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IMPACT ASSESSMENT
Review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases

Accompanying the document

Proposal for a
REGULATION OF THE EUROPEAN PARLIAMENT AND THE COUNCIL

on fluorinated greenhouse gases

{COM(2012) 643 final}
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1. BACKGROUND

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6), commonly called fluorinated gases or "F-Gases", are very potent greenhouse gases (GHG) whose climate impact is up to 23.000 times higher than CO_2. Their emissions are therefore covered by the Kyoto Protocol. Currently, they account for 2% of the GHGs in the EU. In 2010, 98% (by weight) of F-Gases placed on the EU market were HFCs, 2% was SF_6 and about 0.3% were PFCs.

F-Gases are commodities used in a large variety of products and equipment including refrigeration, air conditioning (AC), insulation foams, electrical equipment, aerosols and fire protection. Most F-Gases have been developed by industry specifically to replace ozone-depleting substances (ODS) that are being phased out under the Montreal Protocol and for this reason F-Gases are being increasingly used at world-wide scale.

Whereas other GHG emissions are mainly a by-product resulting from production processes, heating or transport, F-Gas emissions primarily occur either during emissive uses (e.g. as aerosol or solvent) or due to leaks during the use period and improper waste treatment of products and equipment.[1]

In order to limit the rapid growth of F-Gas emissions and contribute to the Kyoto target, the EU adopted in 2006

– a Regulation focusing on preventing leakage during use ("containment") and at end of life of (mostly) stationary equipment as well as a limited number of F-Gas bans in narrowly defined niche application areas ("F-Gas Regulation")[2], and

– a Directive introducing restrictions on the use of F-Gases with a global warming potential (GWP) above 150 in AC systems of new motor vehicles ("MAC directive")[3].

There are two ways of reducing F-Gases emissions from equipment and products. First, the use of F-Gases in applications can be completely avoided or replaced by F-Gases with a lower GWP and secondly, emissions during the use period or at the end of life of products and equipment can be reduced. Except for the MAC Directive, which focuses on AC in new passenger cars only, existing EU F-Gas legislation barely discourages the use of highly climate-relevant F-Gases. On the other hand, alternative substances to F-Gases can be used in nearly all fields of application and are readily available already today.[4,5] Annex XVI gives a sector-by-sector overview over available alternative

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1 With the exception of e.g. HFC-23 (Trifluoromethane), which is formed as by-product of HCFC-22 (Chlorodifluoromethane) synthesis

2 Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases, OJ L161, 14.6.2006, p. 1 ("F-Gas Regulation")

3 Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from AC systems in motor vehicles, OJ L161, 14.6.2006, p. 12 ("MAC-Directive")

4 Becken et al. (2010). *"Avoiding Fluorinated greenhouse gass - Prospects for Phasing Out."* Umweltbundesamt. Dessau, Germany. www.umweltbundesamt.de/uba-info-medien-e/3977.html

technologies and by what time 100% of applications in each sector can be fully replaced by safe and energy-efficient alternatives based on today`s technologies.[6]

In some Member States national legislation exists. By way of example, the Danish legislation bans the use of F-Gases for certain purposes and includes F-Gas taxation and support for R&D of alternative technology. As a result, the import of bulk F-Gases was reduced to a third between 2000 and 2010 and Danish emissions of F-Gases have been declining in recent years, while emissions are rising at EU level.[7] Austria has similarly maintained additional bans on specific appliances using HFCs.

In September 2011 the Commission published a report on the application, effects and adequacy of the existing F-Gas Regulation[8]. It concluded that there is scope for further action to reduce emissions from F-Gases in the EU, in particular by avoiding the use of F-Gases where alternative technologies with no or lower impact on climate change exist. A decrease of up to two-thirds of today's emissions by 2030 is cost-effective due to the availability and maturity of alternatives in many sectors.[9] However, policies in this area have to address a high level of complexity. Apart from taking into account the large variety of products and equipment using F-Gases, the feasibility and cost-effectiveness of reducing emissions in specific application areas may depend on e.g. equipment size and where it is intended to be used. In this context energy efficiency and safety require particular attention.

In September 2011 the European Parliament adopted a Resolution[10] stating that *"fast-action regulatory strategies are available to phase down production and consumption of HFCs [..]"* and urged the *"Commission to come forward with a revision of F-Gas regulations and make proposals for a rapid phasedown of the production and consumption of HFCs"*. In March 2012 this position was reaffirmed in the Parliament's resolution[11] on the 2050 Roadmap, calling for an ambitious proposal to reduce emissions of F-Gases by the end of 2012.

The EU is clearly at the forefront internationally as regards the phasing out of ODS under the Montreal Protocol and in addressing the resulting F-Gas problem through legislation. However, the EU is not at all alone in calling for urgent action on F-Gases: In 2009, 2010, 2011 and 2012 several Parties to the Montreal Protocol including the US

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5 TEAP (2009). *"Assessment of alternatives to HCFCs and HFCs and update of the TEAP 2005 supplement report data". Montreal Protocol. Report of the Technical and Economic Assessment Panel (TEAP). UNEP, Nairobi.* ozone.unep.org/teap/Reports/TEAP_Reports/teap-may-2009-decisionXX-8-task-force-report.pdf

6 Furthermore, costs of introducing alternatives are given in Annex VI

7 Danish Ministry of the Environment: Environmental Protection Agency. *"Denmark is going natural – The Danish road towards natural refrigerants."* Brochure, 2011.

8 COM (2011) 581 final. *"Report from the Commission on the application, effects and adequacy of the Regulation on certain fluorinated greenhouse gases (Regulation (EC) No 842 /2006)"*

9 Schwarz et al. (2011) *"Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases."* Öko-Recherche et al.

10 European Parliament Resolution of 14 September 2011. *"A comprehensive approach to non-CO2 climate-relevant anthropogenic emissions*." P7_TA-PROV(2011)0384.

11 European Parliament resolution of 15 March 2012. "*Competitive low carbon economy in 2050 – EP resolution on a Roadmap for moving to a competitive low carbon economy in 2050"* (2011/2095(INI)), P7_TA-PROV(2012)0086

submitted proposals to phasedown supply and consumption of HFCs globally, which is supported by at least 108 countries[12]. Such action is projected to avoid, in a cost-effective way, more than 100 Gigatonnes of CO_2 equivalents (CO_2eq) by 2050[13]. For perspective, this cumulative figure is roughly 3-4 times the total annual anthropogenic CO_2 emission at this point in time. The EU has supported these proposals as a complement to climate mitigation action under the United Nations Framework Convention on Climate Change (UNFCCC).[14] So far little progress has been achieved in the negotiations since, *inter alia*, China, India and Brazil have refused to discuss this issue under the Montreal Protocol. However, recently a new initiative called "Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants" has been launched which calls for action on HFCs as one of five priority focal areas and is quickly gaining momentum.[15] This initiative has been joined/endorsed so far by Bangladesh, Canada, Colombia, Ghana, Japan, Mexico, Nigeria, Norway, Sweden, the USA, as well as EC, World Bank, UNEP and most recently the G8 countries. More countries have already expressed their interest in joining.

2. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

2.1. Consultations of other Commission Services

This Impact Assessment for the review of the F-Gas Regulation (Agenda Planning 2012/CLIMA/003) was developed by DG CLIMA in close co-operation with relevant Commission Services. The following DGs were invited to an Interservice Steering Group: COMP, EMPL, ENER, ENTR, ENV, JRC, LS, MOVE, RTD, SANCO, SG, TAXUD and TRADE. This group met eight times from April 2010 to March 2012 where it provided input to a preparatory study as well as the follow-up work and the drafting of the impact assessment. DG JRC was asked to carry out a comprehensive macro-economic analysis of possible policy options with the GEM-E3 model (Annex XIV). The final meeting on the draft Impact Assessement on 29 March 2012 was attended by CLIMA, ENER, ENTR, JRC and SG. Written comments to this meeting were provided by SANCO and TRADE.

2.2. External expertise

DG CLIMA commissioned the following studies to underpin the review:

(1) A comprehensive study was carried out by a consortium led by Öko-Recherche ("preparatory study").[9] This study *inter alia* assessed the effectiveness of current policies, the feasibility and cost-effectiveness of the replacement of F-Gases in all main application areas (see Annex XVI), and discussed options for further action to reduce F-Gas emissions. The analysis was based on a

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12 ozone.unep.org/Meeting_Documents/mop/22mop/MOP-22-9E.pdf

13 Velders et al. (2009). *"The large contribution of projected HFC emissions to future climate forcing."* Proceedings of the National Academy of Sciences 106(27): 10949-10954.

14 Council Conclusion from 10 October 2011 on Preparations for the COP17 to the UN Framework Convention on Climate Change and MOP7 of the Kyoto Protocol in Durban.

15 www.unep.org/ccac/

thorough bottom-up analysis, involving the development of a model based on market data, including production, import, exports and sales, for both substances and products/equipment (referred to as AnaFgas model, Annex IV). The study assumes a conservative approach using today`s costs for alternatives and considering only available, safe and energy-efficient technologies. Future reductions in investment costs that are expected from economies-of-scale and learning-by-doing were not factored into the analysis. This study forms the main evidence base for this impact assessment.

(2) As a follow-up to the preparatory study, a consortium led by Öko-Institut assisted DG CLIMA in further refining the social and economic effects of the most promising policy options considered for a review, and examining in more detail the possible design of the option to set quantitative limits for the placing on the market of F-Gases in the EU.

(3) A complementary study on policy options for the management and destruction of ozone-depleting substances and F-Gases contained in equipment and products (so-called "banks") was carried out by SKM ENVIROS.[16]

Three other large and relevant studies by other parties were used for the drafting, thus reinforcing the validity of the results presented in this document. A study commissioned by EPEE (a European umbrella group representing members who produce, design and install heating, cooling and refrigeration technologies), was carried out by Armines/ERIE[17] and estimated the timeframe and feasibility of introducing gases with lower GWP. Secondly, a study published by the German Umweltbundesamt[4] examined the availability of alternatives and their appropriateness in the individual sectors. Finally, the Technical and Economic Assessment Panel (TEAP) of the Montreal Protocol published a report[5] on the assessment of alternatives at global level.

In addition, DG CLIMA set up an expert group consisting of 47 experts from different industrial sectors (24 high-level representatives), Member States (20 nominated a representative), and NGOs (3) to provide guidance and technical input to the preparatory study. The group met twice between October 2010 and May 2011 and provided written advice to DG CLIMA in the preparatory phase of the review.

2.3. Stakeholder consultation and conference

An internet-based consultation was open to individuals and organisations on the website of DG CLIMA from 26th September to 19th December 2011. 261 replies were obtained, of which 164 came from organisations. 75% of the latter were related to industry (see Fig.1). Less than 2% of these stakeholders chose the option "no further action" in

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16 SKM Enviros (2012). *"Further assessment of policy options for the management and destruction of banks of ODS and F-Gases in the EU"* http://ec.europa.eu/clima/policies/ozone/research/docs/ods_f-gas_destruction_report_2012_en.pdf

17 Clodic et al. (2011). *"1990 to 2010 Refrigerant inventories for Europe - Previsions on banks and emissions from 2006 to 2030 for the European Union."* Armines/ERIE http://www.epeeglobal.org/refrigerants/F-Gas-review/

response to a question on the most appropriate action at EU level to contribute to reducing GHG emissions in the absence of global action on HFCs.

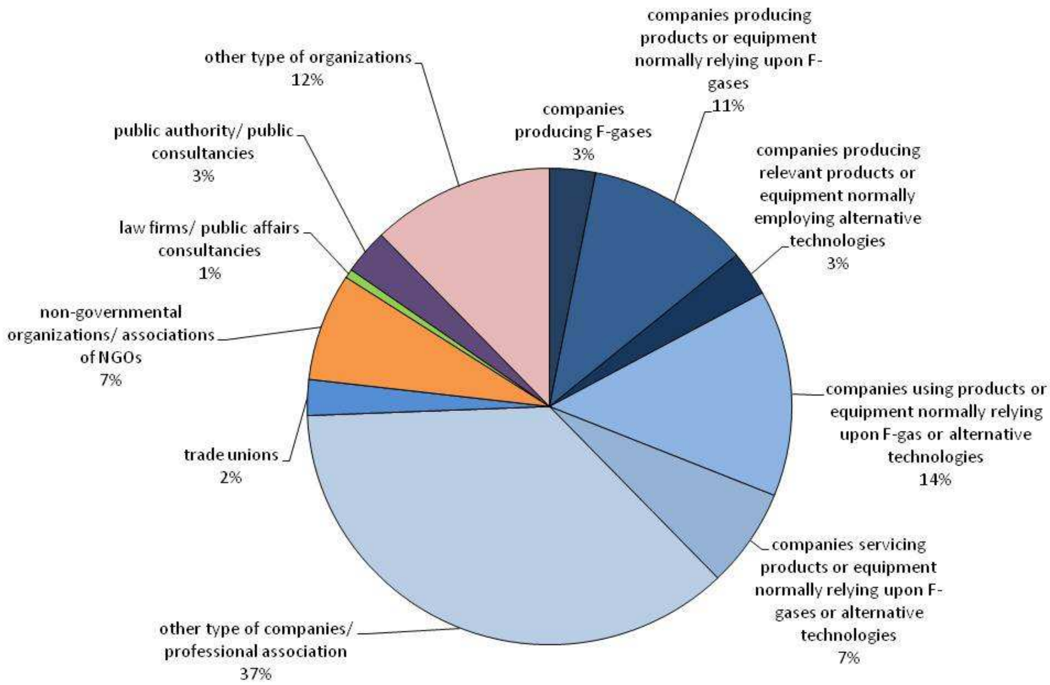

Fig. 1: Respondents to the on-line stakeholder consultation representing organisations

The findings of the consultation were presented at an open stakeholder conference[18] on 13 February 2012, which was attended by over 130 participants from industry, Member States, NGOs and the European Parliament. This meeting gave participants ample time and opportunity to deliver feedback and state their views regarding options for reviewing the Regulation. Almost all stakeholders agreed there was a need for further action on F-Gases compared to the status quo. A large majority of industry preferred or could live with a phasedown of supply of F-Gases as it would allow industry flexibility in cases where alternative technologies were not considered suitable. Bans were considered to be too rigid by those industry players relying on F-Gas technology, while NGOs and industrial participants engaged in alternative technologies considered cost-effective bans to be essential and saw a phasedown as a complementary measure to bans. A few participants preferred to focus on better application of the current Regulation only. Member States had no official positions yet, but indicated support for a phasedown measure (see Annex II). The consultations involved a large number of organisations and umbrella groups. At least 47 stakeholders out of 161 consulted represented the views of SMEs (see Annex III). Industrial users of F-Gas equipment such as FoodDrinkEurope, representing many SMEs, wanted reassurance that existing equipment is not made redundant.

18 http://ec.europa.eu/clima/events/0049/index_en.htm

Subsequently, a number of European Protection Agencies have positioned themselves on the review, considering that the preparatory study[8] is an appropriate basis for further action, especially as energy efficiency and economic impacts are already taken into account in the analysis. They recommend a mixture of measures based on a phasedown drawing on the experience of the ODS phase-out, and additional bans.[19]

Given these extensive consultations and expert involvement, DG CLIMA exceeded the European Commission's minimum consultations standards in the process of drafting this Impact Assessment.

2.4. Scrutiny by the Commission Impact Assessment Board

The Impact Assessment Board of the European Commission assessed a draft version of the present impact assessment and issued its opinion on 25/05/2012. The Impact Assessment Board made several recommendations and, in the light of the latter, the final impact assessment report:

– Describes the wider policy context in more detail, in particular as regards the context of the roadmap (see section 3.1), the alternatives available (see 1 & Annex XVI), the most affected interests (see e.g. 3.4, 6.2.2 and summary table 7), as well as the international context (see 1);

– Clarifies the objectives and their link to concrete monitoring indicators (see 4.3, 8);

– Gives more detail on the policy options (section 5.1-5.5), especially the mechanism of a phasedown (see 5.4, Annex X);

– Clarifies the assessment of impacts on competitiveness, SMEs, consumers, employment, health and safety, as well as the effects on market players, distributional and regional effects i.e. by providing more detail on costs by sector in section 6.2.2 and Table 3, by extending the competitiveness impact section 6.2.6 and addressing price impacts for consumers for the affected products;

– Adds views of stakeholders throughout the text.

[19] Letter of European Network of the Heads of Environment Protection Agencies to Commissioners Potoçnik, Heedegaard, Tajani, and Öttinger. 15. Mai 2012

3. PROBLEM DEFINITION

3.1. The problem that requires action

The 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) stated that developed countries would need, on the basis of existing science, to reduce GHG emissions by 80 to 95% below 1990 emissions by 2050 to achieve the objective of limiting global climate change to a temperature increase of 2°C and thus avoid undesirable climate effects.[20] To reach this target, the European Commission (EC) has laid out a cost-effective pathway to achieve the necessary overall emission reductions in the EU by 2050.[21] This low carbon roadmap establishes the necessary sectoral contributions in 6 areas consistent with an 80% EU reduction in GHG in 2050 on the basis of 1990, namely the power sector, residential & tertiary, industry, transport, non-CO_2 agriculture and other non-CO_2 sectors. To achieve the climate objective at lowest costs, non-CO_2 emissions (including F-gases but excluding non-CO_2 from agriculture) should be reduced between 72-73% by 2030 and 70%-78% in 2050, compared to 1990 levels. If based on the reference year 2005, the roadmap requires a reduction in non-CO_2 emissions (except agriculture) of 60-61% by 2030.[22] F-gases emissions were estimated at 90 Mt CO_2eq in 2005 (see Annex IV). A 60% reduction implies that emissions would have to be reduced to a level of 35 Mt CO_2eq by 2030. Given estimated levels of 104 Mt CO_2eq emission in 2030 based on a full application of current legislation, this would mean a further decrease of ca. 70 Mt CO_2eq is required. The roadmap shows that to be cost-effective the marginal costs of abating emissions should not be higher than ca. €50/t CO_2.[23]

F-Gases, generally, are very potent GHGs with high to very high GWPs of up to several thousand times that of CO_2.[24] F-Gases are used in a large variety of products and equipment including refrigeration, AC, foams, electrical equipment, aerosols and fire protection (Fig. 2); there are 28 diverse main application areas (Fig. 6).

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20 IPCC, 4th Assessment Report, Climate Change 2007: Working Group III: Mitigation of Climate Change, chapter 13.3.3 Proposals for climate change agreements, box 13.7. Scenario category for greenhouse gas concentration levels of 450 ppm CO_2 eq. http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch13.html

21 COM (2011) 112final: "*A roadmap for moving to a competitive low carbon economy in 2050*." http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011DC0112:EN:NOT

22 See Table 17, page 79 of Impact Assessment "*A roadmap for moving to a competitive low carbon economy in 2050*. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF .

23 See Table 31, page 117 of Impact Assessment "*A roadmap for moving to a competitive low carbon economy in 2050*. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF .

24 IPCC, 4th Assessment Report, Climate Change 2007, chapter 2.10.2: Direct GWPs. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

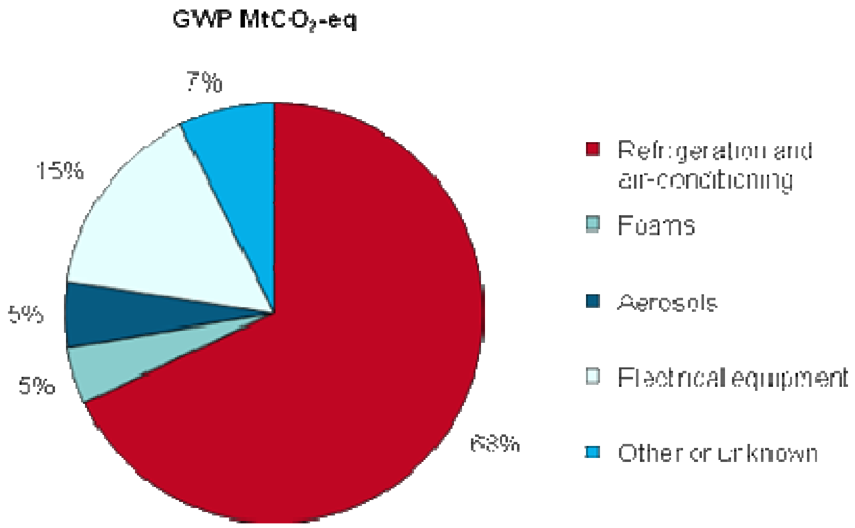

Fig. 2: Sectors using F-gases in new equipment/products in the EU. 2010 data reported under the F-Gas Regulation

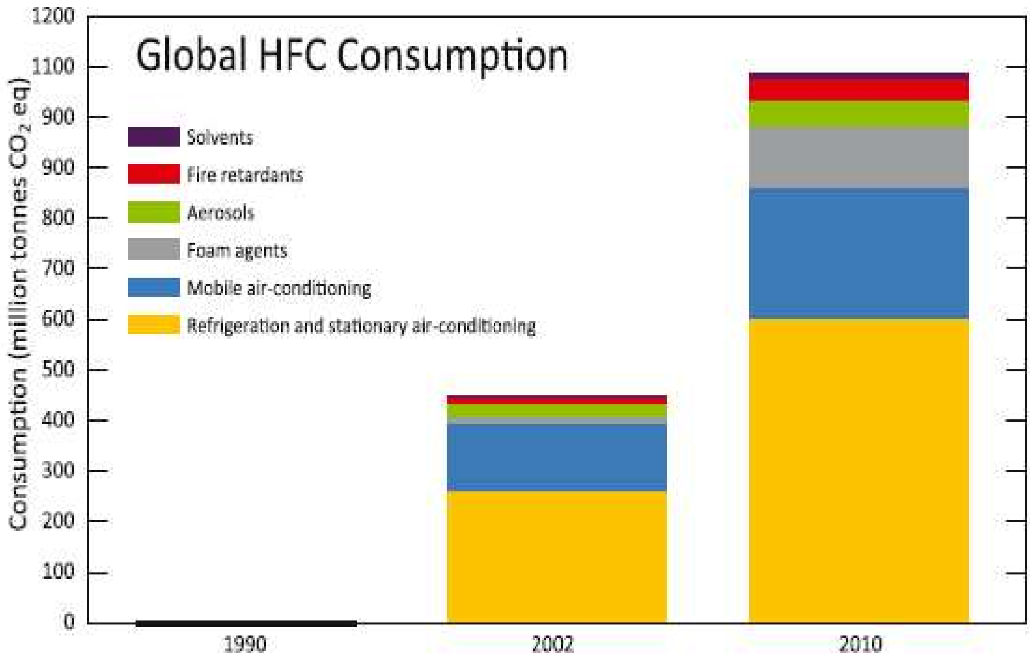

Fig. 3: Global estimated consumption of HFCs in CO_2eq by various sectors. Rapid growth after 1990 is clearly evident. HFCs constitute the largest quantitative percentage of all F-Gases. Source: UNEP[25]

With the successful phase-out of ODS, **the production and use of F-Gases as ODS replacements has been growing strongly in recent years (see Fig. 3 for HFCs, the bulk of F-Gases) and will eventually lead to considerable emissions into the atmosphere, with the potential to substantially influence climate in the future**.[25] To better appreciate the significance: Future HFC emissions could be equivalent to 18-45% of CO_2 emissions based on the IPCC's "450ppm CO_2 emissions pathway"-scenario by 2050.[25] Since equipment and products containing F-Gases have a long lifetime of up to 50 years (e.g. building insulation foams), a lack of public intervention today would result in higher emissions up to several decades into the future.

In 2010, emissions from F-gases in the EU were estimated to be ca. 110 million tonnes (Mt) CO_2eq[8], corresponding to ca. 2% of all GHG emissions. Alternatives to F-Gases exist in many applications[4,5], at costs well below 50€ per tonne CO_2 abated[9] (Annex XVI). In fact, 95% of the overall reduction potential of HFCs (without motor vehicles) can be reached at abatement costs lower than 20€ per tonne CO_2. Analysis shows further that F-Gas emissions could be reduced cost-efficiently by more than two-thirds by 2030[9] (see also Fig. 7 below), which would amount to cumulated emission savings of ca. 625 Mt CO_2eq. in the period from 2015 until 2030.[26] **If reductions in F-Gas emissions will not contribute to the EU 2050 climate targets in a consistent manner, the EU will either risk missing these targets altogether or would have to require more expensive emission reductions in other industrial sectors.** A two-thirds reduction of emissions by 2030 would also be fully compliant with proposals made in the international context of the Montreal Protocol by Micronesia and North-American states (US, Canada, Mexico), thus preparing Europe for a potential international agreement. EU action on F-Gases would also strongly support recent climate action at international level promoted by the "Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants".

3.2. Underlying drivers of the problem

– *Phasing out of ozone-depleting substances (ODS) under the Montreal Protocol*: In order to phase-out ODS, the Montreal Protocol controls their production and consumption. As the choice of alternatives to ODS[27] is not regulated, a shift towards the production and use of F-Gases is taking place world-wide.

25 UNEP (2011). *"HFCs: A critical link in protecting climate and the ozone layer."* http://www.unep.org/dewa/Portals/67/pdf/HFC_report.pdf

26 Based on AnaFGas (Schwarz et al., 2011; cited in footnote No. 9)

27 ODS are also very strong climate gases with high GWPs

- *Increasing use of F-Gas containing equipment and products*: The most relevant uses for F-Gases are in refrigeration & AC (RAC[28]), foams, aerosols and electrical equipment.[29] Many of these application areas, in particular the RAC, are expected to grow strongly in the future[9,30]. This higher demand is a result of economic growth and increasing life standards, a strive for energy efficiency (e.g. heat pumps, foams) and, in the developing countries, also population growth.[25,31]

- *Today`s use are the emissions of the future:* F-Gases are used in appliances such as RAC equipment that have ordinary lifespans of 10-20 years for smaller and 20-30 years for larger systems, throughout which leakage may occur, as well as at the end-of-life treatment. Typical leak rates for larger equipment are 5-15% per year (but smaller for hermetically sealed equipment such as domestic fridges: <1% per year). Foams have lifetimes of 15 (if used in domestic appliances) to 50 years (for building insulation), and emissions usually occur at end-of-life and thereafter (e.g. from waste dumps). Recovery of F-gases from foams is rather costly. The use of F-Gases in aerosols, as solvents and in electrical equipment mostly does not create significant banks of potential emissions. Use in fire equipment does create banks but leakage is very tightly controlled due to safety regulations.[16]

- *Demand for and innovation of alternative technologies is hampered by market failures:* Climate effects of F-Gases are not factored into the price. Industry requires a clear signal in order to switch towards investments into alternative technologies (and to invest into R&D where still needed). Demand increase would also lead to economies of scale for alternative equipment. The current absence of a clear regulatory signal leads to a lower market penetration of green products than would be optimal from a societal perspective.

3.3. Evolution of the problem in the EU

F-Gas emissions can be prevented by avoiding their use in the first place and/or by reducing losses during the lifetime and at the end of life of F-Gas containing equipment. The current F-Gas Regulation mainly focuses on the latter. It includes provisions on

- containment (preventing leakage of F-Gases from stationary equipment) and recovery of F-Gases from end-of-life equipment (Art. 3/4);

- training and certification requirements for personnel handling F-Gases (Art. 5);

- reporting in order to monitor the sales of F-Gases (Art. 6);

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28 RAC includes heat pumps.

29 European Commission (2011). *"Factsheet: EU statistics on fluorinated greenhouse gases 2010."* DG CLIMA. http://ec.europa.eu/clima/policies/F-Gas/docs/statistical_factsheet_2011_en.pdf

30 US-EPA (2011). *"Global Anthropogenic Non-CO_2 greenhouse gas Emissions: 1990-2030."* EPA 430-D-11-003. U.S. Environmental Protection Agency, Washington D.C.

31 EEA (2012). "Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012". Technical report No 3/2012. http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2012

– labelling of equipment containing F-Gases (Art. 7); and

– bans and market restrictions in a few niche areas where superior alternatives were already common place (Art. 8 and 9).

The report[8] on the application of the F-Gas Regulation showed that, while these measures have the potential to reduce emissions, there are unfortunately shortcomings in the current application of the training and certification as well as the containment provisions, while compliance with Art. 6, 7, 8 and 9 was found to be satisfactory or better. Training and certification apply to approximately 600,000 persons and 66,000 companies (of which 98% in the RAC sector), posing a challenge to Member States to swiftly implement the necessary vocational training and certification systems in a timely manner, especially where such systems had not existed previously. Consequently, in some sectors more than 50% of personnel and companies had not been certified by 4 July 2011. Compliance by companies with the schedules for leakage checks and the obligation to install leakage detection systems was found to be unsatisfactory, as there was low awareness among operators due to deficiencies in enforcement. However, it must be noted that many of these shortcomings may be considered initial effects, especially since some requirements became applicable only in 2011, allowing little time for proper application. There is also a growing potential for recovery from systems containing F-gases in the coming years, as such systems will be reaching their end of life. In the stakeholder consultation, 84% of respondents expressed the view that the current status quo of implementing the existing regulation was not sufficient. While some stakeholders believed that better implementation would suffice, others wanted to see further legal action.

The MAC Directive introduced restrictions on the use of F-Gases with a GWP above 150 in mobile AC of new passenger cars. In other sectors, current legislation does little to support an increased use of viable alternatives to F-Gases in new products and equipment.

Potentially, considerable emission reductions are achievable through the existing F-Gas Regulation and MAC Directive.[8] Assuming full application of the two pieces of legislation, the **total emissions of F-Gases would stabilise around today's level of 110 Mt CO_2eq in the EU-27 as a result of existing EU policy** (Fig. 4, solid line)**.** Without any legislation, F-Gases emissions in the EU would grow to over 200 Mt CO_2eq in 2050 (Fig. 4: dotted line), almost doubling today's levels (see Annex IV for details). However, the observed shortcomings in the application of the F-Gas Regulation risk undermining these projected benefits and, if not sufficiently addressed, could lead to forfeiting 38 Mt CO_2eq of cost-efficient emission reductions, ending up at ca. 150 Mt CO_2eq in 2050. While it is important to step up efforts to ensure full compliance, observed low compliance on existing containment measures is a further argument for also reducing use of F-Gases in equipment in the first place.

Furthermore, the SKM study[16] on F-Gas banks concluded that switching to alternatives is key to addressing F-Gas emissions in the waste stream. Although improved implementation of waste legislation can contribute to emission reductions, it can only address an overall small proportion of the problem and cannot substitute for measures addressing the origin of the problem.

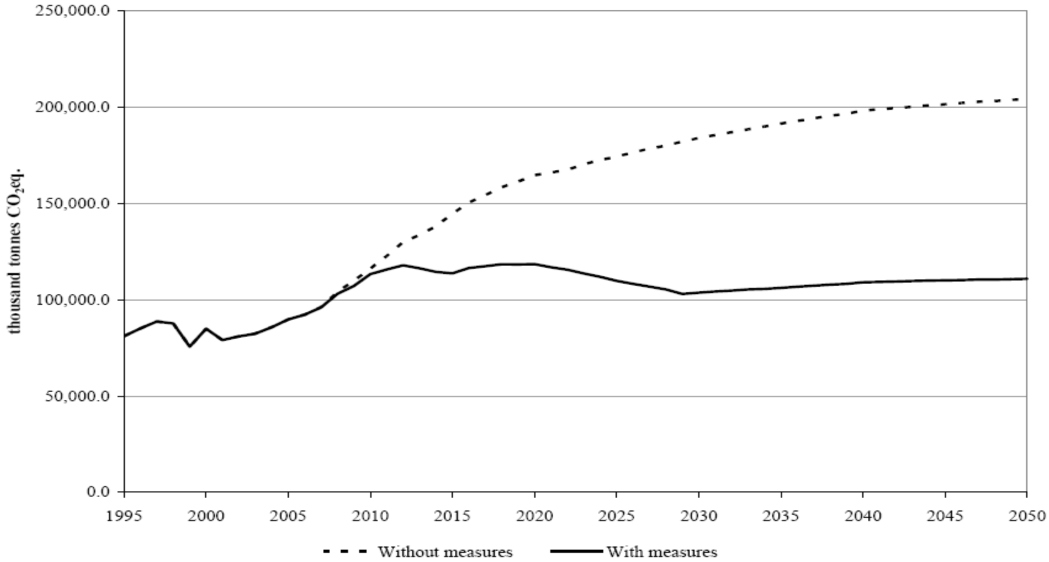

Fig. 4: Projections of F-Gas emissions in the EU with and without the measures in the F-Gas Regulation and the MAC Directive. Source: *Schwarz et al. (2011)*[9]

Last but not least, a full application of the current F-Gas Regulation would at best achieve a stabilisation of emissions, which is fully insufficient to reach the EU's climate goals requiring a fair share reduction in the F-Gas sector of 60% by 2030, compared to 2005. Nor would the current Regulation be anywhere near sufficient if an international agreement to phase down F-Gases is reached, on the basis of the proposals currently on the table. Therefore, **action to complement the existing measures** in the F-Gas Regulation is absolutely essential.

