

Preparatory Study for a Review of the Regulation (EC) No. 842/2006

Methods and major results

Barbara Gschrey, Winfried Schwarz

Öko-Recherche

for the European Commission

Stakeholder Meeting on a review of the F-gas Regulation, 13 February 2012, Brussels

Content

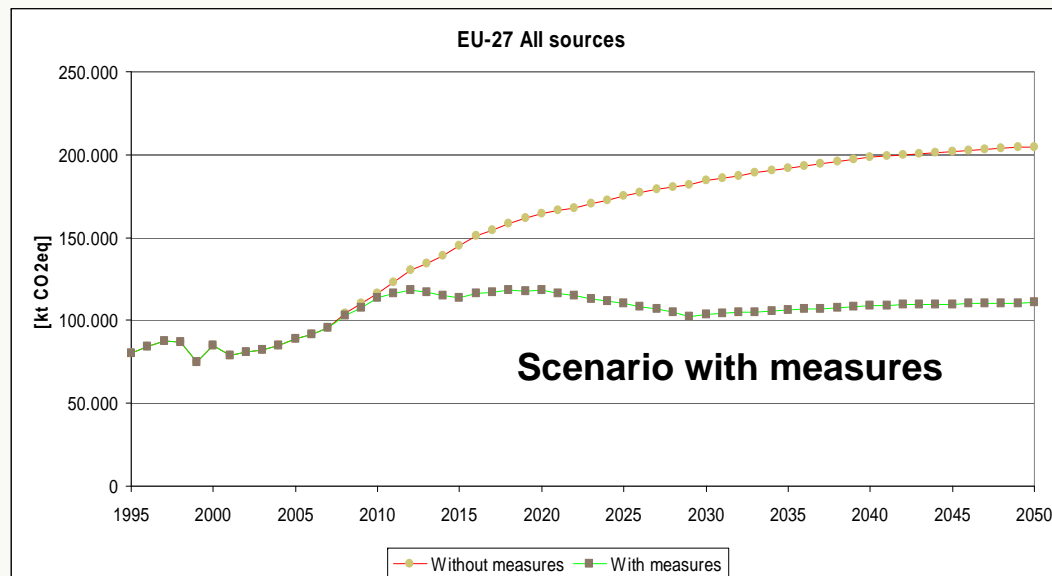
- Projections of F-gas emission in EU-27 until 2050
- How to achieve maximum reductions of F-gas emissions and consumption?
- Identification of abatement technologies for each sector, determination of penetration rates and penetration mix
- Abatement costs and emission reductions in EU in 2030
- What further policy action could be taken within the review of the F-gas Regulation?
 - Identification of policy options
 - Screening of options
 - Ranking of remaining options
- Analysis of impacts of remaining options

Projections of F-gas emission in EU-27 until 2050

Scenario with measures (WM) – F-gas Regulation, MAC Directive				
F-gas emissions (kt CO ₂ eq)	2010	2015	2030	2050
HFCs (w/o mobile AC)	66,859	65,868	87,325	94,570
HFCs (mobile AC)	34,525	36,608	8,426	8,736
SF6	5,452	5,583	2,920	2,533
PFCs and haloproduction	6,417	5,607	4,986	4,985
TOTAL	113,253	113,666	110,824	110,824

Model AnaFgas:

- Assumptions: Full implementation of existing legislation (F-gas Regulation, MAC Directive). Containment measures become fully effective in 2011-2015.
- From 2016 no further emission reductions as growth of relevant sectors offsets the impact of existing measures.
- Significant long-term reductions of HFC consumption and emissions are not possible by use of conventional technology and current measures.**



How to achieve maximum reductions of F-gas emissions and consumption?

To achieve maximum reductions of F-gas emissions and consumption in the long-term, substitution of conventional technologies by **alternative technologies** will be required.

- **Which abatement technology is available for different applications?**
- **When are abatement technologies available?**
- **What are the costs?**

Identification of abatement technologies by sectors

1. **Identification of technically feasible and safe abatement options** for all applications
2. **Comparison** with conventional technology

Main criteria:

- **Reduction potential** of GWP weighted F-gas consumption and emissions
- **Cost effectiveness** (abatement cost €/t CO₂ eq)
- **Energy consumption** must be lower or at least the same as for HFC solutions, to avoid increase in indirect CO₂ emissions

Less efficient alternative technologies are not discarded from the start, if compensation by additional technical measures (e.g. larger heat exchangers) is possible → increase in investment cost

But exclusion of alternatives from further analyses where additional technical measures are not sufficient (e.g. transcritical CO₂ technology in Southern climate)

