005	0.000	0.001	0.0000019
Indirect N2O Emissions from Manure Management	N2O	3	1	5%	50%	0.502	0.000	0.000	0.000	0.000	0.000	0.0000000
Rice cultivations - CH4	CH4	1,876	1,582	5%	10%	0.112	0.000	0.000	0.003	0.000	0.000	0.0000000
Solid waste disposal - CH4	CH4	12,206	14,253	10%	20%	0.224	0.000	0.010	0.027	0.002	0.004	0.0000192
Biological treatment of Solid waste - CH4	CH4	5	113	20%	100%	1.020	0.000	0.000	0.000	0.000	0.000	0.0000000
Biological treatment of Solid waste - N2O	N2O	20	488	20%	100%	1.020	0.000	0.001	0.001	0.001	0.000	0.0000009
Incineration and open burning of waste - CO2	CO2	512	93	10%	20%	0.224	0.000	0.001	0.000	0.000	0.000	0.0000000
Incineration and open burning of waste - CH4	CH4	50	56	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.0000000
Incineration and open burning of waste - N2O	N2O	37	20	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.0000000
Wastewater treatment and discharge - CH4	CH4	3,200	2,375	20%	100%	1.020	0.000	0.000	0.005	0.000	0.001	0.0000017
Wastewater treatment and discharge - N2O	N2O	1,259	1,217	20%	100%	1.020	0.000	0.001	0.002	0.001	0.001	0.0000008
TOTAL		**519,985**	**381,248**				**0.001**					**0.0005**
					Percertage uncertainty in total inventory		**3.1%**				Trend uncertainty	**2.2%**

Table A1.8 Results of the uncertainty analysis including LULUCF (Approach 1). Year 2020

		Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
IPCC category	Gas	Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Energy industries - CO2 liquid fuels	CO2	81,197	14,415	3%	3%	0.042	0.000	0.078	0.028	0.002	0.001	0.000
Energy industries - CO2 solid fuels	CO2	38,647	15,613	3%	3%	0.042	0.000	0.020	0.030	0.001	0.001	0.000
Energy industries - CO2 gaseous fuels	CO2	16,954	51,148	3%	3%	0.042	0.000	0.077	0.099	0.002	0.004	0.000
Energy industries - CO2 other fuels	CO2	143	178	3%	3%	0.042	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - N2O liquid fuels	N2O	288	118	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - N2O solid fuels	N2O	163	68	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - N2O gaseous fuels	N2O	9	30	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - N2O other fuels	N2O	1	1	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - N2O biomass	N2O	16	108	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - CH4 liquid fuels	CH4	74	9	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - CH4 solid fuels	CH4	132	11	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - CH4 gaseous fuels	CH4	11	32	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - CH4 other fuels	CH4	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Energy industries - CH4 biomass	CH4	10	65	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CO2 liquid fuels	CO2	32,805	8,677	3%	3%	0.042	0.000	0.026	0.017	0.001	0.001	0.000
Manufacturing industries and construction - CO2 solid fuels	CO2	25,732	4,985	3%	3%	0.042	0.000	0.024	0.010	0.001	0.000	0.000
Manufacturing industries and construction - CO2 gaseous fuels	CO2	32,234	30,744	3%	3%	0.042	0.000	0.017	0.060	0.001	0.003	0.000
Manufacturing industries and construction - CO2 other fuels	CO2	0	473	3%	3%	0.042	0.000	0.001	0.001	0.000	0.000	0.000
Manufacturing industries and construction - N2O liquid fuels	N2O	926	395	3%	50%	0.501	0.000	0.000	0.001	0.000	0.000	0.000
Manufacturing industries and construction - N2O solid fuels	N2O	243	49	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - N2O gaseous fuels	N2O	164	168	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - N2O other fuels	N2O	0	27	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - N2O biomass	N2O	6	63	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CH4 liquid fuels	CH4	42	15	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CH4 solid fuels	CH4	107	37	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CH4 gaseous fuels	CH4	14	13	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CH4 other fuels	CH4	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing industries and construction - CH4 biomass	CH4	4	209	20%	50%	0.539	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CO2 Road transportation	CO2	92,332	77,832	3%	3%	0.042	0.000	0.030	0.151	0.001	0.006	0.000
Transport - N2O Road transportation	N2O	838	737	3%	40%	0.401	0.000	0.000	0.001	0.000	0.000	0.000

IPCC category	Gas	Emissions		Uncertainty				Sensitivity		Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Transport - CH4 Road transportation	CH4	867	148	3%	40%	0.401	0.000	0.001	0.000	0.000	0.000	0.000
Transport - CO2 Waterborne navigation	CO2	5,470	4,624	3%	3%	0.042	0.000	0.002	0.009	0.000	0.000	0.000
Transport - N2O Waterborne navigation	N2O	38	34	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CH4 Waterborne navigation	CH4	35	17	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CO2 Civil Aviation	CO2	1,493	1,195	3%	3%	0.042	0.000	0.000	0.002	0.000	0.000	0.000
Transport - N2O Civil Aviation	N2O	12	10	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CH4 Civil Aviation	CH4	1	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CO2 Railways	CO2	613	136	3%	5%	0.058	0.000	0.001	0.000	0.000	0.000	0.000
Transport - N2O Railways	N2O	72	16	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CH4 Railways	CH4	1	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CO2 Other transportation - pipelines	CO2	411	675	3%	3%	0.042	0.000	0.001	0.001	0.000	0.000	0.000
Transport - N2O Other transportation - pipelines	N2O	7	10	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Transport - CH4 Other transportation - pipelines	CH4	0	1	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - CO2 commercial, residential, agriculture liquid fuels	CO2	38,274	13,610	3%	3%	0.042	0.000	0.024	0.026	0.001	0.001	0.000
Other sectors - CO2 commercial, residential, agriculture solid fuels	CO2	899	0	3%	3%	0.042	0.000	0.001	0.000	0.000	0.000	0.000
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	CO2	36,338	55,195	3%	3%	0.042	0.000	0.059	0.107	0.002	0.005	0.000
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	CO2	530	5,778	3%	3%	0.042	0.000	0.010	0.011	0.000	0.000	0.000
Other sectors - N2O commercial, residential, agriculture liquid fuels	N2O	996	760	3%	50%	0.501	0.000	0.000	0.001	0.000	0.000	0.000
Other sectors - N2O commercial, residential, agriculture solid fuels	N2O	4	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - N2O commercial, residential, agriculture gaseous fuels	N2O	194	284	3%	50%	0.501	0.000	0.000	0.001	0.000	0.000	0.000
Other sectors - N2O commercial, residential, agriculture other fossil fuels	N2O	15	158	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - N2O commercial, residential, agriculture biomass	N2O	531	1,156	3%	50%	0.501	0.000	0.002	0.002	0.001	0.000	0.000
Other sectors - CH4 commercial, residential, agriculture liquid fuels	CH4	94	17	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - CH4 commercial, residential, agriculture solid fuels	CH4	10	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - CH4 commercial, residential, agriculture gaseous fuels	CH4	41	60	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other sectors - CH4 commercial, residential, agriculture other fossil fuels	CH4	1	8	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000

IPCC category	Gas	Emissions		Uncertainty			Sensitivity			Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Other sectors - CH4 commercial, residential, agriculture biomass	CH4	996	2,153	3%	50%	0.501	0.000	0.003	0.004	0.001	0.000	0.000
Other non specified - CO2 military mobile - liquid fuels	CO2	1,071	625	3%	5%	0.058	0.000	0.000	0.001	0.000	0.000	0.000
Other non specified - N2O military mobile - liquid fuels	N2O	67	15	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Other non specified - CH4 military mobile - liquid fuels	CH4	4	2	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CO2 Solid fuels	CO2	0	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CH4 Solid fuels	CH4	132	26	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CO2 Oil and natural gas - Oil	CO2	2,402	1,486	3%	10%	0.104	0.000	0.000	0.003	0.000	0.000	0.000
Fugitive - CH4 Oil and natural gas - Oil	CH4	310	87	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - N2O Oil and natural gas - Oil	N2O	0	0	3%	50%	0.501	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CO2 Oil and natural gas - Natural gas	CO2	9	5	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CH4 Oil and natural gas - Natural gas	CH4	8,236	3,073	3%	50%	0.501	0.000	0.005	0.006	0.002	0.000	0.000
Fugitive - CO2 Oil and natural gas - venting and flaring	CO2	956	418	50%	10%	0.510	0.000	0.000	0.001	0.000	0.001	0.000
Fugitive - N2O Oil and natural gas - venting and flaring	N2O	1	1	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CH4 Oil and natural gas - venting and flaring	CH4	178	90	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	CO2	681	204	50%	10%	0.510	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - N2O Oil and natural gas - Other - flaring in refineries	N2O	11	7	50%	50%	0.707	0.000	0.000	0.000	0.000	0.000	0.000
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	CH4	202	595	50%	50%	0.707	0.000	0.001	0.001	0.000	0.001	0.000
Mineral industry- CO2 Cement production	CO2	15,846	7,059	3%	10%	0.104	0.000	0.007	0.014	0.001	0.001	0.000
Mineral industry- CO2 Lime production	CO2	1,877	1,611	3%	10%	0.104	0.000	0.001	0.003	0.000	0.000	0.000
Mineral industry- CO2 Glass production	CO2	453	569	3%	10%	0.104	0.000	0.001	0.001	0.000	0.000	0.000
Mineral industry- CO2 Other processes uses of carbonates	CO2	2,544	541	3%	10%	0.104	0.000	0.002	0.001	0.000	0.000	0.000
Chemical industry- CO2 Ammonia production	CO2	1,892	658	3%	10%	0.104	0.000	0.001	0.001	0.000	0.000	0.000
Chemical industry- N2O Nitric acid production	N2O	2,005	39	3%	10%	0.104	0.000	0.003	0.000	0.000	0.000	0.000
Chemical industry - CO2 Adipic acid production	CO2	1	2	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Chemical industry- N2O Adipic acid production	N2O	4,402	80	3%	10%	0.104	0.000	0.006	0.000	0.001	0.000	0.000
Chemical industry- Caprolactam, Glyoxal and Glyoxylic Acid production -N2O	N2O	11	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Chemical industry- CO2 Carbide production	CO2	26	4	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Chemical industry- CO2 Titanium dioxide production	CO2	0	0	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Chemical industry- CO2 Soda ash production	CO2	183	268	3%	10%	0.104	0.000	0.000	0.001	0.000	0.000	0.000
Chemical industry - CO2 Petrochemical and carbon black production	CO2	422	426	3%	10%	0.104	0.000	0.000	0.001	0.000	0.000	0.000
Chemical industry - N2O Petrochemical and carbon black production	N2O	61	4	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000

IPCC category	Gas	Emissions		Uncertainty			Sensitivity			Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Chemical industry- HFCs Fluorochemical production	HFCs	444	1	5%	50%	0.502	0.000	0.001	0.000	0.000	0.000	0.000
Chemical industry- PFCs Fluorochemical production	PFCs	932	418	5%	50%	0.502	0.000	0.000	0.001	0.000	0.000	0.000
Chemical industry- SF6 Fluorochemical production	SF6	114	0	5%	50%	0.502	0.000	0.000	0.000	0.000	0.000	0.000
Metal industry- CO2 Iron and steel production	CO2	3,124	1,215	3%	10%	0.104	0.000	0.002	0.002	0.000	0.000	0.000
Metal industry- CH4 Iron and steel production	CH4	68	30	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Metal industry- CO2 Ferroalloys production	CO2	395	0	3%	10%	0.104	0.000	0.001	0.000	0.000	0.000	0.000
Metal industry- CO2 Aluminium production	CO2	359	0	3%	20%	0.202	0.000	0.000	0.000	0.000	0.000	0.000
Metal industry- PFCs Aluminium production	PFCs	1,975	0	3%	20%	0.202	0.000	0.003	0.000	0.001	0.000	0.000
Metal industry- HFCs Magnesium production	HFCs	0	5	3%	20%	0.202	0.000	0.000	0.000	0.000	0.000	0.000
Metal industry- CO2 Zinc production	CO2	500	224	3%	10%	0.104	0.000	0.000	0.000	0.000	0.000	0.000
Non-Energy products from Fuels and Solvent Use - CO2	CO2	1,712	1,091	30%	50%	0.583	0.000	0.000	0.002	0.000	0.001	0.000
Electronics Industry - HFCs	HFCs	0	32	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.000
Electronics Industry - PFCs	PFCs	0	121	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.000
Electronics Industry - SF6	SF6	0	48	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.000
Electronics Industry - NF3	NF3	77	16	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.000
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	HFCs	0	13,479	30%	50%	0.583	0.001	0.026	0.026	0.013	0.011	0.000
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	HFCs	0	555	30%	50%	0.583	0.000	0.001	0.001	0.001	0.000	0.000
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	HFCs	0	1,600	30%	50%	0.583	0.000	0.003	0.003	0.002	0.001	0.000
Product uses as substitutes for ozone depleting substances - HFCs Aerosols	HFCs	0	227	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.000
Other Product Manufacture and Use - SF6	SF6	294	216	5%	20%	0.206	0.000	0.000	0.000	0.000	0.000	0.000
Other Product Manufacture and Use - N2O	N2O	781	509	5%	10%	0.112	0.000	0.000	0.001	0.000	0.000	0.000
Enteric Fermentation- CH4	CH4	15,564	13,535	3%	20%	0.202	0.000	0.006	0.026	0.001	0.001	0.000
Manure Management - CH4	CH4	4,843	4,147	5%	20%	0.206	0.000	0.002	0.008	0.000	0.001	0.000
Manure Management - N2O	N2O	2,830	2,076	5%	20%	0.206	0.000	0.000	0.004	0.000	0.000	0.000
Field burning of agricultural residues - CH4	CH4	15	15	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.000
Field burning of agricultural residues - N2O	N2O	4	4	30%	50%	0.583	0.000	0.000	0.000	0.000	0.000	0.000
Liming - CO2	CO2	45	31	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.000
Urea application - CO2	CO2	465	472	10%	20%	0.224	0.000	0.000	0.001	0.000	0.000	0.000
Direct N2O Emissions from Managed soils	N2O	8,716	8,458	20%	50%	0.539	0.000	0.005	0.016	0.002	0.005	0.000
Indirect N2O Emissions from Managed soils	N2O	2,538	2,363	20%	50%	0.539	0.000	0.001	0.005	0.001	0.001	0.000
Indirect N2O Emissions from Manure Management	N2O	3	1	5%	50%	0.502	0.000	0.000	0.000	0.000	0.000	0.000
Rice cultivations - CH4	CH4	1,876	1,582	5%	10%	0.112	0.000	0.001	0.003	0.000	0.000	0.000
Solid waste disposal - CH4	CH4	12,206	14,253	10%	20%	0.224	0.000	0.012	0.028	0.002	0.004	0.000

IPCC category	Gas	Emissions		Uncertainty			Sensitivity			Uncertainty in trend		
		Base year	2020	AD	EF	Combined	Contribution to variance	Type A	Type B	introduced by EF uncertainty	introduced by AD uncertainty	in total national emissions
Biological treatment of Solid waste - CH4	CH4	5	113	20%	100%	1.020	0.000	0.000	0.000	0.000	0.000	0.000
Biological treatment of Solid waste - N2O	N2O	20	488	20%	100%	1.020	0.000	0.001	0.001	0.001	0.000	0.000
Incineration and open burning of waste - CO2	CO2	512	93	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.000
Incineration and open burning of waste - CH4	CH4	50	56	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.000
Incineration and open burning of waste - N2O	N2O	37	20	10%	20%	0.224	0.000	0.000	0.000	0.000	0.000	0.000
Wastewater treatment and discharge - CH4	CH4	3,200	2,375	20%	100%	1.020	0.000	0.000	0.005	0.000	0.001	0.000
Wastewater treatment and discharge - N2O	N2O	1,259	1,217	20%	100%	1.020	0.000	0.001	0.002	0.001	0.001	0.000
Forest Land remaining Forest Land - CO2	CO2	-15,002	-25,040	18%	18%	0.251	0.000	0.029	0.048	0.005	0.012	0.000
Forest Land remaining Forest Land - CH4	CH4	540	126	18%	18%	0.251	0.000	0.000	0.000	0.000	0.000	0.000
Forest Land remaining Forest Land - N2O	N2O	2	0	18%	18%	0.251	0.000	0.000	0.000	0.000	0.000	0.000
Land Converted to Forest Land - CO2	CO2	-2,849	-5,221	75%	75%	1.061	0.000	0.006	0.010	0.005	0.011	0.000
Land Converted to Forest Land - CH4	CH4	54	19	75%	75%	1.061	0.000	0.000	0.000	0.000	0.000	0.000
Land Converted to Forest Land - N2O	N2O	0	0	75%	75%	1.061	0.000	0.000	0.000	0.000	0.000	0.000
Cropland Remaining Cropland - CO2	CO2	774	-317	30%	58%	0.653	0.000	0.002	0.001	0.001	0.000	0.000
Cropland Remaining Cropland - CH4	CH4	5	4	30%	58%	0.653	0.000	0.000	0.000	0.000	0.000	0.000
Cropland Remaining Cropland - N2O	N2O	2	1	30%	58%	0.653	0.000	0.000	0.000	0.000	0.000	0.000
Land Converted to Cropland - CO2	CO2	857	284	30%	58%	0.653	0.000	0.001	0.001	0.000	0.000	0.000
Land Converted to Cropland - N2O	N2O	73	15	30%	58%	0.653	0.000	0.000	0.000	0.000	0.000	0.000
Grassland Remaining Grassland - CO2	CO2	5,358	-1,468	15%	23%	0.271	0.000	0.010	0.003	0.002	0.001	0.000
Grassland Remaining Grassland - CH4	CH4	686	114	15%	23%	0.271	0.000	0.001	0.000	0.000	0.000	0.000
Grassland Remaining Grassland - N2O	N2O	257	43	15%	23%	0.271	0.000	0.000	0.000	0.000	0.000	0.000
Land Converted to Grassland - CO2	CO2	-1,180	-5,896	15%	23%	0.271	0.000	0.010	0.011	0.002	0.002	0.000
Land Converted to Wetland - CO2	CO2	0	32	75%	75%	1.061	0.000	0.000	0.000	0.000	0.000	0.000
Land Converted to Settlements - CO2	CO2	6,640	5,207	75%	75%	1.061	0.000	0.001	0.010	0.001	0.011	0.000
Land Converted to Settlements - N2O	N2O	505	363	75%	75%	1.061	0.000	0.000	0.001	0.000	0.001	0.000
Harvest Wood Products - CO2	CO2	-388	-669	25%	50%	0.559	0.000	0.001	0.001	0.000	0.000	0.000
Indirect N2O from Managed soils - LULUCF	N2O	16	3	75%	75%	1.061	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL		**516,337**	**348,847**				**0.002**					**0.001**
						Percentage uncertainty in total inventory	**4.5%**				**Trend uncertainty**	**3.0%**

Emission sources of the Italian inventory are disaggregated into a detailed level, 127 sources, according to the IPCC list in the guidelines and taking into account national circumstances and importance. Considering also the LULUCF sector, sources and sinks of the Italian inventory are disaggregated into 147 categories. Uncertainties are therefore estimated for these categories. To estimate uncertainty for both activity data and emission factors, information provided in the IPCC Guidelines, as well as expert judgement have been used; standard deviations have also been considered whenever measurements were available.

The assumptions on which uncertainty estimations are based on are documented for each category. Figures to draw up uncertainty are checked with the relevant analyst experts and literature references and they are consistent with the IPCC Good Practice Guidance and the 2006 IPCC Guidelines (IPCC, 2000; IPCC, 2006).
The general approach followed for quantifying a level of uncertainty to activity data and emission factors is to set values within a range low, medium and high according to the confidence the expert relies on the value. For instance, a low value (e.g. 3-5%) has been attributed to activity data derived from the energy balance and statistical yearbooks, medium-high values within a range of 20-50% for all the data which are not directly or only partially derived from census or sample surveys or data which are simple estimations. For emission factors, the uncertainties set are usually higher than those for activity data; figures suggested by the IPCC good practice guidance and guidelines (IPCC, 2000; IPCC, 2006) are used when the emission factor is a default value or when appropriate, low values are attributed to measured data whereas the uncertainty values are high in all other cases.
For the base year, the uncertainty estimated by Approach 1 is equal to 2.1%; if considering the LULUCF sector the overall uncertainty increases to 2.7%.
In 2020, the results of Approach 1 suggest an uncertainty of 3.1% in the combined GWP total emissions. The analysis also estimates an uncertainty of 2.2% in the trend.
Including the LULUCF sector in the total uncertainty assessment, Approach 1 shows an uncertainty of 4.5% in the combined GWP total emissions for the year 2020, whereas the uncertainty in the trend is equal to 3.0%. Results are shown in Table A1.8
Further investigation is needed to better quantify the uncertainty values for some specific source, nevertheless it should be noted that a conservative approach has been followed.

A1.4 Approach 2 key category assessment

Approach 2 can be used to identify key categories when an uncertainty analysis has been carried out on the inventory. It is helpful in prioritising activities to improve inventory quality and to reduce overall uncertainty. Under Approach 2, the source or sink category uncertainties are incorporated by weighting the Approach 1 level and trend assessment results with the source category's relative uncertainty.
Therefore, the following equations:

$$\textit{Level Assessment, with Uncertainty} = \textit{Approach 1 Level Assessment} \cdot \textit{Relative Category Uncertainty}$$

$$\textit{Trend Assessment, with Uncertainty} = \textit{Approach 1 Trend Assessment} \cdot \textit{Relative Category Uncertainty}$$

Approach 2 has been applied both to the base and the current year submission.
The results of the Approach 2 key category analysis, without LULUCF categories, are provided in Table A1.11, for 2020, while in Table A1.12 results, including LULUCF categories, are shown. For the base year, results of the analysis excluding and including LULUCF categories are reported in Table A1.13 and Table A1.14.
The application of Approach 2 to the base year gives as a result 30 key categories accounting for the 90% of the total levels uncertainty. Including the LULUCF categories, 35 key categories result accounting for 90% of the total uncertainty levels.
For the year 2020, 26 key categories accounting for the 90% of the total uncertainty levels were identified; when applying the trend analysis the key categories increased to 30.
The application of Approach 2 to the inventory, including the LULUCF categories, results in 29 key categories which account for the 90% of the total levels uncertainty; for the trend analysis, with LULUCF, the number of key categories is 34.

Table A1.9 Results of the key category analysis without LULUCF. Approach 2 Level assessment, year 2020

CATEGORIES	Share	Uncertainty	L*U	Level assessment with uncertainty	Cumulative Percentage
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.04	0.5831	0.0206	0.1660	0.17
Direct N2O Emissions from Managed soils	0.02	0.5385	0.0119	0.0962	0.26
Transport - CO2 Road transportation	0.20	0.0424	0.0087	0.0697	0.33
Solid waste disposal - CH4	0.04	0.2236	0.0084	0.0673	0.40
Enteric Fermentation- CH4	0.04	0.2022	0.0072	0.0578	0.46
Wastewater treatment and discharge - CH4	0.01	1.0198	0.0064	0.0511	0.51
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.14	0.0424	0.0061	0.0494	0.56
Energy industries - CO2 gaseous fuels	0.13	0.0424	0.0057	0.0458	0.60
Fugitive - CH4 Oil and natural gas - Natural gas	0.01	0.5009	0.0040	0.0325	0.64
Manufacturing industries and construction - CO2 gaseous fuels	0.08	0.0424	0.0034	0.0275	0.66
Indirect N2O Emissions from Managed soils	0.01	0.5385	0.0033	0.0269	0.69
Wastewater treatment and discharge - N2O	0.00	1.0198	0.0033	0.0262	0.72
Other sectors - CH4 commercial, residential, agriculture biomass	0.01	0.5009	0.0028	0.0228	0.74
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.00	0.5831	0.0024	0.0197	0.76
Manure Management - CH4	0.01	0.2062	0.0022	0.0181	0.78
Mineral industry- CO2 Cement production	0.02	0.1044	0.0019	0.0156	0.79
Energy industries - CO2 solid fuels	0.04	0.0424	0.0017	0.0140	0.81
Non-Energy products from Fuels and Solvent Use - CO2	0.00	0.5831	0.0017	0.0134	0.82
Energy industries - CO2 liquid fuels	0.04	0.0424	0.0016	0.0129	0.83
Other sectors - N2O commercial, residential, agriculture biomass	0.00	0.5009	0.0015	0.0122	0.85
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.04	0.0424	0.0015	0.0122	0.86
Biological treatment of Solid waste - N2O	0.00	1.0198	0.0013	0.0105	0.87
Manure Management - N2O	0.01	0.2062	0.0011	0.0090	0.88
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	0.00	0.7071	0.0011	0.0089	0.89
Other sectors - N2O commercial, residential, agriculture liquid fuels	0.00	0.5009	0.0010	0.0080	0.89
Manufacturing industries and construction - CO2 liquid fuels	0.02	0.0424	0.0010	0.0078	0.9015
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.00	0.5831	0.0008	0.0068	0.91
Transport - N2O Road transportation	0.00	0.4011	0.0008	0.0062	0.91
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.02	0.0424	0.0006	0.0052	0.92
Fugitive - CO2 Oil and natural gas - venting and flaring	0.00	0.5099	0.0006	0.0045	0.92
Manufacturing industries and construction - CO2 solid fuels	0.01	0.0424	0.0006	0.0045	0.93
Chemical industry- PFCs Fluorochemical production	0.00	0.5025	0.0006	0.0044	0.93
Manufacturing industries and construction - N2O liquid fuels	0.00	0.5009	0.0005	0.0042	0.94
Transport - CO2 Waterborne navigation	0.01	0.0424	0.0005	0.0041	0.94
Rice cultivations - CH4	0.00	0.1118	0.0005	0.0037	0.95
Mineral industry- CO2 Lime production	0.00	0.1044	0.0004	0.0036	0.95
Fugitive - CO2 Oil and natural gas - Oil	0.00	0.1044	0.0004	0.0033	0.95
Other sectors - N2O commercial, residential, agriculture gaseous fuels	0.00	0.5009	0.0004	0.0030	0.96
Product uses as substitutes for ozone depleting substances - HFCs Aerosols	0.00	0.5831	0.0003	0.0028	0.96

Table A1.10 Results of the key category analysis without LULUCF. Approach 2 Trend assessment, base year- 2020

CATEGORIES	Trend assessment with uncertainty	Uncertainty	T*U	Relative trend assessment with uncertainty	Cumulative Percentage
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.03	0.5831	0.0151	0.276	0.28
Energy industries - CO2 liquid fuels	0.09	0.0424	0.0037	0.067	0.34
Energy industries - CO2 gaseous fuels	0.07	0.0424	0.0032	0.058	0.40
Fugitive - CH4 Oil and natural gas - Natural gas	0.01	0.5009	0.0029	0.052	0.45
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.05	0.0424	0.0023	0.043	0.50
Solid waste disposal - CH4	0.01	0.2236	0.0023	0.042	0.54
Direct N2O Emissions from Managed soils	0.00	0.5385	0.0021	0.039	0.58
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.00	0.5831	0.0018	0.033	0.61
Other sectors - CH4 commercial, residential, agriculture biomass	0.00	0.5009	0.0014	0.025	0.64
Manufacturing industries and construction - CO2 liquid fuels	0.03	0.0424	0.0013	0.023	0.66
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.03	0.0424	0.0012	0.022	0.68
Manufacturing industries and construction - CO2 solid fuels	0.03	0.0424	0.0011	0.021	0.70
Energy industries - CO2 solid fuels	0.02	0.0424	0.0010	0.019	0.72
Biological treatment of Solid waste - N2O	0.00	1.0198	0.0009	0.017	0.74
Mineral industry- CO2 Cement production	0.01	0.1044	0.0009	0.017	0.75
Transport - CO2 Road transportation	0.02	0.0424	0.0008	0.015	0.77
Enteric Fermentation- CH4	0.00	0.2022	0.0008	0.015	0.78
Other sectors - N2O commercial, residential, agriculture biomass	0.00	0.5009	0.0007	0.014	0.80
Chemical industry- N2O Adipic acid production	0.01	0.1044	0.0006	0.012	0.81
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.00	0.5831	0.0006	0.011	0.82
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	0.00	0.7071	0.0006	0.011	0.83
Manufacturing industries and construction - CO2 gaseous fuels	0.01	0.0424	0.0006	0.011	0.84
Wastewater treatment and discharge - N2O	0.00	1.0198	0.0006	0.011	0.85
Metal industry- PFCs Aluminium production	0.00	0.2022	0.0006	0.010	0.86
Indirect N2O Emissions from Managed soils	0.00	0.5385	0.0005	0.010	0.87
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.01	0.0424	0.0004	0.008	0.88
Transport - CH4 Road transportation	0.00	0.4011	0.0004	0.007	0.89
Chemical industry- HFCs Fluorochemical production	0.00	0.5025	0.0003	0.006	0.89
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	0.00	0.5099	0.0003	0.005	0.898
Chemical industry- N2O Nitric acid production	0.00	0.1044	0.0003	0.005	0.903
Fugitive - CO2 Oil and natural gas - venting and flaring	0.00	0.5099	0.0003	0.005	0.91
Manufacturing industries and construction - N2O liquid fuels	0.00	0.5009	0.0003	0.005	0.91
Mineral industry- CO2 Other processes uses of carbonates	0.00	0.1044	0.0003	0.005	0.92
Chemical industry- PFCs Fluorochemical production	0.00	0.5025	0.0003	0.005	0.92
Product uses as substitutes for ozone depleting substances - HFCs Aerosols	0.00	0.5831	0.0003	0.005	0.93
Manure Management - CH4	0.00	0.2062	0.0002	0.004	0.93
Metal industry- CO2 Iron and steel production	0.00	0.1044	0.0002	0.004	0.94
Biological treatment of Solid waste - CH4	0.00	1.0198	0.0002	0.004	0.94
Manufacturing industries and construction - CH4 biomass	0.00	0.5385	0.0002	0.004	0.94

Table A1.11 Results of the key category analysis with LULUCF. Approach 2 Level assessment, year 2020

CATEGORIES	Share	Uncertainty	L*U	Level assessment with uncertainty	Cumulative Percentage
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.03	0.5831	0.0184	0.1156	0.12
Forest Land remaining Forest Land - CO2	0.06	0.2511	0.0148	0.0925	0.21
Land Converted to Forest Land - CO2	0.01	1.0607	0.0130	0.0814	0.29
Land Converted to Settlements - CO2	0.01	1.0607	0.0130	0.0812	0.37
Direct N2O Emissions from Managed soils	0.02	0.5385	0.0107	0.0670	0.44
Transport - CO2 Road transportation	0.18	0.0424	0.0078	0.0486	0.49
Solid waste disposal - CH4	0.03	0.2236	0.0075	0.0469	0.53
Enteric Fermentation- CH4	0.03	0.2022	0.0064	0.0403	0.57
Wastewater treatment and discharge - CH4	0.01	1.0198	0.0057	0.0356	0.61
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.13	0.0424	0.0055	0.0344	0.64
Energy industries - CO2 gaseous fuels	0.12	0.0424	0.0051	0.0319	0.68
Land Converted to Grassland - CO2	0.01	0.2715	0.0038	0.0235	0.70
Fugitive - CH4 Oil and natural gas - Natural gas	0.01	0.5009	0.0036	0.0226	0.72
Manufacturing industries and construction - CO2 gaseous fuels	0.07	0.0424	0.0031	0.0192	0.74
Indirect N2O Emissions from Managed soils	0.01	0.5385	0.0030	0.0187	0.76
Wastewater treatment and discharge - N2O	0.00	1.0198	0.0029	0.0183	0.78
Other sectors - CH4 commercial, residential, agriculture biomass	0.01	0.5009	0.0025	0.0159	0.79
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.00	0.5831	0.0022	0.0137	0.81
Manure Management - CH4	0.01	0.2062	0.0020	0.0126	0.82
Mineral industry- CO2 Cement production	0.02	0.1044	0.0017	0.0108	0.83
Energy industries - CO2 solid fuels	0.04	0.0424	0.0016	0.0097	0.84
Non-Energy products from Fuels and Solvent Use - CO2	0.00	0.5831	0.0015	0.0094	0.85
Energy industries - CO2 liquid fuels	0.03	0.0424	0.0014	0.0090	0.86
Other sectors - N2O commercial, residential, agriculture biomass	0.00	0.5009	0.0014	0.0085	0.87
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.03	0.0424	0.0014	0.0085	0.88
Biological treatment of Solid waste - N2O	0.00	1.0198	0.0012	0.0073	0.88
Manure Management - N2O	0.00	0.2062	0.0010	0.0063	0.89
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	0.00	0.7071	0.0010	0.0062	0.896
Grassland Remaining Grassland - CO2	0.00	0.2715	0.0009	0.0059	0.901
Land Converted to Settlements - N2O	0.00	1.0607	0.0009	0.0057	0.91
Other sectors - N2O commercial, residential, agriculture liquid fuels	0.00	0.5009	0.0009	0.0056	0.91
Harvest Wood Products - CO2	0.00	0.5590	0.0009	0.0055	0.92
Manufacturing industries and construction - CO2 liquid fuels	0.02	0.0424	0.0009	0.0054	0.92
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.00	0.5831	0.0008	0.0048	0.93
Transport - N2O Road transportation	0.00	0.4011	0.0007	0.0043	0.93
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.01	0.0424	0.0006	0.0036	0.94
Fugitive - CO2 Oil and natural gas - venting and flaring	0.00	0.5099	0.0005	0.0031	0.94
Manufacturing industries and construction - CO2 solid fuels	0.01	0.0424	0.0005	0.0031	0.94
Chemical industry- PFCs Fluorochemical production	0.00	0.5025	0.0005	0.0031	0.95
Cropland Remaining Cropland - CO2	0.00	0.6530	0.0005	0.0030	0.95
Manufacturing industries and construction - N2O liquid fuels	0.00	0.5009	0.0005	0.0029	0.95

Table A1.12 Results of the key category analysis with LULUCF. Approach 2 Trend assessment, base year-2020

CATEGORIES	Trend assessment	Uncertainty	T*U	Relative trend assessment with uncertainty	Cumulative Percentage
Product uses as substitutes for ozone depleting substances - HFCs Refrigeration and Air conditioning	0.03	0.5831	0.0152	0.23	0.23
Energy industries - CO2 liquid fuels	0.07	0.0424	0.0031	0.05	0.28
Energy industries - CO2 gaseous fuels	0.07	0.0424	0.0030	0.05	0.32
Land Converted to Forest Land - CO2	0.00	1.0607	0.0028	0.04	0.36
Direct N2O Emissions from Managed soils	0.00	0.5385	0.0025	0.04	0.40
Grassland Remaining Grassland - CO2	0.01	0.2715	0.0025	0.04	0.44
Solid waste disposal - CH4	0.01	0.2236	0.0024	0.04	0.48
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.06	0.0424	0.0023	0.04	0.51
Forest Land remaining Forest Land - CO2	0.01	0.2511	0.0023	0.04	0.55
Fugitive - CH4 Oil and natural gas - Natural gas	0.00	0.5009	0.0022	0.03	0.58
Land Converted to Grassland - CO2	0.01	0.2715	0.0021	0.03	0.61
Product uses as substitutes for ozone depleting substances - HFCs Fire protection	0.00	0.5831	0.0018	0.03	0.64
Land Converted to Settlements - CO2	0.00	1.0607	0.0014	0.02	0.66
Other sectors - CH4 commercial, residential, agriculture biomass	0.00	0.5009	0.0013	0.02	0.68
Transport - CO2 Road transportation	0.03	0.0424	0.0012	0.02	0.70
Enteric Fermentation- CH4	0.01	0.2022	0.0011	0.02	0.71
Manufacturing industries and construction - CO2 liquid fuels	0.02	0.0424	0.0010	0.02	0.73
Cropland Remaining Cropland - CO2	0.00	0.6530	0.0010	0.01	0.74
Manufacturing industries and construction - CO2 solid fuels	0.02	0.0424	0.0009	0.01	0.76
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.02	0.0424	0.0009	0.01	0.77
Biological treatment of Solid waste - N2O	0.00	1.0198	0.0009	0.01	0.79
Energy industries - CO2 solid fuels	0.02	0.0424	0.0008	0.01	0.80
Other sectors - N2O commercial, residential, agriculture biomass	0.00	0.5009	0.0007	0.01	0.81
Mineral industry- CO2 Cement production	0.01	0.1044	0.0007	0.01	0.82
Manufacturing industries and construction - CO2 gaseous fuels	0.02	0.0424	0.0007	0.01	0.83
Wastewater treatment and discharge - N2O	0.00	1.0198	0.0007	0.01	0.84
Indirect N2O Emissions from Managed soils	0.00	0.5385	0.0006	0.01	0.85
Product uses as substitutes for ozone depleting substances - HFCs Foam blowing agents	0.00	0.5831	0.0006	0.01	0.86
Fugitive - CH4 Oil and natural gas - Other - flaring in refineries	0.00	0.7071	0.0006	0.01	0.87
Chemical industry- N2O Adipic acid production	0.01	0.1044	0.0005	0.01	0.88
Metal industry- PFCs Aluminium production	0.00	0.2022	0.0005	0.01	0.88
Other sectors - CO2 commercial, residential, agriculture other fossil fuels	0.01	0.0424	0.0004	0.01	0.89
Wastewater treatment and discharge - CH4	0.00	1.0198	0.0004	0.01	0.896
Land Converted to Cropland - CO2	0.00	0.6530	0.0003	0.01	0.901
Manure Management - CH4	0.00	0.2062	0.0003	0.00	0.91
Transport - CH4 Road transportation	0.00	0.4011	0.0003	0.00	0.91
Chemical industry- HFCs Fluorochemical production	0.00	0.5025	0.0003	0.00	0.91
Product uses as substitutes for ozone depleting substances - HFCs Aerosols	0.00	0.5831	0.0003	0.00	0.92
Chemical industry- N2O Nitric acid production	0.00	0.1044	0.0002	0.00	0.92
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	0.00	0.5099	0.0002	0.00	0.93
Mineral industry- CO2 Other processes uses of carbonates	0.00	0.1044	0.0002	0.00	0.93
Fugitive - CO2 Oil and natural gas - venting and flaring	0.00	0.5099	0.0002	0.00	0.93
Manufacturing industries and construction - N2O liquid fuels	0.00	0.5009	0.0002	0.00	0.94

Table A1.13 Results of the key category analysis without LULUCF. Approach 2 Level assessment, base year

CATEGORIES	Share	Uncertainty	L*U	Level assessment with uncertainty	Cumulative Percentage
Direct N2O Emissions from Managed soils	0.02	0.5385	0.0090	0.0925	0.09
Fugitive - CH4 Oil and natural gas - Natural gas	0.02	0.5009	0.0079	0.0813	0.17
Transport - CO2 Road transportation	0.18	0.0424	0.0075	0.0772	0.25
Energy industries - CO2 liquid fuels	0.16	0.0424	0.0066	0.0679	0.32
Wastewater treatment and discharge - CH4	0.01	1.0198	0.0063	0.0643	0.38
Enteric Fermentation- CH4	0.03	0.2022	0.0061	0.0620	0.45
Solid waste disposal - CH4	0.02	0.2236	0.0052	0.0538	0.50
Mineral industry- CO2 Cement production	0.03	0.1044	0.0032	0.0326	0.53
Energy industries - CO2 solid fuels	0.07	0.0424	0.0032	0.0323	0.56
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.07	0.0424	0.0031	0.0320	0.60
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.07	0.0424	0.0030	0.0304	0.63
Manufacturing industries and construction - CO2 liquid fuels	0.06	0.0424	0.0027	0.0274	0.65
Manufacturing industries and construction - CO2 gaseous fuels	0.06	0.0424	0.0026	0.0269	0.68
Indirect N2O Emissions from Managed soils	0.00	0.5385	0.0026	0.0269	0.71
Wastewater treatment and discharge - N2O	0.00	1.0198	0.0025	0.0253	0.73
Manufacturing industries and construction - CO2 solid fuels	0.05	0.0424	0.0021	0.0215	0.75
Non-Energy products from Fuels and Solvent Use - CO2	0.00	0.5831	0.0019	0.0197	0.77
Manure Management - CH4	0.01	0.2062	0.0019	0.0197	0.79
Energy industries - CO2 gaseous fuels	0.03	0.0424	0.0014	0.0142	0.81
Manure Management - N2O	0.01	0.2062	0.0011	0.0115	0.82
Other sectors - CH4 commercial, residential, agriculture biomass	0.00	0.5009	0.0010	0.0098	0.83
Other sectors - N2O commercial, residential, agriculture liquid fuels	0.00	0.5009	0.0010	0.0098	0.84
Fugitive - CO2 Oil and natural gas - venting and flaring	0.00	0.5099	0.0009	0.0096	0.85
Chemical industry- PFCs Fluorochemical production	0.00	0.5025	0.0009	0.0092	0.86
Manufacturing industries and construction - N2O liquid fuels	0.00	0.5009	0.0009	0.0091	0.87
Chemical industry- N2O Adipic acid production	0.01	0.1044	0.0009	0.0091	0.88
Metal industry- PFCs Aluminium production	0.00	0.2022	0.0008	0.0079	0.88
Transport - CH4 Road transportation	0.00	0.4011	0.0007	0.0069	0.89
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	0.00	0.5099	0.0007	0.0068	0.898
Transport - N2O Road transportation	0.00	0.4011	0.0006	0.0066	0.904
Metal industry- CO2 Iron and steel production	0.01	0.1044	0.0006	0.0064	0.91
Other sectors - N2O commercial, residential, agriculture biomass	0.00	0.5009	0.0005	0.0052	0.92
Mineral industry- CO2 Other processes uses of carbonates	0.00	0.1044	0.0005	0.0052	0.92
Fugitive - CO2 Oil and natural gas - Oil	0.00	0.1044	0.0005	0.0049	0.93
Transport - CO2 Waterborne navigation	0.01	0.0424	0.0004	0.0046	0.93
Chemical industry- HFCs Fluorochemical production	0.00	0.5025	0.0004	0.0044	0.93
Rice cultivations - CH4	0.00	0.1118	0.0004	0.0041	0.94
Chemical industry- N2O Nitric acid production	0.00	0.1044	0.0004	0.0041	0.94
Chemical industry- CO2 Ammonia production	0.00	0.1044	0.0004	0.0039	0.95
Mineral industry- CO2 Lime production	0.00	0.1044	0.0004	0.0039	0.95
Fugitive - CH4 Oil and natural gas - Oil	0.00	0.5009	0.0003	0.0031	0.95

Table A1.14 Results of the key category analysis with LULUCF. Approach 2 Level assessment, base year

CATEGORIES	Share	Uncertainty	L*U	Level assessment with uncertainty	Cumulative Percentage
Land Converted to Settlements - CO2	0.0120	1.0607	0.0127	0.1025	0.10
Direct N2O Emissions from Managed soils	0.0157	0.5385	0.0085	0.0683	0.17
Fugitive - CH4 Oil and natural gas - Natural gas	0.0148	0.5009	0.0074	0.0601	0.23
Transport - CO2 Road transportation	0.1663	0.0424	0.0071	0.0570	0.29
Forest Land remaining Forest Land - CO2	0.0270	0.2511	0.0068	0.0548	0.34
Energy industries - CO2 liquid fuels	0.1463	0.0424	0.0062	0.0501	0.39
Wastewater treatment and discharge - CH4	0.0058	1.0198	0.0059	0.0475	0.44
Enteric Fermentation- CH4	0.0280	0.2022	0.0057	0.0458	0.49
Land Converted to Forest Land - CO2	0.0051	1.0607	0.0054	0.0440	0.53
Solid waste disposal - CH4	0.0220	0.2236	0.0049	0.0397	0.57
Mineral industry- CO2 Cement production	0.0285	0.1044	0.0030	0.0241	0.59
Energy industries - CO2 solid fuels	0.0696	0.0424	0.0030	0.0239	0.62
Other sectors - CO2 commercial, residential, agriculture liquid fuels	0.0689	0.0424	0.0029	0.0236	0.64
Other sectors - CO2 commercial, residential, agriculture gaseous fuels	0.0655	0.0424	0.0028	0.0224	0.66
Grassland Remaining Grassland - CO2	0.0097	0.2715	0.0026	0.0212	0.69
Manufacturing industries and construction - CO2 liquid fuels	0.0591	0.0424	0.0025	0.0203	0.71
Manufacturing industries and construction - CO2 gaseous fuels	0.0581	0.0424	0.0025	0.0199	0.73
Indirect N2O Emissions from Managed soils	0.0046	0.5385	0.0025	0.0199	0.75
Wastewater treatment and discharge - N2O	0.0023	1.0198	0.0023	0.0187	0.76
Manufacturing industries and construction - CO2 solid fuels	0.0463	0.0424	0.0020	0.0159	0.78
Non-Energy products from Fuels and Solvent Use - CO2	0.0031	0.5831	0.0018	0.0145	0.79
Manure Management - CH4	0.0087	0.2062	0.0018	0.0145	0.809
Energy industries - CO2 gaseous fuels	0.0305	0.0424	0.0013	0.0105	0.82
Manure Management - N2O	0.0051	0.2062	0.0011	0.0085	0.83
Land Converted to Cropland - CO2	0.0015	0.6530	0.0010	0.0081	0.84
Land Converted to Settlements - N2O	0.0009	1.0607	0.0010	0.0078	0.84
Cropland Remaining Cropland - CO2	0.0014	0.6530	0.0009	0.0074	0.85
Other sectors - CH4 commercial, residential, agriculture biomass	0.0018	0.5009	0.0009	0.0073	0.86
Other sectors - N2O commercial, residential, agriculture liquid fuels	0.0018	0.5009	0.0009	0.0073	0.87
Fugitive - CO2 Oil and natural gas - venting and flaring	0.0017	0.5099	0.0009	0.0071	0.87
Chemical industry- PFCs Fluorochemical production	0.0017	0.5025	0.0008	0.0068	0.88
Manufacturing industries and construction - N2O liquid fuels	0.0017	0.5009	0.0008	0.0068	0.89
Chemical industry- N2O Adipic acid production	0.0079	0.1044	0.0008	0.0067	0.89
Metal industry- PFCs Aluminium production	0.0036	0.2022	0.0007	0.0058	0.899
Transport - CH4 Road transportation	0.0016	0.4011	0.0006	0.0051	0.904
Fugitive - CO2 Oil and natural gas - Other - flaring in refineries	0.0012	0.5099	0.0006	0.0051	0.91
Transport - N2O Road transportation	0.0015	0.4011	0.0006	0.0049	0.91
Metal industry- CO2 Iron and steel production	0.0056	0.1044	0.0006	0.0047	0.92
Land Converted to Grassland - CO2	0.0021	0.2715	0.0006	0.0047	0.92
Other sectors - N2O commercial, residential, agriculture biomass	0.0010	0.5009	0.0005	0.0039	0.93
Mineral industry- CO2 Other processes uses of carbonates	0.0046	0.1044	0.0005	0.0039	0.93

A1.5 Uncertainty assessment (IPCC Approach 2)

Montecarlo analysis was applied in the last submissions to estimate uncertainty of some of the key categories of the Italian inventory. The description of the key categories to which the analysis was applied and the reference year are reported in Table A1.15. Most of the results prove that both approaches (Approach 1 and 2) produce comparable results.

In Table A.1.15 the outcomes of the Approach 1 (error propagation) and Approach 2 (Montecarlo analysis) are shown.

Table A1.15 Comparison between uncertainty assessment by Approach 1 and Approach 2

Sector	***Categories***	***Key***	**Approach 1** *%*	**Approach 2 (Montecarlo)** *%*
Energy	CO_2 stationary combustion liquid fuels	L, T	4.2	3.3
Energy	CO_2 stationary combustion solid fuels	L, T1	4.2	5.1
Energy	CO_2 stationary combustion gaseous fuels	L, T	4.2	5.8
Energy	CO_2 Mobile combustion: Road Vehicles	L, T	4.2	7.4
Energy	CH_4 Mobile combustion: Road Vehicles	-	40.1	77.8
Energy	N_2O Mobile combustion: Road Vehicles	-	50.1	19.4
Energy	CH_4 Fugitive emissions from Oil and Gas Operations	L1, T1	25.2	17.4
Industrial Processes	CO_2 Cement production	L1	10.4	10.0
Agriculture	CH_4 Enteric Fermentation in Domestic Livestock	L	28.3	-21.8; +31.7
Agriculture*	Direct N_2O Agriculture soils	L, T	101.9	21.34
Agriculture*	Indirect N_2O from Nitrogen used in agriculture	L, T	101.9	21.67
Agriculture*	N_2O Manure management	L	101.9	10.19
Agriculture*	CH_4 Manure management	L, T2	101.9	22.96
Waste	CH_4 from Solid waste Disposal Sites	L, T1	36.1	12.6
LULUCF	CO_2 Forest land remaining Forest land	L, T	49.0	42.9
LULUCF	CO_2 Land converted to Forest land	-	106.1	-147.6; 192.3
LULUCF	CO_2 Cropland remaining Cropland	L, T	106.1	-108.5; 210.2
LULUCF	CO_2 Land converted to Cropland	T2	106.1	-408.2; 178.5
LULUCF	CO_2 Grassland remaining Grassland	L, T	106.1	-67.7; 75.0
LULUCF	CO_2 Land converted to Grassland	L, T	106.1	-119.3; 194.5
LULUCF	CO_2 Land converted to Settlements	L, T	106.1	-100.3; 49.2

***** These categories have been processes in the 2012 submission. The other categories have been assessed in the 2011 submission. The results of the key category analysis are therefore to be attributed to the respective annual submission

A summary of the results is described in the following by category.

Additional information on the choice of underlying distributions of each AD, parameter and EF related to an emission estimate, and relevant statistical parameters describing each distribution are documented in an internal report.

Energy: CO_2 from stationary combustion liquid fuels

Montecarlo analysis has been carried out for CO_2 emissions from stationary combustion of liquid fuels, for the reporting year 2009. In Table A1.16 a description of the main statistics resulting from the Montecarlo analysis is shown.

Table A1.16 Statistics of the Montecarlo analysis for CO_2 emissions from stationary combustion of liquid fuels, year 2009

	Value
Trials	5000
Mean	72,096,300
Median	72,096,998
Standard Deviation	1,181,053
Range Minimum	68,046,555
Range Maximum	77,401,681
Uncertainty (%)	**3.28**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.1.

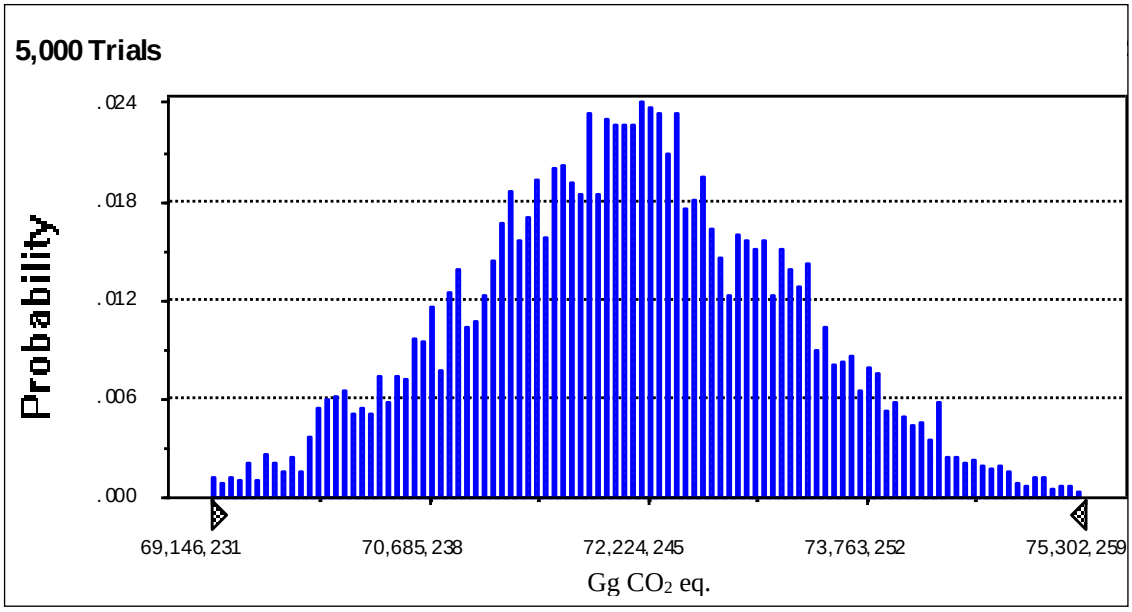


Figure A1.1 Probability density function resulting from Montecarlo analysis for CO_2 emissions from stationary combustion of liquid fuels, year 2009

Energy: CO_2 from stationary combustion solid fuels

Montecarlo analysis has been carried out for the CO_2 emissions from stationary combustion of solid fuels, for the reporting year 2009. In Table A1.17 a description of the main statistics resulting from the Montecarlo analysis is shown.

Table A1.17 Statistics of the Montecarlo analysis for CO_2 emissions from stationary combustion of solid fuels, year 2009

	Value
Trials	5000
Mean	49,289,917
Median	49,285,332
Standard Deviation	1,253,323
Range Minimum	44,384,889
Range Maximum	53,681,603
Uncertainty (%)	**5.08**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.2.

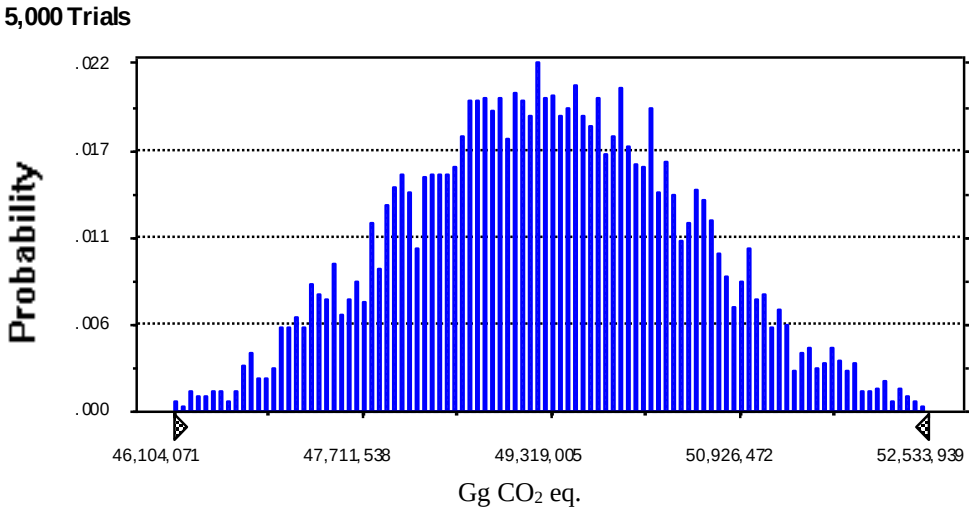


Figure A1.2 Probability density function resulting from Montecarlo analysis for CO_2 emissions from stationary combustion of solid fuels, year 2009

Energy: CO_2 from stationary combustion gaseous fuels

Montecarlo analysis has been carried out for the CO_2 emissions from stationary combustion of gaseous fuels, for the reporting year 2009. In Table A1.18 a description of the main statistics resulting from the Montecarlo analysis is shown.

Table A1.18 Statistics of the Montecarlo analysis for CO_2 emissions from stationary combustion of gaseous fuels, year 2009

	Value
Trials	5000
Mean	149,122,449
Median	149,184,196
Standard Deviation	4,355,657
Range Minimum	133,814,642
Range Maximum	165,672,245
Uncertainty (%)	**5.84**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.3.

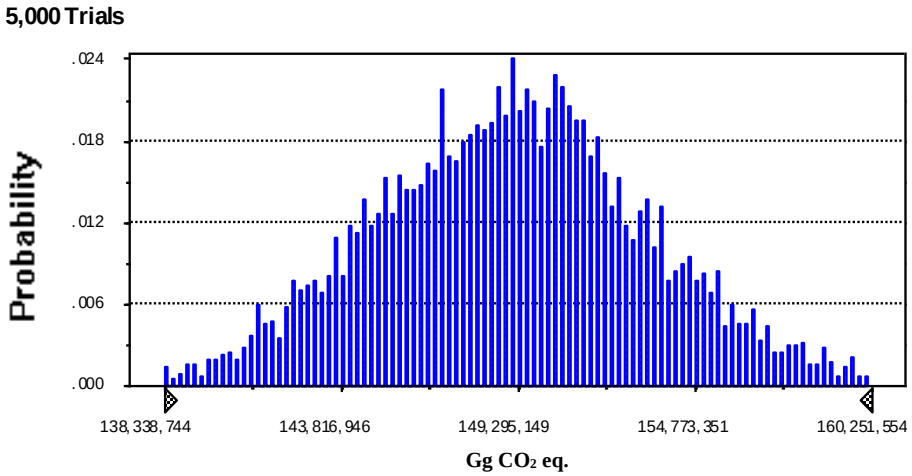


Figure A1.3 Probability density function resulting from Montecarlo analysis for CO_2 emissions from stationary combustion of gaseous fuels, year 2009

Energy: CO_2, CH_4 and N_2O Mobile combustion: Road Vehicles

Uncertainty of road transport emissions, at national level, has been assessed in the framework of study[74] "Uncertainty estimates and guidance for road transport emission calculations" performed by EMISIA[75] on behalf of the Joint Research Centre. The uncertainty has been assessed on the basis of 2005 input parameters of the COPERT 4 model (v. 7.0). In Table A1.19 a description of the statistics resulting for Mobile combustion: Road Vehicles is shown.

Table A1.19 Statistics of the Montecarlo analysis for GHG emissions from Mobile combustion: Road Vehicles, year 2005

	CO_2	CH_4	N_2O
Mean	110,735	19	614
Median	110,622	18	608
Standard Deviation	4,079	7	59
Variation (%)	4	34	10
Uncertainty (%)	**7.37**	**77.78**	**19.41**

The probability density functions, for CO_2, CH_4 and N_2O emissions from mobile combustion, resulting from the Montecarlo assessment is shown in Figure A1.4.

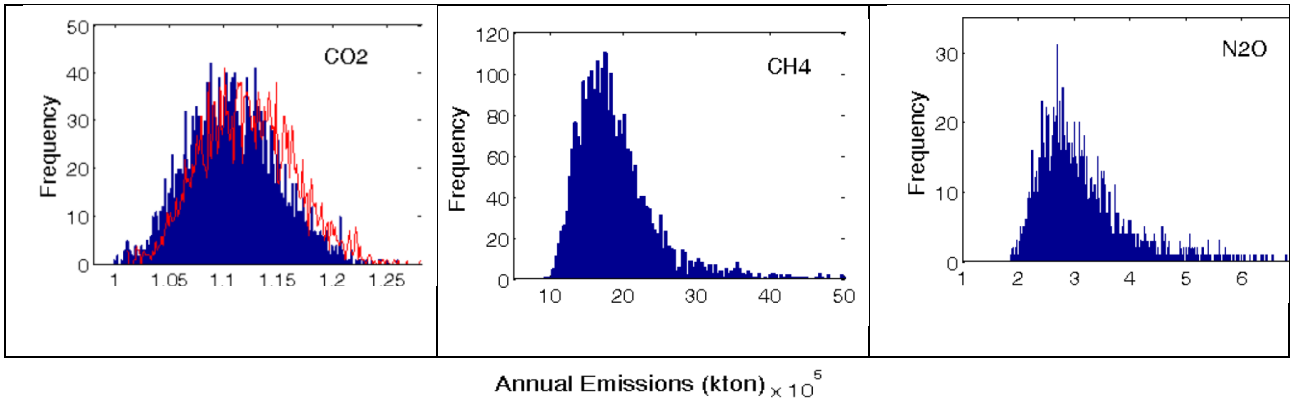


Figure A1.4 Probability density function resulting from Montecarlo analysis for CO_2, CH_4 and N_2O emissions from Mobile combustion: Road Vehicles, year 2005 (Kouridis et al., 2010)

Industrial Processes: CO_2 from Cement production

Montecarlo analysis has been carried out for the CO_2 emissions from cement production, for the reporting year 2009. In Table A1.20 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.20 Statistics of the Montecarlo analysis for CO_2 emissions from cement production, year 2009

	Value
Trials	5000
Mean	13,447,765
Median	13,452,009
Standard Deviation	670,995
Range Minimum	11,167,723
Range Maximum	16,119,133
Uncertainty (%)	**9.98**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.5.

[74] Kouridis C., Gkatzoflias D., Kioutsioukis I., Ntziachristos L., Pastorello P., Dilara P., 2010 .Uncertainty Estimates and Guidance for Road Transport Emission Calculations, Joint Research Centre 2010; URL: http://www.emisia.com/docs/COPERT%20uncertainty.pdf

[75] EMISIA: www.emisia.com

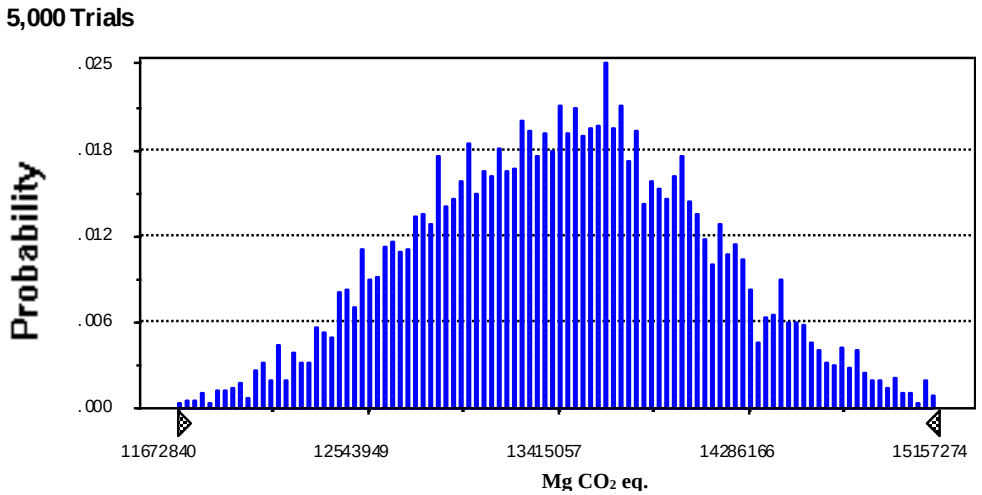


Figure A1.5 Probability density function resulting from Montecarlo analysis for CO_2 emissions from cement production, year 2009

Energy: CH_4 Fugitive emissions from Oil and Gas Operations

Montecarlo analysis has been carried out for CH_4 fugitive emissions from oil and gas operations, for the reporting year 2009. In Table A1.21 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.21 Statistics of the Montecarlo analysis for CH_4 from fugitive emissions, year 2009

	Value
Trials	5000
Mean	4904
Median	4903
Standard Deviation	427
Range Minimum	3027
Range Maximum	6532
Uncertainty (%)	**17.40**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.6.