3.4. Who is affected, in what ways and to what extent?

– Climate change affects everybody. During the first ten years of this millennium temperatures were the highest ever recorded, confirming the finding of the IPCC that total temperature increased already by 0.76°C from 1850–1899 to the period 2001–2005[32]. Evidence is rising strongly that a warming of the climate results in more frequent and more intense "extreme weather events".[33]

– The overall economy and non-F-Gas European industries may suffer a loss of price competitiveness if they must abate emissions at higher costs than possible within the F-Gas sector.

32 IPCC, 4th Assessment Report, Climate Change 2007: Working Group I, Summary for Policymakers.

33 IPCC, 4th Assessment Report, Climate Change 2007: Working Group II, Summary for Policymakers.

– Too little innovation and market penetration of alternative technologies represent a missed opportunity to stimulate innovation, green jobs and growth. Many of these "green growth" companies are SMEs[34], who find it hard to market their products under current market conditions (see Annex II).

– The F-Gas sector comprises a number of different market players who may be affected in different ways by any policy changes; these players include producers of F-Gas, manufacturers of equipment, electricity companies, service companies, importers and exporters, users of equipment, the retail sector and raw material sectors (e.g. metals and products). Currently, industrial sectors relying on F-Gases are affected in different ways. While producers of F-Gases and of equipment and products are only to a very limited extent subject to restrictions related to F-Gases, users of F-Gas equipment are subject to the containment requirements. If more alternative technologies were deployed, end-users of equipment could in several cases have lower costs overall e.g. for small industrial refrigeration, which is relevant for SMEs in particular.

– Emissions from F-Gases are covered by the "Effort Sharing Decision" establishing annual binding GHG emission targets for Member States for the period 2013–2020. Some Member States consider that the current EU legislation does not provide sufficient tools to ensure cost-effective reductions of F-Gas emissions. Therefore, several Member States have adopted national laws that are more stringent than the EU legislation, e.g. in Austria and Denmark the use of F-Gases for certain purposes is prohibited. While such prohibitions have driven innovation, unilateral action is not favoured by business and may pose challenges, in particular for SMEs.

3.5. EU right to act

The right for the Union to act in this field is set out in Articles 191 and 192 of the Treaty on the Functioning of the European Union (TFEU) which in Article 191 explicitly refers to the objective of combating climate change as part of the Union policy on the environment.

Action in this field also respects the principle of subsidiarity. Climate change is a transnational issue and since the EU has a common emission reduction target, Union-wide action is necessary. Such action can better be taken at EU level compared to diverse actions taken at Member State level, thereby achieving a high degree of environmental protection while also taken into account the need to minimise distortions in the internal market by introducing a level-playing field for all enterprises affected. Where appropriate the right of Member States is preserved to implement some provisions, such as the training and certification requirements or penalties, through provisions at Member State level taking into account their national circumstances.

[34] Shecco (2012). "GUIDE 2012: Natural refrigerants – market growth for Europe". http://guide.shecco.com/

4. OBJECTIVES

4.1. General policy objectives

It is the general objective of this initiative to contribute significantly to meeting the global challenge of keeping climate change below 2º C of pre-industrial levels by reducing GHG emissions in the EU by 80 to 95% in 2050 compared to 1990. This target correspond to the necessary reduction levels identified by the Intergovernmental Panel on Climate Change (IPCC) for developed countries and was endorsed both by the Council and the European Council as the EU 2050 emission reduction target.

4.2. Specific policy objectives

It is the specific objective of this initiative to contribute to the achievement of the EU 2050 reduction target by reducing CO_2eq-emissions from F-Gases in the EU, in particular by:

– discouraging the use of F-Gases with high GWP in the EU where suitable alternatives exist;

– encouraging the use of alternative substances or technologies when they result in lower GHG emissions without compromising safety, functionality and energy efficiency, and achieving higher market shares for these technologies;

– preventing leakage from equipment and proper end of life treatment of F-Gases in applications;

– facilitating convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol;

– enhancing sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low GWP;

– creating efficient and proportionate mechanisms for reaching the environmental objectives while limiting any undesirable effects on SMEs and employment, the administrative burden for companies and authorities, the abatement costs per tonne CO2 and preserving the competition in the Internal Market, to the extent possible.

4.3. Operational policy objectives

Consistent with the specific and general objective, the operational objective is to reduce F-Gas emissions in the EU by 60% in 2030 compared to 2005.

A second operational objective is to do so in a cost-effective manner by taking consistent, and cost-efficient measures (up to a maximum of 50€/t CO_2eq), at reasonable costs to industry and with minimum administrative effort.

In addition, an upgrading of the existing legislation through clarifications as well improving the enforceability of legislation should contribute to achieving better implementation and application of the legislation and contribute to achieving the objectives above.

4.4. Consistency with other policies and objectives

The objectives of this initiative are consistent with and reinforce the following policies and objectives:

– The required emission reductions are consistent with the pathway outlined in the 2050 EU Low Carbon Roadmap. The selected sub-options are also cost-effective since they are estimated to have (marginal) abatement costs of less than 50€/t CO_2 by 2030;

– support to novel alternatives will help maintain the competitiveness of the European economy and in particular support green growth as demanded by the EU 2020 priority sustainable growth: building a more competitive low carbon economy, protecting the environment and capitalising on Europe's leadership in developing new green technologies[35];

– improving the legislative text will ensure simplification and clarification of existing policy to enable better implementation in the spirit of better regulation[36];

– measures are introduced to safeguard the interests of SMEs along the "think small first" principle[37];

– special attention is paid to impacts on energy efficiency to ensure consistency in line with EU efforts of eco-design[38] and energy efficiency[39];

– taking action now at European level will lend support to the negotiations for an international agreement under the Montreal Protocol to phase down HFCs.

5. POLICY OPTIONS

5.1. Policy option A: No policy change at EU level (baseline option)

This option includes the existing legislation and assumes, in particular, full application of the provisions of the F-Gas Regulation in all Member States and sectors. This implies that current shortcomings are effectively addressed. 84% of respondents to the online stakeholder survey thought the current status quo (i.e. existing legal rules and implementation) was not sufficient. The steps to remediate current shortcomings include rigorous persecution of non-compliance by Member States as well as measures of encouragement at European level through non-legislative actions such as awareness raising, exchange of best practices and assistance which may take many shapes, e.g. the Commission is currently incorporating labelling rules into the Integrated Tariff of the European Communities to support Member States in enforcing the labelling provisions of the F-Gas Regulation. Numerous suggestions were made by stakeholders during the on-line survey, many of which require better control, policing and enforcement at

35 http://ec.europa.eu/europe2020/priorities/sustainable-growth/index_en.htm
36 http://ec.europa.eu/governance/better_regulation/key_docs_en.htm#_br
37 http://ec.europa.eu/enterprise/policies/sme/small-business-act/index_en.htm
38 http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm
39 http://ec.europa.eu/energy/efficiency/index_en.htm

Member State level. Stakeholders and Member State representatives also made several suggestions for clarifications and simplification in the Regulation, in particular on definitions, in reaction to a pertinent question in the stakeholder survey, which are similarly addressed under this option.

Hence, Option A is the baseline that includes current legislation as well as some necessary measures to approve its application. Options B to E describe further measures that are additional to this baseline.

5.2. Policy option B: Voluntary agreements by industry (non-regulatory)

This option considers additional or enhanced voluntary agreements in the EU to reduce F-Gas emissions. Such action was preferred in particular by industrial stakeholders in the online survey, with the exception of F-Gas producers. Stakeholders reported mixed experiences with voluntary agreements in the past, some reported on successful examples whereas others did not consider voluntary agreements to be adequate and/or enforceable. Such agreements could be considered realistic in the following areas, considering that abatement costs for these applications are estimated to be relatively low[40] (see Annex VI for more details):

– phase-out HFCs in commercial refrigeration (centralised systems, commercial hermetics, condensing units);

– replace HFC-134a in XPS foams;

– replace HFC-23 in fire protection;

– destroy HFC-23 emissions from halocarbon production;

– replace SF_6 and NF_3 in photovoltaic industry;

– and reach an enhanced agreement on the use of PFCs, NF_3, HFC-23 and SF_6 in the semiconductor industry.

5.3. Policy option C: Extended scope of containment measures

This option foresees an extension of the current F-Gas Regulation in its main provisions, i.e. the requirements on containment (Art. 3) and recovery (Art. 4). Such action was strongly supported by many industrial players in the online stakeholder survey.

A number of potential extensions were screened in terms of e.g. effectiveness and efficiency (see details in Annex VII). Eventually, the only sub-option considered to be relevant was an extension of the scope of these requirements to AC in some transport modalities.

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40 3.1€ or less per t of CO2eq abated except for centralised refrigeration systems (23.7€ per t CO_2eq) (see Annex VII)

In order to improve containment, improved product standards on leak tightness of applications containing F-Gases are desirable and should be further pursued.[41] This development of mandatory technical standards is part of the work under the Ecodesign Directive (2009/125/EC) and, possibly, in the future also under the proposed Energy Efficiency Directive[42]. However, considering the large number of appliances, corresponding standards and the timeframes involved, this relevant approach cannot substitute for measures addressing the origin of the problem. Impacts of such standards were hence not explicitly considered under this option.

5.4. Policy option D: Establishment of a phasedown mechanism for placing HFCs on the EU market

This option involves a phasing down of the supply of bulk HFC substances in the EU complemented with measures to cover quantities imported inside of equipment ("pre-charged"). In the online survey, a phasedown was supported by producers of F-Gases and producers of equipment (both alternatives and F-Gases) as well as users of equipment, in addition to strong support from public authorities and many individuals. In the ensuing stakeholder conference meeting on 13 February 2012, there was widespread support for such a measure by industry as it was considered to be more flexible than bans and would allow industry to adapt and continue using F-gases in applications where this was considered to be the optimal solution. However, in particular NGOs considered that bans were also necessary.

The phasedown mechanism assessed implies a gradually declining "cap" for the total placement of bulk HFCs (in tonnes of CO2eq) on the market in the EU with a freeze in 2015, a first reduction step in 2016 and reaching 21% of the levels sold in 2008-2011 by 2030. These levels have been determined so as to fully respect current market needs and the possibilities of replacements in all sectors (compare Annex XVI) with proven, safe and energy-efficient technologies already available today. The expected accelerated future development of alternative technologies will provide an additional safety margin.

Entities placing HFCs on the EU market must hold rights to "place on the market" (POM). ‘Placing on the market’ means the supplying of or making available to a third party within the EU *for the first time* and includes imports of bulk substances. The Commission allocates free quotas of rights to POM to stakeholders based on past reporting data ("grandfathering"). Stakeholders must ensure that they hold enough rights to cover their actual placing on the market and they may transfer rights between them. Compliance checks are carried out by the Commission in the following year, with independent verification of reports. As the participating entities are known through the existing reporting from the F-Gas Regulation and their number is a manageable size of ca. 100 companies, the phasedown is fully implementable through setting of limits by

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[41] The relevant standard EN 378 on safety and environmental requirements for refrigerating, AC and heat pump (RACHP) systems describes the charge limits, and considers toxicity and flammability, sets design requirements, where tightness and leak tests are considered together with safety requirements. It also covers requirements for installation sites and describes how the refrigeration systems have to be maintained, serviced, dismantled. This standard is currently under revision.

[42] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0370:FIN:EN:PDF

the Commission at EU level, making use of the experience gained through the ODS phase-out. A reserve will be available to new market entrants.

Measures to address quantities imported in pre-charged RAC equipment are indispensable for the environmental integrity[43] of the phasedown mechanism and a level playing field in the market. Here one must differ between hermetically sealed and non-hermetically sealed equipment. For the latter, a requirement of filling on the installation site only (instead of being factory pre-charged) is the preferable way to subject these HFCs to the quantitative restrictions of a phasedown (see also Annex X). This requirement is non-discriminatory as it would apply in the same way to products produced in the EU and to those imported. The appliances affected would essentially be "non-monobloc" AC systems (i.e. single-split, multi-split and rooftop systems) and would cover ca. 86% of refrigerants imported in AC equipment. By submitting these quantities to the cap, the replacement of high-GWP HFCs with alternatives is favoured in the vast majority of these appliances, so that over time the on-site filling requirement will affect less and less units. Filling of equipment during the installation on site would also alleviate the expressed concerns of the service industry (mainly SMEs) that currently the installation of new equipment is often done without the legally required use of certified experts, leading to additional and avoidable emissions, malfunctioning and loss of energy efficiency.[44] For the sealed equipment (e.g. AC movables), a placing on the market ban would safeguard the environmental performance of the mechanism as well as attaining a more level playing field for importers vs. domestically produced equipment.

Fig. 5 shows the phasedown schedule. The grey area represents the quantities which need to be placed on the market to satisfy the demand for F-Gases for product and equipment where cost-efficient alternatives do not exist. The schedule is calculated on the basis of the AnaFGas model and up-scaled to match the quantities reported under the F-Gas Regulation. These quantities do not account for the expected technological progress on alternative equipment which will provide an additional safety margin to avoid shortage of supply for applications that are not (yet) replaceable (see Annex X for details).

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43 In 2030, 18% of the total EU demand of HFCs is estimated to be inside imported equipment, based on CO_2eq (currently 11%). If imported equipment did not have to face the same supply restrictions on HFCs as equipment produced in the EU, the share of import and hence uncontrolled supply of HFCs would likely become even higher.

44 AREA (2010). "Postion paper: Review of Regulation 842/2006 on certain fluorinated greenhouse gass – pre-charged non-monobloc AC equipment." www.area-eur.be

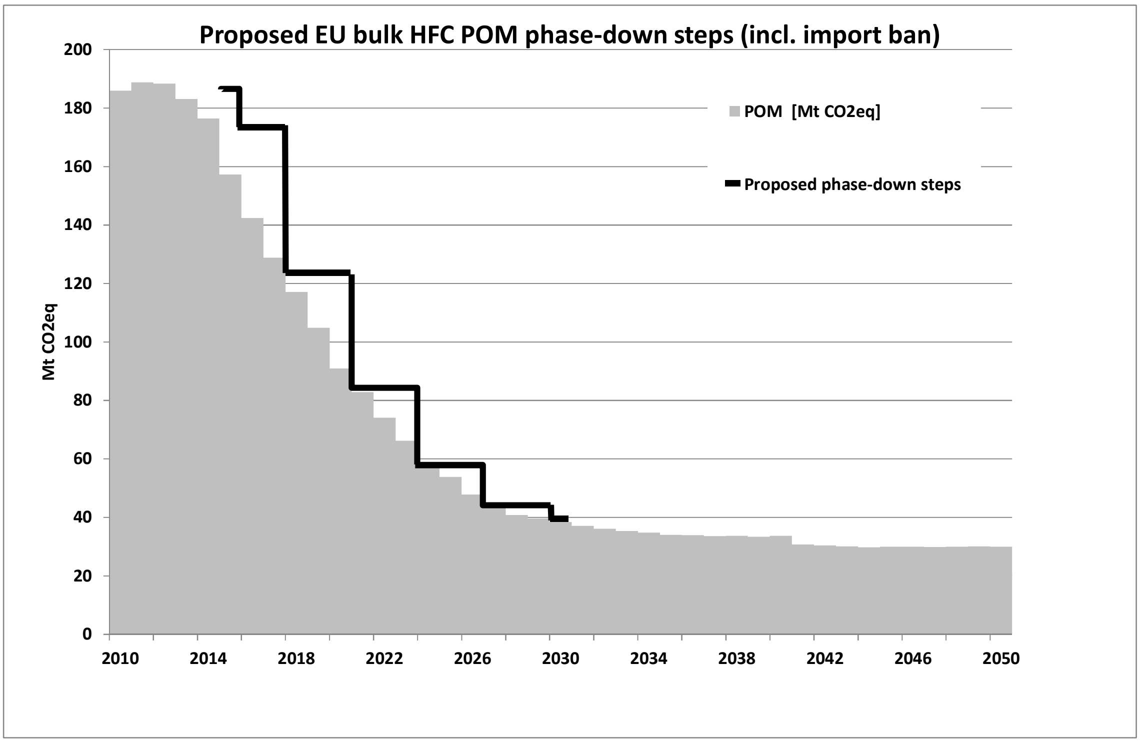

Fig. 5: Key features of phasedown schedule (see Annex X for more details)

The system should be flexible enough to allow modifying the allocation mechanism to improve its functioning where deemed necessary. To accommodate the outcome of a potential international agreement, amendments to the phasedown schedule at a later state should be possible. Furthermore, the Commission should have the possibility to exempt HFC quantities produced or imported for specific uses from the phasedown mechanism if the supply for applications which are critical for health and safety reasons would otherwise not be ensured.

5.5. Policy option E: Bans of production, use or placing on the market of F-Gases in certain applications

This policy option bans, from a specific date onwards, the sale of certain new appliances with F-Gases in the EU or the use of F-Gases in the following sectors where full market penetration of cost-efficient alternatives was considered feasible:

- Commercial refrigeration (stand-alone systems, condensing units, centralised systems);
- Industrial refrigeration[45]
- Transport refrigeration (Refrigerated trucks and trailers);

[45] Penetration rates do not fully reach 100% for this whole sector, but bans may be possible for larger industrial systems above a certain capacity. See also Becken et al. (2010)[4]

– Stationary AC (moveable systems, single split systems, multi split/VRF systems, rooftop systems, displacement chillers);

– HFC-23 in fire protection;

– SF6 in Magnesium die-casting <850 kg/ y and recycling of die casting alloys;

– Non-medical technical aerosols (except if 100% inflammability is required);

– HFC-134a in XPS foam blowing; and

– Mandatory destruction of HFC-23.

Bans were strongly favoured by individuals, public authorities and NGOs, but few industrial players. Some noted that substantive exemptions would be necessary e.g. due to local building codes prohibiting the use of certain alternatives in certain areas. Importers of foreign equipment argued that bans would be detrimental to their business.

5.6. Combination of policy options

The policy options presented above are not all mutually exclusive, as measures contained in the options address e.g. different gases or different application areas, so some could be implemented jointly, which is e.g. the case for Option C that is complementary to all other policy options. The impacts of such combined options would therefore often be a simple addition of the individual impacts of policy options combined. But bans under Option E could also be combined with an HFC phasedown, in particular to steer the choice of alternative technologies in sectors where they are most cost-efficient. In this case the environmental impact and economic costs are to a large extent already included in the impacts of Option D as measures overlap.

All policy options would contain clarification and simplification of the legislative text in order to improve implementation in the spirit of better regulation.

Given the complexity of the sector, many stakeholders in the online survey seemed to suggest that a mix of policies is the best approach forward. A number of European Environmental Protection Agencies have openly declared to favour such a combined approach, based on a phasedown accompanied by bans in certain areas, in order to meet the emission reduction targets in a cost-efficient way.[19]

5.7. Options discarded from further analysis

Additional policy options were screened but discarded from further analysis and are therefore not presented in detail in this section (See Annex VII for details). These policy options were:

– *Suspension of the current F-Gas Regulation*, as it would mean forfeiting significant emission savings.

– *Inclusion under the EU-Emission Trading System (ETS).* The current ETS has been designed to give a price to actual emissions from activities such as energy production, not for gases sold to be used in equipment for long periods of time and with no clear emission endpoint as is the case for most F-Gas applications. Also, the number of players who would have to acquire licenses would be prohibitively high and difficult to monitor. Only few stakeholders selected this measure among the 3 most appropriate options in the online survey (6%).

– *EU harmonized tax schemes.* There are a number of reason why this option was discarded, *inter alia* (i) tax levels and exemptions should reflect national differences and the risk of emissions, (ii) correct tax levels are difficult to set at European level, and (iii) control of the tax scheme at European level would involve a high administrative effort. A minority of stakeholders selected this measure among the 3 most appropriate options in the online survey (19%).

– *Deposit and refund schemes.* A number of existing national differences make it preferable to implement these at national level. A minority of stakeholders selected this measure among the 3 most appropriate options in the online survey (18%).

In addition to discarding these general options, some additional sub-options to policy options B, C, D and E were screened against criteria relating to:

– Effectiveness in terms of level of emission reductions (>1Mt of CO_2eq)[46]. However, to ensure consistency with requirements for similar sectors[47], it is appropriate to retain specific options, even if the threshold is not reached, where the measure is cost-neutral or even beneficial, for example through gains in energy efficiency;

– Efficiency in terms of abatement costs (<50€ per t of CO_2eq abated);

– Technical constraints like safety or loss of energy efficiency; and

– Other constraints such as consistency with other EU policies.

By way of example, a number of sub-options under Option C as regards extending the scope of containment were discarded because the costs were too high (e.g. for refrigerated vans and rail transport marginal costs were estimated to be €291 and €340 /t CO_2eq abated, respectively; see Table A-VII_2 to Table A-VII_7 in Annex VII).

46 This is equivalent to 1% of current EU-27 emissions of F-Gases (as reported in greenhouse gas inventories 2008) or 0.02% of total EU-27 greenhouse gas emissions without contributions from LULUCF

47 For example domestic refrigeration and small commercial stand-alone refrigeration equipment.

6. ANALYSIS OF IMPACTS

F-Gases are used in many diverse application areas. Fig. 6 gives the main 28 (sub)-sectors (in addition to HFC-23 by-production) which are considered in the following analysis. Refrigeration is the most relevant sector in terms of emissions (estimated 34% of total F-Gas emissions in 2010, based on Schwarz et al.[9]), followed by mobile AC (30%), stationary AC (13%), other HFC uses (8%), SF_6 uses (5%), PFCs and other halocarbons (5%), and foams (4%). The strongest long-term growth is expected for stationary AC. A detailed assessment of costs for all sub-sectors is given in Annex VI.

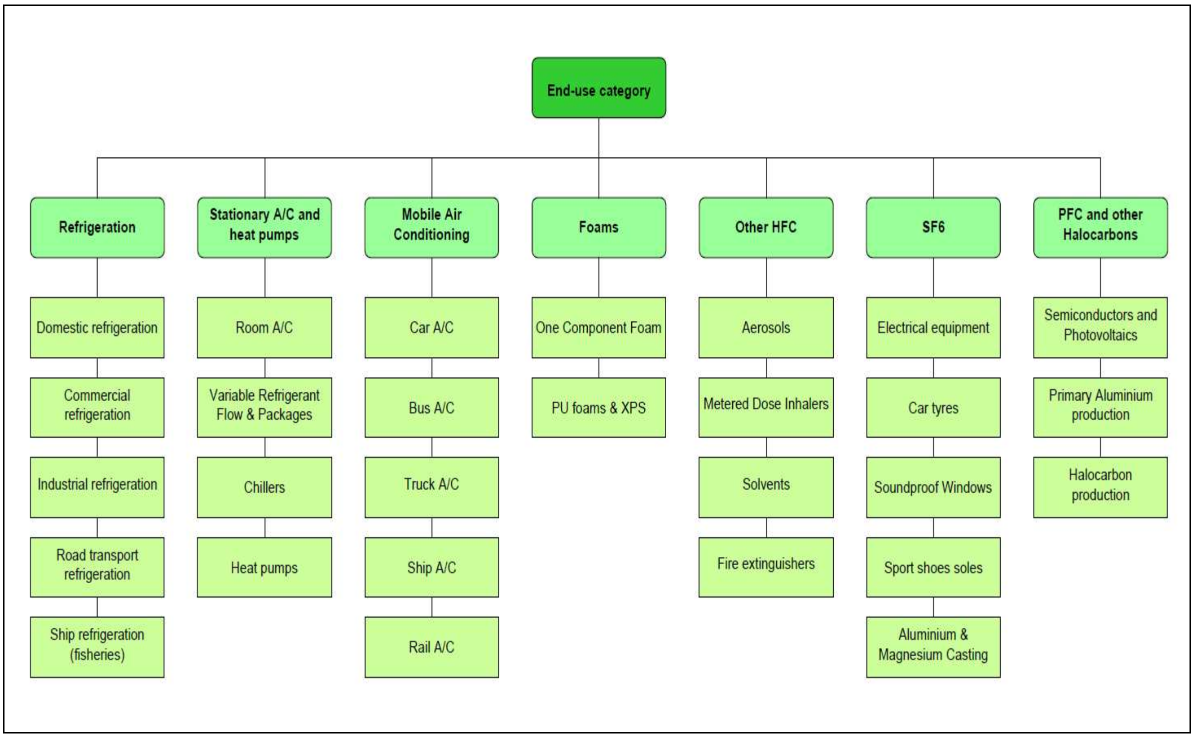

Fig. 6: Main F-Gas application areas and sub-sectors[9]

6.1. Environmental impacts

6.1.1. Approach used

Four key environmental impacts were analysed for the period 2010 until the reference year 2030 (vs. baseline option A):

(1) Reductions in direct F-Gas emissions (in Mt CO_2eq);

(2) New direct emissions resulting from alternative substances (in Mt CO_2eq);

(3) Emissions due to energy efficiency changes resulting from shifts to alternative technologies. The expected difference in annual energy consumption (kWh) between abatement technology and HFC reference

technology was estimated and converted into CO_2 emissions by using a specific CO_2 emission factor per kWh of electricity consumption.

(4) The emissions of ecotoxicologically relevant substances were quantified in metric units of toxic substances.

The bottom-up stock model AnaFgas[48] was used to estimate emission scenarios for F-Gases in the EU-27. Baseline emissions are expected to remain stable from 2010 until 2050, but are higher than 1995 (see Annex IV for further details).[49]

In order to reduce overall emissions**,** measures on direct emissions (use of F-Gases) should not lead to higher indirect emissions (e.g. due to increased energy use of equipment). In order to avoid such a potential trade-off, **only safe and energy-efficient (i.e. at least as efficient as conventional technology) alternatives were considered as feasible replacement substances** in the calculation of scenarios[9] (see Annex XVI).

6.1.2. GHG emission reductions

The largest emission reductions (71 Mt CO2eq) in 2030 **can be achieved with policy option D** (phasedown combined with complimentary measures targeting HFC in imported equipment and products) (see Table 1). For perspective, this is almost twice as high as the yearly reduction of 37 Mt CO_2 in the ETS cap between 2008 and 2012. It is also a reduction of ca. 63% in 2030 compared to emissions reported in 2005, i.e. at the level of emission reductions needed (60-61%) in 2030 from the non-CO_2 sector (without agriculture) to be consistent with the 2° C target as expressed in the roadmap for a competitive low carbon economy.[21] Option E (bans of placing HFCs on the EU market) would also achieve a substantial emission reduction of about 53 Mt CO2eq of emissions in 2030 but still falls short as to the emissions reductions stipulated by the Low Carbon Economy Roadmap, while Option B (voluntary agreements) would achieve considerably lower emission reductions of 22 Mt CO2eq, which are insufficient as regards the climate goals. Option C (enlarged scope) achieves only very small additional emission reductions[50].

Of the two most promising options on environmental grounds (D and E), the emissions reductions from Option E are lower mainly because bans can only be implemented when replacement substances are available for all applications in the sector (=100% penetration rate, see Annex XVI), whereas the phasedown can gradually take effect also in sectors where replacements are only partly available at the onset of the measure. For voluntary agreements (Option B) the reduction potential is relatively low compared to D

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48 A detailed description of the assumptions in model AnaFgas is provided in Annex III of *Schwarz et al. 2011*. A summary is given in Annex IV.

49 All data in this report are calculated with GWP (GWP) values from the Fourth IPCC Assessment Report. These GWPs are different from those values currently used in greenhouse gas inventories, but they will become mandatory from 2015 onwards.

50 The impacts of enhanced product standards on emission reductions within a particular timeframe are difficult to quantify as they depend on market uptake of standardised products and equipment or on the number of personnel and companies applying the standards. As this supportive measure is independent from the revision of the F-Gas Regulation, no quantitative assessment of the impacts was carried out.

and E because a smaller number of sectors would reduce emissions (see Annex V for further detail).

Additional emissions due to replacement substances are very low for all options. **Additional indirect emissions reductions** occur if the energy efficiency of replacements is higher compared to conventional technologies, which is the case e.g. in the refrigeration sector, whereas for others, e.g. foam blowing and AC, the energy efficiency of the abatement technologies is the same as that of the reference technology. A faster replacement schedule in **Option D** in the refrigeration sector **leads to higher indirect emission reductions** in this case compared to the other options. The reduction of indirect emissions is, however, also very low compared to direct emission changes from replacing F-Gases in use today.

The study conducted by ERIE/Armines[17] confirms the findings by *Schwarz et al. (2011)*[9] as it obtained very similar metric tonnes of refrigerant emissions for the main application sectors by 2030. While *Schwarz et al.* is conservative, i.e. based on available technologies, the ERIE/Armines study takes the possible future technological development (i.e. "best non-available technologies") into account. The *ERIE/Armines* study is however much more limited in scope, addressing only 7 main sectors as opposed to 28 (plus HFC-23 by-production) by *Schwarz et al.* Regarding a phasedown option, *ERIE/Armines* conclude that it "seems to be an effective measure to reduce significantly the climate impact of refrigeration, air-conditioning and heat pump equipment [..]".

***Table 1:** Environmental impacts of policy options in 2030 compared to baseline (Option A)*

	Option B **VA**	**Option C** **Extend Scope**	**Option D** **Phasedown**	**Option E** **Bans**
Direct emission changes in [Mt CO_2eq]	- 21.7	- 1.4	- 69.2	- 52.7
Additional emissions from replacement substances [Mt CO_2eq]	+ 0.02	not occurring	+ 0.14	+ 0.1
Additional indirect emissions due to energy-efficiency [Mt CO_2eq]	- 0.51	not occurring	higher efficiency for refrigeration -1.6	higher efficiency for refrigeration - 0.72
SUM [Mt CO_2eq]	**- 22.2**	**- 1.4**	**- 70.7**	**- 53.3**
Emission reduction in 2030 compared to 2005	-10%	+13%	-63%	-44%
Ecotoxicity	low risk	not applicable	low risk	low risk

6.1.3. Ecotoxicity

As regards ecotoxicity, F-Gases and other replacement substances (or their decomposition products) used in abatement technologies could potentially damage the environment if released to the atmosphere in large quantities. HFCs have long atmospheric lifetimes of up to 250 years but eventually decompose in the troposphere to yield hydrofluoric acid (HF) and trifluoroacetic acid (TFA) which are washed out by rainwater. PFCs and SF_6 are even more persistent (several 1000 – 50,000 years) and do not decompose, but are eventually photolysed in the mesosphere.[4] The release of HF and TFA could cause acidification of ecosystems, in particular aqueous ecosystems, as they impact pH values. Among the natural alternatives, hydrocarbon (HCs) emissions could potentially lead to ground level ozone and formation of photochemical smog. Ammonia which is toxic to humans contributes to acidification of ground and aquatic systems.

In the examined policy scenarios, Option B would lead to the formation of small quantities of HF and TFA in the atmosphere. Options D and E would in addition cause the release of hydrocarbons (HC-290, HC-600a), ethanol, and ammonia. Highest emissions from replacement substances would be expected for Option D and were estimated as 6800t HCs, 890t ammonia and 10.300t of unsaturated HFCs, mostly from potential use in refrigeration and AC in 2030. It must be borne in mind that the use of replacement substances reduces the amount of HFC in the atmosphere (and resulting long-term breakdown products). From a purely ecotoxicological point of view, the release of natural replacement substances (HCs, ammonia, ethanol, CO_2,..) to the atmosphere is preferable to the release of HFCs as they occur naturally in much larger concentrations than would be released under any of the options. But also atmospheric concentrations of HFCs are in the parts-per-trillion range which is far below effective ecotoxic levels.[4] **Ecotoxicity effects are therefore assumed to be low for all options, based on state-of-the-art knowledge.**[51,52]

6.2. Economic impacts

Fig. 7 shows that F-Gas emission reductions of ca. 72 Mt CO_2eq could be achieved at marginal costs often far below 50€ per t CO_2eq. Beyond this level there are few other additional possible emission reductions considering only technologies available today. These findings are based on a very comprehensive analysis of replacebility of F-Gases in all main application sectors based on available technologies that are safe and energy-efficient. Detailed data and analysis covering each individual sector is available in Schwarz et al.[9] The discussion in this section profits from this analysis (most relevant

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51 The highest concern is for TFA due to its persistence and mild phytotoxicity. A recent study has shown that TFA concentrations in rainwater in Europe may rise in the future but would in the worst case still be at least a magnitude lower than observed no-effect levels on organisms.[52] Compared to the latter study's assumptions (a total conversion of the European automobile fleet to use an unsaturated HFC that readily decomposes to TFA), future TFA production from all the policy options discussed in this document would be low. Nonetheless, the future use of unsaturated HFCs should be closely monitored.

52 *Henne et al. (2012)*. "Future Emissions and Atmospheric Fate of HFC-1234yf from Mobile Air Conditioners in Europe". Environmental Science & Technology 46: 1650-1658.

background data from the latter study is summarised in e.g. Annexes IV, V, VI, VIII, and XVI of this document).