→ Selection of several technical options per sector

Abatement technologies by sectors

Overview of sectors using HFCs:

<i>Stationary Refrigeration</i>	<i>Stationary AC</i>	<i>Mobile AC + Refrigeration</i>	<i>Fire Protection</i>	<i>Foams and aerosols</i>
Domestic Ref. Comm. stand-alone Condensing units Centralized systems Industrial Ref. small Industrial Ref. large	Factory sealed AC Single split AC VRF multi split AC Rooftop systems Chillers Centrifugal chillers Heat pumps	Ref. vans Ref. Trucks Fishing vessels Rail vehicle AC Cargo ship AC Passenger ship AC	Fixed install. with HFC-227 Fixed install. with HFC-23	XPS (HFC-134a) XPS (HFC-152a) PU spray foam Other PU foam Aerosols

Alternative technologies:

R-290/R-600a direct
R-290 indirect
R-744 (CO₂) (transcritical)
Unsaturated HFC direct

Unsaturated HFC indirect
R-717 (NH₃) (indirect)
HFC/unsat. HFC blends
Fluoro ketones

Sectors using SF6: Magnesium industry, Medium Voltage Secondary Switchgear.

Penetration rates of abatement options

- **Determination of the penetration rate of each abatement option:**

Maximum potential of each alternative option to replace new products or equipment relying on F-gases in a particular sector based on technical feasibility.

Example: “Penetration rate 40% in 2030“ means that 40% of new equipment in a sector can be replaced by that alternative technology in 2030.

- **Different constraints to market penetration of each abatement option might occur:**

- Safety constraints
- Efficiency constraints
- Cost constraints
- Availability of materials and components
- Availability of substances (e.g. refrigerants or blowing agents)
- System complexity and design know-how

- Few abatement options are universally applicable to a particular sector.

Most often several abatement options will be required to reach maximum emission abatement.

Abatement technology by sectors

The “**penetration mix**” combines several abatement options in a sector to an optimum set with maximum emission reduction potential at minimum cost (least cost first). Addition of penetration rates with the same constraints is not possible.

Example: Factory sealed air conditioners

Alternative technology and cost (€/tCO ₂ eq)	Individual penetration rate 2030	Sector penetration mix 2030	Sector abatement cost €/t CO ₂ eq
R-290 dir [-38]	40%	40%	+ 8.90
R-744 (CO ₂) [+39]	20%	20%	
R-1234yf [+41]	70%	40%	
R-600a [-29]	40%		

Key abatement options – Refrigeration

Refrigeration	Key abatement options	Market penetration of abatement options (penetration mix) in 2030 (%)
		Developed countries
Domestic refrigeration	R600a	95
	R744	5
	R1234yf	0
Commercial refrigeration		
Centralized systems	R290 indirect	90
	R290- CO ₂ cascade	0
	CO ₂ transcritical	10
Condensing units	R290 direct	40
	R290 indirect	30
	CO ₂ transcritical	30
Stand-alone units	R290 direct	85
	CO ₂ transcritical	15
Industrial refrigeration		
Small equipment	NH ₃	95
Large equipment	NH ₃	95
Transport refrigeration		
Refrigerated trucks	R290 direct	80
	CO ₂ transcritical	20
Refrigerated vans	CO ₂ transcritical	50
	R-1234yf	50
Reefer containers	CO ₂ transcritical	100
Fishing vessels	NH ₃ CO ₂ cascade	95

In most subsectors the penetration mix of abatement options is 100% in 2030 or before. Exemptions: Industrial refrigeration, fishing vessels.