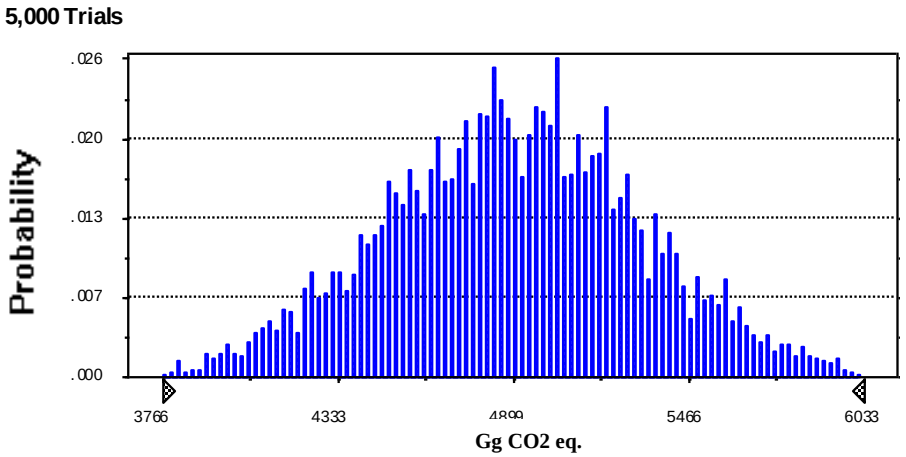


Figure A1.6 Probability density function resulting from Montecarlo analysis for CH_4 from fugitive emissions, year 2009

Agriculture: CH_4 Enteric Fermentation in Domestic Livestock

Montecarlo analysis has been carried out for the CH_4 emissions from enteric fermentation in domestic livestock, for the reporting year 2009. In Table A1.22 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.22 Statistics of the Montecarlo analysis for CH_4 emissions from enteric fermentation, year 2009

	Value
Trials	5000
Mean	519,226
Median	512,480
Standard Deviation	71,264
Range Minimum	340,639
Range Maximum	869,092
Uncertainty (%)	**-21.8; +31.7**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.7.

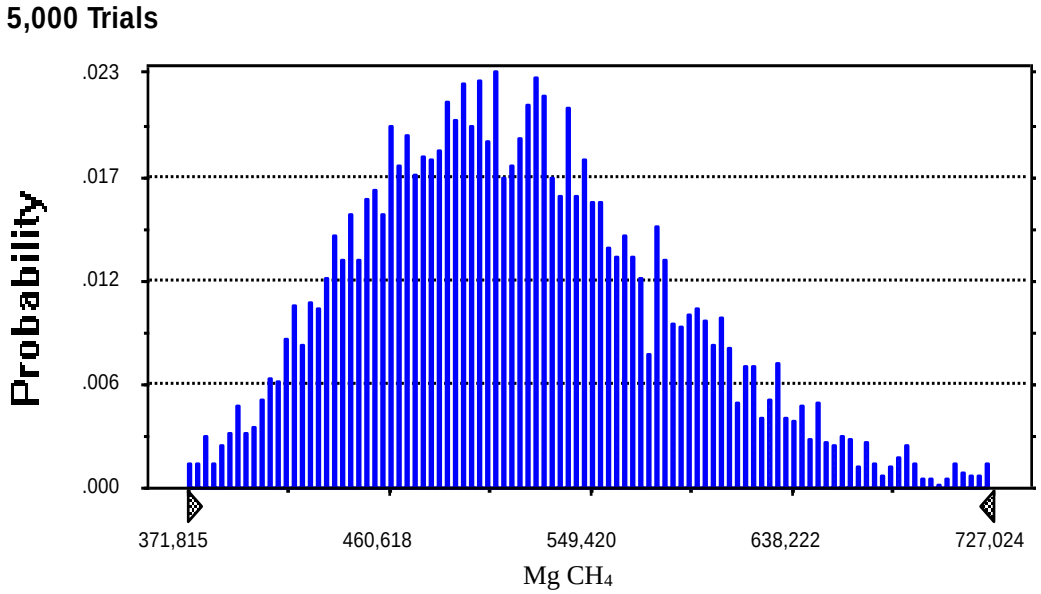


Figure A1.7 Probability density function resulting from Montecarlo analysis for CH_4 emissions from enteric fermentation, year 2009

Agriculture: Direct N_2O Agriculture soils

Montecarlo analysis has been carried out for the Direct N_2O emissions from Agriculture soils, for the reporting year 2010. In Table A1.23 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.23 Statistics of the Montecarlo analysis for Direct N_2O Agriculture soils emissions, year 2010

	Value
Trials	10000
Mean	23.24
Median	23.08
Standard Deviation	2.48
Range Minimum	16.85
Range Maximum	33.43
Uncertainty (%)	**21.34**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.8.

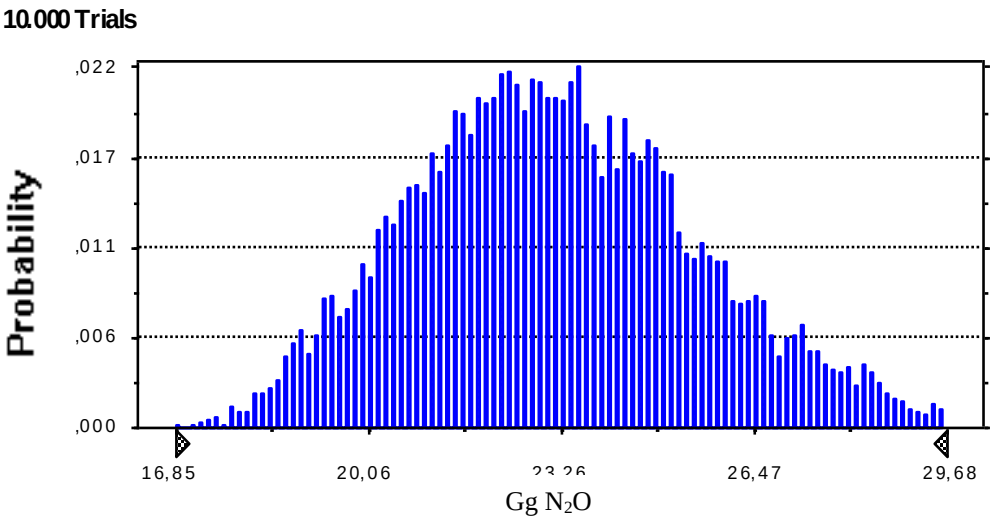


Figure A1.8 Probability density function resulting from Montecarlo analysis for Direct N_2O Agriculture soils emissions, year 2010

Agriculture: Indirect N_2O from Nitrogen used in agriculture

Montecarlo analysis has been carried out for the indirect N_2O emission from nitrogen used in agriculture, for the reporting year 2010. In Table A1.24 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.24 Statistics of the Montecarlo analysis for indirect N_2O emissions from nitrogen used in agriculture, year 2010

	Value
Trials	10000
Mean	20.58
Median	20.47
Standard Deviation	2.23
Range Minimum	13.53
Range Maximum	29.42
Uncertainty (%)	**21.67**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.9.

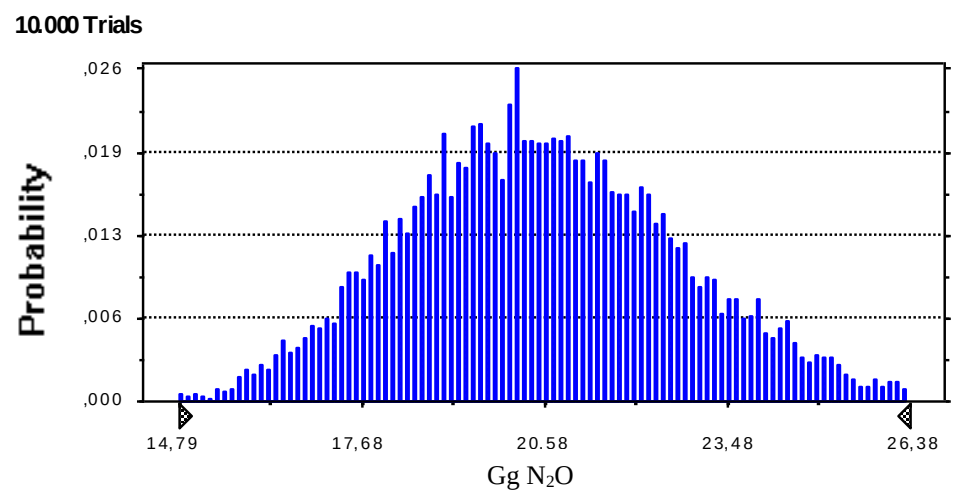


Figure A1.9 Probability density function resulting from Montecarlo analysis for indirect N_2O emissions from nitrogen used in agriculture, year 2010

Agriculture: N_2O manure management

Montecarlo analysis has been carried out for N_2O emissions from manure management, for the reporting year 2010. In Table A1.25 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.25 Statistics of the Montecarlo analysis for N_2O emissions from Manure management, year 2010

	Value
Trials	10000
Mean	11.9438
Median	11.9284
Standard Deviation	0.6087
Range Minimum	9.5877
Range Maximum	14.6361
Uncertainty (%)	**10.19**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.10.

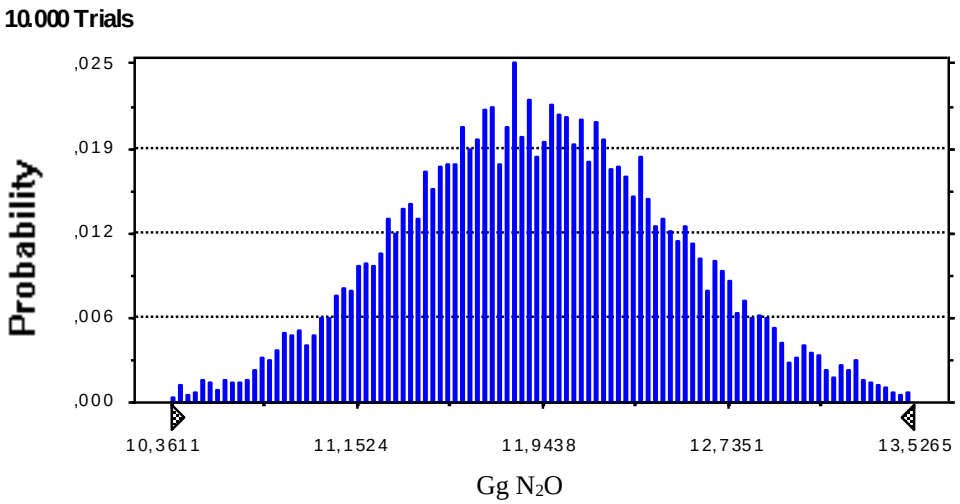


Figure A1.10 Probability density function resulting from Montecarlo analysis for N_2O emissions from Manure management, year 2010

Agriculture: CH_4 manure management

Montecarlo analysis has been carried out for the CH4 emissions from manure management, for the reporting year 2010. In Table A1.26 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.26 Statistics of the Montecarlo analysis for CH_4 emissions from enteric fermentation, year 2010

	Value
Trials	10000
Mean	121.44
Median	120.93
Standard Deviation	13.94
Range Minimum	78.05
Range Maximum	180.80
Uncertainty (%)	**22.96**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.11.

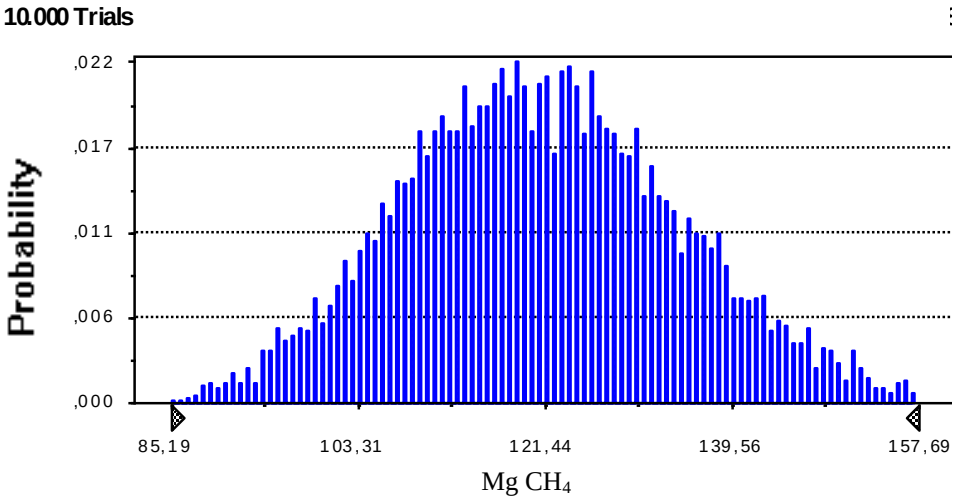


Figure A1.11 Probability density function resulting from Montecarlo analysis for CH_4 emissions from enteric fermentation, year 2010

LULUCF: CO_2 Forest Land remaining Forest Land

Montecarlo analysis has been carried out for the **CO_2** emissions and removals from *Forest Land remaining Forest Land*, considering the different reporting pools (*aboveground*, *belowground*, *litter*, *deadwood and soils*), and the subcategories stands, coppices and rupicolous and riparian forests for the reporting year 2009. In Table A1.27 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.27 Statistics of the Montecarlo analysis for CO_2 emissions and removals from Forest Land remaining Forest Land, year 2009

	Value					
	aboveground	*belowground*	*litter*	*deadwood*	*soils*	**total**
Trials	10000	10000	10000	10000	10000	10000
Mean	433	75	31	64	493	1,097
Median	431	75	31	64	494	1,098
Standard Deviation	82	14	12	12	122	236
Range Minimum	152	24	-16	24	2	197
Range Maximum	822	129	79	117	947	2,063
Uncertainty (%)	**37.86**	**37.18**	**79.40**	**36.87**	**49.33**	**42.93**

In Table A1.28 the results of the uncertainty assessment for the different subcategories are reported, related to the year 2009.

Table A1.28 Uncertainties assessed for the different subcategories, year 2009

	aboveground	*belowground*	*litter*	*deadwood*	*soils*	*total*
Stands	40.78	39.93	88.16	39.32	44.65	**41.91**
Coppie	53.81	54.99	74.81	53.47	67.35	**59.51**
rupicolous and riparian forests	56.53	61.49	79.66	56.91	58.52	**55.03**
Total	**37.86**	**37.18**	**79.40**	**36.87**	**49.33**	**42.93**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.12.

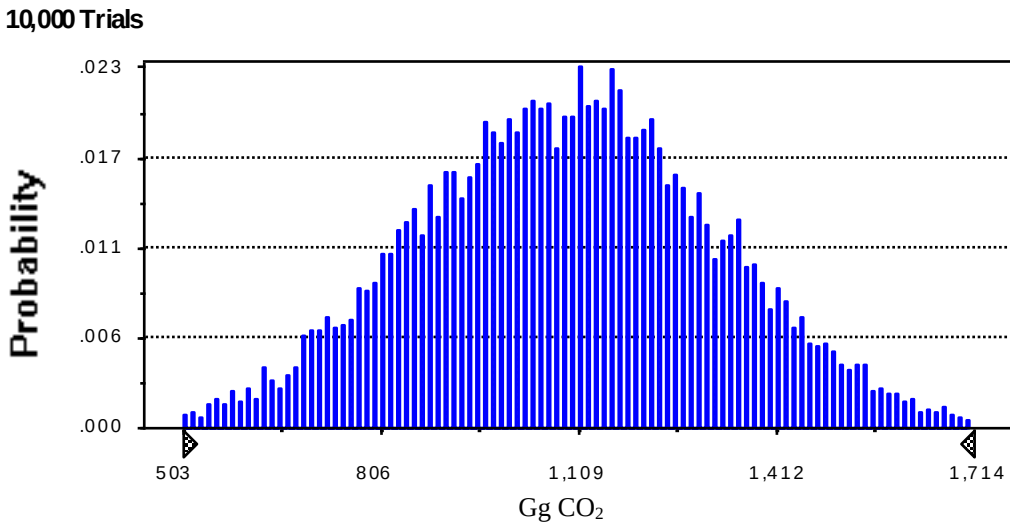


Figure A1.12 Probability density function resulting from Montecarlo analysis for the CO_2 emissions and removals from Forest Land remaining Forest Land category, year 2009

In Table A.1.29 the outcomes of the Approach 1 (error propagation) and Approach 2 (Montecarlo analysis) are shown, for the reporting pools. A general reduction in the uncertainty estimates has to be noted by comparing Montecarlo analysis results with the Approach 1 outcomes.

Table A1.29 Comparison between uncertainty assessment with Approach 1 and Approach 2

	Approach 1 *%*	**Approach 2 (Montecarlo analysis)** *%*
Aboveground	42.68	37.86
Belowground	42.68	37.18
Litter	52.17	79.40
Deadwood	101.62	36.80
Soils	113.00	49.33
Total	**67.98**	**42.93**

LULUCF: CO_2 Land converting to Forest Land

For *Land converting to Forest Land* **category, Approach 2 has been carried out taking into account** the different reporting pools (aboveground, belowground, litter, deadwood and soils), for the year 2009. In Table A1.30 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.30 Statistics of the Montecarlo analysis for Land converting to Forest Land, year 2009

	Value					
	aboveground	*belowground*	*litter*	*deadwood*	*soils*	**total**
Trials	10000	10000	10000	10000	10000	10000
Mean	6	1	0.43	0.83	13.64	22
Median	6	1	0.40	0.82	12.25	20
Standard Deviation	2	0	0.25	0.34	18.63	18
Range Minimum	-1	0	-0.01	-0.18	-48.94	-37
Range Maximum	15	2	1.74	2.21	108.58	108
Uncertainty (%)	**-72.6; 85.8**	**-72.5; 86.2**	**-91.3; 153.1**	**-72.5; 84.8**	**-257.2; 342.8**	**-147.6; 192.3**

The probability function resulting from the Montecarlo assessment is shown in Figure A1.13.

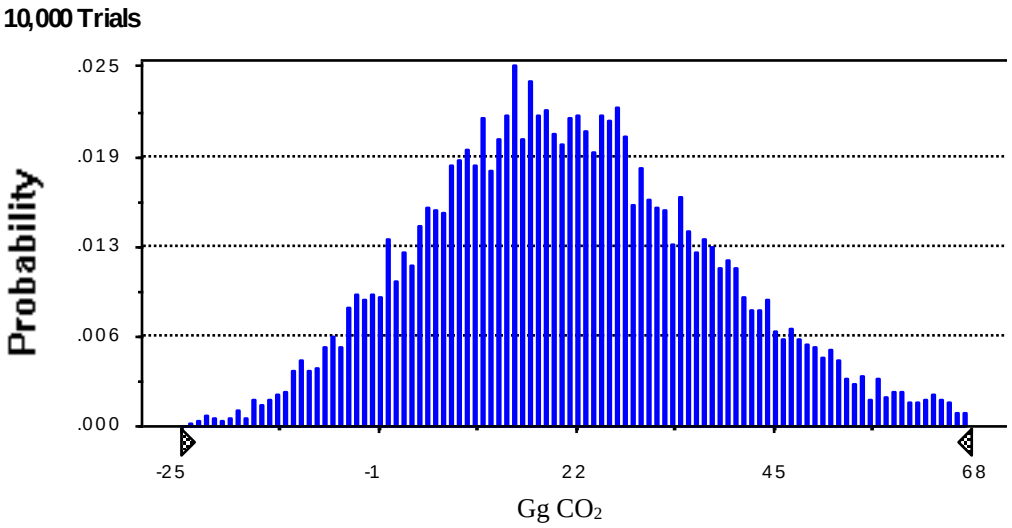


Figure A1.13 Probability density function resulting from Montecarlo analysis for the Land converting to Forest Land, year 2009

LULUCF: CO_2 Cropland remaining Cropland

For CO_2 emissions and removals from Cropland remaining Cropland, Approach 2 has been carried out taking into account the reporting subcategories (*woody crops*, *plantations*, *CO_2 emissions from organic soils*, *CO_2 emissions from lime application*), for the year 2009. In Table A1.31 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.31 Statistics of the Montecarlo analysis for CO_2 emissions and removals from Cropland remaining Cropland, year 2009

	Value				
	woody crops	*plantations*	*CO_2 emissions from organic soils*	*CO_2 emissions from lime application*	**total**
Trials	10000	10000	10000	10000	10000
Mean	3,017	-3.58	-90.26	-4.58	2,919
Median	2,662	-35.06	-81.65	-4.50	2,568
Standard Deviation	2,090	369.65	41.40	1.20	2,124
Range Minimum	-1,403	-1,595	-427.49	-10.59	-1913
Range Maximum	18,326	1739	409.17	-0.97	18,865
Uncertainty (%)	**-100.2; 199.4**	**-2173; 2454**	**-136.4; 57.3**	**-58.5; 46.4**	**-108.5; 210.2**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.14.

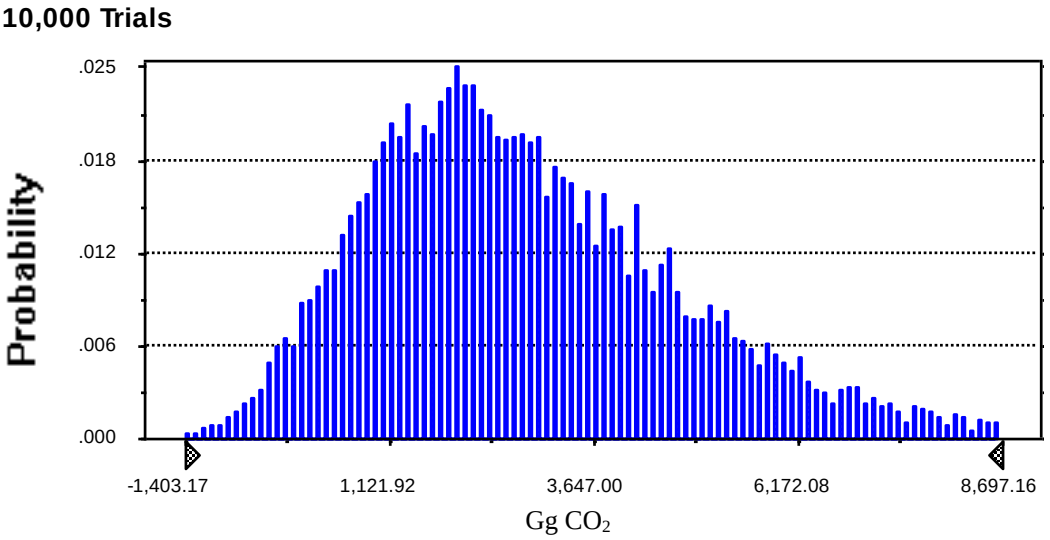


Figure A1.14 Probability density function resulting from Montecarlo analysis for the CO_2 emissions and removals from Cropland remaining Cropland, year 2009

LULUCF: CO_2 Land converting to Cropland

For CO_2 emissions and removals from Land converting to Cropland**, Approach 2 has been carried out taking into account** the *living biomass* and *soils* carbon pools, for the year 2009. In Table A1.32 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.32 Statistics of the Montecarlo analysis for CO_2 emissions and removals from *Land converting to Cropland*, year 2009

	Value		
	Living biomass	*Soils*	**total**
Trials	5000	5000	5000
Mean	7	-112	-105
Median	4	-85	-79
Standard Deviation	11	119	118
Range Minimum	-7	-1,169	-1,097
Range Maximum	149	414	410
Uncertainty (%)	**-150.7; 821.7**	**-384.1; 160.3**	**-408.2; 178.5**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.15.

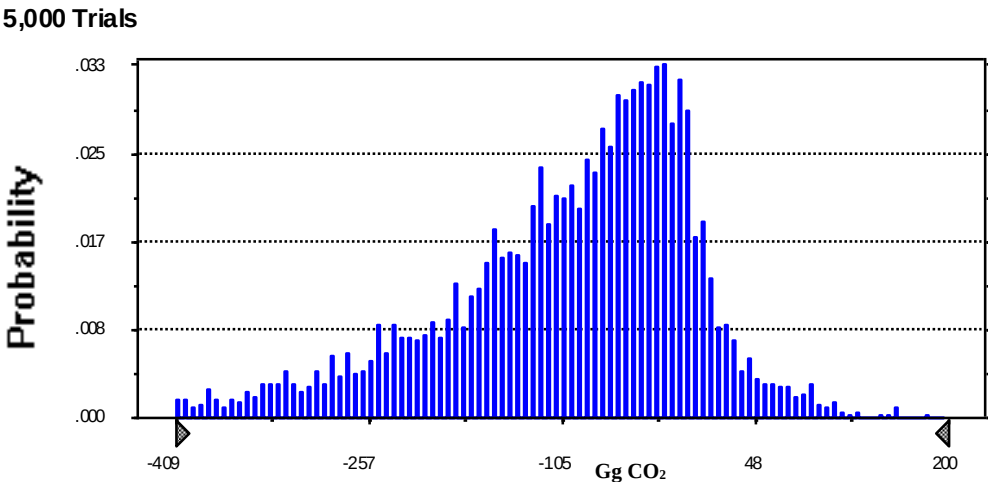


Figure A1.15 Probability density function resulting from Montecarlo analysis for CO_2 emissions and removals from Land converting to Cropland, year 2009

LULUCF: CO_2 Grassland remaining Grassland

For CO_2 emissions and removals from Grassland remaining grassland**, Approach 2 has been carried out taking into account** the different carbon pools, for the year 2009. In Table A1.33 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.33 Statistics of the Montecarlo analysis for CO_2 emissions and removals from Grassland remaining Grassland, year 2009

	Value					
	aboveground	*belowground*	*litter*	*deadwood*	*soils*	**total**
Trials	10000	10000	10000	10000	10000	10000
Mean	26.59	11.05	9.66	3.63	82.86	133.79
Median	25.72	10.61	9.65	3.52	82.25	132.04
Standard Deviation	10.63	5.34	3.45	1.47	30.48	48.08
Range Minimum	-4.54	-3.88	-3.19	-0.69	-8.88	-9.27
Range Maximum	81.63	37.31	23.31	11.27	204.58	354.91
Uncertainty (%)	**-68.6; 94.6**	**-82.6; 114.5**	**-70.4; 70.5**	**-69.9; 95.4**	**-70.6; 74.3**	**-67.7; 75.0**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.16.

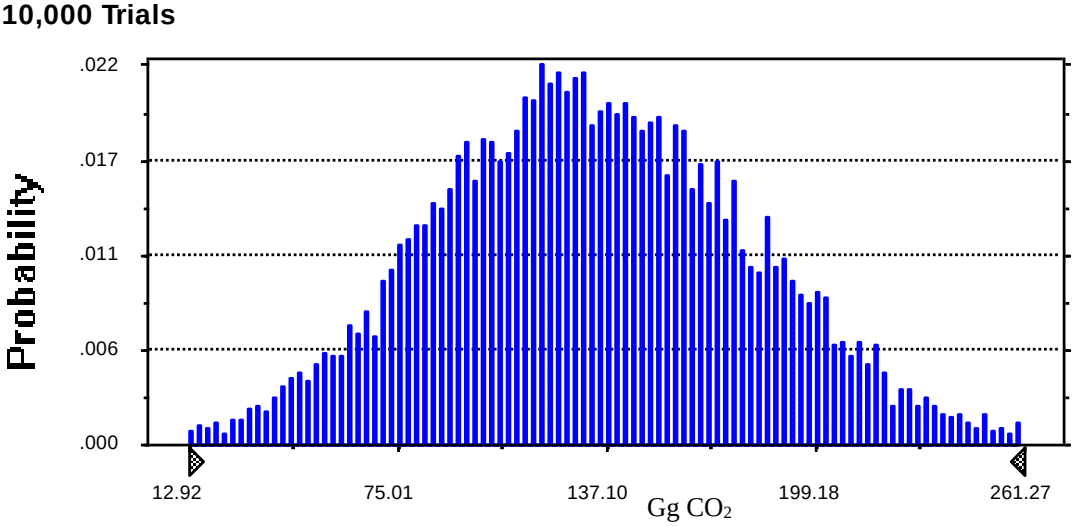


Figure A1.16 Probability density function resulting from Montecarlo analysis for CO_2 emissions and removals from Grassland remaining Grassland, year 2009

LULUCF: CO_2 Land converting to Grassland

For CO_2 emissions and removals from Land converting to Grassland**, Approach 2 has been carried out taking into account** the *living biomass* and *soils* carbon pools, for the year 2009. In Table A1.34 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.34 Statistics of the Montecarlo analysis for CO_2 emissions and removals from Land converting to Grassland, year 2009

	Value		
	Living biomass	*Soils*	**total**
Trials	5000	5000	5000
Mean	-371.6	4,006	3,635
Median	-304.7	3,650	3,283
Standard Deviation	462.0	2,654	2,623
Range Minimum	-5,426	4,813	-6,794
Range Maximum	1,640	20,503	19,126
Uncertainty (%)	**-383.8; 222.9**	**-106.1; 179.8**	**-119.3; 194.5**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.17.

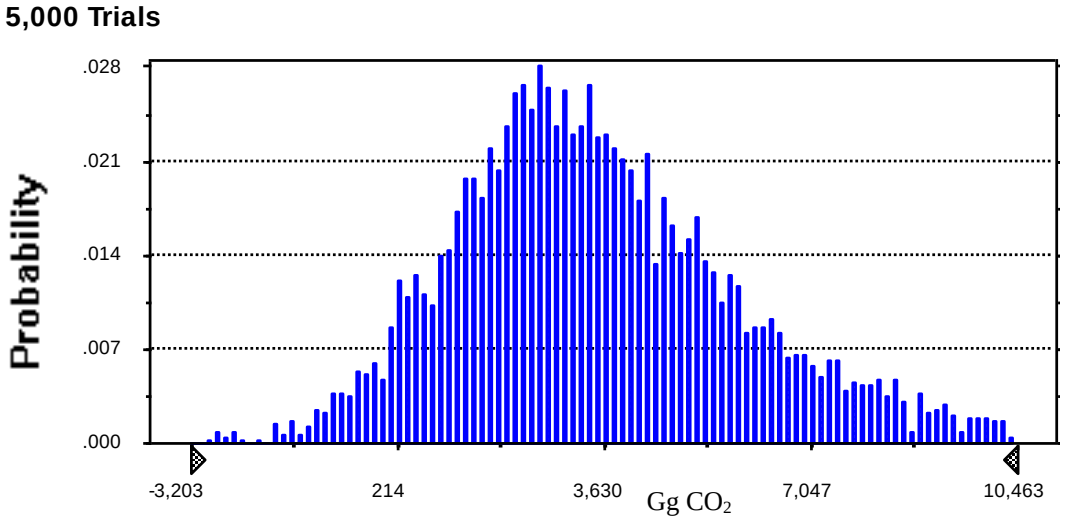


Figure A1.17 Probability density function resulting from Montecarlo analysis for the CO_2 emissions and removals from Land converting to Grassland, year 2009

LULUCF: CO_2 Land converting to Settlements

For CO_2 emissions from Land converting to Settlements**, Approach 2 has been carried out taking into account** the reporting subcategories (*annual crops converting to Settlements, woody crops converting to Settlements, Grassland converting to Settlement, Forest land converting to Settlements*), for the year 2009**.** In Table A1.35 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.35 Statistics of the Montecarlo analysis for CO_2 emissions from Land converting to Settlements, year 2009

	Value				
	Annual crops to SL	*woody crops to SL*	*Grassland to SL*	*Forest land to SL*	**total**
Trials	10000	10000	10000	10000	10000
Mean	-450.9	-377.7	-274.7	-100.4	-4,428.4
Median	-362.8	-312.3	-240.7	-100.7	-4,116.9
Standard Deviation	323.9	262.3	175.8	23.68	1,693.4
Range Minimum	-3,739.5	-4,229.4	-2,423.8	-283.7	-18,736.0
Range Maximum	-22.0	-29.5	-2.3	-40.3	-1.073.8
Uncertainty (%)	**-262.1; 72.0**	**-238.1; 70.8**	**-193.5; 82.9**	**-56.0; 35.1**	**-100.3; 49.2**

In Table A1.36 the results of the uncertainty assessment for the different subcategories are reported, related to the year 2009.

Table A1.36 Uncertainties assessed for the different subcategories, year 2009

	living biomass %	**dead organic matter %**	**Soils %**	**Total %**
annual crops to SL	*-300.9; 75.5*	-	*-267.1; 72.0*	*-262.1;72.0*
woody crops to SL	*-288.8; 74.3*	-	*-235.5; 70.5*	*-238.1; 70.8*
Cropland to SL	-288.8; 67.0	-	-187.0; 62.5	**-193.5; 82.9**
Grassland to SL	-	-	-193.5; 82.9	**-193.5; 82.9**
Forest land to SL	-115.9; 54.3	-56.9; 51.3	68.2; 40.0	**-56.0; 35.1**
Land to SL	-	-	-	**-100.3; 49.2**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.18.

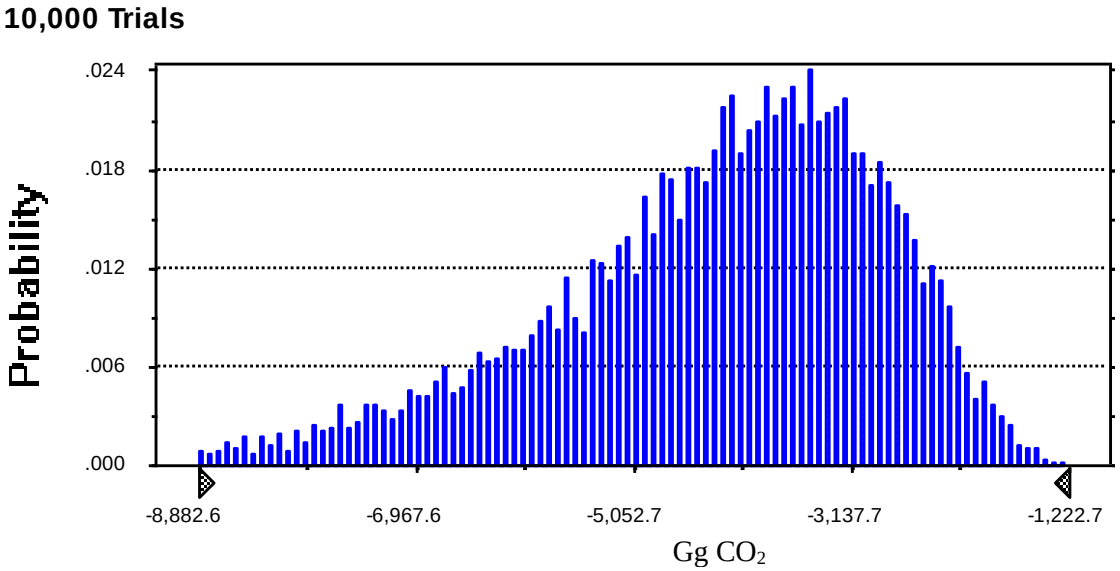


Figure A1.18 Probability density function resulting from Montecarlo analysis for the CO_2 emissions from Land converting to Settlements, year 2009

Waste: CH_4 from Solid waste Disposal Sites

Montecarlo analysis has been carried out for the CH_4 emissions from Solid waste disposal sites, for the reporting year 2009. In Table A1.37 a description of the statistics resulting from the Montecarlo analysis is shown.

Table A1.37 Statistics of the Montecarlo analysis for Solid waste disposal on land category, year 2009

	Value
Trials	5000
Mean	595,157
Median	595,893
Standard Deviation	37,423
Range Minimum	469,077
Range Maximum	728,751
Uncertainty (%)	**12.58**

The probability density function resulting from the Montecarlo assessment is shown in Figure A1.19.

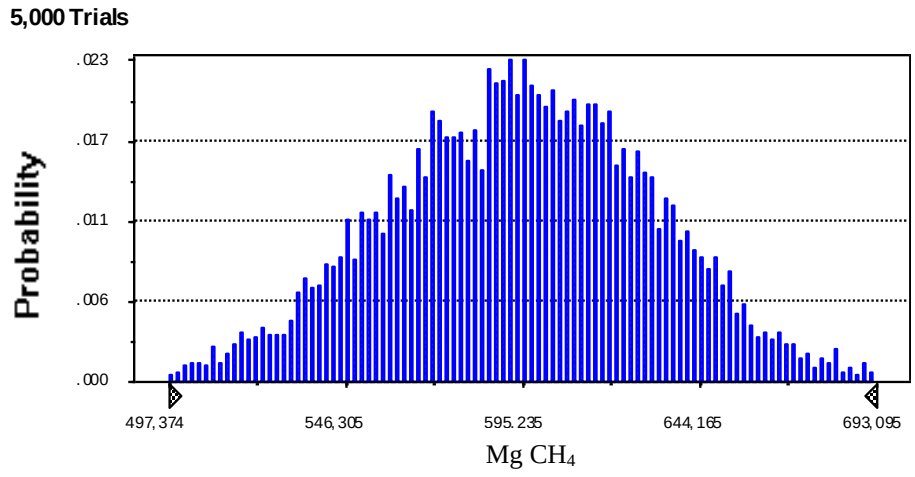


Figure A1.19 Probability density function resulting from Montecarlo analysis for the Solid waste disposal on land category, year 2009

ANNEX 2: ENERGY CONSUMPTION FOR POWER GENERATION

A2.1 Source category description

The main source of data on fuel consumption for electricity production is the annual report "Statistical data on electricity production and power plants in Italy" ("Dati statistici sugli impianti e la produzione di energia elettrica in Italia"), edited from 1999 by the Italian Independent System Operator (TERNA, several years), a public company that runs the high voltage transmission grid. For the period 1990-1998 the same data were published by ENEL (ENEL, several years), former monopolist of electricity distribution. The time series is available since 1963. In these publications, consumptions of all power plants are reported, either public or privately owned.

Detailed data are collected at plant level, on monthly basis. They include electricity production and estimation of physical quantities of fuels and the related energy content; for the largest installations, the energy content is based on laboratory tests. Only the fuel used for electricity production is reported. Up to 1999, the fuel consumption was reported at a very detailed level, 17 different fuels, allowing a quite precise estimation of the carbon content. From 2000 onward, the published data aggregate all fuels in five groups that do not allow for a precise evaluation of the carbon content. In Table A2.1, the time series of fuel consumptions for power sector production is reported.

Table A2.1 Time series of power sector production by fuel, Gg or Mm^3

	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
national coal	58	-	Solids	Solids	Solids	Solids	Solids	Solids	Solids	Solids
imported coal	10,724	8,216	9,633	16,253	14,998	16,245	12,054	10,633	7,175	5,274
lignite	1,501	380								
Natural gas, Mm^3	9,731	11,277	22,334	30,544	29,630	20,365	25,785	23,592	26,065	24,689
BOF(steel converter) gas, Mm^3	509	633	Coal Gases	Coal Gases	Coal Gases	Coal Gases	Coal Gases	Coal Gases	Coal Gases	Coal Gases
Blast furnace gas, Mm^3	6,804	6,428	8,690	12,104	8,822	3,658	4,362	4,772	3,801	2,527
Coke gas, Mm^3	693	540								
Light distillate	5	6	Oil products	Oil products	Oil products	Oil products	Oil products	Oil products	Oil products	Oil products
Diesel oil	303	184	19,352	7,941	2,152	1,133	772	585	617	549
Heavy fuel oil	21,798	25,355								
Refinery gas	211	378								
Petroleum coke	186	189								
Gases from chemical processes	444	803	Others	Others	Others	Others	Others	Others	Others	Others
Other fuels	344	697	5,153	Mm^3= 978 Gg= 15,460	Mm^3= 1,501 Gg= 18,160	Mm^3= 3,509 Gg= 16,257	Mm^3= 3,513 Gg= 16,156	Mm^3= 3,496 Gg= 16,718	Mm^3= 3,568 Gg= 16,012	Mm^3= 3,478 Gg= 15,884
Tar	2	-	-							
Heat recovered from Pyrite	146	3	-							

Source: TERNA, several years

Figures reported in the table show that natural gas has substituted oil products, from 1990 to 2020, becoming the main fuel for electricity production while coal consumption has decreased in the last years.

For the purpose of calculating GHG emissions, a detailed list of 25 fuels was delivered to ISPRA by TERNA for the years from 2000 to 2007. From 2008 the list of the fuels used to estimate emissions was expanded by TERNA, up to 40 different types in 2012. The list includes different variety of renewable sources according to their composition and origin, useful to estimate the percentage of renewable sources for electricity

generation and to comply with national regulations of waste derived fuels. A list of different quantities of fuel oils used according to the sulphur content was also added. Energy data of previous years have not changed (see previous reports). These figures include also amount of fuels used to cogenerate heat and electricity in some power plants.
The detailed information is confidential and only the elaboration applied to calculate emissions at an aggregated level is reported in Table A2.2 and Table A2.3. The consumption of municipal solid waste (MSW) / industrial wastes is separated from the biomass consumption, and reported under other fuels, since the use of this fuel for electricity generation is expanding and emission factors are different.
At national level, other statistics on the fuel used for electricity production exist, the most remarkable being the national energy balance (BEN), published annually (MSE, several years) and those published by Unione Petrolifera, the Oil companies association (UP, several years). In the past, also the association of the industrial electricity producers (UNAPACE, several years) up to the year 1998, and ENI, the former national oil company up to the year 2000, published production data with the associated fuel consumptions (ENI, several years).

A2.2 Methodological issues
Both BEN and TERNA publications could be used for the inventory preparation, as they are part of the national statistical system and published regularly. The preference, up to date, for TERNA data arises from the following reasons:

- BEN data are prepared on the basis of TERNA reports to IEA and EUROSTAT, so both data sets come from the same source;
- before publication in the BEN, TERNA data are revised to be adapted to the reporting methodology: balance is done on the energy content of fuels and the physical quantities of fuels are converted to energy using standard conversion factors; so the total energy content of the fuels is the "right" information extracted from the TERNA reports and the physical quantities are changed to avoid discrepancies; the resulting information cannot be cross checked with detailed plant data (point source evaluation) based on the physical quantities;
- the used fuel types are much more detailed in TERNA database, 40 fuels as above mentioned, whereas in BEN all fuels are added up (using energy content) and reported together in 12 categories: emission factors for certain fuels (coal gases or refinery by-products) are quite different and essential information is lost with this process;
- finally, the two data sets usually differ, even considering the total energy values of fuels or the produced electricity, there are always small differences, usually less than 1%, that increase the already sizable discrepancy between the reference approach and the detailed approach; the BEN adjust the physical quantities according to fixed low heating values and this process combined with the reduction of fuel types adds rounding errors and this may cause the small difference between the production of electricity of the two sources.

The other two statistical publications quoted before, UP (UP, several years) and ENI (ENI, several years), have direct access to fuel consumption data from the associated companies, but both rely on TERNA data for the complete picture. Data from those two sources are used for cross checking and estimation of point source emissions.
For verification purposes, an estimate of CO_2, N_2O and CH_4 emissions, with a rather complex calculation sheet has been used (APAT, 2003). The data sheet summarizes all plants existing in Italy divided by technology, about 60 typologies, and type of fuel used; the calculation sheet can be considered a model of the national power system. The main scope of the model has been to estimate the emissions of pollutants different from CO_2 that are technology dependent. For each year, a run estimated the fuel consumed by each plant type, the pollutant emissions and GHG emissions.
The model has many possible outputs; same of which are built up in such a way to reproduce the data available from statistical source. The model has been revised every year, till 2017, to mirror the changes occurred in the power plants. Moreover, the model is also able to estimate the energy/emissions data related to the electricity produced and used on site by the main industrial producers. Those data are reported in the other energy industries, Tables 1.A.1.b and 1.A.1.c of the CRF, and in the industrial sector section, Table 1.A.2 of the CRF.

Table A2.2 reports the differences between the model and TERNA data for 2017.

For each source, three types of data are presented: electricity production, physical quantities of fuel consumptions and amount of energy used.

Table A2.2 Energy consumption for electricity production, year 2017

Fuels	**TERNA**			**Model**		
	GWe, gross	Gg / Mm^3	Pj	GWe, gross	Gg/ Mm^3	Pj
Coal	32,627.4	12,054	302.4	32,623.6	11,555	302.2
Coke oven gas	870.1	411	7.4	834.9	400	7.1
Blast furnace gas	1,473.3	3,713	14.5	1,474.4	3,279	12.3
Oxi converter gas	157.9	239	1.5	0.0		0.0
Total derived gases	2,501.3	4,362	23.4	2,309.3	3,679	19.5
Coal	**35,128.7**		**325.8**	**34,932.9**		**321.6**
Light distillates	0.1	0	0.00	0.0	0	0.0
Light fuel oil	468.3	105	4.5	474.4	111	18,748.6
Fuel oil - high sulfur content	1,696.0	416	17.1	8,683.7	1,343	235,539.0
Fuel oil - low sulfur content	0.0		0.0	444.2	576	12,008.9
Refinery gas	1,918.1	251	11.7	1,897.7	226	48,735.8
Petroleum coke	0.0	0	0.0	0.0	0	0.0
Oriemulsion	0.0	0	0.0			
total fuel oil	*4,082.6*		*33.3*	*11,500.0*	*2,256*	*75.3*
Gas from chemical proc.	429.7	679	3.8	0.0	0	0.0
Heavy residuals/ tar	6,862.2	4,991	42.1			
Others	85.6		0.8			
total residual	*7,377.5*		*46.7*	*0.0*		*0.0*
Oil+residuals	**11,460.1**		**80.0**	**11,500.0**		**75.3**
Natural gas	**140,349.3**	25,785	**897.5**	**140,344.2**	26,166	**896.6**
Biofuels	4,463.5	925	33.9			33.9
Biogas	8,299.1	3,481	66.7			66.7
Biomass	4,193.2	4,213	50.0	3,972.9	4,731	49.9
Municipal waste	4,930.1	5,348	61.5	4,135.0	5,749	60.2
Grand total	**208,824**		**1,515.4**	**207,648**		**1,504.3**
TERNA /BEN differences				0.6%		0.7%

Source: ISPRA elaborations

Table A2.3 shows all energy and emissions summarized by fuel and split in two main categories of producers: public services and industrial producers for the year 2020, according to the reporting in the CRF. Since 1998, expansion of industrial cogeneration of electricity and split of national monopoly has transformed many industrial producers into "independent producers", regularly supplying the national grid. So part of the energy/emissions of the industrial producers are added to Table 1.A.1.a of the CRF, according to the best information available, including those available at plant level from the EU ETS scheme.

Table A2.3 Power sector, Energy/CO_2 emissions in CRF format, year 2020

	TJ	**CO_2, Gg**
Public Electricity and Heat Production - Table 1.A.1a		
Liquid fuels	12,475	983
Solid fuels	133,823	12,581
Natural gas	800,385	46,357
Refinery gases		
Coal gases		
Biomass	109,943	9,594
Other fuels (incl.waste)		
Total	**1,056,626**	**59,921**

	TJ	CO_2, Gg
Industrial producers and auto-producers - Tables 1.A.1b, 1.A.1c and 1.A.2		
Liquid fuels	16,299	1,239
Solid fuels	-827	-78
Natural gas	209,626	12,141
Refinery gases	26,587	1,501
Other refinery products	48,475	4,191
Coal gases	17,387	2,876
Biomass	110,901	9,677
Other fuels (incl.waste)	48,525	4,585
Total	**476,974**	**26,454**
General total	**1,533,601**	**86,375**

Source: ISPRA elaborations

In conclusion, the main question of the accuracy of the underlying energy data of key sources is connected to the discrepancies between BEN and TERNA in the estimates of electricity produced and of the energy content of the used fuels. The difference is small, but it should not occur because both data sets derive from the same source. On the basis of this consideration, the inventory has been based on TERNA data that are expected to be more reliable. In particular because the emission factors used are based on the energy content of the fuel, the model has been used to reproduce with the TERNA energy consumption figures ignoring discrepancies in the electricity production or in the physical quantities of fuel used.

A2.3 Uncertainty and time-series consistency

The combined uncertainty in CO_2 emissions from electricity production is estimated to be about 4.2% in annual emissions; a higher uncertainty, equal to 50.1%, is calculated for CH_4 and N_2O emissions on account of the uncertainty levels attributed to the related emission factors.
For the year 2009, Montecarlo analysis has been carried out to estimate uncertainty of CO_2 emissions from stationary combustion of solid, liquid and gaseous fuels emissions, resulting in 5.1%, 3.3% and 5.8%, respectively. Normal distributions have been assumed for all the parameters. A summary of the results is reported in Annex 1.
Estimates of fuel consumption for electricity generation in 2020 are reported in Table A2.3.

In Table A2.4, the time series of the total CO_2 emissions from electricity generation activities is reported, including total electricity produced and specific indicators of CO_2 emissions for the total energy production and for the thermoelectric production respectively, expressed in grams of CO_2 per kWh. The emission factors are reported excluding the electricity produced from pumped storage units using water that has previously been pumped uphill, as requested by Directive 2009/28/EC of the European Parliament and of the Council promoting the electricity renewable sources.

The time series clearly shows that although the specific carbon content of the kWh generated in Italy has constantly improved over the years, total emissions have raised till 2006 due to the even bigger increase of electricity production. The decreasing trend starting from 2007 results from an increase in energy production from renewable sources, combined with a further reduction in the use of oil products for electricity production. In the last years the emissions are quite stable notwithstanding the increase of total energy demand and production, as a consequence of the shift from coal to natural gas.

Table A2.4 Time series of CO_2 emissions from electricity production

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Total electricity produced (gross), TWh	216.9	241.5	276.6	303.7	302.1	283.0	289.8	295.8	289.7	293.9	280.5
Total CO_2 emitted, Mt	126.4	133.5	139.8	144.6	120.9	93.7	92.9	93.3	85.6	81.2	72.4
g CO_2/kwh (gross thermo-electric production)	709	682	636	574	524	489	467	447	446	416	400
G CO_2/kwh of total gross production*	593	562	518	487	405	333	323	317	297	278	260

* excluding electricity production from pumped storage units using water that has previously been pumped uphill
Source: ISPRA elaborations

The trend of CO_2 emissions for thermoelectric production is the result of an increase of natural gas share due to the entry into service of more efficient combined cycle plants. The downward trend takes also into account the general increase in efficiency of the power plants.

A2.4 Source-specific QA/QC and verification

Basic activity data to estimate emissions from all operators are annually collected and reported by the national grid administrator (TERNA, several years). Other data are collected directly from operators for plants bigger than 20 MWh, with a yearly survey since 2005 and communicated at international level in the framework of the EU ETS scheme. Activity data and other parameters, as net calorific values, are compared every year at an aggregate level, by fuel; differences and problems have been identified, analysed in detail and solved with sectoral experts.
In addition, time series resulting from the recalculation have been presented to the national experts in the framework of an *ad hoc* working group on air emissions inventories. The group is chaired by ISPRA and includes participants from the local authorities responsible for the preparation of local inventories, sectoral experts, the Ministry of Environment, Land and Sea, and air quality model experts. Top-down and bottom-up approaches have been compared with the aim to identify the potential problems and future improvements to be addressed.

A2.5 Source-specific recalculations

Recalculations occur in the last years, 2017-2019, because of the update of natural gas emission factor. Updated emission factors are provided in Annex 6.

A2.6 Source-specific planned improvements

With the aim to improve the comparison with the international statistics and the relevant definition and classification of fuels we are progressively updating the emission inventory adopting the energy balance activity data provided by the Italian Ministry of Economic Development to the international organization after verification that these time series data reflect the relevant emission inventory categories.
A revision of biomass and waste fuel consumption time series is planned for the next submission on the basis of energy data communicated by the Ministry of Economic Development to the Joint Questionnaire OECD/IEA/EUROSTAT, after a verification and comparison with data up to now used and available in the National Energy Balance reports (MSE, several years). National Energy Balances are available in Italy from 1970 with the same format and comparable data. The submissions to the international questionnaire in some cases follow different rules and different allocation of fuel consumptions. The comparison is oriented to avoid that the use of international statistics results in a loss of information already used for the emission inventory. Moreover, we will check where along the time series changes occurred and for which matter (simple updates of annual data or something related to the different reporting rules).

ANNEX 3: ESTIMATION OF CARBON CONTENT OF COALS USED IN INDUSTRY

The preliminary use of the CRF software in 2001 underlined an unbalance of emissions in the solid fuel rows above 20%. A detailed verification pointed out to an already known issue for Italy: the combined use of standard IPCC emission factors for coals, national emission factors for coal gases and CORINAIR methodology emission factors for steel works processes produces double counting of emissions.
The main reason for this is the specific national circumstance of extensive recovery of coal gases from blast furnaces, coke ovens and oxygen converters for electricity generation. The emissions from those gases are separately accounted for and reported in the electricity generation sector.
Another specific national circumstance is the concentration of steel works in two sites, since the year 2005, with integrated steel plants, coke ovens and electricity self-production and just in one site since 2015. Only pig iron is produced also in one additional location. This has allowed for careful check of the processes involved and the emissions estimates at site level and, with reference to other countries, may or may not have exacerbated the unbalances in carbon emissions due to the use of standard emission factor developed for other industrial sites.
To avoid the double counting a specific methodology has been developed: it balances energy and carbon content of coking coals used by steelworks, industry, for non-energy purposes and coal gasses used for electricity generation.
A balance is made between the coal used for coke production and the quantities of derived fuels used in various sectors. The iron and steel sector gets the resulting quantities of energy and carbon after subtraction of what is used for electricity generation, non-energy purposes and other industrial sectors. According to the 2006 IPCC Guidelines (IPCC, 2006), the use of reductants is also included in this balance because no sufficient information to detail emissions between the energy and industrial processes sectors is available. The carbon balance methodology does not imply to separate off input between the energy and industrial sectors but ensures no double counting occurs.
Until the 2016 submission, the base statistical data are all reported in the BEN (MSE, several years) (with one exception) and the methodology starts with a verification of the energy balance reported in the BEN that seldom presents problems, and then apply the emission factors to the energy carriers, trying to balance the carbon inputs with emissions. The exception mentioned refers to the recovered gases of BOFs (Basic Oxygen Furnace) that are used to produce electricity but were not accounted for by BEN from the year 1990 up to 1999. From the year 2000 those gases are (partially, only in one plant) included in the estimate of blast furnace gas. The data used to estimate the emissions from 1990 to 1999 are reported by GRTN – ENEL (TERNA, several years). The consideration of the BOF gases does not change the following discussion, because its contribution to the total emissions is quite limited.
Starting from the 2017 submission, data submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT have been used and this required specific meetings and additional verification activities in order to make the transition to the new data format, so in 2017 submission it was not yet possible to reconstruct the entire time series and only 2015 data were used. In the 2018 submission the complete time series, from 1990, of solid fuel consumptions and relevant calorific values have been updated on the basis of figures submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT. This required a considerable amount of work for the comprehension and reconstruction of trends. Consequently, this process involved significant changes, especially in the nineties, some of which are still under investigation thanks to the collaboration with the Ministry of Economic Development.
Table A3.1 summarises the quantities of coal and coal by-products used by the energy system in the year 2020; all the data mentioned are those provided by the Ministry of economic development to the the Joint Questionnaire IEA/OECD/EUROSTAT for the same year.
In Table A3.1 the quantities of coke, coke gas and blast furnace gas used by the different sectors are detailed as well as the quantities of the same energy carriers that are self-used, used to produce coke or wasted. Inputs are indicated in the blue cells while outputs are reported in the orange ones.

Table A3.1 Energy balance, 2020, TJ

	TJ input	TJ output	
steam coal	157,615	6,149	clinker/industry
		140,660	thermoelectric power plants
		10,806	blast furnace
anthracite	2,128	2,128	steel plants
sub bituminous and lignite	14	14	clinker/industry
coking coal	49,032	0	coking coal consumption
		1,481	Non-energy use in other sectors
Coke import/export/stock change	4,121		
coke		28	other industry and domestic
			ferroalloys
		10,073	blast furnace consumption
coke oven gas		330	coke oven gas in coke oven and blast furnace
		2,934	coke oven gas reheating
		7,143	coke oven gas thermoelectric
blast furnace gas		0	BF gas in coke oven
		9,814	BF gas thermoelectric
		0	BF gas reheating
BOF gas		430	coal gasses in thermoelectric + reheating
			carbon stored in products
tot	**212,910**	**190,509**	**Input – output= 22,401 TJ → 11.76%**

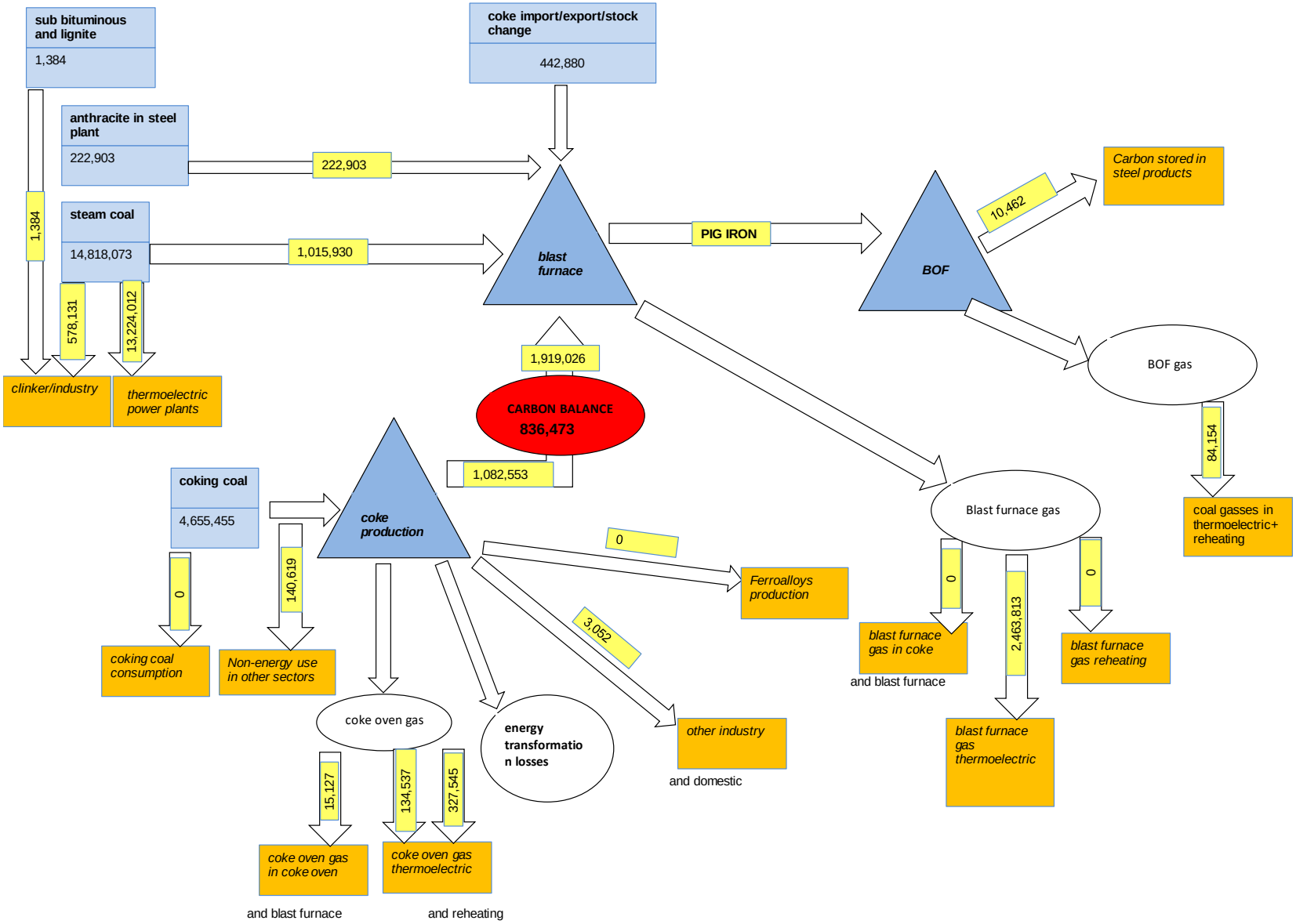
In Table A3.2, the same energy data of Table A3.1 valuated for their carbon content are reported, according to the emission factors reported in Table 3.12 of the NIR.
The balance is the resulting quantity of emissions after subtraction of carbon emissions estimated for coke ovens, electricity production, other coal uses and non-energy uses.
The low implied emission factors in CRF and annual variations in the average CO_2 emission factor for solid fuel are due to the fact that both activity data and emissions reported under this category include the results of the carbon balance.
All main installations of the iron and steel sector are included in EU ETS, but not all sources of emission. Only part of the processes of integrated steel making is subject to EU ETS, in particular the manufacturing process after the production of row steel was excluded up to 2007 and only the lamination processes have been included from 2008 onwards. Additional information from the operators on fuel consumptions and average emission factors is used to verify our calculation and CO_2 emissions at plant level and to calculate average CO_2 emission factors for coal and derived gases from 2005; obviously from the 2015 submission emission factors have been updated on the basis of 2006 IPCC Guidelines, see Annex 6 for further details.

Table A3.2 Carbon balance, 2020, Gg CO_2

	input	output	
steam coal	14,818,073	578,131	clinker/industry
		13,224,012	thermoelectric power plants
		1,015,930	blast furnace
anthracite	222,903	222,903	steel plants
sub bituminous and lignite	1,384	1,384	clinker/industry
coking coal	4,655,455	0	coking coal consumption
		140,619	Non-energy use in other sectors
coke import/export/stock change	442,880		
coke		3,052	other industry and domestic
		0	ferroalloys
		1,082,553	blast furnace consumption
coke oven gas		15,127	coke oven gas in coke oven and blast furnace
		134,537	coke oven gas reheating
		327,545	coke oven gas thermoelectric
blast furnace gas		0	BF gas in coke oven
		2,463,813	BF gas thermoelectric
		0	BF gas reheating
BOF gas		84,154	coal gasses in thermoelectric + reheating
		10,462	carbon stored in products
tot	**20,140,695**	**19,304,222**	**Input-output=836,473 Gg CO_2 unbalance 4.33%**

In 2020 the unbalance in terms of CO_2 is equal to 836,473 Gg; this amount has been subtracted from the total to avoid double counting of carbon. The flowchart of carbon - cycle for the year 2020 is reported below. CO_2 emissions from primary input fuels and from final fuel consumptions are compared. Emissions related to fuel input data are enhanced in light-blue whereas emissions estimated from final fuel consumptions are highlighted in orange. Emissions from the use of coke in blast furnaces result from differences between emissions from final consumption of coke and the value of the carbon balance for 2020. The amount of carbon stored in steel produced was estimated and subtracted from the balance to avoid the subsequent overestimation of CO_2 .The amount of coke used for ferroalloys production has also been subtracted to avoid a double counting of emissions already estimated and reported in the industrial processes sector.

CO_2 emission calculation (Gg) Year 2020



ANNEX 4: CO_2 REFERENCE APPROACH

A4.1 Introduction

The IPCC Reference Approach is a 'top down' inventory based on data on production, imports, exports and stock changes of crude oils, feedstock, natural gas and solid fuels. Estimates are made of the carbon stored in manufactured products, the carbon consumed as international bunker fuels and the emissions from biomass combustion.

The methodology follows the IPCC Guidelines (IPCC, 2006); table 1.A(b) of the Common Reporting Format "Sectoral background data for energy - CO_2 from Fuel Combustion Activities - Reference Approach" is a self-sustaining explanation of the methodology.

However, it was necessary to make a few adaptations to allow full use of the Italian energy and emission factor data (ENEA, 2002 [a]), and these are described in the following. The BEN (MSE, several years [a]) reports the energy balances for all primary and secondary fuels, with data on imports, exports and production. See Annex 5, for an example of the year 2020 and the web site of the Ministry of Economic Development for the whole time series https://dgsaie.mise.gov.it/ben.php . For the reference approach, as for the inventory, data submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT have been used for solid fuels, natural gas, liquid fuels and the update is ongoig forother fuels. Starting with the 2021 submission IEA/OECD/EUROSTAT data have been utilized since 1990.

Starting from those data and using the emission factors reported in chapter 3, Table 3.12, it is possible to estimate the total carbon entering in the national energy system. It has been developed a direct connection between relevant cells of the CRF tables and the BEN tables and a procedure to insert some additional activity data needed.

The 'missing' data refer to import – export of petrol additives, asphalt, other chemical products with energy content, energy use of exhausted lubricants and the evaluation of marine and aviation bunkers fuels used for national traffic.