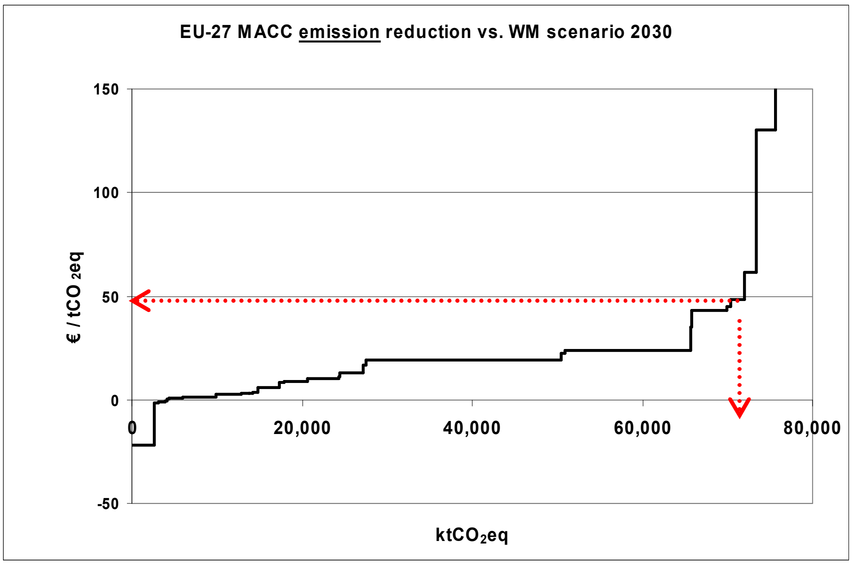

Fig. 7: Marginal emission abatement costs vs. achievable emission reductions by 2030. Source: *Schwarz et al. (2011)*[9] (MACC: Marginal Abatement Cost Curve, WM scenario = Option A). Costs are in € at 2010 levels.

6.2.1. Abatement costs and direct costs to industry

The following key **direct economic impacts** were analysed in a quantitative way for the reference year 2030 in comparison to the baseline scenario (Option A) for subsectors affected by each of the options (see details in Annex VI):

(1) **Abatement costs** for F-Gas emissions (€ per t CO_2eq, assessed for the sector-typical F-Gas reference systems and the most promising (safe) alternative technologies). The considered parameters are:

- Emissions: GWP of substance, charge (amount) of substance used, emission factor for use-phase and disposal, manufacturing emission factor (e.g. for production of foam);
- Energy consumption: e.g. refrigerating capacity, installed electric power, annual running time;
- Cost: investment cost of equipment and of first substance fill, price of substance per kg, price of energy per kWh, equipment lifetime, discount rate.

The **average abatement costs** per t CO_2eq in 2030 for the three policy options with significant emission reduction effects (B, D and E) are very similar (see Table 2). The **marginal costs** are somewhat higher for Option D at €49/t CO2eq but consistent with the projected marginal abatement costs for the implementation of GHG mitigation policies and measures in 2030, namely 50€ / t CO_2. For Option C, average and marginal abatement costs are identical (one sector) and amount to €46/t CO_2eq. **All options are therefore considered cost-efficient.** This finding also holds for higher discount rates or lower prices of F-Gases (see sensitivity analysis in Annex VIII).

(2) **Total** (annualised) net **costs to industry** (€ per year); these include:

– Capital investment costs: These costs include capital investments (as well as interest payments) to install new equipment or to modify a production facility (in the time from 2015 to 2030);

– Operating and maintenance costs: These costs include costs to operate and maintain the equipment as well as changes in all other input costs, e.g. service costs for leakage checks, refill, and energy.

The total net costs to sectors are highest for Option D (1,500 M€/year), due to the largest number of sectors affected, closely followed by Option E (1,330 M€/year) and are smaller for Option B (530 M€/year) and C (66 M€/year) (see Table 2). The individual costs per (sub-) sector vary considerably (see also 6.2.2).

Costs were calculated on an annual basis, using a general discount rate of 4% and product specific lifetimes varying between 10 and 30 years.

***Table 2**: Comparison of direct cost impacts in 2030*

	Unit	Option B VA	Option C Extend Scope	Option D Phasedown	Option E Bans
Average abatement costs in 2030	**€ / t CO_2eq**	17	46	16	17
Marginal abatement costs	**€ / t CO_2eq**	24	46	49	24
Total direct net costs to industry sectors	**M€ / year**	527 (from -0,1 to 417 per sub-sector)	66	1,499 (from -66 to +489 per sub-sector)	1286 (from -5 to +489 per sub-sector)

Source: Schwarz et al. (2011)[9], Table 8-24 and Table 8-25.[53] All costs in € at 2010 levels.

6.2.2. Impacts on sectors

According to Table 3, the direct net costs differ widely for the different subsectors affected by Options B, D and E (Option C only includes one sector). A large part of the costs occurs in commercial refrigeration (commercial hermetics, condensing units and centralized systems (option B, D and E).

***Table 3:** Additional annual cost by sector in 2030*

[53] Option D was recalculated to take account of measures on pre-charged equipment.

	B	C	D	E
Domestic Refrigeration	0	0	0	0
Commercial refrigeration:				
Commercial hermetics	0	0	0	-5
Condensing units	105	0	105	276
Centralized systems	417	0	417	380
Industrial Refrigeration:				
Industrial Ref small	0	0	-1	0
Industrial Ref large	0	0	-66	-5
Transport refrigeration:				
Refrigerated Vans	0	0	21	0
Refrigerated Trucks	0	0	17	1
Fishing vessels	0	0	2	0
Transport AC:				
Cargo ship AC	0	0	6	0
Passenger ship AC	0	0	3	0
Bus AC	0	0	107	0
Truck AC	0	66	244	0
Moveable AC systems	0	0	2	19
Stationary AC:				
Split AC systems	0	0	489	489
Multi-split AC systems	0	0	54	46
Rooftop AC systems	0	0	12	12
Chillers	0	0	36	33
Centrifugal chillers	0	0	1	0
Fire protection:				
Fire protection 227ea	0	0	11	0
Fire protection 23	3	0	3	3
Aerosols	0	0	36	36
Foam blowing:				
XPS-152a	0	0	-1	0
XPS-134a	1	0	1	1
PU other	0	0	0	0
Other: HFC-23 by-product	1	0	0	1
SUM	**527**	**66**	**1499**	**1286**

For Option D, transport AC (trucks and buses) is also important as well as stationary AC (i.e. single-split AC). Under this option, the five subsectors with the highest net costs account for almost 90% of the costs arising in all 25 subsectors affected. Low direct net costs occur for abatement in the remaining sectors (see Annex VI for detailed data on costs per sector). A detailed assessment of the impacts of these costs on turnover and competiveness for the most important sectors is given in section 6.2.6.

– **Direct impacts**

Key economic effects have been assessed comprehensively using two models: To analyse the direct (and indirect) effects on output resulting from changes in costs or investment, an Input-Output model framework (i.e. the *EmIO-F Europe* model, see model description in Annex IX) was used. *EmIO-F Europe* can give a basic assessment of the effect of the additional burden a policy or measure may impose on the economy. Secondly, a general equilibrium model (*GEM-E3*) was used to complement the analysis (see model description in Annex XIV). A comparative description of the latter two models is given in Annex XV. Based on these models, **impacts for the F-Gas application sectors are expected to be small at less than 0.6% of total output in all cases** (Fig. 8, Annex XIV). A sensitivity analysis was carried out and is elaborated in Annex VIII. The result was that even under conditions of a discount rate of 8% (instead of 4%) or halved prices for unsaturated HFCs, cost-efficiency and environmental effectiveness of all policy options B, D and E are not distorted significantly.

At a more detailed level, the Input-Output model shows that direct effects within each application sector may occur in four main areas of commercial activity: (1) equipment manufacturing, (2) supply of chemicals (i.e. F-Gases or replacement substances), (3) services and maintenance, and (4) energy supply (i.e. electricity).

(1) Equipment manufacturing:

As a starting point manufactures of the affected appliances are, in general, facing growing markets e.g. for AC or refrigeration equipment. Option B, D and E would impact on the choice of substance used in the production of a growing number of appliances and may therefore require higher investment costs. Given that the direct impact in all sectors is small, it can be expected that costs per unit will also be relatively small. The analysis with the I/O model assumed that costs can be passed on to consumers without affecting sales (additional investments). Hence, **equipment suppliers would be able to increase their sales due to higher prices (related to the higher investment costs of the equipment).** An analysis based on abatement costs derived with the *AnaFgas* model (*Schwarz et al.*, 2011[9]) shows that **Option D yields the highest sales** as it affects the highest number of appliances. Consequently, effects for Options E, B (and C) are lower, in this order, as fewer sectors are affected (see Table 4). In Section 6.2.6 the assumption on passing on costs is examined further. That section looks at the increase in annual costs and the elasticity of demand for the major pieces of equipment covering more than 90% of the costs. It shows that the overall annual costs increases are small (around 1 to 2 %) and demand for the goods is rather inelastic. Consequently, the expected increases in sales in Table 4 (and output) may be overestimated by around 1%.

Table 4: *Comparison of the net additional sales of domestic suppliers of equipment (M€ / year)*

	Unit	Option B	Option C	Option D	Option E
Additional sales of domestic equipment suppliers	**M€/year**	1,610	Not applicable	3,040	2,060

Source: *Annex VI Table A_VI-2 based on Table 8.24 in Schwarz et al. (2011)[9] with additional adjustments*

Fig. 8 gives the *EmIO-F Europe* model outcome for the direct output effects as a result of the different F-Gas policy options. In line with the discussion above, the model shows higher outputs for the machinery and equipment sector for all options. Highest outputs were modelled for Option D (+0.52%), followed by Option B (+0.32%) and Option E (+0.23%)[54].

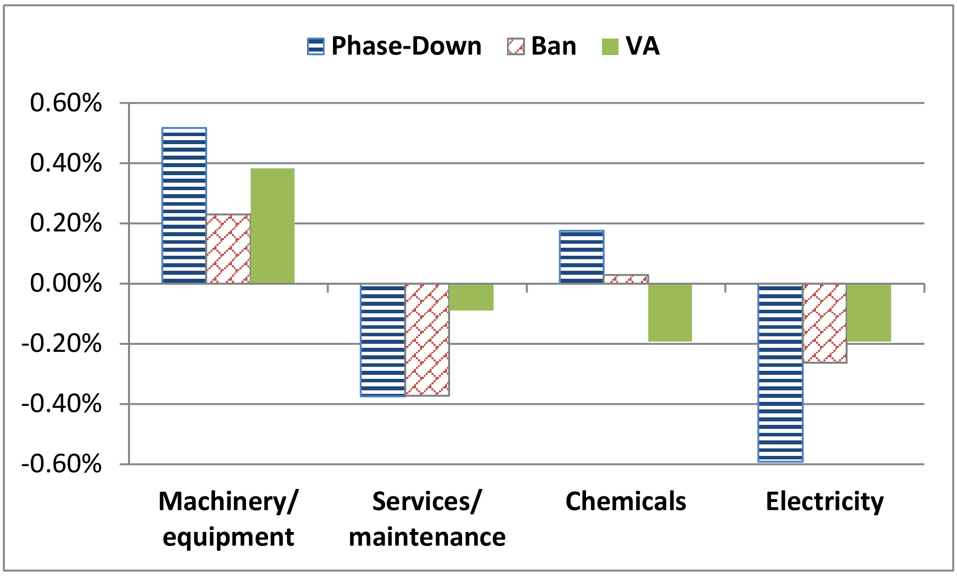

Fig. 8: Effects on output of directly impacted activities, derived with *EMIO-F Europe* (as % of 2007 output; Phasedown = Option D, Ban = Option E, VA = Option B)

These positive impacts on the equipment sector are confirmed by *GEM-E3* (see Annex XIV). Potential advantages for EU manufacturers in terms of additional exports, having a strong position on the market for alternative technologies, are not captured by the models used and are difficult to quantify at the present stage. **In conclusion, manufacturers of equipment can expect to profit from policy options B, D and E, with strongest effects expected from a phasedown measure (Option D).**

54 Option C was not analysed with the model as effects are limited to one application sector only and hence very small for all activity areas

(2) Services/Maintenance:

For service and maintenance companies some losses may be expected due to reduced service needs for F-Gas equipment (Table 5). Options B, D and E focus on replacing HFCs with a high GWP as opposed to Option C and the current F-Gas Regulation, the latter having a strong focus on improved leakage detection and recovery at the end of the life. However, alternative technology using high pressure or flammable substances also require maintenance. Overall, the net effect on the service sector is estimated based on AnaFGas (*Schwarz et al.,* 2011[9]) to be negative in the long run for those policy options that favour most strongly the use of alternative substances (in particular Option D and E; see Table 5).

Table 5: *Comparison of losses from ceased service under Art. 3 and 4 F-Gas Regulation in the long run (M€ / year)*

	Unit	Option B	Option C	Option D	Option E
Losses (-) from ceased service under Art 3+4	**M€/year**	-290	70	-1,280	-1,270

Source: *Schwarz et al. (2011)[9] as well as Annex VI*

Results of the *EmIO-F Europe* model also show that service companies experience (small) negative effects, which are most pronounced for Option D (-0.38%) and E (-0.37%), and less for Option B (-0.09%) (see Fig. 8).

However, these effects may still be overestimated since the baseline assumes full application of the existing legal obligations. In reality, these obligations have not yet been fully applied since implementation and awareness among users are delayed[8]. Moreover, apparently the European Air-Conditioning, Refrigeration and Heat Pump Contractors (AREA) are keen on exploiting the new business opportunities linked to alternatives. In an internal survey[55] they conclude that there is a potential risk of shortage of contractors trained in the use of low GWP refrigerants and advises compulsory training based on harmonised minimum requirements.

In conclusion, maintenance needs due to the existing F-Gas Regulation might decrease, in particular, for the most effective options, phasedown (D) and bans (E), but the effects on relevant companies are expected to be small.

(3) Supply of chemicals:

The replacement of HFCs with low-GWP substances would result in a shift in the sales of F-Gas producers and distributors. Producers and distributors of low-GWP substances are not always the same as those of HFCs. Current F-Gas producing companies in the EU (7-10 in total) are large chemical companies which have production sites distributed

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55 AREA internal survey. "*RACHP contractors' training in the use of low GWP refrigerants*". March 2012.

globally. In the transition from producing high GWP substances to low GWP substances, the impacts will depend on the ability of some producers to benefit more from the HFC replacements through the development of alternative substances than their competitors. As there are several replacement substances (currently two unsaturated HFCs, as well as mixtures of HFCs, hydrocarbons, CO_2 and ammonia) and since all major producers are already developing low GWP replacement substances, a situation in which only a few producers benefit from the lower HFC consumption is unlikely to occur. Current F-Gas producers would likely be the distributors of unsaturated HFCs which are expected to contribute most to the turnover of F-Gas producers and distributors, as a result of the comparably high prices of these chemicals.

The *EmIO-F Europe* model gives small net effects on the output of the chemicals sector for all options (Fig. 8). A small positive effect (0.17 %) is obtained in case of a phasedown (Option D), almost no effect in case of bans (Option E: +0.03%) and a negative impact in case of voluntary agreements (Option B: -0,19%). The *GEM-E3* model suggests small negative impacts on output for Option D and E for the chemical sector (see Table 6 and Annex XIV). Domestic production decreases slightly as it is substituted by imports. In the case of passing on costs to end-users, the price of chemical products further increases and hence production decreases further. Actual effects are likely to be even smaller (and could be even positive) as imports of F-Gases are already addressed in Option D which is not reflected by the model. **In summary, effects on the chemical sector are expected to be small for all options.**

Table 6: *Chemical Production compared to the Baseline in 2030 (% change)*

	Option D	**Option E**
1. Option D	-0.13	-0.06
2. Option D with costs pass-on	-0.35	-0.22

Source: GEM-E3 (see Annex XIV for details)

(4) Energy supply:

The output of this sector is affected by the changes in electricity consumption for new technologies. The model *EMIO-F Europe* forecasts an output reduction of -0.59% for Option D, -0.26% for Option E, and -0.19% for Option B (Fig. 8). This output reduction is explained by a reduced electricity demand (and further emission saving, see also Table 1) of replacement technologies. The effect is highest for Option D as this option stimulates replacement in most sectors, followed by E and B. Several stakeholders in the on-line survey similarly expected that end-users would profit from reduced electricity consumption. The negative impact of Option D and E is confirmed by *GEM-E3*. **In conclusion, electricity demand will decrease, in particular for Option D, and will lead to small output reductions in this area.**

– **Indirect impacts**

Since equipment manufacturers are expected to pass on costs to consumers, the industrial users of such equipment, e.g. supermarkets and the food and drink manufacturing industry, could be indirectly affected by potentially higher investment costs and changes in annual operating costs for new equipment. The difference in annualized net costs for operators investing in new equipment based on alternative technologies range widely. Considerable annualised savings were estimated for new investments in large industrial refrigeration (€ -22,642) which is affected by Option D and E and in many other subsectors new investments would incur only small direct costs for the operators. The highest costs (€ 2,876) for operators were estimated for new centralised commercial systems (supermarkets), affected by Options B, D and E (see Annex VI, Table A_VI-1).

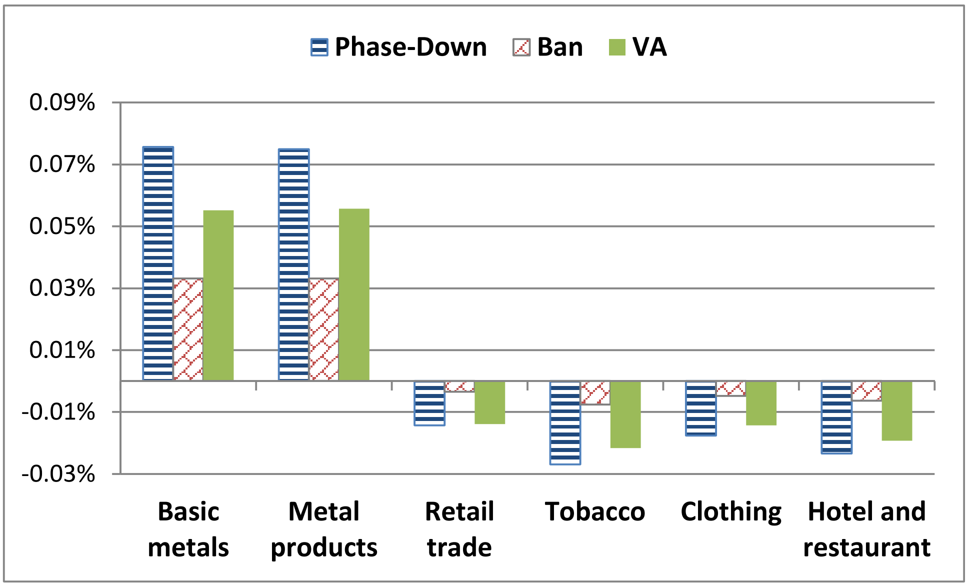

Fig. 9: Effects on output of selected, indirectly impacted sectors determined with *EmIO-F Europe* (% of 2007 sector output; Phasedown = Option D, Ban = Option E, VA (voluntary agreement = Option B)

Fig. 9 displays the impact on selected sectors that are indirectly affected, as obtained with the model *EmIO-F Europe*. The indirect effects range from **small but positive effects on sectors that deliver inputs to the machinery and equipment sector** (e.g. basic metals, metal products) **to very small but negative effects on sectors providing services or products** to final consumers (e.g. retail, clothing, luxury consumption such as tobacco, hotels & restaurants etc.). The latter effects are explained by the fact that consumers would have less money in their pockets to spend on services and end-products, if higher prices of F-Gas equipment are passed on to them. These effects are observed for all Options B, D and E, but are generally most pronounced for Option D, followed by B and E. The reduced consumption pattern leads to a very small reduction in aggregate output of -0.011% in case of Option B, -0.014% in output for the case of Option D, and -0.004% in case of Option E. Results in Fig. 9 assume that additional costs for equipment would reduce final demand for all goods and services (e.g. food, textiles, furniture, restaurants,..) proportionally. *GEM-E3* confirms the positive impacts for the metals sectors (Option D and E) and shows neutral to positive effects for the consumer goods sectors (see Annex XIV). Given that the sales for new equipment might be overestimated (due to the negative impact of price increases on demand) the indirect reduction in demand for other goods might be somewhat smaller.

– **Total impact from both direct and indirect effects**

Overall, the total effect on output based on direct and indirect effects across all sectors is very small. *EmIO-F Europe* predicts a slightly positive effect at 0.006%, 0.009%, and 0.003% for Options B, D and E, respectively (based on Fig. 8 and Fig. 9), while slightly negative (-0.006 for Option D to -0.003 for Option E) are obtained with *GEM-E3* (see Table 10 below).

For clarity and as a number of different industrial players may be affected by the F-Gas policy options as outlined above, the following Table 7 gives a qualitative overview over the most important actors and the impacts they may experience, summarizing the discussions above. For most players, impacts would be small and nobody is expected to lose out significantly, as demand for equipment will rise and not decline. However, actors will have to adjust to the new situation, e.g. retailers would see a shift towards selling more equipment with low GWP substances. Most market players have experienced a similar transition already under the Montreal ODS phase-out, which was achieved successfully and 10 years faster than required in the EU, so they are expected to adapt quickly also to a use reduction of F-Gases, as soon as a clear regulatory signal is set. It is clear that producers of alternative equipment would be the big winners, fostering the growth of green companies, many of which are SMEs similar to what has been observed in some Member States (e.g. DK, AU) where there is more stringent F-Gas legislation already.

Table 7: *Overview of expected impacts of different market players: scales reach from very high positive impacts (+++) to very high negative impacts (---)*

	Impact due to policy options	**Types of company**	**Estimated Impact**
Producers of F-Gases (chemical industry)	direct	7-10 large, globally acting companies	0 *(see 6.2.2, Fig. 8, Table 6)*
Producers of equipment overall (manufacturers)	direct	large and small companies	0/+ *(see 6.2.2, Fig. 8, Table 4)*
Producers of alternative equipment	direct	many SMEs	+++ *(see e.g. 6.2.9)*
Electricity production	direct	large companies	- *(see 6.2.2, Fig. 8)*
Service companies	direct	many SMEs	0/- *(see 6.2.2, Fig. 8, Table 5, 6.2.10, Annex III, Annex VI)*

Importers of equipment	direct	large and small companies	0/- *(see e.g. 6.2.6)*
Exporters of equipment	direct	large and small companies	0/- *(see 6.2.6, Table 12)*
Users of equipment	indirect	large companies, SMEs, microenterprises, consumers	0 *(see 6.2.2, 6.2.6, 6.2.10, Fig. 9, Table 11)*
Retail sectors	indirect	large and small companies	0/- (see 6.2.2, Fig. 9)
Input sectors (Basic metals, metal products)	indirect	large and small companies	0/+ (see 6.2.2, Fig. 9)

6.2.3. Administrative costs

The definition of administrative costs refers to the costs incurred by enterprises, public authorities or citizens in meeting legal obligations to provide information on their actions or production. Information is used in a broad sense to cover labelling, reporting, registration, monitoring and assessment needed to provide information as well as the transfer of information to public authorities. Administrative costs are the sum of business-as-usual costs (costs that would still be incurred if the legislation were to be removed) and administrative burden (incurred due to the legislation). In the following the given costs are on top of costs currently resulting from the monitoring and reporting under the existing F-Gas Regulation, which remain the same for all considered policy options. Table 8 provides an overview of the total additional administrative costs for the policy options (details in Annex XII and XIII). It shows that **administrative costs are small in general**, as they represent only a small percentage of the direct costs to industry, ranging between <0.1% (Options C, D & E) and 2% (Option B).

Table 8: *Administrative costs of the policy options*

	Option B	Option C	Option D	Option E
Total administrative costs [million € / year]	10.7	0	0.2	1.2
Total one-off administrative costs [million €]			1.9	

– Option B

Significantly higher administrative costs were determined for Option B compared to the other policy options. While this may seem surprising at first glance, it results from the fact that

(i) only additional reporting costs are included in the calculations, i.e. on top of existing reporting under the F-Gas Regulation which addresses the bulk of reporting needs of the other options;

(ii) it was considered that voluntary agreements should have quantified and staged objectives and should include a monitoring and reporting system for achieving the objectives, following the recommendations of a pertinent EC communication[56];

(iii) the number of participating companies to experience an additional administrative burden would be large, e.g. the number of individual companies in the commercial refrigeration sector would cover more than 1000 undertakings (see Annex XII); and

(iv) approximately 75% of the estimated annual cost of 10.7 million €/year for Option B are due to independent verification of reported HFC use. Without the independent verification of the reported information, the administrative burden for this option would amount to 2.9 million €/ year.

– Option C

No additional information requirements would occur and hence no additional administrative burden was estimated.

– Option D

The main additional costs for reporting and verification would be incurred by producers and importers of bulk HFCs, meaning ca. 80 companies. The administrative costs for all companies participating in a phasedown mechanism are estimated at €227,000 per year. In addition, one-off costs of 1.9 million Euros are estimated, 90% of which arise from the independent verification of baseline reports.

– Option E

For bans, the administration for companies is rather simple[57] and not a lot of new and additional information is needed. It would, however, require additional administrative costs for audits or inspections by competent authorities in Member States. A total amount of 1.2 million €/year was estimated as the additional administrative burden, 73% of which arise from the audits/inspections conducted on companies by national administrations. This is an important difference to Option B and D, where additional costs would be borne mostly by companies.

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56 Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions: Environmental Agreements at Community Level - Within the Framework of the Action Plan on the Simplification and Improvement of the Regulatory Environment. COM(2002) 412 final of 17.7.2002.

57 In case exemptions to the bans should be foreseen in the implementation, this would probably involve extensive procedures to define and apply for such exemptions. However such procedures do not need to be accounted for in the assessment of administrative costs.

Stakeholders in the on-line consultation saw no large differences between options as regards the administrative burden, but regarded Option D as somewhat less burdensome. Stakeholders also pointed out repeatedly that the additional burden would be small in sectors where reporting already exists (due to the F-Gas Regulation).

6.2.4. Impacts on regions

In the major (sub-)sectors that include domestic refrigeration, commercial refrigeration, transport refrigeration, mobile AC as well as aerosols, a large number of units would be affected by the policy options. As this type of equipment is distributed relatively evenly between Member States, **investments in replacement technologies in these sub-sectors would therefore also be distributed evenly without a regional concentration.** On the other hand, stationary AC units as well as AC systems in buses are more frequently used in warmer Mediterranean climates in the Southern Member States than in the temperate climate in the North. For these subsectors, direct net costs will be 34% higher in Southern Europe than the EU average due to the higher number of installed equipment per inhabitant (Table 9). **This cost effect is observed for Options D and E and would be about 1€ / person, hence relatively small.** Some of the remaining sub-sectors concern only a few installations where there will be only some limited effects as these sectors are very specialised.

Table 9: *Direct net cost effects for AC systems per 1000 persons and sector (€ / 1000 inhabitants)*

	New Split AC	New Bus AC	Other sectors	TOTAL	% of EU average
EU 27 average	940	206	1737	2883	100
Southern EU[58]	1893	239	1737	3868	134
Northern EU	494	191	1737	2422	84

GDP effects were calculated with the macro-economic *GEM-E3* model (see Annex XIV for details). The scenario modelled with *GEM-E3* focuses on the phasedown (Option D) and bans (Option E) only as these options include the highest number of sectors, implying that all other policy options would show smaller effects. Table 10 indicates that in 2030 the **net GDP effects are very small for the EU27 (for Option D and E) but somewhat higher for Southern European countries** (all countries bordering the Mediterranean Sea) assuming an allocation of rights to place on the market through grandfathering (scenario 1 in Table 10). If costs are fully passed on into higher prices for the consumer, the difference between EU and the EU South in terms of GDP losses could be slightly higher (scenario 2, Table 10). The impacts might even be more positive both in the EU27 and the EU South since the *GEM-E3* model does not include

58 Southern EU: Bulgaria, Cyprus, Greece, Italy, Malta, Portugal, Romania, Spain
Northern EU: Rest of EU 27

the importers of F-Gases in the analysis and hence the small negative impacts on GDP are overestimated. Hence, the impact on GDP is generally very small and differences between the EU and the EU-South are small as well (see Annex XIV for details.) Thus, in summary, **even if some regional effects are inherent in the proposed policy options, the economic impacts are very small and will not have significant large effects on certain regions in the EU**.

Table 10: *GDP effects for the EU27 as a whole and Southern Europe in 2030 (% change) for Options D and E (% change)*

	Option D		**Option E**	
	EU27	EU South	EU27	EU South
1. free allocation (grandfathering)	-0.006	-0.008	-0.003	-0.003
2. costs pass-on	-0.012	-0.016	-0.007	-0.009

Source: GEM-E3 (see Annex XIV for details)

6.2.5. Impacts on the functioning of the internal market and competition

For all policy options, the rules will be applicable in the same way to all undertakings in the EU so that a distortion of the internal market is not given. Given that for most appliances several alternatives can be used, a limitation on the use of F-Gases is in general not expected to limit competition in any significant way. In the case of the phasedown (Option D), market players are assigned rights to place on the market (POM) based on past outputs. For new entrants to the market a reserve of rights to POM is implemented, so that competition is similarly safeguarded.

6.2.6. Impacts on competitiveness, trade and investment flows

As regards competitiveness, direct impacts on costs across all F-Gas application sectors are expected to be small for all policy options compared to total output since costs increases are small compared to business-as-usual Moreover, Option B, D and E are designed in a way where domestic producers and importers of appliances will face the same conditions for placing products on the market and hence EU producers of F-Gases and F-Gas equipment will, even though costs may increase, not be put at a disadvantage which could harm their international competitiveness. Furthermore, the activity of servicing/maintenance is not subject to international competition.

However, if Option D did not include measures to target imported substances in pre-charged equipment, only domestically produced products would be affected by the cap which would represent a competitive disadvantage for equipment producers. Such a concern was expressed by companies and industry associations in the stakeholder survey. Sectors of concern would predominantly be stationary AC systems[59] and to a lesser degree AC systems of imported vehicles. The numbers of producers, importers and exporters of pre-charged equipment can be estimated as shown in Annex X. The measures on pre-charged equipment, namely the requirement to fill on site, would treat domestically produced and imported equipment in the same way. Claims that such a requirement would lead to higher production costs for foreign manufacturers are unfounded. According to expert estimates additional costs would be in the order of €0.50 per unit produced in the worst case.[60]

Exports of products and equipment containing HFCs are only relevant in a few (sub)-sectors: mobile ACs (motor vehicles), MDIs (Metered Dose Inhalers: 50% of demand exported) as well as XPS foam insulation boards (20% of demand exported; compare Table A_X-3/4 in Annex X). HFCs used in this equipment are put on the market in the EU and would therefore fall under the phasedown, which may lead to higher costs. In the automotive sector a shift to low GWP substances is already on-going due to the MAC Directive and extra costs compared to the product (vehicle) price are small.

Whether trade flows will change depends, in general, on the different abilities to produce products relying on alternative technologies. Option D, E and B will create an EU demand that spurs development of alternative technologies to a varying extent, with the phasedown having the highest potential to enhance the demand-driven capacity to innovate. Many stakeholders in the on-line consultation and stakeholder conference pointed out that an EU pioneering role for alternatives could result in a competitive "first mover"-advantage for European companies at the international level, if a global agreement to phase out F-Gases is reached. Many of those industrial stakeholders who expressed concerns on competitiveness due to unilateral EU action preferred a phasedown measure (Option D) over bans (Option E) due to its flexibility (Annex II).

However, since it is not *a priori* clear that costs can be passed on to the user, it is appropriate to also look at the possible effects of costs on the expected increase in demand (and sales) from the affected products. The increase in (annualised) costs for the operators investing in **new equipment** based on alternative technologies has been compared with the annualised costs (of using the specific technology) under the baseline for those eight subsectors that are faced with the highest absolute costs or have a big share in the investments (See Annex VI for details). Table 11 shows the increase in total annual costs. Differences between the policy options[61] are apparently small. The expected annualised increase in investment and operation costs of new equipment is highest for centralised systems of commercial refrigeration and lowest for industrial refrigeration (with expected decreases). For all the other sectors overall costs and total costs are small. These increases in costs may have some effect on the expected increase in demand (sales) for the affected products (see Annex VI, Table A_VI-2). Evidence

59 Ca. 3.5 million units sold in the EU in 2008, projected to be 10.4 million units in 2030

60 Personal communication from Oeko-Recherche

61 Option C affects only one sector.

shows that the elasticity of demand (for AC and refrigeration) is rather small (-0.37)[62]; e.g. an increase in expected cost of multi-split AC of 1.6% may therefore lead only to a direct reduction in demand of -0.6%. Hence, this indirect impact of costs increase on the expected increase in demand for equipment will also be rather small. By way of example, under Option D sales of centralised commercial refrigeration systems would increase by 774 million per year (see Annex XVII). As a result of the annual cost (and price) increase, demand might drop and the increase sales might not increase by 774 million, but only by 760 million for that sector (See Annex XVII). In the worst case the expected increase in sales (and investments) for all sectors addressed could be up to 1% smaller than the increase in output expected because some consumers will refrain from buying the new equipment.

