UNIVERSITÀ
POLITECNICA
DELLE MARCHE
Facoltà di Ingegneria

—

IL PROTOCOLLO DI MONTREAL E GLI HFC DOPO L'ACCORDO DI KIGALI

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DUBAI PATHWAY ON HFCs

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MONTREAL PROTOCOL

Scientific **A**ssessment **P**anel

Technology & **E**conomic **A**ssessment **P**anel

Environmental **E**ffect **A**ssessment **P**anel

REFRIGERATION Technical Options Committee	FOAMS T O C	HALONS T O C	METHYL BROMIDE T O C	MEDICAL CHEMICAL T O C

the calculated level of consumption of HFCs, expressed in CO_2 equivalents, does not exceed the percentage, set out for the respective range of years of the annual average of its calculated levels of consumption for the years 2011, 2012, and 2013, plus 15% of its baseline consumption of HCFCs, expressed in CO_2 equivalents:

source: Ozone Secretariat

	100-year GWP
HFC-134	1,100
HFC-134a	1,430
HFC-143	353
HFC-245fa	1,030
HFC-365mfc	794
HFC-227ea	3,220
HFC-236cb	1,340
HFC-236ea	1,370
HFC-236fa	9,810
HFC-245ca	693
HFC-43-10mee	1,640
HFC-32	675
HFC-125	3,500
HFC-143a	4,470
HFC-41	92
HFC-152	53
HFC-152a	124
HFC-23	14,800

non-A5 Parties except below
baseline: 2011-12-13 HFC + 15% HCFC

	level of consumption
2020	90%
2024	60%
2029	30%
2036	20%
2036	15%

A5 Parties except below
baseline: 2020-21-22 HFC + 65% A5 HCFC

	level of consumption
2024	100%
2029	90%
2035	70%
2040	50%
2045	20%

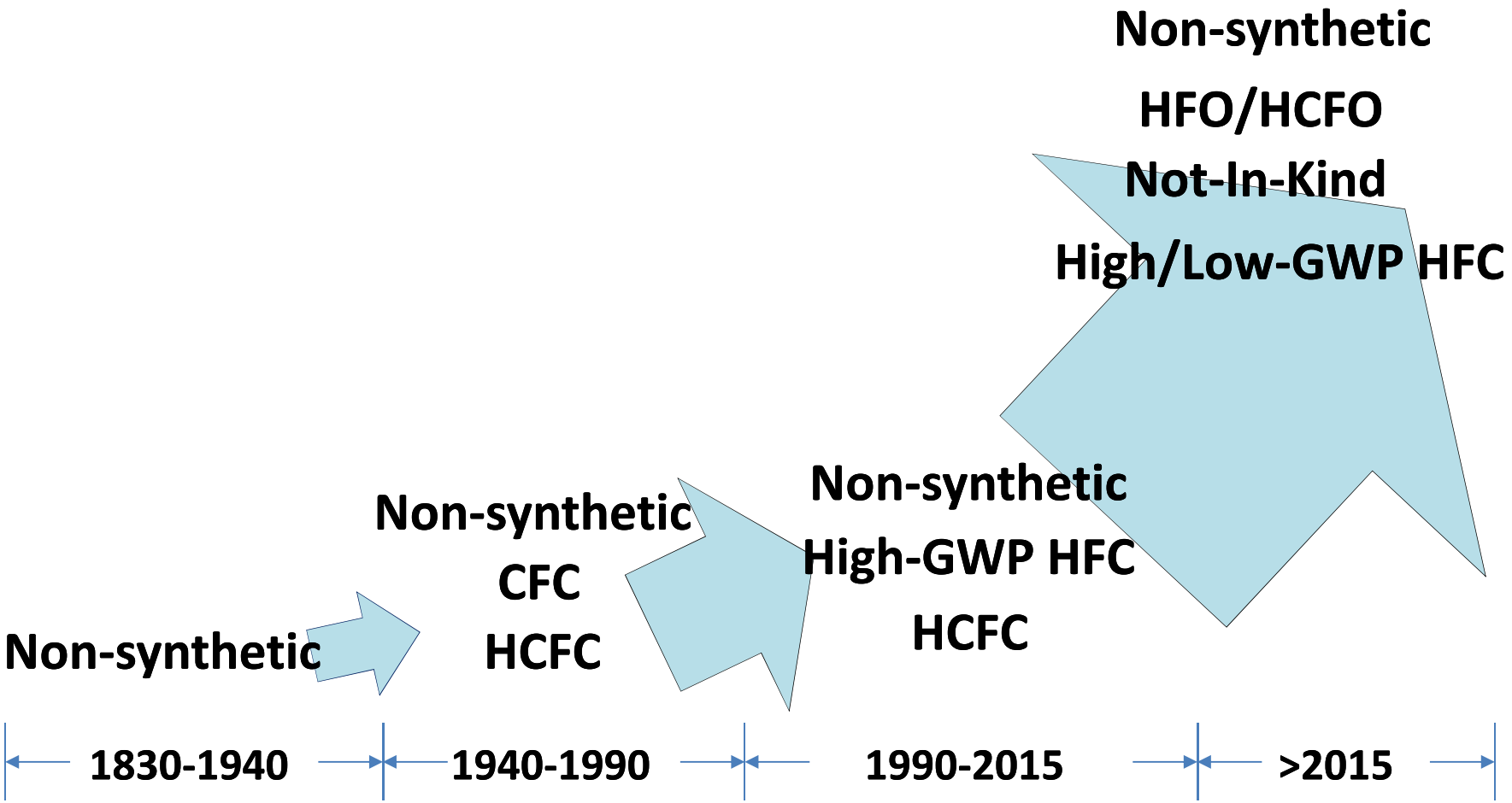
non-A5: ex URSS
baseline: 2011-12-13 HFC + 25% HCFC