Those 'missing' data are in fact reported in the BEN, but all mixed up together with other substances as sulphur and petrochemicals. The aggregate data do not allow the use of the proper emission factor so inventory is based on more detailed statistics from foreign trade surveys.

The carbon stored in products is estimated according to the procedure illustrated in paragraph 3.8 and directly subtracted to the emission balance. In the cases, as Italy, where those products are not considered in the energy balances this bring to an unbalanced control sheet, as discussed in the following.

With reference to table 1.A(b) of the CRF, we make reference to the BEN tables reported in Annex 5. In particular the following data are reported and used for the *Reference Approach*:

1. import-export data of motor oil derive from foreign trade statistics, estimated by an ENEA consultant for the period 1990-1998. BPT data (MSE, several years [b]) are used from 1999 onwards;
2. all other liquid fuels as available in the Joint Questionnaire IEA/OECD/EUROSTAT;
3. all coal data as available in the Joint Questionnaire IEA/OECD/EUROSTAT;
4. natural gas data as available in the Joint Questionnaire IEA/OECD/EUROSTAT;
5. waste production data;
6. biomass fuel data.

The following additional information is needed to complete table 1.A(b) of CRF and it is found in other sources:

1) Orimulsion, this fuel is mixed up with imported fuel oil (on the base of the energy content), the quantities used for electricity generation are reported by ENEL (ENEL, several years), the former electricity monopoly, presently the only user of this fuel, in their environmental report. This fuel is not used any more since 2004.
2) Motor oils and bitumen.
    a) Data on those materials are mixed up in the no energy use by BEN, while detailed data are available in BPT (MSE, several years [b]). The quantities of those materials are quite relevant for the no energy use of oil.
    b) In the BEN those materials are estimated in bulk with other products to have an energy content of about 5100 kcal/kg. Average OECD data are equal to 9000 kcal/kg for bitumen and 9800 kcal/kg for motor oils. In the CRF those products are estimated with the OECD energy content and this could explain part of the unbalance between imported oil and used products.

For further information see the paper by ENEA (ENEA, 2002 [b]) in Italian.

A4.2 Comparison of the sectoral approach with the reference approach

The detailed inventory contains sources not accounted for in the IPCC Reference Approach, as offshore flaring and well testing and non-fuel industrial processes, and so gives a higher estimate of CO_2 emissions.
First of all, the IPCC Reference total CO_2 can be compared with the CRF Table 1A total. Results show the IPCC Reference totals are between -0.76 and -4.1 percent with respect to the comparable 'bottom up' totals.
Differences are observed both for energy and emissions and especially for liquid fuels. Quality control activities have been done and a detail explanation of them will require specific meetings and additional verification activities with the energy experts responsible for the official communication of the energy statistics in order to make the transition to the new data format for the whole time series.
As above mentioned, sectoral approach considers sources not considered in the Reference approach, so negative differences occur between CO_2 emissions from reference approach and the sectoral one. The highest difference is observed for 1999.
Differences between emissions estimated by the reference and sectoral approach are reported in Table A4.1.

Table A4.1 Reference and sectoral approach CO_2 emission estimates 1990-2020 (Mt) and percentage differences

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Sectoral approach	405.1	417.5	440.6	470.2	411.5	343.1	340.6	334.9	331.0	321.0	285.9
Reference approach	396.5	408.3	423.3	458.6	402.0	329.7	331.8	328.1	318.7	313.1	283.7
Δ %	-2.15	-2.22	-3.92	-2.47	-2.31	-3.91	-2.57	-2.04	-3.71	-2.47	-0.76

There are a number of reasons why the totals differ, and these arise from differences in the methodologies and the statistics used.
Explanations for the discrepancies:

1. The IPCC Reference Approach is based on statistics of production, imports, exports and stock changes of fuels whilst the 'bottom-up' approach uses fuel consumption data. The two sets of statistics can be related using mass balances (MSE, several years [a]), but these show that some fuel is unaccounted for. This fuel is reported under 'statistical differences' which consist of measurement errors and losses. A significant proportion of the discrepancy between the IPCC Reference approach and the 'bottom up' approach arises from these statistical differences particularly with liquid fuels.
2. In the power sector, in the detailed approach, statistics from producers are used, whereas for the reference approach the BEN data are used. The two data sets are not connected; in the BEN sections used, only the row data of imports-exports are contained. But if one considers the process of "balancing" the import – production data with the consumption ones and the differences between the two data sets, a sizable part of the discrepancy may be connected to this reason only. In addition, waste consumption data reported in the BEN were not such accurate from 1990 up to 2002 as the subsequent years.
3. The 'bottom up' approach only includes emissions from the no energy use of fuel where they can be specifically identified and estimated such as with fertilizer production and iron and steel production. The IPCC Reference approach implicitly treats the non-energy use of fuel as if it were combustion. A correction is then applied by deducting an estimate of carbon stored from non-energy fuel use. The carbon stored is estimated from an approximate procedure which does not identify specific processes. The result is that the IPCC Reference approach is based on a higher estimate of non-energy use emissions than the 'bottom-up' approach.

The IPCC Reference Approach uses data on primary fuels such as crude oil and natural gas liquids which are then corrected for imports, exports and stock changes of secondary fuels. Thus the estimates obtained will be highly dependent on the default carbon contents used for the primary fuels.
The 'bottom-up' approach is based wholly on the consumption of secondary fuels where the carbon contents are known with greater certainty. In particular the carbon contents of the primary liquid fuels are likely to vary more than those of secondary fuels. Carbon content of solid fuels and of natural gas is quite precisely accounted for.
In the 2013 submission, in response to the review process, waste data for energy recovery have been included in the reference approach resulting in a decrease of the differences especially for the last years.

A4.3 Comparison of the sectoral approach with the reference approach and international statistics

A verification of national energy balance and CO_2 emissions with data communicated to the joint EUROSTAT/IEA/UNECE questionnaire was carried out in 2004 and results are reported in the document "Energy data harmonization for CO_2 emission calculations: the Italian case" (ENEA/MAP/APAT, 2004).

The analysis enhanced the main differences and the critical points to harmonize the data and their reporting. The most critical issues concerned the calorific value, EUROSTAT and MAP should apply the same calorific value; the distribution of fuel consumptions to the relevant sectors, e.g., in some cases EUROSTAT assigned "building materials industry" consumptions in "glass, pottery and building materials industry" consumptions, in other cases in "other industries"; the definition of coke, in particular, the distribution of consumptions between the iron and steel sector final consumption and transformation input; the definition of derived gases have to be harmonized, because differences in allocation of steelworks gases and gas from chemical processes were found.

In addition, "exchange and transfers, returns" and "statistical difference" rows were used in the national statistics to balance the energy resources with the energy uses whereas in the international statistics the two items, in some cases, were cancelled.

From 2004 some improvements were implemented both in the national and international statistics also through the revision of the questionnaire but difference in apparent consumptions still occur.

At European level, further examination is in progress. In the framework of the Monitoring Mechanism Decision jointly with EUROSTAT, a project which compares Eurostat energy data with energy data included in the CRF has been developed. The background of the project is the Energy Statistics Regulation (EC/1099/2008), which is the legal basis of the reporting of energy data to Eurostat, in particular Article 6, paragraph 2, of the regulation stipulating that: "Every reasonable effort shall be undertaken to ensure coherence between energy data declared in the energy statistics regulation, and data declared in accordance with Commission Decision No 280/2004/EC of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol". Member States' reference approach data as submitted in CRF Table 1A(b) under the EU GHG Monitoring Mechanism (as available by 15 May 2011) were compared with Eurostat energy data as available in the Eurostat database in April 2011. The comparison was carried out for the years 2009 and 2008. Specifically, for Italy, major discrepancies identified were only related to the consumption of refinery feedstocks which differs considerably between annual Eurostat data and the CRF: annual Eurostat consumption is 30% and 40% lower than the CRF for 2008 and 2009 respectively. The same issue was identified during the review process and corrected in the following submission. In terms of CO_2 emissions, for Italy the comparison results in a difference in total equal to 2% in 2009, with higher differences for solid and other fuels.

ANNEX 5: NATIONAL ENERGY BALANCE, YEAR 2020

The official national energy balance (BEN) from the year 1998 onwards is available, in Italian, on the website of the Italian Ministry of the Economic Development (MSE): http://dgsaie.mise.gov.it/dgerm/ben.asp/. At the same web address data communicated by Italy to the Joint Questionnaire OECD/IEA/EUROSTAT are available in the format revisited by EUROSTAT. Some differences between data communicated to the international organizations and EUROSTAT publication have been observed and are under investigation; they should mainly due to the use of default instead of country specific energy conversion factors and different classification criteria of fuels.

From 2016, data submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT have been used for solid, liquid and gaseous fuel consumptions. At the time it was not possible to reconstruct the entire time series and data from national energy balance (BEN) have been also used; moreover the complete use of the energy data provided by the MSE to the Joint Questionnaire is planned in substitution, as possible, of the national energy balances. Some inconsistencies have been found in data communicated at Eurostat and referring to the ninety years, especially in the sectoral distribution of fuels; in these cases the information already available in the national energy balances has been maintained because of considered more reliable and consistent in the time series.

The national energy balance consists of two "sets" of tables fuel consumptions expressed in physical quantities (Gg or Mm^3) and in energy equivalents (10^9 kcal). Energy data submitted to the international organisations are provided in different units according to the relevant formats. For example, natural gas data are provided in TJ calculated with the gross calorific values while liquid fuels are provided in thousand metric tons. In the annex, tables reproduce only figures expressed in amount of energy equivalents for the year 2020 (EUROSTAT, 2022).

In general, the reporting methodology of the national energy balance applies the same lower heat value to each primary fuel in various years, to take into account for the variable energy content of each shipment. This means, for example, that the primary fuel quantities of two shipments of imported coal are "adjusted" using their energy content as the main reference (see Table A5.1) and the value reported in physical unit is an "adjusted" quantity of Gg or Mm^3. This process is routinely applied to most primary sources, including imported and nationally produced natural gas. For the final uses of energy, the same methodology is applied but it runs the other way: the physical quantities of energy vectors are the only values actually measured on the market and the energy content is actually estimated using fixed average estimates of lower heat value. Measurements of the actual energy content of fuels show minor variations from one year to another, especially for liquid fuels.

In the case of natural gas, the use of a fixed heat value to summarize all transactions was particularly complicated because Italy used fuel from four main different sources: Russia, Netherlands, Algeria and national production. Since 2003-2004 Norway and Libya have also been added to the supply list. The big customers were actually billed according to the measured heat value of the natural gas delivered. After the end of the state monopoly on this market, the system changed. Since 2004, the price refers to the energy content of natural gas and the metered physical quantities of gas delivered to all final customers have been billed according to an energy content variable from site to site and from year to year. The BEN still tries to summarize all production and consumption using only one conventional heat value.

Therefore, the physical quantities are the most reliable data for the estimations of liquid fuels used in the civil and transportation sector. This information is used to calculate emissions, using updated data for the emission factors which are estimated from samples of marketed fuels.

Table A5.1 – National Energy Balance, year 2020, ktoe

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Primary production	37,672.6	0.0	5,856.0	3,287.2	27,339.3	1,190.1	346.9	843.2	0.0	0.0	Z
Recovered and recycled products	0.0	0.0	0.0	Z	0.0	Z	Z	Z	Z	Z	Z
Imports	131,128.0	4,949.0	65,725.4	54,375.9	2,656.4	0.0	0.0	0.0	Z	0.0	3,421.3
Exports	25,329.4	209.7	23,717.0	258.4	491.6	0.0	0.0	0.0	Z	0.0	652.6
Change in stock	563.6	355.2	-513.4	881.1	-159.4	0.0	0.0	0.0	Z	Z	Z
Gross available energy	144,034.9	5,094.5	47,351.0	58,285.8	29,344.7	1,190.1	346.9	843.2	0.0	0.0	2,768.7
International maritime bunkers	2,439.5	0.0	2,439.5	0.0	0.0	Z	Z	Z	Z	Z	Z
Gross inland consumption	141,595.4	5,094.5	44,911.5	58,285.8	29,344.7	1,190.1	346.9	843.2	0.0	0.0	2,768.7
International aviation	1,494.9	Z	1,494.9	Z	0.0	Z	Z	Z	Z	Z	Z
Total energy supply	140,100.5	5,094.5	43,416.6	58,285.8	29,344.7	1,190.1	346.9	843.2	0.0	0.0	2,768.7
Gross inland consumption (Europe 2020-2030)	139,120.1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
Primary energy consumption (Europe 2020-2030)	132,316.3	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
Final energy consumption (Europe 2020-2030)	102,738.1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation input - energy use	121,212.6	5,502.5	69,982.4	24,224.9	19,956.5	877.6	34.4	843.2	0.0	0.0	229.4
Transformation input - electricity and heat generation - energy use	51,228.9	3,359.6	3,503.1	24,224.9	18,595.0	877.6	34.4	843.2	0.0	0.0	229.4
Transformation input - electricity and heat generation - main activity producer electricity only - energy use	28,163.5	3,332.3	299.9	9,000.4	15,159.2	371.7	6.7	365.0	0.0	0.0	Z
Transformation input - electricity and heat generation - main activity producer combined heat and power - energy use	17,156.9	27.3	2,562.5	10,952.7	3,108.8	476.8	14.1	462.7	0.0	0.0	Z
Transformation input - electricity and heat generation - main activity producer heat only - energy use	437.9	0.0	3.9	270.9	163.1	0.0	0.0	0.0	0.0	0.0	Z

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Transformation input - electricity and heat generation - autoproducer electricity only - energy use	121.6	0.0	1.4	33.6	79.0	7.6	5.3	2.3	0.0	0.0	Z
Transformation input - electricity and heat generation - autoproducer combined heat and power - energy use	5,119.6	0.0	635.4	3,967.3	84.9	21.5	8.2	13.2	0.0	0.0	Z
Transformation input - electricity and heat generation - autoproducer heat only - energy use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z
Transformation input - electricity and heat generation - electrically driven heat pumps	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z	0.0
Transformation input - electricity and heat generation - electric boilers	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z	0.0
Transformation input - electricity and heat generation - electricity for pumped storage	229.4	Z	Z	Z	Z	Z	Z	Z	Z	Z	229.4
Transformation input - electricity and heat generation - derived heat for electricity production	0.0	Z	Z	Z	Z	Z	Z	Z	Z	0.0	Z
Transformation input - coke ovens - energy use	1,186.6	1,186.6	0.0	0.0	0.0	Z	Z	Z	Z	Z	Z
Transformation input - blast furnaces - energy use	956.4	956.4	0.0	0.0	0.0	Z	Z	Z	Z	Z	Z
Transformation input - gas works - energy use	0.0	0.0	0.0	0.0	0.0	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - energy use	66,479.4	Z	66,479.4	Z	Z	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - refinery intake - energy use	60,913.0	Z	60,913.0	Z	Z	Z	Z	Z	Z	Z	Z

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Transformation input - refineries and petrochemical industry - backflows from petrochemical industry - energy use	1,837.5	Z	1,837.5	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - products transferred - energy use	1,879.4	Z	1,879.4	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - interproduct transfers - energy use	0.0	Z	0.0	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - direct use - energy use	0.0	Z	0.0	Z	Z	Z	Z	Z	Z	Z	Z
Transformation input - refineries and petrochemical industry - petrochemical industry intake - energy use	1,849.4	Z	1,849.4	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation input - patent fuel plants - energy use	0.0	0.0	0.0	Z	0.0	0.0	0.0	Z	Z	Z	Z
Transformation input - brown coal briquettes and peat briquettes plants - energy use	0.0	0.0	Z	Z	0.0	0.0	0.0	0.0	Z	Z	Z
Transformation input - coal liquefaction plants - energy use	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation input - for blended natural gas - energy use	82.1	Z	0.0	Z	82.1	Z	Z	Z	Z	Z	Z
Transformation input - liquid biofuels blended - energy use	1,264.7	Z	Z	Z	1,264.7	Z	Z	Z	Z	Z	Z
Transformation input - charcoal production plants - energy use	14.7	Z	Z	Z	14.7	Z	Z	Z	Z	Z	Z
Transformation input - gas-to-liquids plants - energy use	0.0	Z	Z	0.0	Z	Z	Z	Z	Z	Z	Z

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Transformation input - not elsewhere specified - energy use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	Z	Z
Transformation output	99,346.6	885.7	66,975.7	82.1	1,272.1	Z	Z	Z	Z	5,467.4	24,121.3
Transformation output - electricity and heat generation	29,588.7	Z	Z	Z	Z	Z	Z	Z	Z	5,467.4	24,121.3
Transformation output - electricity and heat generation - main activity producer electricity only	15,206.6	Z	Z	Z	Z	Z	Z	Z	Z	Z	15,206.6
Transformation output - electricity and heat generation - main activity producer combined heat and power	10,401.3	Z	Z	Z	Z	Z	Z	Z	Z	3,427.5	6,973.8
Transformation output - electricity and heat generation - main activity producer heat only	368.6	Z	Z	Z	Z	Z	Z	Z	Z	368.6	Z
Transformation output - electricity and heat generation - autoproducer electricity only	67.1	Z	Z	Z	Z	Z	Z	Z	Z	Z	67.1
Transformation output - electricity and heat generation - autoproducer combined heat and power	3,334.9	Z	Z	Z	Z	Z	Z	Z	Z	1,671.4	1,663.5
Transformation output - electricity and heat generation - autoproducer heat only	0.0	Z	Z	Z	Z	Z	Z	Z	Z	0.0	Z
Transformation output - electricity and heat generation - electrically driven heat pumps	0.0	Z	Z	Z	Z	Z	Z	Z	Z	0.0	Z
Transformation output - electricity and heat generation - electric boilers	0.0	Z	Z	Z	Z	Z	Z	Z	Z	0.0	Z
Transformation output - electricity and heat generation - pumped hydro	167.1	Z	Z	Z	Z	Z	Z	Z	Z	Z	167.1

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Transformation output - electricity and heat generation - other sources	43.1	Z	Z	Z	Z	Z	Z	Z	Z	0.0	43.1
Transformation output - coke ovens	1,133.0	885.7	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - blast furnaces	295.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - gas works	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry	66,975.7	Z	66,975.7	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - refinery output	61,471.4	Z	61,471.4	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - backflows	1,784.4	Z	1,784.4	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - products transferred	1,882.4	Z	1,882.4	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - interproduct transfers	0.0	Z	0.0	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - primary product receipts	0.0	Z	0.0	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - refineries and petrochemical industry - petrochemical industry returns	1,837.5	Z	1,837.5	Z	0.0	Z	Z	Z	Z	Z	Z
Transformation output - patent fuel plants	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - brown coal briquettes and peat briquettes plants	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - coal liquefaction plants	0.0	Z	0.0	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - blended in natural gas	82.1	Z	Z	82.1	Z	Z	Z	Z	Z	Z	Z

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Transformation output - liquid biofuels blended	1,264.7	Z	Z	Z	1,264.7	Z	Z	Z	Z	Z	Z
Transformation output - charcoal production plants	7.4	Z	Z	Z	7.4	Z	Z	Z	Z	Z	Z
Transformation output - gas-to-liquids plants	0.0	Z	0.0	Z	Z	Z	Z	Z	Z	Z	Z
Transformation output - not elsewhere specified	0.0	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	Z
Energy sector - energy use	7,175.6	35.5	2,644.7	1,458.2	0.0	0.0	0.0	0.0	Z	1,524.9	1,504.5
Energy sector - electricity and heat generation - energy use	774.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	11.1	763.8
Energy sector - coal mines - energy use	19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	0.0	19.0
Energy sector - oil and natural gas extraction plants - energy use	273.3	Z	0.0	261.9	0.0	Z	Z	Z	Z	0.5	10.9
Energy sector - patent fuel plants - energy use	0.0	0.0	Z	Z	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - coke ovens - energy use	54.2	35.5	0.0	0.0	0.0	0.0	0.0	0.0	Z	7.6	3.2
Energy sector - brown coal briquettes and peat briquettes plants - energy use	0.0	0.0	Z	Z	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - gas works - energy use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - blast furnaces - energy use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - petroleum refineries (oil refineries) - energy use	5,152.0	0.0	2,644.7	1,095.3	0.0	0.0	0.0	0.0	Z	950.9	461.1
Energy sector - nuclear industry - energy use	0.1	Z	Z	Z	Z	Z	Z	Z	Z	0.0	0.1
Energy sector - coal liquefaction plants - energy use	0.0	0.0	Z	Z	Z	Z	Z	Z	Z	0.0	0.0
Energy sector - liquefaction and regasification plants (LNG) - energy use	101.0	Z	Z	101.0	Z	Z	Z	Z	Z	0.0	0.0

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Energy sector - gasification plants for biogas - energy use	0.0	Z	Z	Z	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - gas-to-liquids plants - energy use	0.0	Z	Z	0.0	Z	Z	Z	Z	Z	0.0	0.0
Energy sector - charcoal production plants - energy use	0.0	Z	Z	Z	0.0	0.0	0.0	0.0	Z	0.0	0.0
Energy sector - not elsewhere specified - energy use	801.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	554.7	246.4
Distribution losses	1,781.1	0.0	0.0	224.3	0.0	0.0	0.0	0.0	Z	63.6	1,493.2
Available for final consumption	109,277.8	442.2	37,765.2	32,460.5	10,660.3	312.5	312.5	0.0	0.0	3,879.0	23,663.0
Final consumption - non-energy use	6,803.8	33.1	6,117.4	653.3	0.0	Z	Z	Z	Z	Z	Z
Transformation input, energy sector and final consumption in industry sector - non-energy use	6,582.5	0.0	5,929.2	653.3	0.0	Z	Z	Z	Z	Z	Z
Transformation input - non-energy use	0.0	Z	0.0	Z	0.0	Z	Z	Z	Z	Z	Z
Energy sector - non-energy use	0.0	Z	0.0	Z	0.0	Z	Z	Z	Z	Z	Z
Final consumption - industry sector - non-energy use	6,582.5	Z	5,929.2	653.3	0.0	Z	Z	Z	Z	Z	Z
Final consumption - transport sector - non-energy use	188.2	0.0	188.2	0.0	0.0	Z	Z	Z	Z	Z	Z
Final consumption - other sectors - non-energy use	33.1	33.1	0.0	0.0	0.0	Z	Z	Z	Z	Z	Z
Final consumption - energy use	103,057.1	409.4	32,230.6	31,807.2	10,660.3	312.5	312.5	0.0	Z	3,879.0	23,663.0
Final consumption - industry sector - energy use	23,861.1	409.4	1,753.9	8,081.3	435.1	312.5	312.5	0.0	Z	2,687.3	10,086.4
Final consumption - industry sector - iron and steel - energy use	3,166.6	240.6	80.1	1,188.2	0.0	0.0	0.0	0.0	Z	135.8	1,426.7
Final consumption - industry sector - chemical and petrochemical - energy use	3,410.5	0.0	246.9	908.7	6.8	80.0	80.0	0.0	Z	978.7	1,189.4

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Final consumption - industry sector - non-ferrous metals - energy use	662.6	14.0	48.8	387.9	0.0	0.0	0.0	0.0	Z	1.0	210.9
Final consumption - industry sector - non-metallic minerals - energy use	4,219.5	147.2	955.1	1,864.2	188.9	173.2	173.2	0.0	Z	149.9	741.0
Final consumption - industry sector - transport equipment - energy use	433.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	100.3	333.7
Final consumption - industry sector - machinery - energy use	3,278.3	0.0	196.7	1,231.5	3.0	2.7	2.7	0.0	Z	82.2	1,762.1
Final consumption - industry sector - mining and quarrying - energy use	95.7	0.0	13.4	32.7	0.0	0.0	0.0	0.0	Z	1.7	47.9
Final consumption - industry sector - food, beverages and tobacco - energy use	2,764.3	0.0	93.0	1,053.0	33.4	0.0	0.0	0.0	Z	353.2	1,231.8
Final consumption - industry sector - paper, pulp and printing - energy use	2,040.5	0.0	62.3	603.7	0.4	0.0	0.0	0.0	Z	622.8	751.2
Final consumption - industry sector - wood and wood products - energy use	481.6	0.0	0.0	27.4	140.4	3.8	3.8	0.0	Z	28.9	281.2
Final consumption - industry sector - construction - energy use	376.1	0.0	6.0	205.8	1.7	0.0	0.0	0.0	Z	5.1	157.5
Final consumption - industry sector - textile and leather - energy use	996.9	7.6	35.0	556.3	0.2	0.0	0.0	0.0	Z	12.3	385.6
Final consumption - industry sector - not elsewhere specified - energy use	1,934.5	0.0	16.6	22.0	60.4	52.7	52.7	0.0	Z	215.4	1,567.4
Final consumption - transport sector - energy use	28,976.5	0.0	25,874.9	967.2	1,264.7	0.0	0.0	0.0	Z	Z	869.7
Final consumption - transport sector - rail - energy use	443.4	0.0	44.1	Z	0.0	0.0	0.0	0.0	Z	Z	399.2
Final consumption - transport sector - road - energy use	26,982.9	Z	24,929.4	772.4	1,264.7	0.0	0.0	0.0	Z	Z	16.4

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Final consumption - transport sector - domestic aviation - energy use	344.2	Z	344.2	Z	0.0	Z	Z	Z	Z	Z	Z
Final consumption - transport sector - domestic navigation - energy use	557.2	0.0	557.2	Z	0.0	0.0	0.0	0.0	Z	Z	Z
Final consumption - transport sector - pipeline transport - energy use	216.6	Z	0.0	192.2	0.0	Z	Z	Z	Z	Z	24.4
Final consumption - transport sector - not elsewhere specified - energy use	432.3	0.0	0.0	2.6	0.0	0.0	0.0	0.0	Z	Z	429.6
Final consumption - other sectors - energy use	50,219.6	0.0	4,601.9	22,758.7	8,960.4	0.0	0.0	0.0	Z	1,191.7	12,706.9
Final consumption - other sectors - commercial and public services - energy use	16,557.6	0.0	513.8	6,690.2	2,589.6	0.0	0.0	0.0	Z	292.9	6,471.1
Final consumption - other sectors - households - energy use	30,656.0	0.0	1,871.3	15,932.6	6,289.3	0.0	0.0	0.0	Z	869.6	5,693.2
Final consumption - other sectors - agriculture and forestry - energy use	2,758.9	0.0	2,027.4	135.9	52.6	0.0	0.0	0.0	Z	14.4	528.6
Final consumption - other sectors - fishing - energy use	202.3	0.0	159.3	0.0	28.9	0.0	0.0	0.0	Z	0.0	14.0
Final consumption - other sectors - not elsewhere specified - energy use	44.9	0.0	30.1	0.0	0.0	0.0	0.0	0.0	Z	14.7	0.0
Statistical differences	**-583.1**	**-0.3**	**-582.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Gross electricity production	24,078.2	1,150.4	863.6	11,494.7	10,220.0	206.6	6.2	200.3	0.0	Z	Z
Gross electricity production - main activity producer electricity only	15,373.7	1,144.0	99.0	4,792.5	9,245.6	92.6	1.8	90.8	0.0	Z	Z
Gross electricity production - main activity producer combined heat and power	6,973.8	6.4	678.5	5,269.7	899.0	109.0	2.1	107.0	0.0	Z	Z
Gross electricity production - autoproducer electricity only	67.1	0.0	0.4	13.3	51.3	2.1	1.4	0.8	0.0	Z	Z

SIEC	Total	Solid fossil fuels	Oil and petroleum products (excluding biofuel portion)	Natural gas	Renewables and biofuels	Non-renewable waste	Industrial waste (non-renewable)	Non-renewable municipal waste	Nuclear heat	Heat	Electricity
NRG_BAL/TIME	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
Gross electricity production - autoproducer combined heat and power	1,663.5	0.0	85.6	1,419.2	24.0	2.8	1.1	1.8	0.0	Z	Z
Gross heat production	5,467.4	22.5	753.0	3,495.2	986.2	139.9	11.7	128.2	0.0	Z	0.0
Gross heat production - main activity producer combined heat and power	3,427.5	22.5	561.1	1,872.4	835.8	128.2	7.0	121.2	0.0	Z	0.0
Gross heat production - main activity producer heat only	368.6	0.0	3.3	247.5	117.8	0.0	0.0	0.0	0.0	Z	0.0
Gross heat production - autoproducer combined heat and power	1,671.4	0.0	188.6	1,375.4	32.6	11.7	4.7	7.1	0.0	Z	0.0
Gross heat production - autoproducer heat only	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Z	0.0

ANNEX 6: NATIONAL EMISSION FACTORS

Monitoring of the carbon content of the fuels used nationally is an ongoing activity at ISPRA. The purpose is to analyse regularly the chemical composition of the used fuel or relevant commercial statistics to estimate the carbon content / emission factor (EF) of the fuels. For each primary fuel (natural gas, oil, coal) a specific procedure has been established.
Starting from 2021 submission the updated atomic weights of Carbon and Oxygen (NIST Chemistry WebBook, SRD 69 - National Institute of Standard and Technology, USA) have been used since 2005 (National Institute of Standard and Technology, USA) to convert carbo content to CO_2 content and viceversa.

A6.1 Natural gas

The national market is characterized by the commercialisation of gases with different chemical composition in variable quantities from one year to the other. Since 1990 natural gas has been produced in Italy and imported by pipelines from Russia, Algeria and the Netherlands. Moreover, an NGL facility is importing gas from Algeria and Libya. From 2003-2004 onwards Norway and Libya have also been added to the supply list, through new pipeline connections, and from 2008 a new NGL facility has entered into service, using mainly liquefied gas from Oman. There are also sizeable underground storage facilities and additional pipelines/NGL facilities are planned.
The estimation of an average EF for natural gas is the only way to calculate total emissions from this source in Italy, because the origin of the gas used by final consumers can not be tracked trough the national statistics and it is subject to variations during the year, according to supply. Only the main industrial installations perform routine checks to estimate the average chemical composition / energy content of natural gas used.
Another task connected to the use of natural gases of different origin and composition is linked to the estimation of an average content of methane to estimate fugitive emissions of this gas from the transmission / distribution network. Since the beginning of the inventory estimations, the average EF of the used gas in Italy has been estimated by the inventory team and it changes every year.
From 2008 in the energy balance, BEN 2008, (MSE, several years [a]) some modifications have occurred; a new average lower heat value has been derived from Eurostat methodology. This new conversion factor did imply a methodological revision to estimate the average national EF. Additionally, the IPCC 2006 guidelines, see table A6.1, contain important information to consider: the recognition of a certain variability of the EF for this source; the estimation of a lower and upper bound for the EFs; the link between energy content and EF; the statement that, by converting to energy units all EFs, their variability can be reduced. Moreover default oxidation factor is estimated to be equal to 1 (full oxidation) (IPCC, 2006).
Each of natural gases transmitted by the grid operator is regularly analysed at import gates, for budgetary reasons. Energy content for cubic meters, percentage of methane and other substances are calculated. For example, methane content can considerably vary: national produced gas sold to the grid is almost 99% methane (% moles), the one coming from Algeria has less than 85% of methane and significant quantities of propane-butane. Also carbon content varies significantly.
Natural gas properties are more stable referring to the country of origin, with small variations in chemical composition from year to year. Speciation of gas from each import manifold is regularly published by national transmission grid operator (Snam Rete Gas, several years). Other information is also available from the main final users (TERNA, several years).
So, for each year, the average methane and carbon content of the natural gas used in Italy are estimated, using international trade statistical data, and a national emission factor is estimated.
The list of factors for the years of interest is reported in Table A6.1.
As shown in the table, the ranges of national EFs are within the lower and upper threshold of the IPCC 2006 guidelines.
With regard the oxidation factors, increasing values have been used from 0.995 in the 1990 to 1.000 in 2005 according to the improvement of combustion efficiency in the nineties.

Table A6.1 Natural gas carbon emission factors

	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / 10^3 std cubic mt	t CO_2 / toe
Natural gas (dry) IPCC '96	55.820	55.820	1.928	2.337
Natural gas, IPCC '06 average	56.100	56.100	1.932	2.349
lower	54.300			
upper	58.300			
National Emission Factors				
Natural gas , 1990	56.103	55.822	1.935	2.337
Natural gas, 1995	56.236	55.955	1.947	2.343
Natural gas , 2000	56.415	56.258	1.955	2.355
Natural gas , 2001	56.337	56.212	1.946	2.353
Natural gas , 2002	56.914	56.819	1.985	2.379
Natural gas, 2003	56.483	56.420	1.974	2.362
Natural gas, 2004	56.450	56.418	1.973	2.362
Natural gas, 2005	56.475	56.475	1.978	2.365
Natural gas, 2006	56.553	56.553	1.979	2.368
Natural gas, 2007	56.444	56.444	1.976	2.363
Natural gas, 2008, with 8190 lhv	57.732	57.732	1.980	2.417
Natural gas, 2009, with 8190 lhv	57.914	57.914	1.986	2.425
Natural gas, 2010, with 8190 lhv	57.945	57.945	1.987	2.426
Natural gas, 2011, with 8190 lhv	57.427	57.427	1.969	2.404
Natural gas, 2012, with 8190 lhv	57.702	57.702	1.979	2.416
Natural gas, 2013, with 8190 lhv	57.447	57.447	1.970	2.405
Natural gas, 2014, with 8190 lhv	57.473	57.473	1.971	2.406
Natural gas, 2015, with 8190 lhv	57.633	57.633	1.976	2.413
Natural gas, 2016, with 8190 lhv	58.140	58.140	1.994	2.434
Natural gas, 2017, with 8190 lhv	58.000	58.000	1.989	2.428
Natural gas, 2018, with 8190 lhv	57.846	57.846	1.984	2.422
Natural gas, 2019, with 8190 lhv	57.746	57.746	1.980	2.418
Natural gas, 2020, with 8190 lhv	57.918	57.918	1.986	2.425

Source: ISPRA elaborations

The methodology used to estimate the EF is based on the available data. Each year the quantities of natural gas imported or produced in Italy are published on the web by the MSE http://dgerm.sviluppoeconomico.gov.it/dgerm/bilanciogas.asp.Those data are produced by the national grid operator and are concerned on all imported gas by point of entrance in the country and all natural gas produced.
To compare quantities of different gases, the physical quantities of imported/produced gas are normalized to a higher heat value (hhv) equal to 9100 kcal/m^3 and standard conditions. Other data input used in the estimation are the average chemical composition and the hhv of the gas at each import "gate" and for the national production. Those data are published by Snam in its yearly "Bilancio di Sostenibilità" (Snam Rete Gas, several years) and with them it is possible to estimate the average carbon content of the fuel. Those data are referred to the physical quantities of imported / produced gas.
So the total quantities of imported gas (normalized at the hhv of 9100) published by MSE are transformed back to the physical quantities of actually imported gas using the hhv ratio and then average carbon content of the total gas imported or produced in Italy can be estimated. Those data are then referred back to the normalized quantities of gas used in national statistics.
Data on final consumption of gas refers to the lower heat value (lhv). In particular the electricity production companies regularly estimate the actual lhv of the gas they are using and this figure is published yearly by TERNA. Operator's data are used to verify the calculation results. Weighted average lhv of the imported and produced natural gas in 2016 is 8442 kcal/m^3.
As mentioned above, in the BEN 2008 the average lhv has been changed from 8250 kcal/m^3 (historical value) to 8190 kcal/m^3, to harmonize national data with Eurostat methodology. Eurostat considers the lhv as being 10% less than hhv, regardless of the actual value. This change influences the EF if it is referred to the energy content (lhv) of the fuel, but it has no influence if the EF is referred to cubic meters.

A6.2 Diesel oil, petrol and LPG

ISPRA set periodical investigations on the carbon content of the main transportation fuels sold in Italy, petrol, diesel and LPG, with the aim of testing the average fuels. The goal of this work is the verification of CO_2 emission factors of Italian energy system, with a particular focus on the transportation sector. The results of analysis of fuel samples performed by "Stazione Sperimentale Combustibili" (APAT, 2003; Innovhub, several years) were compared with emission factors used in Reference Approach of the Intergovernmental Panel for Climate Change (IPCC, 1997; IPCC, 2006) and emission factors considered in the COPERT 4 programme (EMISIA SA, 2012).

These two methodologies are widely used to prepare data at the international level but, when applied to the Italian data set produce results with significant differences, around 2- 4%. The reason has been traced back to the emission factors that are referred to the energy content of the fuel for IPCC and to the physical quantities for the COPERT methodology.

The results of the study link the chemical composition to the lhv for a series of fuels representative of the national production, allowing for more precise evaluations of the emission factors.

IPCC 1996 emission factors for diesel fuels and IPCC-Europe for LPG are almost identical to the experimental results (less than 1% difference), and it has been decided to use IPCC emission factors for the period 1990-1999 and the measured EF from the year 2000 onwards. The figures from the last surveys have been used for the years 2017-2020.

Concerning petrol, instead, IPCC 1996 emission factors is quite low and it has to be updated, the reason may be linked to the extensive use of additives in recent years to reach a high octane number after the lead has been phased out. For 2000 and the following years the experimental factor are used, for the period 1990-1999 it has been decided to use an interpolate factor between IPCC emission factors and the measured value, using the lhv as the link between the national products and the international database.

The list of emission factors used is reported in Table A6.2.

Table A6.2 Fuels, national production, carbon emission factors

	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Petrol, IPCC / OECD	68.559	3.071	2.870
Petrol, IPCC Europe	72.270	3.148	3.026
Petrol (Italian National Energy Balance), interpolated emission factor 1990-1999	71.034	3.123	2.974
Petrol, experimental averages 2000-2011	71.864	3.143	3.009
Petrol, experimental averages 2012-2016	73.338	3.140	3.071
Petrol, experimental averages 2017-2020	73.081	3.152	3.060
Gas oil, IPCC / OECD	73.274	3.175	3.068
Gas oil, IPCC Europe	73.260	3.108	3.067
Gas oil, 1990 – 1999	73.274	3.129	3.068
Gas oil, engines, experimental averages 2000-2011	73.892	3.171	3.094
Gas oil, engines, experimental averages 2012-2016	73.648	3.151	3.084
Gas oil, engines, experimental averages 2017-2020	73.510	3.150	3.078
Gas oil, heating, experimental averages 2000-2011	74.438	3.175	3.117
Gas oil, heating, experimental averages 2012-2016	73.578	3.155	3.081
Gas oil, heating, experimental averages 2017-2020	73.927	3.169	3.095
LPG, IPCC / OECD	62.392	2.952	2.612
LPG, IPCC / Europe	64.350	3.000	2.694
LPG, 1990 – 1999	62.392	2.873	2.612
LPG, experimental averages 2000-2016	65.592	3.026	2.746
LPG, experimental averages 2017-2020	65.984	3.026	2.763
Biodiesel, experimental averages 2017-2020	74.938	2.803	3.137

Source: ISPRA elaborations

A6.3 Fuel oil

The main information available nationally of fuel oil EF is a sizable difference in carbon content between high sulphur and light sulphur brands. The data were elaborated from literature and from an extensive series of samples (more than 400) analysed by ENEL and made available to ISPRA. Carbon content varies to a certain extent also between the medium sulphur content and the very low sulphur products, but the main discrepancies refer to the high sulphur type. According to the available statistical data, it was possible to trace back to the year 1990 the produced and imported quantities of fuel oil divided between high and low sulphur products and to estimate the average carbon emission factor for the years of interest, see Table A6.3 for details.

Table A6.3 Fuel oil, average of national and imported products, carbon emission factors

	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Fuel oil , IPCC, 1996	77.400	76.626	3.154	3.208
Fuel oil , IPCC, 2006 average	77.400	77.400	3.127	3.241
lower	75.500			
upper	78.800			
National emission factors				
Fuel oil, average 1990	77.339	76.565	3.113	3.206
Fuel oil, average 1995	77.425	76.650	3.129	3.209
Fuel oil, average 2000	76.665	76.239	3.140	3.192
Fuel oil, average 2001	76.655	76.315	3.141	3.195
Fuel oil, average 2002	76.709	76.454	3.148	3.201
Fuel oil, average 2003	76.921	76.750	3.158	3.213
Fuel oil, average 2004	76.939	76.853	3.162	3.218
Fuel oil, average 2005	75.877	75.877	3.144	3.177
Fuel oil, average 2006	75.955	75.955	3.144	3.180
Fuel oil, average 2007	76.328	76.328	3.147	3.196
Fuel oil, average 2008	76.682	76.682	3.145	3.211
Fuel oil, average 2009	76.635	76.635	3.145	3.209
Fuel oil, average 2010	76.865	76.865	3.145	3.218
Fuel oil, average 2011	77.063	77.063	3.147	3.226
Fuel oil, average 2012	76.507	76.507	3.145	3.203
Fuel oil, average 2013	76.695	76.695	3.145	3.211
Fuel oil, average 2014	76.698	76.698	3.145	3.211
Fuel oil, average 2015	76.606	76.606	3.144	3.207
Fuel oil, average 2016	76.606	76.606	3.144	3.207
Fuel oil, average 2017	76.690	76.690	3.144	3.211
Fuel oil, average 2018	76.692	76.692	3.144	3.211
Fuel oil, average 2019	76.594	76.594	3.143	3.207
Fuel oil, average 2020	76.497	76.497	3.143	3.203

Source: ISPRA elaborations

Data for all years are within IPCC 2006 ranges, but it can be noticed that are on the lower side from year 2000 onwards. The change from an average to a low EF is due to the harmful emissions limits and fuel regulations introduced in Italy between 1990 and 2000. Most of the fuel used from 2000 onwards is not heavy, high sulphur, fuel oil but light type, low sulphur. With regard the oxidation factors, increasing values have been used from 0.99 in the 1990 to 1.00 in 2005 according to the improvement of combustion efficiency in the nineties.

A6.4 Coal

Italy has only negligible national production of coal; most part is imported from various countries and there are differences in carbon content of coal mined in different parts of the world. The variations in carbon content can be linked to the hydrogen content and to the LHV of the coal.

An additional national circumstance refers to the absence of long term import contracts. The quantities shipped by the main exporters change considerably from year to year. Detailed data are available in BPT (MSE, several years [b]) supplied from the Ministry of Economic Development and reported for the submission year in Table A6.4.

Table A6.4 – Coal imported by country in 2020 (Mg)

Country	Coaking coal	Coke	Anthracite	Steam coal	Lignite	Total Coal	Tar	Petroleum coke
CZECH REPUBLIC		4,609				**4,609**		
FRANCE		4,756				**4,756**		
GERMANY		63,182			1,309	**64,491**		
GREECE						**0**		14,600
HUNGARY		278,159				**278,159**		
POLAND			1,195			**1,195**		
SLOVAKIA			48			**48**		24
SLOVENIA				214,830		**214,830**		32,208
SPAIN		34,818				**34,818**		
TOTAL EU	**0**	**385,524**	**1,243**	**214,830**	**1,309**	**602,906**	**0**	**46,832**
ABUDHABI						**0**		15,346
AUSTRALIA	414,487					**414,487**		
BOSNIA-ERZEGOVINA		33,626				**33,626**		
CANADA	109,134					**109,134**		
COLOMBIA				584,490		**584,490**		
INDONESIA				67,093		**67,093**		
KAZAKISTAN				304,277		**304,277**		
RUSSIA			78,549	3,936,746		**4,015,295**		
SOUTH AFRICA		8,002				**8,002**		
SOUTH KOREA						**0**	3,069	
U.S.A.	1,108,220			369,317		**1,477,537**		655,436
TOTAL NON_EU	**1,631,841**	**41,628**	**78,549**	**5,261,924**	**0**	**7,013,941**	**3,069**	**670,782**
TOTAL	**1,631,841**	**427,152**	**79,792**	**5,476,754**	**1,309**	**7,616,847**	**3,069**	**717,614**

Source: MSE, several years [b]

Therefore an attempt was made to find out a methodology allowing for a more precise estimation of the carbon content of this fuel. It is possible, using literature data for the coals and detailed statistical records of international trade, to find out the weighted average of carbon content and of the LHV of the fuel imported to Italy each year. The still unresolved problem is how to properly link statistical data, referred to the coal "as it is" without specifying moisture and ash content of the product, to the literature data, referring to sample coals. The intention is to improve the quality of the collected statistical data including moisture content of coals; currently this obstacle has been overcome with the following procedure:

- using an ample set of experimental data on coals imported in a couple of years on an extensive series of samples, more than 200, analysed by ENEL (the main electricity producing company in Italy) it was possible to correlate "as it is" LHV and carbon content to the average properties of the coals imported in the same period of time and calculated from literature data (EMEP/CORINAIR, 2007);
- for each inventory year, it was possible to calculate the weighted average of LHV and carbon content of imported coals using available literature data;
- using this calculated data and the correlation found out, the estimate of carbon content of the average "as it is" coal reported in the statistics was possible.

Using this methodology and the available statistical data, it was possible to trace back to the year 1990 the average LHV of the imported coal and estimate average carbon EF for each year, see Table A6.4 for detailed data. The results do not show impressive changes yearly; anyway a noticeable difference in the emission factor is highlighted in the table. In Table A6.5 updated coal EFs are reported. National emission factors result in the range given by the lower and upper values for "other bituminous coal" in the IPCC 2006 Guidelines (IPCC, 2006).

From the 2011 submission, with the aim to improve the estimation of the coal CO_2 emission factors an in depth analysis of data reported in the framework of the European emissions trading scheme has been carried out. In consideration that these data referring to emission factors and activity data are validated and the amount of fuel reported accounts for more than 90% of the national coal fuel consumption, the average coal CO_2 emission factors, resulting from ETS data, have been applied from 2005.

With regard the oxidation factors, increasing values have been used from 0.98 in the 1990 to 1.00 in 2005 according to the improvement of combustion efficiency in the nineties.

Table A6.5 – Coal, average carbon emission factors

	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Other bituminous coal, IPCC 1996	94.600	92.708	2.427	3.881
Other Bituminous coal, IPCC 2006, av	94.600	94.600	2.441	3.961
lower	89.500			
upper	99.700			
National emission factors				
Steam coal, 1990	96.512	94.582	2.502	3.960
Steam coal, 1995	95.926	94.007	2.519	3.936
Steam coal, 2000	93.312	92.276	2.427	3.863
Steam coal, 2001	95.304	94.457	2.463	3.955
Steam coal, 2002	94.727	94.096	2.457	3.940
Steam coal, 2003	95.385	94.961	2.476	3.976
Steam coal, 2004	95.382	95.170	2.476	3.985
Steam coal, 2005	94.305	94.305	2.399	3.948
Steam coal, 2006	93.741	93.741	2.346	3.925
Steam coal, 2007	94.078	94.078	2.324	3.939
Steam coal, 2008	93.451	93.451	2.287	3.913
Steam coal, 2009	93.847	93.847	2.325	3.929
Steam coal, 2010	93.697	93.697	2.317	3.923
Steam coal, 2011	93.365	93.365	2.318	3.909
Steam coal, 2012	93.667	93.667	2.346	3.922
Steam coal, 2013	93.645	93.645	2.331	3.921
Steam coal, 2014	94.029	94.029	2.339	3.937
Steam coal, 2015	94.619	94.619	2.335	3.962
Steam coal, 2016	95.092	95.092	2.350	3.981
Steam coal, 2017	93.886	93.886	2.361	3.931
Steam coal, 2018	94.340	94.340	2.345	3.950
Steam coal, 2019	95.278	95.278	2.375	3.989
Steam coal, 2020	94.014	94.014	2.356	3.936

Source: ISPRA elaborations

A6.5 Other fuels

Country specific emission factors have been calculated for other fuels and included in the inventory on account of the analysis of data reported by plants in the framework of the European emissions trading scheme. In consideration that these data referring to emission factors and activity data are validated and the amount of fuels reported accounts for more than 90% of the national fuels consumption, the average CO_2 emission factors have been applied from 2005.

In the following, values of CO_2 emission factors are specified for the different fuels. From 2005, figures result from a weighted average of ETS data; before that period, emission factors derive from literature data or other national data collection.

Oxidation factors have been considered equal to 1 for all the fuels (IPCC, 2006) with exception of residual gases of chemical processes where the oxidation factors resulting from ETS data have been used.

Table A6.6 – Refinery gas, average carbon emission factors

Refinery gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Refinery gas, 1990-2004	57.600	57.600	2.851	2.412
Refinery gas, 2005	58.320	58.320	2.756	2.442
Refinery gas, 2006	57.369	57.369	2.644	2.402
Refinery gas, 2007	57.110	57.110	2.645	2.391
Refinery gas, 2008	58.137	58.137	2.686	2.434
Refinery gas, 2009	57.477	57.477	2.673	2.406
Refinery gas, 2010	56.750	56.750	2.652	2.376
Refinery gas, 2011	57.291	57.291	2.689	2.399
Refinery gas, 2012	57.269	57.269	2.701	2.398
Refinery gas, 2013	57.447	57.447	2.649	2.405
Refinery gas, 2014	57.095	57.095	2.634	2.390
Refinery gas, 2015	56.865	56.865	2.653	2.381
Refinery gas, 2016	58.210	58.210	2.652	2.437
Refinery gas, 2017	58.110	58.110	2.644	2.433
Refinery gas, 2018	58.307	58.307	2.657	2.441
Refinery gas, 2019	56.465	56.465	2.660	2.364
Refinery gas, 2020	56.146	56.146	2.639	2.351

Source: ISPRA elaborations

Table A6.7 – Coke oven gas, average carbon emission factors

Coke oven gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / 10^3 std cubic mt	t CO_2 / toe
Coke oven gas, 1990-2004	42.111	42.111	0.807	1.763
Coke oven gas, 2005	42.128	42.128	0.754	1.764
Coke oven gas, 2006	42.678	42.678	0.743	1.787
Coke oven gas, 2007	42.416	42.416	0.714	1.776
Coke oven gas, 2008	42.250	42.250	0.733	1.769
Coke oven gas, 2009	42.980	42.980	0.748	1.799
Coke oven gas, 2010	42.816	42.816	0.735	1.793
Coke oven gas, 2011	43.328	43.328	0.746	1.814
Coke oven gas, 2012	44.046	44.046	0.773	1.844
Coke oven gas, 2013	42.861	42.861	0.760	1.794
Coke oven gas, 2014	43.767	43.767	0.775	1.832
Coke oven gas, 2015	43.314	43.314	0.751	1.813
Coke oven gas, 2016	43.700	43.700	0.758	1.830
Coke oven gas, 2017	43.877	43.877	0.758	1.837
Coke oven gas, 2018	44.008	44.008	0.763	1.843
Coke oven gas, 2019	44.820	44.820	0.792	1.877
Coke oven gas, 2020	45.854	45.854	0.844	1.920

Source: ISPRA elaborations

Table A6.8 – Blast furnace gas, average carbon emission factors

Blast furnace gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / 10^3 std cubic mt	t CO_2 / toe
Blast furnace gas, 1990-2004	270.575	270.575	0.954	11.328
Blast furnace gas, 2005	263.653	263.653	0.870	11.039
Blast furnace gas, 2006	255.948	255.948	0.849	10.716
Blast furnace gas, 2007	261.469	261.469	0.835	10.947
Blast furnace gas, 2008	256.133	256.133	0.838	10.724
Blast furnace gas, 2009	259.560	259.560	0.834	10.867
Blast furnace gas, 2010	257.390	257.390	0.863	10.776
Blast furnace gas, 2011	255.351	255.351	0.877	10.691
Blast furnace gas, 2012	252.808	252.808	0.885	10.585
Blast furnace gas, 2013	251.428	251.428	0.929	10.527
Blast furnace gas, 2014	245.964	245.964	0.958	10.298
Blast furnace gas, 2015	250.072	250.072	0.931	10.470

Blast furnace gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / 10^3 std cubic mt	t CO_2 / toe
Blast furnace gas, 2016	247.893	247.893	0.952	10.379
Blast furnace gas, 2017	249.927	249.927	0.877	10.464
Blast furnace gas, 2018	250.282	250.282	0.862	10.479
Blast furnace gas, 2019	249.335	249.335	0.877	10.439
Blast furnace gas, 2020	251.043	251.043	0.883	10.511

Source: ISPRA elaborations

Table A6.9 – Oxygen furnace gas, average carbon emission factors

Oxygen furnace gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / 10^3 std cubic mt	t CO_2 / toe
Oxygen furnace gas, 1990-2004	195.086	195.086	1.504	8.168
Oxygen furnace gas, 2005	197.579	197.579	1.437	8.272
Oxygen furnace gas, 2006	202.372	202.372	1.390	8.473
Oxygen furnace gas, 2007	195.871	195.871	1.320	8.201
Oxygen furnace gas, 2008	196.465	196.465	1.277	8.226
Oxygen furnace gas, 2009	196.970	196.970	1.253	8.247
Oxygen furnace gas, 2010	197.029	197.029	1.216	8.249
Oxygen furnace gas, 2011	198.482	198.482	1.160	8.310
Oxygen furnace gas, 2012	198.199	198.199	1.226	8.298
Oxygen furnace gas, 2013	185.522	185.522	1.068	7.767
Oxygen furnace gas, 2014	200.970	200.970	1.335	8.414
Oxygen furnace gas, 2015	201.532	201.532	1.351	8.438
Oxygen furnace gas, 2016	203.868	203.868	1.309	8.536
Oxygen furnace gas, 2017	199.257	199.257	1.305	8.343
Oxygen furnace gas, 2018	192.862	192.862	1.353	8.075
Oxygen furnace gas, 2019	194.622	194.622	1.387	8.148
Oxygen furnace gas, 2020	195.877	195.877	1.387	8.148

Source: ISPRA elaborations

Table A6.10 – Heavy residual fuels, average carbon emission factors

Heavy residual fuels	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Heavy residual fuels, 1999-2006	81.817	81.817	3.213	3.426
Heavy residual fuels, 2007	81.823	81.823	3.214	3.426
Heavy residual fuels, 2008	80.350	80.350	3.156	3.364
Heavy residual fuels, 2009	79.612	79.612	3.125	3.333
Heavy residual fuels, 2010	79.036	79.036	3.108	3.309
Heavy residual fuels, 2011	79.160	79.160	3.091	3.314
Heavy residual fuels, 2012	79.359	79.359	3.098	3.323
Heavy residual fuels, 2013	80.756	80.756	3.145	3.381
Heavy residual fuels, 2014	80.499	80.499	3.135	3.370
Heavy residual fuels, 2015	79.738	79.738	3.105	3.338
Heavy residual fuels, 2016	79.700	79.700	3.104	3.337
Heavy residual fuels, 2017	80.104	80.104	3.120	3.354
Heavy residual fuels, 2018	79.824	79.824	3.109	3.342
Heavy residual fuels, 2019	79.929	79.929	3.113	3.346
Heavy residual fuels, 2020	80.466	80.466	3.134	3.369

Source: ISPRA elaborations

Table A6.11 – Synthesis gas, average carbon emission factors

Synthesis gas	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Synthesis gas, 1999-2005	98.103	98.103	0.906	4.107
Synthesis gas, 2006	98.566	98.566	0.982	4.127
Synthesis gas, 2007	98.321	98.321	0.830	4.117

Synthesis gas, 2008	98.860	98.860	0.886	4.139
Synthesis gas, 2009	105.956	105.956	0.956	4.436
Synthesis gas, 2010	110.487	110.487	0.910	4.626
Synthesis gas, 2011	109.188	109.188	0.915	4.571
Synthesis gas, 2012	106.913	106.913	0.881	4.476
Synthesis gas, 2013	100.817	100.817	0.895	4.221
Synthesis gas, 2014	100.596	100.596	0.898	4.212
Synthesis gas, 2015	100.732	100.732	0.930	4.217
Synthesis gas, 2016	103.993	103.993	0.929	4.354
Synthesis gas, 2017	103.043	103.043	0.983	4.314
Synthesis gas, 2018	109.145	109.145	1.009	4.570
Synthesis gas, 2019	104.034	104.034	0.948	4.356
Synthesis gas, 2020	102.912	102.912	0.870	4.309

Source: ISPRA elaborations

Table A6.12 – Residual gas of chemical processes, average carbon emission factors

Residual gas of chemical processes	t CO_2 / TJ (stechiometric)	Oxidation factor	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Residuals gas of chem. processes, 1990-2007	51.500	0.995	51.243	2.365	2.145
Residuals gas of chem. processes, 2008	51.308	0.995	51.052	2.505	2.137
Residuals gas of chem. processes, 2009	50.588	0.995	50.342	2.502	2.108
Residuals gas of chem. processes, 2010	50.361	0.996	50.151	2.295	2.100
Residuals gas of chem. processes, 2011	50.610	0.995	50.379	2.514	2.109
Residuals gas of chem. processes, 2012	51.246	0.996	51.016	2.252	2.136
Residuals gas of chem. processes, 2013	47.524	1.000	47.524	2.073	1.990
Residuals gas of chem. processes, 2014	42.961	1.000	42.961	2.012	1.799
Residuals gas of chem. processes, 2015	47.850	1.000	47.850	2.165	2.003
Residuals gas of chem. processes, 2016	47.368	1.000	47.368	1.791	1.983
Residuals gas of chem. processes, 2017	47.594	1.000	47.594	1.726	1.993
Residuals gas of chem. processes, 2018	47.279	1.000	47.279	1.764	1.979
Residuals gas of chem. processes, 2019	52.316	1.000	52.316	1.705	2.190
Residuals gas of chem. processes, 2020	46.417	1.000	46.417	1.686	1.943

Source: ISPRA elaborations

Table A6.13 – Petroleum coke for no refinery plants, average carbon emission factors

Petroleum coke	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Petroleum coke, 1990-2004	97.500	97.500	3.169	4.082
Petroleum coke, 2005	92.957	92.957	3.097	3.892
Petroleum coke, 2006	93.295	93.295	3.125	3.906
Petroleum coke, 2007	93.427	93.427	3.193	3.912
Petroleum coke, 2008	93.525	93.525	3.203	3.916
Petroleum coke, 2009	94.106	94.106	3.227	3.940
Petroleum coke, 2010	93.679	93.679	3.160	3.922
Petroleum coke, 2011	93.715	93.715	3.219	3.924
Petroleum coke, 2012	93.303	93.303	3.207	3.906
Petroleum coke, 2013	93.178	93.178	3.128	3.901
Petroleum coke, 2014	93.513	93.513	3.122	3.915
Petroleum coke, 2015	93.771	93.771	3.132	3.926
Petroleum coke, 2016	93.459	93.459	3.121	3.913
Petroleum coke, 2017	93.465	93.465	3.129	3.913
Petroleum coke, 2018	93.680	93.680	3.122	3.922
Petroleum coke, 2019	93.498	93.498	3.117	3.915
Petroleum coke, 2020	93.368	93.368	3.126	3.909

Source: ISPRA elaborations

Table A6.14 – Petroleum coke for refinery plants, average carbon emission factors

Petroleum coke	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Petroleum coke, 2010	100.684	100.684	3.428	4.215
Petroleum coke, 2011	99.331	99.331	3.413	4.159
Petroleum coke, 2012	100.081	100.081	3.435	4.190
Petroleum coke, 2013	99.336	99.336	3.415	4.159
Petroleum coke, 2014	95.879	95.879	3.400	4.014
Petroleum coke, 2015	96.778	96.778	3.432	4.052
Petroleum coke, 2016	101.995	101.995	3.416	4.270
Petroleum coke, 2017	96.734	96.734	3.430	4.050
Petroleum coke, 2018	97.295	97.295	3.422	4.074
Petroleum coke, 2019	96.929	96.929	3.437	4.058
Petroleum coke, 2020	97.082	97.082	3.442	4.065

Source: ISPRA elaborations

Table A6.15 –Coke, average carbon emission factors

Coke	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Coke, 1990-2004	110.368	108.161	3.170	4.528
Coke, 2005	110.916	110.916	3.246	4.644
Coke, 2006	111.049	111.049	3.181	4.649
Coke, 2007	111.814	111.814	3.191	4.681
Coke, 2008	111.649	111.649	3.187	4.675
Coke, 2009	111.303	111.303	3.161	4.660
Coke, 2010	109.079	109.079	3.125	4.567
Coke, 2011	110.380	110.380	3.188	4.621
Coke, 2012	112.969	112.969	3.309	4.730
Coke, 2013	111.113	111.113	3.172	4.652
Coke, 2014	109.195	109.195	3.198	4.572
Coke, 2015	109.728	109.728	3.206	4.594
Coke, 2016	109.533	109.533	3.217	4.586
Coke, 2017	108.755	108.755	3.237	4.553
Coke, 2018	108.864	108.864	3.218	4.558
Coke, 2019	108.590	108.590	3.169	4.546
Coke, 2020	107.471	107.471	3.181	4.500

Source: ISPRA elaborations

Table A6.16 –Coking coal, average carbon emission factors

Coking coal	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Coking coal, 1990-2004	94.600	94.600	2.668	3.961
Coking coal, 2005	92.466	92.466	2.971	3.871
Coking coal, 2006	94.058	94.058	2.968	3.938
Coking coal, 2007	94.479	94.479	2.971	3.956
Coking coal, 2008	94.869	94.869	2.961	3.972
Coking coal, 2009	94.718	94.718	2.970	3.966
Coking coal, 2010	94.627	94.627	3.007	3.962
Coking coal, 2011	95.459	95.459	2.999	3.997
Coking coal, 2012	95.380	95.380	3.014	3.993
Coking coal, 2013	94.381	94.381	2.982	3.952
Coking coal, 2014	93.983	93.983	2.991	3.935
Coking coal, 2015	94.457	94.457	2.995	3.955
Coking coal, 2016	94.171	94.171	2.967	3.943
Coking coal, 2017	94.004	94.004	2.967	3.936
Coking coal, 2018	95.361	95.361	2.974	3.993
Coking coal, 2019	94.676	94.676	2.948	3.964
Coking coal, 2020	94.947	94.947	2.966	3.975

Source: ISPRA elaborations

Table A6.17 –Anthracite, average carbon emission factors

Anthracite	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Anthracite, 1990-2004	98.300	98.300	2.625	4.116
Anthracite, 2005	93.035	93.035	2.856	3.895
Anthracite, 2006	95.127	95.127	2.817	3.983
Anthracite, 2007	97.722	97.722	2.796	4.091
Anthracite, 2008	97.183	97.183	2.764	4.069
Anthracite, 2009	98.335	98.335	2.861	4.117
Anthracite, 2010	97.416	97.416	2.844	4.079
Anthracite, 2011	99.465	99.465	2.911	4.164
Anthracite, 2012	98.717	98.717	2.870	4.133
Anthracite, 2013	98.348	98.348	2.886	4.118
Anthracite, 2014	97.960	97.960	2.877	4.101
Anthracite, 2015	101.373	101.373	2.906	4.244
Anthracite, 2016	101.630	101.630	2.924	4.255
Anthracite, 2017	103.107	103.107	3.027	4.317
Anthracite, 2018	100.405	100.405	3.005	4.204
Anthracite, 2019	105.114	105.114	3.033	4.401
Anthracite, 2020	104.757	104.757	2.964	4.386

Source: ISPRA elaborations

Table A6.18 –Industrial waste (fossil), average carbon emission factors

Industrial waste	t CO_2 / TJ (stechiometric)	t CO_2 / TJ	t CO_2 / t	t CO_2 / toe
Industrial waste, 2005-2012	79.968	79.968	1.924	3.348
Industrial waste, 2013	79.076	79.076	1.853	3.311
Industrial waste, 2014	81.851	81.851	1.931	3.427
Industrial waste, 2015	78.976	78.976	1.988	3.307
Industrial waste, 2016	78.592	78.592	2.019	3.291
Industrial waste, 2017	82.164	82.164	2.090	3.440
Industrial waste, 2018	80.019	80.019	2.034	3.350
Industrial waste, 2019	81.243	81.243	2.093	3.401
Industrial waste, 2020	79.915	79.915	2.070	3.346

Source: ISPRA elaborations

ANNEX 7: AGRICULTURE SECTOR

Additional information used for estimating categories 3A, 3B and 3D from the agriculture sector is reported in this section.