A second issue is the impact of the additional costs for those sectors that are buying the new equipment. The sectors that use commercial refrigeration see their costs increase by up to 4.8% in the case of centralised systems. The refrigeration costs are however only part of the total costs for these companies and can be distributed over a large range of products (e.g. in the case of supermarkets), so the costs increase will be very small. The sectors that use industrial refrigeration experience a decrease in the costs (up to 1.4%) which will decrease their total costs to some degree with positive impacts on output. Stakeholders in this area, e.g. FoodDrinkEurope, only wanted to be reassured that there will be no forced replacement of existing equipment. Replacement of end-of-life equipment by alternative equipment was not considered a problem. None of the policy options entail bans on the use of existing HFC appliances and hence will not force users to scrap equipment before its end of life. Large supermarket chains are already making voluntary efforts to introduce alternatives at large scales.[34] For the other selected subsectors, the additional costs linked to new investments are between -1.4 and 2% of the costs associated with the baseline F-Gas equipment. It is apparent that even for those sectors with additional costs at the high end, the additional costs per unit compared to baseline unit costs remain low and **impacts on end-users are therefore expected to be rather small.**

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[62] DOE (2004). Appendix 10 A. Relative price elasticity of demand for appliances. (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/home_appliances_tsd/appendix_10a.pdf.). Department of Energy, Washington. Based on: Golder,O and G. Tellis (1998) Beyond diffusion: an affordability model of the growth of new consumer durables, Journal of Forecasting, 17, pp 259-280 and D. Revelt and K. Train (1997) Mixed logit with repeated choices: household choices of appliances efficiency level, Review of economics and statistics (July).

Table 11: *Average change in annualized costs for operators investing in new equipment compared to the baseline scenario (Option A: % change)*

	B	C	D	E
Condensing units commercial refrigeration	0.9	n/a	0.9	0.9
Centralized Systems commercial refrigeration	4.7	n/a	4.8	4.7
Bus AC	n/a	n/a	2.1	n/a
Trucks and trailers AC	n/a	1.2*	0.1	0.0
Single-split Room AC	n/a	n/a	1.6	1.6
Multi-split AC	0.0	0.0	0.8	0.0
Industrial refrigeration large	0.0	0.0	-1.4	-1.4
Chillers	0.0	0.0	0.4	0.4

Source: Annex VI and Schwarz et al. 2011 (p. 243-272)[9]. Costs include capital costs, interest costs as well as all other costs (costs linked to containment and recovery provisions only)*

The impacts on competitiveness (i.e. on output and trade (imports and exports)) have also been analysed with the GEM-E3 model for Options D and E, which entail the highest costs. Table 12 summarises the results per economic sector.[63] Impacts are generally very small, with highest effects in the range of -0.13 and -0.16 for production and exports in the chemical sector under Option D. Effects on imports are even smaller (see Annex XIV for details). Based on the model, **the impacts on output and trade are therefore expected to be small, with negative or positive effects depending on the sector.**

[63] The modelled scenario assumes that costs of the right to use F-gases are allocated for free and their (opportunity) costs are not passed on to the final price. Other scenarios were also modelled (see Annex XIV).

Table 12: *Impacts on production and exports per sector for Options D and E in 2030 (% change compared to baseline)*

	Production		**Exports**	
OPTION	D	E	D	E
Agriculture	0.01	0.01	0.03	0.03
Chemical	-0.13	-0.06	-0.16	-0.07
Coal	-0.01	-0.01	0.07	0.08
Construction	0.01	0.00	0.01	0.01
Consumer goods	0.01	0.00	0.02	0.01
Electric Goods	0.04	0.02	0.03	0.01
Electricity	-0.01	-0.01	0.01	0.01
Energy Intensive	0.00	0.00	0.01	0.01
Gas	0.01	0.00	0.05	0.02
Market services	0.00	0.00	0.02	0.01
Metals	0.02	0.01	0.02	0.01
Non-market services	0.00	0.00	0.03	0.01
Oil	0.00	0.00	0.02	0.01
Other equipment	0.02	0.02	0.03	0.01
Transport	0.00	0.00	0.01	0.00
Transport Equipment	0.02	0.01	0.02	0.01

Source: GEM-E3

6.2.7. Third countries and international relations

At international level measures on the reduction of F-Gas emissions, in particular HFCs are being considered. The initiative to control HFCs under the Montreal Protocol has so far not been successful, even though already in 2010 more than 108 Parties to the Montreal Protocol expressed support for this approach.[64]

All options for the reduction of HFC emissions would demonstrate the determination of the EU to tackle increasing F-Gas emissions. The underlying analysis, which demonstrates that the use of HFC alternatives is technically feasible and cost-efficient, will strengthen the EU position in further negotiations on an international agreement on

[64] Annex III to the Report of the Twenty-Second Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, Bangkok, November 2010. ozone.unep.org/Meeting_Documents/mop/22mop/MOP-22-9E.pdf

HFCs. The adoption of a phasedown (Option D) and of bans (Option E) would create a substantial market for low-GWP technologies and thus incentivise the development of such technologies also in exporting third countries. It can be expected that these market opportunities will also result in higher penetration rates of such technologies in non-EU countries, even if these countries do not support binding commitments through an international agreement at the present stage.

Bans on certain new applications (Option E) apply equally to domestically produced and imported products and equipment. Nevertheless, some third country producers have voiced that they would consider bans to be *de facto* discriminatory vis-à-vis imports because those producers would not set-up a new production line to serve the EU Market only. The complementary measures on certain equipment pre-charged with HFC (part of Option D) addresses imports as well. The proposed measures have, therefore, to be notified under the TBT (Agreement on Technical Barriers to Trade).

6.2.8. Impacts on consumer prices

Effects on consumer prices depend on the extent that producers or retailers pass through any additional costs they may experience. Potential effects on consumer prices can easily be categorised based on abatement costs. Those measures that exhibit negative abatement costs (see Annex VI) can be assumed to impose no or positive (through reduced prices) effects on consumers. Table 11 shows the increase in annualized costs for the consumer for the most affected products in case costs would be fully passed through. Higher costs of equipment are to a large degree compensated by decreased operating costs. Costs of domestic refrigeration are hardly affected (€0.004/year for option D) and annual costs of AC (single-split, multi-split or chillers) might increase by 0.4 to 1.6%. **It can therefore be expected that the effect on specific as well as general consumer prices will remain small for all policy options**. This is confirmed by the *GEM-E3* results which suggest a macroeconomic price effect between -0.01% to +0.00% for Options D and E depending on cost pass-through.

6.2.9. Impacts on innovation and research

Legislation could drive innovation, economic development and green jobs in Europe. By way of example, Denmark has successfully supported alternatives backed up by strict national F-Gas legislation and has seen important increases in the use of natural refrigerants in RAC equipment. While market shares of e.g. commercial and industrial refrigeration equipment using natural alternatives are still low today in Europe, market prospects in Europe as seen by industry are very good in the field.[65]

Options B, D and E promote the use of alternative substances and technologies. Therefore, these policy options would stimulate research and development and facilitate the development and dissemination of new production methods, technologies and products. **These effects would be largest for Option D, followed by Options E and B.** Option E provides binding legal requirements driving the innovation process just like Option D but would affect a smaller number of sectors. In Option B the driver for

[65] Shecco (2012). "*GUIDE 2012: Natural Refrigerants – Market Growth for Europe*". guide.shecco.com

innovation is based only on voluntary commitments and less sectors would be covered, so a smaller effect than for D and E is expected. Option C, the improvement of the F-Gas Regulation does not require new technologies and innovations to the extent that Options B, D and E do and would therefore have only minor positive impacts on innovation and research.

6.2.10. Impacts on small and medium enterprises (SMEs: see also Annex III)

The companies currently placing F-Gases on the EU market and reporting under the F-Gas regulation were classified based on the number of employees and the annual turnover. As a result, 36% of the affected companies are large, 15% medium, and 26% small enterprises (for 23% data found was not sufficient to fully categorize their status). Producers of F-Gases are almost exclusively large companies, while wholesalers, distributors, import/export companies and service companies are often SMEs. SMEs and microenterprises are also found as operators/end-users of relevant equipment, e.g. in the food and drink industry.

Many SMEs in the F-Gas sector are **wholesalers** who would be less affected by additional substantive costs because policy Options B, C, D and E do not require adaption of their service delivery processes in a substantial way. In addition, SMEs placing on the market only small quantities of HFCs benefit from the foreseen minimum thresholds for the application of the phasedown mechanism under Option D. On the other hand, Option E would affect importers of foreign equipment relying strongly on F-Gases, as pointed out at the stakeholder meeting and the on-line consultation. Option D would provide more flexibility to allow foreign producers to adapt, and thus would be preferable to Option E for SME importers.

As for **producers of equipment** it should be emphasised that a strengthened policy approach (in particular Options D and E) would provide opportunities for small innovative companies. Denmark has successfully supported alternatives by national legislative measures and support to R&D and thus stimulated market growth of Danish SMEs in the sector.[7, 66]

As for **companies servicing F-Gas equipment**, the effects explained above (6.2.2) will also affect small enterprises as demand for the enhanced maintenance requirements under the F-Gas regulation should decline in the long run when less F-Gases would be used in equipment. However, at least in the medium term this should not be noticeable to service companies as the containment obligations stemming from the existing F-Gas Regulation are only slowly being fully understood and implemented on the ground by affected companies, leaving a lot of growth potential for the service sector in this field. Furthermore, the inclusion of additional sectors in existing maintenance requirements should create additional demand for servicing companies just as novel equipment using alternatives will create new service and maintenance needs, in particular for substances

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66 Founded at the same time as the entry into force of the Danish ban on certain HFC uses, a Danish start-up, founded by 2 persons in 2006, succeeded in becoming a leading brand for CO_2 refrigeration technology.

that are flammable and/or used at high pressures. Making best use of such opportunities will however require initial investments in particular with regard to training.[67] Finally, service companies which have limited their business activities to leak checking and recovery usually are also involved in the installation of new equipment and its on-site construction (and would profit from the latter activities under a strengthened approach, in particular if on-site filling is prescribed). In summary, even though F-Gas servicing needs due to the existing Regulation would decline in particular for the most effective policy options, SMEs in the service sector will experience new business opportunities under a strengthened approach (i.e. in particular D and E), so that they are not expected to suffer any significant negative consequences.

As for SMEs in sectors that might be **indirectly affected** (as suppliers or sellers of products/services to end-users, e.g. foodstuff, clothing, gastronomy,..), the discussion in 6.2.2 (and Fig. 9) showed that such effects are very small overall, with some sectors providing input to the machinery and equipment sector affected positively, while very small negative effects on the products-for-endusers sectors could occur. All policy options aim at reducing the use of F-Gases with high GWP in new equipment and **do not force the replacement of old equipment**. Hence, SMEs would not be burdened with any new costs for replacing existing equipment. This is particularly relevant for the competitiveness of SMEs and microenterprises in the food-and-drink industry.[68]

Options B and D would impose a (small) additional **administrative burden** on companies for the verification of the reported information (see 6.2.3). It is the intention to introduce quantitative thresholds similar as is the case for reporting requirements to protect small companies, especially microenterprises.

6.3. Social impacts

In the following impacts on employment and safety, occupational and health risks are presented. All other types of social impacts, including rights related to job quality, social inclusion of particular groups, gender issues, governance issues, access to justice of media, crime and security, culture or social protection are not affected by any of the proposed policy options.

6.3.1. Employment impacts and labour market

Net employment effects of the policy options were analysed in detail including:

(1) Direct employment effects at the level of regulator or regulated entities;

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67 AREA, the European organisation of refrigeration, AC and heatpump contractors, who represent ca. 9000 servicing companies that are mostly SMEs and micro-enterprises, is already working on guidance documents and qualification requirements related to the use of low GWP refrigerants. www.area-eur.be/_Rainbow/Documents/AREA%20-%20PP%20Low%20GWP%20refrigerants%20(110629).pdf

68 There are 274,000 food and drink companies in Europe, 99.1% of which are SMEs. SMEs also accounted for 48.7% of turnover and 63% of employment in the food and drink industry in 2010.

(2) Indirect employment effects that occur further up the production chain as a result of the increased investment activity in specific sectors or economic areas;

(3) Employment effects induced through demand shifts that i) occur to finance the investments (demand reduction) or ii) result from revenue recycling, e.g. increased government expenditure (demand increase).

In the following, employment effects of Options B (voluntary agreements), D (phasedown) and E (bans) are compared. Option C was not analysed in detail because its limited scope means that costs are very small and employment effects therefore negligible. Based on the *EmIO-F Europe* Input-Output model (see Annex IX) and EU27 employment data for 2007, the effect of additional investments, reduced running costs and consumer reaction on employment was estimated. Fig. 10 shows employment effects for those activity areas directly impacted by the change in F-Gas policy. The effects are in line with the output effects discussed previously (6.2.2). As most of the change in activity is related to additional investment in machinery and equipment, the (positive) effect is most pronounced in this area. On the other hand, the model predicts negative effects for services and maintenance. The overall effect on service companies is, however, likely to be more balanced (see discussion in 6.2.2). Electricity demand is lower for new equipment, hence a negative effect on employment in this area is observed. The same is true for the chemicals sector which shows positive but rather small effects. For Option D, the effects are more pronounced (both positive and negative) than for the other two options, as more sectors are involved, with a small overall positive benefit on employment. As discussed before the impacts on sales (and investments) might be somewhat smaller (1%) if costs are passed through in prices and lower sales of equipment, e.g. the total effect for machinery (option D) would not be 0.3%, but only 0.297%.

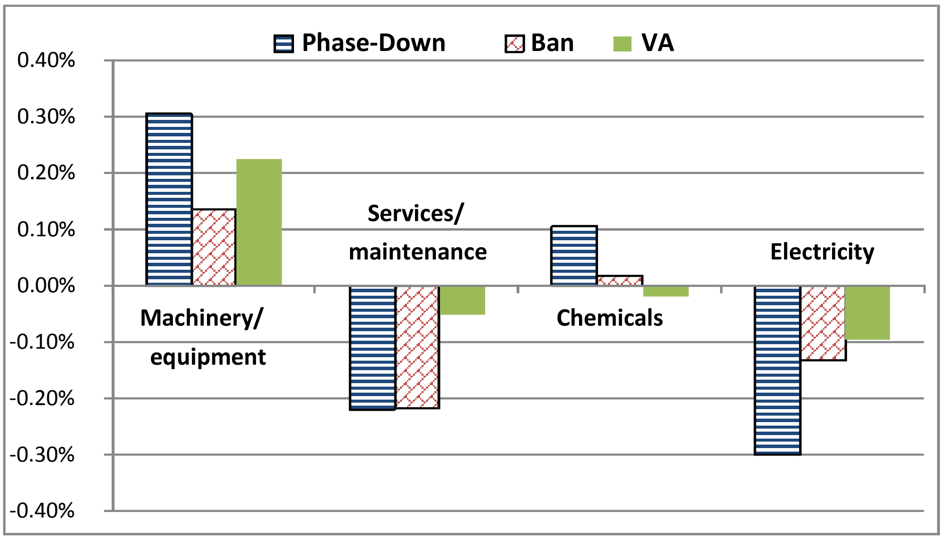

Fig. 10: Employment effects for activity areas in directly impacted sectors (% of 2007 sector employment) based on EmIO-F Europe

Fig. 11 details employment effects based on *EmIO-F Europe* for selected, indirectly affected sectors. Positive effects occur for those sectors providing inputs for production to the machinery/equipment sector (basic metals and metal products), while small negative effects occur in the retail and consumer goods sectors due to the reduced demand by consumers.

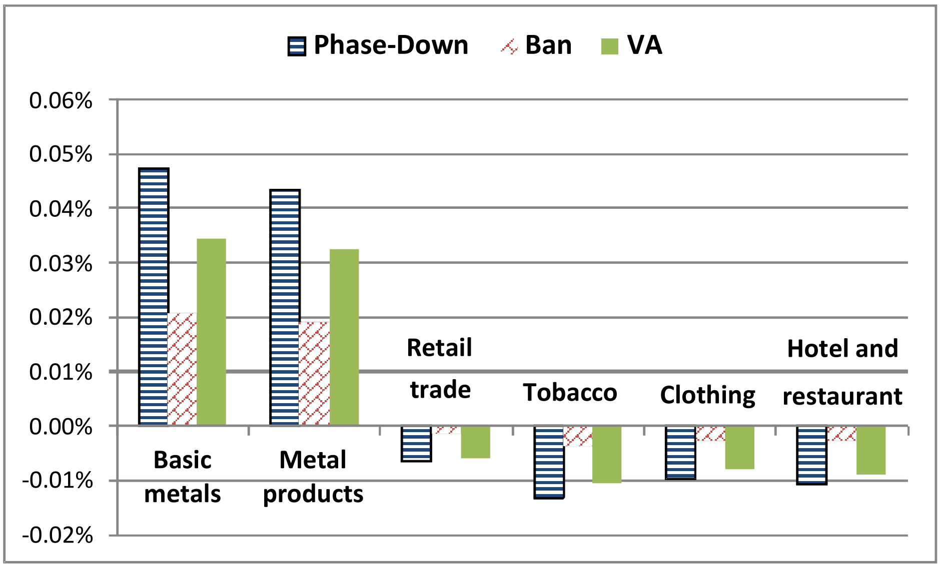

Fig. 11: Employment effects on selected, indirectly impacted sectors (as % of 2007 sector employment), based on *EmIO-F Europe*

Fig. 12 summarises direct and indirect employment effects for policy Options B, D and E in terms of number of jobs created, based on *EmIO-F Europe*. All sectors related to investment expenditures will experience a stimulus, while ongoing expenditure would be reduced and thus affect employment negatively, and consumer reaction might lead to less sales due to higher prices. In total, Option D would have a net total positive effect on employment of around 7180 jobs, Option E would have a net effect of 3740 and Option B would create around 630 net jobs. The net effect on employment are small positive effects in case of Option D and to a lesser degree, for Option E, while almost no effect is observed for Option B.

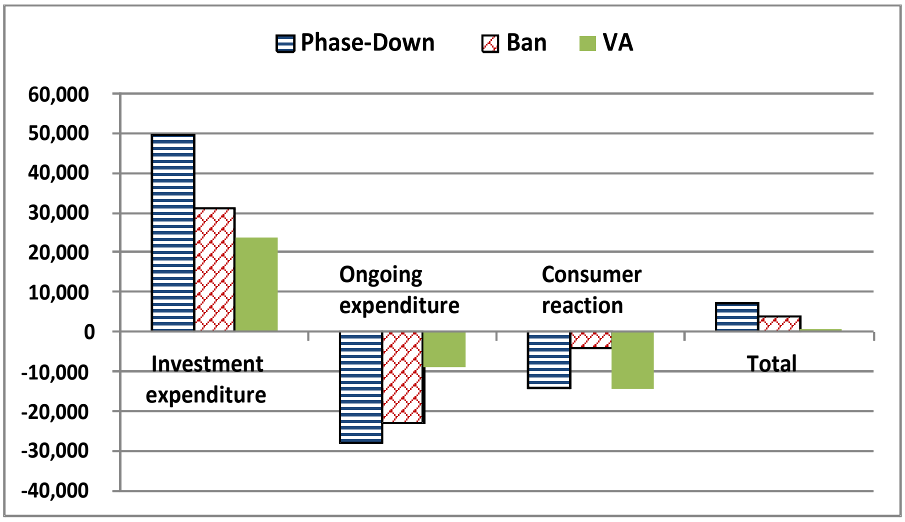

Fig. 12: Effect on employment (number of employees), *EmIO-F Europe* model

For comparison, employment impacts for Option D and E have also been estimated with the macro-economic *GEM-E3* model (Annex XIV) for Option D and E. The results differ somewhat from EmIO-F: 1600 jobs could be lost by Option D; in case costs are passed on to consumers the net employment would decrease further to -15,800 jobs (In case rights to use F-gases would be auctioned and revenues used to cut labour costs impacts would be positive: +5400 jobs) Option E would have similar, but smaller impacts of -1,000 to -11,600 in case of costs pass-on (and +4000 in case of auctioning) Since *GEM-E3* does not account for the fact that F-Gas imports are addressed by measures, the impacts shown are likely to be overestimated. Overall, both models agree on the magnitude of effects, which are in the order of several thousand jobs created or lost. By comparison, these numbers are small compared to the total number of jobs in 2030 (some 231 million jobs in the EU as a whole), representing a maximum effect of -0.007% in the worst case.

In conclusion, both models predict **small effects in the order of up to several thousand jobs in case of a strengthened F-Gas Regulation, an effect that is highest for the phasedown mechanism (Option D).**

6.3.2. Safety, occupational and health risks

Many substances used in abatement technologies are flammable and therefore constitute a potential occupational hazard. Hydrocarbon (HC) refrigerants such as already commonly used in private fridges are classified as highly flammable and unsaturated HFC refrigerants which are also likely to be used as substitutes for HFCs have recently been classified as "mildly flammable" [69]. This classification also applies to ammonia

[69] The unsaturated HFC-1234ze, which is considered not only a possible alternative refrigerant (for centrifugal chillers) and aerosol propellant but also an alternative blowing agent for XPS foam, is not flammable at room temperature (<30°C). However, the process temperature on foam blowing is significantly higher than 30°C so that adequate safety measures must be taken in the factory, comparable to those when hydrocarbons/organic solvents are used.

(NH_3) and e.g. HFC-32. Some substances are toxic (NH_3), and some are operated at high pressures (CO_2).

The feasibility analysis of replacement substances for the different application sectors carried out by *Schwarz et al. (2011)*[9] which forms the basis for the effectiveness and efficiency assessment of the policy options is based on the precondition that only proven and safe (and energy-efficient) alternative technologies should be deployed. For this reason **health and occupational risks for alternatives as a result of the policy options are not expected to be high**, as long as safety standards and procedures are followed. Even though no comprehensive data to quantify the increased health risks due to the use of flammable HCs or highly pressurised CO_2 and NH_3 systems at larger scale seems to be available, the use in some sectors such as commercial and industrial refrigeration is already widespread in Europe without giving rise to a high number of accidents.

Halogen-free alternatives such as propane, butane (HCs), CO_2 received a more favourable toxicological rating than F-Gases and pose no health risks to employees if regulations are observed. Given proper handling, NH_3 is also an acceptable alternative substance for refrigeration purposes.[4] Product design must take the flammability or pressure needs into account, e.g. combustible substances are contained in enclosed or encapsulated explosion-proof systems only. Health risks from flammable substances for non-professionals are met by technical safety standards and safety installations (charge limits in occupied spaces, operation in indirect mode for higher charges, etc.). Health risks for professionals as a result of improper handling or installation cannot be fully ruled out but can be minimised by appropriate training and education, which is obligatory for persons who come into contact with dangerous substances, and is prescribed by existing legislation (F-Gas Regulation). It is considered to include in the legal proposal the need for training requirements for certified personnel handling alternatives in order to further minimise any safety risks. The costs for training and education are already included in the investment costs of equipment, which is based on alternative technologies such as HCs, ammonia or CO_2. Stakeholders pointed out during the consultation that different safety standards and regulations in Member States should be harmonised in order to minimise risks but also to avoid that different standards remain a barrier to innovative solutions and internal trade.

7. COMPARING THE OPTIONS

Table 13 compares the most important impact parameters for all policy options vs. the baseline (Option A).

Option D, the HFC phasedown mechanism complemented by measures on pre-charged equipment **achieves the highest environmental effectiveness**, i.e. the fastest and largest replacement of HFCs with high GWP. Options E also achieves considerable emission savings albeit significantly lower than Option D, while Option B and C achieve much less emission reductions altogether.

Table 13: *Summary table of environmental, economic and social impacts of the policy options*

IMPACTS	***Option B*** Vas	***Option C*** Enlarged Scope	***Option D*** Phasedown	***Option E*** Bans
ENVIRONMENTAL				
Emission Reductions SUM [Mt CO_2eq]	22.2	1.4	70.7	53.3
Ecotoxicological Relevance	low risk	negligible	low risk	low risk
ECONOMIC				
Average abatement costs [€/t CO_2eq]	17	46	16	17
Total direct costs [(M€/year]	527	66	1,499	1,286
Administrative costs [M€/year]	10.7	0	0.2 (+ 1.9 one-off)	1.2
Direct effects on sector output [% of 2007, I/O model]	0.006	negligible	0.009	0.003
- machinery/ equipment	0.38	negligible	0.52	0.23
- services/ maintenance	-0.09	negligible	-0.38	-0.37
- chemicals	-0,19	negligible	0.17	0.03
- electricity	-0.19	negligible	-0.59	-0.26
GDP impacts (% change, *GEM-E3* model)	smaller than D	negligible	-0.006	-0.003
Impacts Regions	negligible	negligible	small effects on EU South	smaller than D
Impacts SMEs	no significant effects	negligible	no significant effects	no significant effects
Internal market	none	none	none	None
Competiveness, trade & investment	small	negligible	small positive for alternatives	Small positive for alternatives
Third countries	negligible	negligible	incentivises alternatives globally	incentivises alternatives globally
Consumer prices	negligible	negligible	negligible	negligible
Innovation & research	facilitates to low degree new technologies	negligible	facilitates new technologies and products	facilitates new technologies and products
SOCIAL				
Employment: impact in 2030 [No. of jobs]	+600	negligible	-16,000 to +7,000	-12,000 to +4,000
Safety & health risks	negligible	negligible	negligible	negligible

All policy options achieve their respective emission reductions cost-efficiently, i.e. at abatement costs below 50€ / t CO_2eq.

Economic impacts on GDP, employment, industry sectors, regions, etc. are low in general. Due to the higher use of replacement substances in Option D the total direct costs are highest, but lead to stronger positive sectoral effects in some areas (machinery and equipment) but small negative effects in others (services and energy). SMEs are not expected to face considerable negative effects, but for Options D and E there is a small effect on Southern European countries. **Options D and E are the only options that will strongly stimulate innovation and market uptake of green technologies**.

Additionally, **administrative costs are relatively low** for all options, but highest for Option B mostly due to the need for additional verified reporting by a high number of companies affected.

The qualitative ranking in Table 14 below further summarises environmental, economic and social effects, using 0 for neutral effects, +/++/+++ for positive impacts and –/--/--- for costs and negative impacts. For the economic impacts mainly the abatement costs, the administrative costs and effects on output were considered for the ranking. This table clearly indicates the most positive total impact of **policy option D**, the HFC phasedown mechanism complemented with measures on pre-charged equipment.

Only Option D is fully effective as regards the objectives, as only this option would make a sufficiently large contribution in emissions reductions to the low carbon roadmap at the levels needed to take overall cost-efficient mitigative action (see Table 14). This is achieved at levels that are considered cost-efficient (at < €50 / tonne CO_2) according to the Roadmap. Option D also stimulates innovation and comes at a low cost to the economy and society as a whole while giving flexibility to industry. **It is therefore the only policy option that is coherent with the objectives.**

Table 14: *Ranking of policy options*

IMPACTS	***Option B*** **VA's**	***Option C*** **Enlarged scope**	***Option D*** **Phasedown**	***Option E*** **Bans**
ENVIRONMENTAL	+	**0**	+++	++
ECONOMIC	**0**	**0**	**0**	**0**
SOCIAL	**0**	**0**	**0**	**0**
Cost-Effective Contribution to Roadmap	No (emission reductions only capture 30% of cost-effective actions)	No (emission reductions negligible)	Yes (all emission reductions up to cost-efficient level captured)	No (emission reductions only capture 75% of cost-effective actions

As set out in section 5.6, all policy options are not mutually exclusive. By way of example, Option C is complementary to all the other policy options and could therefore be implemented alongside e.g. Option D. Some bans in Option E are also complementary to Option D, e.g. if they concern F-Gases not covered by the phasedown (SF_6 in magnesium die casting) and the mandatory destruction of HFC-23, or could be implemented alongside to address low-hanging fruits in sectors where the use of alternatives is already commonplace, i.e. domestic and commercial refrigeration.

In this way, Option D implemented together with Option C, as well as complementary bans on emissive uses of SF6, mandatory destruction of HFC-23 by-production, together with action on domestic and commercial refrigeration would achieve an emission reduction of ca. 72 Mt CO_2eq. All economic and social effects would for all practical purposes be identical to Option D, as this option alone addresses the vast majority of sectors and applications of such a package.

Stakeholders including many industrial umbrella groups have also to a large degree expressed their preference for a package of measures at the stakeholder conference meeting and as a main element would prefer a phasedown, as opposed to use bans (Annex II).

8. MONITORING AND EVALUATION

The main objective is to reduce emissions and deliver a fair, cost-efficient contribution from the F-Gas sector to mitigative action, e.g. the Low Carbon Roadmap. Effectiveness of the chosen policy option as regards emissions can be closely followed in the future through the reporting of GHG emissions by Member States to the UNFCCC[70] and the EU Monitoring Mechnism[71], which includes emission data on F-Gases.

Furthermore, the baseline (Option A) allows the annual collection of data on bulk F-Gases in the EU due to existing reporting requirements in the current F-Gas Regulation[2]. These obligations apply to companies producing, importing or exporting F-Gas quantities and preparations >1 tonne and reports are to be submitted annually to the EC and the competent authorities of the Member State concerned. Data is currently available for the years 2007-2010.

This existing reporting scheme under the F-Gas Regulation is generally suitable for retrospectively verifying the bulk F-Gas quantities placed on the EU market and also provides important data for an effective monitoring and evaluation of the policy options discussed. Additional monitoring and reporting needs arise in the following areas to ensure the evaluation of the effectiveness of the implemented F-Gas policies as well as coherence with possible international obligations:

70 unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php

71 Decision 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.

- Extend coverage of substances (to meet international developments and include unsaturated HFCs)

- Extend the company reporting requirements to quantities contained in imported or exported pre-charged products and equipment (needed for implementing Option D or E)

- Complement the one tonne threshold for company reporting with a GWP-based *de minimis* rule (for implementing Option D) of 1,000 t CO_2eq per year (on average similar in magnitude to the one tonne threshold which already applies under the current regulation[72])

- Introduce reporting obligations for reclamation and destruction of F-Gases by specialised facilities to fully monitor recovered HFC quantities from reuse/recycling or reclamation

- Additional reporting for exporters in an EU phasedown mechanism (Option D)

- Improve reporting systems which Member States need to calculate emission data under Art. 6(4) of the F-Gas Regulation

- Independent verification of company reports on POM to assure accuracy (Option D)

Based on the reporting data alongside the UNFCCC emissions data, progress on emission reductions, the use of individual substances and the introduction of alternatives, the performance of policies and their environmental impact can be calculated in the future. A review clause would be appropriate to take account of new technical developments, while at the same time safeguarding planning certainty for industry.[73]

[72] The abolition of the threshold had been considered but was discarded in *Schwarz et al. 2011* as the impact on the accuracy of reporting was found to be negligible and would not justify the additional administrative burden.

[73] F-Gas producers indicated that lead times of 10 years are needed for an adequate planning process.

ANNEX I: Glossary of Terms

AC	Air conditioning
AnaFgas	Analysis of Fluorinated GHGs in EU-27 (bottom-up stock model to derive demand and emission scenarios for F-Gases in relevant sectors and sub-sectors for the EU-27) (see Annex IV)
CFCs	Chlorofluorocarbons (belong to ODS)
COP	Conference of parties
CO_2eq	CO_2 equivalents
COM	European Commission
CN	Combined Nomenclature
CRF	Common reporting format (UNFCCC)
EC	European Commission
EEA	European Environment Agency
EmIO-F (Europe)	Employment Input-Output Model for Analysis of Policies and Measures for the European Union (see Annex IX and XV)
ETS	Emission Trading System
FAR	Fourth IPCC Assessment Report
F-Gases	Fluorinated Gases: HFCs, PFCs and SF_6
GEM-E3	macro-economic general equilibrium model (see Annex XIV and XV)
GHG	Greenhouse gases
GWP	Global warming potential
HCs	Hydrocarbons, e.g. propane, butane
HCFCs	Hydrochlorofluorocarbons (belong to ODS)
HF	Hydrofluoric acid
HFCs	Hydrofluorocarbons (belong to F-Gases)
HFC-23	Trifluoromethane

HS code	Harmonized System code
IPCC	International Panel on Climate Change
LULUCF	Land Use/Land Use Change/Forestry
MAC Directive	Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC
MDI	Metered Dose Inhaler
Mg	Magnesium
MS	Member State(s)
NF_3	Nitrogentrifluoride
NH_3	Ammonia
OCF	One-component foams
ODS	Ozone-depleting substances: e.g. CFCs, HCFCs, Halons
ORC	Organic Rankine Cycle
PFCs	Perfluorocarbons (belong to F-Gases)
POM	Placing on the market
PU	Polyurethane
RAC	refrigeration and AC equipment (includes heatpumps)
SAR	Second IPCC Assessment Report
SF_6	Sulphurhexafluoride (belongs to F-Gases)
SME	Small and medium enterprise
SO_2F_2	Sulfurylfluoride
TAR	Third IPCC Assessment Report
TBT	Agreement on Technical Barriers to Trade
TFA	Trifluoric Acetic Acid
UNFCCC	United Nations Framework Convention on Climate Change

(M)t CO_2eq	(million) tonnes CO_2 equivalents
VA(s)	Voluntary agreement(s)
WAM	Emission scenario for EU if F-Gas legislation is strengthened
WM	Emission scenario for EU if current F-Gas legislation is maintained unchanged (= baseline Option A)
WOM	(Hypothetical) emission scenario for EU in the case that no EU F-Gas legislation existed
WTO	World Trade Organisation
XPS	Extruded Polystyrene

ANNEX II: Stakeholder Consultations

1. CONFERENCE REPORT ON STAKEHOLDER MEETING IN BRUSSELS, 13 FEBRUARY 2012

1.1. Conference Objectives

The meeting aimed at informing stakeholders about first results of the online stakeholder consultation, as well as options for future action. A second objective was to provide a platform for an open exchange of views with stakeholders to conclude the consultation process.