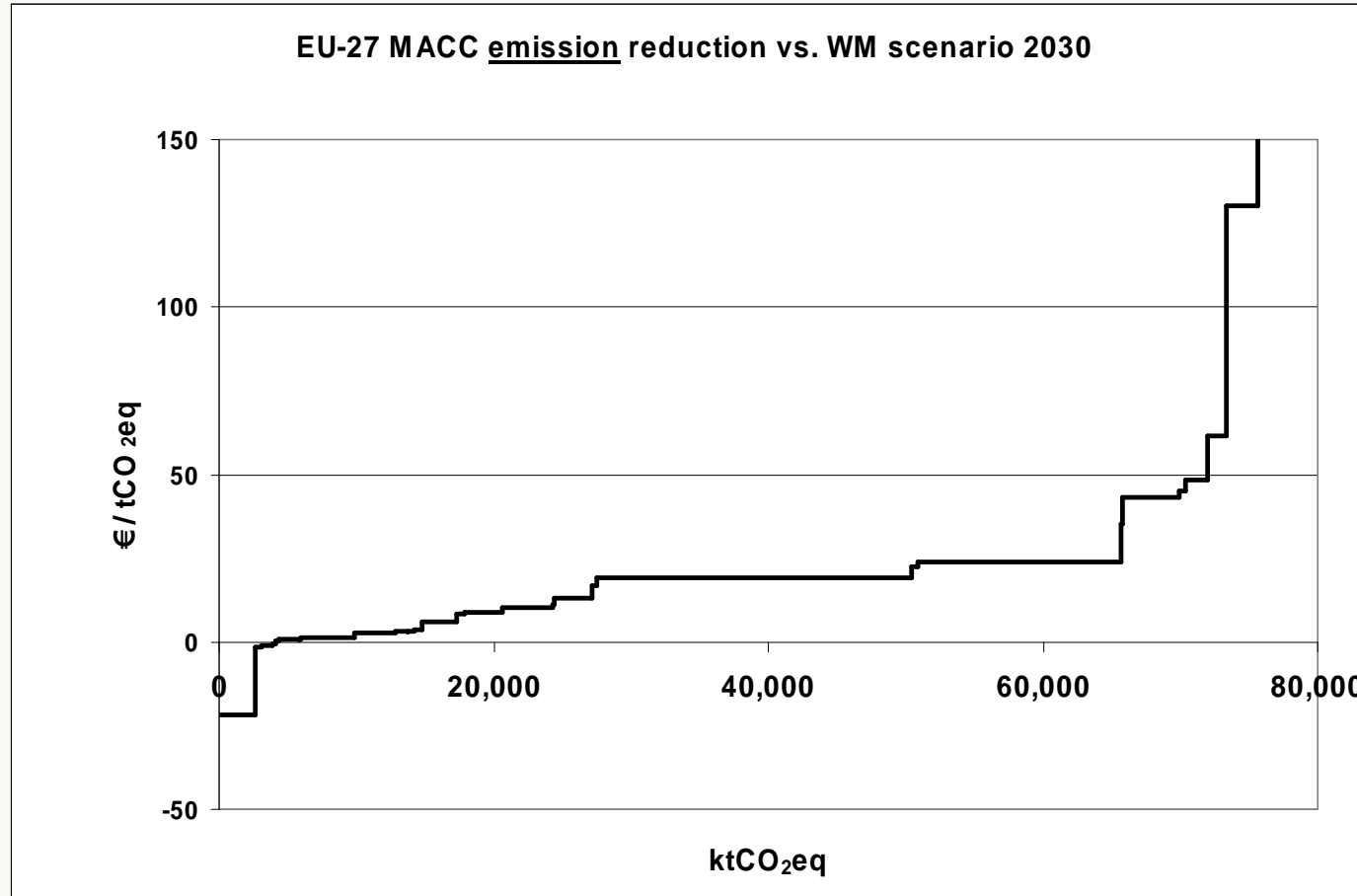
Key abatement options – Stationary AC and heat pumps

Stationary AC and heat pumps	Key abatement options	Market penetration of abatement options (penetration mix) in 2030 (%)
		Developed countries
Factory sealed AC	R290 direct	40
	CO ₂ transcritical	20
	R-1234yf	40
Single split AC	R290 direct	40
	CO ₂ transcritical	20
	R-1234yf	40
Multi split AC	R290 liquid secondary	70
	CO ₂ transcritical	30
	R-1234yf	0
Rooftop AC	R290 direct	65
	CO ₂ transcritical	35
	R290 evapo secondary	0
Small chillers	R290 direct	60
	CO ₂ transcritical	20
	NH ₃	20
Large chillers	R290 direct	15
	CO ₂ transcritical	0
	NH ₃	60
	R718	25
Centrifugal chillers	R290	20
	R-1234yf	50
	R718	30
Heat pumps	R290 direct	60
	CO ₂ transcritical	20
	R-1234yf	20

In all subsectors the penetration mix of abatement options is 100% in or before 2030.

EU: Abatement costs and emission reduction in 2030

Marginal emission abatement cost: -22 to +556 €/t CO₂ eq. (average: 21 €/t CO₂ eq.)
Total potential F-gas emission reduction : 75,765 kt CO₂ eq. (HFCs and SF₆)



F-gas emission reductions of ca 65,700 ktCO₂eq can be abated at < 25 €/tCO₂eq.

What further policy action could be taken within the review of the F-gas Regulation? - I

1. *Identify of a wide but credible set of options*

Option 1: No policy change.

Option 2: Discontinue existing provisions of the F-gas Regulation.

Option 3: Non-regulatory options at EU level .

- Voluntary agreements for specific sectors.
- Improved coordination.



Option 4: Regulatory options.