A7.1 Enteric fermentation (3A)

The time series of the parameters used for estimating the Dairy Cattle EF using the Tier 2 approach, are reported in Table A.7.1. Information on the equations used for estimating the different net energy (NE_m, NE_g, etc.) is described in the 2006 IPCC Guidelines (IPCC, 2006).

Table A.7.1 Parameters used for the Tier 2 approach - dairy cattle

	NE_m (MJ/day)	NE_a (MJ/day)	NE_g (MJ/day)	NE_l (MJ/day)	NE_w (MJ/day)	NE_p (MJ/day)	REM	REG	GE (MJ/day)
1990	46.95	0.40	0.97	33.52	0.00	4.57	0.51	0.31	**260.66**
1995	46.95	0.40	0.97	43.38	0.00	4.45	0.51	0.31	**289.83**
2000	46.95	0.40	0.97	44.31	0.00	4.35	0.51	0.31	**292.33**
2005	46.95	0.40	0.97	50.84	0.00	4.27	0.52	0.32	**301.97**
2010	46.95	0.40	0.97	55.54	0.00	4.23	0.52	0.32	**307.49**
2011	46.95	0.40	0.97	54.87	0.00	4.24	0.52	0.32	**305.21**
2012	46.95	0.40	0.97	52.55	0.00	4.17	0.52	0.32	**301.61**
2013	46.95	0.40	0.97	52.06	0.00	4.19	0.52	0.32	**299.92**
2014	46.95	0.40	0.97	55.55	0.00	4.21	0.52	0.32	**308.79**
2015	46.95	0.40	0.97	56.89	0.00	4.18	0.52	0.32	**312.24**
2016	46.95	0.40	0.97	58.81	0.00	4.24	0.52	0.32	**316.14**
2017	46.95	0.40	0.97	61.89	0.00	4.26	0.52	0.32	**323.31**
2018	46.95	0.40	0.97	65.46	0.00	4.26	0.52	0.33	**331.20**
2019	46.95	0.40	0.97	67.67	0.00	4.26	0.53	0.33	**335.36**
2020	46.95	0.40	0.97	71.74	0.00	4.30	0.53	0.33	**345.77**

Source: ISPRA elaborations

For non-dairy cattle, emission factors are derived by the Nitrogen Balance Inter-regional Project that involved Emilia Romagna, Lombardy, Piedmont and Veneto regions, where animal breeding is concentrated and for that they have been assumed representative of the national level.
The project was aimed to develop models to calculate the nitrogen balance for different types of breeding, including cattle. The following information was collected: the movement of the heads and feed at farm level, animal nutrition plans, feed consumption per animal category and bred, management techniques, reproductive phase and the productive results, mortality, age, weight at different growth and fattening phases, number and type of stable places in the herd, the type of simple feed or compound feed used, the estimated nitrogen content, the composition of the feed ration, average levels daily consumption per animal category and stage of breeding cycle (Xiccato *et al.*, 2004).
The survey data related to replacement heifers and other non-dairy cattle are described below.

Replacement heifers

Breeding performance
In Table A.7.2 the national average values of the main characteristics of the replacement heifers breeding are reported. Friesian, Brown and Red-spotted livestock breeds have been considered.
The national value is the average of the result of the survey carried out in Veneto, Emilia Romagna, Lombardy and Piedmont which monitores the feed consumption, the composition of the rations and the numeric movements and weight of livestock in the period between 2002 and 2003. For Veneto, specifically, data from 89 representative farms, for a total of 8,466 heads, were collected (Regione Veneto, 2008; Bittante *et al.*, 2004).

Table A.7.2 Main characteristics of the replacement heifers breeding

	Unit of measure	Average value	Sd (2)
Age at weaning	day	85	23
Age at first calving	month	28.5	
Live weight at birth	kg/head	39	
Average live weight at weaning	kg/head	101	19
Average live weight at first calving	kg/head	540	
Feed ration distribution			
Traditional	%	25	
Unifeed	%	38	
Mixed	%	37	
Intake of dry matter from weaning at first calving	kg/head/period	6473	1459
Daily dry matter intake	kg/d	8.24	1.89
Average crude protein ration (Nx6,25)	kg/kg	0.121	0.018
Nitrogen balance			
N consumed from birth to weaning	kg/head/period	5.3	2.7
N consumed from weaning to calving	kg/head/period	123.9	29.7
N retention in products from birth to calving	kg/head/period	14.41	
N excreted from birth to calving	kg/head/period	114.8	29.6
N annually excreted	kg/head/year	48.3 (1)	12.5

(1) the value was divided by the average weight and used to calculate the annual average nitrogen excretion for females from breeding between 1 and 2 years and more than 2 years (reported in CRPA, 2006[a]); (2) Standard deviation

Feed consumption and composition of rations

Average value of dry matter intake from weaning at first calving is 6473 kg/head/period (8.24 kg of dry matter intake per day).

Animals receive rations based, even in summer, on hay fodder, corn silage and fibrous products with minimal additions of feed concentrates.

The protein content of these rations is on average 12% of dry matter intake. The use of fresh grass is generally avoided, the best fodder is normally reserved for dairy cows and the inferior fodder for the replacement heifers.

Digestibility

The feed ration is rich in fiber (as described above) and therefore less digestible than the ration of fattening animals. Methane conversion factors were estimated as a function of digestibility on the basis of factors in the 2006 IPCC guidelines.

Other cattle

Breeding performance

In Italy, the following breeding models of the beef sector are mainly widespread (CRPA, 2011[b]):

- farms oriented to the fattening phase only, widespread in particular in Veneto and other regions of the Po Valley. This production model mainly uses imported calves over 6 months old, whose final fattening phase is carried out in confinement farms ("*ristallo*"). This type of breeding in the northern Italian plain guarantees the largest physical flow of product to the beef supply chain in Italy;
- zootechnical farms that follow the cow-calf line, implemented in Italy mainly in the regions of Central-Southern Italy and in Piedmont, through the breeding of cows of specialized breeds for the production of meat, mostly of national origin (Marchigiana, Chianina, Piemontese);
- extensive breeding with national rustic breeds, followed in particular in southern Italy and islands, generally located in the internal hilly and mountainous areas.

Less than 30% of the animals in the meat supply chain belong to native meat breeds. Meat supply is mainly represented by cattle between 1 and 2 years of age (60%), "late-career" cattle over two years of age account for about one-fifth of the national supply, as well as cattle slaughtered before one year of age (ISMEA, 2020).

Feed consumption and composition of rations

Since the beginning of the sixties, the intensive farming under confinement, the most prevalent in the Po valley, has been closely linked to the development of the cultivation of maize, as the main energy source, and the availability of flour from imported soybean, as a protein source (Regione Veneto, 2008). In the same years, in agricultural areas in Northern Italy a substantial abandonment of the cattle from traditional meat, based on a wide use of permanent and/or temporary fodder was recorded. This process has developed as a result of the

development of the product ensiling technique obtained by chopping of the whole plant, harvested in the milky-wax ripeness phase of kernels (corn silage). The use of corn silage increases by about 50% the amount of energy per hectare, reducing, consequently, the cost of the unit forage (Regione Veneto, 2008). The use of corn silage and concentrated feed, suitably integrated, in diets for cattle, increases the speed of growth of animals, improving the energy efficiency of the ration, reducing the duration of the production cycle and raising the yields of slaughter and the qualitative level of carcasses and meat (Regione Veneto, 2008).
In the survey conducted on 135 farms in Veneto, Lombardy and Piedmont useful information on the average type of the feed composition and crude protein content of rations for Charolais cattle can be drawn (Cozzi, 2007 – see Table A.7.3). Despite some differences between farms located in different regions it is observed that in all cases the corn silage, the corn mash and cereals are the main constituents of rations. The use of dried beet pulp, in particular in the Veneto region, is significant. In Veneto and Lombardy, the long-fiber forages are represented almost exclusively by straw, while in Piedmont these are partially or totally replaced by permanent pasture hay. The supplement of protein is generally based on soybean flour. The protein content is in all cases around 14% of dry matter, a little more content than that found by Xiccato *et al.*, (Xiccato *et al.*, 2005) on 40 farms in Veneto (14.4% + 0.9%) and a slightly higher than that found by Mazzenga *et al.*, (Mazzenga *et al.*, 2007) on 406 farms in the Po valley (13% + 1.1%).

Table A.7.3 Feed and chemical composition of of total mixed rations for Charolais cattle in different regions (Cozzi, 2007) – data of feed ration in dry matter

Diet	Veneto	Lombardy	Piedmont
Farms, n.	101	23	11
Feed ration, kg			
Silage corn	2.99	3.46	2.12
Mash corn	0.52	0.91	1.76
Cereals, flour and grains	0.86	0.58	0.67
Dried beet pulp	0.39	0.21	0.18
Fodder long fiber	0.61	0.61	0.87
Protein supplements, vitamins and	2.00	2.26	2.09
Molasses and vegetable fats	0.09	0.09	0.17
Chemical composition:			
Dry matter %	55.2	52.6	62.3
Crude protein %	14.0	13.9	14.0
Total forages	4.50	5.19	4.92
Total concentrates	2.95	2.93	2.93
Total feed	7.45	8.11	7.86
% of concentrates	40%	36%	37%
% of forages	60%	64%	63%

Digestibility
As mentioned above, the rations consist mainly of silage and cereals and for fattening animals, the ration has been assumed more digestible. Therefore, for these categories of animals, lower default values of the methane conversion factor (from the 2006 IPCC Guidelines) with respect to the breeding categories have been assigned

CH_4 conversion factors for non-dairy cattle category
In response to the 2018 UNFCCC review process, the 2019 ESD review (EMRT observation of February 2019) and the 2019 UNFCCC review process, additional information on the CH_4 conversion factors for non-dairy cattle category is provided.
For non-dairy cattle category, different CH_4 conversion factors have been estimated for the different sub-categories, depending on the assumption on feed digestibility; in fact, usually a more digestible diet is used in the case of fattening animals while a richer in fiber diet is used in the case of breeding animals (CRPA, 2006[a]). CRPA, which is the research center on animal production and provides technical support to the relevant regional and national authorities on this matter, carried out the studies cited for the national inventory in 1997 and 2006, on the basis of their knowledge of the sector, which derives from the information collected at farm level during the years in the intensive farms where more than 90% of cattle are reared, and taking in account the 1996 IPCC Guidelines.
Methane conversion factors Ym have been chosen for the different species based on the average characteristic in terms of dry matter intake (DMI), average weight and typical diet according to the range provided in the IPCC 1996 Guidelines (4%±0.5 related to good diet and 6%±0.5 for poor diet). The DMI is calculated as a

percentage of weight. For cattle less than one year, DMI is estimated to be 4.8 kg/head/day; for cattle aged 1 to 2 years for slaughter, DMI is considered to be 2.1% by weight; for breeding males from 1 to 2 years, DMI is considered equal to 1.9% of weight; for breeding females aged 1 to 2 years, DMI is considered to be 2.1% by weight; for male cattle of more than 2 years, DMI is estimated at 17.1 kg/head/day; for females over 2 years DMI is estimated at 11.5 kg/head/day; for other cows, DMI is considered to be 1.9% by weight (CRPA, 1997 [a]).
In the 2006 IPCC Guidelines two values for Ym are proposed: one for cattle, for the fed diets containing 90% or more concentrates (3%±1), the other for other Cattle and Buffaloes that are primarily fed low quality crop residues and by-products (6.5%±1), not providing any suggestion for intermediate quality of feed diets.
Therefore, based on data collected at farm level, intermediate quality of feed diets was found in which concentrates do not reach 90% but can be exceed 70% depending on the different breeds.
Some published examples of average diet for typical breeds of cattle for slaughter 1-2 year aged reared in Italy for 2012, 2014 and 2015 provided by ISMEA (which is the public institute for study and research on the agriculture market supporting the relevant Ministry) in cooperation with CRPA are reported in Table A.7.4-6.

Table A.7.4 Composition of diet of fattening cattle (kg dry matter/head/d) - reference year 2012

Regions	**Veneto**	**Piemonte**	**Piemonte**
Breed	**Charolais/Limousine**	**Blonde d'Aquitaine**	**Piemontese**
Stable places (n.)	**940**	**426**	**110**
Silage corn	2.41	0.43	0.40
Mash corn	0.85	0.85	0.52
Other silage (triticale, ryegrass)	0.06		
Surpressed beetroot pulp	0.60		
Hay	0.44	1.31	1.39
Straw	0.52	0.61	0.26
Corn flour	1.83	2.26	1.74
Glutinous corn semolina	0.78		
Bran	0.09	0.17	0.26
Soybean extraction flour	0.44	0.61	0.26
Protein supplements*	0.87	2.52	2.70
Dried pulps	0.52	0.44	
Vegetable fats	-	-	-
Total forages	4.87	3.19	2.57
Total concentrates	4.52	6.00	4.96
Total feed	9.40	9.19	7.53
% of concentrates	48%	65%	66%
% of forages	52%	35%	34%

*Feed formulated for the integration of energy feeds and/or farm cereals. Source: Ismea – CRPA

Table A.7.5 Composition of diet of fattening cattle (kg dry matter/head/d) - reference year 2014

Regions	**Veneto**	**Piemonte**
Breed	**Charolais/Limousine**	**Blonde d'Aquitaine**
Stable places (n.)	**790**	**300**
Silage corn	2.81	0.36
Mash corn	1.11	0.91
Surpressed beetroot pulp	0.42	
Hay	0.17	1.31
Straw	0.61	0.44
Corn flour	2.18	2.70

Regions	Veneto	Piemonte
Breed	**Charolais/Limousine**	**Blonde d'Aquitaine**
Stable places (n.)	**790**	**300**
Glutinous corn semolina	0.44	
Bran	0.17	0.35
Soybean extraction flour	0.35	0.44
Protein supplements*	1.04	2.26
Dried pulps	0.44	0.09
Vegetable fats	0.03	0.07
Total forages	5.12	3.01
Total concentrates	4.61	5.83
Total feed	9.73	8.84
% of concentrates	47%	66%
% of forages	53%	34%

*Feed formulated for the integration of energy feeds and/or farm cereals. Source: Ismea – CRPA

Table A.7.6 Composition of diet of fattening cattle (kg dry matter/head/d) - reference year 2015

Regions	Toscana, Umbria	Marche, Abruzzo	Emilia Romagna
Breed	**Chianina**	**Marchigiana**	**Marchigiana**
Stable places (n.)	**140**	**145**	**400**
Silage corn	-	-	1.44
Mash corn	-	-	0.98
Alfalfa hay	2.78	1.57	0.78
Straw	0.13	0.61	0.44
Protein supplements*	1.22	0.26	0.96
Corn flour	2.44	3.39	2.78
Barley flour	1.57	1.48	0.61
Bran	0.17	0.30	0.30
Soybean extraction flour	0.35	0.44	0.52
Favino flour	0.78	1.04	-
Total forages	2.91	2.18	3.63
Total concentrates	6.53	6.92	5.18
Total feed	9.44	9.09	8.81
% of concentrates	69%	76%	59%
% of forages	31%	24%	41%

*Feed formulated for the integration of energy feeds and/or farm cereals. Source: Ismea – CRPA

As the data show, for autochthon breed (as Chianina, Marchigiana, Piemontese) the percentage of concentrates in the diet is in average greater than 60% and can reach 75% of the daily intake ration.
The country specific Ym, for the different subcategories, have been verified calculating Ym values with the formula proposed by Ellis *et al* (Ellis *et al*, 2007) based on daily DMI and forages proportion (FP) in the diet, considering the national weight and DMI values and assuming percentages of forages between 30% and 80%, provided by the CRPA experts. Cattle < 1 year (reported in Table A.7.7) in Italy is baby beef: the average weight is 236 kg and daily consumption is in average 7.5 kg (5 kg of concentrates and 2.5 kg of silage and dry forage); dry matter intake is about 5 kg (equal to 2.1% live weight) and the percentage of forages is only about 30%. Cattle 1-2 year for breeding female (reported in Table A.7.7) include pregnant heifers of suckler cows and their energy requirements are low, about 155 MJ per day. This average value corresponds to a diet consisting of at least 80% dry matter from fodder. The forage percentages of 40-50% assumed for the cattle for slaughter 1-2 years (M+F) and cattle 1-2 years for breeding male categories in Table A.7.7 are in line with

the data reported in Tables A.7.3-6, where rations have forage percentages ranging from 24 to 64%. The comparison between the Ym values calculated with the Ellis *et al* formula and the country specific values results in very close values, as reported in Table A.7.7. The penultimate column 'Ym' of Table A.7.7 represents the result obtained with the Ellis *et al* formula, while the last column 'Country specific Ym' represents the data used in the inventory and reported in CRPA, 2006[a].

Table A.7.7 Ym estimation on the basis of DMI and forages proportion

	weight	DMI			forage proportion (on diet)	CH4 production*	Ym	Country specific Ym
	kg	*as % weight*	*as kg/d*	*as MJ/day*	*% forages on dry matter*	*MJ/day*		
cattle < 1 year	236	2.1%	4.8	89.0	30%	3.72	4.2%	4
cattle for slaughter 1-2 years (M+F)	520	2.1%	10.9	200.0	40%	8.31	4.2%	4
cattle 1-2 years for breeding male	550	1.9%	10.6	194.3	50%	8.58	4.4%	4.5
cattle 1-2 years for breeding female	400	2.1%	8.4	154.6	80%	8.55	5.5%	6

* the following formula has been applied: Ym=-1.02+0.681*DMI+4.81*FP

A7.2 Manure management (3B)

In this section the country-specific methodology for estimating the amount of manure sent to the bio-digesters and the amount of methane produced, to be subtracted from the total amount of methane deriving from manure management, is explained.

The inventory of methane emissions from manure management is based on a country specific methodology which also takes into account the share of manure sent to bio-digesters annually to recover power and heat.

In Italy the number of bio-digesters has been increasing for the last years in a significant way. Anaerobic digestion of animal manure allows for the recovery of energy and heat and also for reducing methane emissions to air.

1) The anaerobic bio-digesters in Italy and relevant assumptions

The information available concerning heat and power production from biogas at anaerobic digesters fed with animal manure and agriculture residues (energy crops, agro-industrial by-products) is supplied by TERNA and CRPA.

TERNA, the Italian electricity transmission grid operator, reports annually the production of energy from traditional sources and from renewable. As for energy from biogas production in anaerobic digesters TERNA accounts for the number of digesters connected to the national grid and reports the power capacity, the energy production, combined heat and energy production and provides the figures separately for two categories:

- Bio-digesters receiving animal manure
- Bio-digesters receiving agriculture residues

The information is collected electronically and submitted by bio-digesters operators. TERNA's data about installed power, energy production, biogas used for energy production are then available for the inventory purposes (see data from renewable sources in sections "power plants" and "production" at https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche).

CRPA is the Research Centre on Animal Production, among other activities it has been studying the implementation of anaerobic digestion in the agricultural sector of our country and it has been carrying out surveys to build a picture of the anaerobic digestion plants in the livestock and agro-industrial sector in Italy. In the surveys total number of Italian anaerobic systems is considered, so the plants not connected to the national energy grid are included too. CRPA archive includes also information about the feed (plants working with animal manure, energy crops and agro-industrial by-products). Information about technologies and changes in technologies along the inventory time series is then also available for the inventory purposes.

Comparing the number of plants using manure in the CRPA surveys and those to TERNA, there is evidence that many operators using manure together with crops as a feed to digesters report their information to TERNA under the most general category agriculture residues.

Based on official data by TERNA and on information collected by CRPA (CRPA, 2013; CRPA, 2011[a]; ENAMA, 2011; CRPA, 2008[a]) the inventory team provides with the following picture concerning bio-digesters in Italy:

- As for technology, up to 2005 anaerobic digestion of animal manure was implemented at about less

than 100 plants. In the '90s typical reactor was a coverage storage structure where manure was stored and anaerobic digestion could occur, the output of the process being biogas mainly burned to recover heat for the livestock facility. In the following years, due to an increasing interest into anaerobic digestion and thanks to incentives to the sector, the implementation of multiple substrates (biomass) co-digestion at the same digester can be observed. As a consequence, the type of process reactor has been changing too, with CSTR (completely stirred tank reactor) reactors becoming the largest share out of the total number of digesters.

- The number of installations has been significantly increasing for the last years (following table), thus affecting also the amount of CH_4 emissions released actually to the atmosphere, that's why the GHG emissions inventory shall take into account also this practice.

In the Table A.7.8 a summary of the information provided by TERNA and the estimated data for biogas production is supplied.

Table A.7.8 Anaerobic digesters in Italy

N° of plants and productions	*Anaerobic digesters*		*Energy production*			*Biogas production*
	Total	Animal manure	Total	Animal manure	Agricultural residues	Total
	n.	n.	GWh	GWh	GWh	Mm^3
1990	-	-	-	-	-	-
1995	5	4	10.7	8.1	2.6	Not available
2000	10	5	8.8	4.9	3.9	Not available
2005	24	14	142	26	117	Not available
2010	176	95	611.2	221	390.2	837
2013	1,299	379	5,717	817	4,900	2,991
2014	1,362	421	6,440	989	5,451	3,339
2015	1,466	493	6,557	1,067	5,490	3,186
2016	1,529	539	6,654	1,160	5,494	3,203
2017	1,629	602	6,737	1,194	5,543	3,275
2018	1,654	615	6,792	1,237	5,555	3,268
2019	1,699	636	6,820	1,255	5,565	3,511
2020	1,734	656	6,892	1,294	5,599	3,537

Source: TERNA and estimated data for biogas production

Official information about biogas used and energy production at bio-digesters, provided by TERNA, and information about feed of the bio-digesters, provided by CRPA, allow for estimating the amount of slurry and manure fed annually to the Italian bio-digesters.

The biogas average yield and the chemical characteristics of substrates fed to digesters are described in Table A.7.9 supplied by CRPA (CRPA, 2012).

Table A.7.9 Average yields and average chemical characteristics of some substrates used for biogas production

Tabella 8 - Rese medie e caratteristiche chimiche medie di alcuni substrati utilizzabili per la produzione di biogas

Matrice	Solidi volatili (kg/t)	Biogas (m^3/kg SV)	CH_4 (%)	NTK (% ST)	Matrice	Solidi volatili (kg/t)	Biogas (m^3/kg SV)	CH_4 (%)	NTK (% ST)
Liquami zootecnici									
Liquame suino	30	0,50	67	8	Liquame bovino	82	0,35	55	4,7
Solido separato bovino	200	0,4	55	2,5	Letame bovino	210	0,40	55	2,7
Prodotti vegetali									
Insilato di sorgo zuccherino	282	0,6	53	1,8	Insilato di grano	289	0,60	53	1,7
Insilato di erba	248	0,56	52	2,7	Insilato di mais	310	0,65	53	1,4
Scarti agro-industriali animali									
Siero di latte	55	0,75	60	2,3	Sangue bovino	101	0,65	65	11,4
Contenuti ruminali bovini	176	0,75	53	2,6	Fanghi di macelli suini	160	0,35	60	3
Fango di flottazione avicolo	85	0,35	60	14,7	Fanghi di macelli bovini	122	0,35	60	4,8
Scarti agro-industriali vegetali									
Scarti di lavorazione del mais dolce	154	0,48	55	2,2	Buccette e semi di pomodori	291	0,35	55	3,1
Scarti di leguminose	169	0,6	60	4,9	Scarti di lavorazione della patata	230	0,60	53	1,5

Dati CRPA

As for the types of feed treated in bio-digesters there has been a significant shift from single substrate feed to multiple substrates feed during the last years (CRPA, 2013; CRPA, 2011[a]); the share of bio-digesters treating animal manure only has been decreasing while the share of plants operating co-digestion of multiple substrates feed has been increasing.

Table A.7.10 Type of feed sent to anaerobic digesters over the years

Type of feed over the years	2007	2010	2011	2012
animal manure only (%)	56	36	29	18
animal manure+energy crops+ agricultural residues (%)	38	55	58	62
energy crops only (%)	6	9	13	20

Source: CRPA

Because of multiple substrates fed to bio-digesters, the following average characteristics of the feed, as supplied by CRPA, are considered for the Italian bio-digesters in order to calculate the total amount of feed from animal manure anaerobic digestion (CRPA, 2018).

Table A.7.11 Type of feed sent to anaerobic digesters

Type of feed	Units	animal manure	energy crops	agro-industrial by-products
Animal manure only	% in the feed	100	0	0
Animal manure + energy crops + agro-industrial by-products	% in the feed	28	52	20
Animal manure + energy crops	% in the feed	38	62	0
Animal manure + agro-industrial by-products	% in the feed	69	0	31
Energy crops + agro-industrial by-products	% in the feed	0	81	19

Source: CRPA

On the basis of the information reported above and in consideration of the typical feed of the bio-digesters the average parameters for animal manure, energy crops and agro-industrial by-products are those reported in Table A.7.12. The biogas methane content is generally reported to range from 50% to 65%, for the inventory

purposes and according to CRPA methane content is assumed to be 55% (CRPA/AIEL, 2008; CRPA, 2008[b]). As regards the average volatile solids content, values for animal manure and agro-industrial by-products have been changed based on the recent study of CRPA (CRPA, 2018).

Table A.7.12 Average parameters by the type of feed sent to anaerobic digesters

Parameters	Units	animal manure	energy crops	agro-industrial by-products
Average biogas producing potential	m^3 biogas/kg VS	0.4	0.6	0.6
Average CH_4 content	%	55	55	55
Average volatile solids content	VS kg/t feed	139	280	237

Source: CRPA

On the basis of all this information total biogas generated from the amount of slurry and manure fed to bio-digesters can be estimated assuring that for the inventory purposes it does not include biogas generated based on other carbon sources than animal manure.

2) Losses from bio-digesters

Based on the information collected about the Italian bio-digesters, losses of biogas/methane can be characterized as:

- Biogas losses from anaerobic digestion unit (biogas escaping from the digester)
- Biogas losses from digestate storage
- Biogas losses from the combustion unit in the power&heat production step

As for point 1) according to the available literature on Italian bio-digesters (Fabbri *et al.*, 2011) and to the NIR of other EU Country (UBA, 2014) and to the 2019 EMEP/EEA Guidebook (see chapter 5.B.2 Biological treatment of waste – anaerobic digestion at biogas facilities, paragraph 2.3), where manure is processed in bio-digesters with similar technology implemented, the average losses of biogas is reported to be about 1% of the total biogas produced.

As for point 2) according to the IPCC Guidelines this contribution to the emission is equal to zero when covered storage units are in place. Based on our information, digestate covered storage units are in places at the Italian bio-digesters.

As for point 3) emissions resulting from power&heat production step are not to be allocated under agriculture for the purposes of the GHG emissions inventory and are already estimated and allocated in the energy sector.

3) Methodology and parameters

Based on the information supplied by TERNA and CRPA, a country specific methodology to estimate the *amount of animal manure treated in the bio-digesters* has been developed for the years 2007, 2010, 2011 and 2012 onwards. The amount of animal manure sent to anaerobic digesters is used to estimate both the equivalent number of heads and their related *CH_4 emissions to be subtracted* from the total CH_4 emissions from manure management and *CH_4 emissions from losses of the digesters*.

N_2O emissions from manure management have been revised too, because the emission factors (EFs) for animal manure sent to digesters are different from EFs for the other manure management systems (liquid system and solid storage).

In addition, for the reporting purposes the CH_4 producing potentials (Bo), the percentages of nitrogen allocation (by climate region and manure management systems) and methane conversion factors (MCF) have been revised for the relevant animal categories.

Amount of animal manure treated in bio-digesters

Official data about power capacity of digesters (TERNA) have been disaggregated based on the *distribution of digesters' installed power by type of feed* (CRPA).

On the basis of the operating hours, calculated from TERNA data on total energy production divided by the total installed power at digesters, the *energy production by type of feed* has been calculated for the relevant years.

TERNA data are used also to calculate the average energy efficiency and the lower heating value (LHV) that applied to energy productions allow for deriving the *amount of biogas used to produce energy per type of feed*.

Taking into account the percentage of biogas losses at digesters, equal to 1%, and the percentage of biogas flared at digesters, equal to 4%, it is possible to estimate the *biogas produced per type of feed* from biogas

used. In 2017 submission, in response to the UNFCCC review process, the percentage of biogas flared has been estimated.
From biogas produced per type of feed it is possible to estimate the *total amount of feed* using the maximum biogas producing capacity (m^3 biogas/kg VS – volatile solid) and the VS content in the feed (kg VS/t feed).
In order to estimate the *amount of animal manure sent to digesters*, multiple substrates in the feed have to be considered taking in account the shares of different substrates in the feeds.

CH_4 emissions to be subtracted
In order to take into account the practice of manure management in anaerobic bio-digesters, the equivalent, in terms of MMS (liquid and solid), CH_4 emissions should be calculated on the basis of the amount of manure treated in these plants considering the equivalent number of heads and then subtracted from the total CH_4 emissions from manure management. This is because the country specific methodology calculates the average EFs by livestock on the basis of national and international literature which refer to the "conventional" MMS of liquid and solid manure.
Manure sent to digesters has been distributed according to the type of manure (liquid/slurry and solid) and the animal category using the distribution of the national inventory.
Based on the coefficients of the national inventory related to annual production of manure per head and animal category and type of manure, it is possible to estimate *the number of head equivalent* per animal category and type of manure.
Finally, *CH_4 emissions from manure* sent to digesters are calculated multiplying these equivalent heads by EFs of the inventory expressed in kg CH_4/head per year.

CH_4 emissions from losses of bio-digesters
Losses from digesters are equal to 1% of biogas produced. Considering that CH_4 content is equal to 55% of biogas the resulting amount of CH_4 is calculated and added to the total CH_4 emissions from manure management and distributed by animal category.

N_2O emissions
On the basis of CRPA data on measurements of nitrogen quantities in livestock manure (downstream of releases to housing and storage) per animal category and type of manure, the nitrogen quantities in livestock manure sent to anaerobic digestion were estimated. The coefficients, expressed as g N/kg manure, were calculated gross of losses and then the losses to housing were deducted. The resulting coefficients were then multiplied by the quantities of manure sent for anaerobic digestion. The whole time series was updated in submission 2021.
Consequently, the amount of nitrogen stored in the other storage system has been revised too subtracting these N amounts from the relevant animal categories and their type of manure.
Emission factor of the 2006 IPCC Guidelines has been used to estimate the N_2O emissions from manure stored in digesters. The value is zero as reported in the 2006 IPCC Guidelines (IPCC, 2006).

MCF for anaerobic digester
The methane conversion factor has been calculated according to Formula 1 in table 10.17 in the 2006 IPCC Guidelines:
MCF = [{CH_4 prod - CH_4 used - CH_4 flared + (MCFstorage /100 * Bo * VSstorage * 0.67)}/ (Bo* VSstorage * 0.67)] *100

Where:
CH_4 prod = methane production in digester, (kg CH_4).
Note: When a gas tight coverage of the storage for digested manure is used, the gas production of the storage should be included.
CH_4 used = amount of methane gas used for energy, (kg CH_4)
CH_4 flared = amount of methane flared, (kg CH_4)
MCFstorage = MCF for CH_4 emitted during storage of digested manure (%)
VSstorage = amount of VS excreted that goes to storage prior to digestion (kg VS)
When a gas tight storage is included: MCFstorage = 0; otherwise MCFstorage = MCF value for liquid storage

The equation (CH_4 prod - CH_4 used - CH_4 flared) is equal to CH_4 emissions from losses of bio-digesters that is equal to 1% of biogas produced (as reported above): 1347 Mmc (millions of cubic meters of biogas produced

from manure in 2020) * 0.01 * 0.55 (methane content is assumed to be 55%) = 7.41 Mmc CH_4. The amount of volatile solids (VS) has been calculated multiplying the amount of animal manure by different type of feed treated in bio-digesters to the average VS content by different type of feed (these values can be obtained from the values shown in Table A.7.12): 2153 kt (animal manure only) * 139 kg VS/t feed + 927 kt (animal manure from the co-digestion of multiple substrates such as "animal manure + energy crops + agro-industrial by-products")* 232 kg VS/t feed + 4333 kt (animal manure from the co-digestion of multiple substrates such as "animal manure + energy crops") * 226 kg VS/t feed + 7618 kt (animal manure from the co-digestion of multiple substrates such as "animal manure + agro-industrial by-products") * 169 kg VS/t feed = 2786 kt VS. CH_4 producing capacity (Bo) is equal to 0.22 mc CH_4/kg VS. MCF = 7.41 Mmc CH_4 / 2786 kt VS / 0.22 mc CH_4/kg VS *100 = 1.21%. In addition, digestate covered storage units are in places at the Italian bio-digesters so according to the Guidelines $MCF_{storage}$ is equal to 0.
The figure 0.22 mc CH_4/kg VS used in the calculation is an average of the values related to pigs slurry, cattle slurry and solid manure, cattle separate solid manure. These values represent the maximum methanigenous potential and have been measured in the laboratory trying to simulate in a controlled environment what happens in an anaerobic digester (as reported in CRPA, 2012). This value is different respect to the values in CRF table3.B(a)s1 that have been estimated with the equation 10.23 of the 2006 IPCC Guidelines. However, the measured and estimated data should be comparable.
In response to the 2018 UNFCCC review process, more information on the estimate of weighted average values of MCF and Bo for animal manure digested in anaerobic digesters have been provided above, reporting a numerical example of how the MCF value is calculated including information on the data sources for the different parameters used.
The biogas flared at bio-digesters has been assumed equal to 4% of the total biogas produced (CRPA, 2016[a]).
In the CRF table 3B(a)s2, the nitrogen allocation and MCF supplied by climate region and manure management systems are reported.
The average CH_4 producing potential reported in Table 3B(a)s1 of the CRF has been revised accordingly using the average MCF for all manure management systems and the 2006 IPCC Guidelines' Equation 10.23.

4) Time series of total manure sent to anaerobic digestion

The amount of animal manure treated in the bio-digesters has been developed for the years 2007, 2010, 2011 and 2012 onwards, as described in the previous paragraphs. In order to develop the complete time series, the following assumptions have been considered taking in account the information provided by TERNA:

- For the years 1990 no changes in the estimation occurred because digesters were not in place;
- For the years 1991-2000 the amount of animal manure treated in the bio-digesters has been estimated based on the energy production from anaerobic digestion of animal manure;
- For the years 2001-2006 the amount of animal manure treated in the bio-digesters has been estimated based on the biogas from animal manure used for energy production;
- For the years 2008 and 2009 the amount of animal manure treated in the bio-digesters has been estimated based on the total biogas used for energy production.

In Table A.7.13 the percentages of animals in temperate zone based on data from the FSS 2005, provided by ISTAT, and the average temperature at provincial level are shown.
In Table A.7.14-16 all data, parameters and equations used to estimate CH_4 emission from manure management for cattle and buffalo are reported. These data are: the average monthly temperature; storage temperatures and timescale for emptying manure storages; the amount of manure generated by each subcategory of cattle and buffalo (m^3/head day^{-1}); the *methane emission rates* (g CH_4/m^3 day^{-1}) calculated on the basis of the equations 5.1 and 5.2 reported in the paragraph 5.3.2; the specific conversion factors (g CH_4/kg VS); the content of VS in manure (g VS/head day^{-1}) produced by different subcategories of cattle (dairy and non-dairy cattle) and buffalo (cow buffaloes and other buffaloes); the slurry and solid manure EFs (kg CH_4/head $year^{-1}$) calculated with Equations 5.3 and 5.4 respectively; the total (slurry and solid manure) amount of VS handled in slurry/liquid and solid manure management systems for the entire reporting period; the total (slurry and solid manure) CH_4 emission factors.

Table A.7.13 Distribution of animals from the FSS 2005 (ISTAT) and average temperature at provincial level

Code of provinces	Name of provinces	Average temperature aggregated per province by weighting with livestock units	Non-dairy cattle	Dairy cattle	Buffalo	Other swine	Sows	Sheep	Goats	Horses	Mules and asses	Broilers (2)	Laying hens (2)	Other poultry	Rabbits
001	Torino	13.3	185,441	60,950	137	141,054	9,422	11,842	5,399	16,626	285	1,384,201	605,549	121,305	476,111
002	Vercelli	13.0	6,139	3,361	0	19,044	3,023	4,530	2,747	378	177	240,844	90	367,320	38,487
003	Novara	12.4	11,634	11,941	659	36,837	4,066	442	1,464	2,024	0	163,436	135,522	26,764	206,579
004	Cuneo	13.1	360,266	79,864	0	731,302	51,882	24,890	7,375	353	7	1,906,594	513,460	794,541	1,533,321
005	Asti	13.5	44,507	965	0	16,147	1,305	2,118	3,771	2,531	83	517,799	407,027	34,957	144,573
006	Alessandria	13.5	37,346	3,671	0	24,322	1,120	3,109	3,929	277	80	73,144	216,432	360,226	43,049
007	Aosta	(1)	17,379	22,332	0	26	0	2,586	3,339	116	32	9	2,602	98	1,832
008	Imperia	14.4	2,372	353	0	3	0	843	2,686	53	0	26	557	4	7,288
009	Savona	12.9	4,030	58	0	107	0	16,799	450	154	8	5,370	19,638	156	84,045
010	Genova	12.1	5,357	1,551	0	134	39	4,984	3,266	2,844	149	12,259	46,343	5,251	29,698
011	La Spezia	13.7	3,063	591	0	184	11	2,627	978	654	36	5,012	12,435	1,077	43,258
012	Varese	11.9	13,632	5,249	7	2,161	88	5,275	2,655	3,128	465	50,165	344,100	175,959	22,252
013	Como	12.0	11,270	7,743	2	844	178	5,475	9,227	3,616	591	135,711	29,395	13,744	88,340
014	Sondrio	11.4	9,318	15,448	0	835	13	7,028	12,890	654	503	679,686	58,918	24	293
015	Milano	13.4	62,266	36,960	1,782	105,264	7,399	2,833	1,551	2,431	122	97,755	710,011	59,622	5,330
016	Bergamo	13.7	112,201	69,614	643	301,455	30,604	28,808	14,355	9,783	753	1,475,925	1,529,460	516,977	5,959
017	Brescia	13.6	342,654	148,660	859	1,325,421	107,005	40,160	10,360	6,638	12	14,969,749	3,551,027	2,087,292	78,676
018	Pavia	13.6	20,446	9,054	0	239,372	15,395	0	2,045	640	23	2,104	174,942	215,736	0
019	Cremona	13.6	165,913	115,308	676	619,897	70,275	2,299	65	1,255	18	2,799,928	1,541,962	1,641,787	6,804
020	Mantova	13.7	265,591	109,883	0	1,055,515	60,972	0	870	683	87	1,182,334	5,613,807	817,826	17,568
021	Bolzano	11.3	67,713	83,892	0	13,775	311	50,645	19,508	6,354	428	85	139,010	2,096	40,398
022	Trento	11.0	17,303	29,737	0	7,205	171	29,731	9,778	3,313	571	1,182,144	397,493	34,367	174,295
023	Verona	13.3	190,794	35,635	0	308,473	11,067	56	177	9,441	0	16,208,619	4,569,421	11,982,064	3,443,690
024	Vicenza	13.4	125,108	55,512	17	40,793	2,005	5,790	456	1,482	525	3,768,250	462,832	802,257	196,126
025	Belluno	10.7	7,385	5,953	0	51,281	10,121	3,693	840	1,578	525	2,673	163	3,312	84,823
026	Treviso	13.4	155,378	23,915	1,260	90,117	13,957	1	149	293	2	2,551,739	1,784,328	123,347	2,367,946
027	Venezia	13.8	50,470	10,028	366	64,423	4,807	0	1,291	1,784	48	766,865	2,518,034	409,170	17,047
028	Padova	13.7	157,703	35,518	916	116,291	12,043	3,763	86	3,291	41	1,988,851	1,801,912	1,194,511	3,613,169
029	Rovigo	13.8	42,008	3,964	0	63,709	6,297	1,633	427	805	648	529,387	117,033	586,075	12,874
030	Udine	13.5	28,891	32,597	0	61,905	2,591	2,065	1,821	1,717	202	2,801,700	5,597	284,658	871,719
031	Gorizia	13.4	3,379	3,626	0	26,850	0	0	0	107	0	248,250	131,708	924,779	69,399
032	Trieste	13.2	598	201	0	1,395	0	0	0	0	0	8,303	6,894	9,909	3,825
033	Piacenza	13.0	46,684	31,700	13	73,967	4,598	44	8	2,589	273	84,174	173,053	0	153

Code of provinces	Name of provinces	Average temperature aggregated per province by weighting with livestock units	Non-dairy cattle	Dairy cattle	Buffalo	Other swine	Sows	Sheep	Goats	Horses	Mules and asses	Broilers (2)	Laying hens (2)	Other poultry	Rabbits
034	Parma	13.6	68,174	99,234	0	143,740	9,496	20	91	4,681	33	89,323	43,864	314	8,811
035	Reggio nell'Emilia	13.5	66,270	79,949	247	458,294	21,186	607	725	3,827	243	361,411	76,942	42,922	3,023
036	Modena	13.4	67,416	60,029	0	406,547	41,590	64	208	2,533	120	87,552	214,697	113,066	631,984
037	Bologna	13.9	20,526	8,482	0	41,449	3,503	12,056	236	9,883	163	47,197	1,276,246	122,438	0
038	Ferrara	13.7	45,143	10,999	0	23,212	3,623	0	98	4,385	91	0	102,049	57,109	7,138
039	Ravenna	13.7	13,141	3,179	0	43,760	3,106	14,092	682	3,522	764	698,792	2,308,670	3,301,798	379,957
040	Forlì-Cesena	13.7	18,275	2,382	1	93,476	15,742	26,716	1,127	3,380	12	16,350,182	7,581,497	7,795,705	243,449
041	Pesaro e Urbino	13.5	30,155	2,429	0	12,423	623	100,473	1,654	3,286	64	39,984	311,955	51,308	298,142
042	Ancona	14.0	9,137	1,141	0	14,308	1,415	11,661	486	137	25	1,382,625	67,488	19,237	108,960
043	Macerata	13.9	13,794	1,378	0	9,894	738	46,279	903	589	102	1,167,510	67	0	375,329
044	Ascoli Piceno	14.3	20,587	288	0	77,063	1,228	76,380	4,166	3,286	507	1,060,249	2,310,685	4,027	164,214
045	Massa-Carrara	13.2	4,167	926	57	3,480	263	11,899	855	2,752	386	14,659	21,813	931	54,446
046	Lucca	14.2	3,560	988	0	847	6	16,156	289	262	0	33,688	53,335	958	39,418
047	Pistoia	14.7	8,092	86	0	673	38	5,605	388	4,210	804	0	516	0	1,645
048	Firenze	14.2	13,514	3,265	0	36,506	1,557	31,180	1,899	3,729	678	101,134	48,525	135,053	29,539
049	Livorno	15.0	1,999	459	0	273	153	11,793	133	1,723	175	980	3,449	59,521	7,174
050	Pisa	14.4	9,570	1,548	0	31,749	5,708	54,005	869	1,172	335	8,725	246,875	1,619	3,208
051	Arezzo	13.2	9,710	246	22	76,399	8,336	33,407	3,649	1,144	491	187,271	105,848	1,436	283,164
052	Siena	13.5	19,327	1,026	0	25,569	3,053	144,022	788	693	311	3,574	285,186	7,576	41,695
053	Grosseto	14.8	24,968	5,363	395	30,962	2,853	375,071	1,617	7,262	241	6,741	16,471	8,498	68,160
054	Perugia	13.6	41,054	11,904	0	223,062	4,769	145,178	6,516	7,151	251	2,786,387	1,035,490	310,913	146,088
055	Terni	13.7	14,305	1,268	0	16,236	1,279	34,266	780	3,671	286	312,851	71,851	0	170,015
056	Viterbo	14.4	21,859	10,870	921	14,188	1,027	290,585	415	2,287	641	509,739	124,450	80,398	238,483
057	Rieti	14.6	26,425	7,172	868	3,744	204	92,899	4,755	9,425	861	362,698	126,234	1,552	51,895
058	Roma	15.3	50,058	30,440	178	7,339	60	136,543	1,068	9,081	847	352,347	4,391	411	74,045
059	Latina	15.9	37,987	31,533	28,647	13,181	96	62,152	20,800	2,925	509	39,081	292,776	1,160	632,981
060	Frosinone	14.4	38,070	12,196	9,745	11,437	140	83,099	4,415	3,602	318	53,017	53,417	1,036	61,351
061	Caserta	15.5	27,251	23,498	94,898	14,949	861	31,420	393	206	115	129,455	487,659	4,417	113,682
062	Benevento	14.0	34,280	11,568	486	27,936	7,221	84,341	7,127	755	1,581	2,272,767	14,875	2,544	63,136
063	Napoli	16.2	3,224	2,032	49	3,245	180	55	3,886	10	65	111,888	327,038	262,730	2,960
064	Avellino	13.1	23,552	7,994	0	7,708	78	68,246	4,530	993	473	106,903	210,764	9,201	150,075
065	Salerno	16.2	50,412	36,366	55,014	41,469	1,763	112,374	38,780	3,231	1,189	93,292	106,829	7,965	88,775
066	L'Aquila	12.0	12,215	4,450	0	14,687	807	104,169	1,516	11,451	833	2,537	65,951	583	151,727
067	Teramo	14.8	26,091	12,463	0	26,659	2,743	157,028	1,411	2,608	73	182,779	77,359	218,748	50,584

Code of provinces	Name of provinces	Average temperature aggregated per province by weighting with livestock units	Non-dairy cattle	Dairy cattle	Buffalo	Other swine	Sows	Sheep	Goats	Horses	Mules and asses	Broilers (2)	Laying hens (2)	Other poultry	Rabbits
068	Pescara	14.9	12,430	4,218	0	12,178	737	49,259	191	152	136	201,951	54,764	163	121,929
069	Chieti	15.4	21,034	3,141	0	13,904	1,146	23,913	1,610	1,567	285	968,714	96,927	11,236	65,367
070	Campobasso	13.8	18,793	13,149	229	27,232	1,345	60,164	3,301	1,482	29	7,067,027	144,105	923	3,226
071	Foggia	15.2	27,297	6,128	4,543	10,279	61	100,938	23,540	2,851	1,403	699,034	14,783	102	6,242
072	Bari	14.4	35,866	31,546	199	5,149	752	64,117	3,937	3,065	32	4,673	306,370	1,409	117,228
073	Taranto	15.0	22,345	25,796	0	12,844	178	24,980	6,611	3,611	93	1,163	211,415	60,027	80,720
074	Brindisi	16.0	2,156	7,166	0	559	40	6,321	5,116	531	57	1,097	324,767	300	34,077
075	Lecce	16.6	3,546	2,251	0	503	235	27,399	6,805	552	24	14	165,333	13	238
076	Potenza	14.3	65,499	25,430	99	56,040	1,998	404,287	77,440	4,746	581	72,778	44,609	2,889	512,259
077	Matera	15.4	15,452	9,590	515	7,642	293	102,658	37,197	2,988	103	3,752	74,191	5,249	314,349
078	Cosenza	15.9	35,907	5,883	82	44,360	2,064	170,629	84,350	3,003	227	145,554	160,280	2,669	98,547
079	Catanzaro	16.1	4,183	920	0	6,377	343	24,168	7,030	38	0	622	9,367	0	475
080	Reggio di Calabria	17.5	19,585	1,807	0	14,070	1,037	50,802	38,585	253	0	13,029	48,974	253	40,978
081	Trapani	18.1	3,430	888	0	186	69	57,240	1,065	3,544	73	129	31,954	34	3,647
082	Palermo	17.2	46,032	4,790	0	2,679	875	132,035	12,444	1,562	63	32	316,059	0	290
083	Messina	17.4	65,155	2,062	0	13,432	1,005	93,336	52,551	6,483	1,776	102	376,100	106	0
084	Agrigento	17.9	3,567	1,073	0	2,436	237	46,636	1,332	19	20	0	26,829	0	35,568
085	Caltanissetta	16.8	5,459	1,216	0	116	28	48,617	1,889	332	30	0	76,878	0	0
086	Enna	16.1	48,664	1,489	0	4,227	440	110,030	5,190	594	172	5	65,692	0	0
087	Catania	17.4	17,120	2,856	0	311	110	38,035	2,502	1,389	5	16	241,512	212	16,676
088	Ragusa	18.1	49,505	26,664	0	4,967	315	18,496	0	903	90	392,370	721,491	0	561
089	Siracusa	17.8	57,381	8,293	71	16,803	35	75,830	6,523	1,098	426	242,604	654,764	0	30,031
090	Sassari	15.1	117,502	2,374	0	31,935	14,538	1,217,792	30,994	5,935	1,098	0	100,557	0	140,560
091	Nuoro	14.9	64,036	5,800	0	35,439	13,568	918,328	85,029	10,951	687	42,136	211,093	282,830	272,447
092	Cagliari	15.8	16,639	1,074	0	82,024	23,342	819,856	156,043	2,633	856	67,976	681,328	920,414	464
093	Pordenone	13.8	26,760	14,452	0	147,435	40,071	997	0	665	10	1,303,096	262,413	138,240	78,768
094	Isernia	13.1	16,093	7,221	131	11,785	174	45,531	3,122	1,008	35	641,701	1,511	0	14,747
095	Oristano	16.6	37,907	24,089	0	11,760	7,127	455,419	10,775	3,026	556	14,240	6,134	767	25,286
096	Biella	12.4	8,850	3,617	0	16,082	5,709	13,521	2,721	606	240	222	765	97,447	0
097	Lecco	12.5	4,335	1,634	0	2,460	339	1,924	1,189	1,908	277	288,301	5,001	1,219	7,950
098	Lodi	13.6	53,611	46,294	353	358,589	25,804	0	6	745	0	16	1,257,958	92	0
099	Rimini	13.5	4,523	166	0	22,083	1,454	7,946	0	1,077	150	184,953	145,785	621,136	0
100	Prato	14.0	0	0	0	0	0	0	0	187	0	0	0	0	0
101	Crotone	16.8	21,933	846	0	3,727	50	44,091	21,369	756	235	373,670	102,356	77	4,724

Code of provinces	Name of provinces	Average temperature aggregated per province by weighting with livestock units	Non-dairy cattle	Dairy cattle	Buffalo	Other swine	Sows	Sheep	Goats	Horses	Mules and asses	Broilers (2)	Laying hens (2)	Other poultry	Rabbits
102	Vibo Valentia	15.3	6,206	2,529	3	2,082	108	48,520	3,067	143	0	235	52,649	0	1,697
103	Verbano-Cusio-Ossola	11.6	2,570	2,567	0	163	7	12,443	11,160	624	200	381	1,854	223	1,049
Total			4,409,921	1,842,004	205,093	8,478,427	721,843	7,954,167	945,895	278,471	30,254	97,532,025	52,692,584	38,370,412	20,504,282
N animals in temperate zone			794,593	240,996	184,001	354,560	56,455	4,055,304	574,903	55,655	10,226	3,649,259	5,567,619	1,218,114	1,732,221
% animals in temperate zone			18.02	13.08	89.72	4.18	7.82	50.98	60.78	19.99	33.80	3.74	10.57	3.17	8.45

(1) Temperature data above 1000 m were not considered; (2) 2005 FSS data before recalculation based on the updated estimate of laying hens and broilers described in the paragraph 5.3.2 Other livestock categories.

Table A.7.14. Data, parameters and equations used to estimate CH4 emission from manure management for cattle and buffalo (solid manure)

CATTLE and BUFFALO

heads (heads)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Calves	300,000	458,936	408,000	500,049	507,452	492,126	492,461	485,250	468,628	461,877	463,597
Male cattle	1,994,704	1,829,546	1,564,000	1,372,963	1,116,364	959,551	1,012,847	1,035,862	1,059,268	1,048,733	1,047,980
Female cattle	2,503,044	2,242,966	2,428,000	2,065,176	2,090,412	2,183,502	2,302,364	2,346,675	2,387,475	2,468,778	2,481,914
Other non dairy cattle	312,649	657,856	588,000	471,733	372,089	319,685	300,331	290,486	314,501	352,442	361,142
Dairy cattle	2,641,755	2,079,783	2,065,000	1,842,004	1,746,140	1,826,484	1,821,764	1,791,120	1,693,332	1,643,117	1,638,382
Cow buffalo	61,800	93,528	116,000	137,242	244,599	230,323	238,702	249,059	246,152	232,605	232,887
Other buffaloes	32,700	54,876	76,000	67,851	120,487	144,135	146,419	151,733	155,185	169,681	174,140

solid manure

solid manure (m3 head-1day-1)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	average m3/heads day-1 1990-2000	average m3/heads day-1 from 2001
Calves	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000
Male cattle	0.0177	0.0187	0.0181	0.0188	0.0175	0.0154	0.0149	0.0151	0.0152	0.0153	0.0153	0.018	0.017
Female cattle	0.0207	0.0207	0.0211	0.0214	0.0197	0.0179	0.0175	0.0174	0.0176	0.0173	0.0172	0.021	0.020
Other non dairy cattle	0.0356	0.0356	0.0356	0.0356	0.0326	0.0287	0.0280	0.0280	0.0280	0.0280	0.0280	0.036	0.032
Dairy cattle	0.0504	0.0504	0.0504	0.0504	0.0432	0.0366	0.0352	0.0352	0.0352	0.0352	0.0352	0.050	0.043
Cow buffalo	0.0598	0.0583	0.0568	0.0553	0.0466	0.0357	0.0335	0.0335	0.0335	0.0335	0.0335	0.058	0.046
Other buffaloes	0.0187	0.0182	0.0178	0.0174	0.0165	0.0154	0.0152	0.0152	0.0152	0.0152	0.0152	0.018	0.016

CH_4 EF per solid manure model 1990-2000	temperature	temp storage	storage time (days)	FE CH4 (g/m3 day) - methane emission rate	Calves m3/head	Male cattle m3/head	Female cattle m3/head	Other non dairy cattle m3/head	Dairy cattle m3/head	Cow buffalo m3/head	Other buffaloes m3/head	Calves g CH_4/head	Male cattle g CH_4/head	Female cattle g CH_4/head	Other non dairy cattle g CH_4/head	Dairy cattle g CH_4/head	Cow buffalo g CH_4/head	Other buffaloes g CH_4/head
January	5.1	11.3	75.0	0.3	0.0	41.6	48.7	82.8	117.1	135.6	42.4	0.0	12.9	15.1	25.7	36.3	42.1	13.2
February	6.3	12.7	105.0	0.4	0.0	52.6	61.6	104.7	148.1	171.4	53.6	0.0	18.9	22.1	37.6	53.1	61.5	19.2
March	9.2	17.0	15.0	0.5	0.0	8.3	9.7	16.6	23.4	27.1	8.5	0.0	4.6	5.4	9.1	12.9	14.9	4.7
April	12.3	23.4	45.0	1.0	0.0	24.2	28.3	48.1	68.0	78.7	24.6	0.0	25.1	29.4	49.9	70.6	81.8	25.6
May	17.1	37.9	75.0	4.4	0.0	41.6	48.7	82.8	117.1	135.6	42.4	0.0	184.3	215.7	366.5	518.6	600.3	187.7
June	20.8	55.4	105.0	25.6	0.0	56.4	66.0	112.2	158.7	183.7	57.4	0.0	1444.3	1690.3	2872.2	4063.9	4703.9	1471.0
July	23.6	73.2	15.0	100.0	0.0	8.3	9.7	16.6	23.4	27.1	8.5	0.0	832.6	974.4	1655.7	2342.7	2711.7	848.0
August	23.3	71.5	45.0	100.0	0.0	25.0	29.2	49.7	70.3	81.3	25.4	0.0	2497.8	2923.3	4967.2	7028.1	8135.0	2544.0
September	19.6	48.8	75.0	13.2	0.0	40.3	47.2	80.1	113.4	131.2	41.0	0.0	530.8	621.2	1055.5	1493.4	1728.6	540.6
October	14.6	29.4	105.0	1.9	0.0	58.3	68.2	115.9	164.0	189.8	59.4	0.0	110.3	129.0	219.3	310.2	359.1	112.3
November	8.7	16.3	15.0	0.5	0.0	8.1	9.4	16.0	22.7	26.2	8.2	0.0	4.1	4.8	8.2	11.6	13.4	4.2
December	6.1	12.4	45.0	0.3	0.0	25.0	29.2	49.7	70.3	81.3	25.4	0.0	8.7	10.1	17.2	24.4	28.2	8.8
Total	13.9	27.4		1.6	0.0	389.7	456.1	775.0	1096.5	1269.2	396.9	0.0	5674.2	6640.9	11284.1	15965.8	18480.3	5779.2
								VS production (g VS/head day-1)					1916.29	2242.78	3810.87	5391.98	6241.17	1951.74
								Specific conversion factor (gCH4/KgVS head day-1)					8.11	8.11	8.11	8.11	8.11	8.11

CH_4 EF per solid manure model from 2001	temperature	temp storage	storage time (days)	FE CH4 (g/m3 day) - methane emission rate	Calves m3/head	Male cattle m3/head	Female cattle m3/head	Other non dairy cattle m3/head	Dairy cattle m3/head	Cow buffalo m3/head	Other buffaloes m3/head	Calves g CH_4/head	Male cattle g CH_4/head	Female cattle g CH_4/head	Other non dairy cattle g CH_4/head	Dairy cattle g CH_4/head	Cow buffalo g CH_4/head	Other buffaloes g CH_4/head
January	4.7	10.9	75.0	0.3	0.0	39.6	45.8	74.9	100.7	106.1	38.2	0.0	11.8	13.6	22.2	29.9	31.5	11.3
February	5.4	11.6	105.0	0.3	0.0	50.1	57.9	94.6	127.3	134.2	48.3	0.0	16.0	18.5	30.2	40.6	42.9	15.4
March	9.3	17.2	15.0	0.6	0.0	7.9	9.2	15.0	20.1	21.2	7.6	0.0	4.4	5.1	8.4	11.3	11.9	4.3
April	12.7	24.4	45.0	1.2	0.0	23.0	26.6	43.5	58.4	61.6	22.2	0.0	26.5	30.6	50.1	67.3	71.0	25.6
May	17.6	40.1	75.0	5.5	0.0	39.6	45.8	74.9	100.7	106.1	38.2	0.0	219.8	254.1	415.1	558.3	588.6	212.0
June	21.5	59.3	105.0	37.7	0.0	53.7	62.1	101.4	136.4	143.8	51.8	0.0	2024.5	2340.4	3823.8	5142.5	5421.8	1952.4
July	24.2	78.2	15.0	100.0	0.0	7.9	9.2	15.0	20.1	21.2	7.6	0.0	792.6	916.3	1497.0	2013.3	2122.6	764.4
August	23.9	75.9	45.0	100.0	0.0	23.8	27.5	44.9	60.4	63.7	22.9	0.0	2377.8	2748.8	4491.0	6039.8	6367.9	2293.1
September	19.8	50.1	75.0	15.1	0.0	38.4	44.3	72.4	97.4	102.7	37.0	0.0	578.4	668.6	1092.4	1469.1	1548.9	557.7
October	15.0	30.6	105.0	2.1	0.0	55.5	64.1	104.8	140.9	148.6	53.5	0.0	118.3	136.7	223.4	300.4	316.7	114.0
November	9.1	16.9	15.0	0.5	0.0	7.7	8.9	14.5	19.5	20.5	7.4	0.0	4.2	4.8	7.9	10.6	11.2	4.0
December	5.3	11.4	45.0	0.3	0.0	23.8	27.5	44.9	60.4	63.7	22.9	0.0	7.5	8.6	14.1	19.0	20.0	7.2
Total	14.0	27.9		1.6	0.0	371.0	428.9	700.7	942.3	993.5	357.8	0.0	6181.7	7146.1	11675.6	15702.0	16555.0	5961.4
								VS production (g VS/head day-1)					1824.28	2108.86	3445.54	4633.77	4885.49	1759.26
								Specific conversion factor (gCH4/KgVS head day-1)					9.28	9.28	9.28	9.28	9.28	9.28

VS production (g VS/head day-1)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Calves	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Male cattle	1896.0	2001.1	1932.3	2012.2	1867.8	1650.2	1590.4	1612.2	1625.7	1633.1	1635.3
Female cattle	2210.8	2216.4	2254.2	2289.8	2109.9	1911.2	1872.9	1863.8	1879.9	1851.2	1841.9
Other non dairy cattle	3810.9	3810.9	3810.9	3810.9	3484.2	3075.9	2994.3	2994.3	2994.3	2994.3	2994.3
Dairy cattle	5392.0	5392.0	5392.0	5392.0	4618.6	3912.3	3771.0	3771.0	3771.0	3771.0	3771.0
Cow buffalo	6403.9	6241.2	6078.4	5915.7	4984.8	3821.3	3588.6	3588.6	3588.6	3588.6	3588.6
Other buffaloes	1998.6	1951.7	1904.9	1858.1	1767.0	1653.1	1630.3	1630.3	1630.3	1630.3	1630.3

CH_4 EF (kg CH4/head year)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Calves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Male cattle	5.61	5.93	5.72	6.82	6.33	5.59	5.39	5.46	5.51	5.53	5.54
Female cattle	6.55	6.56	6.67	7.76	7.15	6.48	6.35	6.32	6.37	6.27	6.24
Other non dairy cattle	11.28	11.28	11.28	12.91	11.81	10.42	10.15	10.15	10.15	10.15	10.15
Dairy cattle	15.97	15.97	15.97	18.27	15.65	13.26	12.78	12.78	12.78	12.78	12.78
Cow buffalo	18.96	18.48	18.00	20.05	16.89	12.95	12.16	12.16	12.16	12.16	12.16
Other buffaloes	5.92	5.78	5.64	6.30	5.99	5.60	5.52	5.52	5.52	5.52	5.52

Table A.7.15. Data, parameters and equations used to estimate CH4 emission from manure management for cattle and buffalo (slurry manure)

slurry

slurry (m3 head-1day-1)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	average m3/heads day-1 1990-2000	average m3/heads day-1 from 2001
Calves	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
Male cattle	0.018	0.019	0.019	0.019	0.020	0.019	0.019	0.020	0.020	0.020	0.020	0.018	0.019
Female cattle	0.011	0.011	0.011	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.011
Other non dairy cattle	0.015	0.015	0.015	0.015	0.014	0.012	0.012	0.012	0.012	0.012	0.012	0.015	0.014
Dairy cattle	0.021	0.021	0.021	0.021	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.021	0.027
Cow buffalo	0.016	0.017	0.018	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.017	0.019
Other buffaloes	0.011	0.012	0.012	0.012	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.012	0.011