1.2. Summary of Presentations and Interventions

– **Presentations**

Consultants from Öko-Recherche presented their preparatory study for the review of the Regulation on certain fluorinated gases (F-Gas Regulation), focusing in particular on the feasibility and cost-effectiveness of alternatives in different sectors, and calculating future penetration rates for these alternatives. They also screened the most promising policy options in terms of effectiveness of emission reductions, cost efficiency, energy efficiency, technical constraints and other criteria such as coherence with other policies. The highest emission reduction potential was achievable by limiting the amounts of F-Gases placed on the market ("phasedown"), followed by bans and by voluntary agreements.

Subsequently, DG CLIMA presented the Commission's review report (COM (2011) 581) of 26 September 2011, which assessed the current state of implementation of the F-Gas Regulation, its impacts and long-term adequacy of reducing the climate effects due to F-Gas emissions. Some shortcomings in the implementation of the Regulation were highlighted. A full implementation could enable a stabilisation of F-Gas emissions at today's levels. In view of the climate goals and a growing feasibility of replacing F-Gases in many sectors with alternatives, further cost-effective reductions of greenhouse gas emissions were justified. Potentially, up to 2/3 of today's emissions could be eliminated in the EU by 2030.

DG CLIMA presented initial results from the online stakeholder consultation that took place from September to December 2011. 261 stakeholders replied to this questionnaire of which 77% came from the industrial sectors. Almost all stakeholders agreed there was a need for further action on F-Gases compared to the status quo and over 40% of respondents also considered further legislative action to be necessary. Many suggestions for improving containment were also made. On the question of the most adequate policy approaches there were quite divergent views and sectoral differences. In addition, some industry respondents expressed concerns as regards their competitiveness, while manufacturers of equipment using alternatives, administrations, NGOs and many individuals saw concrete benefits in a shift away from F-Gases, especially for fast movers.

DG CLIMA then presented the current state of play regarding the reflections on potential EU action in the field of F-Gases in order to reach the EU climate goals in a cost-effective way. The Commission was currently assessing further the environmental, economic and social impacts of major policy options such as voluntary agreements, improving containment, progressively limiting the supply of F-Gases ("phasedown"), and possible bans on the use of F-Gases in certain applications. These options were being considered on top of a full application of the existing F-Gas Regulation. Given the need to address different F-Gases, different uses and varying availability of alternatives as well as old and new equipment and products, a mix of policy measures appeared necessary. The Commission planed to adopt a legislative proposal in the second half of 2012.

– **Discussion and Comments**

Stakeholders were invited to provide feedback, in particular, on what package of F-Gas measures could best meet the objective of contributing consistently and cost-effectively to the EU 2050 greenhouse gas emission reduction target.

Almost all stakeholders took the floor.

- A large majority of industry acknowledged the need for further EU action and preferred or could live with a phasedown option as it was considered to be more flexible than bans and would allow industry to adapt and continue using F-Gases in applications where this was considered to be the optimal solution. NGOs and a few industrial participants favoured bans where alternatives to F-Gases would lead to lower overall greenhouse gas emissions and NGOs saw a phasedown rather as a complementary measure to bans. Others, such as importers of equipment, pointed out that bans would be detrimental to their business. A few participants wanted to focus on containment only. Member States had no official positions yet, but indicated support for a phasedown measure.

- Many would also like to see action at the global level and encouraged the Commission to endeavour to get an agreement through the Montreal Protocol to avoid unfair competition and a need for product differentiation between the EU market and markets elsewhere.

- A need for a mix of policies was confirmed by many stakeholders.

Other comments mentioned by some stakeholders included:

- Full implementation and application of the current legislation should be ensured.

- Measures related to containment of F-Gases should be strengthened and the scope should be extended. Also, requirements regarding "end of life" treatment should be enhanced.

- The experiences with voluntary agreements were very mixed. Such agreements were favoured by some, whereas others did not consider them to be adequate and enforceable.

- A level playing field should be ensured. Consequently, the chosen mix of policies should affect imported products containing F-Gases to the same extent as products produced and used in the EU and it should not hamper export. It could be considered to tax gases in pre-charged equipment or require the installation of the gas to be done by certified personnel in the EU.

- It would be unfair to introduce bans on the use of F-Gases in products that could be substituted by products not subject to bans, e.g. banning F-Gases in certain foams while leaving other foams unregulated.

- Existing equipment should not be made redundant; therefore, it would be crucial that potential bans target only the use of F-Gases in new equipment.

- Product liability issues should be taken into account for alternative technologies that were e.g. flammable.

- Different safety and building codes across the EU represented barriers to the use of alternatives and EU harmonisation should be considered.

- Availability of F-Gases should be safeguarded for certain necessary uses in e.g. in fire protection and medical aerosols.

- Training and certification rules for personnel dealing with alternative technologies should be harmonised to ensure sufficiently trained contractors in order to enable uptake of alternatives and to limit distortion of competition.

- Alignment with other policies, e.g. requirements related to environmental performance of energy related products (ecodesign) and waste was essential. Impacts on energy efficiency should be further assessed, in particular for heat pumps.

- Sufficient time for transition and clear dates would be needed to enable industry to plan ahead.

- Effects on SMEs should be considered.

- Policy should promote a direct shift to natural refrigerants, while intermediate steps involving first a shift to F-Gases with a lower GWP and subsequently to natural refrigerants would be costly and should be avoided.

- To avoid use of SF6 in switchgear, the EU should ban the use in the future and at the same time jointly finance with industry R&D on alternative uses to SF6 in large switchgear since currently alternatives do not exist.

- HFC23 destruction should be made mandatory

The following questions were raised by stakeholders:

- *The findings of the Öko-Recherche study show a high feasibility to replace F-Gases with natural refrigerants. Why are F-Gases with low GWP not included as alternatives to a higher extend in the model?*

Öko-Recherche response: The EU objective is to reduce emissions cost effectively hence, where technically feasible and cost effective (costs lower than 50 € per CO2 equivalent in 2030) gases with no recorded GWP have been favoured, regardless of whether a shift to relatively low GWP F-Gases would be less costly. A study conducted by ERIE/Armines confirms the Öko-Recherche results and gives similar metric tonnes by 2030 for the main application sectors, but is more limited in its scope. Alternatives were only taken into account if they could at least meet the energy efficiency related to technologies using conventional F-Gases.

- *Are other studies also considered in the impact assessment?*

DG CLIMA response: The Öko-Recherche study is a comprehensive study covering all sectors and F-Gases and it provides a good basis to develop policies. In addition, studies made by ERIE/Armines in 2011 and the German Umweltbundesamt in 2010 as well as an upcoming study on "banks" by SKM/ENVIROS are taken into consideration. DG CLIMA would also welcome further input from projects announced by EPEE on a phasedown mechanism and by AREA on training requirements.

- *Have inadvertent emissions during production processes been considered in the study?*

Öko-Recherche response: No.

- *How would the trend for F-Gas projections be iF-Gases covered by the F-Gas Regulation alone and disregarding the MAC Directive?*

DG CLIMA response: The projected F-Gas emissions that are regulated by the F-Gas Regulation alone would increase in the future if no further action is taken.

- *Does the Commission have good experiences with voluntary agreements?*

DG CLIMA response: The voluntary agreements in this context are non-regulatory voluntary agreements between industry players. The experiences with that type of voluntary agreements appear to be mixed. The semiconductor industry's agreement to reduce perfluorocarbons has lead to a reduction in greenhouse gas emissions.

- *Will there be set-asides for necessary uses in e.g. fire protection and medical aerosols?*

DG CLIMA response: Needs for F-Gases where no cost efficient alternative exists are taken carefully into consideration.

- *Are taxes considered at EU level?*

DG CLIMA response: EU-harmonised taxes requiring unanimity in the Council and covering so many different sectors are difficult to establish at an optimal level and it is difficult to foresee the resulting emission reductions. By introducing e.g. cap under a "phasedown" the outcome is assured. Hence, at this stage an EU harmonised tax is not considered as a relevant option, however, Member States could introduce taxes on F-Gases.

- *Will training measures be included into the Regulation?*

DG CLIMA response: The Commission is considering all options including possible measures related to training.

- *How will pre-charged equipment be handled?*

DG CLIMA response: We are looking into this with a view to ensure a consistent approach to reduce emissions and a level playing field for producers inside and outside the EU.

- *Will the impact assessment be made public?*

DG CLIMA response: Yes, when the Commission adopts a legislative proposal it will be accompanied by an impact assessment in the form of a staff working paper.

1.3. Concluding remarks

DG CLIMA thanked participants for the comments made at the meeting and during the online stakeholder consultation and underlined that the comments were very useful for the further work on the impact assessment and the legislative proposal.

DG CLIMA noted that proper implementation of existing legislation was crucial and that Member States had been asked to step up their efforts. The meeting had revealed a large consensus on the need for further EU legislative action and a preference for a "phasedown" mechanism as a key driver while noting that a phasedown can be designed in many ways. Also, given the complexity of the subject a mix of measures would be appropriate. Moreover, many had flagged the need to work towards a global phasedown under the Montreal Protocol. Finally, many called for more harmonisation of, in particular, safety requirements.

DG CLIMA mentioned that this conference was seen as the last step in a long consultation process with stakeholders which started in 2010 with an expert stakeholder group following the preparatory study by Öko-Recherche, included the 3-month online stakeholder consultation as well as this open stakeholder conference. DG CLIMA would further analyse all the contributions obtained and thoroughly examine the impacts of different policy options and work on the legislative proposal foreseen later in 2012.

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1.4. Agenda of meeting

STAKEHOLDER MEETING

On a Review of

REGULATION (EC) NO 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL "ON CERTAIN FLUORINATED GREENHOUSE GASS"

Monday 13 February 2012 – 10:00 / 17:00 HOURS

Room 0A, Centre de Conference Albert Borschette, Rue Froissart 36, B-1049 BRUSSELS

1. **Opening**

2. **Presentation by Öko-Recherche GmbH of the Preparatory study for a Review of the Regulation on certain fluorinated greenhouse gass (Regulation (EC) No 842/2006)**

   - Questions and clarifications

3. **Presentation by DG CLIMA of the Commission Report on the application, effects and adequacy of the Regulation on certain fluorinated greenhouse gass (Regulation (EC) No 842/2006)); COM(2011) 581 final**

   - Questions and clarifications

4. **Presentation by DG CLIMA of the results of the online stakeholder consultation on reducing fluorinated greenhouse gas emissions**

   - Questions and clarifications

5. **Introduction by DG CLIMA of policy options to achieve cost-effective reductions of fluorinated greenhouse gas emissions**

   - Exchange of views and statements

6. **Closing**

1.5. Registered Participants

	Surname	First name	
Mr	BECKER	Malte	Electrolux Home Products Corporation N.V.
Mr	TARABBIA	Christian	Whirlpool EMEA
Mr	D'HAESE	Alain	European Aerosol Federation (FEA)
Ms	FOURNEAU	Virginie	Dehon Group
Mr	LELIÉVRE-DAMIT	Alain	Climalife - dehon group
Ms	MARTIN	Delphine	Climalife - dehon group
Mr	KUNZE	Peter	ACEA - European Automobile Manufacturers Association
Mr	ELDER	Alan	EUROFEU
Mr	CAMERON	Alasdair	Environmental Investigation Agency
Mr	LARSSON	Tove	FoodDrinkEurope
Mr	REESON	Stephen	FoodDrinkEurope
Ms	PAPAZAHARIOU	Christiana	LG Electronics France
Mr	HWANG	Herman	LG Electronics France
Mr	SCUMPIERU	Mihai	Mitsubishi Electric AC Systems Europe Ltd
Mr	LOWRIE	Richard	Mitsubishi Electric AC Systems Europe Ltd
Mr	NICOLLE	Darcy	AmCham EU
Mr	COWPERTHWAITE	Stephen	UK - DEFRA
Mr	ANDERSEN	Jacob	UK - DEFRA
Mr	WÖHRL	Stefan	German Association of the Automotive Industry
Mr	MESSNER	Kevin	Association of home appliance Manufacturers (AHAM)
Mr	HOOGKAMER	Joop	EUROVENT

Ms	DHONT	Hilde	Daikin Europe N.V.
Mr	DIERYCKX	Martin	Daikin Europe N.V.
Ms	FLRTCHER	Rory	ASSURE Secretariat
Mr	THIE	Stefan	JBCE
Mr	BAUMBACH	Frank	MAC Partners Europe
Mr	DIERYCKX	Martin	AGORIA
Mr	GREALY	Joe	Transfrigoroute International
Mr	STUMPF	André	Transfrigoroute International
Mr	McCARTHY	Adam	Johnson Controls
Mr	BLACK	Jon	European Industrial Gases Association AISBL (EIGA)
Mr	DEVIN	Eric	CEMAFROID SNC - France
Ms	PIGACHE	Claire	EADS
Mr	CAMPBELL	Nick	ARKEMA SA
Mr	GOELLER	Juergen	Carrier EMEA and Carrier Transicold EMEA
Ms	O'NEILL	Michelle	Ingersoll Rand International Ltd.
Ms	WEIKER	Christine	European Cold Storage and Logistics Association - ECSLA
Mr	BAUMEISTER	Frank	European Cold Storage and Logistics Association - ECSLA
Mr	KENICHI	Ichihara	Fujitsu General
Mr	LORENZO VOLPI	Ilja	CER
Mr	JANIN	Olivier	AREA
Mr	LINDLEY	Andy	Mexichem Fluor Ltd
Mr	Nigel	GRANT	BEAMA Ltd
Mr	CORDIOLI	Giacomo	ANIE-Energia (Italy)
Mr	AMBROSI	Robert	Sub-Zero, Inc
Mr	OETJEN	Jan	Sub-Zero, Inc

Mr	ENGELHARDT	Rolf	DE - Federal Ministry for the Environment
Ms	MUNZERT	Elisabeth	DE - Federal Ministry for the Environment
Mr	SATHIAMOORTHY	Muhunthan	BP
Ms	ROBINSON	Andrea	BP
Mr	MOSEMANN	Dieter	Eurammon
Mr	BIASSE	Jean-Marc	T&D Europe
Mr	PORTE	Wim	EATON
Mr	DE HAAN	Ton	EATON
Mr	OTEGUI	Enrique	AFBEL
Ms	VOIGT	Andrea	EPEE
Ms	van der LOO	Fanny	EPEE
Mr	SLEDSENS	Ton	Natuur & Milieu
Ms	BECKEN	Katja	DE - German Federal Environment Agency
Ms	ANGELOSANTE	Antonella	IT - Ministry for the Environment, Land and Sea
Ms	SPINETTI	Roberta	IT - Ministry for the Environment, Land and Sea
Mr	KATAOKA	Osami	JRAIA/JROAME
Mr	MARATOU	Alexandra	Shecco
Mr	RICHTERS	Arne	Shecco
Ms	FINEL	Nufar	FI - Finish Environmental Institute
Ms	NURMI	Eeva	FI - Ministry of Environment
Mr	Nankivell	Mike	ACRIB
Mr	RAUSCHER	Nadine	EXIBA
Ms	CLARKE	Jean	IE - Department of Environment, Community and Local Government
Ms	COLLINS	Caitriona	EPA
Mr	GARNACHO	Laura Gallego	CAMBIO CLIMÁTICO – DEPARTAMENTO DE ECONOMÍA

Mr	BEIGHTON	Samuel	Wragge & Co LLP.
Mr	J. LEVINE	Lewis	Wragge & Co LLP.
Mr	WALTHAUS	Herman	NL - Ministry of Infrastructure and Environment
Mr	COCCIONI	Renzo	ZVEI - German Electrical and Electronic Manufacturers' Association
Mr	BASSI	Marino	EMBRACO
Ms	KÖPPEN	Andrea	EHI
Ms	POPP	Dana	EHI
Mr	KYLMALIIKKEIDEN LIITTO	Suomen	Finnish Refrigeration Enterprises Association
Mr	KYLMAYHDISTYS	Suomen	The Finnish Society of Refrigeration
Mr	JONES	Arthur	Tyco International
Ms	BORSKA	Jana	CZ - Ministry of Environment of the Czech Republic
Mr	JUST	Samuel	FR - Ministère de l'Ecologie, du Développement Durable des Transports et du Logement
Mr	CACCIATORI	Federico	ANIMA
Mr	PAUWELS	Marleen	EFCTC (European Fluorocarbon Technical Committee)
Mr	BONASO	Carlo	Frigo 2000 srl
Mr	LINKE	Wilfried	BDH
Mr	SCHMITT	Peter Boris	Henkel AG & Co. KGaA
Ms	RABAZAUSKAITE-SURVILE	Jurga	LT – Ministry of Environment of the Republic of Lithuania
Mr	LAURINAVICIUS	Vladislavas	Board of National Association of Refrigeration
Mr	MARTINEZ-SCHÜTT	Diego	CDM Watch
Mr	FRACCAROLI	Nicola	CDM Watch
Mr	SZYMANSKI	Rafal	PL - Ministry of the Environment
Ms	MATHIS	Pamela	ICF International
Mr	AARNIO	Ulriikka	Climate Action Network Europe

Mr	Van GERWEN	Rene	Refrigerants Naturally
Dr.	THEWISSEN	Harry	EECA ESIA
Mr	GOEMAN	Bart	3M Belgium
Mr	BUREAU	Maxime	3M Belgium
Mr	KRENZ	Thorsten	Deutsche Bahn
Ms	LANDER	Annika	MAN SE
Ms	CONRAD	Silke	Daimler AG
Mr	LEE	Nicholas	PSA Peugeot Citroën
Ms	MERCEDES VÁZQUEZ	MIRANDA	RED ELÉCTRICA DE ESPAÑA
Dr.	RAINER	Jakobs	IZW e.V. Information Centre of Heat Pumps and Refrigeration
Mr	LENDERS	Jan Willem	The German Association of Energy and Water Industries
Ms	SAAR	Dorothee	Deutsche Umwelthilfe e.V.
Ms	NOURIGAT	Cécile	Burson-Marsteller
Mr	SÉNÉJEAN	Benoit	ADHAC
Mr	GROZDEK	Marino	HR - Ministry of Environment and Nature Protection
Mr	LEMOINE	Sébastien	Carrier Transicold Europe
Mr	ZBYSZEWSKI	Sandamali	Acumen public affairs
Dr.	WYATT	David	IPAC
Mr	HOFTJIZER	Joris	Westye Group Europe, Inc
Ms	ÚJFALUSI	Maria	SE - Environmental Protection Agency
Mr	AHMADZAI	Husamuddin	SE - Environmental Protection Agency
Ms	SCACANOVA	Klara	R744.com
Mr	DIEGUEZ	Jorge	Dupont
Mr	VANDERSTRAETEN	Stefaan	AGORIA
Ms	PERRY	Clare	EIA

Ms	JACOBI	Reeli	Ministry of the Environment
Mr	BASSO	Paolo	European Photovoltaic Industry Association (EPIA)
Mr	WILMART	Alain	BE - Ministry of Environment
Mr	LEES	Jeannine	BE - Ministry of Mobility
Mr	DAUWE	Tom	VITO
Mr	MOORKENS	Ils	VITO
Mr	BONNE	Jan	MAYEKAWA
Dr	SCHWARZ	Winfried	Öko-Recherche GmbH
Ms	GSCHREY	Barbara	Öko-Recherche GmbH
Mr	KIMMEL	Thomas	Öko-Recherche GmbH
Ms	TRANHOLM - SCHWARZ	Bente (chair)	European Commission
Mr	KASCHL	Arno	European Commission
Mr	KLAASSEN	Gerardus	European Commission
Ms	PLIMON	Isabella	European Commission
Mr	KESTNER	Matthew	European Commission
Ms	BASIN	Bérangère	European Parliament

2. EXECUTIVE SUMMARY OF THE ANALYSIS OF THE ON-LINE STAKEHOLDER CONSULTATION

2.1. Participation

259 stakeholders participated in the online consultation, 95 identified themselves as individuals (37%) and 164 as organised stakeholders (63%). 77% of the organised stakeholders represented companies, professional associations or trade unions; the remaining organised stakeholders included non-governmental organisations (NGOs) or associations of NGOs (7%), relatively few public authorities (3%) and some other organisations.

62 stakeholders were active at EU or the international level, e.g. including umbrella groups, NGOs, and international companies. All major application sectors were covered. The stationary refrigeration sector accounted for 24% of stakeholders, stationary AC sectors for 21% and the heat pump sector for 24%.

2.2. Methodology

As regards the evaluation of the results a quantitative focus based only on the number of responses given to a particular option in this multiple-choice questionnaire is not appropriate for several reasons.

1. Industrial stakeholders clearly outnumber other organisations such as NGOs and administrations.
2. Certain industries participated very actively whereas other application sectors replied at comparably low numbers; hence the opinion of particular sectors is overrepresented relative to the size of the sector.
3. Submissions by umbrella organisations and associations of NGOs would in a purely quantitative approach be counted only once (just as the position of a single company) although they already represent concerted (and thus very valuable) positions of multiple members or even sectors.
4. Some companies replied more than once since national branches, different departments or daughter companies sent their responses separately, largely using the same text as the mother companies or headquarters.

As a result a more differentiated approach to deriving results was taken by relating answers to the type of respondents giving them. Further, qualitative aspects of the contributions (e.g. textual contributions) were integrated into the analysis and particular weight was placed on concerted positions of umbrella organisations rather than single opinions.

2.3. Policy action addressing F-gas emissions

84% of respondents found that the current status quo of implementing the existing regulation was not sufficient. While some stakeholders believed that better implementation would suffice, others wanted to see further legal action. Different opinions as regards the latter were linked to stakeholder types as well as sector particularities.

As for obstacles preventing the switch to alternative technologies, the results indicated that the barriers differ between sectors. This reflects that safe and cost-effective alternatives are not yet available to the same degree in all application sectors. Overall, higher initial investments were the main barrier identified.

In the absence of a global HFC phasedown, the preferred policy actions for organised stakeholders were strengthening containment and recovery, voluntary agreements for specific sectors, and limits to the placing of HFCs on the EU market, in this order. The options preferred by individuals were additional prohibitions, strengthening containment and recovery, and voluntary agreements.

Stakeholders provided numerous suggestions to improve containment and recovery pointing out the importance of control and enforcement of the existing legislation and harmonisation of the situation within the EU as well as the need to broaden the scope of the existing legislation. Further propositions included measures improving awareness and information exchange, the introduction of financial incentives and taxes as well as some technical measures.

2.4. Impacts of policy options

When asked who would be most negatively affected, organised stakeholders and individuals selected most often the commercial or industrial end-users of relevant products/ equipment as well as producers of products/ equipment normally relying on F-gases. Individuals also assumed that F-gas producers would experience negative impacts, a concern not shared by the producers themselves.

A majority of industry stated concerns on a strengthened approach with regard to the competitiveness of European businesses in general. However, impacts were likely to differ between product groups. Also, industry associations expressed concerns that non-EU competitors and companies not covered by a strengthened approach might benefit. It was suggested that respecting industrial planning timescales would help minimize negative impacts. Also, it was important to avoid equipment redundancy before their end of life.

Benefits of a strengthened approach would occur for manufacturers of products and equipment relying on alternatives as well as for servicing companies and users of relevant products and equipment. Improved containment and higher energy efficiency due to regular maintenance would result in advantages for end users. NGOs and public authorities highlighted competitive advantages in the alternative refrigeration and AC market.

In additional comments, environmental NGOs underlined the economic and environmental benefits for Member States and consumers that could be achieved through an HFC phase out. Measures affecting the industry, considered to be responsible for HFC use in the first place, were fairer than measures impacting users and service companies. Public authorities highlighted "marketing opportunities for fast movers".

Stakeholders saw no large differences for the different options in relation to the administrative burden. In sectors where certain reporting requirements already exist, it was suggested that the additional administrative burden could be rather small. Established monitoring, consistent enforcement, control and sanctioning were considered crucial for the implementation of further measures. Environmental NGOs pointed out that sectoral bans on use and marketing would bring about the smallest administrative burden.

2.5. General Conclusions

- Only a tiny minority of all respondents (2%) thought that no further action would be an appropriate response for the EU in the absence of progress at the global level. Similarly, only 10% of respondents thought the current status quo (i.e. existing legal rules and level of implementation) is sufficient.
- A great number of suggestions for improvement on implementation and containment of leakages were made. In addition, over 40% of respondents including some industrial players clearly indicated a need for further legal action.
- Stakeholders were divided on the most appropriate policy options. This was linked to stakeholder type (e.g. industry, NGO, national administration,..) but also to sectoral differences between industrial players. The preferred type of action largely depends on the application sectors and whether requirements already exist or not. This seems to indicate that there is no magic solution in the form of a single policy option that can address the complexities of the different sectors and applications. Over 500 suggested measures collected as part of the consultation indicate that an appropriate mix of policies may be the best way forward.
- The expected impacts similarly varied according to interest groups and application sectors. Many, but not all, industrial players expressed some concerns on the grounds of competitiveness. Other stakeholders including administrations, companies in the field of alternatives, NGOs and many individuals saw concrete opportunities and benefits in a shift away from F-Gases, especially for "fast movers" and "green technologies".
- Such benefits are expected in particular if a global agreement to phase down/out F-Gases can be achieved.

ANNEX III: Consultations of SMEs

Table A_III-1: *The SME test*

(1) Consultation with SMEs representatives	*See section 2.3, Annex II as well as the list of organisations given below*
(2) Preliminary assessment of businesses likely to be affected	*See sections 3.4, 6.2 (in particular 6.2.2, 6.2.10) as well as Annex II & information below* Companies currently placing HFCs on the EU market and reporting under the F-Gas regulation were analysed: 36% of the affected companies are large, 15% medium, 26% small enterprises and for 23% no data was found to fully categorize the status. Small companies are mostly wholesalers, distributors and producers of equipment, while manufacturers and producers of HFCs in Europe are almost exclusively large companies. In addition SMEs also provide service and maintenance for the F-Gas sector (e.g. Art 3, Art 4 existing F-Gas Regulation). SMEs and microenterprises are also found as operators/end-users of relevant equipment, e.g. in the food and drink industry.
(3) Measurement of the impact on SMEs	*See sections 6.2 (in particular 6.2.2, 6.2.10) & 7 as well as Annex II & information below* The effects on SMEs have been analysed via (i) an assessment of direct abatement costs in different sectors, (ii) an Input-Output model (see Annex IX, XV), (iii) a general equilibrium model (Annex XIV, XV), and (iv) a qualitative analysis based on the experience with the existing F-Gas regulation. Many SMEs are **wholesalers/distributors** which will be less affected because the policy options B, C, D and E do not require adapting the nature of their service delivery process in a substantial way. In addition, SMEs placing on the market only small quantities of HFCs benefit from the foreseen minimum

	thresholds for the application of the phasedown mechanism under Option D. On the other hand, option E would affect **importers of foreign equipment** relying strongly on F-Gases, as pointed out at the stakeholder meeting and the on-line consultation. Option D would provide more flexibility to allow foreign producers to adapt, and thus would be preferable to option E for SME importers. As for **producers of equipment** it should be emphasised that a strengthened policy approach (in particular Options D and E) would provide opportunities for small innovative companies. Denmark has successfully supported alternatives by national legislative measures and support to R&D and thus stimulated market growth of Danish SMEs in the sector.[6, 74] As for **companies servicing F-Gas equipment**, the effects explained above (6.2.2) will also affect small enterprises as demand for the enhanced maintenance requirements under the F-Gas regulation should decline in the long run when less F-Gases would be used in equipment. However, at least in the medium term this should not be noticeable to service companies as the containment obligations stemming from the existing F-Gas Regulation are only slowly being fully understood and implemented on the ground by affected companies, leaving a lot of growth potential for the service sector in this field. Furthermore, the inclusion of additional sectors in existing maintenance requirements should create additional demand for servicing companies and companies working with alternative technologies. Novel equipment using alternatives will also create new service and maintenance needs, in particular for substances that are flammable and/or used at high pressures. Making best use of such opportunities will however require initial investments in particular with regard to training.[75] Finally, service companies which have limited their business activities to leak checking and recovery usually are also involved in the installation of new equipment and its on-site construction (and would profit from the latter activities under a strengthened approach, in particular if on-site filling is prescribed). In summary, even though F-Gas servicing needs due to the existing Regulation would decline in

74 Coincidentally with the entry into force of the Danish ban on certain HFC uses, a Danish start-up, founded by 2 persons in 2006, succeeded in becoming a leading brand for CO_2 refrigeration technology.

75 AREA, the European organisation of refrigeration, AC and heat pump contractors, who represent ca. 9000 servicing companies that are mostly SMEs and micro-enterprises, is already working on guidance documents and qualification requirements related to the use of low GWP refrigerants. http://www.area-eur.be/_Rainbow/Documents/AREA%20-%20PP%20Low%20GWP%20refrigerants%20(110629).pdf

	particular for the most effective policy options, SMEs in the service sector will experience new business opportunities under a strengthened approach (i.e. in particular D and E) so that they are not expected to suffer any significant negative consequences. As for SMEs in sectors that might be **indirectly affected** (as suppliers or sellers of products/services to end-users, e.g. foodstuff, clothing, gastronomy,..), the discussion in 6.2.2 (and Fig. 9) showed that such effects are very small overall, with some sectors providing input to the machinery and equipment sector affected positively, while very small negative effects on the products-for-endusers sectors could occur. All policy options aim at reducing the use of F-Gases with high GWP in new equipment and **do not force the replacement of old equipment**. Hence, SMEs would not be burdened with any new costs for replacing existing equipment. This is particularly relevant for the competitiveness of SMEs and microenterprises in the food-and-drink industry.[76] Options B and D would impose a (small) additional **administrative burden** on companies for the verification of the reported information (see 6.2.3). It is the intention to introduce a threshold similar as is the case for reporting requirements to protect small companies. SMEs expressed the view during the consultations that the Commission should ambitiously pursue an agreement at the global level, as producing for markets governed by different rules would be difficult for SMEs that target global markets. Further information on the consultation process with SMEs is given in Annex II.
(4) Assess alternative options and mitigating measures	Considering that policy option A (no policy change) will not lead to a reduction in F-Gases in line with the low carbon roadmap, policy options B,C,D and E have to be considered. The content and structure of these policy options should ensure that any plausible negative impacts on SMEs are minimized or averted. In addition to the general policy design, this is done via e.g. the use of thresholds: - option B and D would impose a (small) additional administrative burden on companies for the verification of the

[76] There are 274,000 food and drink companies in Europe, 99.1% of which are SMEs. SMEs also accounted for 48.7% of turnover and 63% of employment in the food and drink industry in 2010.

	reported information (see 6.2.3). It is the intention to use a threshold (e.g. 10,000t CO_2eq.) for this requirement in order to protect small enterprises from any disproportionate administrative costs. A threshold of 1000 tonnes CO_2eq or 1 metric tonne of HFC applies to the reporting requirements (in average corresponding to the currently applicable threshold). - under option D companies need quotas to place HFCs on the market. A threshold of 1000 tonnes CO_2eq will be used to exclude very small HFC market players. (see Annex X)

The following organisations which include SMEs among their members were consulted during the on-line stakeholder consultation and/or the open stakeholder conference:

European-level umbrella organisations

- Alliance Froid Climatisation Environnement (AFCE)
- Eurofins
- Euroheat & Power
- European Aerosol Federation
- European Association of Refrigeration, AC, and Heat Pump Contractors (AREA)
- European Cold Storage and Logistics Association (ECSLA)
- European Committee of Domestic Equipment Manufacturers (CECED)
- European Committee of Air Handling and Refrigeration (Eurovent)
- European Garage Equipment Association (EGEA)
- European Heat Pump Association (EHPA)
- European Partnership for Energy and the Environment (EPEE)
- FoodDrinkEurope
- PU Europe
- T&D Europe

– Transfrigoroute International (TI)

National-level organisations

– Agoria (BE)

– AC and Refrigeration Industry Board (ACRIB, UK)

– Asociación de Empresas Gestoras de Residuos y Recursos Especiales (ASEGRE, ES)

– Asociación de Fabricantes de Equipos de Climatización (AFEC, ES)

– Associazione Italiana Costruttori Antincendio (UMAN, IT)

– Associazione dei Tecnici del Freddo (ATF, IT)

– British Refrigeration Association (BRA, UK)

– Bundesverband der Deutschen Energie und Wasserwirtschaft (BDEW, DE)

– Bundesverband der Deutschen Giesserei-Industrie (BDG, DE)

– CLIMAFORT (FR)

– Conferederation of Employers and Industries of Spain (CEOE, ES)

– Fachverband der Elektro- und Elektronikindustrie (FEEI, DE)

– Fachverband der Gas- und Wärmeversorgungsunternehmen (AU)

– Fédération des services énergie environnement (FEDENE)

– Federation of Environmental Trade Associations (FETA, UK)

– Finnish Refrigeration Enterprices Association (FI)

– Fire Industry Association (FIA, UK)

– Heating, Ventilating and AC Manufacturers Association (HEVAC, UK)

– Österreichischer Kälte- und Klimatechnischer Verein (ÖKKV, AU)

– Polish Refrigeration and AC employers association (KFCh, PO)

– Turkish AC & Refrigeration Manufacturers` Association (ISKID, TU)

– Unie der belgischen frigoristen (BE)

- VKE – Norwegian Refrigeration and HVAC Association (NO)
- Zentralverband Elektrotechnik- und Elektronikindustrie e.V. (ZVEI)

In addition **single SMEs provided feedback** incl.:

- Ambient control
- Calorex Heatpumps
- Clima-D
- Elektrotechnische Werke Fritz Diescher & Söhne
- Konvekta
- Lucas Rupp Weider Wärmepumpen
- Stratox
- Sub Zero

ANNEX IV: Background Information on the Business as Usual Scenario (No Further Action – Option A)

1. F-GAS EMISSIONS

F-Gas emissions and the differences between the scenarios WM (= option A, no further legislative action) and WOM (= without existing F-Gas legislation) are presented in Table A_IV-1 for selected years. The data in this table is calculated with GWP values from the 4th IPCC Assessment Report.