	level of consumption
2020	95%
2024	65%
2029	30%
2036	20%
2036	15%

A5: India, Pakistan, GCC, Iran, Iraq
baseline: 2024-25-26 HFC + 65% A5 HCFC

	level of consumption
2028	100%
2032	90%
2037	80%
2042	70%
2047	15%

source: Ozone Secretariat


Non-synthetic
HFO/HCFO
Not-In-Kind
High/Low-GWP HFC
Non-synthetic
High-GWP HFC
HCFC
Non-synthetic
CFC
HCFC
Non-synthetic
1830-1940
1940-1990
1990-2015
>2015

R/AC sub-sector	<2016	>2016
Domestic refrigeration	R600a/R134a	R600a/HFO
Commercial refrigeration	R404A/R744	R744/HFO/water loop
Industrial refrigeration	R717/R744/R404A	R717/R744
Transport refrigeration	R404A/R744	R744/R290/HFO
Mobile Air Conditioning	R134a	HFO/R744/dual loop
Small Size AC	R410A/R407C/R134a	R290/R32/HFOblend
Large Size AC	R410A/R407C/R134a	R32/HFOblend
Chillers	R410A/R407C/R134a	HFOblend
Heat Pumps	R410A/R134a/R744/R245fa	R744/HFOblend

R/AC sub-sector	<2016	>2016
Domestic refrigeration	R600a/R134a	R600a/HFO
Commercial refrigeration	R404A/R744	R744/HFO/water loop
Industrial refrigeration	R717/R744/R404A	R717/R744
Transport refrigeration	R404A/R744	R744/R290/HFO

- ✓ solutions becoming available for most of the sub-sectors
- ✓ flammable (R600a) or toxic (R717) solutions are not a problems for these sub-sectors
- ✓ blends under development as R404A replacement

R/AC sub-sector	<2016	>2016
Mobile Air Conditioning	R134a	HFO/R744/dual loop

- ✓ The main reason to develop HFO-1234yf was related to MAC applications
- ✓ At this stage there is still some uncertainty also where it concerns the application of HFC-HFO mixtures (containing HFO-1234ze(E)) for MACs
- ✓ HFO application concerns regard the production of trifluoroacetic acid (TFA) when the fluid breaks-down in the atmosphere and the fact that when it burns (car fire) it produces hazardous substances such as hydrogen fluoride (HF)
- ✓ electric vehicles which need heating and cooling on board are best suited for R744 heat pumps

R/AC sub-sector	<2016	>2016
Small Size AC	R410A/R407C/R134a	R290/R32/HFOblend
Large Size AC	R410A/R407C/R134a	R32/HFOblend
Chillers	R410A/R407C/R134a	HFOblend
Heat Pumps	R410A/R134a/R744/R245fa	R744/HFOblend

- ✓ **The most challenging issue is the lack of suitable alternatives for the replacement of HCFC-22 and R-410A in stationary AC**
- ✓ **There are many HFC-HFO blends under development, but it is likely to be so that there can only be a very limited amount of them in future; no refrigerant based society can cope with the large number of blends proposed**

Montreal Protocol
blends under development

Designation	Refrigerants	Composition	GWP	Replacement for
R-444A	HFC-32 /-152a/-1234ze	12/5/83	92	HFC-134a replacement MAC
R-444B	HFC-32/-152a/-1234ze	41.5/10/48.5	296	HCFC-22 replacement
R-445A	R-744/-134a/-1234ze	6/9/85	135	HFC-134a replacement MAC
R-446A	HFC-32/-1234ze/HC-600	68/29/3	461	R-410A replacement
R-447A	HFC-32/-125/-1234ze	68/3.5/28.5	583	R-410A replacement
R-448A	HFC-32/-125/-1234yf/-134a/-1234ze	26/26/20/21/7	1390	R-404A replacement
R-449A	HFC-32/-125/-134a/-1234yf	24.3/24.7/25.3/25.7	1400	R-404A replacement
R-450A	HFC-134a/-1234ze	42/58	605	HFC-134a replacement
R-452A	HFC-32/-125/-1234yf	11/59/30	2140	R-404A replacement (transp. refr.)
R-452B	HFC-32/125/1234ze	68/8/24	710	R-410A replacement
R-454A	HFC-32/1234yf	65/35	250	R-410A replacement
R-456A	HFC-32/-134a/-1234ze	6/45/49	650	HFC-134a replacement
R-457A	HFC-134a/-1234yf/-152a	18/70/12	150	R-404A replacement
R-513A	HFC-134a/-1234yf	44/56	630	HFC-134a replacement

source: Kujipers, GL2016

- ✓ **no single refrigerant can be found to cover the broad range of applications;**
- ✓ **synthetic and natural refrigerants will co-exist in the future and can be complimentary;**
- ✓ **continuous introduction of HFO-HFC mixtures will have to come to a convergence in the near future;**
- ✓ **development of natural refrigerants, especially CO2, show future improvements by the design of better cycles;**
- ✓ **it cannot be only the "low-GWP" argument the one that will be determining for the application of certain fluids;**
- ✓ **Not-In-Kind solutions begin to appear in the market as potentially interesting, at least in perspective;**
- ✓ **the best final solution will probably be the most appropriate combination of energy efficiency, costs, broad environmental performance including safety, and many usage aspects.**

grazie per l'attenzione