CH_4 EF per slurry manure model 1990-2000	temperature	storage time (days)	FE CH4 (g/m3 day) - methane emission rate	Calves m3/head	Male cattle m3/head	Female cattle m3/head	Other non dairy cattle m3/head	Dairy cattle m3/head	Cow buffalo m3/head	Other buffaloes m3/head	Calves g CH_4/head	Male cattle g CH_4/head	Female cattle g CH_4/head	Other non dairy cattle g CH_4/head	Dairy cattle g CH_4/head	Cow buffalo g CH_4/head	Other buffaloes g CH_4/head
January	5.1	75.0	3.7	55.0	43.0	25.4	35.5	49.9	38.6	27.0	201.1	157.1	93.0	129.7	182.4	141.2	98.9
February	6.3	105.0	4.2	69.6	54.3	32.2	44.9	63.1	48.8	34.2	293.5	229.3	135.7	189.3	266.1	206.1	144.3
March	9.2	15.0	5.9	11.0	8.6	5.1	7.1	10.0	7.7	5.4	65.3	51.0	30.2	42.1	59.2	45.9	32.1
April	12.3	45.0	8.6	31.9	24.9	14.8	20.6	29.0	22.4	15.7	276.2	215.7	127.7	178.2	250.4	194.0	135.8
May	17.1	75.0	15.3	55.0	43.0	25.4	35.5	49.9	38.6	27.0	842.1	657.8	389.3	543.2	763.6	591.3	414.0
June	20.8	105.0	24.0	74.5	58.2	34.5	48.1	67.6	52.3	36.6	1790.3	1398.4	827.7	1154.8	1623.3	1257.2	880.1
July	23.6	15.0	33.4	11.0	8.6	5.1	7.1	10.0	7.7	5.4	367.5	287.1	169.9	237.1	333.2	258.1	180.7
August	23.3	45.0	32.5	33.0	25.8	15.3	21.3	29.9	23.2	16.2	1071.1	836.6	495.2	690.9	971.2	752.1	526.5
September	19.6	75.0	20.7	53.2	41.6	24.6	34.3	48.3	37.4	26.2	1099.4	858.8	508.3	709.2	996.9	772.0	540.4
October	14.6	105.0	11.3	77.0	60.1	35.6	49.7	69.8	54.1	37.9	872.6	681.6	403.5	562.9	791.2	612.8	429.0
November	8.7	15.0	5.6	10.6	8.3	4.9	6.9	9.7	7.5	5.2	60.0	46.9	27.7	38.7	54.4	42.1	29.5
December	6.1	45.0	4.1	33.0	25.8	15.3	21.3	29.9	23.2	16.2	134.9	105.4	62.4	87.0	122.3	94.7	66.3
Total	13.9		10.5	514.9	402.2	238.1	332.1	466.9	361.6	253.1	7074.1	5525.6	3270.6	4563.1	6414.3	4967.6	3477.5
							VS production (g VS/head day-1)				1123.733	877.749	519.545	724.863	1018.921	789.118	552.404
							Specific conversion factor (gCH4/KgVS head day-1)				17.25	17.25	17.25	17.25	17.25	17.25	17.25

CH_4 EF per slurry manure model from 2001	temperature	storage time (days)	(g/m3 day) - methane emission rate	Calves m3/head	Male cattle m3/head	Female cattle m3/head	Other non dairy cattle m3/head	Dairy cattle m3/head	Cow buffalo m3/head	Other buffaloes m3/head	Calves g CH_4/head	Male cattle g CH_4/head	Female cattle g CH_4/head	Other non dairy cattle g CH_4/head	Dairy cattle g CH_4/head	Cow buffalo g CH_4/head	Other buffaloes g CH_4/head
January	4.7	75.0	3.5	55.0	45.0	24.5	31.7	62.9	43.5	26.2	191.9	157.1	85.5	110.6	219.4	151.9	91.4
February	5.4	105.0	3.8	69.6	56.9	31.0	40.1	79.5	55.1	33.1	262.1	214.5	116.7	151.1	299.7	207.5	124.8
March	9.3	15.0	6.0	11.0	9.0	4.9	6.3	12.6	8.7	5.2	66.2	54.2	29.5	38.1	75.7	52.4	31.5
April	12.7	45.0	9.1	31.9	26.1	14.2	18.4	36.5	25.3	15.2	290.7	238.0	129.5	167.6	332.5	230.2	138.5
May	17.6	75.0	16.4	55.0	45.0	24.5	31.7	62.9	43.5	26.2	901.7	738.2	401.6	519.8	1031.2	713.9	429.4
June	21.5	105.0	26.0	74.5	61.0	33.2	43.0	85.2	59.0	35.5	1939.2	1587.5	863.6	1117.9	2217.7	1535.2	923.5
July	24.2	15.0	36.1	11.0	9.0	4.9	6.3	12.6	8.7	5.2	396.9	324.9	176.8	228.8	453.9	314.2	189.0
August	23.9	45.0	34.8	33.0	27.0	14.7	19.0	37.7	26.1	15.7	1149.8	941.3	512.1	662.9	1315.0	910.3	547.6
September	19.8	75.0	21.3	53.2	43.6	23.7	30.7	60.9	42.1	25.4	1135.5	929.6	505.7	654.6	1298.6	899.0	540.8
October	15.0	105.0	11.9	77.0	63.0	34.3	44.4	88.1	61.0	36.7	914.7	748.9	407.4	527.3	1046.1	724.2	435.6
November	9.1	15.0	5.9	10.6	8.7	4.7	6.1	12.2	8.4	5.1	62.9	51.5	28.0	36.2	71.9	49.8	29.9
December	5.3	45.0	3.7	33.0	27.0	14.7	19.0	37.7	26.1	15.7	122.3	100.1	54.5	70.5	139.9	96.8	58.3
Total	14.0		10.7	514.9	421.5	229.3	296.9	588.9	407.6	245.2	7433.8	6085.8	3310.7	4285.7	8501.6	5885.3	3540.4
							VS production (g VS/head day-1)				1123.733	919.965	500.465	647.846	1285.150	889.654	535.181
							Specific conversion factor (gCH4/KgVS head day-1)				18.12	18.12	18.12	18.12	18.12	18.12	18.12

VS production (g VS head-1 day-1)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Calves	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7	1123.7
Male cattle	868.4	916.6	885.1	921.7	929.9	925.2	915.3	927.8	935.6	939.8	941.1
Female cattle	518.9	516.9	520.8	536.7	508.7	464.1	454.6	456.7	459.3	458.4	458.0
Other non dairy cattle	724.9	724.9	724.9	724.9	656.0	569.9	552.7	552.7	552.7	552.7	552.7
Dairy cattle	1018.9	1018.9	1018.9	1018.9	1427.1	1444.4	1447.8	1447.8	1447.8	1447.8	1447.8
Cow buffalo	737.9	789.1	840.4	891.6	892.9	894.6	895.0	895.0	895.0	895.0	895.0
Other buffaloes	540.5	552.4	564.3	576.2	540.2	495.3	486.3	486.3	486.3	486.3	486.3

CH_4 EF (kg CH4/head year)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Calves	7.07	7.07	7.07	7.43	7.43	7.43	7.43	7.43	7.43	7.43	7.43
Male cattle	5.47	5.77	5.57	6.10	6.15	6.12	6.05	6.14	6.19	6.22	6.23
Female cattle	3.27	3.25	3.28	3.55	3.37	3.07	3.01	3.02	3.04	3.03	3.03
Other non dairy cattle	4.56	4.56	4.56	4.80	4.34	3.77	3.66	3.66	3.66	3.66	3.66
Dairy cattle	6.41	6.41	6.41	6.74	9.44	9.56	9.58	9.58	9.58	9.58	9.58
Cow buffalo	4.65	4.97	5.29	5.90	5.91	5.92	5.92	5.92	5.92	5.92	5.92
Other buffaloes	3.40	3.48	3.55	3.81	3.57	3.28	3.22	3.22	3.22	3.22	3.22

Table A.7.16. Data, parameters and equations used to estimate CH4 emission from manure management for cattle and buffalo (total manure)

Total (solid manure and slurry)

Total SV (kg dm/head/day)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Calves	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Male cattle	2.76	2.92	2.82	2.93	2.80	2.58	2.51	2.54	2.56	2.57	2.58
Female cattle	2.73	2.73	2.77	2.83	2.62	2.38	2.33	2.32	2.34	2.31	2.30
Other non dairy cattle	4.54	4.54	4.54	4.54	4.14	3.65	3.55	3.55	3.55	3.55	3.55
Dairy cattle	6.41	6.41	6.41	6.41	6.05	5.36	5.22	5.22	5.22	5.22	5.22
Cow buffalo	7.14	7.03	6.92	6.81	5.88	4.72	4.48	4.48	4.48	4.48	4.48
Other buffaloes	2.54	2.50	2.47	2.43	2.31	2.15	2.12	2.12	2.12	2.12	2.12

Total average SV (kg dm/head/day)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Cattle	4.00	3.89	3.90	3.90	3.65	3.31	3.21	3.19	3.17	3.14	3.13
Dairy cattle	6.41	6.41	6.41	6.41	6.05	5.36	5.22	5.22	5.22	5.22	5.22
Non dairy cattle	2.76	2.88	2.86	2.85	2.62	2.37	2.32	2.32	2.35	2.35	2.34
Buffalo	5.55	5.36	5.16	5.36	4.70	3.73	3.58	3.59	3.57	3.49	3.47

Total CH_4 EF (kg CH4/head year)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Calves	7.07	7.07	7.07	7.43	7.43	7.43	7.43	7.43	7.43	7.43	7.43
Male cattle	11.08	11.70	11.29	12.92	12.48	11.71	11.44	11.60	11.70	11.75	11.77
Female cattle	9.81	9.82	9.95	11.31	10.51	9.55	9.35	9.34	9.41	9.31	9.27
Other non dairy cattle	15.85	15.85	15.85	17.71	16.15	14.19	13.80	13.80	13.80	13.80	13.80
Dairy cattle	22.38	22.38	22.38	25.01	25.09	22.81	22.36	22.36	22.36	22.36	22.36
Cow buffalo	23.61	23.45	23.29	25.94	22.80	18.87	18.08	18.08	18.08	18.08	18.08
Other buffaloes	9.32	9.26	9.19	10.11	9.56	8.88	8.74	8.74	8.74	8.74	8.74

CH_4 emissions (t)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Calves	2,122	3,247	2,886	3,717	3,772	3,658	3,661	3,607	3,484	3,434	3,446
Male cattle	22,103	21,398	17,663	17,733	13,933	11,238	11,591	12,017	12,391	12,324	12,332
Female cattle	24,562	22,018	24,166	23,356	21,980	20,845	21,536	21,911	22,463	22,972	23,011
Other non dairy cattle	4,955	10,425	9,318	8,354	6,008	4,537	4,145	4,009	4,341	4,865	4,985
Dairy cattle	59,123	46,546	46,215	46,072	43,813	41,666	40,728	40,043	37,857	36,734	36,628
Cow buffalo	1,459	2,193	2,701	3,561	5,577	4,346	4,316	4,503	4,451	4,206	4,211
Other buffaloes	305	508	699	686	1,152	1,280	1,280	1,326	1,357	1,483	1,522
Total	114,628	106,334	103,649	103,479	96,235	87,570	87,257	87,417	86,343	86,017	86,135

Total CH_4 IEF (kg CH4/head year)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EF non dairy cattle (kg/head)	**10.52**	**11.00**	**10.83**	**12.05**	**11.18**	**10.18**	**9.96**	**9.99**	**10.09**	**10.06**	**10.05**
EF dairy cattle (kg/head)	**22.38**	**22.38**	**22.38**	**25.01**	**25.09**	**22.81**	**22.36**	**22.36**	**22.36**	**22.36**	**22.36**
EF buffalo (kg/head)	**18.66**	**18.20**	**17.71**	**20.70**	**18.43**	**15.02**	**14.53**	**14.55**	**14.47**	**14.14**	**14.09**

Bo (m3 CH_4/kg VS)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Calves	0.283	0.283	0.291	0.295	0.299	0.349	0.358	0.358	0.358	0.358	0.367
Male cattle	0.181	0.181	0.185	0.196	0.202	0.240	0.247	0.247	0.247	0.247	0.253
Female cattle	0.162	0.162	0.166	0.178	0.182	0.212	0.217	0.217	0.217	0.218	0.224
Other non dairy cattle	0.157	0.157	0.162	0.174	0.176	0.205	0.210	0.210	0.210	0.210	0.216
Dairy cattle	0.192	0.192	0.198	0.218	0.186	0.219	0.218	0.218	0.218	0.218	0.222
Cow buffalo	0.178	0.174	0.169	0.182	0.178	0.170	0.166	0.166	0.166	0.166	0.166
Other buffaloes	0.198	0.192	0.187	0.199	0.190	0.175	0.170	0.170	0.170	0.170	0.170

A7.3 Agricultural soils (3D)

Sewage sludge applied to soils

In Table A.7.17 parameters used for estimating direct and indirect N_2O emissions from sewage sludge applied to soils are presented.

Table A.7.17 Time series of sewage sludge activity data

Year	Total amount sewage sludge for agriculture (t dry matter)	N content (%)	N sewage sludge (t)
1990	98,164	5.2	5,071
1995	157,512	5.2	8,137
2000	217,424	5.0	10,954
2005	215,742	4.1	8,874
2010	248,215	4.0	10,040
2011	299,159	3.7	11,119
2012	274,095	4.7	12,864
2013	203,545	4.0	8,053
2014	201,156	4.1	8,301
2015	222,225	3.7	8,303
2016	191,410	3.9	7,410
2017	172,844	4.1	7,116
2018	173,358	4.2	7,247
2019	168,417	4.1	6,977
2020	162,993	4.1	6,759

Source: ISPRA elaborations from MATTM (MATTM, 2014)

Bedding material in the estimates for the category animal manure applied to soils

A description of the types of agricultural residues considered in the estimates of the animal manure applied to soils (3Da2a), crop residues (3Da4) and field burning of agricultural residues (3F) categories is reported.

First of all, the agricultural residues are distinguished between removable and fixed. The last term is used to differentiate them from removable residues (such as straw and cereal stalks and residues of woody crops), "fixed" (no- removable) residues refer to residues which remain on the ground after harvest. The fixed residues include the remaining cereal stalks and the residues of other crops (such as beans, tubers, forages, grass, vegetables, etc.). The distinction between fixed and removable residues is required in the UNECE/LRTAP Convention.

From the cultivation of the crop (e.g. wheat), the product (grain), the removable residue (straw and wheat stalks) and the fixed residue (portion of the wheat stalks that remains on the ground after harvest) are obtained. As regards the removable residues, it is assumed that a portion (10% of residues) is burnt (first is removed from the field and then burned in the open air) and the corresponding emissions are reported in the waste sector (5C open burning of agricultural waste). Another portion (90% of residues) is used for various purposes (feed, bedding, construction, etc.). As regards the fixed residues, it is assumed that a portion (10% of residues) is burnt (the combustion of the residues takes place in the field) and the corresponding emissions are reported in the agriculture sector in 3F field burning of agricultural residues category. Another portion (90% of residues) is returned to soils and the corresponding emissions are reported in crop residues category (3Da4).

Considering the example of wheat, the total amount of durum wheat residues is thus distributed (2020 data):

72% are the removable residues used for various purposes (feed, bedding, construction, etc.),

18% are the fixed residues returned to soils,

8% are the removable residues burnt (removed from the field and then burned in the open air),

2% are the fixed residues burnt (the combustion of the residues takes place in the field).

As regard the estimate of the amount of straw used as bedding and the nitrogen content (see Table A.7.18), the following data are used: the number of dairy cattle, non-dairy cattle and buffalo (excluding pigs for which assumes only the liquid storage); the average weight of the subcategories of cattle and buffalo categorie; the types of housings in each subcategory; the amount of straw per day (per tonnes of live weight, per type of housing for cattle and buffalo subcategories); the nitrogen content in straw. Data on the amount of straw per day (per tonnes of live weight, per type of housing, for cattle and buffalo) are contained in the Ministerial Decree of 25 February 2016 on the use of zootechnical effluents, combined with the manure production

coefficients used in the estimation of methane emissions from storage. As recommended during the 2019 UNFCCC review, data on the quantity of bedding material used in solid manure management system are provided for 2019: 1.54 kg dm (straw)/head/day for dairy cattle and fattening cattle; 1.69 kg dm (straw)/head/day for replacement cows; 2.37 kg dm (straw)/head/day for other non dairy cattle; 2.52 kg dm (straw)/head/day for buffalo. The amount of nitrogen estimated from bedding materials was added to the nitrogen input from manure applied to soils (3Da2a category) to estimate N_2O emissions.

Table A.7.18 Time series of estimated annual straw consumption (dry matter) and N content

Year	Dairy cattle – straw consumed	Non-dairy cattle – straw consumed	Buffalo – straw consumed	Total straw consumed	N in organic bedding material (straw consumed)
			tons		
1990	1,828,772	2,690,186	90,119	4,609,076	23,567
1995	1,439,743	2,807,096	138,572	4,385,411	22,231
2000	1,429,510	2,665,677	175,378	4,270,564	21,623
2005	1,275,139	2,324,528	183,317	3,782,984	19,092
2010	1,034,808	2,126,596	326,327	3,487,730	17,510
2011	1,023,142	2,144,971	316,765	3,484,878	17,521
2012	1,064,732	2,076,711	311,542	3,452,985	17,263
2013	1,049,731	2,104,932	359,540	3,514,204	17,554
2014	1,014,541	2,048,752	330,020	3,393,313	16,945
2015	994,450	2,066,601	334,438	3,395,488	17,006
2016	974,331	2,151,178	343,985	3,469,493	17,346
2017	957,942	2,187,695	357,990	3,503,627	17,606
2018	905,642	2,260,611	358,435	3,524,688	17,734
2019	878,785	2,317,346	359,099	3,555,231	17,970
2020	876,253	2,327,018	363,300	3,566,570	18,042

Crop residues (FCR)

In Tables A.7.19-24, the cultivated surface, crops production, residues production and parameters used for emission calculation of nitrogen input from crop residues (FCR) for each type of crop are shown, respectively. As recommended during the 2019 UNFCCC review, to enhance transparency on the total amount of crop residues generated and shares of the crop residue amounts used for different purposes (such as bedding material (3.D.a.2.a), left on fields (3.D.a.4), burnt on-site (3.F) and off-site (1.A, 5.C.2)), a flow-chart is reported in Figure A.7.1.

Table A.7.19 Cultivated surfaces for the estimation of crop residues

Cultivated surfaces (ha)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Wheat	2,759,926	2,482,119	2,321,893	2,122,896	1,830,475	1,732,580	1,853,637	1,902,157	1,874,179	1,882,516	1,912,418
Rice	214,124	239,259	220,348	224,015	247,653	246,541	235,052	216,019	219,532	227,329	234,134
Barley	469,344	381,482	343,701	319,944	272,213	270,386	246,127	237,268	232,713	242,895	246,370
Maize, stalks	767,780	942,475	1,063,555	1,113,166	926,776	994,773	976,558	908,114	869,947	727,366	660,727
Maize, cobs	767,780	942,475	1,063,555	1,113,166	926,776	994,773	976,558	908,114	869,947	727,366	660,727
Rye	8,105	7,108	3,479	2,654	4,513	4,850	4,988	4,825	3,837	4,113	4,172
Oats	156,628	134,647	140,748	174,799	130,024	126,254	120,012	104,862	103,525	108,956	107,059
Sorghum	23,676	34,417	33,900	31,578	40,311	42,335	37,099	51,066	51,914	45,374	43,840
Triticum	4,215	3,716	5,882	6,766	21,658	21,621	22,019	35,558	37,307	36,955	28,725
Potatoes	120,481	89,350	81,894	69,912	62,400	61,902	58,398	50,388	52,349	50,416	48,138
Sweet potatoes	526	597	1,268	1,431	457	492	254	279	313	354	624
Sugar beet	274,000	283,993	249,154	253,043	62,266	45,545	53,514	40,712	51,986	38,124	32,297
Sunflower	111,797	230,402	216,852	129,874	100,475	118,099	111,678	127,628	111,350	114,449	110,716
Cabbage	26,296	22,345	24,778	27,556	27,196	26,015	26,374	29,974	25,265	25,213	23,368
Artichoke	48,172	51,273	50,283	50,127	50,321	49,577	35,593	46,954	46,440	41,299	43,838
Asparagus	6,046	6,520	5,516	6,442	6,359	6,347	6,010	5,560	6,313	6,397	6,476
Salad	48,725	49,288	51,219	50,010	47,371	45,838	43,358	46,180	42,085	40,647	43,427
Spinach	7,573	7,959	6,992	7,367	6,406	6,810	4,862	6,660	6,574	6,461	6,502
Tomato	136,379	114,917	136,265	138,759	119,977	111,389	98,210	95,191	103,109	107,178	103,940
Cauliflower	19,405	23,991	24,827	18,150	17,867	16,990	17,098	15,657	16,377	15,624	16,259
Pumpkin and zucchini	13,253	13,490	14,621	16,736	17,354	18,071	16,955	18,011	18,934	18,614	19,234
Cucumber	4,373	3,814	2,048	2,331	2,219	2,420	2,130	2,415	2,191	2,071	2,082
Eggplant	10,574	10,334	12,355	12,169	10,816	11,063	9,770	10,059	10,331	10,148	10,031
Pepper and chili	14,864	13,099	14,489	13,787	11,881	12,882	11,358	12,135	11,555	11,521	11,037
Onion	17,453	15,725	14,562	12,281	12,603	13,004	10,749	11,513	12,531	11,877	12,710
Garlic	4,707	4,070	3,677	3,163	2,966	3,124	2,980	3,133	3,182	3,044	3,303
Bean,freshseed	29,096	23,943	23,448	23,146	19,027	20,292	17,256	19,646	16,590	17,059	18,686
Bean,dryseed	23,002	14,462	11,046	8,755	7,001	6,235	6,154	5,312	4,904	5,870	5,895
Broadbean,freshseed	16,564	14,180	11,998	9,484	8,487	7,440	6,515	9,235	8,484	7,914	7,592
Broadbean,dryseed	104,045	63,257	47,841	48,507	52,108	43,477	46,130	42,584	41,074	42,157	50,167
Pea,freshseed	28,192	21,582	11,403	11,636	8,691	24,026	15,283	14,190	15,821	14,940	16,255
Pea,dryseed	10,127	6,625	4,498	11,134	11,692	10,770	9,861	9,458	9,970	11,181	14,113
Chickpea	4,624	3,023	3,996	5,256	6,813	5,830	7,928	8,259	9,037	11,167	13,940
Lentil	1,048	1,038	1,016	1,786	2,458	2,156	2,629	2,643	2,463	3,099	3,215
Vetch	5,768	6,532	6,800	7,142	7,560	7,575	7,580	7,608	7,675	7,795	7,786
Lupin	3,303	3,070	3,300	2,500	3,401	3,372	3,361	3,370	3,376	3,358	3,330

Cultivated surfaces (ha)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Soyabean	521,169	195,191	256,647	152,331	159,511	165,955	152,993	184,146	232,867	308,979	288,060
Alfalfa	987,000	823,834	810,866	779,430	745,128	728,034	599,031	708,208	699,296	667,325	677,524
Clovergrass	224,087	125,009	114,844	103,677	102,691	101,819	86,976	108,310	115,902	119,942	124,864
Waxy Corn	97,435	271,532	285,148	270,739	282,407	297,540	295,983	326,706	342,657	339,787	320,988
Grass Barley	11,291	35,913	44,745	43,834	40,055	40,201	18,290	39,385	51,192	51,045	52,012
Waxy Barley	3,615	9,967	11,807	11,549	21,813	10,865	8,338	9,958	8,900	8,230	9,032
Ryegrass	20,719	52,000	57,520	57,324	61,213	59,064	55,843	58,276	63,646	76,636	84,915
Other grasses	84,925	224,471	171,828	141,733	129,913	134,073	134,400	128,172	144,289	137,752	236,464
Gramineae	8,906	33,615	77,386	74,394	120,408	91,842	96,330	111,826	141,693	125,229	84,001
Leguminosae	13,772	33,118	78,001	59,569	57,128	57,552	54,767	79,689	88,816	65,635	74,462
Other mixtures	140,222	349,350	282,921	261,488	269,885	257,392	276,295	235,346	277,685	307,785	262,155
Sainfoin (*Lupinella*)	21,521	39,677	39,257	20,082	18,930	18,335	10,177	27,211	18,091	14,460	16,609
Sulla	51,469	112,049	106,194	89,865	89,032	80,922	77,721	82,602	92,255	90,017	93,192
Polyphytic meadows	109,860	224,444	213,389	177,689	204,313	180,107	160,073	253,142	156,994	144,946	251,241
Total	8,557,961	8,796,747	8,783,759	8,295,171	7,388,997	7,338,554	7,131,255	7,365,714	7,337,464	7,088,614	7,108,652

Table A.7.20 Crops production for the estimation of crop residues

Crops production (t)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Wheat	8,108,500	7,946,081	7,427,660	7,717,129	6,849,858	6,641,807	7,654,248	7,312,025	7,141,926	7,394,495	8,037,872
Rice	1,290,700	1,320,851	1,245,555	1,444,818	1,574,320	1,560,128	1,601,478	1,433,111	1,415,906	1,505,804	1,598,027
Barley	1,702,500	1,387,069	1,261,560	1,214,054	944,257	950,934	940,234	875,553	848,681	955,131	988,285
Maize, stalks	5,863,900	8,454,198	10,139,639	10,427,930	8,495,946	9,752,373	7,888,668	7,899,617	9,250,045	7,073,897	6,839,499
Maize, cobs	5,863,900	8,454,198	10,139,639	10,427,930	8,495,946	9,752,373	7,888,668	7,899,617	9,250,045	7,073,897	6,839,499
Rye	20,800	19,780	10,292	7,876	13,926	14,381	16,083	14,306	11,529	13,183	13,170
Oats	298,400	301,322	317,926	429,153	288,880	297,079	292,357	246,916	241,138	261,366	260,798
Sorghum	114,200	214,802	215,200	184,915	275,572	299,862	157,808	316,919	368,782	294,218	313,788
Triticum	10,480	13,210									
Potatoes	2,308,700	2,080,896	2,053,043	1,755,686	1,558,030	1,557,489	1,486,292	1,272,211	1,365,440	1,355,409	1,368,920
Sweet potatoes	11,300	14,273	14,496	20,251	8,681	10,195	4,959	6,354	6,723	7,547	12,456
Sugar beet	11,768,400	13,188,317	11,569,182	14,155,683	3,549,871	2,501,159	2,492,466	2,159,381	3,784,435	2,183,878	2,046,297
Sunflower	403,500	533,581	460,714	289,365	212,900	274,520	185,494	285,233	250,377	248,007	268,331
Cabbage	491,600	450,687	482,147	478,972	502,955	485,725	474,539	495,763	458,572	467,412	416,513
Artichoke	487,000	517,229	512,946	469,975	480,112	474,550	364,871	457,799	451,461	401,335	365,991
Asparagus	28,382	33,479	30,492	43,496	43,973	44,131	41,005	37,188	43,358	44,055	43,719
Salad	901,700	906,200	968,833	1,010,470	990,572	965,474	900,079	948,040	924,748	846,754	938,045
Spinach	87,300	106,500	92,959	99,367	90,608	94,820	69,752	90,113	96,662	92,385	91,882
Tomato	5,469,068	5,172,611	7,487,358	7,187,014	6,026,766	6,478,837	5,592,302	5,321,249	5,598,082	6,410,249	6,437,572
Cauliflower	375,800	470,800	518,030	430,669	427,407	407,160	414,142	381,634	405,053	385,972	388,281
Pumpkin and zucchini	338,800	356,000	412,779	488,054	509,512	553,070	485,101	501,227	540,219	533,495	554,045
Cucumber	90,278	83,032	54,010	72,572	59,598	66,431	57,289	64,929	59,918	55,599	56,456
Eggplant	270,900	301,600	357,031	338,803	303,046	317,429	297,894	302,673	308,722	300,182	317,585
Pepper and chili	343,200	325,100	365,624	362,994	296,074	307,773	291,661	307,122	285,203	282,896	271,256
Onion	486,200	471,965	437,359	358,926	380,855	413,794	337,450	350,947	425,187	378,300	450,645
Garlic	41,200	34,939	31,639	29,598	26,501	30,086	27,104	28,405	29,248	27,123	29,568
Bean,freshseed	234,400	200,700	218,379	218,757	185,752	185,530	149,071	178,504	164,325	148,713	162,952
Bean,dryseed	35,900	23,647	20,274	18,908	13,181	11,837	11,809	11,804	11,049	12,215	11,702
Broadbean,freshseed	90,100	85,512	72,948	53,796	50,837	47,361	40,650	56,623	51,553	46,527	46,452
Broadbean,dryseed	114,600	98,730	71,762	86,920	104,241	82,470	95,996	77,948	74,736	79,772	100,013
Pea,freshseed	168,100	129,600	72,078	71,411	52,092	99,536	80,834	71,848	79,977	74,702	99,078
Pea,dryseed	34,400	19,756	12,107	34,464	30,872	27,295	23,987	21,445	23,044	26,240	39,511
Chickpea	4,200	3,358	4,140	6,113	9,143	8,446	11,219	12,077	13,072	16,761	22,328

Lentil	800	865	758	1,234	1,697	1,944	1,842	2,040	1,873	2,484	2,876
Vetch	4,700	6,134	6,800	8,000	8,555	8,646	8,643	8,736	8,859	9,050	9,016
Lupin	4,200	5,144	4,800	3,500	4,810	4,749	4,725	4,728	4,759	4,748	4,717
Soyabean	1,750,500	732,448	908,290	553,002	552,454	564,638	422,130	624,360	933,140	1,116,982	1,081,340
Alfalfa	30,094,610	27,858,100	25,662,700	25,924,100	21,928,700	20,833,200	15,142,100	18,389,700	19,342,200	17,255,600	20,880,700
Clovergrass	6,304,100	2,899,100	2,397,800	2,203,300	1,982,500	1,955,700	1,511,700	1,947,300	2,089,200	2,107,700	2,342,800
Waxy Corn	5,445,099	14,033,200	13,517,200	14,334,200	14,088,600	15,625,900	15,151,400	15,083,700	19,046,500	16,668,600	16,977,600
Grass Barley	187,415	518,100	790,900	816,800	677,800	548,400	262,000	482,300	710,900	729,200	761,100
Waxy Barley	84,982	285,300	351,200	334,800	979,100	324,700	238,400	298,200	245,800	224,600	237,200
Ryegrass	734,816	1,800,000	1,855,400	1,717,500	1,696,600	1,758,200	1,629,700	1,622,100	2,046,800	2,223,200	2,298,500
Other grasses	2,236,744	5,060,400	3,649,400	3,057,900	2,306,900	2,415,000	1,964,200	2,272,400	2,692,900	2,390,000	3,765,700
Gramineae	202,038	557,800	1,471,600	1,191,900	1,261,800	980,900	1,152,900	1,068,300	1,604,400	1,277,500	612,500
Leguminosae	160,962	387,700	1,365,400	1,059,700	785,700	597,300	400,100	702,700	745,900	550,500	669,500
Other mixtures	3,112,241	7,869,200	5,840,000	5,422,300	3,198,800	3,668,600	3,082,600	2,841,200	3,279,400	3,569,200	3,985,100
Sainfoin (*Lupinella*)	412,452	793,800	751,000	334,400	281,900	268,200	148,000	303,400	245,200	208,200	225,500
Sulla	705,718	1,876,900	1,723,400	1,262,200	1,214,300	1,011,600	774,300	903,200	1,143,800	1,140,500	1,167,000
Polyphytic meadows	2,828,675	5,346,900	4,561,400	3,838,900	4,048,700	3,435,900	3,599,000	2,819,200	2,880,400	2,563,500	3,069,000

Table A.7.21 Parameters used for emission of nitrogen input from crop residues (FCR)

Crops	Residues/Crop product mass ratio (1)	Residues/Crop surface (t/ha) (2)	Dry matter of residues (%) (3)	Reincorporated fraction (4)	Protein in dry matter (5)	N content of aboveground residues (5)	Ratio of belowground residues to above-ground biomass (R_{BG-BIO}) (6)	N content of belowground residues (N_{BG}) (6)	Dry matter fraction of harvested product (DRY) (6)	Slope (6)	Intercept (6)
Wheat	0.1725		85	0.91	0.03	0.0048	0.24	0.009	0.89		
Rice	0.1675		75	0.6	0.045	0.0072	0.16	0.014	0.89		
Barley	0.2		85	0.91	0.04	0.0064	0.22	0.014	0.89		
Maize, stalks	0.13		40	1	0.045	0.0072	0.22	0.007	0.87		
Maize, cobs	0.02		50	1	0.035	0.0056	0.22	0.007	0.87		
Rye	0.175		85	0.91	0.04	0.0064	0.24	0.011	0.88		
Oats	0.175		85	0.91	0.04	0.0064	0.25	0.008	0.89		
Sorghum		0.625	85	0.91	0.045	0.0072	0.24	0.006	0.89		
Triticum	0.2		85	0.91	0.04	0.0064	0.25	0.008	0.88		
Potatoes	0.4		40	0.9	0.09	0.0144	0.2	0.014	0.22		
Sweet potatoes	0.4		40	0.9	0.09	0.0144	0.2	0.014	0.22		
Sugar beet	0.07		20	0.9	0.125	0.02	0.2	0.014	0.16		
Sunflower	0.4		60	0.9	0.025	0.004	0.24	0.006	0.94		
Cabbage	2.5		15	0.9	0.175	0.028	0.2	0.014	0.07		
Artichoke	2.5		15	0.9	0.135	0.0216	0.2	0.014	0.08		
Asparagus		2.8	8	0.9	0.09375	0.015	0.2	0.014	0.08		
Salad		3.4	4.5	0.9	0.09375	0.015	0.2	0.014	0.06		
Spinach		3.4	8	0.9	0.09375	0.015	0.2	0.014	0.08		
Tomato	0.3		15	0.9	0.08	0.0128	0.2	0.014	0.06		
Cauliflower		3.8	8	0.9	0.09375	0.015	0.2	0.014	0.08		
Pumpkin and zucchini		9.5	4.5	0.9	0.09375	0.015	0.2	0.014	0.08		
Cucumber		8.5	4.5	0.9	0.09375	0.015	0.2	0.014	0.04		
Eggplant		9.5	8	0.9	0.09375	0.015	0.2	0.014	0.08		
Pepper and chili		9.5	8	0.9	0.09375	0.015	0.2	0.014	0.07		
Onion		0.7	8	0.9	0.09375	0.015	0.2	0.014	0.09		
Garlic		0.7	30	0.9	0.09375	0.015	0.2	0.014	0.09		
Bean,freshseed		17.7	20	0.9	0.125	0.02	0.19	0.008	0.91		
Bean,dryseed		0.6699	85	0.9	0.1	0.016	0.19	0.01	0.9		

Crops	Residues/Crop product mass ratio (1)	Residues/Crop surface (t/ha) (2)	Dry matter of residues (%) (3)	Reincorporated fraction (4)	Protein in dry matter (5)	N content of aboveground residues (5)	Ratio of belowground residues to above-ground biomass (R_{BG-BIO}) (6)	N content of belowground residues (N_{BG}) (6)	Dry matter fraction of harvested product (DRY) (6)	Slope (6)	Intercept (6)
Broadbean,freshseed		17.7	20	0.9	0.125	0.02	0.19	0.008	0.91		
Broadbean,dryseed		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Pea,freshseed		17.7	20	0.9	0.125	0.02	0.19	0.008	0.91		
Pea,dryseed		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Chickpea		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Lentil		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Tare		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Lupin		0.6699	85	0.9	0.1	0.016	0.19	0.008	0.91		
Soyabean		2.6	47.5	0.9	0.075	0.012	0.19	0.008	0.91		
Alfalfa			90	0.2	0.16875	0.027	0.4	0.019	0.9		
Clovergrass			90	0.2	0.16875	0.027	0.4	0.022	0.9		
Other temporary forages				0.2		0.018	0.6	0.013	0.9	0.3	0
Perennial grasses				0.2		0.015	0.8	0.012	0.9	0.3	0

(1) CESTAAT, 1988 and ENEA, 1994; (2) CRPA/CNR, 1992 and ENEA, 1994; (3) IPCC, 1997; CRPA/CNR, 1992; CESTAAT, 1988; Borgioli, 1981; CREA expert judgment; (4) Values are the complement of the fraction of fixed residues burned (CRPA, 1997 [b]). Values also include the non-combusted portion of burned grain residues, which have a combustion coefficient C of 90%, except for rice, which is 80%; (5) Nitrogen in dry matter is equal to raw protein in residues (dry matter fraction) (CESTAAT, 1988; Borgioli, 1981) dividing by factor 6.25 (100 g of protein/16 g of nitrogen); (6) Table 11.2 of the 2006 IPCC Guidelines.

Table A.7.22 Aboveground residues production for the estimation of crop residues

t dry matter	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Wheat	1,188,909	1,165,094	1,089,081	1,131,524	1,004,360	1,084,218	1,178,553	1,021,458	1,016,543	964,292	960,960
Rice	162,144	165,932	156,473	181,505	197,774	189,167	200,752	190,452	186,036	188,203	190,078
Barley	289,425	235,802	214,465	206,389	160,524	162,372	168,008	167,328	171,756	182,316	185,407
Maize, stalks	304,923	439,618	527,261	542,252	441,789	367,843	355,654	314,522	321,310	325,455	352,097
Maize, cobs	58,639	84,542	101,396	104,279	84,959	70,739	68,395	60,485	61,790	62,587	67,711
Rye	3,094	2,942	1,531	1,172	2,072	1,961	1,959	1,651	1,582	1,861	1,707
Oats	44,387	44,822	47,292	63,837	42,971	38,878	38,794	34,070	36,201	35,418	36,103
Sorghum	14,798	21,511	21,188	19,736	25,194	28,359	27,400	25,563	24,748	29,249	33,070
Triticum	1,782	2,246									
Potatoes	369,392	332,943	328,487	280,910	249,285	216,865	219,027	215,510	209,216	214,149	229,544
Sweet potatoes	1,808	2,284	2,319	3,240	1,389	1,208	1,993	1,359	1,197	885	989
Sugar beet	164,758	184,636	161,969	198,180	49,698	30,574	28,648	34,350	27,181	24,908	24,908
Sunflower	96,840	128,059	110,571	69,448	51,096	59,522	64,399	58,481	59,723	70,281	71,507
Cabbage	184,350	169,008	180,805	179,615	188,608	175,280	156,193	163,570	166,381	171,682	157,739
Artichoke	182,625	193,961	192,355	176,241	180,042	150,501	137,246	145,426	146,180	142,057	137,655
Asparagus	16,929	18,256	15,444	18,038	17,805	17,913	18,134	18,725	19,216	20,042	20,721
Salad	165,665	167,579	174,144	170,035	161,060	138,199	147,651	147,015	148,447	144,305	139,112
Spinach	25,748	27,061	23,774	25,049	21,781	21,966	22,106	20,313	22,416	21,377	20,879
Tomato	246,108	232,767	336,931	323,416	271,204	288,461	289,691	270,714	260,915	259,993	281,156
Cauliflower	73,739	91,166	94,343	68,970	67,895	59,371	61,784	60,633	60,268	59,546	58,930
Pumpkin and zucchini	125,904	128,155	138,898	158,987	164,863	176,831	182,727	178,005	177,378	181,298	191,430
Cucumber	37,171	32,419	17,405	19,813	18,865	17,600	17,694	17,326	17,248	17,469	17,825
Eggplant	100,453	98,173	117,371	115,602	102,751	96,404	95,290	89,762	90,818	90,686	90,330
Pepper and chili	141,208	124,441	137,648	130,975	112,871	109,454	104,854	98,066	99,960	97,700	95,065
Onion	12,217	11,008	10,193	8,597	8,822	8,314	8,897	8,574	8,118	9,845	8,971
Garlic	3,295	2,849	2,574	2,214	2,076	2,131	2,312	2,431	2,501	2,388	2,301
Bean,freshseed	103,000	84,758	83,004	81,936	67,354	60,388	66,149	65,909	65,021	64,617	63,420
Bean,dryseed	13,098	8,235	6,290	4,985	3,986	3,342	3,357	3,417	3,651	3,181	3,155
Broadbean,freshseed	58,637	50,197	42,473	33,573	30,044	28,016	26,876	26,738	28,267	26,989	26,097
Broadbean,dryseed	59,245	36,019	27,241	27,621	29,671	24,005	28,566	29,117	28,710	34,169	35,293
Pea,freshseed	99,800	76,400	40,366	41,193	30,766	52,887	57,542	53,922	55,078	57,336	57,186
Pea,dryseed	5,766	3,772	2,561	6,340	6,658	6,367	8,036	9,706	10,202	13,054	11,824
Chickpea	2,633	1,721	2,275	2,993	3,879	6,359	7,938	11,403	14,818	11,957	10,579

t dry matter	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Lentil	597	591	579	1,017	1,400	1,765	1,831	2,836	3,085	3,337	3,196
Vetch	3,284	3,719	3,872	4,067	4,305	4,439	4,433	4,457	4,457	4,457	4,457
Lupin	1,881	1,748	1,879	1,424	1,937	1,912	1,896	1,900	1,900	1,900	1,900
Soyabean	643,644	241,061	316,959	188,129	196,996	381,589	355,754	398,185	403,335	337,565	316,325
Alfalfa	1,963,673	1,817,741	1,674,491	1,691,548	1,430,848	1,125,928	1,362,466	1,094,719	1,265,967	1,365,787	1,390,608
Clovergrass	567,369	260,919	215,802	198,297	178,425	189,693	210,852	174,285	195,093	197,100	191,291
Other temporary forages	2,507,313	6,404,657	6,098,715	6,052,511	5,338,221	6,207,568	6,529,520	5,954,334	7,046,994	7,223,184	7,834,582
Total	**10,046,247**	**13,098,813**	**12,720,426**	**12,535,653**	**10,954,243**	**11,608,386**	**12,263,377**	**11,176,715**	**12,463,706**	**12,662,625**	**13,326,109**

Table A.7.23 Estimate of nitrogen from crop residues of perennial grasses (1)

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Surface (ha)	855,117	931,388	893,737	828,835	879,405	924,270	842,531	835,706	832,613	856,000	832,254
Production (t)	15,213,383	16,945,600	15,841,500	13,853,700	14,478,400	11,766,500	10,236,000	9,074,800	9,127,600	9,499,900	9,445,691
Crop (kg dm/ha) (2)	16,012	16,375	15,953	15,043	14,817	11,458	10,934	9,773	9,866	9,988	10,215
AG_{DM} (t/ha) (3)	4.80	4.91	4.79	4.51	4.45	3.44	3.28	2.93	2.96	3.00	3.06
R_{AG} (kg dm/ kg dm) (4)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
R_{BG} (kg dm/ kg dm) (5)	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
F_{CR} of perennial grasses (t N) (6)	36,640	40,812	38,153	33,365	34,870	28,338	24,652	21,856	21,983	22,880	22,749

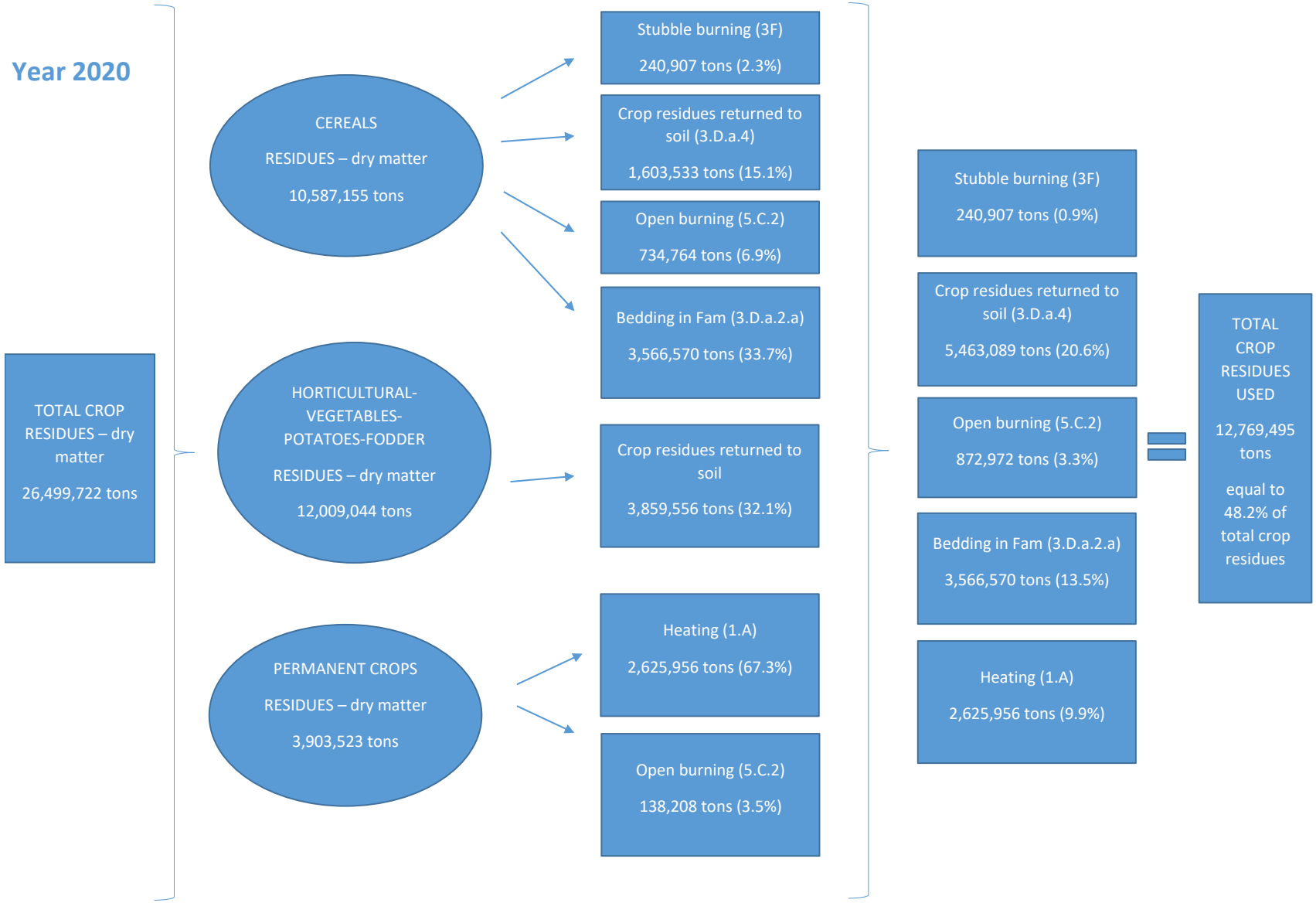
(1) According to the equations 11.6 and 11.7 of the 2006 IPCC Guidelines; (2) Harvested annual dry matter yield - kg harvested fresh yield / ha * DRY (dry matter fraction); (3) Above-ground residue dry matter calculated as (Crop/1000)*slope+intercept; (4) Ratio of above-ground residues dry matter to harvested yield, calculated as AG_{DM}*1000/Crop; (5) Ratio of below-ground residues to harvested yield, calculated as $R_{BG\text{-}BIO}$*[(AG_{DM}*1000+Crop)/Crop]; (6) Calculated according to equation 11.6 assuming $Frac_{Renew}$=1/5, Area burnt=0, $Frac_{Remove}$=0.8.

Table A.7.24 Total nitrogen content in the aboveground and belowground crop residues

Total nitrogen (t N)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Wheat	23,349	22,881	21,388	22,222	19,725	21,293	23,146	20,060	19,964	18,938	18,872
Rice	3,637	3,722	3,284	3,810	4,151	3,971	4,214	3,997	3,905	3,950	3,990
Barley	7,244	5,902	5,368	5,166	4,018	4,064	4,205	4,188	4,299	4,563	4,641
Maize, stalks	10,521	15,169	18,193	18,711	15,244	12,693	12,272	10,853	11,087	11,230	12,149
Maize, cobs	8,275	11,931	14,309	14,716	11,989	9,983	9,652	8,536	8,720	8,832	9,555
Rye	75	71	37	28	50	47	47	40	38	45	41
Oats	878	887	936	1,263	850	769	768	674	716	701	714
Sorghum	265	447	445	395	555	604	621	513	574	634	728
Triticum	32	41	0	0	0	0	0	0	0	0	0
Potatoes	7,244	6,529	6,442	5,509	4,888	4,253	4,295	4,226	4,103	4,199	4,501
Sweet potatoes	35	45	45	64	27	24	39	27	23	17	19
Sugar beet	8,699	9,749	8,552	10,464	2,624	1,614	1,513	1,814	1,435	1,315	1,315
Sunflower	1,034	1,368	1,181	742	546	636	688	625	638	751	764
Cabbage	5,258	4,821	5,157	5,123	5,380	4,999	4,455	4,665	4,746	4,897	4,499
Artichoke	4,171	4,430	4,393	4,025	4,112	3,437	3,134	3,321	3,338	3,244	3,144
Asparagus	282	305	259	304	300	302	305	316	324	338	348
Salad	2,852	2,884	3,001	2,941	2,792	2,395	2,564	2,554	2,584	2,513	2,424
Spinach	439	465	408	431	375	379	381	352	388	371	363
Tomato	4,443	4,202	6,083	5,839	4,896	5,208	5,230	4,887	4,710	4,694	5,076
Cauliflower	1,286	1,591	1,654	1,221	1,202	1,054	1,094	1,072	1,065	1,053	1,042
Pumpkin and zucchini	2,128	2,169	2,357	2,701	2,801	3,002	3,103	3,022	3,017	3,083	3,255
Cucumber	616	538	290	331	314	293	295	288	287	291	297
Eggplant	1,698	1,668	1,993	1,960	1,743	1,639	1,624	1,527	1,547	1,546	1,541
Pepper and chili	2,369	2,092	2,315	2,206	1,898	1,840	1,762	1,647	1,680	1,641	1,598
Onion	322	298	276	231	240	231	259	243	226	281	262
Garlic	64	55	50	44	41	42	45	47	48	46	45
Bean,freshseed	2,335	1,932	1,922	1,902	1,572	1,384	1,517	1,501	1,496	1,475	1,462
Bean,dryseed	275	175	137	114	88	75	75	75	80	72	74
Broadbean,freshseed	1,269	1,098	930	730	657	611	589	585	616	593	574
Broadbean,dryseed	1,102	710	533	560	617	492	593	592	598	708	728
Pea,freshseed	2,181	1,671	888	903	673	1,136	1,260	1,171	1,194	1,229	1,227
Pea,dryseed	139	87	58	149	149	138	183	222	232	305	273
Chickpea	48	32	42	56	74	124	157	228	301	239	214
Lentil	11	11	10	18	25	32	33	50	55	60	58
Vetch	59	68	71	76	80	83	83	84	84	84	84
Lupin	36	35	37	28	37	37	37	37	31	31	32
Soyabean	10,351	3,983	5,161	3,083	3,191	6,246	5,879	6,316	6,545	5,544	5,233

Total nitrogen (t N)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Alfalfa	76,990	71,268	65,652	66,320	56,099	44,144	53,418	42,921	49,635	53,548	54,521
Clovergrass	24,699	11,359	9,395	8,633	7,767	8,258	9,179	7,587	8,493	8,580	8,328
Other temporary forages	107,212	265,491	248,641	240,532	205,788	230,420	243,191	220,708	264,245	268,402	291,795
Perennial grasses	36,640	40,812	38,153	33,365	34,870	28,338	24,652	21,856	21,983	22,880	22,749
Total	**360,563**	**502,989**	**480,045**	**466,910**	**402,447**	**406,289**	**426,556**	**383,425**	**435,051**	**442,924**	**468,534**

Figure A.7.1. Flow-chart on the amount of crop residues generated and shares of the crop residue amounts used for different purposes



Note: part of the 26,499,722 tons of total crop residues is used to feed the anaerobic digesters, but at the moment it is not possible to quantify their size; the quantity of stubble burning and open burning refer to the amount of dry residues burnt.

ANNEX 8: Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information

A8.1 Annual inventory submission

This appendix shows Tables 10s1 and 10s6 from the Common Reporting Format 2019, submitted in 2021, in which time series of emission estimates are reported in CO_2 eq.

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	(kt CO_2 eq)										
Total (net emissions)[2]	515229.35	515229.35	500968.91	501881.47	507614.13	488668.28	508331.28	501162.08	517173.23	532036.99	528099.22
1. Energy	425321.96	425321.96	425391.80	425084.21	420184.19	415291.55	437941.49	434832.93	440710.12	453429.84	457798.05
A. Fuel combustion (sectoral approach)	412204.46	412204.46	412446.21	412077.42	407105.86	402536.79	425567.56	422753.25	428492.09	441255.58	446645.90
1. Energy industries	137645.79	137645.79	132005.09	131214.78	125364.78	127807.84	140631.13	135285.00	137657.39	138910.22	133486.79
2. Manufacturing industries and construction	92277.96	92277.96	89603.57	89611.67	88145.16	89930.47	90311.59	89441.22	93524.26	96975.41	101954.66
3. Transport	102214.58	102214.58	104840.05	110007.22	111672.36	111557.78	114292.37	116069.20	118037.83	122486.47	123877.07
4. Other sectors	78923.57	78923.57	84691.29	79846.26	80342.57	71649.49	78766.93	80673.36	77935.79	81751.92	86123.35
5. Other	1142.57	1142.57	1306.22	1397.49	1580.99	1591.21	1565.55	1284.47	1336.82	1131.56	1204.03
B. Fugitive emissions from fuels	13117.50	13117.50	12945.59	13006.79	13078.33	12754.77	12373.93	12079.67	12218.03	12174.26	11152.16
1. Solid fuels	132.48	132.48	117.10	130.00	86.92	81.43	74.27	69.75	70.22	66.37	63.66
2. Oil and natural gas and other emissions from energy production	12985.02	12985.02	12828.49	12876.79	12991.41	12673.34	12299.66	12009.92	12147.80	12107.89	11088.50
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial Processes	40421.81	40421.81	39989.72	39374.60	36421.21	35030.74	38315.54	35300.89	35852.89	36476.23	36993.38
A. Mineral industry	20720.45	20720.45	20682.33	21476.60	19076.44	18591.19	20239.69	18575.37	18844.17	19106.28	19903.26
B. Chemical industry	10493.12	10493.12	10817.54	10286.35	9789.85	9119.81	10313.58	9174.74	9389.37	9462.66	9308.19
C. Metal industry	6420.72	6420.72	5743.38	4826.99	4790.28	4400.09	4320.19	3703.31	3486.82	3281.64	2727.16
D. Non-energy products from fuels and solvent use	1712.38	1712.38	1693.24	1712.56	1643.89	1599.54	1554.18	1501.08	1503.14	1440.69	1441.16
E. Electronic industry	NO	NO	NO	NO	NO	NO	223.49	219.30	241.30	300.73	285.37
F. Product uses as ODS substitutes	NO	NO	0.37	19.48	46.60	213.06	371.86	560.83	781.06	1323.39	1950.97
G. Other product manufacture and use	1075.14	1075.14	1052.86	1052.63	1074.14	1107.05	1292.54	1566.27	1607.04	1560.85	1377.28
H. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Agriculture	35672.25	35672.25	36440.91	35887.94	36189.23	35842.47	35751.01	35579.98	36185.56	35525.87	35912.54
A. Enteric fermentation	15496.60	15496.60	15731.26	15238.77	15065.75	15138.05	15318.96	15457.20	15422.55	15281.92	15467.57
B. Manure management	7659.62	7659.62	7683.21	7368.50	7312.77	7153.30	7294.14	7300.67	7278.57	7329.32	7402.30
C. Rice cultivation	1876.46	1876.46	1790.95	1859.66	1949.95	1999.61	1988.96	1959.37	1945.39	1837.61	1800.07
D. Agricultural soils	10110.98	10110.98	10637.93	10803.85	11158.51	10885.80	10563.01	10354.44	10937.26	10486.23	10628.41
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	18.72	18.72	20.35	19.89	19.10	19.24	18.47	19.50	17.74	20.04	19.65
G. Liming	1.36	1.36	1.36	1.37	1.38	1.38	1.39	1.38	1.39	1.37	2.01
H. Urea application	464.84	464.84	519.31	536.33	621.90	588.39	512.05	439.22	525.41	526.32	550.90
I. Other carbon-containing fertilizers	43.68	43.68	56.54	59.56	59.88	56.70	54.03	48.20	57.27	43.05	41.62
J. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry[2]	-3491.09	-3491.09	-18821.62	-16819.37	-4005.58	-16965.09	-23672.83	-25217.14	-16888.36	-14451.86	-23660.73

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	(kt CO_2 eq)										
A. Forest land	-17255.01	-17255.01	-29350.45	-27935.30	-17467.72	-27895.54	-31000.71	-30748.19	-23108.38	-21585.32	-26584.82
B. Cropland	2429.73	2429.73	658.72	893.60	111.88	37.79	1215.86	1891.34	1136.97	633.86	-20.97
C. Grassland	4547.87	4547.87	992.34	1039.00	4515.45	1772.69	-2162.88	-2580.28	-1242.36	518.59	-3163.62
D. Wetlands	NE,NO	NE,NO	4.98	4.98	4.98	4.98	4.98	8.16	8.16	8.16	8.16
E. Settlements	7145.02	7145.02	8936.90	8937.84	8937.90	8938.82	8941.05	6979.92	6980.16	6980.23	6980.71
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products	-387.80	-387.80	-94.49	209.02	-140.92	142.18	-706.26	-799.58	-690.80	-1031.74	-901.01
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	17304.42	17304.42	17968.10	18354.10	18825.08	19468.61	19996.08	20665.43	21313.02	21056.90	21055.97
A. Solid waste disposal	12206.20	12206.20	12831.04	13263.97	13844.03	14481.35	15123.16	15799.93	16368.61	16101.54	16149.69
B. Biological treatment of solid waste	25.00	25.00	30.35	35.70	41.05	60.30	57.81	47.94	122.42	148.16	196.45
C. Incineration and open burning of waste	598.74	598.74	644.52	634.51	592.33	595.78	550.86	549.82	576.41	571.02	495.23
D. Waste water treatment and discharge	4474.49	4474.49	4462.20	4419.91	4347.67	4331.18	4264.25	4267.74	4245.58	4236.18	4214.60
E. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6. Other ***(as specified in summary 1.A)***	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items:											
International bunkers	8818.95	8818.95	8835.43	8641.87	9048.85	9177.56	9977.88	9088.01	9490.05	10130.58	10832.73
Aviation	4321.24	4321.24	5168.25	5111.50	5269.20	5443.93	5850.69	6206.23	6280.00	6828.64	7546.62
Navigation	4497.71	4497.71	3667.18	3530.36	3779.64	3733.63	4127.19	2881.79	3210.05	3301.95	3286.11
Multilateral operations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 emissions from biomass	14177.23	14177.23	16543.74	15524.59	15895.45	16387.90	16974.70	16992.41	18313.70	18535.77	20112.35
CO_2 captured	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
Long-term storage of C in waste disposal sites	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Indirect N_2O	3077.39	3077.39	3137.36	3195.01	3080.97	2927.34	2850.84	2761.37	2670.74	2542.60	2376.78
Indirect CO_2 [3]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total CO_2 equivalent emissions without land use, land-use change and forestry	518720.44	518720.44	519790.53	518700.84	511619.71	505633.37	532004.11	526379.22	534061.59	546488.84	551759.95
Total CO_2 equivalent emissions with land use, land-use change and forestry	515229.35	515229.35	500968.91	501881.47	507614.13	488668.28	508331.28	501162.08	517173.23	532036.99	528099.22
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	(kt CO_2 eq)										
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	(kt CO_2 eq)									
Total (net emissions)[2]	536177.49	527505.07	529083.39	556122.27	555568.91	555666.83	544191.78	561551.26	530476.15	471359.59
1. Energy	459631.20	458435.11	465345.75	483129.42	486996.42	487640.33	481855.86	475936.40	466981.98	417629.43
A. Fuel combustion (sectoral approach)	448484.11	447897.32	454965.31	472299.48	477153.23	477885.27	472707.13	466944.61	458000.07	409168.45
1. Energy industries	144905.91	143433.32	154461.39	159565.47	161420.92	159933.55	162191.22	159160.53	156081.95	134100.12
2. Manufacturing industries and construction	96373.06	91751.93	89608.86	95805.00	94675.63	92444.14	89285.76	91418.91	86928.19	64675.57
3. Transport	123830.21	125621.47	128029.88	128152.80	129863.97	128259.94	129517.26	129578.62	122628.56	117040.01
4. Other sectors	82493.99	86710.80	82528.83	88052.34	89984.33	95924.19	90627.72	85794.49	91541.04	92411.33
5. Other	880.94	379.79	336.36	723.87	1208.38	1323.45	1085.17	992.07	820.32	941.42
B. Fugitive emissions from fuels	11147.09	10537.79	10380.44	10829.94	9843.19	9755.06	9148.73	8991.78	8981.91	8460.97
1. Solid fuels	97.11	108.48	107.24	134.39	84.70	90.06	65.87	113.79	96.57	59.36
2. Oil and natural gas and other emissions from energy production	11049.98	10429.31	10273.19	10695.55	9758.49	9664.99	9082.86	8877.99	8885.34	8401.61
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial Processes	39123.39	41079.21	41483.23	43179.25	46293.02	47211.30	43359.71	43511.23	41071.67	35905.97
A. Mineral industry	20749.02	21531.35	21554.56	22429.73	23186.82	23304.75	23361.75	23781.94	21498.18	17249.99
B. Chemical industry	9993.72	10310.98	10047.59	10149.45	11344.57	10672.78	5792.32	5013.38	3931.14	3126.70
C. Metal industry	2765.65	3034.16	2789.26	2501.04	2424.40	2780.42	2671.06	2646.16	2652.38	1918.36
D. Non-energy products from fuels and solvent use	1421.07	1374.95	1378.22	1359.82	1344.95	1358.94	1353.58	1342.79	1273.98	1159.63
E. Electronic industry	375.04	311.68	337.62	351.84	325.27	303.12	225.16	180.07	189.67	155.88
F. Product uses as ODS substitutes	2453.85	3246.76	4177.21	5188.08	6430.11	7587.68	8710.16	9422.71	10371.22	11195.82
G. Other product manufacture and use	1365.03	1269.33	1198.78	1199.28	1236.91	1203.61	1245.68	1124.17	1155.10	1099.59
H. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Agriculture	36682.43	36321.28	35668.67	35408.27	34777.81	34192.12	33657.88	34261.21	33088.49	32456.45
A. Enteric fermentation	15128.38	14474.29	14032.56	14093.08	13294.80	13292.92	12873.24	13373.51	13229.81	13286.45
B. Manure management	7192.50	7530.03	7313.29	7310.20	7109.95	7095.37	7027.57	7184.14	7111.82	7075.97

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	(kt CO_2 eq)									
C. Rice cultivation	1656.41	1654.63	1713.11	1749.98	1825.64	1752.21	1754.91	1802.01	1650.14	1834.71
D. Agricultural soils	12115.78	12056.68	11979.95	11621.38	11896.19	11467.95	11392.34	11290.64	10524.46	9819.53
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	18.47	17.18	19.27	17.65	21.40	19.93	19.43	19.71	20.79	19.48
G. Liming	1.85	2.12	6.32	6.24	10.20	14.36	11.78	15.66	18.46	17.40
H. Urea application	525.37	539.23	560.22	564.97	576.04	506.92	539.36	536.96	498.22	371.58
I. Other carbon-containing fertilizers	43.67	47.13	43.95	44.77	43.59	42.47	39.27	38.58	34.78	31.33
J. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry[(2)]	-21113.14	-31478.22	-35826.41	-27883.28	-34205.39	-35241.38	-36005.44	-13114.55	-31080.65	-35181.54
A. Forest land	-25693.82	-31641.05	-35197.88	-29101.34	-33515.93	-34541.49	-34106.73	-18194.38	-30333.84	-32907.37
B. Cropland	-540.50	-2804.80	-2070.54	-1627.97	-1857.39	-1893.36	-2543.83	-2550.38	-1792.15	-2091.56
C. Grassland	-1425.02	-3811.46	-5221.59	-3729.61	-5272.80	-6125.57	-6471.13	533.63	-6083.78	-6797.57
D. Wetlands	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	129.57
E. Settlements	6982.23	6984.58	6987.21	6989.40	6991.93	7804.20	7813.84	7817.42	7858.95	6794.26
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products	-453.55	-223.02	-341.14	-431.28	-568.73	-502.68	-715.11	-738.36	-747.35	-318.22
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	21853.62	23147.68	22412.15	22288.61	21707.04	21864.46	21323.78	20956.97	20414.65	20549.29
A. Solid waste disposal	17199.56	18445.82	17718.96	17538.10	16942.30	17002.39	16429.34	16103.82	15633.16	15747.61
B. Biological treatment of solid waste	249.24	323.23	397.18	437.22	430.90	488.61	519.39	533.09	520.38	530.50
C. Incineration and open burning of waste	289.60	309.22	259.43	281.92	281.12	317.01	328.51	296.34	292.72	330.59
D. Waste water treatment and discharge	4115.22	4069.41	4036.58	4031.37	4052.71	4056.45	4046.54	4023.72	3968.39	3940.58
E. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6. Other ***(as specified in summary 1.A)***	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items:										
International bunkers	12216.70	12691.71	12339.80	14212.28	14820.14	15440.21	16690.80	17587.10	17893.26	15598.95
Aviation	8029.05	7932.51	6872.02	7985.94	8024.82	8555.29	9284.24	9849.49	9455.53	8340.27
Navigation	4187.65	4759.19	5467.78	6226.34	6795.32	6884.92	7406.56	7737.61	8437.74	7258.68
Multilateral operations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 emissions from biomass	19182.31	18820.12	13721.14	20267.20	16411.39	23618.21	26958.13	34588.46	41524.16	43007.03