Table A_IV-1: *F-Gas emissions in EU-27 in the WOM and WM scenarios in 2000-2050 (kt CO_2eq) and differences between the scenarios (kt CO_2eq; %)*

	2000	2005	2008	2010	2015	2020	2030	2050
WOM	84,929	90,335	104,013	116,114	144,580	164,561	183,928	204,162
WM	84,929	90,335	103,104	113,253	113,666	118,489	103,657	110,824
Diff in kt CO_2	0	0	909	2,861	30,914	46,072	80,271	93,338
Diff. In %	0	0	0.9%	2.5%	21.4%	28.0%	43.6%	45.7%

F-Gas emissions as presented in Table A_IV-1 are derived from the model AnaFgas.[77] The modelled emissions are only partly based on emission data reported by the Member States to the UNFCCC in form of CRF (common reporting format) tables, although CRF data represent the best available empiric information source on F-Gas activity data and emissions in Member States. Sectors largely relying on CRF data include fire protection, solvents, semiconductor manufacture, primary aluminium production, production of halocarbons, and XPS foam. In other sectors CRF data are too general, often incomplete, not sufficiently transparent and of varying quality. For this reason, additional efforts were made to improve the emission data for fluorinated gases in these sectors.

Numbers for current and historic emissions differ due to the use of different GWPs in the calculations. The emissions in CO_2eq presented herein, such as Table A_IV-1 above, are calculated with GWPs from the IPCC 4th Assessment Report. These GWPs were agreed at COP 17 as the future metric for the reporting of greenhouse gas inventories after the 1st commitment period under the Kyoto Protocol. Previously, until the inventory reports for the reporting year 2012, GWPs from the Second Assessment Report of the IPCC were used.

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77 A detailed description of the assumptions in model AnaFgas is provided in Annex III of *Schwarz et al. 2011*.

A comparison of the F-Gas emissions reported by CRF and F-Gas emissions calculated by the model AnaFgas has been undertaken for validation. Table A_IV-2 summarizes the total EU F-Gas emissions for the years 2000-2009. In the first line emissions from the recent CRF submission (EU CRF table 10s4.2) in 2011 are listed. The second line contains total F-Gas emissions from the model AnaFgas. For this validation exercise, the GWP values are in both time series from the 2nd IPCC AR so that only methodological differences between the model AnaFgas and the greenhouse gas inventories are reflected.

Table A_IV-2: *Comparison of emission estimates between AnaFgas and Member States' greenhouse gas inventories*

kt CO_2eq	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CRF	66,205	63,833	66,949	69,303	70,113	73,485	74,657	78,551	80,950	81,352
Model	74,023	69,197	70,722	71,701	74,285	77,694	79,887	83,077	89,210	92,707
Diff in %	12%	8%	6%	3%	6%	6%	7%	6%	10%	14%

From the comparison it can be seen that:

(1) CRF reports and model output feature the same upward trend from 2001 to 2009.

(2) The deviation between the annual emission data ranges between 3% and 14%.

(3) The model emissions are always higher than the national greenhouse gas inventories.

The third point is not surprising because the model sets completeness standards equivalent to the requirements of 2006 IPCC Guidelines for all Member States. The 2006 IPCC Guidelines are not yet legally binding for the inventory reporting and will only be binding starting with the inventory submission for the year 2013. 2006 IPCC Guidelines are considerably refined with regard to methodologies for fluorinated gases and provide methodologies in areas in which current IPCC guidelines lack such methodologies. Only some MS already report these additional sources of F-Gases already now in their greenhouse gas inventories. This is considered to be the main reason for the deviation between the modelled emissions and the reported greenhouse gas inventories.

2. THE MODEL ANAFGAS

The model AnaFgas (Analysis of Fluorinated greenhouse gass in EU-27) is a bottom-up stock model to derive demand and emission scenarios for F-Gases in relevant sectors and sub-sectors for the EU-27 Member States (see Fig. A_IV-1). It models demand for and emissions of HFCs, PFCs and SF_6 as well as HCFC-22 for the period 1995 to 2050 based on market data and estimates of the quantity of equipment or products sold each year containing these substances, and the amount of substances required in the EU to manufacture and/or maintain equipment and products over time. All emission and demand estimates are derived from bottom-up approaches, i.e. by estimating demand and emissions per sector through the use of underlying driving factors. These include annual changes in equipment stock, composition and charge of the equipment, leakage during equipment lifetime and during disposal.

The lag between use of a chemical and actual emission of this chemical is reproduced. Aggregating emission and use over the different end-uses, the model produces estimates of total year-specific annual demand for and emissions of each substance expressed in metric tonnes or GWP-weighted (kt CO_2eq).

Seven sectors with a total of 29 sub sectors are separately represented in the model (see Figure A_IV-1). In total 21 different fluorinated gases (excluding ozone-depleting gases) are included in the model (11 HFCs, 5 PFCs, 2 unsaturated HFCs, 1 fluoroketone, SF_6, NF_3) and calculations can either be based on metric tonnes or GWP (GWP).

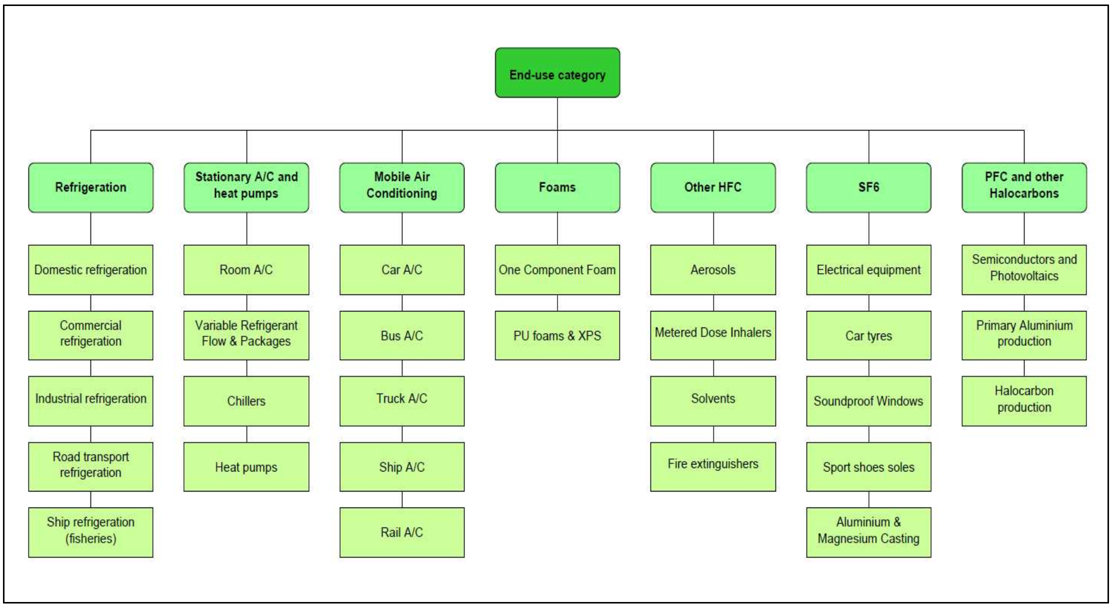

Figure A_IV-1: Sectors and sub-sectors represented by the model AnaFgas

3. HFC DEMAND AND EMISSIONS IN EU-27 UNTIL 2050 FOR DIFFERENT SECTORS

In the following the projected emissions per sectors are presented.

Total F-Gas emissions in the EU-27 are projected to remain at stable levels from about 2010 onwards (Table A_IV-3). In spite of the containment measures of the existing F-gas Regulation, emissions from stationary AC strongly increase by 25 Mt CO_2eq until 2050, due to increased use. In addition, emissions from the refrigeration sector increase by 5 Mt CO_2eq from 2015 to 2050. As a result, the reduction in emissions from AC of motor vehicles by almost 30 Mt CO_2 eq. is offset by 2050.

Table A_IV-3: *F-Gas emissions by sectors in EU-27 as projected in the baseline scenario (AnaFgas)*

F-gas emissions (kt CO_2eq)	2010	2015	2020	2030	2050
Refrigeration	39,347	32,093	34,363	35,556	37,277
Stationary AC	15,058	20,641	28,206	36,992	40,971
Mobile AC motor vehicles	32,526	34,819	28,293	6,604	6,889
Mobile AC ships + rail	1,999	1,789	1,812	1,822	1,846
Foam	3,299	3,631	3,974	4,634	5,746
Other	9,155	9,503	9,893	10,143	10,576
- thereof MDI	*2,921*	*3,065*	*3,202*	*3,453*	*3,886*
Total HFC	101,384	102,476	106,541	95,750	103,306
Total HFCs w/o mobile AC motor vehicles	68,858	67,657	78,248	89,146	101,460
SF_6	5,452	5,583	6,966	2,921	2,533
PFCs and haloproduction	6,417	5,607	4,982	4,986	4,985
Total	**113,253**	**113,666**	**118,489**	**103,657**	**110,824**

The effect of containment and recovery measures set out by the F-gas Regulation is expected to occur in the period until 2015 if the provisions will be fully implemented and applied. The sector where the effects of containment and recovery measures are most significant in absolute terms is commercial refrigeration (Figure A_IV-2). After reductions in the period 2010-2015 due to the F-gas Regulation, constant long-term levels for emissions and demand are projected.

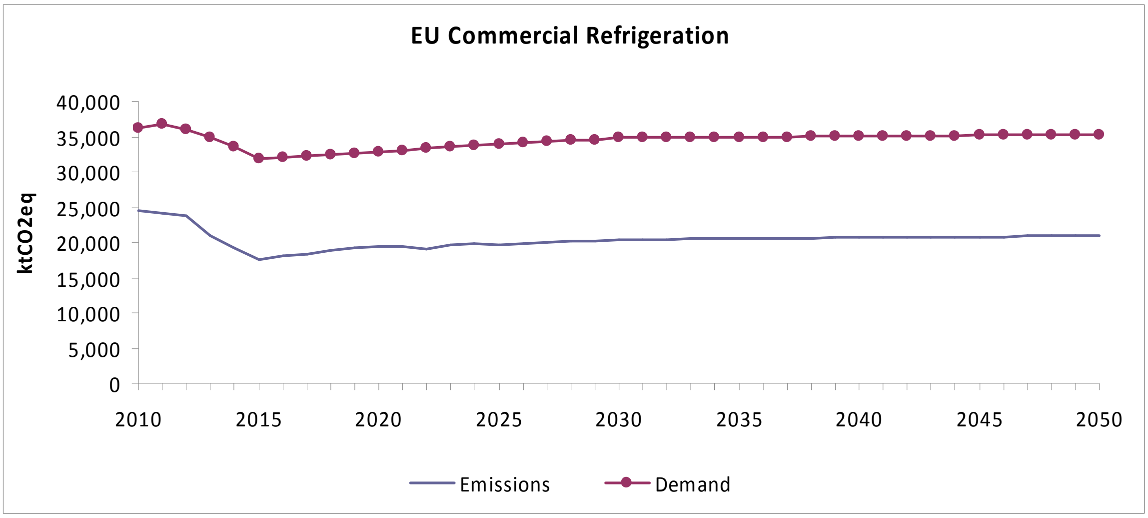

Figure A_IV-2: HFC emissions and demand (kt CO_2eq) in commercial refrigeration (2010-2050), for EU-27 under baseline scenario.

In the stationary AC and heat pump sector containment provisions apply to certain equipment with charges >3 kg. Effects of these measures will be offset by the growth in subsectors with equipment of charges <3 kg (Figure A_IV-3). Before the market becomes saturated in 2035, considerable growth is expected, which makes stationary AC the largest individual HFC sector in Europe. In this graph, demand includes imported HFCs in pre-filled systems.

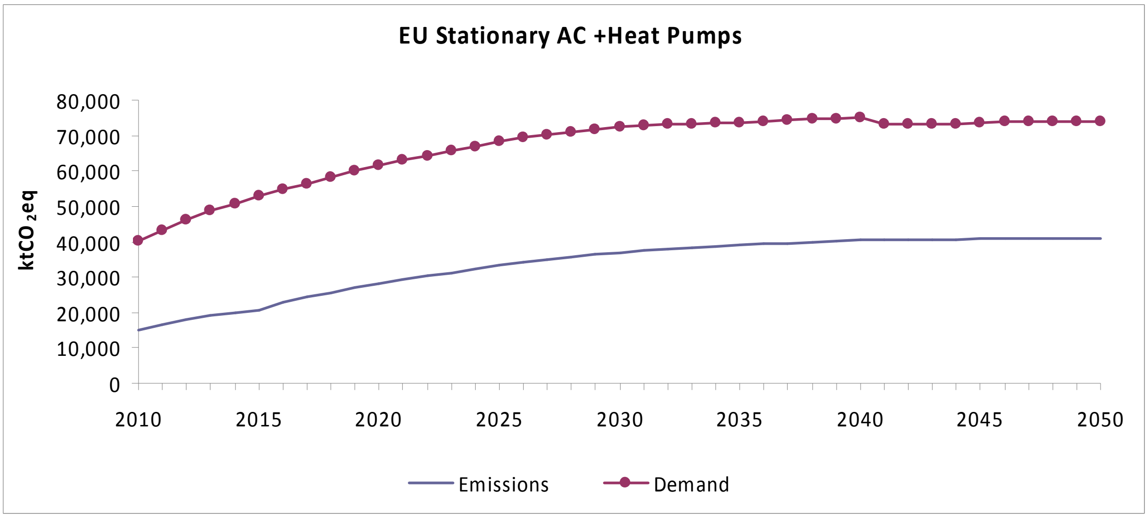

Figure A_IV-3: HFC emissions and demand (kt CO_2eq) for stationary AC and heat pumps (2010-2050), for EU-27 under baseline scenario.

4. F-GAS SOURCES CURRENTLY NOT ADDRESSED BY EU LEGISLATION

At the moment, certain sources of F-Gas emissions in EU-27 are addressed neither by the F-Gas Regulation nor the MAC Directive. These sources include:

- HFC emissions from mobile AC systems contained in vehicles other than motor vehicles (ship AC and rail AC);
- HFC emissions from mobile refrigeration systems such as refrigerated trucks, refrigerated containers or fishing vessels;
- HFC emissions from foams other than OCF;
- HFC emissions from halocarbon production;
- HFC-23 by-product emissions;
- PFC emissions (e.g. from primary aluminium production or from the semiconductor industry);
- SF_6 emissions from certain applications such as photovoltaic manufacture, particle accelerators, air-borne military radar systems, etc.;
- F-Gas emissions from Organic Rankine Cycles (ORC; i.e. generation of power from heat recovery).

Emissions of other F-Gases not currently included in the scope of the F-Gas Regulation: NF_3 emissions, SO_2F_2 emissions and emissions of unsaturated HFCs.

ANNEX V: Technical Assessment of Environmental Impacts

1. Emissions for Policy Options B, C, D, E vs. Baseline (Option A)

This Annex presents the F-Gas emission trends in the WM scenario (= no further policy action: option A) and the WAM scenario ("with additional measures")) for the different policy options.

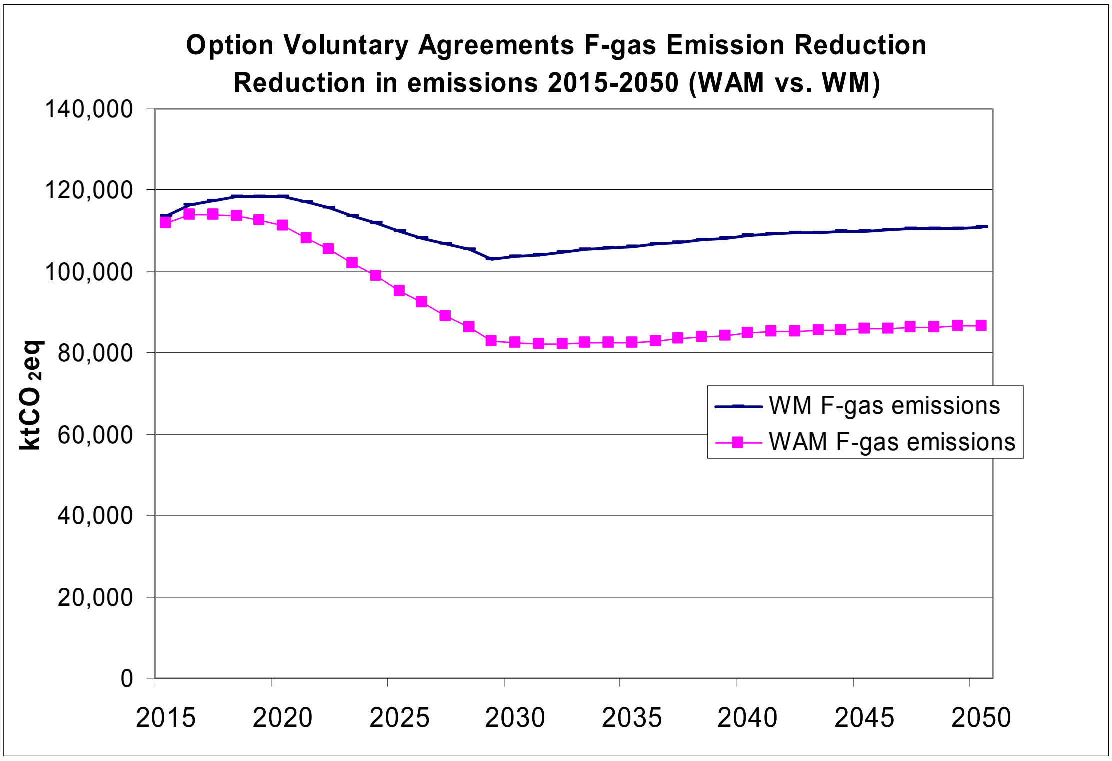

Fig. A_V-1: Maximum F-Gas emission reduction potential (WAM) of the **option B** "voluntary agreements", compared to F-Gas emissions in the WM (baseline) scenario in the period 2015-2050. Source: AnaFgas

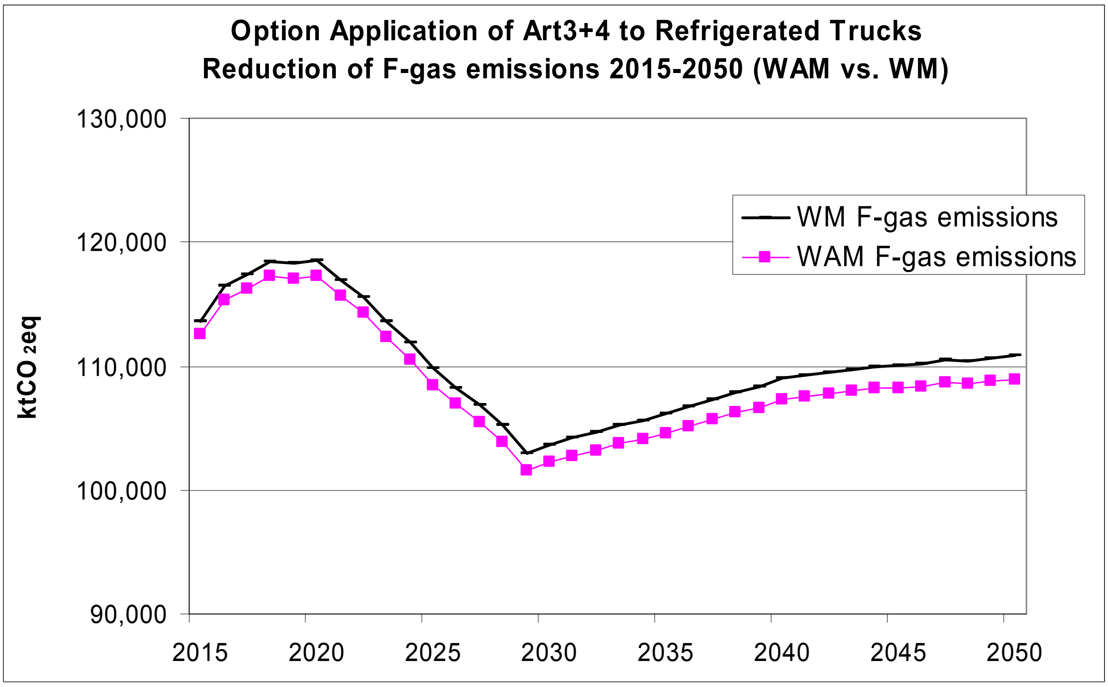

Fig. A_V-2: F-Gas emission reduction potential (WAM) of the option C "Inclusion in the scope of Articles 3 and 4: Refrigerated road transport – trucks and trailers" compared to total F-Gas emissions in the WM (baseline) scenario in 2015-2050. Source: AnaFgas

N.B.: The Y-axis does not start from 0 but from 90,000 ktCO2eq in order to better illustrate the difference between WM and WAM scenario.

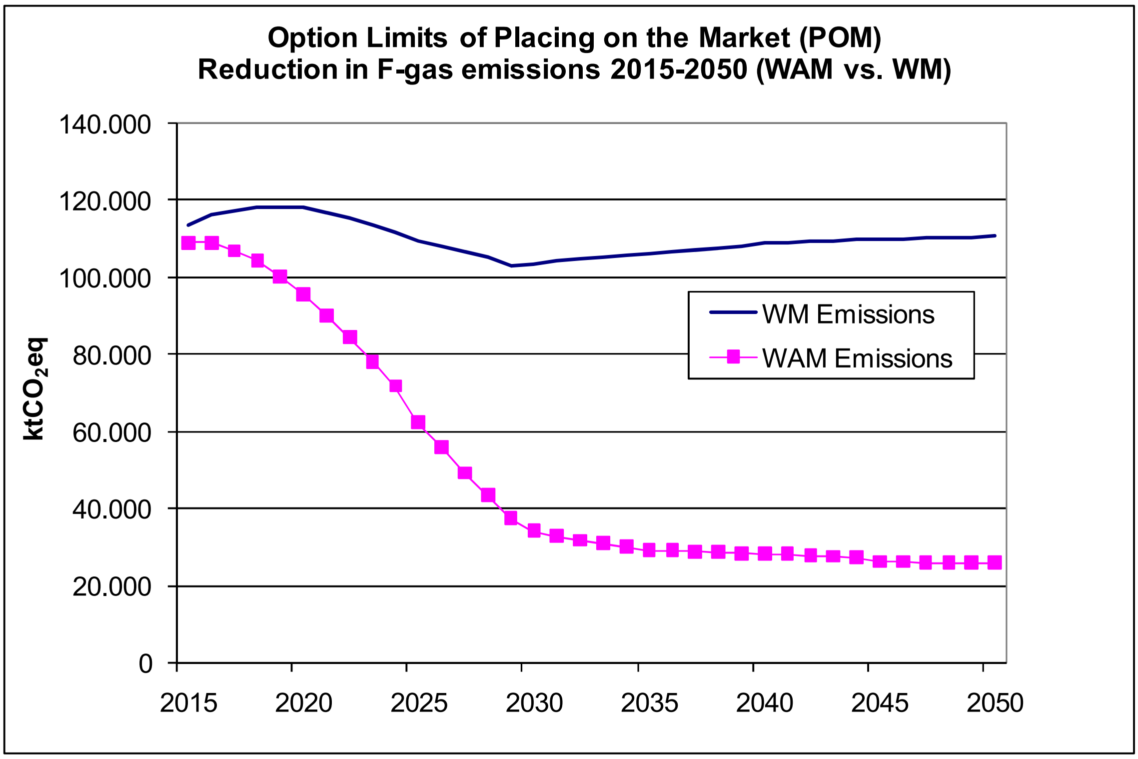

Fig. A_V-3: F-Gas emission reduction potential (WAM) of the **option D** "Limits of Placing on the Market of HFCs" compared to total F-Gas emissions in all sectors in the WM (baseline) scenario. Source: AnaFgas

The emission reduction potential in 2030 amounts to 71.7 Mt CO2 eq, which is almost 70% of the total F-Gas emissions of 103.7 Mt CO2 eq in 2030.

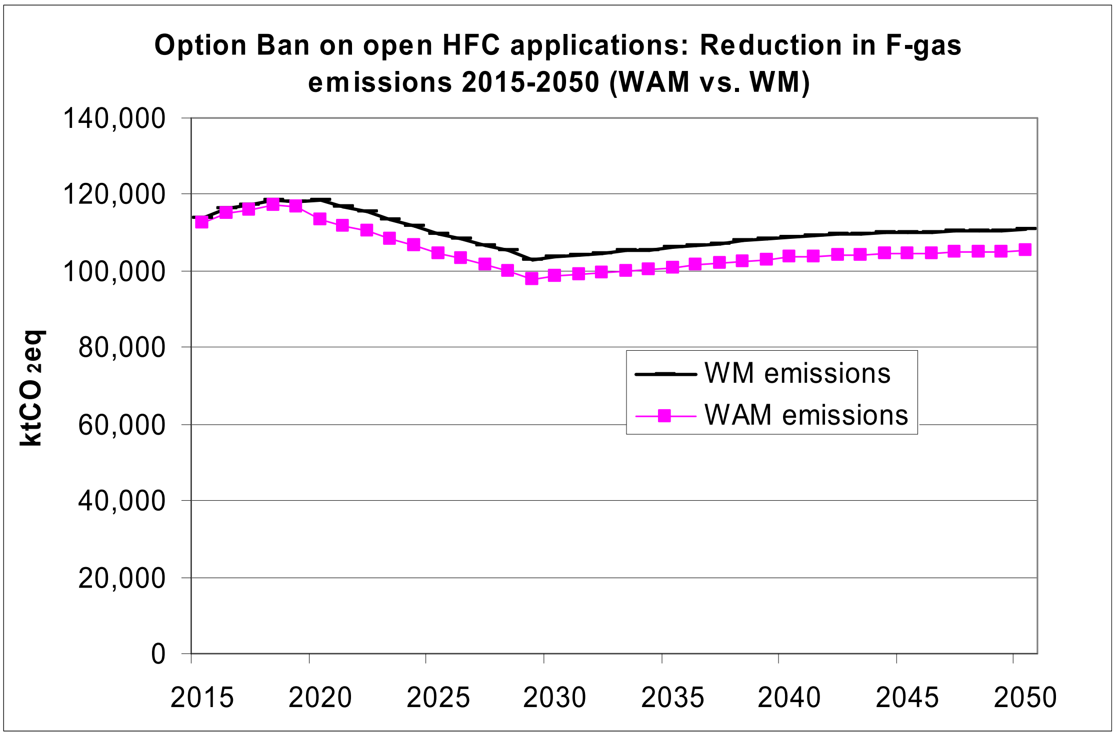

Fig. A_V-4: Emission reduction potential (WAM) of the option "ban of use of HFCs for open applications" compared to total F-Gas emissions of the WM (baseline) scenario in the period 2015-2050. Source: AnaFgas

N.B.: "Open applications" include (i) non-medical technical aerosols and (ii) HFC-134a in XPS foam blowing, and form part of option E

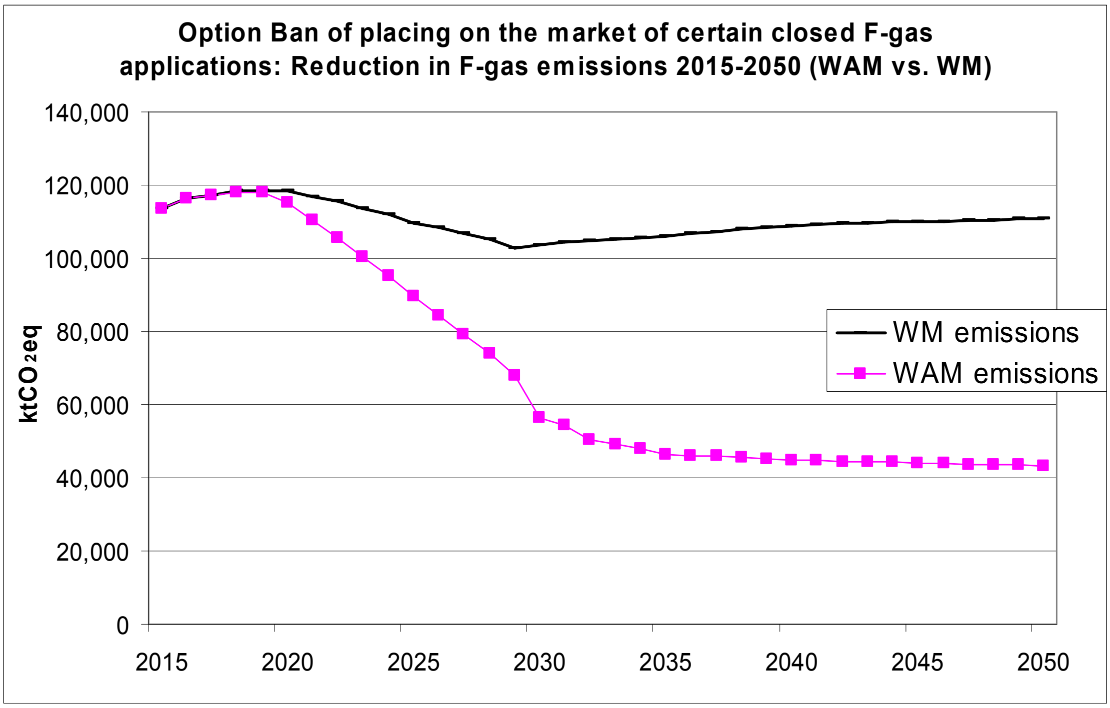

Fig. A_V-5: Emission reduction potential (WAM) of the option "ban of the POM of certain closed applications containing HFCs" compared to total F-Gas emissions of the WM (baseline) scenario in the period 2015-2050. Source: AnaFgas

N.B.: "Closed applications" include commercial refrigeration, industrial refrigeration, transport refrigeration, stationary AC, HFC-23 in fire protection, SF_6 in Mg die casting, and mandatory destruction of HFC-23

Bans on open and closed applications (Fig. A_V-4 and A_V-5) together make up policy option E (refer to chapter 5.5 of main part). The emission reduction potential for banning both open and closed applications in 2030 amounts to 52.7 Mt CO_2eq, which is 50.4% of the total F-Gas emissions of 103.7 Mt CO2 eq in 2030.