- Include gases currently not included in Annex I.
- Provide information and guidelines.
- Improve containment and recovery in certain sectors.
- Ban the use of F-gases in open applications/ the placing on the market of F-gas applications.
- Ban the use of F-gases in closed applications where safe and energy-efficient alternatives are available.
- Set quantitative limits for placing on the market of HFCs
- Enhanced technical standards.
- Development and dissemination of BAT and BREF notes and documents.
- Obligation to destroy HFC-23 emissions from halocarbon destruction.

Option 5: Market-based approaches.

- Include additional activities under the EU-ETS.
- Tax schemes.
- Deposit and refund schemes.

What further policy action could be taken within the review of the F-gas Regulation? - II

2. Screening and ranking of options: Narrow down the options by screening them for constraints and by assessing them against criteria of

- Effectiveness:**

- expected contribution to the EU emission reductions until 2030.
- emission reduction of 1 million t CO₂ eq. was used as a threshold (1% of current EU-27 emissions of fluorinated gases or 0.02% of total EU-27 GHG emissions without LULUCF).

- Efficiency:**

- ‘efficient’ or ‘cost effective’ if objectives are achieved at least cost, or if its desired impact is maximized at a given level of resources.
- In deciding on the climate and energy package, a threshold of 30 €/t CO₂ eq. was used for the setting the GHG emission reduction targets until 2020 under the ETS Directive and the Effort Sharing Decision.
- The time horizon used in this study is longer and extends until 2030, therefore a slightly higher threshold of 50 €/t CO₂ eq. of mitigation costs in 2030 was used in this assessment.

- Technical constraints**

- Other qualitative aspects such as coherence with other EU policies.**

Screening – Voluntary agreements (VA)

Self-regulation or co-regulation	Add. em. red. 2030	Abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq			
VA with Industry to phase-out/down HFCs in centralized systems, commercial hermetics, condensing units	18,818	-0.8 to 23.7	++	++	penetration rate 100% in 2020		Include
New VA with photovoltaic Industry to replace SF ₆ , NF ₃	100	n. a.	-	+	penetration rate 100% in 2015	Photovoltaics industry likely to be willing to engage	Include
Update International VA with semiconductor Industry for PFCs, NF ₃ , HFC-23, SF ₆	Not estimated	n. a.	-	+		VA expired in 2010	Include
New VA for XPS foams (HFC-134a)	1,553	1.0	+	+	penetration rate 100% in 2015		Include
New VA for domestic refrigeration	12	1.0	-	+	penetration rate 100%	Very small number of units containing F-gases remaining	exclude
New VA for HFC-23 in fire protection	961	3.1	+/-	+	penetration rate 100%	Very high GWP. No use in >20 MS, alternatives available	Include
New VA for HFC-23 by product emissions	370	<2	-	+	destruction technology is available	HFC-23 destruction technology lacking in only 1 production facility	Include

Screening – Improve containment & recovery

Improve containment and recovery in certain sectors	Add. em. red. 2030	Abate. costs 2030	Effectiveness	Efficiency	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq		
Inclusion in the scope of Articles 4 (1): <i>Refrigerated road transport - vans</i>	11	291	-	-	Difficult implementation and verification due to high number of operators	exclude
Inclusion in the scope of Articles 3 and 4: <i>Refrigerated road transport – trucks and trailers</i>	1,430	46	+	+		include
Inclusion in the scope of Articles 3 and 4: <i>Rail transport</i>	16	340	-	-	80% of operators fulfil service requirements anyway	exclude
Inclusion in the scope of Articles 3 and 4: <i>Ref. maritime transport – cargo ships</i>	273	10.5	-	+	F-gas Regulation not the most appropriate instrument to address this sector: The Commission is currently considering options to reduce GHG emissions from the maritime sector, taking into account its international nature and unique characteristics. It would be appropriate to also consider addressing F-gases in such coherent approach.	exclude
Inclusion in the scope of Articles 3 and 4: <i>Ref. maritime transport – passenger ships</i>	405	8.5	-	+		
Inclusion in the scope of Articles 3 and 4: <i>Ref. maritime transport – fishing vessels</i>	360	0.5	-	+		