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	(kt CO_2 eq)									
CO_2 captured	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
Long-term storage of C in waste disposal sites	10249.61	9542.73	8470.02	8039.55	8016.06	8131.58	7203.64	7050.40	7064.69	6684.88
Indirect N_2O	2259.84	2204.57	2106.94	2103.47	2036.24	1934.72	1849.08	1793.47	1573.89	1451.66
Indirect CO_2 (3)	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
Total CO_2 equivalent emissions without land use, land-use change and forestry	557290.63	558983.29	564909.80	584005.54	589774.30	590908.21	580197.22	574665.81	561556.79	506541.13
Total CO_2 equivalent emissions with land use, land-use change and forestry	536177.49	527505.07	529083.39	556122.27	555568.91	555666.83	544191.78	561551.26	530476.15	471359.59
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change from base to latest reported year
	(kt CO_2 eq)											%
Total (net emissions)(2)	476268.25	471621.16	461385.79	410809.33	388805.50	398666.49	399039.49	413600.02	394101.81	377672.46	348846.95	-32.43
1. Energy	428903.22	416018.15	399105.28	366695.06	346450.28	358776.32	355381.05	349941.86	345416.08	335080.92	298900.44	-29.72
A. Fuel combustion (sectoral approach)	420006.59	406947.68	390221.87	357846.79	338054.41	350745.13	348086.91	342627.34	338491.36	328468.61	292909.04	-28.94
1. Energy industries	137507.25	133402.95	128349.27	109169.69	100529.58	106089.57	104,970.58	105,082.68	96,067.67	91,894.25	81,796.78	-40.57
2. Manufacturing industries and construction	70165.02	70986.56	66558.94	56829.27	52639.60	55634.32	54,407.12	53,171.68	54,279.23	49,991.47	45,856.13	-50.31
3. Transport	115527.34	114460.24	107046.05	103890.60	108674.91	106068.64	104,875.72	100,770.34	104,276.16	105,321.91	85,435.97	-16.40
4. Other sectors	96114.50	87552.41	87904.74	87331.16	75610.97	82474.28	83,300.61	83,263.04	83,517.00	80,794.05	79,178.28	0.32
5. Other	692.47	545.52	362.86	626.06	599.34	478.33	532.88	339.60	351.30	466.93	641.88	-43.82
B. Fugitive emissions from fuels	8896.63	9070.47	8883.41	8848.28	8395.87	8031.19	7294.14	7314.52	6924.72	6612.32	5991.39	-54.33
1. Solid fuels	86.34	91.70	80.00	58.41	57.10	52.64	49.33	36.67	34.28	32.15	25.70	-80.60
2. Oil and natural gas and other emissions from energy production	8810.29	8978.77	8803.41	8789.87	8338.77	7978.55	7,244.81	7,277.85	6,890.44	6,580.16	5,965.69	-54.06

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change from base to latest reported year
	(kt CO_2 eq)											%
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
2. Industrial Processes	36964.06	37298.54	34546.03	33583.83	33186.27	33232.52	33497.93	33695.55	34603.67	33985.41	31049.05	-23.19
A. Mineral industry	17341.49	16713.25	13775.44	12281.06	11593.65	11203.07	10,595.40	10,771.03	10,878.27	10,911.62	9,780.40	-52.80
B. Chemical industry	3290.80	3092.62	2887.13	3105.74	2898.87	2922.73	3,042.28	2,770.83	3,210.70	2,309.83	1,899.86	-81.89
C. Metal industry	2006.11	2204.78	2020.51	1730.90	1675.21	1611.37	1,764.18	1,725.60	1,730.84	1,645.85	1,474.40	-77.04
D. Non-energy products from fuels and solvent use	1128.35	1145.86	1057.80	1047.34	1018.04	974.67	985.57	1,058.27	1,092.50	1,095.20	1,090.71	-36.30
E. Electronic industry	207.01	241.55	218.41	233.40	260.11	246.60	241.26	244.73	248.25	268.81	217.25	100.00
F. Product uses as ODS substitutes	12041.57	12955.26	13585.52	14255.68	14900.54	15382.19	16,009.82	16,214.88	16,477.76	16,854.19	15,861.10	100.00
G. Other product manufacture and use	948.73	945.22	1001.22	929.70	839.86	891.89	859.42	910.22	965.34	899.92	725.33	-32.54
H. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
3. Agriculture	31555.19	32032.38	32333.67	31514.86	31267.88	31206.67	32140.80	31683.77	31459.98	31353.65	32684.53	-11.42
A. Enteric fermentation	12884.04	12885.15	12930.88	13085.01	12931.88	13035.03	13,315.07	13,429.21	13,381.32	13,363.95	13,534.85	-13.04
B. Manure management	6873.67	6823.53	6637.37	6532.57	6392.19	6353.42	6,334.43	6,334.97	6,232.51	6,205.85	6,224.92	-18.91
C. Rice cultivation	1822.19	1805.45	1789.14	1661.30	1613.42	1668.26	1,714.89	1,645.74	1,601.25	1,583.17	1,582.05	-15.69
D. Agricultural soils	9574.98	10095.47	10364.02	9735.66	9868.00	9672.09	10,161.45	9,798.83	9,783.64	9,752.42	10,820.46	-3.85
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
F. Field burning of agricultural residues	19.25	18.98	20.15	19.01	18.77	19.57	20.96	18.98	18.91	18.67	18.85	0.73
G. Liming	18.31	25.42	15.88	14.12	11.97	13.50	11.95	17.47	15.45	16.24	9.98	636.38
H. Urea application	335.10	350.76	550.91	450.42	411.00	424.93	561.07	418.45	405.26	396.45	471.95	1.53
I. Other carbon-containing fertilizers	27.65	27.63	25.33	16.77	20.66	19.87	20.98	20.12	21.65	16.88	21.47	-50.84
J. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
4. Land use, land-use change and forestry[(2)]	-41535.82	-33519.99	-24493.95	-39625.08	-40535.34	-43092.59	-40234.88	-19882.07	-35522.57	-40679.76	-32401.01	788.25
A. Forest land	-36145.91	-32026.64	-27466.97	-36859.27	-37962.00	-39221.26	-36,121.43	-20,403.05	-31,857.32	-36,254.89	-30,115.27	74.53
B. Cropland	-865.98	784.55	2031.56	1750.00	1412.98	575.37	-1,308.03	-1,005.45	-577.45	-523.04	-13.80	-100.81
C. Grassland	-9209.57	-7229.96	-4095.43	-9622.30	-9020.61	-9400.16	-8,381.47	-4,122.33	-8,952.37	-8,045.52	-7,207.48	-240.72
D. Wetlands	129.57	129.57	129.57	129.57	129.57	129.57	31.61	31.61	31.61	31.61	31.61	100.00
E. Settlements	4688.35	4694.97	4699.86	4708.07	4716.52	4735.35	5,546.10	5,548.67	5,555.37	5,563.34	5,569.15	-22.06
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change from base to latest reported year
	(kt CO_2 eq)											%
G. Harvested wood products	-141.65	120.09	201.82	265.26	186.42	88.54	-6.11	59.33	264.10	-1,469.13	-668.52	72.39
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
5. Waste	20381.59	19792.07	19894.75	18640.66	18436.42	18543.57	18254.59	18160.92	18144.65	17932.24	18613.95	7.67
A. Solid waste disposal	15561.47	15013.61	15102.79	13880.73	13824.78	14033.68	13,689.70	13,645.07	13,628.59	13,444.19	14,253.06	16.77
B. Biological treatment of solid waste	619.07	630.87	629.89	659.27	713.65	642.00	653.13	643.40	633.65	624.39	600.81	2303.66
C. Incineration and open burning of waste	257.74	257.71	283.17	302.57	188.96	177.49	183.33	168.35	165.29	169.31	168.36	-71.88
D. Waste water treatment and discharge	3943.32	3889.88	3878.91	3798.08	3709.04	3690.40	3,728.42	3,704.10	3,717.12	3,694.36	3,591.72	-19.44
E. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
6. Other *(as specified in summary 1.A)*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
Memo items:												
International bunkers	15858.74	16485.80	15444.77	14034.93	13721.67	15361.43	17030.90	18513.80	19246.85	19142.21	9438.43	7.02
Aviation	8885.42	9286.31	8999.10	8942.76	9096.40	9647.07	10,376.89	11,247.82	12,056.25	12,497.87	3,820.48	-11.59
Navigation	6973.33	7199.50	6445.67	5092.16	4625.27	5714.36	6,654.01	7,265.98	7,190.60	6,644.34	5,617.95	24.91
Multilateral operations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	0.00
CO_2 emissions from biomass	42587.98	36933.15	42902.08	46205.49	43159.80	45618.16	44,787.09	46,898.27	45,388.51	45,751.53	44,836.52	216.26
CO_2 captured	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	0.00
Long-term storage of C in waste disposal sites	6620.25	5772.69	5050.28	4839.50	4438.06	4009.23	3,020.78	3,268.17	3,005.30	2,854.33	2,602.28	-63.13
Indirect N_2O	1391.23	1337.77	1280.52	1135.98	1107.07	1048.35	1,026.38	1,006.33	953.84	923.76	829.01	-73.06
Indirect CO_2 (3)	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	0.00
Total CO_2 equivalent emissions without land use, land-use change and forestry	517804.06	505141.14	485879.74	450434.41	429340.84	441759.07	439274.37	433482.10	429624.38	418352.22	381247.96	-26.67
Total CO_2 equivalent emissions with land use, land-use change and forestry	476268.25	471621.16	461385.79	410809.33	388805.50	398666.49	399039.49	413600.02	394101.81	377672.46	348846.95	-32.43
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS EMISSIONS	Base year(1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)										
CO_2 emissions without net CO_2 from LULUCF	439549.77	439549.77	439094.03	439315.22	431604.73	425796.75	449826.01	444029.28	449754.08	461945.88	466424.83
CO_2 emissions with net CO_2 from LULUCF	433847.59	433847.59	418701.32	420854.98	425188.36	406999.20	424921.43	417729.97	431335.44	445699.60	441593.16
CH_4 emissions without CH_4 from LULUCF	49331.22	49331.22	50203.24	50023.30	50328.25	50714.35	51346.99	51854.80	52407.19	51943.24	51937.81
CH_4 emissions with CH_4 from LULUCF	50617.19	50617.19	50788.12	50674.48	51631.34	51490.84	51649.73	52189.22	53152.23	52901.45	52412.73
N_2O emissions without N_2O from LULUCF	26080.24	26080.24	27103.25	26639.01	27076.29	26547.98	27630.89	27743.69	28722.63	28997.30	29565.84
N_2O emissions with N_2O from LULUCF	27005.36	27005.36	28089.47	27628.70	28183.99	27603.96	28559.89	28491.43	29507.88	29833.51	30261.85
HFCs	444.00	444.00	449.30	471.91	494.10	664.06	926.65	668.42	1004.12	1525.70	1988.67
PFCs	2906.86	2906.86	2509.91	1818.77	1672.06	1422.70	1492.31	1234.58	1281.12	1329.37	1327.60
Unspecified mix of HFCs and PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	24.97	24.97	24.97	24.97	24.97
SF_6	408.35	408.35	430.80	432.63	444.29	487.52	679.72	761.72	813.39	688.56	463.55
NF_3	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	76.57	61.78	54.09	33.83	26.69
Total (without LULUCF)	518720.44	518720.44	519790.53	518700.84	511619.71	505633.37	532004.11	526379.22	534061.59	546488.84	551759.95
Total (with LULUCF)	515229.35	515229.35	500968.91	501881.47	507614.13	488668.28	508331.28	501162.08	517173.23	532036.99	528099.22
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year(1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)										
1. Energy	425321.96	425321.96	425391.80	425084.21	420184.19	415291.55	437941.49	434832.93	440710.12	453429.84	457798.05
2. Industrial processes and product use	40421.81	40421.81	39989.72	39374.60	36421.21	35030.74	38315.54	35300.89	35852.89	36476.23	36993.38
3. Agriculture	35672.25	35672.25	36440.91	35887.94	36189.23	35842.47	35751.01	35579.98	36185.56	35525.87	35912.54
4. Land use, land-use change and forestry(5)	-3491.09	-3491.09	-18821.62	-16819.37	-4005.58	-16965.09	-23672.83	-25217.14	-16888.36	-14451.86	-23660.73
5. Waste	17304.42	17304.42	17968.10	18354.10	18825.08	19468.61	19996.08	20665.43	21313.02	21056.90	21055.97
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)(5)	515229.35	515229.35	500968.91	501881.47	507614.13	488668.28	508331.28	501162.08	517173.23	532036.99	528099.22

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS
SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS EMISSIONS	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2 emissions without net CO_2 from LULUCF	470487.19	470568.08	477998.97	495961.64	501563.23	502255.44	496846.73	490566.29	478868.68	424694.44
CO_2 emissions with net CO_2 from LULUCF	447965.20	437967.41	441315.78	466828.12	466377.38	466084.28	459980.81	475199.83	446607.05	388267.42
CH_4 emissions without CH_4 from LULUCF	51913.39	52253.41	50573.91	50823.43	48682.42	49204.75	47769.14	48499.31	47888.22	47799.43
CH_4 emissions with CH_4 from LULUCF	52627.65	52731.64	50834.07	51407.12	49032.04	49504.08	48008.31	49884.15	48393.72	48402.82
N_2O emissions without N_2O from LULUCF	30270.07	30484.69	29843.06	29510.50	30478.18	29280.56	24286.61	23771.33	22156.52	21111.22
N_2O emissions with N_2O from LULUCF	30964.66	31128.92	30439.69	30177.06	31109.02	29911.01	24907.92	24638.41	22832.00	21753.32
HFCs	2488.94	3284.11	4208.87	5225.09	6461.21	7619.16	8742.14	9453.48	10391.31	11205.71
PFCs	1488.50	1502.53	1491.23	1882.18	1950.88	1939.95	1935.14	1886.20	1712.39	1215.36
Unspecified mix of HFCs and PFCs	24.97	24.97	24.97	24.97	24.97	24.97	24.97	24.97	24.97	24.97
SF_6	604.31	852.72	740.72	549.89	584.55	550.00	570.29	452.66	495.92	472.03
NF_3	13.26	12.79	28.06	27.84	28.86	33.38	22.20	11.57	18.79	17.97
Total (without LULUCF)	557290.63	558983.29	564909.80	584005.54	589774.30	590908.21	580197.22	574665.81	561556.79	506541.13
Total (with LULUCF)	536177.49	527505.07	529083.39	556122.27	555568.91	555666.83	544191.78	561551.26	530476.15	471359.59
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1. Energy	459631.20	458435.11	465345.75	483129.42	486996.42	487640.33	481855.86	475936.40	466981.98	417629.43
2. Industrial processes and product use	39123.39	41079.21	41483.23	43179.25	46293.02	47211.30	43359.71	43511.23	41071.67	35905.97
3. Agriculture	36682.43	36321.28	35668.67	35408.27	34777.81	34192.12	33657.88	34261.21	33088.49	32456.45
4. Land use, land-use change and forestry[5]	-21113.14	-31478.22	-35826.41	-27883.28	-34205.39	-35241.38	-36005.44	-13114.55	-31080.65	-35181.54
5. Waste	21853.62	23147.68	22412.15	22288.61	21707.04	21864.46	21323.78	20956.97	20414.65	20549.29
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)[5]	536177.49	527505.07	529083.39	556122.27	555568.91	555666.83	544191.78	561551.26	530476.15	471359.59

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS

SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS EMISSIONS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change from base to latest reported year
	CO_2 equivalent (kt)											(%)
CO_2 emissions without net CO_2 from LULUCF	436117.44	424256.27	403696.91	369679.72	349390.36	361163.18	358182.54	352735.39	349005.04	339233.21	302278.60	-31.23
CO_2 emissions with net CO_2 from LULUCF	393801.74	389711.47	377461.34	329563.66	308220.55	317478.71	317209.67	330784.87	312870.00	297856.18	269189.98	-37.94
CH_4 emissions without CH_4 from LULUCF	47340.84	45911.77	46466.49	45008.77	44050.81	44112.22	43681.28	43672.28	42981.95	41982.45	42780.07	-13.38
CH_4 emissions with CH_4 from LULUCF	47691.08	46478.71	47666.61	45165.14	44325.21	44376.44	43987.69	45183.36	43143.37	42185.32	43042.57	-15.06
N_2O emissions without N_2O from LULUCF	20331.05	19846.33	20123.67	19297.43	19004.49	18866.63	19308.42	19059.33	18987.32	18756.73	19471.13	-28.44
N_2O emissions with N_2O from LULUCF	20760.69	20304.20	20665.18	19632.03	19364.56	19194.28	19740.02	19616.69	19438.37	19251.12	19896.24	-29.11
HFCs	12055.42	12971.38	13597.95	14270.54	14918.54	15403.09	16030.03	16235.46	16495.79	16870.73	15876.24	3475.73
PFCs	1520.39	1661.28	1499.21	1705.41	1564.34	1688.33	1613.73	1313.68	1657.27	1027.55	538.62	-81.47
Unspecified mix of HFCs and PFCs	24.97	24.97	24.97	24.97	24.97	24.97	24.97	24.97	23.15	23.54	22.86	100.00
SF_6	393.79	441.36	445.61	421.88	359.16	472.25	399.42	417.49	451.73	440.17	264.14	-35.32
NF_3	20.17	27.78	24.93	25.70	28.17	28.42	33.98	23.50	22.13	17.84	16.31	100.00
Total (without LULUCF)	517804.06	505141.14	485879.74	450434.41	429340.84	441759.07	439274.37	433482.10	429624.38	418352.22	381247.96	-26.67
Total (with LULUCF)	476268.25	471621.16	461385.79	410809.33	388805.50	398666.49	399039.49	413600.02	394101.81	377672.46	348846.95	-32.43
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00

Table A8.1.1 GHG emission trends by gas and by sector, CRF year 2020

TABLE 10 EMISSION TRENDS

SUMMARY

Inventory 2020
Submission 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change from base to latest reported year
	CO_2 equivalent (kt)											(%)
1. Energy	428903.22	416018.15	399105.28	366695.06	346450.28	358776.32	355381.05	349941.86	345416.08	335080.92	298900.44	-29.72
2. Industrial processes and product use	36964.06	37298.54	34546.03	33583.83	33186.27	33232.52	33497.93	33695.55	34603.67	33985.41	31049.05	-23.19
3. Agriculture	31555.19	32032.38	32333.67	31514.86	31267.88	31206.67	32140.80	31683.77	31459.98	31353.65	32684.53	-11.42
4. Land use, land-use change and forestry[5]	-41535.82	-33519.99	-24493.95	-39625.08	-40535.34	-43092.59	-40234.88	-19882.07	-35522.57	-40679.76	-32401.01	788.25
5. Waste	20381.59	19792.07	19894.75	18640.66	18436.42	18543.57	18254.59	18160.92	18144.65	17932.24	18613.95	7.67
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
Total (including LULUCF)[5]	476268.25	471621.16	461385.79	410809.33	388805.50	398666.49	399039.49	413600.02	394101.81	377672.46	348846.95	-32.43

A8.2 Supplementary information under Article 7, paragraph 1

A8.2.1 KP-LULUCF

Table A8.2.1.1 Activity coverage and other information relating to activities under Article 3, paragraph 3, forest management under Article 3.4, and elected activities under Article 3.4

Table NIR 1. SUMMARY TABLE

Activity	CHANGE IN CARBON POOL REPORTED(1)							GREENHOUSE GAS SOURCES REPORTED(2)							
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP(4)	Fertilization(5)	Drained, rewetted and other soils(6)		Nitrogen mineralization in mineral soils(8)	Indirect N_2O emissions from managed soil(5)	Biomass burning(9)		
					Mineral	Organic(3)		N_2O	CH_4(7)	N_2O	N_2O	N_2O	CO_2(10)	CH_4	N_2O
Article 3.3 activities															
Afforestation and reforestation	R	R	R	R	R	NO	R	NO	NO	NO	R	R	R	R	R
Deforestation	R	R	R	R	R	NO	R	NO	NO	NO	NO	NO	NO	NO	NO
Article 3.4 activities															
Forest management	R	R	R	R	NR	NR	R	NO	NO	NO	NO	NO	R	R	R
Cropland management	R	R	NO	NO	R	R			NO		R		R	R	R
Grazing land management	NO	NO	NO	NO	R	NO			NO		NO		NO	NO	NO
Revegetation	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
Wetland drainage and rewetting	NA	NA	NA	NA		NA		NA	NA	NA		NA	NA	NA	NA

(1) Indicate R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4, or instantaneous oxidation (IO) for carbon stock changes in harvest wood products (HWP). With the exception of HWP, if changes in a carbon pool are not reported , verifiable information in the national inventory report (NIR) must be provided that demonstrates that these unaccounted pools were not a net source of anthropogenic greenhouse gas emissions. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the NIR.
(2) Indicate R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring) for greenhouse gas sources reported, for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the NIR.
(3) Includes CO_2 emissions/removals from organic soils, including CO_2 emissions from dissolved organic carbon associated with drainage and rewetting. On-site CO_2 emissions/removals from drainage and rewetting from organic soils and off-site CO_2 emissions via water-borne carbon losses from organic soils should be reported here for wetland drainage and rewetting. These emissions could be reported for other activities as appropriate.
(4) HWP from lands reported under deforestation, which originated from the deforestation event at the time of the land-use change shall be accounted for on the basis of instantaneous oxidation (IO).
(5) N_2O emissions from fertilization of afforestation/reforestation, deforestation, forest management, revegetation and wetland drainage and rewetting should be reported here when these emissions are not reported under the agriculture sector.
(6) CH_4 and N_2O emissions from drained and rewetted organic soils should be reported here, as appropriate, when emissions are not reported under the agriculture sector. For wetland drainage and rewetting only emissions from organic soils are included.
(7) CH_4 emissions from drained soils and drainage ditches should be reported here, as appropriate.
(8) N_2O emissions from nitrogen mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils under afforestation/reforestation, deforestation, forest management, cropland management, grazing land management and revegetation should be reported here when these emissions are not reported under the agriculture sector.
(9) Emissions from burning of organic soils should also be included here, as appropriate.
(10) If CO_2 emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning. Parties that include CO_2 emissions from biomass burning in their carbon stock change estimates should report IE (included elsewhere).

Table A8.2.1.2 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 1990

Table NIR 2. LAND TRANSITION MATRIX 1990

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other[6]	Total area at the end of the previous inventory year[7]
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	73.77	NO							73.77
Deforestation		14.44							14.44
Article 3.4 activities									
Forest management		0.72	7511.12						7511.84
Cropland management[3] (if elected)	NO		NO	10729.52	NO	NO	NO		10729.52
Grazing land management[3] (if elected)	NO		NO	NO	3825.93	NO	NO		3825.93
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	78.68	NO	NO	NO	NO	NO	NO	7899.42	7978.10
Total area at the end of the current inventory year	152.45	15.17	7511.12	10729.52	3825.93	NA,NO	NA,NO	7899.42	30133.60

Table A8.2.1.3 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2013

Table NIR 2. LAND TRANSITION MATRIX 2013

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other[6]	Total area at the end of the previous inventory year[7]
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1670.08	NO							1670.08
Deforestation		40.39							40.39
Article 3.4 activities									
Forest management		3.69	7471.45						7475.15
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3653.92	NO	NO		3653.92
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	8235.96	8294.27
Total area at the end of the current inventory year	1728.40	44.08	7471.45	8999.78	3653.92	NA,NO	NA,NO	8235.96	30133.60

Table A8.2.1.4 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2014

Table NIR 2. LAND TRANSITION MATRIX 2014

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES						
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)	Other[6]	Total area at the end of the previous inventory year[7]
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1728.40	NO							1728.40
Deforestation		44.08							44.08
Article 3.4 activities									
Forest management		3.69	7467.76						7471.45
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3653.92	NO	NO		3653.92
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	294.75	NO	NO	7882.89	8235.96
Total area at the end of the current inventory year	1786.71	47.78	7467.76	8999.78	3948.68	NA,NO	NA,NO	7882.89	30133.60

Table A8.2.1.5 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2015

Table NIR 2. LAND TRANSITION MATRIX 2015

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES						
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)	Other[6]	Total area at the end of the previous inventory year[7]
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1786.71	NO							1786.71
Deforestation		47.78							47.78
Article 3.4 activities									
Forest management		3.69	7464.06						7467.76
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7824.58	7882.89
Total area at the end of the current inventory year	1845.03	51.47	7464.06	8999.78	3948.68	NO,NA	NO,NA	7824.58	30133.60

Table A8.2.1.6 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2016

Table NIR 2. LAND TRANSITION MATRIX 2016

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other[6]	Total area at the end of the previous inventory year[7]
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1845.03	NO							1845.03
Deforestation		51.47							51.47
Article 3.4 activities									
Forest management		3.69	7460.37						7464.06
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7766.26	7824.58
Total area at the end of the current inventory year	1903.34	55.17	7460.37	8999.78	3948.68	NO,NA	NO,NA	7766.26	30133.60

Table A8.2.1.7 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2017

Table NIR 2. LAND TRANSITION MATRIX 2017

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other[6]	Total area at the end of the previous inventory year[7]
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1903.34	NO							1903.34
Deforestation		55.17							55.17
Article 3.4 activities									
Forest management		3.69	7456.68						7460.37
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7707.95	7766.26
Total area at the end of the current inventory year	1961.66	58.86	7456.68	8999.78	3948.68	NO,NA	NO,NA	7707.95	30133.60

Table A8.2.1.8 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2018

Table NIR 2. LAND TRANSITION MATRIX 2018

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES						
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)	Other[6]	Total area at the end of the previous inventory year[7]
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	1961.66	NO							1961.66
Deforestation		58.86							58.86
Article 3.4 activities									
Forest management		3.69	7452.98						7456.68
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7649.64	7707.95
Total area at the end of the current inventory year	2019.97	62.56	7452.98	8999.78	3948.68	NO,NA	NO,NA	7649.64	30133.60

Table A8.2.1.9 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2019

Table NIR 2. LAND TRANSITION MATRIX 2019

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES						
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)	Other[6]	Total area at the end of the previous inventory year[7]
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	2019.97	NO							2019.97
Deforestation		62.56							62.56
Article 3.4 activities									
Forest management		3.69	7445.59						7449.29
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7595.02	7653.33
Total area at the end of the current inventory year	2078.28	66.25	7445.59	8999.78	3948.68	NO,NA	NO,NA	7595.02	30133.60

Table A8.2.1.10 Areas and changes in areas between the previous and the current inventory year. Land transition matrix 2020

Table NIR 2. LAND TRANSITION MATRIX 2020

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other[6]	Total area at the end of the previous inventory year[7]
	Afforestation and reforestation	Deforestation	Forest management[5]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	2078.28	NO							2078.28
Deforestation		66.25							66.25
Article 3.4 activities									
Forest management		3.69	7441.90						7445.59
Cropland management[3] (if elected)	NO		NO	8999.78	NO	NO	NO		8999.78
Grazing land management[3] (if elected)	NO		NO	NO	3948.68	NO	NO		3948.68
Revegetation[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[3] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[4]	58.31	NO	NO	NO	NO	NO	NO	7536.70	7595.02
Total area at the end of the current inventory year	2136.60	69.95	7441.90	8999.78	3948.68	NO,NA	NO,NA	7536.70	30133.60

[1] This table should be used to report land area and changes in land area subject to the various activities in the inventory year. For each activity it should be used to report area change between the end of the previous inventory year and the end of the current inventory year. For example, the total area of land subject to forest management in the previous inventory year and which was deforested in the current inventory year, should be reported in the deforestation column and in the forest management row.
[2] In accordance with relevant decisions. Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

[3] Lands subject to cropland management, grazing land management, revegetation or wetland drainage and rewetting that after 2013 are subject to activities other than those under Article 3.3 and 3.4, should still be tracked and reported under cropland management, grazing land management, revegetation or wetland drainage and rewetting, respectively.
[4] Other refers to the area that is reported under Article 3.3 or 3.4 in the current inventory for the first time. This footnote does not apply to the cell belonging to the column and the row "other" to "other".
[5] Changes in area from cropland management, grazing land management, revegetation and wetland drainage and rewetting to forest management should be reported only in the case of carbon equivalent forest conversions.
[6] "Other", in this column, is the area of the country that has never been subject to any activity under Article 3.3 or 3.4

[7] The value in the cell of row "Total area at the end of the current inventory year" corresponds to the total land area of a country. The total land area should be the same for the current inventory year and the previous inventory year in this matrix.

Table A8.2.1.11 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 1990
Table 4(KP). SUMMARY TABLE – 1990

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				24.82
A.1. Afforestation and reforestation[6]	NA,NO,IE	NO,NA	NO,NA	NA,NO,IE
A.2. Deforestation	NA,NO	NO	0.08	24.82
B. Article 3.4 activities				1119.28
B.1. Forest management	-387.80	NO	NO	-387.80
B.2. Cropland management (if elected)	1301.03	0.22	0.25	1381.46
B.3. Grazing land management (if elected)	115.77	NO	0.03	125.62
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.12 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2013
Table 4(KP). SUMMARY TABLE – 2013

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-4314.66
A.1. Afforestation and reforestation[6]	-6279.36	0.65	0.02	-6257.04
A.2. Deforestation	1916.89	NO	0.09	1942.37
B. Article 3.4 activities				-33152.65
B.1. Forest management	-30196.62	2.81	0.09	-30100.15
B.2. Cropland management (if elected)	-2309.78	0.31	0.06	-2283.25
B.3. Grazing land management (if elected)	-769.26	NO	NO	-769.26
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.13 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2014
Table 4(KP). SUMMARY TABLE – 2014

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-6212.62
A.1. Afforestation and reforestation[6]	-8195.05	0.85	0.03	-8165.72
A.2. Deforestation	1927.62	NO	0.09	1953.11
B. Article 3.4 activities				-34859.23
B.1. Forest management	-31219.91	3.56	0.11	-31097.40
B.2. Cropland management (if elected)	-2587.42	0.03	0.03	-2578.34
B.3. Grazing land management (if elected)	-1183.49	NO	NO	-1183.49
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.14 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2015
Table 4(KP). SUMMARY TABLE – 2015

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-6606.32
A.1. Afforestation and reforestation[6]	-8614.44	1.30	0.04	-8569.89
A.2. Deforestation	1938.09	NO	0.09	1963.57
B. Article 3.4 activities				-36596.80
B.1. Forest management	-32428.29	5.24	0.16	-32248.17
B.2. Cropland management (if elected)	-3506.92	0.10	0.00	-3503.61
B.3. Grazing land management (if elected)	-845.01	NO	NO	-845.01
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.15 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2016
Table 4(KP). SUMMARY TABLE – 2016

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-7062.39
A.1. Afforestation and reforestation[6]	-9088.61	1.54	0.05	-9035.85
A.2. Deforestation	1947.97	NO	0.09	1973.45
B. Article 3.4 activities				-35670.95
B.1. Forest management	-29270.86	6.02	0.19	-29064.14
B.2. Cropland management (if elected)	-5696.29	0.08	0.07	-5673.70
B.3. Grazing land management (if elected)	-933.11	NO	NO	-933.11
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.16 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2017
Table 4(KP). SUMMARY TABLE – 2017

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-6324.47
A.1. Afforestation and reforestation[6]	-8625.05	9.46	0.30	-8299.86
A.2. Deforestation	1949.69	NO	0.09	1975.39
B. Article 3.4 activities				-19240.87
B.1. Forest management	-14352.77	35.95	1.13	-13117.29
B.2. Cropland management (if elected)	-5632.92	0.32	0.15	-5581.17
B.3. Grazing land management (if elected)	-542.41	NO	NO	-542.41
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.17 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2018
Table 4(KP). SUMMARY TABLE – 2018

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-3501.85
A.1. Afforestation and reforestation[6]	-5521.23	1.05	0.03	-5485.32
A.2. Deforestation	1957.77	NO	0.09	1983.47
B. Article 3.4 activities				-30166.50
B.1. Forest management	-24407.03	3.85	0.12	-24274.59
B.2. Cropland management (if elected)	-5380.95	0.09	0.20	-5318.02
B.3. Grazing land management (if elected)	-573.89	NO	NO	-573.89
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.18 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2019
Table 4(KP). SUMMARY TABLE – 2019

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-5993.63
A.1. Afforestation and reforestation[6]	-8020.40	0.98	0.03	-7986.88
A.2. Deforestation	1967.55	NO	0.09	1993.25
B. Article 3.4 activities				-36275.27
B.1. Forest management	-30338.37	3.49	0.11	-30218.27
B.2. Cropland management (if elected)	-5501.09	0.13	0.27	-5417.10
B.3. Grazing land management (if elected)	-639.91	NO	NO	-639.91
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

Table A8.2.1.19 Report of supplementary information for Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol - 2020
Table 4(KP). SUMMARY TABLE – 2020

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO_2 emissions/ removals[3]	CH_4[4]	N_2O[5]	Net CO_2 equivalent emissions/removals
	(kt)			
A. Article 3.3 activities				-7141.56
A.1. Afforestation and reforestation[6]	-9185.09	1.27	0.04	-9141.59
A.2. Deforestation	1974.33	NO	0.09	2000.03
B. Article 3.4 activities				-27803.19
B.1. Forest management	-23334.92	4.54	0.14	-23179.07
B.2. Cropland management (if elected)	-4030.68	0.14	0.05	-4011.22
B.3. Grazing land management (if elected)	-612.90	NO	NO	-612.90
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

(1) All estimates in this table include emissions and removals from projects under Article 6 hosted by the reporting Party.
(2) If cropland management, grazing land management, revegetation and/or wetland drainage and rewetting are elected, this table and all relevant CRF tables shall also be reported for the base year for these activities.
(3) For the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+). Net changes in carbon stocks are converted to CO_2 by multiplying C by 44/12 and by changing the sign for net CO_2 removals to be negative (-) and net CO_2 emissions to be positive (+).
(4) CH_4 emissions reported here for cropland management, grazing land management, revegetation and/or wetland drainage and rewetting, if elected, include only emissions from drainage or rewetting of organic soils and from biomass burning (with the exception of savanna burning and agricultural residue burning which are reported in the agriculture sector).
(5) N_2O emissions reported here for cropland management, if elected, include only emissions from biomass burning (with the exception of savannah burning and agricultural residue burning which are reported in the agriculture sector).
(6) As both afforestation and reforestation under Article 3.3 are subject to the same provisions specified in the annex to decision 2/CMP.7, they can be reported together.

A8.2.2 Standard electronic format

Table A8.2.2.1 Total quantities of Kyoto Protocol units by account type at beginning of reported year

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

	Account type	Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Party holding accounts	NO	698.870	NO	975.569	NO	NO
2	Entity holding accounts	NO	399.901	NO	3.912.703	142.719	NO
3	Retirement account	NO	NO	NO	NO	NO	NO
4	Previous period surplus reserve account	NO					
5	Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
6	Non-compliance cancellation account	NO	NO	NO	NO		
7	Voluntary cancellation account	NO	10.175	NO	28.326	NO	NO
8	Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
9	Article 3.1 ter and quater ambition increase cancellation account	NO					
10	Article 3.7 ter cancellation account	NO					
11	tCER cancellation account for expiry					NO	
12	lCER cancellation account for expiry						NO
13	lCER cancellation account for reversal of storage						NO
14	lCER cancellation account for non-submission of certification report						NO
15	tCER replacement account for expiry	NO	NO	NO	NO	NO	
16	lCER replacement account for expiry	NO	NO	NO	NO		
17	lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
18	lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
	Total	NO	1.108.946	NO	4.916.598	142.719	NO

Table A8.2.2.2.a Annual internal transactions

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 2 (a). Annual internal transactions

	Transaction type	Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
	Article 6 issuance and conversion												
1	Party-verified projects		NO					NO		NO			
2	Independently verified projects		NO					NO		NO			
	Article 3.3 and 3.4 issuance or cancellation												
3	3.3 Afforestation and reforestation			NO				NO	NO	NO	NO		
4	3.3 Deforestation			NO				NO	NO	NO	NO		
5	3.4 Forest management			NO				NO	NO	NO	NO		
6	3.4 Cropland management			NO				NO	NO	NO	NO		
7	3.4 Grazing land management			NO				NO	NO	NO	NO		
8	3.4 Revegetation			NO				NO	NO	NO	NO		
9	3.4 Wetlands drainage and management			NO				NO	NO	NO	NO		
	Article 12 afforestation and reforestation												
10	Replacement of expired tCERs							NO	NO	NO	NO	NO	
11	Replacement of expired lCERs							NO	NO	NO	NO		
12	Replacement for reversal of storage							NO	NO	NO	NO		NO
13	Cancellation for reversal of storage												NO
14	Replacement for non-submission of certification report							NO	NO	NO	NO		NO
15	Cancellation for non-submission of certification report												NO

	Other cancelation												
16	Voluntary cancellation							NO	27.700	NO	22.271	NO	NO
17	Article 3.1 ter and quater ambition increase cancellation							NO					
	Sub-total		NO	NO				NO	27.700	NO	22.271	NO	NO

	Transaction type	**Retirement**					
		Unit type					
		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	Retirement	NO	NO	NO	NO	NO	NO
2	Retirement from PPSR	NO					
	Total	NO	NO	NO	NO	NO	NO

Table A8.2.2.2.b Total annual external transactions

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 2 (b). Total annual external transactions

		Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
	Total transfers and acquisitions												
1	CDM	NO	NO	NO	NO	163	NO	NO	NO	NO	NO	NO	NO
2	CH	NO	NO	NO	201.000	NO	NO	NO	NO	NO	NO	NO	NO
3	EU	NO	NO	NO	NO	NO	NO	NO	NO	NO	39.029	NO	NO
	Sub-total	NO	NO	NO	201.000	163	NO	NO	NO	NO	39.029	NO	NO

Table A8.2.2.2.c Annual transactions between PPSR accounts

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 2 (c). Annual transactions between PPSR accounts

		Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
	Transfers and acquisitions between PPSR accounts												
	Sub-total	NO						NO					

Table A8.2.2.2.d Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 2 (d). Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation fund

		Amount transferred or converted						Amount contributed as SoP to the adaptation fund					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	First international transfers of AAUs	NO						NO					
2	Issuance of ERU from party-verified projects		NO						NO				
3	Issuance of independently verified ERUs		NO						NO				

Table A8.2.2.2.e Total annual transactions

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 2 (e). Total annual transactions

1	**Total (Sum of sub-totals in table 2a and table 2b)**	NO	NO	NO	201.000	163	NO	NO	27.700	NO	61.300	NO	NO

Table A8.2.2.3 Annual expiry, cancellation and replacement

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 3. Annual expiry, cancellation and replacement

	Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
		Unit type			Unit type						Unit type					
		tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
	Temporary CERs															
1	Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
2	Expired in holding accounts	NO													NO	
	Long-term CERs															
3	Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
4	Expired in holding accounts		NO													NO
5	Subject to reversal of storage		NO		NO	NO	NO	NO		NO						NO
6	Subject to non-submission of certification Report		NO		NO	NO	NO	NO		NO						NO
	Carbon Capture and Storage CERs															
7	Subject to net reversal of storage			NO							NO	NO	NO	NO		
8	Subject to non-submission of certification report			NO							NO	NO	NO	NO		
	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table A8.2.2.4 Total quantities of Kyoto Protocol units by account type at end of reported year

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

	Account type	Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Party holding accounts	2.410.291.421	698.870	NO	975.569	NO	NO
2	Entity holding accounts	NO	372.201	NO	4.052.403	142.882	NO
3	Retirement account	NO	NO	NO	NO	NO	NO
4	Previous period surplus reserve account	NO					
5	Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
6	Non-compliance cancellation account	NO	NO	NO	NO		
7	Voluntary cancellation account	NO	37.875	NO	50.597	NO	NO
8	Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
9	Article 3.1 ter and quater ambition increase cancellation account	NO					
10	Article 3.7 ter cancellation account	NO					
11	tCER cancellation account for expiry					NO	
12	lCER cancellation account for expiry						NO
13	lCER cancellation account for reversal of storage						NO
14	lCER cancellation account for non-submission of certification report						NO
15	tCER replacement account for expiry	NO	NO	NO	NO	NO	
16	lCER replacement account for expiry	NO	NO	NO	NO		
17	lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
18	lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
	Total	2.410.291.421	1.108.946	NO	5.078.569	142.882	NO

Table A8.2.2.5.a Summary information on additions and subtractions

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 5 (a). Summary information on additions and subtractions

		Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Assigned amount units issued	2.410.291.421											
2	Article 3 paragraph 7 ter cancellations							NO					
3	Cancellation following increase in ambition							NO					
4	Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
5	Non-compliance cancellation							NO	NO	NO	NO		
6	Carry-over		1.108.946		2.112.952				NO		NO		
7	Carry-over to PPSR	NO						NO					
	Total	2.410.291.421	1.108.946		2.112.952			NO	NO	NO	NO	NO	NO

Table A8.2.2.5.b Summary information on annual transactions

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 5 (b). Summary information on annual transactions

		Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2	Year 2 (2014)	NO	NO	NO	168.770	NO	NO	NO	NO	NO	168.671	NO	NO
3	Year 3 (2015)	NO	NO	NO	3.365.100	NO	NO	NO	NO	NO	2.051.147	NO	NO
4	Year 4 (2016)	NO	NO	NO	715.832	NO	NO	NO	NO	NO	297.919	NO	NO
5	Year 5 (2017)	NO	NO	NO	647.472	NO	NO	NO	7.659	NO	393.002	NO	NO
6	Year 6 (2018)	NO	NO	NO	278.361	NO	NO	NO	NO	NO	22.474	NO	NO
7	Year 7 (2019)	NO	NO	NO	622.614	29.694	NO	NO	1	NO	57.784	NO	NO
8	Year 8 (2020)	NO	NO	NO	237.830	113.025	NO	NO	2.515	NO	269.662	NO	NO
9	Year 2021	NO	NO	NO	201.000	163	NO	NO	27.700	NO	61.300	NO	NO
10	Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
11	Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	6.236.979	142.882	NO	NO	37.875	NO	3.321.959	NO	NO

Table A8.2.2.5.c Summary information on annual transactions between PPSR accounts

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 5 (c). Summary information on annual transactions between PPSR accounts

		Additions						Subtractions					
		Unit type						Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO						NO					
2	Year 2 (2014)	NO						NO					
3	Year 3 (2015)	NO						NO					
4	Year 4 (2016)	NO						NO					
5	Year 5 (2017)	NO						NO					
6	Year 6 (2018)	NO						NO					
7	Year 7 (2019)	NO						NO					
8	Year 8 (2020)	NO						NO					
9	Year 2021	NO						NO					
10	Year 2022	NO						NO					
11	Year 2023	NO						NO					
	Total	NO						NO					

Table A8.2.2.5.d Summary information on expiry, cancellation and replacement

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 5 (d). Summary information on expiry, cancellation and replacement

		Requirement to replace or cancel			Replacement						Cancellation					
		Unit type			Unit type						Unit type					
		tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2	Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3	Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4	Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5	Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6	Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7	Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8	Year 8 (2020)	131.267	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
9	Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
10	Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
11	Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	131.267	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table A8.2.2.5.e Summary information on retirement

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 5 (e). Summary information on retirement

	Year	Retirement					
		Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO	NO	NO	NO	NO	NO
2	Year 2 (2014)	NO	NO	NO	NO	NO	NO
3	Year 3 (2015)	NO	NO	NO	NO	NO	NO
4	Year 4 (2016)	NO	NO	NO	NO	NO	NO
5	Year 5 (2017)	NO	NO	NO	NO	NO	NO
6	Year 6 (2018)	NO	NO	NO	NO	NO	NO
7	Year 7 (2019)	NO	NO	NO	NO	NO	NO
8	Year 8 (2020)	NO	NO	NO	NO	NO	NO
9	Year 2021	NO	NO	NO	NO	NO	NO
10	Year 2022	NO	NO	NO	NO	NO	NO
11	Year 2023	NO	NO	NO	NO	NO	NO
	Total	NO	NO	NO	NO	NO	NO

Table A8.2.2.6.a,b,c Memo item: corrective transactions relating to addition and subtractions, replacement and retirement

Party	Italy
Submission year	2022
Reported year	2021
Commitment period	2

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 (b). Memo item: Corrective transactions relating to replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

A8.2.3 National registry

A8.2.3.1 Changes to national registry

Changes to national registry are described in Chapter 12.

A8.2.3.2 Reports

i) **list of discrepancies**
   no discrepancies occurred during the reporting period
ii) **notifications from EB of CDM**
   no CDM notifications were received by the Registry during the reporting period
iii) **non-replacements**
   no non-replacements occurred during the reporting period
iv) **invalid units**
   no invalid units to list for the reporting period

A8.2.4 Adverse impacts under Article 3, paragraph 14 of the Kyoto Protocol

Chapter 14 presents information on the commitments to tackle adverse impacts under Article 3, paragraph 14, of the Kyoto Protocol. Additional information which can be added is the list of all registered CDM projects in which Italy is involved.

Table A8.2.3.1 Information of the 129 registered CDM projects where Italy is involved (as for 01/03/2022)

Title	Host Parties	Other Parties	Impacts assessment
Project for GHG emission reduction by thermal oxidation of HFC 23 in Gujarat, India.	India (b)	Switzerland, Japan, Netherlands, Italy, United Kingdom of Great Britain and Northern Ireland	
Brazil NovaGerar Landfill Gas to Energy Project	Brazil (b)	Netherlands, Italy, Luxembourg, Switzerland, Japan, Spain	
La Esperanza Hydroelectric Project	Honduras (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	Nussbaumer (2009) + CDCF, Gold Standard *
Project for GHG Emission Reduction by Thermal Oxidation of HFC23 in Jiangsu Meilan Chemical CO. Ltd., Jiangsu Province, China	China (b)	Canada, Netherlands, Italy, Denmark, Finland, France, Sweden, Germany, United Kingdom of Great Britain and Northern Ireland, Switzerland, Japan, Norway, Spain	
Santa Rosa	Peru (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	Nussbaumer (2009) + CDCF
DSL Biomass based Power Project at Pagara	India (a)	Italy, Germany, United Kingdom of Great Britain and Northern Ireland	Sirohi (2007)
GHG emission reduction by thermal oxidation of HFC 23 at refrigerant (HCFC-22) manufacturing facility of SRF Ltd	India (b)	Netherlands, Italy, France, Germany, United Kingdom of Great Britain and Northern Ireland, Switzerland	Sirohi (2007)
Biogas Support Program - Nepal (BSP-Nepal) Activity-1	Nepal (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	Nussbaumer (2009) + CDCF, SD Tool *
Biogas Support Program - Nepal (BSP-Nepal) Activity-2	Nepal (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	Nussbaumer (2009) + CDCF, SD Tool *
Olavarría Landfill Gas Recovery Project	Argentina (c)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	Nussbaumer (2009) + CDCF
Moldova Biomass Heating in Rural Communities (Project Design Document No. 1)	Republic of Moldova (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	Nussbaumer (2009) + CDCF, SD Tool *
Moldova Biomass Heating in Rural Communities (Project Design Document No. 2)	Republic of Moldova (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	Nussbaumer (2009) + CDCF, SD Tool *
Moldova Energy Conservation and Greenhouse Gases Emissions Reduction	Republic of Moldova (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	SD Tool *

Title	Host Parties	Other Parties	Impacts assessment
Aleo Manali 3 MW Small Hydroelectric Project, Himachal Pradesh, India	India (a)	Switzerland, Italy, United Kingdom of Great Britain and Northern Ireland	Nussbaumer (2009), Sirohi (2007)
Landfill gas recovery at the Norte III Landfill, Buenos Aires, Argentina.	Argentina (b)	Switzerland, Italy	
5 MW Wind Power Project at Baramsar and Soda Mada, district Jaisalmer, Rajasthan, India.	India (a)	Italy	Nussbaumer (2009), Sirohi (2007)
Project for HFC23 Decomposition at Changshu 3F Zhonghao New Chemical Materials Co. Ltd, Changshu, Jiangsu Province, China	China (b)	Canada, Netherlands, Italy, Denmark, Finland, France, Sweden, Germany, United Kingdom of Great Britain and Northern Ireland, Switzerland, Japan, Norway, Spain	
Puente Gallego Landfill gas recovery project, Gallego, Rosario, Argentina.	Argentina (b)	Switzerland, Italy	
Djebel Chekir Landfill Gas Recovery and Flaring Project – Tunisia	Tunisia (c)	Italy	
Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin	China (b,d)	Japan, Italy, Spain, Luxembourg, France	Cóndor et al. (2010)
Project for HFC23 Decomposition at Zhejiang Dongyang Chemical Co., Ltd., China	China (b)	Switzerland, Netherlands, Italy, United Kingdom of Great Britain and Northern Ireland	
Project for HFC23 Decomposition at Limin Chemical Co., Ltd. Linhai, Zhejiang Province, China	China (b)	Switzerland, Netherlands, Italy, United Kingdom of Great Britain and Northern Ireland	
Recovery of associated gas that would otherwise be flared at Kwale oil-gas processing plant, Nigeria	Nigeria (b)	Italy	
Landfill Gas Recovery and Flaring for 9 bundled landfills in Tunisia	Tunisia (c)	Italy	
India-FaL-G Brick and Blocks Project No.1	India (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	Nussbaumer (2009) + CDCF
HFC23 Decomposition Project at Zhonghao Chenguang Research Institute of Chemical Industry, Zigong, SiChuan Province, China	China (b)	Switzerland, Netherlands, Italy, United Kingdom of Great Britain and Northern Ireland	
Huadian Inner Mongolia Huitengxile 100.25MW Wind Farm Project	China (c)	Italy	Boyd et al. (2009)
Yunnan Whitewaters Hydropower Development Project	China (c)	Italy	Nussbaumer (2009)
La Venta II	Mexico (c)	Japan, Italy, Luxembourg, Spain	
Allain Duhangan Hydroelectric Project (ADHP)	India (c)	Germany, Italy	

Title	Host Parties	Other Parties	Impacts assessment
Guangrun Hydropower Project in Hubei Province, P.R. China	China (c)	Canada, Netherlands, Italy, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	Nussbaumer (2009) + CDCF
Landfill gas recovery and electricity generation at "Mtoni Dumpsite", Dar Es Salaam, Tanzania	United Republic of Tanzania (c)	Italy	
Rongcheng Dongchudao Wind Farm	China (a)	Italy,	
Laizhou Diaolongzui Wind Farm	China (c)	Italy	
Hebbakavadi Canal Based Mini Hydro Project in Karnataka, India	India (a)	Switzerland, Italy	
Quezon City Controlled Disposal Facility Biogas Emission Reduction Project	Philippines (a)	Switzerland, Sweden, Italy, Spain	
Chile: Quilleco Hydroelectric Project	Chile (b)	Netherlands, Italy, Luxembourg, United Kingdom of Great Britain and Northern Ireland, Japan, Spain	
Montevideo Landfill Gas Capture and Flare Project	Uruguay (c)	Belgium, Italy, Sweden, Germany, Spain	
Yunnan Lazhai Hydropower Project	China (c)	Italy, Spain	
Guyana Skeldon Bagasse Cogeneration Project	Guyana (c)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	
Laguna de Bay Community Waste Management Project: Avoidance of methane production from biomass decay through composting -1	Philippines (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	
Uganda Nile Basin Reforestation Project No.3	Uganda (a,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Coke Dry Quenching (CDQ) Waste Heat Recovery for Power Generation Project of Wugang No. 9 and 10 Coke Ovens	China (c)	Italy	
Community-Based Renewable Energy Development in the Northern Areas and Chitral (NAC), Pakistan	Pakistan (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	
Guizhou Zhenyuan Putian Hydropower Station	China (a)	Italy	
Animal Manure Management System (AMMS) GHG Mitigation Project , Shandong Minhe Livestock Co. Ltd., Penglai, Shandong Province, P.R. of China	China (c)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	
Shenyang Laohuchong LFG Power Generation Project	China (c)	Switzerland, Italy	
Kunming Dongjiao Baishuitang LFG Treatment and Power Generation Project	China (c)	Switzerland, Italy	
Yingpeng HFC23 Decomposition Project	China (b)	France, Italy, Ireland, United Kingdom of Great Britain and Northern Ireland	

Title	Host Parties	Other Parties	Impacts assessment
Moldova Soil Conservation Project	Republic of Moldova (b,d)	Canada, Netherlands, Italy, Finland, Luxembourg, France, Sweden, United Kingdom of Great Britain and Northern Ireland, Japan, Norway, Spain	Cóndor et al. (2010)
Expansion Project of Huadian Inner Mongolia Huitengxile Wind Farm	China (c)	Italy	
Monterrey II LFG to Energy Project	Mexico (c)	Belgium, Denmark, Sweden, Germany, Italy	*
Hubei Eco-Farming Biogas Project Phase I	China (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Salta Landfill Gas Capture Project	Argentina (a)	Canada, Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	
Yunnan Tengchong Longchuan River Stage I Hydropower Plant, China	China (c)	Sweden, Netherlands, Italy	
NISCO Converter Gas Recovery and Utilization for Power Generation Project	China (c)	Italy	
Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil	Brazil (b,d)	Netherlands, Italy, Finland, Luxembourg, France, Sweden, Ireland, Switzerland, Japan, Norway, Spain	
Yunnan Maguan Laqi Hydropower Project	China (c)	Italy, Spain	
Assisted Natural Regeneration of Degraded Lands in Albania	Albania (b,d)	Canada, Italy, Luxembourg, France, Japan, Spain	Cóndor et al. (2010)
Composting of Organic Content of Municipal Solid Waste in Lahore	Pakistan (b)	Belgium, Denmark, Sweden, Italy, Germany	
Jiangsu Xiangshui 201MW Wind Power Project	China (c)	Sweden, Italy	
Félou Regional Hydropower Project	Mali (c)	Belgium, Germany, Sweden, Italy, Spain	
Yunnan Maguan Mihu River 3rd Level Hydropower Station	China (c)	Italy	
Sichuan Mabian Yi Minority Autonomous County Yonglexi Hydropower Station	China (a)	Italy	
Chongqing Wanzhou Xiangjiazui Hydropower Station	China (a)	Italy	
Wugang Gas-Steam Combined Cycle Power Plant (CCPP) Project	China (c)	Italy	
Aberdare Range/ Mt. Kenya Small Scale Reforestation Initiative Kamae-Kipipiri Small Scale A/R Project	Kenya (a,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Aberdare Range / Mt. Kenya Small Scale Reforestation Initiative Kirimara-Kithithina Small Scale A/R Project	Kenya (a,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Wugang Waste Gas Recovery and Power Generation Project	China (c)	Italy	
Landfill biogas extraction and combustion plant in El Inga I and II landfill (Quito, Ecuador)	Ecuador (c)	Italy	

Title	Host Parties	Other Parties	Impacts assessment
Gas-Steam Combined Cycle Power Plant (CCPP) Project of Laiwu Iron & Steel Group Corp.	China (c)	Netherlands, Italy	
Rwanda Electrogaz Compact Fluorescent Lamp (CFL) distribution project	Rwanda (a)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Shanxi Shuangliang Cement Company LTD. 4.5MW Waste Heat for Power Generation Project	China (c)	Italy	
Xianggelila Huajiaopo Hydropower Station	China (a)	Italy	
Jinping Maocaoping Hydropower Station	China (a)	Italy	
Micro-hydro Promotion	Nepal (a)	Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Belgium, Sweden, Germany, Switzerland, Japan, Norway, Spain	SD Tool *
Olkaria II Geothermal Expansion Project	Kenya (c)	Canada, Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Municipal Solid Waste (MSW) Composting Project in Ikorodu, Lagos State	Nigeria (b)	Italy, Portugal, Luxembourg, Sweden, Germany, Ireland, Belgium, Norway	
AES Tietê Afforestation/Reforestation Project in the State of São Paulo, Brazil	Brazil (b,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Mungcharoen Green Power - 9.9 MW Rice Husk Fired Power Plant Project	Thailand (a)	Italy	
Southern Nicaragua CDM Reforestation Project	Nicaragua (a,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Jinping Maguo River Hydropower Station	China (a)	Italy	
Uganda Nile Basin Reforestation Project No.5	Uganda (a,d)	Japan, Italy, Spain, Luxembourg, France	
Yunnan Yingjiang Zhina River 2nd Level Hydropower Station Phase 1 and Phase 2	China (c)	Italy	
Improving Rural Livelihoods Through Carbon Sequestration By Adopting Environment Friendly Technology based Agroforestry Practices	India (b,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Hydro electric power project by SJVNL in Himachal Pradesh	India (c)	Belgium, Germany, Sweden, Italy	
India-FaL-G Brick and Blocks Project No.2.	India (a)	Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	Nussbaumer (2009) + CDCF
Monterrey I LFG to Energy Project	Mexico (c)	Belgium, Denmark, Sweden, Germany, Italy	
Yunnan Er'yuan Misha River Longdi Hydropower Station	China (a)	Italy	
Yunnan Yingjiang Zhina River 1st Level Hydropower Station	China (a)	Italy	
India-FaL-G Brick and Blocks Project No.3	India (a)	Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	

Title	Host Parties	Other Parties	Impacts assessment
Fujian Shanghang Jiantou 9.8 MW hydropower Station Project	China (a)	Italy	
Uganda Nile Basin Reforestation Project No 1	Uganda (a,d)	Japan, Italy, Spain, Luxembourg, France	
Uganda Nile Basin Reforestation Project No 2	Uganda (a,d)	Japan, Italy, Spain, Luxembourg, France	
Uganda Nile Basin Reforestation Project No 4	Uganda (a,d)	Japan, Italy, Spain, Luxembourg, France	
Jiangsu Hantian Cement Waste Heat Recovery Power Generation Project	China (c)	Italy	
Redevelopment of Tana Hydro Power Station Project	Kenya (c)	Netherlands, Italy, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	
Improving Kiln Efficiency in the Brick Making Industry in Bangladesh	Bangladesh (a)	Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Shanxi Linfen 2×6MW Coke Oven Gas Power Generation Project	China (c)	Italy	
Tongdao County Laorongtan Hydropower Station Project	China (a)	Italy	
Biogas Support Program - Nepal Activity-3	Nepal (a)	Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Biogas Support Program - Nepal Activity-4	Nepal (a)	Netherlands, Italy, Denmark, Finland, Sweden, Luxembourg, Switzerland, Austria, Germany, Belgium, Japan, Norway, Spain	SD Tool *
Nam Mo Hydropower Project	Viet Nam (c)	Italy	
Nam Non Hydropower Project	Viet Nam (c)	Italy	
Improving Kiln Efficiency in the Brick Making Industry in Bangladesh (Bundle-2)	Bangladesh (a)	Netherlands, Italy, Denmark, Finland, Austria, Luxembourg, Switzerland, Sweden, Germany, Belgium, Japan, Norway, Spain	SD Tool *
WISCO 1234# Coke Dry Quenching (CDQ) Waste Heat Recovery for Cogeneration Project in Hubei Province	China (c)	Italy	
Yunnan Province Deqin County Chunduole Hydropower Station	China (c)	Italy	
Sichuan Province Li County Luganqiao Hydropower Project	China (c)	Italy	
Xuanen County Shuangxi Hydropower Project	China (c)	Italy	
Fujian Shanghang Huilong 9.9 MW hydropower Station Project	China (a)	Italy	
Guodian Weifang Binhai Wind Farm Phase II Project	China (c)	Italy	
Carbon Sequestration in Small and Medium Farms in the Brunca Region, Costa Rica (COOPEAGRI Project)	Costa Rica (b,d)	Canada, Italy, Luxembourg, France, Japan, Spain	
Use of Charcoal from Renewable Biomass Plantations as Reducing Agent in Pig Iron Mill in Brazil	Brazil (b)	Netherlands, Italy, Luxembourg, Australia, Switzerland, Japan, Spain	

Title	Host Parties	Other Parties	Impacts assessment
Ningxia Helanshan Wind-farm (Touguan) Dalisi 49.5MW Wind Power Project	China (c)	Italy	
Ningxia Taiyangshan Windfarm Shenpeng 49.5MW Project	China (c)	Italy	
Wushan Houxihe Hydropower Station Project	China (c)	Italy	
Kainji Hydropower Rehabilitation Project, Nigeria	Nigeria (c)	Belgium, Germany, Sweden, Italy	
Optimisation of Kiambere Hydro Power Project	Kenya (c)	Netherlands, Italy, Luxembourg, Austria, Germany, Belgium, Japan, Spain	
Aeolis Beberibe Wind Park	Brazil (c)	Italy	
Aeolis 2011 Wind Parks	Brazil (c)	Italy	
Yanyuan County Majingzi Hydropower Project	China (a)	Italy	
Partial substitution of fossil fuels with biomass at “Les Ciments Artificiels Tunisiens” cement plant, Tunis.	Tunisia (c)	Italy	
Golden Jumping Group 12MWp Solar Power Project	China (a)	Italy	
LFG Recovery and Electricity Production at the Bubanj Landfill Site, Nis, Serbia	Serbia (a)	Italy	
Hydropower Plant Otilovici	Montenegro (a)	Italy	
Partial Fuel Switching to Agricultural Wastes & Refuse Derived Fuel (RDF) at Kattameya cement plant	Egypt (c)	Italy	
Phu Quy Wind Power Project	Viet Nam (a)	Italy	
Partial Fuel Switching to Agricultural Wastes, Sewage Sludge & Refuse Derived Fuel (RDF) at Helwan cement plant	Egypt (c)	Italy	
Niger Acacia Senegal Plantation Project	Niger (c,d) (**)	Japan, Italy, Luxembourg, Spain	CCB, Withdrawn

Source: https://cdm.unfccc.int/Projects/projsearch.html

(a)AMS, Small scale; (b) AM - Large scale; (c) ACM - Consolidated Methodologies; (d) Afforestation/reforestation; (*) project included in the UNEP Risoe Centre Database and labelled SD Tool, Gold Standard & CCB project (validation); CCB= obtained the CCB standards (UNEP Risoe database); CDCF= Community Development Carbon Fund; (**) new project with Italy involved compared to previous submission.

ANNEX 9: METHODOLOGIES, DATA SOURCES AND EMISSION FACTORS

This appendix shows methodologies, data sources and emission factors used for the Italian greenhouse gas emission inventory.