2. REPLACED UNITS IN EACH SECTOR AS A RESULT OF POLICY OPTIONS B, C, D AND E IN 2030

Table A_V-1: *Number of replaced HFC based stock units by policy options B, D and E in 2030 for each sector*

Option	Option B Voluntary agreements [stock units]	Option E: Option Bans of use in certain open and closed applications [stock units]	Option D: Quantitative limits for placing on the market of HFCs [stock units]
Domestic Refrigeration	not affected	not affected	2,783,400
Commercial Refrigeration			
Hermetic Commercial	5,737,300	5,307,000	5,737,300
Condensing units	3,020,000	2,421,300	3,020,000
Centralized systems	144,900	134,000	144,900
Industrial Refrigeration			
Industrial Ref small	not affected	500	6,000
Industrial Ref large	not affected	200	2,900
Transport refrigeration			
Refrigerated Vans	not affected	not affected	601,800
Refrigerated Trucks	not affected	63,200	532,300
Refrigerated Ships	not affected	not affected	400
Mobile AC			
Ship AC	not affected	not affected	4,200
Bus AC	not affected	not affected	609,400
Truck AC	not affected	not affected	19,520,300
Stationary AC			
Moveable AC systems	not affected	34,283,800	3,428,380
Split AC systems	not affected	96,697,500	96,697,500
Multi split AC systems	not affected	1,376,200	1,570,583
Rooftop AC systems	not affected	522,500	522,500
Chillers	not affected	714,600	771,866
Centrifugal chillers	not affected	not affected	3,800
Fire protection			
Fire protection 227ea	not affected	not affected	48,600
Fire protection 23	24,500	24,500	24,500
Foam blowing			
XPS-152a	not affected	not affected	13 (prod. lines)
XPS-134a	13 (prod. lines)	13 (prod. lines)	13 (prod. lines)
PU other	not affected	not affected	77 (prod. lines)
Other			
Aerosols	not affected	9,000,000 cans	9,000,000 cans
Manufacture of HCFC-22 and HFC-32	not affected	not affected	not affected

Source: AnaFgas

Table A_V-2: *Number of replaced HFC based stock units by policy options C in 2030 for each sector*

Option	Option C: Extended Scope [stock units]
Domestic Refrigeration	not affected
Commercial Refrigeration	already covered
Industrial Refrigeration	already covered
Transport refrigeration	
Refrigerated Vans	not affected
Refrigerated Trucks	631,000
Refrigerated Ships	not affected
Mobile AC	
Stationary AC	already covered
Fire protection	already covered
Foam blowing	not applicable
Other	
Aerosols	not applicable
Manufacture of HCFC-22 and HFC-32	not affected

As a result of a lower number of affected sectors and sub-sectors, the number of replaced units is the lowest under the option "extended scope" (option C: only one sector), followed by "voluntary agreements" (option B), "bans of the use of F-Gases in certain applications" (option E) and is highest for the option "limits to placing on the market" combined with measures on pre-charged equipment (option D).

However, within the relevant sectors the number of replaced units also differs between policy options. In sectors which could theoretically be covered by any of the three policy options, the number of replaced units in 2030 is often lower for "bans of the use of F-Gases in certain applications" (option E), compared to the other two options. This is due to the fact that the introduction of replacement solutions follows the penetration rates of these technologies in the options "voluntary agreements" (option B) and "limits to placing on the market" (option D), i.e. that every year all available replacement solutions for new equipment are installed according to the penetration mix. In the option "regulatory bans of the use of F-Gases in certain applications" (option E) on the other hand, a ban can be established only when the penetration mix in the sector has already reached 100% (unless specific exemptions can be clearly defined). This leads to a delay in the replacement of HFC-based systems, and consequently to a lower number of replaced units in 2030 for option E.

ANNEX VI: Assessment of cost impacts on sectors (Competitiveness proofing)

1. ABATEMENT AND DIRECT COSTS

Table A_VI-1: *Overview of cost impacts for the policy options at sub-sectoral level*

Subsectors affected	Average emission abatement cost	Direct net costs to sector*	Direct cost per operator
	€/tCO_2eq	M€/year	€ /year
Option B: Voluntary agreements			
Commercial hermetics	-0.8	-0.12	-0.02
Condensing units	1.2	105.0	34.7
Centralized systems	23.7	416.8	2,876
Fire protection HFC-23	3.1	3.18	130
XPS-134a[78]	1.0	1.2	98,000 (production line)
HFC-23 by-product emissions	< 2	0.55	0.55
Total voluntary agreements	16.8b	526.6a	-
Option C: Extended scope			
Trucks and trailers	46	66.4	105.2
Option D: HFC phasedown mechanism			
Domestic Refrigeration	1.0	0.01	0.004
Commercial hermetics	-0.8	-0.12	-0.02
Condensing units	1,2	105.0	34.7
Centralized systems	23.7	416.8	2,876
Industrial Ref small	-0.9	-0.92	-153
Industrial Ref large	-21.6	-65.9	-22,642
Refrigerated Vans	45.1	20.9	34.7
Refrigerated Trucks	2.6	16.8	31.6

[78] Considering an annual output of a typical production line of ca. 75,000 cubic metres of foam, and a wholesale price of € 300 per cubic metre foam board, the annual production is worth over 20 M€. Compared to this total value, the additional costs of € 98,000 account for only 0.5% of the annual output value of products and thus still represents only a small financial load to the operators.

Subsectors affected	Average emission abatement cost	Direct net costs to sector*	Direct cost per operator
	€/tCO_2eq	M€/year	€ /year
Fishing vessels	3.4	1.96	5,368
Cargo ship AC	16.7	5.60	1,507
Passenger ship AC	35.0	2.90	6,190
Bus AC	48.5	107.1	175.1
Truck AC	43.1	243.9	12.5
Moveable AC systems	8.9	1.9	0.55
Split AC systems	19,0	488.7	5.1
Multi split AC systems	13.1	53.5	34.1
Rooftop AC systems	8.2	11.8	22.5
Chillers	5.9	36.3	47.0
Centrifugal chillers	11.1	1.49	381
Fire protection 227ea	22,3	10.9	225
Fire protection 23	3.1	3.18	130
Aerosols	10.0	36.3	4.0
XPS-152a	-1.6	-0.7	-56,400 (production line)
XPS-134a	1.0	1.2	98,000 (production line)
PU other	3.5	0.32	4,130
Total limits placing on market	**16.2**	**1,499.00**	**-**
Option E: Bans for POM			
Ban the POM of certain open applications containing F-Gases			
Aerosols	10	36.3	n. e.
XPS-134a	1	1.2	98,000 (production line)
Total ban open appl.	**7**	**37.5**	**3.2**
Ban the POM of certain closed applications containing F-Gases			
Commercial hermetics	-0.8	-4.64	-0.9
Condensing units	1.2	276.1	34.0

Subsectors affected	Average emission abatement cost	Direct net costs to sector*	Direct cost per operator
	€/tCO_2eq	M€/year	€ /year
Centralized systems	23.7	380.1	2,835
Industrial Ref small	-0.9	-0.07	-153
Industrial Ref large	-21.6	-5.10	-22,642
Refrigerated Trucks	2.6	0.96	15.3
Moveable AC systems	8.9	18.76	0.5
Split AC systems	19.0	488.72	5.1
Multi split AC systems	13.1	45.74	33.2
Rooftop AC systems	8.2	11.78	22.6
Chillers	5.9	33.05	46.3
Fire protection 23	3.1	3.18	130.1
Total ban closed applications	**16.9**	**1,248.6**	**-**
Mandatory destruction of HFC-23 emissions from halocarbon production			
Destruction of HFC-23 emissions to the extent possible	<2	0.55	n.a.

n.e. = not estimated; n.a. = not applicable

** In option E, the additional direct net costs to the sectors include the additional cost for equipment arising to the operators in the sectors, not only the sales of domestic equipment suppliers to the operators.*

Source: Schwarz et al.[9]: Table 8.24 with additional corrections

2. ABATEMENT COST CURVE

Fig. A_VI-1 shows that F-Gas emission reductions of ca 72 Mt CO_2eq can be abated at a price of <50€ per tonne CO_2eq. This would eliminate almost 70% of today`s emissions due to F-Gases despite a growing use of the relevant equipment..

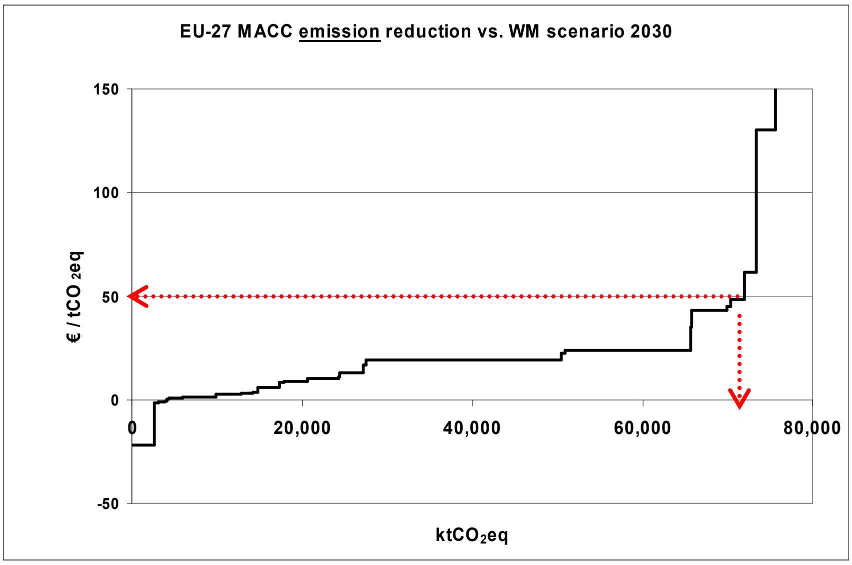

Fig. A_VI-1: Marginal emission abatement costs vs. achievable emission reductions by 2030. Source: Schwarz et al. (2011)[9] (MACC: Marginal Abatement Cost Curve)

3. INVESTMENT AND SERVICE COSTS, EMPLOYMENT EFFECTS

Table A_VI-2: *Overview of investment costs, loss and gains from service and qualitative assessment of employment effects*

Subsectors affected	Equipment investment cost / Sales of equipment suppliers*	Loss (-) / Gains (+) from service Art 3+4 or new service for NH_3+CO2 M€/y	Employment (domestic equipment manufacture + service)
	M€/year	M€/year	
Option B: Voluntary agreements			
Commercial hermetics	81.3	-14.3	++
Condensing units	752.7	-204.7	+++
Centralized systems	773.9	-81.4	+++
Fire protection HFC-23	0.0	-2.2	0

Subsectors affected	Equipment investment cost / Sales of equipment suppliers*	Loss (-) / Gains (+) from service Art 3+4 or new service for NH_3+CO2 M€/y	Employment (domestic equipment manufacture + service)
	M€/year	M€/year	
XPS-134a	2.5		+
HFC-23 by-product emissions	0.3		+
Total voluntary agreements	**1,610.7**	**-302.7**	**+++**
Option C: Extended scope			
Trucks and trailers	n.a.	+71.3	++
Option D: Quantitative limits for the placing on the market of HFCs			
Domestic Refrigeration	2.0	-0.3	+
Commercial hermetics	81.3	-14.3	++
Condensing units	752.7	-204.7	+++
Centralized systems	773.9	-81.4	+++
Industrial Ref small	67.3	-0.6	++
Industrial Ref large	498.7	+2.2	+++
Refrigerated Vans	17.8	+2.5	+
Refrigerated Trucks	141.7	+7.0	++
Fishing vessels	6.3	+0.7	+
Cargo ship AC	2.8	+3.2	+
Passenger ship AC	0.4	+0.0	0
Bus AC	34.7	+4.6	+
Truck AC	2.3		+
Moveable AC systems	7.4	-0.9	-
Split AC systems	157.6	-483.5	+
Multi split AC systems	69.6	-268.7	0
Rooftop AC systems	66.5	-83.6	0
Chillers	339.2	-139.3	+±
Centrifugal chillers	3.0	-3.0	0
Fire protection 227ea	5.4	-4.4	0

Subsectors affected	Equipment investment cost / Sales of equipment suppliers*	Loss (-) / Gains (+) from service Art 3+4 or new service for NH_3+CO2 M€/y	Employment (domestic equipment manufacture + service)
	M€/year	M€/year	
Fire protection 23	0.0	-2.2	0
Aerosols	0		0
XPS-152a	2.5		+
XPS-134a	2.5		+
PU other	3.3		+
Total limits placing on market	**3,039**	**1,275**	**+++**
Option E: Bans for POM			
Ban the POM of certain open applications containing F-Gases			
Aerosols	0	n.a.	0
XPS-134a	2.5	n.a.	+
Total ban open appl.	**2.5**	**n.a.**	**+**
Ban the POM of certain closed applications containing F-Gases			
Commercial hermetics	70.7	-13.3	++
Condensing units	602.2	-163.4	+++
Centralized systems	714.1	-75.6.0	+++
Industrial Ref small	5.2	+0.1	+
Industrial Ref large	38.6	+0.2	+++
Refrigerated Trucks	16.5	+0.6	+
Moveable AC systems	7.4	-85.7	0
Split AC systems	157.6	-483.5	+++
Multi split AC systems	61.2	-235.7	++
Rooftop AC systems	66.5	-83.7	+
Chillers	314.0	-128.9	+++
Fire protection 23	0	-2.2	0
Total ban closed appl.	**2,054.0**	**-1,271.3**	**+++**
Mandatory destruction of HFC-23 emissions from halocarbon production			

Subsectors affected	Equipment investment cost / Sales of equipment suppliers*	Loss (-) / Gains (+) from service Art 3+4 or new service for NH_3+CO2 M€/y	Employment (domestic equipment manufacture + service)
	M€/year	M€/year	
Destruction of HFC-23 emissions to the extent possible	0.3	n.a.	0

n.e. = not estimated; n.a. = not applicable

** In option E, only the additional sales of domestic equipment suppliers/manufacturers are included. In the sectors of stationary AC, the cost for equipment arising to operators are higher than the sales of domestic equipment manufacturers.*

Source: Schwarz et al.2011[9], with additional corrections

4. IMPACTS ON SERVICE COMPANIES

After replacement of HFCs in systems of refrigeration, stationary AC, and fire protection equipment >3 kg, enhanced servicing activities according to Articles 3 and 4(1) of the F-Gas Regulation are no longer required. In the sectors with charges <3 kg, i.e. domestic refrigeration, commercial hermetics, moveable air conditioners, single-split air conditioners, and, partly, condensing units, application of Article 4(1) will discontinue. Discontinuation of Articles 3 and 4(1) leads to a net loss in service activities and in turnover for service companies in the long run. These effects on service companies have been quantified in the following way:

1st step: The service costs of the HFC reference unit resulting from application of Art 3 and/or Art 4(1) of the F-Gas Regulation, have been determined (see Schwarz et al., 2011[9], Annex V, EU sector sheets).

2nd step: The service costs of the HFC reference unit (1st step) and the number of replaced HFC units by 2030 (AnaFgas) were multiplied, which results in the loss in turnover of service companies by 2030.

3rd step: In the case of HFC replacement by CO_2 (high pressure equipment) and NH_3 (toxicity) new service costs occur (Schwarz et al., 2011[9], Annex V, EU sector sheets), which were estimated in this step.

In option B, servicing activities according to Articles 3 and 4(1) of the F-Gas Regulation are not required anymore in some sectors. This leads to a loss in service turnover of 345 M€/year. New servicing needs arise for CO_2 systems and cause gains of 57 M€/year. Net loss for service companies would be 289 M€/year. Losses are particularly high for condensing units (-186 M€/year) and rather low for service of fire protection equipment (-2.2 M€/year).

In option D, after the replacement of HFCs in systems of refrigeration, stationary AC, and fire protection, servicing activities according to Articles 3 and 4(1) of the F-Gas Regulation are no longer required in these sectors. In the sectors with charges <3 kg, i.e. domestic refrigeration, commercial hermetics, moveable air conditioners, single-split AC, and, partly, condensing units, application of Article 4(1) is no longer required. Discontinuation of Articles 3 and 4(1) leads to a net loss in service activities and turnover of -1,356 M€/year in Option D. This sum already includes earnings from new service and maintenance for ammonia and CO_2 systems of +114 M€/year. Losses are particularly high in four sectors, namely single split and multi-split AC units, chillers, and condensing units (-1,070 M€/year; 79%). In transport refrigeration (vans, trucks, fishing vessels) earnings can be expected, which are, however, comparably small.

The same effect would occur for bans in closed applications in option E, a discontinuation of Articles 3 and 4(1) would lead to a total loss in service turnover of -1,270 M€/year. This sum already includes earnings from new service and maintenance for ammonia and CO_2 systems of +78 M€/year. Service losses are particularly high for single split and multi-split AC units (-711 M€/year; 56%). The numbers differ from option D as the emission reduction effects are also lower due to a later introduction of the replacement substances.

As discussed in chapter 6.2.10, these "theoretical" losses for service companies are not expected to materialise in the short and medium term, since

(i) containment obligations stemming from the existing F-Gas Regulation are only slowly being fully understood and implemented on the ground by affected companies, leaving a lot of growth potential for the service sector in this field compared to the current situation;

(ii) service companies which have limited their business activities to leak checking and recovery usually are also involved in the installation of new equipment and its on-site construction (and stand to profit from the latter activities under a strengthened approach, in particular if on-site filling is prescribed).

ANNEX VII: Detailed results of Screening of Policy Options

1. DISCARDED POLICY OPTIONS

In the following more detailed information related to other considered but eventually discarded policy options is presented:

– **Suspension of current provisions of F-Gas Regulation**

A general suspension of existing provisions would disadvantage Member States and industry compliant with current legislation. Such a measure would also not be in line with the climate and energy package and the 2050 roadmap, that require contributions from all sectors to the EU emission reduction targets in 2020 and beyond until 2050.

– **Inclusion of additional activities under the EU-ETS**

The scope for inclusion of F-Gases under the EU-ETS Directive is rather limited. The Directive applies either to industrial installations that directly emit greenhouse gass or to aircraft operators, but not to household or industrial appliances and equipment that mostly contribute to emissions via leakages, at the end of the lifetime or through the use of a product, i.e. with a timelag of several years to decades after production. It would e.g. be impractical to require all individuals buying domestic fridges to acquire licenses for the F-Gases contained therein.

There are only few remaining sources of F-Gases that are directly emitted from industrial installations. PFCs from aluminium production are already covered under the F-Gas Directive. One potential application would be the use of SF_6 in magnesium die casting. However, most installations already phased out SF_6 due to the ban included in the F-Gas Regulation for quantities above 850kg per year and the remaining installations are addressed by policy option E.

– **EU harmonized tax schemes**

Experiences from Denmark and Norway with the implementation of tax schemes for fluorinated gases showed that

- The effect of taxes will strongly depend on the tax level chosen and on the development of prices for HFCs and other F-Gases. It is rather difficult to assess price elasticity for F-Gases in the context of the future development of global markets with significant growth projections of production levels in Asian countries. In this situation, it is rather uncertain, which would be the appropriate tax level. The uncertainties around the future development of prices for F-Gases with an uncertain level of production growth in emerging countries are a feature which is clearly distinct from other environmental taxes on products with more stable prices.

– The level of taxes needs to be determined nationally and should allow regular adjustments to the economic situation.

– Exemptions from tax should be chosen carefully and depend on national circumstances in Member States.

– Furthermore, substantial administrative effort to establish, operate and control such tax scheme for fluorinated gases at EU level would be needed over several years, in particular for a tax that is imposed on F-Gases in manufactured products due to the wide range of such products on the market charged with different F-Gases.

As other policy options are available to reach the environmental objectives, fiscal measures at EU level have been discarded at this stage, also considering the predominant Member State competence for those provisions.

– **Deposit and refund schemes**

Deposit and refund schemes provide financial incentives that can efficiently reduce demand and supply and foster responsible use of F-Gases, enhance recovery, recycling and reclamation, and support the use of low or zero GWP substances if linked to the GWP of specific substances. However, the level of the financial incentives should take into account the following aspects:

– Reclamation costs of recovered refrigerants (including costs for transport to reclamation facilities);

– Initial costs for set-up of the scheme (including infrastructure) and current costs of administration and control;

– Costs for refunds or rebates;

– Flexibility to allow regular adjustments to the economic situation;

– Deposit and refund schemes need to reflect the structure of supply of F-Gases, which are likely to vary substantially from one use to another and from one Member State to another.

Therefore, no generic scheme seems to be universally applicable in EU-27 and deposit and refund schemes seem to be a policy option that is preferably to be implemented at MS level and not at EU level.

2. DISCARDED SUB-OPTIONS OF POLICY OPTIONS B, C, D AND E

In addition to the general options discarded described under (1), some additional subsectors or specific applications were excluded from policy options B, C, D and E because of a more detailed screening exercise related to effectiveness, efficiency and other technical constraints which are presented in Table A_VII-1.

The screening criteria were the following:

– Effectiveness in terms of level of emission reductions (> 1Mt CO_2eq);

– Efficiency in terms of abatement costs (<50€ per t of CO_2eq abated);

– Technical constraints like safety or loss of energy efficiency;

– Other constraints such as consistency with other EU policies.

This screening analysis was performed in the same way as for the considered (sub)-options under policy options B to E (see next section (3)).

Table A_VII-1: *Sub-options discarded based on detailed screening for effectiveness, efficiency and other criteria as specified*

Application	**Discarded because of**
Option B: New VA for domestic refrigeration	Effectiveness criterion not fulfilled, very low emission reduction potential of 12 kt CO2eq. by 2030 due to small number of units containing F-Gases remaining on the EU market
Option C: Inclusion in the scope of Articles 4 (1): Refrigerated road transport – vans	Efficiency criterion not fulfilled, abatement costs about 290 €/t CO_2eq., effectiveness criterion not fulfilled, very low emission reduction potential of 11 kt CO_2eq. by 2030, implementation and verification is considered difficult due to high number of 'van operators'
Option C: Inclusion in the scope of Articles 3 and 4: Rail transport	Efficiency criterion not fulfilled, abatement costs about 340 €/t CO_2eq.very low emission reduction potential of 16 kt CO_2eq. by 2030 because 80% of operator already fulfil service requirements
Option C: Lowering the applicable charge threshold of certain equipment containing F-Gases already covered by Article 4(1)	Efficiency criterion not fulfilled, abatement costs > 1,750 € / t CO_2eq.for all sub-options
Option E: Ban of HFC-152a in XPS foam blowing	Effectiveness criterion not fulfilled, low emission reduction potential of 460 kt CO_2eq.
Option E: Ban of HFC in PU spray foam blowing	Efficiency criterion not fulfilled, abatement costs about 60 €/t CO_2eq., relevant mainly in Spain and Portugal
Option E: Ban of HFC in other PU foam blowing	Effectiveness criterion not fulfilled, low emission reduction potential of 590 kt CO_2eq. by 2030
Option E: Ban of HFC indomestic refrigeration	Effectiveness criterion not fulfilled, very low emission reduction potential of 12 kt CO_2eq. by 2030
Option E: Ban of HFC in centrifugal chillers	Effectiveness criterion not fulfilled, very low emission reduction potential of 9 kt CO_2eq. by 2030

Application	Discarded because of
Option E: Ban of HFC in refrigerated vans	Effectiveness criterion not fulfilled, low emission reduction potential of 420 kt CO_2eq. by 2030
Option E: Ban of HFC in heat pumps	Efficiency criterion not fulfilled, abatement costs about 130 €/t CO_2eq..
Option E: Ban of HFC in fishing vessels and ship AC	F-Gas Regulation not the most appropriate instrument to address this sector: The Commission is currently considering options to reduce greenhouse gas 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.
Option E: Ban of HFC in rail vehicle AC	Effectiveness criterion and efficiency criterion not fulfilled, very low emission reduction potential of 16 kt CO_2eq. by 2030 and abatement costs about 560 €/t CO_2eq., penetration rate < 100% until 2030
Option E: Ban of HFC-227ea in fire protection	Effectiveness criterion not fulfilled, low emission reduction potential of 170 kt CO_2eq. by 2030, penetration rate < 100% until 2030
Option E: Ban of SF_6 in medium voltage secondary switchgear	Effectiveness criterion and efficiency criterion not fulfilled, very low emission reduction potential of 60 kt CO_2eq. by 2030 and abatement costs about 350 €/t CO_2eq., penetration rate < 100% until 2030

N.B.: Effectiveness criterion was considered not to be fulfilled if emission reduction potential at EU-27 level was below 1 Mt CO_2eq. until 2030. Efficiency criterion was considered not to be fulfilled if abatement costs were higher than 50 €/tCO_2eq.

3. SCREENING OF SUB-OPTIONS FOR POLICY OPTIONS B, C, D & E

Table A_VII-2: *Options to address F-Gas emissions in EU-27 through voluntary agreements*

Self-regulation or co-regulation	Additional emission reductions 2030	Abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/ t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
VA with industry to phase-out/down HFCs in centralized systems, commercial hermetics, condensing units	18,818	-0.8 to 23.7	++	++	alternatives available, penetration rate 100% in 2020		Include
New VA with photovoltaic industry to replace SF_6 and NF_3	100	n.a.	-	+	alternatives available, 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 and SF_6	reduction potential n.e.	n.a.	-	+		VA expired in 2010	Include

Self-regulation or co-regulation	Additional emission reductions 2030	Abatement costs 2030	Effectiveness	Efficiency	Technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/ t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
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 installed by most producers, only 1 production facility without	Include
Total	**21,702***						

** without semiconductor and photovoltaic industry, and domestic refrigeration; n.a.: not applicable; n.e.: not estimated.*

Table A_VII-3: *Options to address F-Gas emissions through extending the scope of the F-Gas Regulation*

Improve containment and recovery in certain sectors	**Additional emission reductions 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq		
Improve containment and recovery						
Inclusion in the scope of Articles 4 (1): *Refrigerated road transport - vans*	11	291	-	--	Difficult implementation and verification due to high number of operators	exclude
Inclusion in the scope of Articles 3 and 4: *Refrigerated road transport – trucks and trailers*	1,430	46	+	+		include
Inclusion in the scope of Articles 3 and 4: *Rail transport*	16	340	-	--	80% of operators already fulfil service requirements	exclude

Improve containment and recovery in certain sectors	Additional emission reductions 2030	Abatement costs 2030	Effectiveness	Efficiency	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq		
Inclusion in the scope of Articles 3 and 4: *Refrigerated maritime transport – cargo ships*	273	10.5	-	+	F-Gas Regulation not the most appropriate instrument to address this sector: The Commission is currently considering options to reduce greenhouse gas 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: *Refrigerated maritime transport – passenger ships*	405	8.5	-	+		
Inclusion in the scope of Articles 3 and 4: *Refrigerated maritime transport – fishing vessels*	360	0.5	-	+		
Lowering the applicable charge threshold of certain equipment containing F-Gases already covered by Article 4(1)						
Domestic refrigeration	1	324,722	-	---		exclude

Improve containment and recovery in certain sectors	**Additional emission reductions 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq		
Commercial hermetics	13	29,575	-	---		
Moveable air conditioners	644	3,707	-	---		
Split air conditioners	6,057	2,204	+	---		
Heat pumps	740	1,756	-	---		
Extending the training and certification requirements to personnel undertaking activities currently not covered under Article 5						
	Not quantifiable	Not quantifiable			Effectiveness likely to be very low.	exclude
Introducing maximum leakage rates for certain systems and equipment containing F-Gases						
	Not available	Not available			Does not include accidents; problems related to measurability of leakage rates; effectiveness likely to be low	exclude
Introducing obligation for producers and suppliers of F-Gases to take back recovered F-Gases for reclamation and destruction						

Improve containment and recovery in certain sectors	**Additional emission reductions 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq		
	Not available	Not available			Include as an area for coordination and exchange of best practice as specific measures may vary across Member States.	exclude

Table A_VII-4: *Options to address SF_6 and HFC emissions from open applications in EU-27 through use bans*

Ban the use of SF_6 in open applications	**Additional emission reductions 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/ t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
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 (consistency).	include
Inclusion of HFCs from open applications of technical aerosols and XPS and PU foam in the scope of Article 9							
Ban of HFCs in technical aerosols	3,637	10	+	+	95% in 2020	Exemptions need to be defined	include

Ban the use of **SF_6 in open applications**	**Additional emission reductions 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/ t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Ban of HFC-152a in XPS foam blowing in 2015	460	-1.60	-	++	100% in 2015	GWP of 152a is much lower (124) than GWP of 134a (1,430). Could possibly 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 the use of SF_6 in open applications	Additional emission reductions 2030	Abatement costs 2030	Effectiveness	Efficiency	technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/ t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Ban of HFC in other PU foam blowing	587	3.5	-	+	up to 95% in 2015	Exemptions need to be defined.	exclude
Total	**5,190***						

* only the sub-options included for further analysis

Table A_VII-5: *Options to address F-Gas emissions from closed applications in EU-27 by placing on the market bans*

Ban the placing on the market of certain closed F-Gas applications	**Additional emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Domestic refrigeration	12	1.0	-	+	2015		exclude
Commercial hermetic systems	147	-0.8	--	++	2020		include
Condensing units	2,849	1.2	+	+	2020		include
Centralised systems	12,055	23.7	++	+	2020		include

Ban the placing on the market of certain closed F-Gas applications	**Additional emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
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. Combination of small + large ref. possible (threshold 50 kg)	include
Moveable AC	2,781	8.9	+	+	2020		include

Ban the placing on the market of certain closed F-Gas applications	**Additional emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
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

Ban the placing on the market of certain closed F-Gas applications	Additional emission reduction 2030	Abatement costs 2030	Effectiveness	Efficiency	technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Refrigerated vans	421	45.1	-	+/-	2020		exclude
Heat pumps	1,356	130.2		-	2020		exclude
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 greenhouse gas emissions from the maritime sector, taking into account its	Depends on choice of policy instrument

Ban the placing on the market of certain closed F-Gas applications	**Additional emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Cargo ship AC	232	16.7	-	+	2020		

Ban the placing on the market of certain closed F-Gas applications	Additional emission reduction 2030	Abatement costs 2030	Effectiveness	Efficiency	technical feasibility / penetration rates	Other qualitative criteria	Final evaluation
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
Passenger ship AC	97	35,0	-	+	penetration rate not 100%		
Refrigerated trucks and trailers	322	2.6	-	+	2030		include
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

Ban the placing on the market of certain closed F-Gas applications	**Additional emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**technical feasibility / penetration rates**	**Other qualitative criteria**	**Final evaluation**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			
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
Destruction of HFC-23 emissions from halocarbon production	370	<2	+	+++	100%	Industrial process emiss.; very high GWP; international commitments	include
Total	**47,459***	**18.9***					

**: only sub-options included for further analysis*

Table A VII-6: Option to address F-Gas supply in EU-27 through quantitative limits for the placing on the market of F-Gases. Reference year 2030

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_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2 eq.	Threshold: 50€/tCO_2eq			
Maximum supply reductions in all sectors relying on HFCs : 136,500 kt CO_2eq	69,239	16.5	+++	++	No need for 100% due to nature of measure	High flexibility	include

Table A VII-7: Options to address inadvertent HFC-23 emissions in EU-27 through the obligation for destruction of these emissions

HFC.23 emissions from halocarbon production	**Add. emission reduction 2030**	**Abatement costs 2030**	**Effectiveness**	**Efficiency**	**Technical feasibility / penetration rates**	**Other Qualitative criteria**	**Final evaluati on**
	kt CO_2eq	€/t CO_2eq	Threshold: 1,000 kt CO_2eq	Threshold: 50€/tCO_2eq			

Destruction of HFC-23 emissions from halocarbon production to the extent technically feasible	370	<2	+	+++	100%	Industrial process emissions; very high GWP; international commitments	include

ANNEX VIII: Sensitivity Analysis of Cost Estimation

1. General

The economic impacts largely rely on cost data. This applies not only to economic impacts in a strict sense such as effects on specific abatement costs, on costs to the industry sectors and to individual end-users but also to social impacts such as effects on prices for equipment or employment.

It is evident that all monetary variables which are included in Annex V of *Schwarz et al. (2011)*[9] influence the economic and social situation of the actors in the relevant sectors. In this section, a sensitivity analysis is conducted for those cost parameters which significantly affect the abatement costs (€/t CO_2eq) and thus the cost efficiency of the potential emission reductions. The most important parameters are considered to be the following:

– The **assumed purchase prices** of unsaturated HFCs such as HFC-1234yf (€60/kg), HFC-1234ze (€40/kg as a refrigerant, €12/kg as foam blowing agent or aerosol propellant) and the blend DR-11 (€30/kg) influence the abatement costs of the alternative technical options which rely on these substances. It is anticipated that the cost will considerably decrease up to 2030 because large-scale production of the chemicals would be established by then. In the sensitivity analysis the effect of a price reduction of 50% ("half price") is assumed, compared to the prices mentioned above ("base case").

Table A_VIII-1: *Assumptions for purchase prices of alternative substances*

	"base case" scenario	**"half price" scenario**
HFC-1234yf	€60 /kg	€30/ kg
HFC-1234ze	€40 /kg as a refrigerant; €12 /kg as foam blowing agent or aerosol propellant	€20 /kg as a refrigerant; €6 /kg as foam blowing agent or aerosol propellant
DR-11	€30 /kg	€15/ kg

– The **discount rate for the annualisation of investment costs** strongly influences the total annual costs to operators in each individual sector, for application of conventional HFCs as well as of low-GWP alternatives. A discount rate of 4% was used in *Schwarz et al. (2011)*[9] as a general assumption and might be appropriate from the perspective of the national economy (long-term capital market interest). However, a discount rate of 4% is too low compared to the return rate from the perspective of individual operators. An alternative discount rate of 8% will be used for cost estimates and results will be compared to those based on a 4% discount rate ("base case").

The impact of a doubled discount rate and halved cost of unsaturated HFCs on emission reduction in 2030 was analysed separately for the three policy options: Option B "Voluntary agreements", option D "Quantitative limits for the placing on the market of certain F-Gases", and option E "Ban of placing on the market of certain open and closed applications".