Screening – Ban open F-gas applications

Ban the use of F-gases in open applications/ the POM of open F-gas applications	Add. em. red. 2030	Abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq			
Inclusion of magnesium die casting <850 kg/ y and recycling of die casting alloys in the scope of Article 8	250	0.4	-	+	100% in 2015	Operators have started replacing SF ₆ , are ready to phase-out. Costs are low, smaller installations could be treated in the same way as larger ones.	include
Ban of HFCs in technical aerosols	3,637	10	+	+	95% in 2020	Exemptions need to be defined	include
Ban of HFC-152a in XPS foam blowing in 2015	460	-1.60	-	++	100% in 2015	GWP of HFC-152a is much lower (124) than GWP of HFC-134a (1,430). Could be considered combined with HFC-134a.	exclude
Ban of HFC-134a in XPS foam blowing in 2015	1,553	1.0	+	++	100% in 2015	Very few companies in EU	include
Ban of HFC in PU spray foam blowing	1,369	61.6	+	+/-	100% in 2015	Relevant mainly in Spain and Portugal	exclude
Ban of HFC in other PU foam blowing	587	3.5	-	+	up to 95% in 2015	Exemptions need to be defined.	exclude

Screening – Ban closed F-gas applications: Refrigeration

Ban the placing on the market of certain closed F-gas applications	Add. em. red. 2030	Abatement costs 2030	Effectiveness	Efficiency	technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq			
Domestic refrigeration	12	1.0	-	+	2015		exclude
Commercial hermetic systems	147	-0.8	-	++	2020		include
Condensing units	2,849	1.2	+	+	2020		include
Centralized systems	12,055	23.7	++	+	2020		include
Small industrial refrigeration	67	-0.9	+/-	++	95% in 2030	Exemptions need to be defined for small systems, e.g. <50 kg (similar to Sweden).	include
Large industrial refrigeration	202	-21.6	+	++	95% in 2030	Exemptions need to be defined. Comb. of small + large ref. (+/- 50 kg) possible	
Refrigerated vans	421	45.1	-	+/-	2020		exclude
Refrigerated trucks and trailers	322	2.6	-	+	2030		include

Screening – Ban closed F-gas applications: Stat. AC

Ban the placing on the market of certain closed F-gas applications	Add. em. red. 2030	Abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq		
Moveable AC	2,781	8.9	+	+	2020	include
Single split AC	22,970	19.0	++	+	2020	include
Multi split AC	2,172	13.1	+	++	2020	include
Rooftop AC systems	573	8.2	-	++	2020	include
Displacement chillers	1,989	5.9	+	++	2020	include
Centrifugal chillers	9	7.5	-	++	2030	exclude
Heat pumps	1,356	130.2		-	2020	exclude

Screening – Ban closed F-gas applications: Other

Ban the placing on the market of certain closed F-gas applications	Add. em. red. 2030	Abatement costs 2030	Effectiveness	Efficiency	technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq	Threshold: €50/t CO ₂ eq			
Fishing vessels	27	3.4	-	+	penetration rate not 100%	F-gas Reg. is not the most appropriate Instrument to address this sector: The Commission is currently considering options to reduce GHG emissions from the maritime sector, taking into account its international nature and unique characteristics. It would be appropriate to also consider addressing F-gases in such coherent approach.	exclude
Cargo ship AC	232	16.7	-	+	2020		
Passenger ship AC	97	35,0	-	+	penetration rate not 100%		
Rail vehicle AC	16	555.6	--	-	penetration rate not 100%		exclude
HFC-23 In fire protection	961	3.1	+/-	+	2015	Very high GWP. No use in 21 MS, alternatives available	include
HFC-227ea In fire protection	167	22.3	-	+	penetration rate not 100%		exclude
Medium Voltage secondary switchgear	61	347.7	-	-	penetration rate not 100%		exclude

Screening – Limits of POM of F-gases

Set quantitative limits for the placing on the market of HFCs	Add. emission reduction 2030	Average emission abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO ₂ eq	€/t CO ₂ eq	Threshold: 1,000 kt CO ₂ eq.	Threshold: €50/t CO ₂ eq			
Maximum supply reductions in all sectors relying on HFCs : 136,500 kt CO ₂ eq	71,740	16.2	+++	++	As outlined for all sectors.	High flexibility	include

What further policy action could be taken within the review of the F-gas Regulation? - III

Comparison of options based on emission reduction potential:

Proposed policy option	Additional emission reduction potential in 2030 (kt CO ₂ eq)
Voluntary agreements	21,702
Improve containment and recovery under F-gas Regulation: Refrigerated trucks and trailers	1,430
Ban the POM of certain open applications containing HFCs	5,190
Ban the use of SF ₆ in open applications	250
Ban the POM of certain closed applications containing F-Gases	47,089
Set quantitative limits for the placing on the market of F-gases in EU	71,740
Obligation for destruction of HFC-23 emissions from halocarbon production	370

Policy options cover at least partially the same applications.

Thank you for your attention.

Download of the study and its annexes:

http://ec.europa.eu/clima/policies/f-gas/index_en.htm