Table A9.1 Methods, activity data and emission factors used for the Italian inventory

Information on methods used could be the tier method, the model or a country-specific approach. Activity data could be from national statistics or plant-specific. Emission factors could be the IPCC default emission factors as outlined in 2006 IPCC guidelines for national greenhouse gas inventories and in the IPCC good practice guidance, country-specific emission factors, plant-specific emission factors or CORINAIR emission factors developed under the 1979 Convention on Long-Range Transboundary Air Pollution.
Information on methods used could be the tier method, the model or a country-specific approach. Activity data could be from national statistics or plant-specific. Emission factors could be the IPCC default emission factors as outlined in 2006 IPCC guidelines for national greenhouse gas inventories and in the IPCC good practice guidance, country-specific emission factors, plant-specific emission factors or CORINAIR emission factors developed under the 1979 Convention on Long-Range Transboundary Air Pollution.

Table I -1: Summary report for methods, activity data and emission factors used (Energy)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
1. Energy												
1.A. Fuel combustion												
1.A.1. Energy industries												
Liquid fuels	Yes				No				No			
Solid fuels	Yes				No				No			
Gaseous fuels	Yes				No				No			
Other fossil fuels	No				No				No			
Biomass	No				No				No			
Peat	No				No				No			
a. Public electricity and heat production												
Liquid fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Solid fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Gaseous fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Other fossil fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Biomass		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Peat		NO	NO	NO		NO	NO	NO		NO	NO	NO
b. Petroleum refining												
Liquid fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
Gaseous fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
c. Manufacture of solid fuels and other energy industries												
Liquid fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Solid fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
Gaseous fuels		T3	NS, PS	CS		T3	NS, PS	CR,D		T3	NS, PS	CR,D
1.A.2 Manufacturing Industries and Construction												
Liquid fuels	Yes				No				Yes			
Solid fuels	Yes				No				No			
Gaseous fuels	Yes				No				No			
Other fossil fuels	No				No				No			
Biomass	No				No				No			
a. Iron and Steel												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
b. Non-Ferrous Metals												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
c. Chemicals												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Other fossil fuels		NO	NO	NO		NO	NO	NO		NO	NO	NO
Biomass		NO	NO	NO		NO	NO	NO		NO	NO	NO
d. Pulp, Paper and Print												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
Biomass		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Solid fuels		NO	NO	NO		NO	NO	NO		NO	NO	NO
e. Food Processing, Beverages and Tobacco												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
Biomass		T2	NS, PS	CS		T2	NS, PS	CR,D		T2	NS, PS	CR,D
f. Non-metallic Minerals												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Biomass		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Other fossil fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
g. Other												
Liquid fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Solid fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Gaseous fuels		T2	NS, PS	CS		T2	NS, PS	CR, D		T2	NS, PS	CR, D
Other fossil fuels		NO	NO	NO		NO	NO	NO		NO	NO	NO
1.A.3 Transport												
a. Domestic Aviation	Yes				No				No			
Aviation Gasoline		T1,T2	NS	CS		T1,T2	NS	CR		T1,T2	NS	CR
Jet Kerosene		T1,T2	NS	CS		T1,T2	NS	CR		T1,T2	NS	CR
b. Road Transportation	Yes				Yes				No			
Gasoline		T2	NS, AS	CS		T3	NS, AS	M		T3	NS, AS	M
Diesel Oil		T2	NS, AS	CS		T3	NS, AS	M		T3	NS, AS	M
Liquefied Petroleum Gases (LPG)		T2	NS, AS	CS		T3	NS, AS	M		T3	NS, AS	M
Other liquid fuels		T1	M	D								
Gaseous fuels		T2	NS, AS	CS		T3	NS, AS	M		T3	NS, AS	M
Biomass		T2	NS, AS	CS		T3	NS, AS	M		T3	NS, AS	M

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
c. Railways	No				No				No			
Liquid fuels		T2	NS	CS		T1	NS	CR		T1	NS	CR
d. Navigation	Yes				No				No			
Residual Fuel Oil		T1,T2	NS	CS		T1,T2	NS	CR		T1,T2	NS	CR
Gas/Diesel Oil		T1,T2	NS	CS		T1,T2	NS	CR		T1,T2	NS	CR
Gasoline		T1,T2	NS	CS		T1,T2	NS	CR		T1,T2	NS	CR
e. Other Transportation												
Gaseous fuels	No	T2	NS	CS	No	T1	NS	CR	No	T1	NS	CR
1.A.4 Other Sectors												
a. Commercial/Institutional												
Liquid fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Solid fuels	No	NO	NO	NO	No	NO	NO	NO	No	NO	NO	NO
Gaseous fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Other fossil fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Biomass	No	T2	NS	CS	Yes	T2	NS	CR	Yes	T2	NS	CR
b. Residential												
Liquid fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Solid fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Gaseous fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Biomass	No	T2	NS	CS	Yes	T2	NS	CR	Yes	T2	NS	CR
c. Agriculture/Forestry/Fishing												
Liquid fuels	Yes	T2	NS	CS	No	T2	NS	CR	Yes	T2	NS	CR
Gaseous fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Biomass	No	T2	NS	CS	Yes	T2	NS	CR	Yes	T2	NS	CR
Solid fuels	Yes	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
1.A.5 Other												
b. Mobile												
Liquid fuels	No	T2	NS	CS	No	T2	NS	CR	No	T2	NS	CR
Solid fuels	No	NO	NO	NO	No	NO	NO	NO	No	NO	NO	NO

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	**Method applied (2)**	**Activity data (3)**	**Emission factor (4)**	**Key source (1)**	**Method applied (2)**	**Activity data (3)**	**Emission factor (4)**	**Key source (1)**	**Method applied (2)**	**Activity data (3)**	**Emission factor (4)**
1.B Fugitive Emissions from Fuels												
1. Solid Fuels												
a. Coal Mining and Handling: Operation	No	T1	NS	OTH	No	T1,T2	NS	D				
b. Solid Fuel Transformation					No	T1	NS	CR				
2 Oil and Natural Gas and Other Emissions from Energy Production												
a. Oil: Operation	Yes	T1,T2	NS	CS,D	No	T1,T2	NS	CS,D				
b. Natural Gas: Operation	No	T1,T2	NS	CS,D	Yes	T1,T2	NS	CS,D				
c. Venting and Flaring: Operation	No	T1	NS	D	No	T2	NS	CS	No	T1	NS	D
d. Other Emissions from Energy Production: Flaring in refineries	No	T2	NS	CS	No	T1	NS	CR	No	T1	NS	D

Table I -2: Summary report for methods, activity data and emission factors used (Industrial processes and product use)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O				HFCs				PFCs				SF_6				NF_3			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
2. Industrial Processes and Product Use																												
2.A Mineral Industry																												
1. Cement production: no classification	Yes	T2	NS	CS, PS																								
2. Lime production: no classification	Yes	T2	NS	CS, PS																								
3. Glass production	No	T2	NS	CS, PS																								
4. Other process uses of carbonates: no classification	Yes	T2	NS	CS, PS																								
2.B Chemical Industry																												
1. Ammonia production: no classification	Yes	T2	PS	PS																								
2. Nitric acid production: no classification									Yes	T2	PS	D, PS																
3. Adipic acid production	Yes	T3	PS	PS					Yes	T3	PS	D, PS																
4. Caprolactam, glyoxal and glyoxylic acid production									No	T2	PS	CS																
5. Carbide production	No	D	PS	CR																								
6. Titanium dioxide production	No	T2	PS	PS																								
7. Soda ash production	No	T2	PS	PS																								
8. Petrochemical and carbon black production	No	T2	PS	CR, PS	No	D,T1	NS, PS	CR, CS,D																				
9. Fluorochemical production													Yes	CS	PS	PS	Yes	CS	PS	PS								
10. Other chemical industry: no classification	No	NA	NA	NA	No	NA	NA	NA	No	NA	NA	NA	No	NA	NA	NA	No	NA	NA	NA	No	NA	NA	NA	No	NA	NA	NA
2.C Metal Industry																												
1. Iron and steel production: no classification	Yes	T2	NS, PS	CR, CS, PS	No	D	NS	CS,D																				
2. Ferroalloys production	No	T1	NS, PS	D																								

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O				HFCs				PFCs				SF_6				NF_3			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
3. Aluminium production: no classification	No	T1,T2	NS, PS	D,PS													Yes	T1, T2	NS, PS	D, PS								
4. Magnesium production													No	T2	PS	PS					No	T2	PS	PS				
5. Lead production																												
6. Zinc production	No	T2	PS	CS																								
2.D Non-energy Products from Fuels and Solvent Use	Yes																											
1. Lubricant use		T1	NS	D																								
2. Paraffin wax use		T1	NS	D																								
3. Other: no classification		CR, CS, T2	NS, AS	CR, CS, M,PS																								
2.E. Electronics industry																												
1. Integrated circuit or semiconductor													No	T2	PS	CS	No	T2	PS	CS	No	T2	PS	CS	No	T2	PS	CS
2. TFT flat panel display																												
3. Photovoltaics																												
4. Heat transfer fluid													No	CS	PS	PS	No	CS	PS	PS	No	NA	NA	NA	No	NA	NA	NA
2.F. Product uses as substitutes for ODS																												
1. Refrigeration and air conditioning: no classification													Yes	T2	AS, NS	CS,D, PS												
2. Foam blowing agents: no classification													Yes	T2	AS, NS	D												
3. Fire protection													Yes	T2	AS, NS	CS												
4. Aerosols: no classification													No	T2	AS, NS	CS												
5. Solvents													No	NA	NA	NA												
2.G. Other product manufacture and use																												
1. Electrical equipment																					No	T2	AS NS	CS				

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O				HFCs				PFCs				SF_6				NF_3			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
2. SF_6 and PFCs from other product use																					No	CS	PS	PS				
3. N_2O from product uses									No	CS	AS, NS	CS																

Table I -3: Summary report for methods, activity data and emission factors used (Agriculture)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
3. Total agriculture												
3.A. Enteric fermentation					Yes							
1. Cattle						T2	NS	CS				
Dairy Cattle						T2	NS	CS				
Non-Dairy Cattle						T2	NS	CS				
2. Sheep						T2	NS	CS				
3. Swine						T1	NS	D				
4. Other livestock						T1, T2	NS	D, CS				
3.B. Manure Management												
1-4. CH4 Emissions					Yes	T1, T2	NS	D, CS				
1-4. N2O Emissions and NMVOC Emissions									Yes	T2	NS	D, CS
5. Indirect N2O Emissions									Yes	T2	NS	D, CS
3.C. Rice Cultivation												
1. Irrigated					Yes	T2	NS	CS				
3.D. Agricultural soils												
1. Direct N2O Emissions From Managed Soils									Yes	CS,T1	NS	D, CS
b. Indirect N2O Emissions From Managed Soils									Yes	T1	NS	D, CS
3.F Field Burning of Agricultural Residues												
1. Cereals					No	T1	NS	D, CS	No	T1	NS	D, CS
3.G. Liming												
1. Limestone CaCO3	No	T1	NS	D								
3.H. Urea application	No	T1	NS	D								

Table I -4: Summary report for methods, activity data and emission factors used (Land use, land-use change and forestry)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
4. Total LULUCF												
4.A. Forest land												
1. Forest land remaining forest land	Yes	T2, T3	NS	CS,D	No	T2	NS	CS,D	No	T2	NS	CS,D
2. Land converted to forest land	Yes	T1, T2	NS	CS,D	No	T2	NS	CS,D	No	T2	NS	CS,D
4.B. Cropland												
1. Cropland remaining cropland	Yes	T1, T2	NS	CS,D	No	T1	NS	D	No	T1	NS	D
2. Land converted to cropland	Yes	T1	NS	CS,D					No	T1	NS	D
4.C. Grassland												
1. Grassland remaining grassland	Yes	T1, T2, T3	NS	CS,D	Yes	T1	NS	CS	No	T1	NS	CS
2. Land converted to grassland	Yes	T1	NS	CS,D								
4.D. Wetlands												
1. Wetlands remaining wetlands												
2. Land converted to wetlands	No	T1	NS	D								
4.E. Settlements												
1. Settlements remaining settlements												
2. Land converted to settlements	Yes	T1	NS	D					Yes	T1	NS	D
4.F. Other land												
1. Other land remaining other land												
2. Land converted to other land												
4.G. Harvested wood products	No	T2	NS	CS								

Table I -5: Summary report for methods, activity data and emission factors used (Waste)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2				CH_4				N_2O			
	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
5.Total waste												
5.A Solid waste disposal					Yes							
1. Managed waste disposal sites						T2	NS	CS				
2. Unmanaged waste disposal sites						T2	NS	CS				
5.B Biological treatment of solid waste					No				Yes			
1. Composting						D	NS	CS		D	NS	D
2. Anaerobic digestion at biogas facilities						D	NS	D				
5.C Incineration and open burning of waste	No				No				No			
1. Waste incineration		D	NS, PS	CS		D	NS, PS	CR		D	NS,PS	CR
2. Open burning of waste		T1	NS	CS,D		T1	NS	CS,D		T1	NS	CS,D
5.D Wastewater treatment and discharge					Yes				Yes			
1. Domestic wastewater						T1	NS	D		T1	NS	D
2. Industrial wastewater						T1	NS	D		T1	NS	CR

Legend for tables I -1 to I -5

(1) Key categories of the Italian inventory.		
(2) Method applied:		
D (IPCC default)	**T1a, T1b, T1c** (IPCC Tier 1a, Tier 1b and Tier 1c, respectively)	**CR** (CORINAIR)
RA (Reference Approach)	**T2** (IPCC Tier 2)	**CS** (Country Specific)
T1 (IPCC Tier 1)	**T3** (IPCC Tier 3)	**OTH** (Other)
(3) Activity data used		
NS (national statistics)	**IS** (International statistics)	**AS** (associations, business organizations)
RS (regional statistics)	**PS** (Plant Specific data)	**Q** (specific questionnaires, surveys)
(4) Emission factor used:		
D (IPCC default)	**CS** (Country Specific)	**OTH** (Other)

CR (CORINAIR)	**PS** (Plant Specific)	**M** (Model)

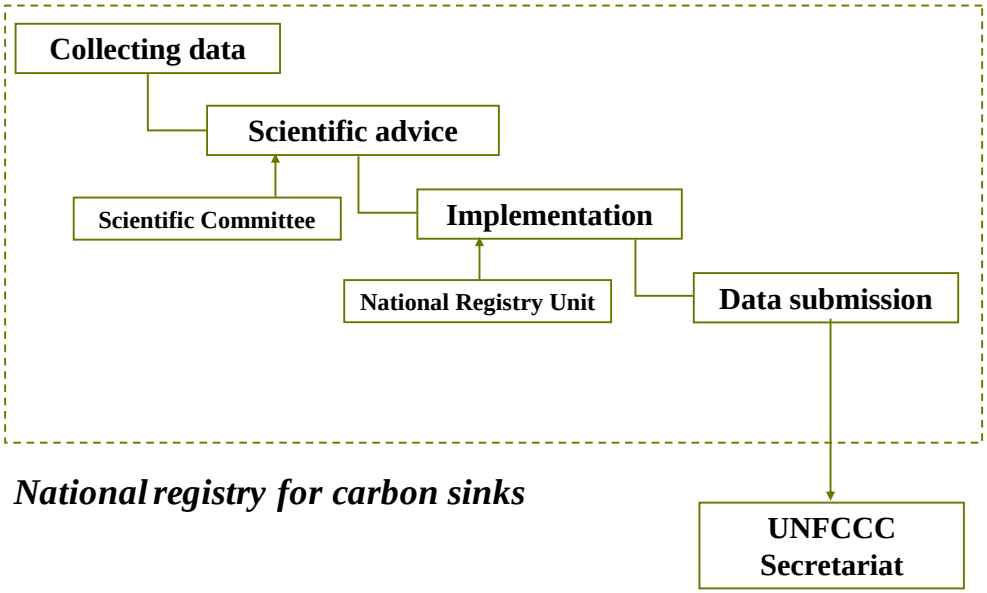
ANNEX 10: THE NATIONAL REGISTRY FOR CARBON SINKS

The "National Registry for carbon sinks"[76], instituted by a Ministerial Decree on 1st April 2008, is part of National Greenhouse Gas Inventory System in Italy (ISPRA, 2018); is part of the Italian National System; it is the instrument to estimate, following the COP/MOP decisions and in accordance with the IPCC guidelines, the greenhouse gases emissions by sources and removals by sinks in the land subject to art. 3.3 and art. 3.4 activities of the Kyoto Protocol and to account for their net removals in order to allow the Italian Registry to issue the corresponding amount of RMUs.

Italy has elected cropland management (CM) and grazing land management (GM) as additional activities under Article 3.4. Following the Decision 2/CMP.7, in the second commitment period forest management (FM) is a mandatory activity under Article 3.4.

Italy considers the entire national territory as managed, i.e. subject to human activities, consequently the entire national forest area is subject to human activities that, by-law, are aimed at sustainably manage the forest.

The forest management reference level (FMRL[77]) for Italy, inscribed in the appendix to the annex to decision 2/CMP.7, is equal to –21.182 Mt CO_2 eq. per year assuming instantaneous oxidation of HWP, and –22.166 Mt CO_2 eq applying a first-order decay function for HWP. Italy selected to account for Article 3.3 and 3.4 activities at the end of the commitment period.



The forest definition adopted by Italy for the KP reporting is the same used for the Convention reporting and for the Italian national forest inventories and it corresponds to the definitions of the Food and Agriculture Organization of the United Nations for its Global Forest Resource assessment (FAO FRA 2000). Thresholds are consistent with those of the forest definition given in Decision 16/CMP.1.

Thus, Forest is a land with the following threshold values for tree crown cover, land area and tree height:

a. a minimum area of land of 0.5 hectares;
b. tree crown cover of 10 per cent;
c. minimum tree height of 5 meters.

[76] The legal basis is in the

[77] Submission of information on forest management reference levels by Italy:
http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_italy_2011.pdf
Communication of 11 May 2011 regarding harvested wood products value by Italy:
http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_italy_corr.pdf

Forest roads, cleared tracts, firebreaks and other open areas within the forest as well as protected forest areas are included in forest.
Italy considers the entire national territory as managed, i.e. subject to human activities, consequently the entire national forest area is subject to human activities that, by-law, are aimed at sustainably manage the forest.
The key elements of the accounting system in the National Registry for carbon sinks are:

a. **National Land-Use Inventory (IUTI)**
   aimed at identifying and quantifying:
   – lands subject to art. 3.3 and art. 3.4 activities since 31 December 1989, according to their land use and land use changes across time (from 1990 onward);

b. **National Inventory of Carbon Stocks (ISCI)**
   aimed at quantifying:
   - carbon stocks and carbon stock changes in each land-use category, from 1990 onward.

c. **National Census of Forest Fires (CIFI)**
   aimed at identifying and quantifying:
   – areas affected by fires, from 1990 onward.

d. **National Inventory of non-CO2 emissions from forest fires (IEIF)**
   aimed at quantifying:
   – non-CO_2 emissions from areas affected by fires, from 1990 onward.

e. **Cropland and Grazing land Management**
   aimed at quantifying:
   a. Area subject to various management practices under CM and GM
   b. GHG emissions and removals from areas under CM and GM.

a. National Land-Use Inventory (IUTI)

The National Land-Use Inventory (IUTI) is aimed at identifying the land uses and land-use changes over the national territory based on a survey of sample points throughout Italian national territory considered as a population of adimensional points. By using on-screen interpretation of digital orthophotos, land use is classified with a high degree of accuracy and precision. The following set of multi-temporal orthophotos was used as basis of photo-interpretation process:

→ 1990, the black and white high resolution full national coverage aerial photography database of TerraItaly[78] was used to produce orthophotos in scale 1:75.000, spatial resolution of 1 m (the aerial photos, taken on 1988/89, have the same image acquisition standard adopted by USGS-National High-Altitude Program at that time: panchromatic film, 400 lines per millimetre);
→ 2000, TerraItaly[79] 2000 dataset, digital colour aerial orthophotos with spatial resolution of 1 m;
→ 2008, TerraItaly 2008 dataset, digital colour aerial orthophotos with spatial resolution of 0.5 m.
→ 2012, AGEA[80] colour and infrared digital orthophotos with spatial resolution 0.5 m; years 2010-12.
→ 2016, AGEA color and infrared digital orthophotos with spatial resolution 50 cm; years 2014-16.

[78] http://www.cgrit.it/prodotti/voli_italia.html
[79] http://www.terraitaly.it/
[80] http://www.agea.gov.it/portal/page/portal/AGEAPageGroup/HomeAGEA

Furthermore, visual interpretation was supported by ancillary information from available thematic forest and land use maps at regional and sub-regional scales, and the freely available remote sensed data from Google Earth Engine (GEE).

a.1 Time:

IUTI adopts statistical sampling procedures to estimate the area covered by IPCC land use categories in Italy at four points in time (1990, 2008, 2012 and 2016). 1990, 2008 assessments were carried out using a sampling grid with 1,206,000 points. The 2012 land use assessment has been carried out in the framework of the III NFI, on a IUTI's subset of plots (i.e. 301,300 plots, covering the entire country). The 2016 IUTI assessment has been carried out using a 1% subsample within the whole national territory (about 13,000 sample points).
IUTI data are collected according to the 6 IPCC land use categories, although for forest land the data collected by the national forest inventories (1985, 2005, 2012) are used. From IUTI and NFI data consistent time-series of areas of each land-use and and-use change category are derived, as well as of each land subject to art. 3.3 and art. 3.4 of the Kyoto Protocol.

a.2 Space:

The localization of sampling points is carried out according to a tessellation stratified sampling design (also known as unaligned systematic sampling). The sampling grid, and the relative sample plots (figure A10.1), is uniformly distributed throughout the entire Italian national territory, using a non-aligned systematic sampling. The set of sample points was extracted using a 0.5 km square grid, for a total of about 1,206,000 geo-referenced points randomly located in each square cell and fully covering the Italian territory. A subset of the IUTI sample is represented by the 301,300 first phase sample points of the national forest inventory (NFI).

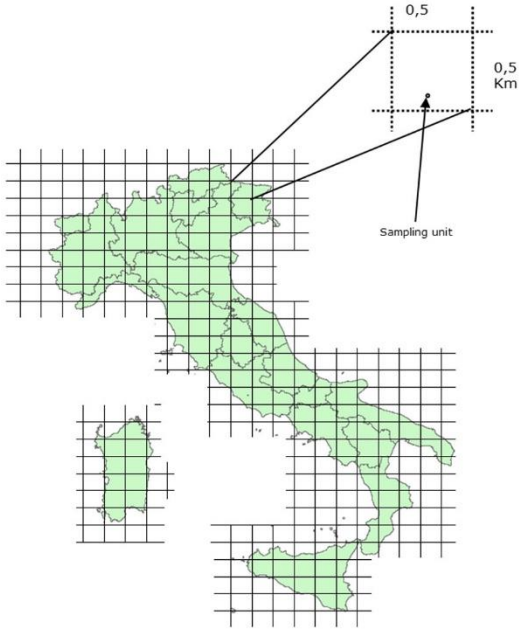


Figure A10.1: IUTI sampling grid

For reducing the sampling efforts, the one-per-stratum stratified sampling (OPSS) has been adopted in 2016. The original 1,206,000 IUTI quadrats were aggregated into 13,000 clusters, in which 1 IUTI point were then selected and classified in 2016, following the one-per-stratum sampling strategy (OPSS). The results showed that while the initial sampling efforts were reduced by 100 times, the RSE estimates increased by approximately 10 times. In absolute terms, these results are then rather encouraging, because the largest LU classes show RSE estimates invariably smaller than 3%, while the smallest ones show RSE estimates always below 9%.

Categories and subcategories:
Land use categories (Table A10.1) are defined according to IPCC requirements:

Table A10.1: IUTI classification system

IPCC Category Level I	IUTI Category Level II	*Code*
1. Forest land	*Woodland*	***1.1***
	Wooded land temporarily unstocked	***1.2***
2. Cropland	*Arable land and other herbaceous cultivations*	***2.1***
	Arboreal cultivations (Fruit orchards and plant nurseries)	***2.2***
		2.2
3. Grassland	*Grassland, pastures and uncultivated herbaceous areas*	***3.1***
	Other wooded land	***3.2***
4. Wetlands	*Marshlands and open waters*	***4***
5. Settlements	*Urban development*	***5***
6. Other land	*Non-productive areas or areas with scarce or absent vegetation*	***6***

Each plot is photo-interpreted in order to classify it into IUTI land use classes at different points in time (1990, 2008, and for 2012 in a subset only). In the plots where a land use change to or from forest is detected between 1990 and 2008, i.e. afforestation/reforestation/deforestation activities, the land use classification is performed also in an intermediate point in time (2000), in order to estimate, by interpolation, the annual gain/loss of forest area in different time periods (1990-2000 and 2000-2008).

a.3 Quality assurance/Quality control:
Data supplied by IUTI is collected in the "*National Registry for the carbon sinks*" of Kyoto Protocol, and fulfil quality needs, outlined in the IPCC guidelines and required by UNFCCC relevant decisions. The photointerpreters have been trained in order to ensure a standard photointerpretation approach. An internal expert panel was set to classify each plot for which the photointerpreter had not confidence in its judgement
The same panel has also carried out the quality control of a sub-sample of plots (5%) selected randomly. The control activities have produced the same classification as carried out by the photointerpreters in more than of 95% of the cases.

Classification methodology
The adopted classification methodology ensures that any unit of land can be classified univocally[81] under a category, by means of*:*
- a systematic sampling design to select plots;
- a list of definitions for each IPCC land-use category classification and each country-specific subdivision;
- a list of land-use indicators able to indicate the presence of a certain use on the land;
- a classification hierarchy among categories and subdivisions to facilitate land use classification (table A10.2)

The land use classification follows two steps. In the first step lands are subdivided between those fully anthropogenic (cropland, settlements, some intensively managed grassland and some other land), and those prevalently natural (forest, natural grassland, some other land). In the second step, the lands in the two aggregates, i.e. anthropogenic and prevalently natural, are classified according to land use categories and subdivisions.

[81] i.e. Exclusion of multiple equally valid classifications of the same unit of land (e.g. cropland vs forest land, forest land vs grassland), and exclusion of the null case (i.e. a unit of land that doesn't match any of the land use categories)

Table A10.2: Classification hierarchy

A. LAND WITH ITS ORIGINAL CHARACTERISTICS OF PHYSIOGNOMY AND VEGETATION SIGNIFICANTLY MODIFIED BY HUMAN ACTION, CULTIVATED, CLEARED OR SUBJECT TO URBANIZATION WORK, AND DOMINATED BY ANTHROPIC ARTEFACTS DUE TO RESIDENTIAL, INDUSTRIAL, SOCIO-CULTURAL AND AGRICULTURAL ACTIVITIES.

AI. **Land occupied by other agricultural cultivations**

AI1. Herbaceous cultivations in open fields, subject to regular rotation, for the production of cereals, pulses, other food products or forage.

ARABLE

AI2. Arboreal cultivations not subject to regular rotation, destined permanently to the production of fruit or wood products.

AI2a. *Arboreal cultivations destined prevalently to the production of fruit for nutritional purposes (apple orchards, vineyards, olive groves, etc) or for the production of arboreal or shrub species for ornamental purposes*

ORCHARDS and NURSERIES

AI2b. *Arboreal cultivations destined prevalently to the production of wood products or of woody biomass for energy generation purposes*

ARBOREAL CULTIVATIONS FOR WOOD PRODUCTS

AII. **Areas with residential and industrial buildings and services, transport routes, infrastructures and urban green areas (parks and gardens)**

SETTLEMENTS

B. NATURAL OR SEMI-NATURAL LAND NOT SIGNIFICANTLY MODIFIED BY HUMAN ACTION OR IN PHASE OF RENATURALIZATION.

BI. **Formations constituted by trees able to reach the height on maturity *in situ* of 5 m, but temporarily lacking in canopy cover following accidental events or anthropic action.**

WOODED LAND TEMPORARILY WITHOUT ABOVE-GROUND COVER

BII. **Formations constituted by trees able to reach the height on maturity *in situ* of 5 m and procuring a degree of canopy cover on the terrain of ≥ 5%.**

BII1. Formation with a degree of cover < 10%

OTHER WOODED AREAS

BII2. Formation with a degree of cover ≥ 10%

WOODLAND

BIII. **Formations never as above**

BIII1. Formations constituted by shrubs or trees not able to reach a height on maturity *in situ* of 5 m, and procuring a degree of canopy cover on the terrain of ≥ 10%

OTHER WOODED LAND

BIII2. Formations constituted by shrubs or trees not able to reach a height on maturity *in situ* of 5 m and procuring a degree of canopy cover on the terrain of < 10%, and silvi-pastural formations with canopy cover from trees able to reach a height on maturity *in situ* of 5 m but with cover < 5%

BIII2a. *Natural herbaceous formations of ground species with a degree of herbaceous cover of ≥ 40%.*

PASTURES, MEADOWS and UNCULTIVATED HERBACEOUS AREAS

BIII2b. *Natural herbaceous formations with a degree of herbaceous cover of < 40% or land completely lacking herbaceous cover*

BIII2b1. *Land without vegetation or with sporadic herbaceous vegetation. Rocky outcrops and beaches.*

OTHER LAND

C. AREAS WITHOUT VEGETATION AND COVERED BY STILL OR FLOWING WATER OR AREAS OCCUPIED BY PARTICULAR ECOSYSTEMS OTHER THAN TERRESTRIAL ECOSYSTEMS (FLOATING VEGETATION, WET VEGETATION, SALTWATER VEGETATION, ETC).

MARSHLANDS AND OPEN WATERS

To achieve land use classification, a 0.5 ha neighbourhood of the sample plot is investigated. The operative procedure consists in digital orthophotos processing, considering plots: for each plot identified on the territory

by coordinates in a known reference system, the land use category, defined according to the classification system, is established.
A grid, composed of 9 squares (3 x 3) of 2,500 m² each, for an overall surface area of 22,500 m² is overimposed to the plot. This graphic object, at the centre of which the center of the plot, i.e. the sampling point, is situated, allows to assess whether the area intercepted by the sampling point has an extension equal to or greater than the established threshold (equivalent to the surface area of 2 of the 9 cells displayed).
If the surface area value is very close to the threshold and the use of the cells still leaves doubts, a graphic tool for surface area measurement is used for the classification process. The contour of the polygon containing the sampling point is mapped, computing the extent of the area.
In figures A10.2, A10.3 and A10.4, examples from land use classification system are reported. In figure A10.1 the sampling point is classified as 3.1 grassland, given that trees covering the sampling point have a surface area between 500 and 5000 m². In Figure A10.2, the sampling point is classified as 1.1 woodland, while in figure A10.3, the sampling point is classified as 3.1 grassland.

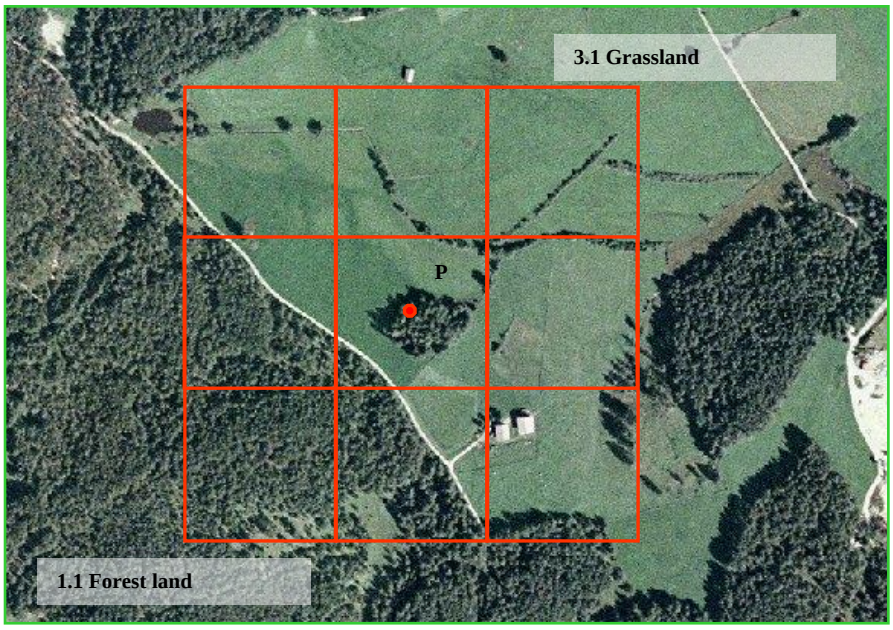


Figure A10.2: Land use classification system - grassland

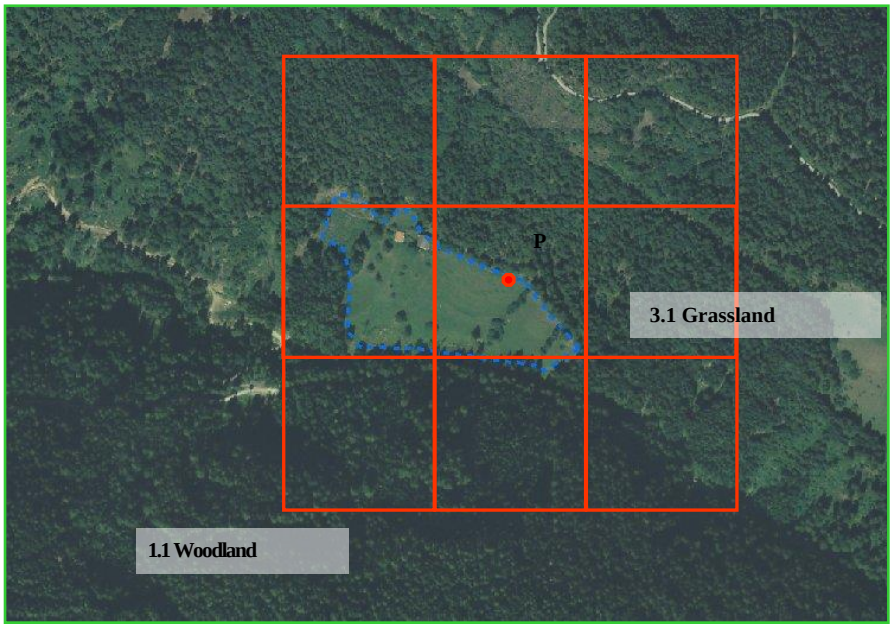


Figure A10.3: Land use classification system - Woodland

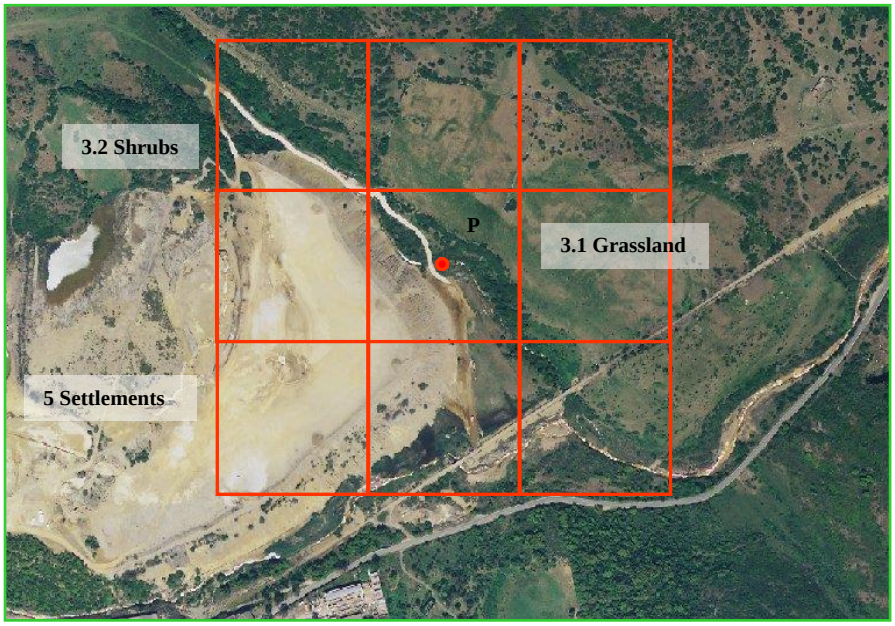


Figure A10.4: Land use classification system – grassland

b. National Inventory of Carbon Stocks (ISCI)

The National Inventory of the Carbon Stocks is a sampling of carbon stocks related to the different land-use categories.

The National Inventory of the Carbon Stocks includes:

- carbon stock changes in the forest land land-use category, the dataset is derived from the NFIs[82] data;
- carbon stock changes in the land in conversion to or from forest land. For the land in conversion NFI data are integrated with studies and additional surveys to estimate, at regional level, the C stock levels related to non-forest land uses (i.e. *settlements*, *cropland*, *grassland*, *wetlands*).

b.1 Time:

ISCI annually provides time series of carbon stock levels and carbon stock changes for the category forest land remaining forest land and for the land in conversion to and from forest land, as well as for the related KP LULUCF activities.

b.2 Space:

ISCI cover the entire national territory at regional (NUTS2) level.

b.3 Quality assurance:

Data supplied by ISCI is collected in the "*National Registry for the carbon sinks*" of Kyoto Protocol, and fulfil quality needs, outlined in the IPCC Guidelines and required by UNFCCC relevant decisions.

c. National Census of Fires (CIFI)

The National Census of Fires is a system aimed to detect, locate and classify areas affected by fires; it provides data on burned forest land area and fires occurring in other land use categories.

[82] Italian National Forest Inventories: http://www.sian.it/inventarioforestale/jsp/home_en.jsp

The core of CIFI is the detailed database, provided by the "Carabinieri Forestali"[83], collecting data related to any fire event occurred in 15 administrative Italian regions[84] (the 5 autonomous regions are not included), and reporting, for each fire event, the following information:

- *burned area [ha]*
- *forest typology (27 classes in line with the NFI nomenclature)*
- *scorch height [m]*
- *fire's type (crown, surface or ground fire)*

Data and information related to fire occurrences in the 5 remaining autonomous regions are collected at regional level, with different level of disaggregation and details (for example, in Sardinia region, the amount of biomass burned is reported instead of the scorch height).

Therefore, the data used in the estimation process may be subdivided into the following groups with similar characteristics:

a. time series from 2008 onward for the 15 Regions: burned area, per forest types, scorch height, fire type;
b. time series from 2008 onward for the 5 autonomous regions/provinces: burned area;
c. time series from 1990 to 2007 for the 20 Italian regions: burned area.

Statistics related to fires occurring in other land use categories (i.e. cropland, grassland and settlements) are collected in the framework of *ad hoc* expert panel on fires has been set up, formed by experts from different institutions from ISPRA, the Ministry of Agriculture, Food and Forest Policies (MIPAAF) and "Carabinieri Forestali", currently in charge for the official data collection on burned area.

c.1 Time:

CIFI annually provides time series of forest areas affected by fires.

c.2 Space:

CIFI covers the entire national territory at regional (NUTS2) level.

Key elements:

The key elements are:

- ground surveys to record boundaries of burned areas and ancillary data as damage evaluation (percentage of oxidised biomass) and forest typology (following NFI classification);
- remote sensed data to integrate data from ground surveys, in order to cross-check burned areas;

c.3 Quality assurance:

Data supplied by CIFI is collected in the "*National Registry for the carbon sinks*" of Kyoto Protocol, and fulfil quality needs, outlined in the IPCC guidelines and required by UNFCCC relevant decisions.

d. National Inventory of non-CO_2 emissions from fires (IEIF)

The fires GHG emissions National Inventory is aimed to estimate non-CO_2 emissions from forest fires (CO_2 emissions are not reported since already computed by the National Inventory Carbon Stocks as decreases in carbon stocks) and GHG emissions from fires in land subject to cropland management and grazing land management activities.

d.1 Time:

The fires GHG emissions National Inventory annually provides time series of GHG emissions from fires.

[83] http://www.carabinieri.it/arma/oggi/organizzazione/organizzazione-per-la-tutela-forestale-ambientale-e-agroalimentare

[84] The Italian territory is subdivided in 20 administrative regions, 5 of which are autonomous: Valle d'Aosta, Friuli Venezia Giulia, Sardegna, Sicilia and Trentino Alto Adige, the latest subdivided in two autonomous provinces (Trento and Bolzano).

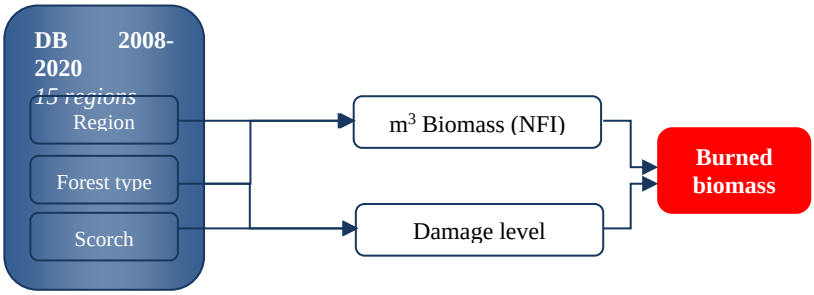
d.2 Space:

IEIF supplies estimates of emissions associated with fires detected by National Census of Fires.

Key elements:

On the basis of the different datasets available, in each year and group of regions, different approaches and assumptions have been followed to estimate non-CO2 emissions from forest fires.

a. The estimation of non-CO_2 emissions from fires in the 15 regions is based on two main elements: the fire intensity (assessed through the scorch height) and the forest typologies. A large database has been used for fires occurred in forest and other wooded land for the period 2008-2020.



In case of missing data, record by record, a gap filling procedure has been adopted, as described in the Annex 15; the estimation process for the GHG fires emissions for the 5 autonomous regions/provinces is also reported in the Annex 15.

d.3 Quality assurance:

Data supplied by IEIF is collected in the "*National Registry for the carbon sinks*" of Kyoto Protocol, and fulfill quality needs, outlined in the IPCC guidelines and required by UNFCCC relevant decisions.

e. Cropland and grazing land management

These sections of the national registry for carbon sinks have been added following the decision by Italy to elect cropland management (CM) and grazing land management (GM) under Article 3.4 of the Kyoto Protocol for the second commitment period (2013-2020). The Ministry for the Environment, Land and Sea (MATTM) jointly with the Ministry of Agriculture, Food and Forest Policies (MIPAAF) has established a Committee of National experts at institutional and scientific level, aimed at dealing with all issues related to reporting and coordination of activities related to LULUCF reporting, included also the needs set out by the Kyoto Protocol; a focus will be applied to verification activities carried out in the framework of the implementation of EU Decision n. 529/2013[85].

e.1 Cropland management

This section of the *national registry for carbon sinks* is aimed at collecting information and preparing estimates of GHG emissions and removals from cropland management activity.

Land subject to cropland management have been assessed have been assessed on the basis of the definition included in the Annex to the decision 16/CMP.1[86] and disaggregated in the following subdivisions:

[85] Decision n. 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities**:** http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013D0529

[86] *Grazing land management* is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.

1. any crops subject to inspections and certifications, in accordance with the EU Regulations on **organic production**[87]**;**
2. annual crops cultivated using "**conservative practices**", including management practices aimed at preserving the soil[88] (e.g.: tillage practices to prevent/reduce soil erosion; cover crop; minimum tillage, zero tillage and sod seeding, mulching);
3. any crops grown using "**sustainable management systems**[89]". These practices are intended to improve the efficiency of nutrients by reducing the losses due to leaching, runoff and evaporation; maintain the soil in good structural conditions; prevent erosion and landslides, preserve the soil organic matter and possibly enhance it;
4. **set-aside**[90] requiring cover crops, spontaneous or sown, all the year long and agronomic practices consisting of mowing or another equivalent operation in order to preserve the normal soil fertility, avoid fires, especially during drought conditions, and avoid pests spread;
5. any crops grown using "**ordinary agriculture**". Land which doesn't fall within one of the above kinds of management;
6. Any crops subject to **greening practices**, in accordance with the EU Regulation 1307/2013.

Regarding area data sources:

a. Data for cropland under **organic practices** are derived from the National System on Organic Farming (SINAB, http://www.sinab.it/) of the Ministry of Agriculture, Food and Forest Policies (MIPAAF). Data from SINAB are collected at national level starting form 1990.
b. Data for cropland under "**conservative practices**" are derived from the Implementation Report Tables[91] (AIRs) of the regional Rural Development Programmes (RDPs). Data have been collected at regional level (NUTS2), from 2008, and have been standardized considering the different definitions adopted for these practices at NUTS level.
c. Data for cropland under "**sustainable management systems**" are derived from the AIRs of the regional RDPs[92] and the Annual Report of the Operative Programmes on fruit and vegetables in the framework of the CMO[93]. Data are collected at regional level (NUTS2), from 2000, for the total aggregate cropland, consequently the disaggregation between annual and woody cropland is done applying the indicators contained in the national database[94]. Verification activities have been carried out through information collected by the Regions with largest share of areas under these management systems.
d. Data for cropland **set aside** are derived from Eurostat[95] and are available for 1990, 1993, 1995, 1997, 2000, 2003, 2005 and 2007. Data for the missing years have been estimed by interpolation.

[87] Council Regulation (EEC) No 2092/91: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991R2092:EN:HTML, Commission Regulation (EC) n. 889/2008: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0889&from=EN; Council Regulation (EC) n. 834/2007: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:f86000&from=IT; Council Regulation (EEC) n. 2092/91**:** http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991R2092:EN:HTML; Rural Development Regulations – organic farming measure (Regulations (ex) 2078/1992, (ex) 1257/1999, (ex) 1698/2005 and 1305/2013)

[88] in accordance with the Regulation (EEC) n. 2078/92: http://ec.europa.eu/agriculture/envir/programs/evalrep/text_en.pdf, (ex) 1257/1999, Council Regulation (EC) n. 1698/2005: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005R1698&from=en, and Regulation (EU) n. 1305/2013: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:EN:PDF

[89] in accordance with the national guidelines on integrated production and with the EU Regulations on the Rural Development (Regulations (ex) 2078/1992, (ex) 1257/1999, (ex) 1698/2005 and 1305/2013

[90] EU Regulations ((ex) 1094/88; (ex) 1765/92 e 1251/99: (ex) 1782/03 and 1307/2013) and National decree on cross compliance implementation (ex) DM 22.12.2009 and DM 23.1.2015

[91] http://ec.europa.eu/agriculture/cap-indicators/output/working-document-rd-monitoring-implementation-report-tables_en.pdf in the framework of the EU's rural development policy: http://ec.europa.eu/agriculture/rural-development-2014-2020/index_en.htm; for 2007-2014 referred to action 214.6)

[92] for 2007-2014 referred to action 214.1 – tables O.214(1) and O.AGRI.ENV

[93] Common Organisation of the Markets (CMO) in agricultural products http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU_5.2.4.html

[94] Indicatori Agricoli Territoriali", National Rural Network: http://indiciterritorialiagricoli.ismea.it

[95] Fallow land and set-aside land: https://open-data.europa.eu/it/data/dataset/aLDul3sogcS8Hur7m4HWg

e. Data for cropland using "**ordinary agriculture**" are obtained by difference between the total area detected by national statistics (ISTAT) and the data related to the abovementioned subcategories.

CM activities	management practices	definition	CAP regulations	Data source
CM - annual crops	Arable land (Ordinary)	A kind of agriculture that doesn't evidence any kind of soil carbon stock technical maintenance		ISTAT
	Organic arable land	Management of waste crop; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	National Information system on organic agriculture (SINAB)
	Sustainable arable land	Crop rotation; Grassing; Specific erosion prevention; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2018
	Set aside	Natural grassing; At least one mowing	Reg. (EEC) N. 1765/1992; National decree on cross compliance implementation n. 30125/2009 and subsequent revisions	Eurostat: 1990-2016
	Conservative practices	Zero tillage; Organic manure; Grassing; Cover crops; Minimum tillage; Crop rotation	RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE): 2008-2018
CM – perennial crops	woody crops (Ordinary)	A kind of agriculture that doesn't evidence any kind of soil carbon stock technical maintenance		ISTAT
	Organic perennial woody crops	Management of waste crop; Organic manure; Extended crop rotation; Selection of better crop varieties; Cover crops	Reg. (EEC) n. 2078/92, Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008, RDPs 2000-2006: Reg. (EC) n. 1257/99, RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	National Information system on organic agriculture (SINAB)
	woody crops - Sustainable management	Crop rotation; Grassing; Specific erosion prevention; Cover crops; Minimum tillage	National decree on sustainable agriculture n. 2722/2008; RDPs 2000-2006: Reg. (EC) n. 1257/99; RDPs 2007-2013: Reg. (EC) n. 1698/2005 and Reg. (EC) n. 74/2009	Annual Implementation Reports (RAE) and Annual Report on Operational Programs: 2000-2018

e.1.1 Time

Annual data of land subject to cropland management and related estimates of emissions and removals are provided.

e.1.2 Space

The reporting area boundaries for cropland management have been identified with the administrative boundaries of Italy (NUTS1) and administrative regions (NUTS2). The spatial assessment for cropland management refers to the cadastral unit or to a part of it, where the cropland management is carried out.

e.2 Grazing land management

This section of the *national registry for carbon sinks* is aimed at collecting information and preparing estimates of GHG emissions and removals from grazing land management activity.

Land subject to *grazing land management* have been assessed on the basis of the definition included in the Annex to the decision 16/CMP.1[96], and are those predominantly covered by herbaceous vegetation (introduced or indigenous) for a period longer than five years, used for grazing or fodder harvesting and /or under practices to control the amount and type of vegetation. As preliminary step, only the area related to the 'improved grazing land' has been reported within GM; this area corresponds to lands subject to inspections and certifications procedures, in accordance with the EU Regulations[97] on organic production, as well as by the Rural Development Regulations[98] on the organic farming measure. Data of grazing lands managed with organic practices are taken from the National System on Organic Farming (SINAB, http://www.sinab.it/) of the Ministry of Agriculture, Food and Forest Policies (MIPAAF).

GM activities	management practices	definition	CAP regulations	Data source
GM	grazing land	Renewal and/or thickening of crops	National decree on cross compliance implementation n. 30125/2009 and subsequent revisions	ISTAT, Eurostat
	organic grazing land	Renewal and/or thickening of crops; Connection to zoothecnics	RDPs 2000-2006: Reg. (EC) n. 1257/1999; RDPs 2007 - 2013: Reg. (EC) n. 1998/2005 and Reg. (EC) n. 74/2009; Reg. (EC) n. 834/2007 and Reg. (EC) n. 889/2008; Reg. (EC) n. 1804/2007	National Information system on organic agriculture (SINAB)

Carbon stock changes in land subject to *grazing land management* have been estimated on the basis of the guidance of 2013 KP Supplement (IPCC, 2014). Tier 1 method has been applied to biomass and DOM assuming that the abovementioned pools are at long-term equilibrium, so annual carbon stock changes have not been estimated. Annual changes in carbon stocks in mineral soils have been estimated applying the method described for grassland (see NIR sections 6.4.4, 9.5.3).

e.2.1 Time

Annual data of land subject to grazing land management and related estimates of emissions and removals are provided.

e.2.2 Space

The reporting area boundaries for grazing land management have been identified with the administrative boundaries of Italy (NUTS1) and administrative regions (NUTS2). The spatial assessment for grazing land management refers to the cadastral unit or to a part of it, where the grazing land management is carried out.

e.3 Quality assurance

Data will be annually collected in the section related to cropland and grazing land management and have to fulfill quality requirements outlined in the IPCC Guidelines and required by UNFCCC relevant decisions.

[96] *Grazing land management* is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.

[97] Commission Regulation (EC) n. 889/2008: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0889&from=EN; Council Regulation (EC) n. 834/2007: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:f86000&from=IT; Council Regulation (EEC) n. 2092/91: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991R2092:EN:HTML

[98] Regulation (EEC) n. 2078/92: http://ec.europa.eu/agriculture/envir/programs/evalrep/text_en.pdf;
Council Regulation (EC): n. 1257/1999 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999R1257&from=en;
Council Regulation (EC) n. 1698/2005: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005R1698&from=en;
Regulation (EU) n. 1305/2013: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:EN:PDF

ANNEX 11: THE NATIONAL REGISTRY

According to Article 7 of the Kyoto Protocol each Party included in Annex I shall incorporate in its annual greenhouse gas inventory the necessary supplementary information for the purposes of ensuring compliance with Article 3 of the Kyoto Protocol.
Supplementary information under article 7, paragraph 1, with regards to units holdings and transactions during the year 2021, is reported in the SEF submission (figures are also included in tables A8.2.2.1 - A8.2.2.5c of this document).
This annex reports supplementary information with regards to the national registry and in accordance with the guidelines set down in Decision 15 CMP.1 (Annex II.E Paragraph 32).
More detailed information can be found in the relevant annexes that have been submitted to UNFCCC along with this document.

(a) ***The name and contact information of the registry administrator designated by the Party to maintain the national registry***
The Italian Registry is administrated by ISPRA (national Institute for Environmental Protection and Research) under the supervision of the national Competent Authority for the implementation of the European directive 2003/87/EC, jointly established by the Ministry for Environment, Land and Sea and the Ministry for Economic Development. ISPRA, as Registry Administrator, is responsible for the management and functioning of the Registry, including Kyoto protocol obligations.
The contact person is: Mr Riccardo Liburdi
address: Via Vitaliano Brancati 48 – 00144 Rome – Italy
telephone: +39 0650072544
e-mail: riccardo.liburdi@isprambiente.it
No change of name or contact occurred during the reported period.

(b) ***The names of the other Parties with which the Party cooperates by maintaining their national registries in a consolidated system***
Italy maintains its national registry in a consolidated manner with all the Parties that are also EU Member States and with the European Union, sharing the same platform hosted and facilitated by the European Commission.
There was a change in the cooperation arrangement during the reported period as the United Kingdom of Great Britain and Northern Ireland no longer operate their registry in a consolidated manner within the Consolidated System of EU registries, CSEUR.

(c) ***A description of the database structure and capacity of the national registry***
The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries.
During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). All tests were executed successfully and lead to successful certification on 1 June 2012.
There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last submission).
No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan.
No change to the capacity of the national registry occurred during the reported period.

(d) ***A description of how the national registry conforms to the technical standards for data exchange between registry systems for the purpose of ensuring the accurate, transparent and efficient exchange of data between national registries, the clean development mechanism registry and the transaction log (decision 19/CP.7, paragraph 1)***
The overall change to a Consolidated System of EU Registries triggered changes to the registry software and required new conformance testing. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries.
During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data

Exchange Standard (DES). All tests were executed successfully and lead to successful certification on 1 June 2012.
The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B.
It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B).
No other change in the registry's conformance to the technical standards occurred for the reported period.

(e) ***A description of the procedures employed in the national registry to minimize discrepancies in the issuance, transfer, acquisition, cancellation and retirement of ERUs, CERs, tCERs, lCERs, AAUs and/or RMUs, and replacement of tCERS and lCERs, and of the steps taken to terminate transactions where a discrepancy is notified and to correct problems in the event of a failure to terminate the transactions***
The overall change to a Consolidated System of EU Registries also triggered changes to discrepancies procedures, as reflected in the updated *manual intervention document* and the *operational plan*. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries.
No change of discrepancies procedures occurred during the reported period.

(f) ***An overview of security measures employed in the national registry to prevent unauthorized manipulations and to prevent operator error and of how these measures are kept up to date***
The overall change to a Consolidated System of EU Registries also triggered changes to security, as reflected in the updated *security plan*. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries.
No changes regarding security were introduced.

(g) ***A list of the information publicly accessible by means of the user interface to the national registry***
Non-confidential information required by Decision 13/CMP.1 annex II.E paragraphs 44-48, is publicly accessible via the Union Registry website at:
https://unionregistry.ec.europa.eu/euregistry/IT/public/reports/publicReports.xhtml
and it is also available on the informative website at :
https://www.isprambiente.gov.it/en/services/emission_trading_registry/public-reports

Information is updated on a monthly basis and is provided with the following exceptions:

- paragraph 45(d)(e): account number, representative identifier name and contact information is deemed as confidential according to Annex III and VIII (Table III-I and VIII-I) of Commission Delegated Regulation (EU) No 2019/1122;
- paragraph 46: no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project did not occur in the specified period;
- paragraph 47(a)(d)(f): holding and transaction information is provided on an account type level, due to more detailed information being declared confidential by article 80 of Commission Delegated Regulation (EU) No 2019/1122.

No change to list of publicly available information occurred during the reported period.

(h) ***The Internet address of the interface to its national registry***
The registry is available at https://unionregistry.ec.europa.eu/euregistry/IT/index.xhtml and the URL has not changed since last submission.

(i) ***A description of measures taken to safeguard, maintain and recover data in order to ensure the integrity of data storage and the recovery of registry services in the event of a disaster***
The overall change to a Consolidated System of EU Registries also triggered changes to data integrity measures, as reflected in the updated *disaster recovery plan*. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries.
No change of data integrity measures occurred during the reported period.

(j) ***The results of any test procedures that might be available or developed with the aim of testing the performance, procedures and security measures of the national registry undertaken pursuant to the provisions of decision 19/CP.7 relating to the technical standards for data exchange between registry systems.***
The consolidated EU system of registries successfully completed a full certification procedure in June 2012. Notably, this procedure includes connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). This included a full Annex H test. All tests were executed successfully and led to successful certification on 1 June 2012.
No change occurred during the reported period.

ANNEX 12: OVERVIEW OF THE CURRENT SUBMISSION IMPROVEMENTS

A12.1 Results of the UNFCCC review process

During the last UNFCCC review process, some issues were raised which have been taken into account to improve the current submission. Responses to the main recommendations, received in the draft review report, are described in the following table.

Member State:	ITALY			
Reporting year:	2022			
CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
Article 3, paragraph 14, of the Kyoto Protocol KP reporting adherence	The ERT recommends that the Party, in its annual submission, report any changes in the information it provided under Article 3, paragraph 14, of the Kyoto Protocol in accordance with decision 15/CMP.1 in conjunction with decision 3/CMP.11. If there have been no changes, the ERT recommends that the Party highlight this in the NIR in order to improve the transparency of the reported information.	G.1	The NIR has been updated	Chapter 13
Comparison with international data – refinery feedstocks Accuracy	The Party reported in CRF table 1.A(b) a figure for the stock change of refinery feedstocks (–75,646.85 TJ in 2019) which differed substantially from that provided to the IEA (18 kt in 2019, which is approximately 765 TJ). During the review, Italy clarified that there is a difference in the modalities of reporting the national energy balance compared with the format of the joint questionnaire submitted to the IEA. The Party also stated that it plans to conduct further analysis by involving experts responsible for the compilation of the national energy balance in order to harmonize the submissions. The ERT recommends that the Party check the value reported in the CRF table 1.A(b) on stock change of the refinery feedstock and report in the NIR on any further analysis of the comparison of the data reported in the CRF and those reported to the IEA.	E.4	Additional information has been included in the NIR	Annex 4
1.A.1.a Public electricity and heat production – waste – CO2, CH4, N2O Accuracy	The Party reported in CRF table 1.A(b) the amount of waste (non-biomass fraction) production in 2019. The ERT noted that this figure was 53 per cent lower than that reported to the IEA. During the review, Italy clarified that the value provided related only to waste for electricity production and did not include the waste for heat production and that for 2019 the value would be approximately 17 per cent higher if the latter were included. The ERT recommends that the Party undertake a review of the amount of waste used in the energy sector and account for waste used not only for electricity production but also for heat production and make any appropriate amendments to the CRF tables.	E.5	The figures have been revised according to the reccomendation	Annex 4
1.A.3.b Road transportation – biomass – CO2, CH4, N2O Trasparency	The Party reported in its NIR (section 3.5.3.2.1.1, p.92) that biogasoline accounts for 0.4 per cent of total road gasoline consumption. The NIR refers to fossil fuel fraction in biodiesel when describing the assessment of CO2 emissions from biofuels (p. 93) without specifying the share of biodiesel, it was unclear from the text whether emissions estimates had been compiled only for biodiesel or also for biogasoline. During the review, Italy clarified that emissions had also been estimated for biogasoline consumption. The ERT recommends that the Party specify in the NIR that emission estimates also have been compiled for biogasoline consumption.	E.6	The relevant information has been provided in the NIR	Chapter 3 paragraph 5

2.B.1 Ammonia production – CO2 Transparency	The ERT recommends that Italy investigate the reasons for the difference between apparent consumption and the amount of urea used in the inventory and include the results of this investigation in the NIR.	I.4	Italy is carrying out the requested investigations and a revision of official statistics is on going by ISTAT. In any case it will not affect emissions in the IPPU sector but if any in Agriculture.	Chapter 4 paragraph 3
2.D.3 Other (non-energy products from fuels and solvent use) – CO2 Convention reporting adherence	The ERT recommends that the Party present national totals with and without indirect CO2 emissions in CRF table summary 2. The Party continues to report total national emissions including indirect CO2 emissions in CRF tables (e.g. CRF table summary 2 or CRF table 10 on emission trends) under the heading for total national emissions excluding indirect CO2 emissions and "NA" for the totals of national emissions including indirect CO2 emissions indicated instead of numerical values to reflect the reporting of indirect CO2 emissions from solvents. The Party stated its arguments in the NIR (p. 580) and also during the review. Italy stated that CRF table summary 2 is populated automatically and the reporting of the notation key "NO" therein is the result of using this notation key under "indirect CO2 emissions" in background tables for the IPPU sector. It also stated that reporting indirect CO2 emissions in the totals would reduce transparency because emissions would be reported at an aggregated level and not at the level at which they occur, and that implementing the recommendation would result in a different national total with implications for other relevant assessments (e.g. trend and key category assessments). Italy referred to the conclusions from the 17th meeting of GHG inventory lead reviewers (available at https://unfccc.int/sites/default/files/resource/conclusions-GHG_LRs-2020.pdf) to support its assessment further. The ERT considers that this approach is not in accordance with paragraph 29 of the UNFCCC Annex I inventory reporting guidelines, according to which, for Parties that decide to report indirect CO2, the national totals shall be presented with and without indirect CO2.	I.5	The national totals have been reported both with and without indirect emissions in the NIR and relevant information has been added to improve the transparency	Chapter 2
2.D.3 Other (non-energy products from fuels and solvent use) – CO2 Convention reporting adherence	The ERT recommends that the Party report indirect CO2 emissions in CRF table 6 as "IE" instead of "NO". The Party continues to use notation key "NO" for indirect emissions from the IPPU sector in CRF table 6 although indirect emissions are reported for this sector under category 2.D.3 (NIR, p.153). During the review, the Party stated that it seems inappropriate to use "IE" in CRF table 6. It noted that "IE" would only apply to indirect CO2 emissions attributed to category 2.D.3 and using "IE" would conceal where such emissions occur. See ID# I.5 above.	I.6	The notation key has been changed	
3.A.2 Sheep – CH4 Transparency	Improve the transparency of reporting on the enteric fermentation of sheep by providing information on the assumptions used to adjust the DE% values for mature ewes and other mature sheep. The ERT noted the provided explanations on the selection of DE% value. It considers, however, that the recommendation is still not fully resolved as it is still not clear in the NIR which assumptions were used to adjust the DE% values for mature ewes and other mature sheep	A.1	Additional information has been provided in the NIR	Chapter 5 paragraph 5.2.2 and 5.2.6

3.A.1 Cattle – CH4 - Transparency	The ERT recommends that the Party conduct further verification of country-specific Ym values for the non-dairy cattle category, as indicated by Italy during the review, and report the results of the verification in the NIR to demonstrate that country-specific values better represent the national circumstances and that a justification is provided in the NIR	A.16	Additional information has been provided in the NIR	Chapter 5 paragraph 5.2.2 and 5.2.6 and Annex 7 paragraph A7.1
3.B Manure management – CH4 - Transparency	The ERT recommends that the Party provide in the NIR the values used for conversions from volume to mass unit for slurry and solid manure when estimating CH4 emissions from cattle and buffalo manure management	A.17	Requested information has be provided in the NIR	Chapter 5 paragraph 5.3.2
3.B Manure management – CH4 - Accuracy	The ERT recommends that the Party revise the CH4 EFs used to estimate emissions from pasture, paddock and range for cattle (dairy and non-dairy) and buffalo by correcting the allocation of MCF and manure handled by climate zone, in line with equation 10.23 of the 2006 IPCC Guidelines (vol.4, chap.10), and recalculate CH4 emissions for this subcategory	A.18	Emission factors have been corrected and estimates recalculated	Chapter 5 paragraph 5.3.2 Methane emissions (cattle and buffalo)
3.C Rice cultivation – CH4 - Transparency	The ERT recommends that the Party provide an explanation in the NIR of the increase in the share of rice cultivation area with single aeration, which is one of the key drivers for the decrease in CH4 emissions from rice cultivation	A.19	Requested information has been provided in the NIR	Chapter 5 paragraph 5.4.3
3.B.4 Other livestock – N2O - Consistency	The ERT recommends that the Party report consistently on ostrich manure management emissions between CRF tables 3.B(a) and 3.B(b) including estimates or appropriate notation key together with justification of the exclusion of N2O emissions from ostrich manure management as being an insignificant source, in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. The ERT also recommends that Italy correct the MMS for ostriches in CRF table 3.B(a)s2.	A.20	N2O emissions from ostrich manure management have been estimated and reported in the CRF. MMS for ostriches in CRF table 3.B(a)s2 has been corrected	Chapter 5 paragraph 5.5.2 Other livestock categories
3.D.a.1 Inorganic N fertilizers – N2O - Transparency	The ERT recommends that the Party provide an explanation in the NIR (e.g. as a footnote to table 5.38) of the amount of fertilizer distributed (t/year), N content (%) and amount of N (t N/year) in the fertilizer for other nitrogenous fertilizers.	A.21	Requested information has been provided in the NIR	Chapter 5 paragraph 5.5.2
4. General (LULUCF)	Report more detailed explanatory information and a justification for recalculations in the NIR	L.1	Additional information has been included in the NIR	Chapter 6 paragraph 1 of the NIR
4.A Forest Land -CO2	Document the For-est Model validations in the NIR	L.4	Complete NFI2015 results will be available in the late 2022, supplying data related to current increment and stocks; therefore the For-est model validation against the	chapter 6 paragraph 2

			latest NFI data is planned to be implemented for 2023 submission.	
4.G HWP – CO2 (L.16, 2019) Transparency	Document in the NIR the methodology used for estimating CO2 emissions from SWDS reported in CRF table 4.Gs1 and the rationale for the reported half-life value of 3.89 years.	L.12	Additional information has been included in the NIR	Chapter 6 paragraph 13 of the NIR
4. General (LULUCF)	The ERT recommends that the Party to ensure that key category analysis is reported in a consistent manner in chapter 6 and in the rest of the NIR.	L.15	The key category analysis has been revised.	Chapter 6 paragraph 1 of the NIR
4. General (LULUCF) – CO2	The ERT recommends, with specific reference to cropland and settlements remaining settlements, that the Party use the notation key “NA” in all circumstances where a tier 1 assumption of carbon stocks being in equilibrium (i.e. gains equal losses) is used (see also ID# KL.15 below).	L.16	In LULUCF categories, the notation key "NA" is used, with a comment for each NA occurence, to report carbon stock changes from carbon pools where carbon stock changes are neutral (i.e. FL-Fl (soil), Other wooded land under GL-GL (soil)). for KP activities, the notation key "NE" is used with a comment for each NE occurence (FM (soil), CM-GM (litter, deadwood)), addressing an UNFCCC review recommendation (KL1-ARR 2018, KL1-ARR 2019)	
4.G HWP – AD	The ERT recommends that the Party include in CRF table 4.Gs2 the full series of AD from 1961 onward for HWP used for the estimation of emissions.	L.19	The information requested is available at the link reported in the NIR	Chapter 6 paragraph 13 of the NIR
4.G HWP – CO2	The ERT recommends that the Party estimate HWP in SWDS using methods consistent with the 2006 IPCC Guidelines for the waste sector and report under the information item in CRF table 4.Gs1 and under the memo item in CRF table 5, and also include these in their HWP estimates if they meet the significance criteria of a key category, in accordance with guidance provided in the 2006 IPCC Guidelines (vol. 4, chap. 12, pp.12.8–12.10 and figure 12.1).	L.20	Additional information has been included in the NIR	Chapter 6 paragraph 13 of the NIR
4.G HWP – CO2	The ERT recommends that the Party report in the NIR information which identifies deforestation-sourced HWP as negligible in Italy as justification for not estimating additional deforestation-sourced HWP emissions or sequestrations under the Convention compared with those estimated under the Kyoto Protocol.	L.21	Additional information has been included in the NIR	Chapter 6 paragraph 13 of the NIR
5.C.1 Waste incineration – CO2 Transparency	The ERT recommends that the Party improve the transparency of reporting on waste incineration by including the values of carbon content for the whole time series and the reason for the changes in carbon content, fossil carbon fraction and oxidation factor in order to facilitate the replication of the estimation. Table 7.23 (section 7.4.2, p.308) of the NIR was supplemented with information on carbon content of different incinerated waste types. However, no information could be found in the NIR on the oxidation	W.7	The NIR has been updated accordingly	Chapter 7 paragraph 4

	factor used. During the review, the Party clarified that the oxidation factor used is 100 per cent.			
5. General (waste) – CO2 Accuracy	Italy reported negative values in CRF table 5 whereas annual change on total long-term carbon storage in SWDS should be greater than, or equal to, zero. Moreover, the ERT noted that the estimates provided by the IPCC Waste Model, which the Party uses for verification, are significantly lower than the figures reported in the CRF tables (for example, for 2019, the IPCC Waste Model calculated 571 kt C, whereas 1,083 kt C is included in CRF table 4.Gs1). During the review, the Party stated that it will assess the results produced by the IPCC Waste Model and consider importing this calculation into its national model for the next annual submission. See also ID# L.20 above. The ERT recommends that Italy revise its estimates of the annual change in total long-term C storage in HWP waste in CRF table 5 ensuring that the corresponding CO2 emissions are greater than, or equal to, zero.	W.9	HWP have been estimated using the IPCC waste model (MS excel- 2006 IPCC Guidelines) and the CRF tables have been updated accordingly	
5.D.1 Industrial wastewater – CH4 Accuracy	The Party reported in its NIR (section 7.5.2, p.314) that it used the value 1.25 as the correction factor for additional industrial BOD discharged into sewers for the calculation of total amount of organically degradable material in the wastewater. The ERT noted that this parameter was applied to all wastewater, whereas the 2006 IPCC Guidelines (vol. 5, chap. 6, p.6.14) provide different default values for collected and uncollected wastewater, namely 1.25 and 1.00, respectively. During the review, the Party confirmed that it had used the value 1.25 for uncollected wastewater, as industries and establishments (e.g. restaurants, butchers and grocery stores) might discharge additional BOD into domestic wastewater. The ERT recommends that the Party provide a justification in the NIR for using the value 1.25 as the correction factor for all additional industrial BOD discharged into sewers or revise its current practice and apply the default value of 1.00 for uncollected wastewater, especially in the case of rural population using latrines.	W.10	The NIR has been updated accordingly	Chapter 7 paragraph 5
5.D.1 Domestic wastewater – CH4 Accuracy	The ERT noted that anaerobic processes are used in sludge treatment of wastewater (NIR, pp.312–313), but the NIR does not specify if the CH4 emissions from leakage from anaerobic digestion of sewage sludge in wastewater treatment plants were estimated. During the review, the Party confirmed that such emissions were not estimated. The ERT noted that, considering the level of biogas production in 2019 reported by Eurostat (2,137 TJ) and the default leakage rate of 5 per cent from the 2006 IPCC Guidelines (vol. 5, chap. 4, p.4.4), the potential underestimation of CH4 emissions would be below the threshold of significance for Italy. The ERT recommends that the Party estimate CH4 emissions from leakage from anaerobic digestion of sewage sludge by using either country-specific information on the leakage rate or, if no country-specific information is available, the default value of 5 per cent from the 2006 IPCC Guidelines (vol. 5, chap. 4, p.4.4).	W.11	Emissions have been added	Chapter 7 paragraph 5

5.D.1 Domestic wastewater – CH4 Transparency	The Party reported estimates of TOW of generated sludge in table 7.34 of the NIR. The ERT noted that these TOW values are exactly half of the total TOW values in wastewater treatment plants but found no explanation for this in the NIR. During the review, the Party confirmed that TOW in sludge were indeed estimated as half of TOW, according to international literature such as Metcalf and Eddy, 1991, which proposes that the typical reduction in VS achieved in anaerobic digestion for mixed sludge (primary plus secondary) varies from 45 to 60 per cent. The ERT recommends that the Party include information on the approach used to estimate TOW in sludge in the NIR.		The NIR has been updated accordingly	Chapter 7 paragraph 5
General (KP-LULUCF)	The ERT recommends that the Party ensure that time series consistency is maintained in the publishing of CRF table NIR-2 by ensuring that, for all categories in all reported years, the area total at the end of the previous year aligns with the previous year's total at the end of the current year and that a consistent total national area is reported in all years.	KL.8	CRF table NIR-2 has been filled with correct data	
General (KP-LULUCF) – CO2, CH4, N2O	The ERT recommends that the Party report transparent and detailed information in the NIR on how its method for applying the natural disturbances provision in FM and AR avoids the expectation of net credits and net debits (see ID# KL.11 below). The ERT encourages the Party to conduct quality assurance on its approach for the next annual submission by personnel not directly involved in the inventory compilation/development process, to support its conclusions.	KL.9	Italy did not apply natural disturbance provision. Additional information has been included in the NIR	Chapter 9 paragraph 4 and 5 of the NIR
General (KP-LULUCF) – CO2, CH4, N2O	Noting that the 2022 submission would be the final annual submission under the second commitment period of the Kyoto Protocol, the ERT recommends that the Party clearly report on its final decision on applying the natural disturbances provision. In the case that the Party decides to apply the provision, the ERT recommends that Italy include all information on areas and emissions from activities relevant to natural disturbances in CRF tables 4(KP-I)A.1.1 and 4(KP-I)B.1.3, allowing the accounting of emissions and removals and the effect of natural disturbances for FM, and also make proper use of these tables to subsequently exclude emissions from accounting in the CRF accounting table.	KL.10	Italy did not apply natural disturbance provision. Additional information has been included in the NIR	Chapter 9 paragraph 4 and 5 of the NIR
AR – CO2, CH4, N2O	The ERT recommends that the Party use methods for estimating the natural disturbance background level and margin ensuring that there is no expectation of net credits or debits and that the methods for natural disturbances are consistent between AR and FM in accordance with decision 2/CMP.7, annex, para. 33(b) and footnote 9.	KL.11	Italy did not apply natural disturbance provision. Additional information has been included in the NIR	Chapter 9 paragraph 4 and 5 of the NIR
AR – CO2, CH4, N2O	The ERT recommends that the Party provide transparent information in the NIR regarding the areas of wildfire in AR from 1990 onward and justify its methods for the estimation of emissions from biomass burning in AR. The ERT also recommends that the Party explains in detail in the NIR how it uses the estimates from biomass burning in construction of the natural disturbances background level and margin.	KL.12	Italy did not apply natural disturbance provision. Additional information has been included in the NIR	Chapter 9 paragraph 4 and 5 of the NIR
FM – CO2, CH4, N2O	The ERT recommends that the Party provide comprehensive and transparent information in the NIR as to how the FMRLcorr is calculated, demonstrating that the policy assumptions used in the construction of the FMRLcorr are the same as for the FMRL, including how the harvesting rate assumptions used for FMRL are maintained in the FMRLcorr and how wildfire emissions have been updated in the FMRLcorr in a manner consistent with the calculation of the natural disturbance background level for FM.	KL.13	Additional information has been included in the NIR; in relation to the calculation the natural disturbances background level and margin for FM, Italy did not apply natural disturbance provision.	Chapter 9 paragraph 5 of the NIR

CM	The ERT recommends that the Party provide additional information in the NIR regarding the consequences of excluding land areas which are reported under CM and GM only in the base year.	KL.14	Additional information has been included in the NIR	Chapter 9 paragraph 5 of the NIR
CM – CO2	The ERT recommends, with specific reference to CM and GM, that the Party use the notation key “NA” in all circumstances where a tier 1 assumption of carbon stocks being in equilibrium (i.e. gains equal losses) is applied.	KL.15	In LULUCF categories, the notation key "NA" is used, with a comment for each NA occurence, to report carbon stock changes from carbon pools where carbon stock changes are neutral (i.e. FL-Fl (soil), Other wooded land under GL-GL (soil)). for KP activities, the notation key "NE" is used with a comment for each NE occurence (FM (soil), CM-GM (litter, deadwood)), addressing an UNFCCC review recommendation (KL1-ARR 2018, KL1-ARR 2019)	
GM – N2O	The ERT recommends that the Party estimate and report N2O emissions from N mineralization or immobilization where CSCs are negative and report the areas and CSCs in mineral soils (including where N2O emissions are not occurring owing to increasing carbon stocks and negative FSOM in mineral soils) in CRF table 4(KP-II)3, and ensure that the reporting under the Convention is consistent with this.	KL.16	The N2O emissions from N mineralization or immobilization have been estimated and reported, where CSCs are negative, in CRF table 4(KP-II)3.	

A12.2 Results of the ESD technical review process

During the last ESD technical review process, no issues were raised in the review report and no revised estimates or technical corrections were deemed necessary. Anyway, issues identified during the review have been taken into account as much as possible to improve the current submission.

ANNEX 13: REPORTING UNDER EU REGULATION No 525/2013

A13.1 Article 10 of the EU Regulation

Implementing Regulation Article 10: Reporting on consistency of reported emissions with data from the emissions trading system

1.Member States shall report the information referred to in Article 7(1)(k) of Regulation (EU) No 525/2013 in accordance with the tabular format set out in Annex V to this Regulation.

2.Member States shall report textual information on the results of the checks performed pursuant to Article 7(1)(l) of Regulation (EU) No 525/2013.

Allocation of verified emissions reported by installations and operators under Directive 2003/87/EC to source categories of the national greenhouse gas inventory	
Member State:	Italy
Reporting year:	2022
Basis for data: verified ETS emissions and greenhouse gas emissions as reported in inventory submission for the year X-2	

Total emissions (CO2 -eq)					
Category[1]	Gas	Greenhouse gas inventory emissions [kt CO_2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
Greenhouse gas emissions (total emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC)	Total GHG	448134.988	164503.972	36.71%	
CO2 emissions (total CO2 emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC)	Total CO_2	367380.296	164282.349	44.72%	

CO_2 emissions					
Category[1]		Greenhouse gas inventory emissions [kt CO_2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO_2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
1.A Fuel combustion activities, total	CO_2	349961.714	NA	NA	
1.A Fuel combustion activities, stationary combustion [4]	CO_2	349376.885	146585.194	0.420	
1.A.1 Energy industries	CO_2	108537.553	108207.619	0.997	
1.A.1.a Public electricity and heat production	CO_2	78792.748	78471.691	0.996	
1.A.1.b Petroleum refining	CO_2	22138.770	22138.770	1.000	
1.A.1.c Manufacture of solid fuels and other energy industries	CO_2	7606.036	7597.159	0.999	

CO_2 emissions					
Category[1]		Greenhouse gas inventory emissions [kt CO_2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO_2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
Iron and steel total (1.A.1.c, 1.A.2, 1.B, 2.C.1) [5]	CO_2	21763.455	19980.188	0.918	
1.A.2. Manufacturing industries and construction	CO_2	55702.364	36953.702	0.663	
1.A.2.a Iron and steel	CO_2	12716.568	10942.178	0.860	
1.A.2.b Non-ferrous metals	CO_2	1042.396	456.471	0.438	
1.A.2.c Chemicals	CO_2	11366.815	6305.702	0.555	
1.A.2.d Pulp, paper and print	CO_2	4851.327	3945.230	0.813	
1.A.2.e Food processing, beverages and tobacco	CO_2	3662.957	1681.645	0.459	
1.A.2.f Non-metallic minerals	CO_2	13307.919	10275.587	0.772	
1.A.2.g Other	CO_2	8754.381	3346.890	0.382	
1.A.3. Transport	CO_2	102697.554	625.064	0.006	
1.A.3.e Other transportation (pipeline transport)	CO_2	665.458	625.064	0.939	
1.A.4 Other sectors	CO_2	82439.414	798.808	0.010	
1.A.4.a Commercial / Institutional	CO_2	24174.533	798.808	0.033	
1.A.4.c Agriculture/ Forestry / Fisheries	CO_2	6798.173	0	0.000	
1.B Fugitive emissions from Fuels	CO_2	2701.607	2103.255	0.779	
1.C CO2 Transport and storage	CO_2				
1.C.1 Transport of CO2	CO_2				
1.C.2 Injection and storage	CO_2				
1.C:3 Other 2.A Mineral products	CO_2				
2.A Mineral products	CO_2	12281.062	12048.098	0.981	
2.A.1 Cement Production	CO_2	8877.183	8849.563	0.997	
2.A.2. Lime production	CO_2	1874.736	1874.736	1.000	
2.A.3. Glass production	CO_2	545.531	545.531	1.000	
2.A.4. Other process uses of carbonates	CO_2	983.613	778.268	0.791	
2.B Chemical industry	CO_2	1304.898	1867.686	1.431	
2.B.1. Ammonia production	CO_2	642.915	1210.719	1.883	Includes emissions from urea production
2.B.3. Adipic acid production (CO2)	CO_2	1.736	1.736	1.000	
2.B.4. Caprolactam, glyoxal and glyoxylic acid production	CO_2				
2.B.5. Carbide production	CO_2	5.016	0	0.000	
2.B.6 Titanium dioxide production	CO_2				
2.B.7 Soda ash production	CO_2	230.577	230.577	1.000	
2.B.8 Petrochemical and carbon black production	CO_2	424.654	424.654	1.000	
2.C Metal production	CO_2	1678.116	1678.116	1.000	
2.C.1. Iron and steel production	CO_2	1440.852	1440.852	1.000	
2.C.2 Ferroalloys production	CO_2	34.655	34.655	1.000	
2.C.3 Aluminium production	CO_2				
2.C.4 Magnesium production	CO_2				
2.C.5 Lead production	CO_2				

CO_2 emissions					
Category[1]		Greenhouse gas inventory emissions [kt CO_2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO_2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
2.C.6 Zinc production	CO_2	202.610	202.610	1.000	
2.C.7 Other metal production	CO_2				

N_2O emissions					
Category[1]	Gas	Greenhouse gas inventory emissions [kt CO_2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO_2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
2.B.2. Nitric acid production	N_2O	111.542	111.566	1.000	rounding of activity data in the ETS calculation
2.B.3. Adipic acid production	N_2O	110.051	110.056	1.000	rounding of activity data in the ETS calculation
2.B.4. Caprolactam, glyoxal and glyoxylic acid production	N_2O				

PFC emissions					
Category[1]	Gas	Greenhouse gas inventory emissions [kt CO2eq][3]	Verified emissions under Directive 2003/87/EC [kt CO_2eq][3]	Ratio in % (Verified emissions/ inventory emissions)[3]	Comment[2]
2.C.3 Aluminium production	PFC				

[1] The allocation of verified emissions to disaggregated inventory categories at four digit level must be reported where such allocation of verified emissions is possible and emissions occur. The following notation keys should be used: NO = not occurring IE = included elsewhere C = confidential negligible = small amount of verified emissions may occur in respective CRF category, but amount is < 5% of the category

[2] The column comment should be used to give a brief summary of the checks performed and if a Member State wants to provide additional explanations with regard to the allocation reported. Member States should add a short explanation when using IE or other notation keys to ensure transparency.

[3] Data to be reported up to one decimal point for kt and % values

[4] 1.A Fuel combustion, stationary combustion should include the sum total of the relevant rows below for 1.A (without double counting) plus the addition of other stationary combustion emissions not explicitly included in any of the rows below.

[5] To be filled on the basis of combined CRF categories pertaining to 'Iron and Steel' , to be determined individually by each Member State; e.g. (1.A.2.a+ 2.C.1 + 1.A.1.c and other relevant CRF categories that include emissions from iron and steel (e.g. 1A1a, 1B1))
Notation: x = reporting year

A13.2 Article 12 of the EU Regulation

Implementing Regulation Article 12: Reporting on consistency with energy data

1.Under Article 7(1)(m)(iii) of Regulation (EU) No 525/2013, Member States shall report textual information on the comparison between the reference approach calculated on the basis of the data included in the greenhouse gas inventory and the reference approach calculated on the basis of the data reported pursuant to Article 4 of Regulation (EC) No 1099/2008 of the European Parliament and of the Council (1) and Annex B to that Regulation.

2.Member States shall provide quantitative information and explanations for differences of more than +/– 2 % in the total national apparent fossil fuel consumption at aggregate level for all fossil fuel categories for the year X-2 in accordance with the tabular format set out in Annex VI.

Member State:	ITALY
Reporting year:	2022

FUEL TYPES			Apparent consumption reported in GHG inventory (TJ) (3)	Apparent consumption using data reported pursuant to Regulation (EC) No 1099/2008 (TJ) (3)	Absolute difference (1) (TJ) (3)	Relative difference (2) % (3)	Explanations for differences
Liquid fossil	Primary fuels	Crude oil	2,329,952	2,329,952	0	0.0%	
		Orimulsion					
		Natural gas liquids					
	Secondary fuels	Gasoline	-274,157	-274,157	0	0.0%	
		Jet kerosene	-18,887	-18,887	0	0.0%	
		Other kerosene	-2,876	-2,876	0	0.0%	
		Shale oil					
		Gas/diesel oil	-137,893	-137,893	0	0.0%	
		Residual fuel oil	-156,891	-156,891	0	0.0%	
		Liquefied petroleum gases (LPG)	97,579	97,579	0	0.0%	
		Ethane					
		Naptha	9,023	9,023	0	0.0%	
		Bitumen	-45,656	-45,656	0	0.0%	
		Lubricants	-21,874	-21,874	0	0.0%	
		Petroleum coke	29,972	29,972	0	0.0%	
		Refinery feedstocks	115,336	115,336	0	0.0%	
		Other oil	-28,675	-14,667	-14,008	48.9%	
	Other liquid fossil						
	Liquid fossil total		1,894,953	1,908,961	-14,008	-0.7%	
Solid fossil	Primary fuels	Anthracite	2,128	2,128			
		Coking coal	49,032	49,032	0	0.0%	
		Other bituminous coal	158,452	158,452	0	0.0%	
		Sub-bituminous coal		0	0		
		Lignite	14	14	0	0.0%	
		Oil shale and tar sand					
		Peat					
	Secondary fuels	BKB and patent fuel					

		Coke oven/gas coke	31,323	31,323	0	0.0%	
		Coal tar	-378	-378	0	0.0%	
	Other solid fossil						
	Solid fossil totals		240,571	240,571	0	0.0%	
Gaseous fossil		Natural gas (dry)	2,440,601	2,440,311	290	0.0%	
Other gaseous fossil							
Gaseous fossil totals			2,440,601	2,440,311	290	0.0%	
	Waste (non-biomass fraction)		50,264	49,502	762	1.5%	
Other fossil fuels							
Peat							
Total			4,626,389	4,639,345	-12,956	-0.3%	

(1) Apparent consumption reported in GHG inventory minus apparent consumption using data reported pursuant to Regulation (EC) No 1099/2008

(2) Absolute difference divided by apparent consumption reported in GHG inventory

(3) Data to be reported up to one decimal point for kt and % values

ANNEX 14: For-est model

For-est is a book keeping model (figure A14.1) that calculates annually the C stock of the aboveground biomass pool, as derived from the growing stock, by adding the annual net increment and subtracting annual losses associated with formal and informal[99] harvest (industrial roundwood and fuelwood), forest fires and other mortality, which includes all other disturbances[100] (i.e. drought, grazing, wind).

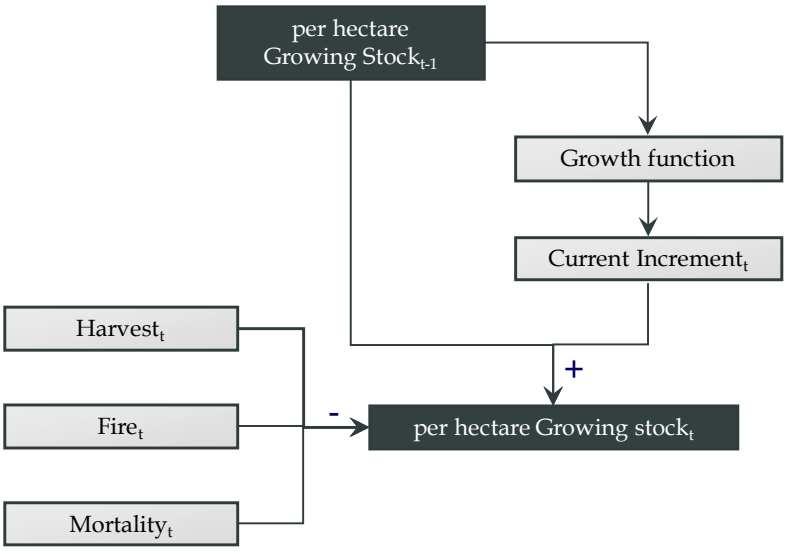


Figure A14.1 *For-est* model flow-chart

The model is applied to each of the 26[101] forest inventory typology, at regional/provincial scale (NUTS2 - 19 regions[102] and 2 provinces), using as model input data for the forest area and initial growing stock of the first NFI (NFI1985) and forest area of the second and third NFIs (NFI2005, NFI2015). An independent verification (Tabacchi et al., 2010) of the model results versus measured data was carried out in the year 2008 by comparison of the growing stock calculated by the model vs the data collected in the second national forest inventory[103], showing that the difference between the measured and modeled biomass C stocks is around -7%; which means that the model has underestimated by almost 0.3% net C stocks per year across the period 1985-2008.
Consistently, the time series of growing stock values in each forest inventory typology in each region/province is estimated applying the following steps:

1. deriving the initial growing stock volume for the year 1985 from the NFI data (MAF/ISAFA, 1988);
2. for each year, the current increment per hectare [m^3 $ha^{-1}yr^{-1}$] is computed with the forest inventory typology specific derivative Richards function, for each forest inventory typology using as independent variable x the per hectare growing stock.
3. for each year, the following losses are calculated:

[99] "Informal harvest" includes all harvest not captured by the official system of statistics either because occurring outside the chain of data collection, e.g. domestic fuelwood collection, or because may have occurred outside the planned harvest, e.g. small areas for which no harvesting plan is required and illegal harvest.

[100] Although natural mortality does not explicitly include losses caused by exceptional occurrences of those other disturbances, such exceptional losses are included in the national GHG inventory through the subsequent salvage logging of those lost biomass stocks.

[101] 4 different management system of practices (High stands, Coppices, Plantations, Protective) are combined with 22 forest types to classify 26 forest inventory typologies:

Stands*: 1. norway spruce, 2. silver fir, 3. larches, 4. mountain pines, 5. mediterranean pines, 6. other conifers, 7. European beech, 8. turkey oak, 9. other oaks, 10. other broadleaves*.

Coppices: *11. European beech, 12. sweet chestnut, 13. hornbeams, 14. other oaks, 15. turkey oak, 16. evergreen oaks, 17. other broadleaves, 18. conifers*.

Plantations: *19. eucalyptuses coppices, 20. other broadleaves coppices, 21. poplar stands, 22. other broadleaves stands, 23. conifers stands, 24. others*.

Protective Forests: *25. rupicolous forest, 26. riparian forests*

[102] Abruzzo, Alto Adige/Sud Tirolo, Basilicata, Calabria, Campania, Emilia Romagna, Friuli Venezia Giulia, Lazio, Liguria, Lombardia, Marche, Molise, Piemonte, Puglia, Sardegna, Sicilia, Toscana, Trentino, Umbria, Valle d'Aosta, Veneto.

[103] https://www.sian.it/inventarioforestale/jsp/risultati_introa.jsp?menu=3

a. harvest, statistical data collected from ISTAT on industrial roundwood production (all assigned to "*stands*" forests), fuelwood (all assigned to "*coppices*" forests) and wood outside forest (all assigned to "*plantations*" forests). Aiming at taking into account the informal[104] harvest, the time series has been recalculated, applying a correction factor, on regional basis, to the commercial harvested wood statistical data (table A14.2). The correction factor[105], was inferred from the outcome of a 2005 NFI survey[106] (table A14.1), carrying out a regional assessment of the harvested biomass. In each region/province, harvested quantities are assigned to each forest inventory typology in proportion of its total annual increment. The correction factors, at regional level, are reported in table A14.3.

Table A14.1 NFI survey - harvested volume

Region	Harvested volume	S.E.	Harvested volume	S.E.
	m^3	%	m^3ha^{-1}	%
Piemonte	1,360,223	31	1.6	30.9
Valle d'Aosta	-	-	-	-
Lombardia	1,039,728	52.7	1.7	52.7
Alto Adige (Bolzano)	862,811	62.4	2.6	62.4
Trentino	1,348,355	40.7	3.6	40.6
Veneto	475,573	40	1.2	39.9
Friuli - Venezia Giulia	462,541	67.3	1.4	67.3
Liguria	372,380	61.9	1.1	61.9
Emilia Romagna	362,005	62.2	0.6	62.2
Toscana	1,745,382	28.1	1.7	28
Umbria	1,294,494	43.6	3.5	43.6
Marche	418,031	74.9	1.4	74.9
Lazio	1,576,155	54.5	2.9	54.5
Abruzzo	388,752	51.8	1	51.7
Molise	200,825	54.5	1.5	54.4
Campania	915,244	59.6	2.4	59.6
Puglia	255,981	60.5	1.8	60.5
Basilicata	7,820	71.4	0	71.4
Calabria	624,762	53	1.3	53
Sicilia	23,477	58	0.1	57.9
Sardegna	62,323	53.3	0.1	53.2
Italia	**13,796,864**	**12.9**	**1.6**	**12.9**

[104] Data on biomass removed in commercial harvest have been judged underestimated, particularly fuelwood consumption (APAT - ARPA Lombardia, 2007, UNECE – FAO, Timber Committee, 2008, Corona et al., 2007).
[105] A correction factor for each Italian region (21) has been pointed out. The mean value is 1.57, obtained as ratio of data from official statistics and NFI survey data. The variance is equal to 0.82.
[106] NFI survey on harvested volume: http://www.sian.it/inventarioforestale/caricaDocumento?idAlle=442

Table A14.2 ISTAT data: harvested volume

Region	Harvested volume
	m³
Piemonte	363,846
Valle d'Aosta	16,279
Lombardia	1,060,701
Alto Adige (Bolzano)	589,191
Trentino	484,906
Veneto	270,880
Friuli - Venezia Giulia	180,544
Liguria	96,515
Emilia Romagna	485,777
Toscana	1,477,135
Umbria	471,070
Marche	192,068
Lazio	875,408
Abruzzo	203,632
Molise	159,104
Campania	518,376
Puglia	101,776
Basilicata	299,019
Calabria	753,042
Sicilia	59,850
Sardegna	139,751
Italia	**8,798,869**

Table A14.3 Correction factors

Region	Correction factor
Piemonte	3.74
Valle d'Aosta	1.00
Lombardia	1.00
Alto Adige (Bolzano)	1.46
Trentino	2.78
Veneto	1.76
Friuli - Venezia Giulia	2.56
Liguria	3.86
Emilia Romagna	1.00
Toscana	1.18
Umbria	2.75
Marche	2.18
Lazio	1.80
Abruzzo	1.91
Molise	1.26
Campania	1.77
Puglia	2.52
Basilicata	1.00
Calabria	1.00
Sicilia	1.00
Sardegna	1.00
Italia	**1.57**

b. fires, burnt area from Forest service statistics, assigned to forest inventory typologies proportionally to their area. The growing stock loss caused by forest fires is estimated on the basis of the average growing stock per hectare. The methodology used for emission estimates due to forest fires is described in the Annex 15.
c. mortality, an average constant ratio of mortality to total growing stock (Federici et al, 2008) estimated by expert judgement for evergreen (1.16%) and deciduous (1.17%) forests;

4. for protective forest (i.e. rupicolous and riparian forests) only, an average constant ratio of 3% (expert judgement - Federici et al., 2008) of C stock losses associated with drain and grazing.starting from 1986, for each year, the final growing stock per hectare [m^3 ha^{-1}] is computed adding to the final growing stock volume of the previous year the increment calculated for the current year and subtracting the losses occurred in the year as due to harvest, fires and mortality.

The procedure can be summarized as follows:

$$v_i = \frac{V_{i-1} + I_i - H_i - F_i - M_i - D_i}{A_i}$$

where:

$$I_i = f(v_{i-1}) \cdot A_{i-1}$$

v_i is the volume per hectare of growing stock for the current year

V_{i-1} is the total previous year growing stock volume

I_i is the total current increment of growing stock for the current year

H_i is the total amount of harvested growing stock for the current year

F_i is the total amount of burned growing stock for the current year

Mi is the annual rate of mortality

D is the annual rate of drain and grazing for the protective forest

A_i is the total area referred to a specific forest typology for the current year

v_{i-1} is the previous year growing stock volume per hectare

A_{i-1} is the total area referred to a specific forest typology for the previous year

f is the Richards function reported above

The annual current increment is estimated thought the use of a non-linear function, the Richards function, that has the growing stock as its independent variable. The Richards' 4 parameters allow the needed flexibility to represent the various potential growth rates, including the initial, nearly constant, rate. To calculate the 4 parameters for each forest inventory typology the Richards function has been fitted through the data of growing stock [m^3 ha^{-1}] and increment [m^3 $ha^{-1}yr^{-1}$] obtained from the collection of Italian yield tables.

$$y = a \cdot \left[1 \pm e^{(\beta - kt)}\right]^{\frac{1}{v}}$$ (*Richards function*)

The per hectare growing stock (i.e. the biomass density of the stand) is the independent variable *x*, while the dependent variable *y* is the increment computed with the Richards function - first derivative.

$$\frac{dy}{dt} = \frac{k}{v} \cdot y \cdot \left[1 - \left(\frac{y}{a}\right)^v\right] + y_0$$ (*Richards function - first derivative*)

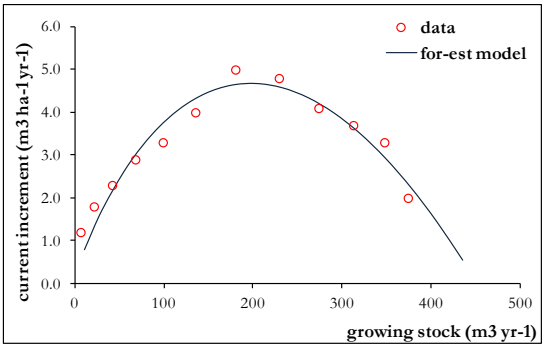
where the general constrain for the parameters are the following:

$a,k>0$ $\quad -1 \leq v \leq \infty$ and $v \neq 0$

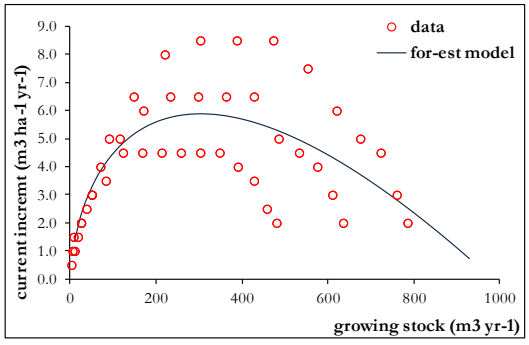
The constant y_0 is the growing stock volume at 1-year age.

The Richards function, first derivative, has been fitted against data taken from all quality classes of each yield table (Figure A14.2), in order to calculate a set of variables' values for each forest inventory tipology.

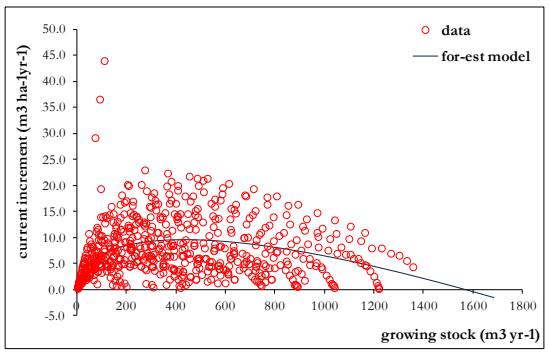
The curves have been derived from a collection of around 100 Italian yield tables.



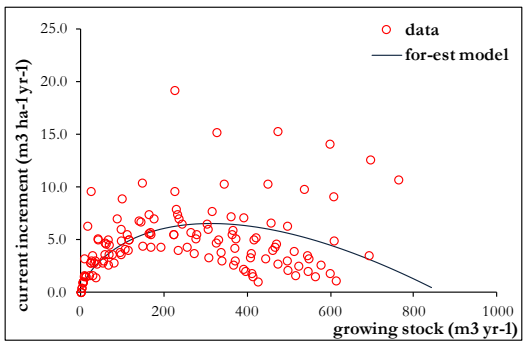
A14.2a Trentino, *larches*



A14.2b Lombardia, *norway spruce*



A14.2c Piemonte, *other conifers*



A14.2d Campania, *European beech*

Figure A14.2: *For-est* model fitting

The per hectare growing stock and associated gain and losses are converted into aboveground biomass stock applying the following equation:

$$\text{Aboveground tree biomass (d.m.)} = GS \cdot BEF \cdot WBD \cdot A$$

where:

GS = volume of growing stock (MAF/ISAFA, 1988) [m^3 ha^{-1}] of specific forest inventory typology;

BEF = Biomass Expansion Factors which expands growing stock volume to volume of aboveground woody biomass (ISAFA, 2004);

WBD = Wood Basic Density for conversions from fresh volume to dry weight (d.m.) [t m^{-3}] (Giordano, 1980);

A = forest area of specific forest inventory typology [ha]

The BEFs and WBDs have been estimated for each forest inventory typology and are reported in following table A14.4.

	Inventory typology	BEF *aboveground biomass / growing stock*	WBD *Dry weigth t/ fresh volume*
Stands	norway spruce	1.29	0.38
	silver fir	1.34	0.38
	larches	1.22	0.56
	mountain pines	1.33	0.47
	mediterranean pines	1.53	0.53
	other conifers	1.37	0.43
	european beech	1.36	0.61
	turkey oak	1.45	0.69
	other oaks	1.42	0.67
	other broadleaves	1.47	0.53
Coppices	european beech	1.36	0.61
	sweet chestnut	1.33	0.49
	hornbeams	1.28	0.66
	other oaks	1.39	0.65
	turkey oak	1.23	0.69
	evergreen oaks	1.45	0.72
	other broadleaves	1.53	0.53
	conifers	1.38	0.43
Plantations	eucalyptuses coppices	1.33	0.54
	other broadleaves coppices	1.45	0.53
	poplars stands	1.24	0.29
	other broadleaves stands	1.53	0.53
	conifers stands	1.41	0.43
	others	1.46	0.48
Protective	rupicolous forest	1.44	0.52
	riparian forest	1.39	0.41

Table A14.4 Biomass Expansion Factors and Wood Basic Densities

Applying a Root/Shoot ratio (R) to the aboveground volume and the same WBDs the belowground biomass is derived for each forest inventory typology. The Rs have been estimated for each forest inventory typology and are reported in table A11.2. Data on root to shoot ratios have been taken from the following European projects: CANIF[107] (*CArbon and NItrogen cycling in Forest ecosystems*), CARBODATA[108] (*Carbon Balance Estimates and Resource Management - Support with Data from Project Networks Implemented at European Continental Scale*), CARBOINVENT[109] (*Multi-source inventory methods for quantifying carbon stocks and stock changes in European forests*) and COST[110] Action E21- Contribution of forests and forestry to mitigate greenhouse effects.

$$\text{Belowground tree biomass (d.m.)} = \text{Abovegroundtree biomass} \cdot R$$

where:

R = Root/Shoot ratio dimensionless of each specific forest inventory tipology

	Inventory typology	**R** *Root/shoot ratio*
Stands	norway spruce	0.29
	silver fir	0.28
	Larches	0.29
	mountain pines	0.36
	mediterranean pines	0.33
	other conifers	0.29
	european beech	0.20
	turkey oak	0.24
	other oaks	0.20
	other broadleaves	0.24
Coppices	european beech	0.20
	sweet chestnut	0.28
	Hornbeams	0.26
	other oaks	0.20
	turkey oak	0.24
	evergreen oaks	1.00
	other broadleaves	0.24
	Conifers	0.29
Plantations	eucalyptuses coppices	0.43
	other broadleaves coppices	0.24
	poplars stands	0.21
	other broadleaves stands	0.24
	conifers stands	0.29
	others	0.28
Protecti	rupicolous forest	0.42
	riparian forest	0.23

Table A14.5 Root/Shoot ratio and Wood Basic Densities

The biomass stocks and stock changes are converted to carbon units applying the IPCC default carbon fraction (CF) value of 0.47 t C (t d.m.)$^{-1}$.

The dead wood mass has been estimated using coefficients calculated from Italian national forest inventory (NFI) survey, in 2008 and 2009, which specifically intended to investigate the carbon storage of forests. Samples of dead-wood were collected across the country from the plots of the national forest inventory network, and their

[107] CANIF-*CArbon and NItrogen cycling in Forest ecosystems* http://www.bgc-jena.mpg.de/bgc-processes/research/Schulze_Euro_CANIF.html; Scarascia Mugnozza G., Bauer G., Persson H., Matteucci G., Masci A.(2000). Tree biomass, growth and nutrient pools. In: Schulze E.-D. (edit.) Carbon and Nitrogen Cycling in European forest Ecosystems, Ecological Studies 142, Springer Verlag, Heidelberg. Pp. 49-62. ISBN 3-540-67239-7

[108] CARBODATA - Carbon Balance Estimates and Resource Management - Support with Data from Project Networks Implemented at European Continental Scale: http://afoludata.jrc.it/carbodat/proj_desc.html

[109] CARBOINVENT - Multi-source inventory methods for quantifying carbon stocks and stock changes in European forests; http://www.joanneum.at/carboinvent/

[110] COST Action E21 - Contribution of forests and forestry to mitigate greenhouse effects: http://www.cost.eu/domains_actions/fps/Actions/E21;http://www.afs-journal.org/index.php?option=com_article&access=standard&Itemid=129&url=/articles/forest/pdf/2005/08/F62800f.pdf

basic densities measured in order to calculate conversion factors for estimating the dry weight of dead-wood (Di Cosmo et al., 2013). The values used, aggregated at regional level, may be found on the NFI website: http://www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp.
The definition of the deadwood pool, coherent with the definition adopted by the NFI, is related to "*All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, stumps larger than or equal to 10 cm in diameter and standing trees with DBH > 4,5 cm*". Additional explanation on the data and parameters used for deadwood are included in the paper Di Cosmo et al., 2013, and in the NFI website (http://www.sian.it/inventarioforestale/jsp/necromassa.jsp).
In Table A14.3 dead wood coefficients are reported.

	Inventory typology	**dead wood (dry matter)** *t ha^{-1}*
stands	norway spruce	6.360
	silver fir	7.770
	Larches	3.830
	mountain pines	4.385
	mediterranean pines	2.670
	other conifers	4.290
	european beech	3.350
	turkey oak	1.770
	other oaks	1.690
	other broadleaves	3.990
coppices	european beech	3.350
	sweet chestnut	12.990
	hornbeams	2.730
	other oaks	1.690
	turkey oak	1.770
	evergreen oaks	1.370
	other broadleaves	2.690
	Conifers	4.290
plantations	eucalyptuses coppices	0.670
	other broadleaves coppices	0.670
	poplars stands	0.480
	other broadleaves stands	0.670
	conifers stands	3.040
protective	rupicolous forest	2.730
	riparian forest	4.790

Table A14.6 Dead-wood expansion factor

Carbon amount contained in litter pool has been estimated using the values of litter carbon content, per hectare, assessed by the Italian national forest inventory. The values used, aggregated at regional level, may be found on the NFI website: http://www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp. The average value of litter organic carbon content, for Italy, is equal to 2.67 t C ha^{-1}.
A comparison between carbon in the aboveground, deadwood and litter pools, estimated with the described methodology, and the II NFI data (INFC2005) is reported in Table A14.7.

	INFC2005 *t C*	**For-est model** *t C*	*differences* *t C*	*%*
aboveground	456,857,390	425,240,589	-31,616,801	**-6.92**
deadwood	15,987,541	15,869,766	-117,775	**-0.74**
litter	28,170,660	28,138,039	-32,621	**-0.12**

Table A14.7 Comparison between estimated and INFC2005 carbon stocks

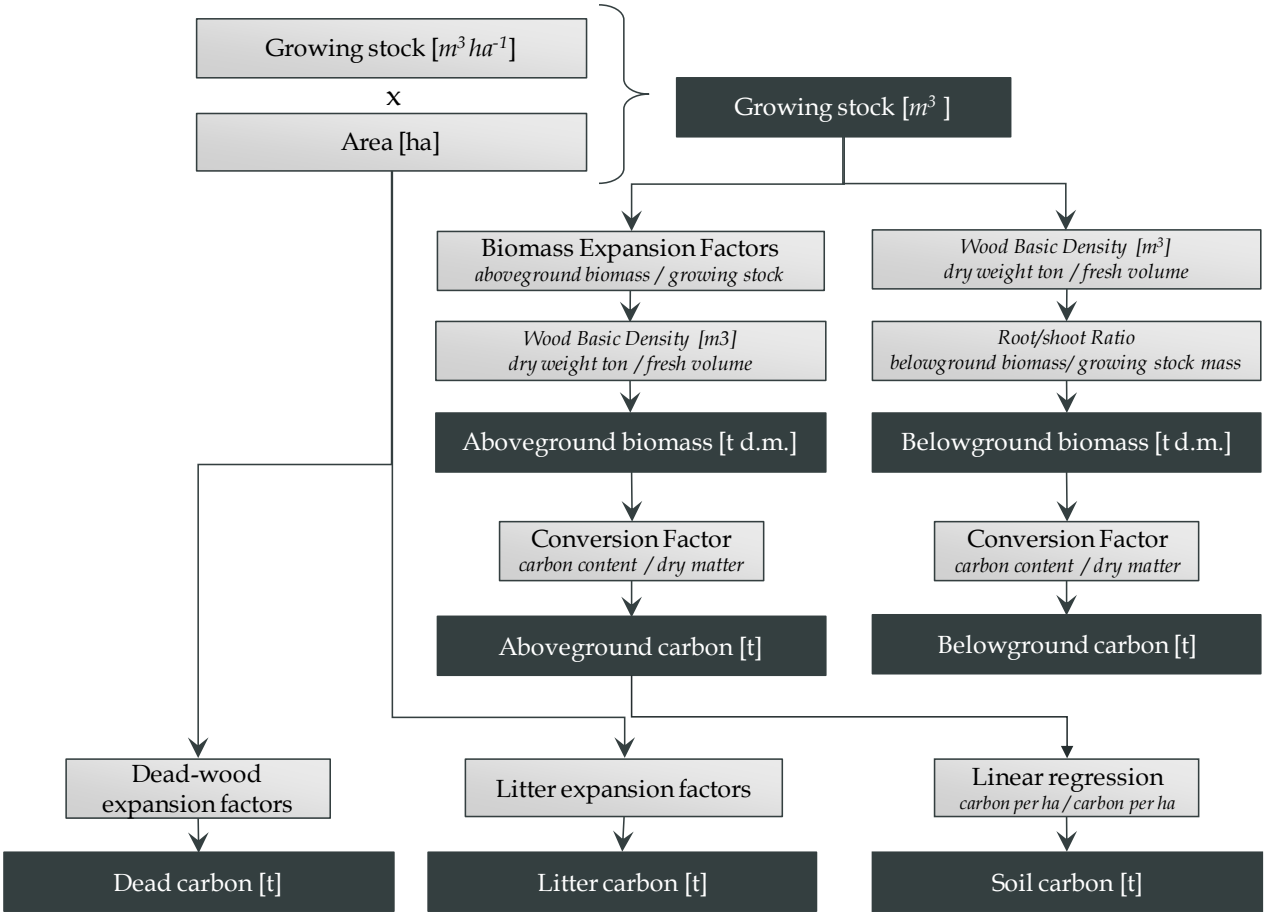


Figure A14.3 *For-est* model complete flow-chart

ANNEX 15: For-fires model

For-fires is a bookkeeping model that calculates the non-CO_2 emissions from fires affecting forest and other wooded land categories. The model is based on the approach developed by Bovio (2007); to this aim, the template used by Carabinieri Force[111], for each forest event, was modified in 2007 to collect the data needed to implement this approach. The model was implemented by Chiriacò and Perugini (Chiriacò et al., 2013) jointly with ISPRA.

A15.1 Method description

For-fires model is based on the on the equation 2.27 of the 2006 IPCC Guidelines (vol.4, ch. 2):

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

where

L_{fire} amount of greenhouse gas emissions released from fire
A: burned area (hectares)
M_B: mass of fuel available for combustion (t ha^{-1})
C_f combustion factor (dimensionless)
Gef emission factors (g kg^{-1} dry matter burnt)

The key driver for fires emissions release is the assessment of the burned and oxidised biomass in each fire event. According to Chiriacò et al. (2013), the combustion factor (C_f) term is the most critical to be estimated as it represents the fraction of pre-disturbance biomass that is actually combusted during the fire event. Its estimation has been carried out on the basis of the approach developed by Bovio (2007), which assess forest fire damage in Italy, taking into account two main elements: the burned forest typology, and the fire intensity (assessed through the scorch height).
The Bovio (2007) approach groups the forest typologies into 9 forest vegetation classes considering the possible effect that a fire event can have on them because of specific forest characteristics and their distribution over the country (Table).

Table A15.1: Bovio (2007) forest vegetation classes and forest typologies: correspondence matrix

Forest vegetation class	forest typology
A	european beech stands
	sweet chestnut stands
	hornbeam stands
	riparian forests
	other broadleaves
B	turkey oak stands
	other oak stands
	evergreen oak stands
	cork oaks
C	Larches
	norway spruce
	silver fir
	mountain pines above 500 m a.s.l.
	black pine above 500 m a.s.l.
D	mountain pines below 500 m asl
	black pine below 500 m asl
	mediterranean pines
	other conifers
E	european beech coppices
	sweet chestnut coppices
F	turkey oak coppices
	other oak coppices
	evergreen oak coppices

[111] the Armed Forces and Police Authority where the State Forestry Service is embedded, following the legislative decree 19/08/2016, n. 177

	hornbeam coppices
G	shrublands (including mediterranean maquis)
H	other broadleaves with a mean height lower than 3.5m (temporary unstocked broadleaves forests)
I	other conifers with a mean height than3.5m (temporary unstocked conifer forests)

Bovio (2007) assumed that, in each forest vegetation class, the damage level depends on the fire intensity, which, in turn, can be estimated as a function of scorch height. In Table A15.2, the damage level as a function of scorch height (and fire intensity), for each forest vegetation class, is shown.

Table A15.2: Damage level of forest typologies as a function of fire intensity and forest vegetation class

Forest vegetation	**Scorch height (m)**				
class	<1	1-2.5	2.5-3.5	3.5-4.5	>4.5
A	0.10	0.15	0.30	0.60	0.90*
B	0.08	0.20	0.30	0.80	0.90
C	0.10	0.25	0.50	0.80	0.90
D	0.08	0.30	0.55	0.85	0.95
E	0.05	0.15	0.40	0.65	0.90*
F	0.05	0.20	0.35	0.60	0.95
G	0.10	0.30	0.60	0.80	0.95
H	0.30	0.70	0.80	0.90	1.00
I	0.25	0.40	0.70	0.90*	1.00*

** values not included in Bovio (2007); they have been assumed based on the damage levels assigned to the other forest vegetation classes for the corresponding scorch height categories*

A15.2 Activity data

The activity data needed to estimate the annual loss (burned) biomass caused by forest fires are:

- *year;*
- *burned area [ha];*
- *forest typology (27 NFI typologies)* to assess the available combustion fuel and the combustion factor;
- *mean scorch height [m]* to assess the combustion factor.

A detailed database, annually provided by Carabinieri Force, has been used; the database collects data, from 2008 onward, related to any fire event occurred in 15 administrative Italian regions[112] (the 5 autonomous regions are not included), reporting, for each fire event, the following information:

- *year;*
- *administrative region name;*
- *burned area [ha];*
- *forest typology (27 classes in line with the NFI nomenclature);*
- *scorch height [m];*
- *fire's type (crown, surface or ground fire)*.

The database was checked in order to select only the observations with known scorch height (and corresponding damage level), and the assignation of the fire event to a forest category that does exist in the corresponding region according to the NFI[113]. For these observations, the burned biomass per hectare is estimated according to the logical pathway summarised in Figure A15.1.

[113] It is possible that some forest categories have been erroneously assigned to a specific administrative region because of problems in the forest identification on the field (e.g. due to the important damage caused by the fire event).

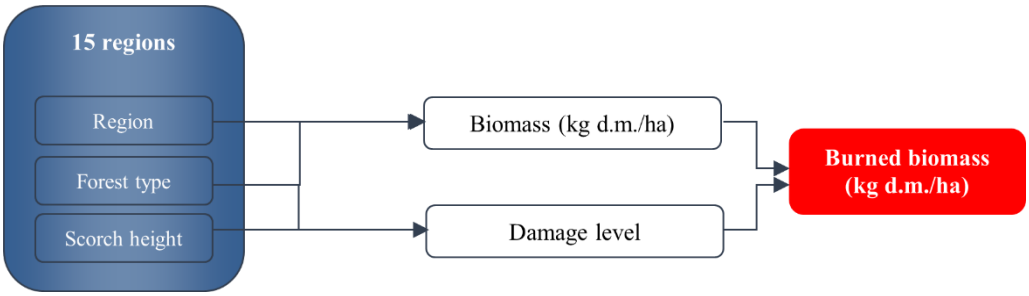


Figure A15.1: Logical pathway to estimate the burned biomass on hectare basis caused by forest fires

Data and information on fire occurrences in the 5 remaining autonomous regions are collected at regional level, with different level of disaggregation and details (e.g., in Sardinia region, the amount of biomass burned is reported instead of the scorch height).
For the period 1990-2007, national statistics on areas affected by fire per region and aggregated forest types are available for (ISTAT, several years [a]). The aggregated forest types are high forest (conifers, broadleaves, mixed) and coppice (simple, compound and degraded).
Therefore, the data used in the estimation process may be subdivided into the following groups with similar characteristics:

a. time series from 2008 onward for the 15 Regions: data related to burned area, divided into different forest types, scorch height and fire's type;
b. time series from 2008 onward for the 5 autonomous regions/provinces: data related to burned area;
c. time series from 1990 to 2007 for the 20 Italian regions: data related to burned area.

A15.3 Methodological issues

Based on three different datasets identified in the previous section A15.2, different approaches and assumptions have been followed to estimate non-CO_2 emissions from fires.

a. Time series from 2008 onward for the 15 Regions

The estimation of non-CO_2 emissions from fires in the 15 regions has been carried out on the basis of the approach developed by Bovio (Bovio, 2007). The burnt biomass has been assessed, for each fire event, based on the damage level (assessed through the scorch height) and the forest typologies affected by fire. These two elements allow an assessment of the fraction of biomass burnt in a fire event.
In case of some data missing, record by record, a gap filling procedure has been specifically applied according to the causes of the missing or unreliable data. The main causes are:

1. Scorch height data missing (unknown damage level)
2. No volume is associated with the record – this is due to the probable misclassification of the forest type by the surveyors, which have attributed a forest type that is not present in the region, thus no data from NFI can be attributed (unknown damage level)
3. Scorch height and volume missing: In case information on both issues is missing (unknown damage level)

For these fire events, the gap-filling procedure follows a logical framework shown in the Figure A15.2.

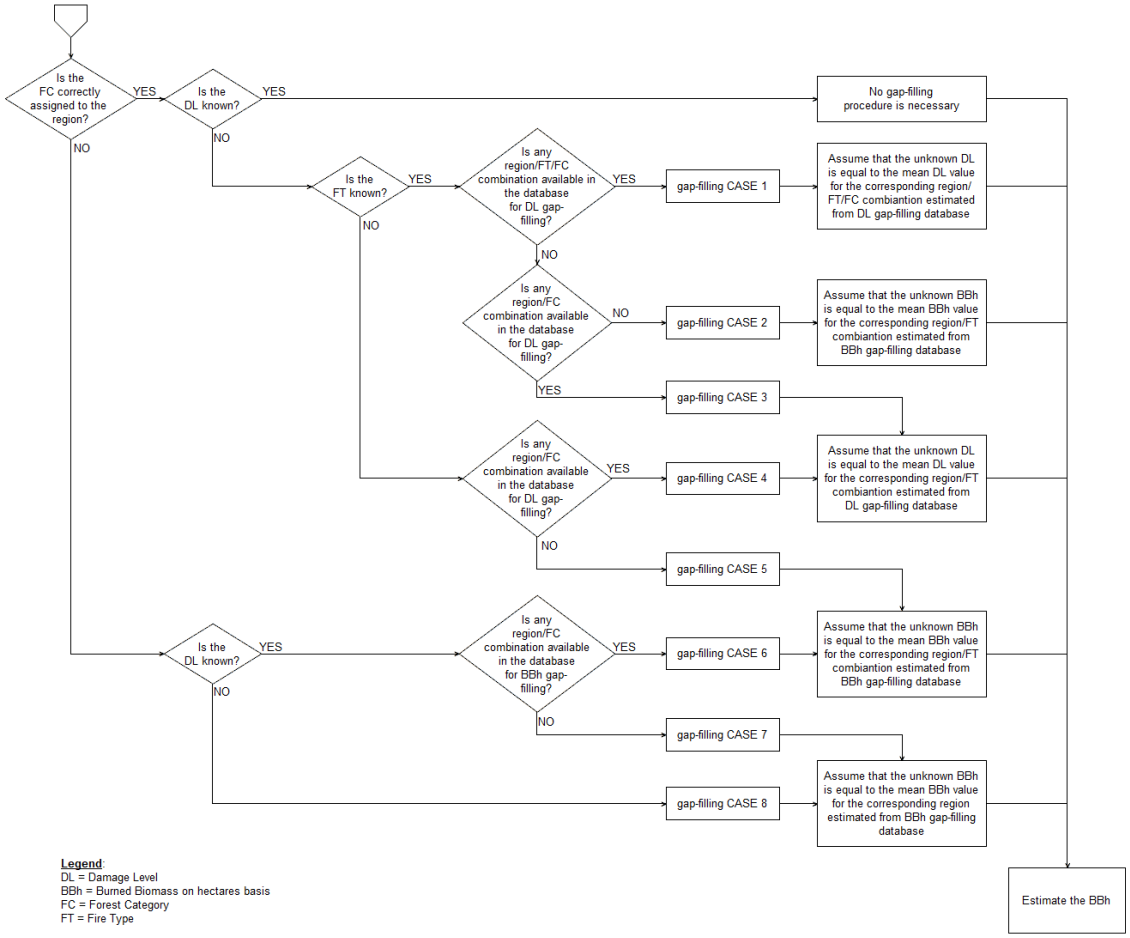


Figure A15.2: Workflow of gap-filling procedure

In summary, it is not possible to directly calculate the burnt biomass if:

- the damage level (which is derived from the flame height) is missing;
- the forest category burned by a fire event is not correctly assigned to a specific region.

When these issues occur singularly or simultaneously, damage level or burnt biomass per hectare are assigned on the basis of the corresponding mean values estimated from the full dataset for the period 2008-2016 considering the region/forest category/fire type parameters (or their combination), when available. This choice, i.e., use of 2008-2016 data to deduce average values, estimation is due to the fact that:

- the year 2017 was not included in the dataset since the 2017 was not representative; in fact it was characterised by an extremely dry summer period, in which the overall surface covered by fires was anomalous compared to the past (on average +263% over the period 1990-2016) and in which the damage caused by the fires themselves was significantly more important than in the previous period (2008-2016);
- a possible annual extension of this period from 2008 to the last reported year constantly affects the gap-filling procedure causing annually recalculations of the relative GHG emissions along the whole time-series.

Finally, it has to be noted that the average values, instead of the maximum average ones, have been applied to implement the gap-filling procedure, addressing the 2019 UNFCCC review process's recommendation. Finally, the total burned biomass is estimated multiplying the burned (lost) biomass per hectare by the burned area of the corresponding fire event.

b. Time series from 2008 onward for the 5 autonomous regions/provinces

The emissions from fires have been estimated on the basis of the average values assessed for the 15 regions from 2008 on. In particular the burnt biomass per hectare for fires has been estimated by applying the above described gap filling procedure. The implementation consists in the following:

A. clustering the 15 regions (those considered in the full dataset 208-2016) into three groups with similar climatic conditions and forest types (Northern, Central and Southern Italy);
B. estimating, for each cluster, the burnt biomass per hectare as the mean of burnt volume per hectare of the related regions;

C. classifying the 5 autonomous regions on the basis of the clusters identified at step A;
D. assigning to each of the 5 autonomous regions the burnt biomass per hectare of the corresponding cluster estimated at step B.

Finally, the total burned biomass is estimated multiplying the estimated burned (lost) biomass per hectare by the total annual burned area for each year of the time-series (1990-2019), a datum that is available from ISTAT (several years [a]).

c. Time series from 1990 to 2007 for the 20 Italian regions

The emissions from fires for the period 1990-2007 for the 20 Italian regions have been estimated on the basis of the average values computed among 2008 and 2016, taking into account the fire's type and each region. The average values, instead of the maximum average values adopted in the previous submissions, have implemented to address the 2019 UNFCCC review process's recommendation. The selected value of released carbon is then multiplied by the burned area of the region in each year from 1990 to 2007.

CH_4, N_2O, CO and NO_x have been estimated following the IPCC 2006 methodology (eq. 2.27, vol. 4, ch. 4), multiplying the C released, estimated as described above, by the emission ratios elaborated for EMEP/EEA 2009 (table 3.3, ch. 11.B), as shown in the table A15.3; in the same table emission factors for CO, NMVOC NH_3 and SO_2 also reported.

Table A15.3: CO, CH_4, NMVOC, NO_x, NH_3, N_2O, SO_2 emission factors

Pollutant/GHG	*emission factor*	*unit*	*reference*
CO	0.23	*g X/g C*	EMEP-EEA 2009
CH_4	0.015	*g X/g C*	EMEP-EEA 2009
NMVOC	0.021	*g X/g C*	EMEP-EEA 2009
NO_X	0.008	*g X/g C*	EMEP-EEA 2009
NH_3	0.0018	*g X/g C*	EMEP-EEA 2009
N_2O	0.0004	*g X/g C*	EMEP-EEA 2009
SO_2	0.0016	*g X/g C*	EMEP-EEA 2009

PM10, PM2.5, dioxin and polycyclic aromatic hydrocarbon (PAH) emissions have been also estimated, by multiplying the burnt biomass (dry matter) by the emission factors reported in the table A15.4. For black carbon, emissions have been estimated considering a percentage, i.e., 42%, of the PM2.5 emissions.

Table A15.4: PM10, PM2.5, dioxin and polycyclic aromatic hydrocarbon (PAH) emission factors

pollutant	*emission factor*	*unit*	*reference*
PM10	0.011	*g X/g C*	EMEP-EEA 2009
PM2.5	0.009	*g X/g C*	EMEP-EEA 2009
Dioxin	10	*ng C/kg C*	EEA-EMEP 2013
PAH	8.58	*g/t*	EMEP-EEA 2009

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