2. OPTION B "VOLUNTARY AGREEMENTS IN CERTAIN HFC APPLICATIONS"

After screening, the option B "Voluntary agreements" includes only five application sectors of F-Gases: Commercial hermetics, commercial condensing units, commercial centralised systems, fire protection with HFC-23, and XPS manufacture with HFC-134a as blowing agent. Despite the small number, the emission reduction potential is comparably high because the reduction potential of alternative low-GWP solutions is assumed to follow the penetration rates of the relevant technologies without delay, as it is the assumption in the option "Quantitative limits for the placing on the market".

2.1. Effects of prices for unsaturated HFCs

The specific emission abatement costs in the five sectors are below the threshold of €50 /t CO_2eq. This efficiency criterion is met not only in the base case where the value is 16.8 € /t CO_2 eq. but also if the prices of unsaturated HFCs are halved: 16.6 € t CO_2 eq. (see *Table A_VIII-2*, col. 2). This very small difference results from the assumption that there is only one sector for which unsaturated HFCs (HFC-1234ze) are considered a realistic technical alternative to HFCs. This sector is XPS manufacture, where the price reduction for HFC-1234ze leads to a reduction in the sector specific abatement cost from 1.0 € /t CO_2eq to -1.5 € /t CO_2eq.

Table A_VIII-2: *Option B Voluntary agreements: Impact of doubled discount rate and halved cost of unsaturated HFCs on emission reduction 2030*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFCs	**High cost**	**Half cost**	**High cost**
Maximum reduction potential	21,332	21,332	21,332
Abated at< €50/tCO_2eq	21,332	21,332	21,183
Abatement cost (€/tCO_2eq)	16.8	16.6	30.4
Sectors > 50€/tCO_2eq	0	0	1
Not abated emissions (>€50/tCO_2eq)	0	0	149

Table A_VIII-3: *Option B: Sector excluded by screening as efficiency too low*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFCs	**High cost**	**Half cost**	**High cost**
			Commercial hermetics

2.2. Effects of discount rate

Under a doubled discount rate of 8 % instead of 4 % the average abatement cost increase from € 16.8 to 30.4€/t CO_2eq. (see Table A_VIII-2, column 3). The comparably high growth results from the fact that all five sectors are affected if the investment costs are annualised with the higher discount rate. In one sector (commercial hermetic (refrigeration systems)) the abatement costs rise over the threshold of 50 € /t CO_2eq, so that the cost effective overall emission reduction potential of the policy option is reduced. It decreases only by 0.15 Mt CO_2eq, from 21.33 to 21.18 Mt CO_2eq because the affected sector is very small.

2.3. Conclusions

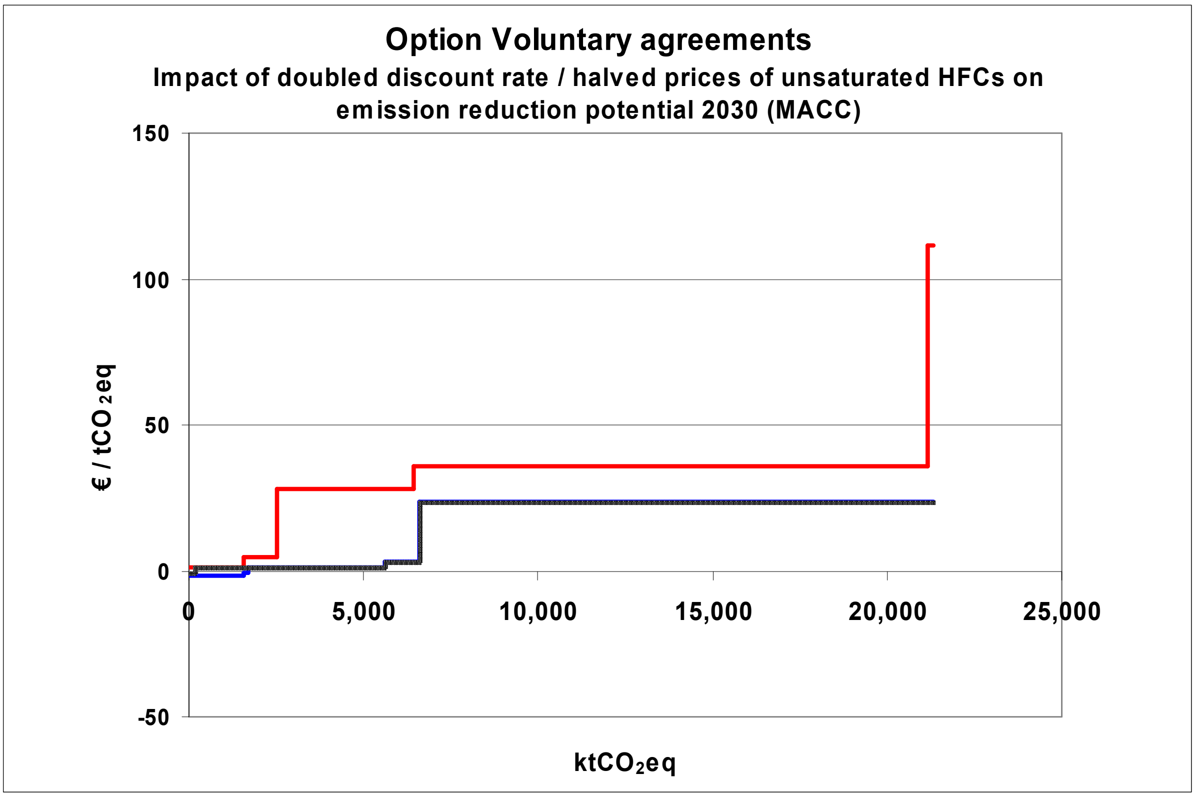

Fig. A_VIII-1: Option B: Impact of doubled discount rate and halved prices of unsaturated HFCs on the MACC of the 2030 HFC emission reduction potential

N.B.:. The middle curve displays the base case. The upper curve indicates the effect of a discount rate of 8%. The emission reduction potential at abatement costs below €50 /tCO_2eq is only slightly lower than that in the two other cases, amounting to ca. 21 Mt CO_2eq. As can be seen on the x-axis from 1.5 Mt CO_2eq onwards the curve for the base case is congruent with the curve for "half price of unsaturated HFCs" because there is no difference between the abatement costs in four of the five sectors concerned.

Fig. A_VIII-1 shows that the three curves do not substantially split from each other. In summary, even under a very high discount rate (indicating focus on short-term profitability) this option can be considered effective and efficient.

3. OPTION D "QUANTITATIVE LIMITS FOR THE PLACING ON THE MARKET OF CERTAIN HFCS"

This option assumes that the emission reduction potential follows the gradual growth of the penetration rates of alternative technologies i.e. that in each year all technically feasible replacement solutions for new equipment are utilised according to the assumed penetration mix even though the full market penetration potential might not have been achieved yet. The technically feasible reduction potential by 2030 is estimated at 72.9 Mt CO_2eq. The emission reductions which can be achieved at high efficiency is lower. Screening showed the following result: The reduction potential can reach 69.2 Mt CO_2 if all relevant sectors with emission abatement costs below 50 €/t CO_2eq make the assumed transitions to low-GWP options. The efficiency criterion causes the exclusion of four sectors from the option: PU spray foam, heat pumps, rail vehicle AC, with potential emission reduction of 3.7 Mt CO_2eq. The estimated average emission abatement cost for the remaining 25 sectors is 16.5 €/t CO_2eq (for all these data see Table A_VIII-4, first column).

Table A_VIII-4: *Option D "Quantitative limit for the placing of HFCs on the market": Impact of doubled discount rate and halved cost of unsaturated HFCs on emission reduction 2030 for option D "Quantitative limits for the placing on the market of certain F-Gases"*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFC	**High cost**	**Half cost**	**High cost**
Maximum emission reduction potential 2030	72,915	72,915	72,915
Abated at < €50/tCO_2eq	69,239	70,608	64,441
Average abatement cost (€/tCO_2eq)	16.5	9.9	28.1
Sectors > 50€/tCO_2eq	3	2	7
Not abated emissions (>€50/tCO_2eq)	3,676	2,307	8,474

Table A_VIII-5: *Option D: Sectors excluded in the screening due to low efficiency*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFCs	**High cost**	**Half cost**	**High cost**
	Heatpumps	Heatpumps	Heatpumps
	Rail mobile AC	Rail mobile AC	Rail mobile AC
	PU spray foam		PU spray foam
			Bus mobile AC
			Refrigerated vans
			Large industrial refrigeration
			Commercial hermetics

3.1. Effects of prices for unsaturated HFCs

Table A_VIII-4 (column 2) shows that the reduction in prices for all unsaturated HFCs by 50% leads to a decrease of the average abatement cost from 16.5 to 9.9 €/tCO_2eq. As a result, PU spray foam (application of HFC-1234ze) will be included in the option because the abatement costs of the sector mix of low-GWP alternatives decrease from 62 to 42 € /t CO_2eq., falling below the efficiency threshold of € 50/t CO_2 eq. As a consequence, the overall emission reduction potential increases by 1.4 Mt CO_2eq, from 69.2 to 70.6 Mt CO_2eq. It must be added that Schwarz et al. (2011)[9] assume that unsaturated HFCs are included in the 2030 penetration mix only in 16 of the 25 sectors of concern.

3.2. Effects of discount rate

The third column of *Table A_VIII-4* reveals that the quantitative impact from a discount rate of 8% compared to 4% is significantly higher than the impact of the price reduction of unsaturated HFCs.

The average abatement costs per t CO_2eq increase to € 28.1, and cause a drop in efficiently abated emissions to 64.4 Mt CO_2eq (compared to 69.2 Mt CO_2eq in the base case). In contrast to the base case, four additional sectors will be excluded from the option because of low cost effectiveness (threshold is € 50/t CO_2eq): bus AC, refrigeration of vans, large industrial refrigeration and commercial hermetic systems.

It must be mentioned that under the assumption of a discount rate of 4%, the abatement cost for large industrial refrigeration are the lowest of all sectors (- 22 €/tCO_2eq) but turn positive, to even + 65 €/tCO_2eq, if a discount rate of 8 % is applied. This is a result of the high absolute investment cost of large ammonia-based refrigeration plants which are assumed to replace conventional R-404A systems. This means that operators' commitment to short-term profitability is in the industrial refrigeration sector particularly detrimental to the introduction of low-GWP alternatives.

3.3 Conclusions

The price reduction of unsaturated HFCs by 50% increases the cost-effective emission reduction potential of the option "Quantitative limits for the placing on the market of HFCs" by 1.4 Mt CO_2eq (+ 2%) while the doubling of the discount rate decreases the cost effective emission reduction potential by 4.8 Mt CO_2eq (- 7%).

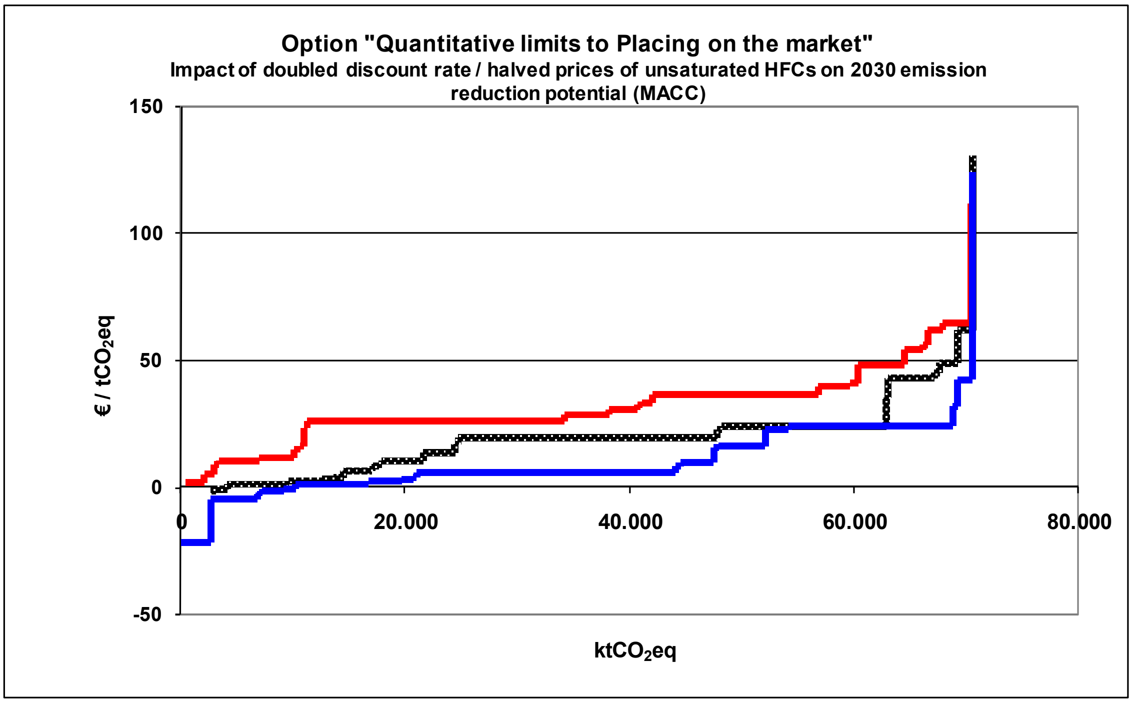

Fig. A_VIII-2: Option D: Impact of doubled discount rate and halved prices of unsaturated HFCs on the MACC of the 2030 HFC emission reduction potential

N.B.: The middle curve displays the base case. The upper curve indicates the effect of a discount rate of 8%, showing that 64.4 Mt CO_2eq can be reduced with abatement costs below €50 /tCO_2eq. The lower curve represents the impact of a price reduction of unsaturated HFCs by 50%; the cost effective emission reduction potential is higher, amounting to 70.6 Mt CO2eq. It is the same reduction potential as in the base case (middle curve).

Fig. A_VIII-2 shows that the three curves do not substantially differ indicating that even doubling of the discount rate would not put the policy option "Quantitative limits for the placing on the market of certain F-Gases" at risk.

It can be concluded that even under a high discount rate (indicating focus on short-term profitability) the option can be considered effective and efficient.

4. OPTION E "BAN THE PLACING ON THE MARKET OF CERTAIN OPEN AND CLOSED APPLICATIONS OF F-GASES"

In the option “Quantitative limits for the placing on the market” it was assumed that the reduction potential of replacement solutions follows the penetration rates of alternative technologies without delay, i.e. every year all available replacement solutions for new equipment are installed according to the penetration mix. In the option “Ban the placing on the market of certain open and closed applications of F-Gases” a ban can, however, only be established if the penetration mix is at 100% (or less provided that specific exemptions can be clearly specified). Therefore, in the screening process a considerable number of sectors have been excluded from the ban option because the assumed penetration mix of low-GWP alternatives will not reach the required market penetration by 2030. Even when 100% penetration can be reached by 2030, there is a delay in the introduction of low-GWP alternatives which reduces the 2030 emission reduction potential compared to the option “Quantitative limits for the placing on the market” (or “Voluntary agreements”) in sectors where two (or three) options are feasible.

Furthermore, certain small sectors with emission reduction potential < 1 Mt CO_2eq are considered to be too small to be included in the ban option. The total number of sectors for which bans are technically feasible before 2031 and sufficiently effective is 16 (out of 27). However, two of the remaining sectors do not fulfil the efficiency criterion <50€ /t CO_2eq, and are also excluded from the option (heat pumps, PU spray foam).

The 2030 emission reduction potential of bans in the remaining 14 sectors of closed and open applications was estimated at 52.3 MtCO_2eq by Schwarz et al. (2011)[9]. A precondition is that all sectors make the assumed transitions to low-GWP options. The estimated average abatement cost for the 14 sectors is 15.9 €/tCO_2eq. (*Table A_VIII-6*, column 1).

Table A_VIII-6: *Option E Ban of placing on the market of certain open and closed applications with HFCs: Impact of doubled discount rate and halved cost of unsaturated HFCs on the 2030 emission reduction*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFC	**High cost**	**Half cost**	**High cost**
Maximum reduction potential	57,092	57,092	57,092
Abated at< €50/tCO_2eq	52,278	52,278	51,929
Avabatement cost (€/tCO_2eq)	15.9	8.3	26.5
Sectors> 50€/tCO_2eq	2	2	4
Not abated emissions (>€50/tCO_2eq)	4,814	4,814	5,163

Table A_VIII-7: *Option E: Sectors excluded by screening for lack of cost efficiency*

Discount rate	**4%**	**4%**	**8%**
Unsaturated HFCs	**High cost**	**Half cost**	**High cost**
	Heatpumps	Heatpumps	Heatpumps
	PU spray foam	PU spray foam	PU spray foam
			Industrial refrigeration
			Commercial hermetics

4.1. Effects of prices for unsaturated HFCs

As can be seen in *Table A_VIII-6* (column 2), the reduction in prices by 50% for all unsaturated HFCs leads to a decrease of the average abatement costs from 15.9 to 8.3 €/tCO_2eq. Compared to the calculations with higher prices of unsaturated HFCs, no additional sector falls below the efficiency threshold of € 50/t CO_2eq. As a consequence, the overall emission reduction potential is the same for both price estimates.

4.2. Effects of discount rate

The third column of *Table A_VIII-6* reveals that there is a quantitative impact from the doubling of the discount rate not only to the average emission abatement costs, which will almost double, but also to the emission reduction potential, which will be reduced by a small amount.

The average abatement costs per t CO_2eq increase to € 27.5, and cause a drop in efficiently abated emissions by 0.35 Mt CO_2eq from 52.3 Mt CO_2eq. Two sectors more than in the base case will be excluded from the option because of low cost effectiveness (threshold €50/t CO_2eq): large industrial refrigeration and commercial hermetic systems.

Under a discount rate of 4 % the abatement costs for large industrial refrigeration are the lowest of all sectors (-22€/t CO_2eq) but turn positive, to + 65 €/t CO_2eq, if a discount rate of 8 % is applied. This is a result of the high absolute investment costs of large ammonia-based refrigeration plants which are assumed to replace conventional R-404A systems. This means that operators' commitment to short-term profitability is in the industrial refrigeration sector particularly detrimental to the introduction of low-GWP alternatives. The increase in abatement costs in the sector of commercial hermetic systems is in the same range, rising from -0.8 € to +111 €/t CO_2eq. This is also due to the fact that the investment costs of systems with low-GWP refrigerants (R-290 and R-744) are substantially higher than for systems with conventional HFCs, even if the absolute difference is comparably small.

4.3. Conclusions

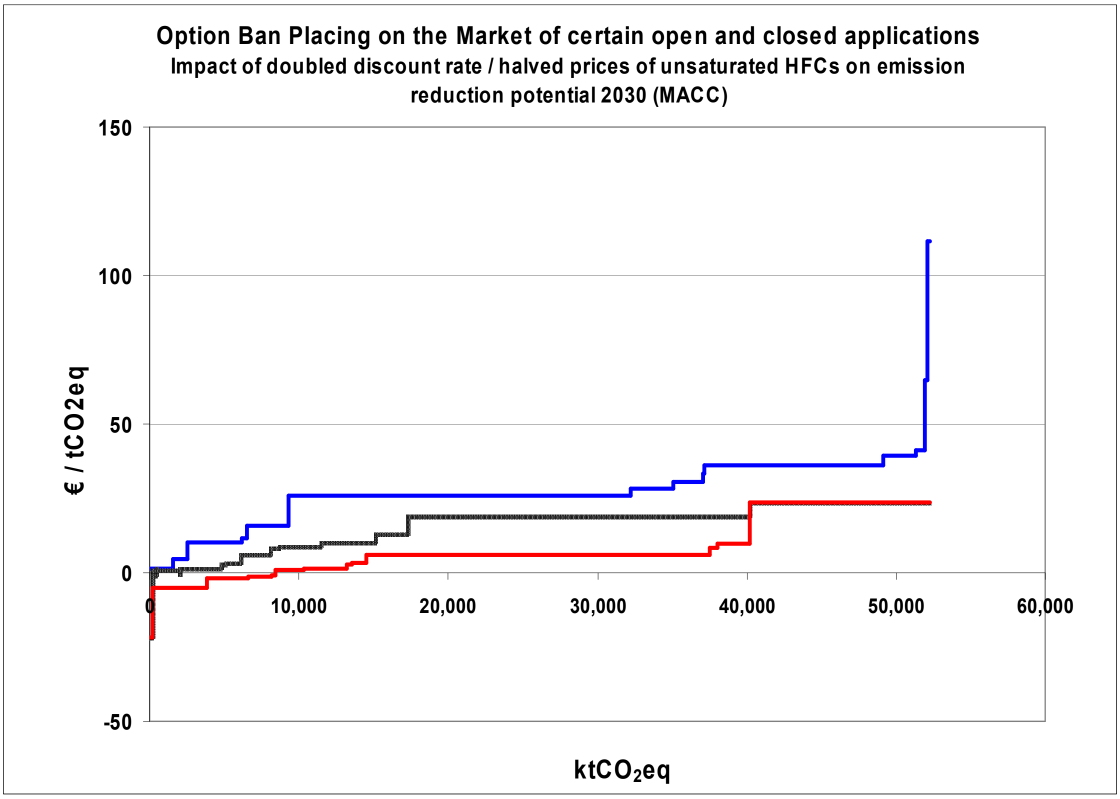

Fig. A_VIII-3: Option E: Impact of doubled discount rate and halved prices of unsaturated HFCs on the MACC of the 2030 HFC emission reduction potential

N.B.: The middle curve displays the base case. The upper curve indicates the effect of a discount rate of 8%, showing that 51.9 Mt CO_2eq can be reduced with abatement costs below €50 /tCO_2eq. The lower curve represents the impact of a price reduction of unsaturated HFCs by 50%; the cost effective emission reduction potential is higher, amounting to 52.2 Mt CO2eq. It is the same reduction potential as in the base case (middle curve).

Fig A_VIII-3 shows that the three curves do not substantially split from each other, indicating that even doubling of the discount rate would not set the policy option E "Ban placing on the market of certain open and closed applications" at risk. In summary, even under a very high discount rate (indicating focus on short-term profitability) the option E can be considered effective and efficient.

<u>ANNEX IX: Model Description of the *EmIO-F Europe* Input-Output model and Sensitivity Analysis of Employment impacts</u>

1. INTRODUCTION

This Annex contains a more detailed description of the model *EmIO-F Europe* - Employment Input-Output Model for Analysis of Policies and Measures for the European Union and the results of a sensitivity analysis of the employment impacts.

2. THE INPUT-OUTPUT MODEL

EmIO Europe is a static Input-Output Model to determine direct and indirect output and employment effects of environmental policies and measures for the European Union. In this case, the model is calibrated to accommodate the effects of the revised F-Gas regulation (hence EmIo-F). The model is based on the Eurostat Input-Output Table (EU-27) for domestic production at basic prices for the year 2007 as well as Eurostat employment data for the same year. The inverse (Leontief) coefficient matrix is calculated and used to analyse the direct effect a demand shift (e.g. investment) has on the output of a sector and all indirect effects triggered in other sectors providing intermediate inputs to production of this sector. The vector of employment coefficients (derived by dividing the level of employment per sector by aggregate output of this sector) defines the level of employment per unit of production and can thus be used to investigate the effect on employment of an increase or decrease in production activity.

The Model incorporates 59 NACE Rev.1.1 2-digit sectors. The relevant sectors for an F-Gas related analysis are: 29 “Machinery and equipment n.e.c.”, 24 “Chemicals, chemical products and man-made fibres” and 40 “Electrical energy, gas, steam and hot wa-ter”. Sector 29 not only includes manufacturing of machinery and equipment, but also repair and maintenance (e.g. 29.23 “Non-domestic cooling and ventilation equipment”). From 2012 onwards (reporting year 2008) countries will report to Eurostat according to NACE Rev.2. In this more disaggregated classification sector, the sectors for servicing and maintenance will be differentiated from manufacturing sectors and thus permit a more detailed treatment of the effects on investment in new equipment vs. changes in service and maintenance needs.

To apply the model, information on both investment and operation and maintenance (O&M) activities induced by the policy measure is required and needs to be assigned to sectors within the Input-Output model. This includes information on increased investment and O&M activity stimulated by the policy or measure in some areas (blue box in A_IX-1) as well as information on decreased activity due to the policy or measure in other sectors (red box in A_IX-1). In case, information is provided on a more detailed level, the data needs to be aggregated in accordance with the sectoral aggregation level of the input-output statistics. In the process of aggregation, some activities may need to be assigned to one and the same sector (e.g. machinery and equipment or services relating to maintenance and repairs) and information on positive and negative stimulation and their individual effects on employment may no longer be disentangled. The overall net effect, however, would be assessed.

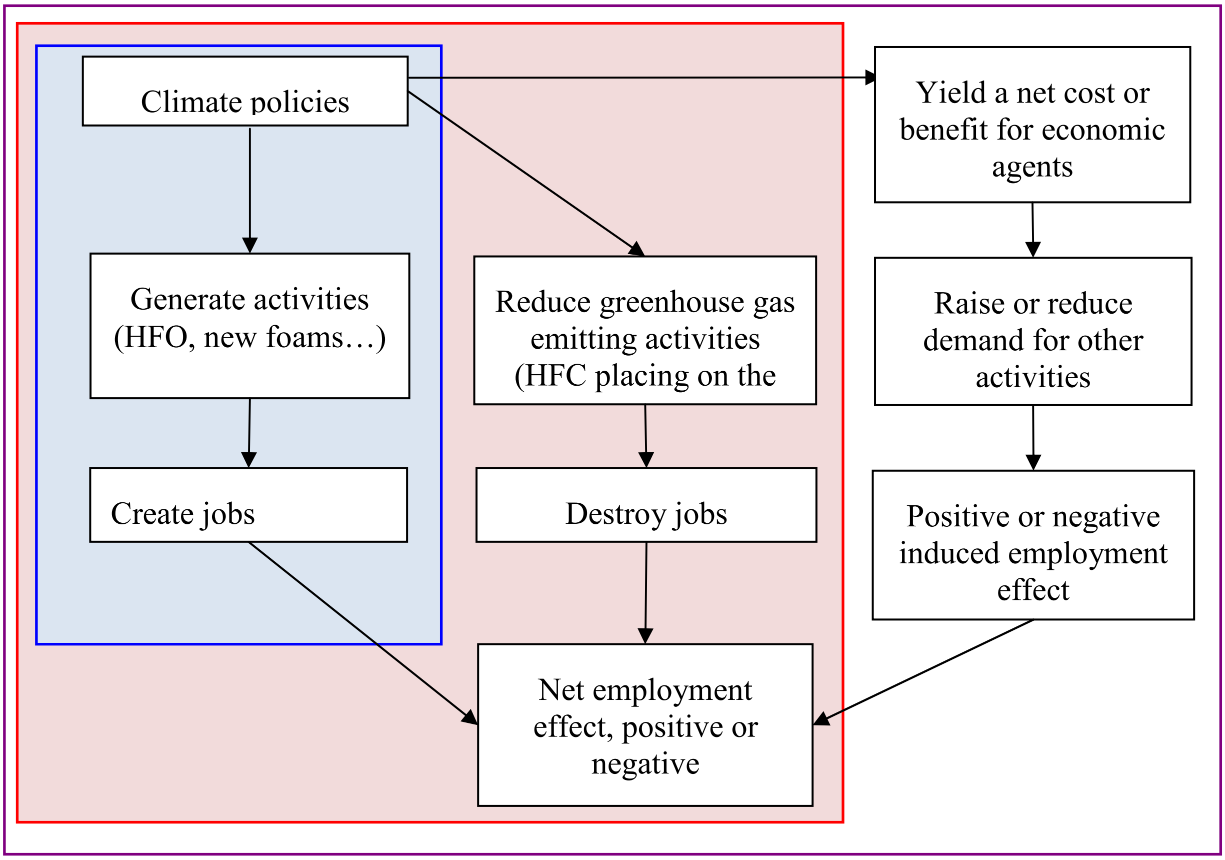

Fig. A_IX-1: Main economic mechanisms of job creation and destruction

Source: adapted from Quirion and Demailly (2008)[79]

This approach may present a bias towards the most expensive technical and organisational option, because a large amount of these costs is due to additional labour costs. It is therefore important to account for the fact that economic agents (households, businesses, governments) will necessarily pay for these extra costs and will therefore reduce other expenses, thus inducing a negative effect on output and employment. Taking into account this "income effect" (purple (larger) box in the above Fig. A_IX-1) requires some additional assumptions, notably relating to which economic actors will bear the extra costs and how they will change their saving and consumption in response to these extra costs. EmIO Europe can distinguish whether the cost of the policy or measure is borne by consumers, by industry or by the government. As F-Gases are mainly associated with end-use products, we assume that any additional costs to the production sectors will be fully passed on to consumers.

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[79] P. Quirion and D. Demailly (2008), "*-30% de CO2 = + 684000 emplois, l'équation gagnante pour la France*", study for WWF France, http://www.centre-cired.fr/perso/quirion/quirion_emploi_wwf.pdf

Currently two variations are implemented in EmIO Europe to account for consumer reaction. Both have been applied in the current context: i) the additional costs incurred from compliance with the policy will reduce final demand proportionally for all production sectors (proportional scenario), ii) the additional costs will not affect demand for basic products (such as food, textiles, furniture, electronic equipment, most services) but will reduce demand for products from those sectors that are affected by the regulation (subsistence scenario).

The model further distinguishes two methodological variants concerning the financing of changes in activities (e.g. investment):

(1) One variant labelled "Ex-post financing by consumers" which models the net effect (direct and indirect) on production stimulated by the policy (i.e. investment in hardware, changed maintenance requirements, purchase of materials and changed electricity consumption) and shows the effect of a change in household consumption after this initial impulse has been fed through the economy.

(2) A second variant labelled "Ex-ante financing by consumers" which simultaneously takes into consideration the initial impulse and the induced reduction in demand by consumers needed to finance this impulse. Total impact on employment is thus based on direct and indirect production effects as well as consumer demand effects (purple (larger) box in Fig. A_IX-1).

In the context of the F-Gas regulation variant 2) concerning the financing of investments was applied in EmIo Europe, i.e. the effect on consumer was assessed after the initial impulse and induced demand reaction of the policy was fed through the economy.

Summarising an analysis of output and employment effects in response to a policy or measure needs to tackle all those sectors that are affected because of the regulation-induced changes in demand for goods and products. These include direct output and employment effects because of the change in investment or production, such as increased investment in a specific technology, as well as indirect output and employment effects because of the change in demand of products and goods further up the production chain. While direct output and employment effects can be assessed based on simple input coefficients (e.g. additional output and employment per unit of in-vestment, additional output and employment per unit of turnover etc.), assessing indirect effects requires an economic approach that covers all economic sectors and their interactions. Using a more comprehensive modelling framework based on official input-output statistics, e.g. input-output analysis as applied by EmIO Europe, allows addressing both direct and indirect output and employment effects.

EmIO Europe can give a basic assessment of the effect of the additional burden a policy or measure may impose on the economy as well of the effect of recycling of revenues that may be raised by a policy or measure. The financial burden to cover needed investments can be expressed as a reduction in demand distributed across sectors, while revenue recycling may – even at the same time – stimulate demand across the same or others sectors. The model can differentiate these demand induced third-stage employment effects for households, industry and/or government.

EmIO Europe provides a fairly easy-to-use tool for understanding linkages between different parts of the economy. It has the advantage of

– Providing direct and indirect effects

– Giving a relatively high resolution of sectoral detail (for the EU: NACE Rev1.1 59 2-digit sectors, higher resolution in NACE Rev.2)

– Input-output and employment data readily available (data on investment, however, is required)

– Medium degree of complexity

– Simple relationships (Leontief production structure for production sectors)

– No special software requirement: Spreadsheets

– High transparency

However, one has to keep in mind that the Input-Output Model is static and therefore assumes fixed ratios for inputs and production. Furthermore, it lacks supply-side information or budget constraints. The model can be used to give a good indication of the magnitude and direction of the effects. It can be considered a basic assessment and may also provide a first stage of a more comprehensive assessment.

3. SENSITIVITY ANALYSIS OF EMPLOYMENT IMPACTS

This section presents a sensitivity analysis of the output effects by relaxing some of the assumptions made. As the calculation of the output effect is an intermediate step in the calculation of the employment effects those effects are likely of the same sign and magnitude.

The first assumption concerns the way in which households react to increased costs by reducing their demand for goods. Up to now we have assumed that the additional costs incurred from compliance with the policy reduces final demand proportionally for all production sectors (*proportional scenario*). If instead the additional costs do not affect demand for basic products (such as food, textiles, furniture, electronic equipment, most services) but will reduce demand for products from those sectors that are affected by the regulation (*subsistence scenario*). The analysis shows that the output effect of the subsistence scenario is less pronounced. This is due to the fact that more of the demand reduction concerns imports in the subsistence scenario (24% instead of 16%) and thus does not stimulate production activity in the EU. Figure A_IX-2 compares the output effects of the two variations for all three policy options.

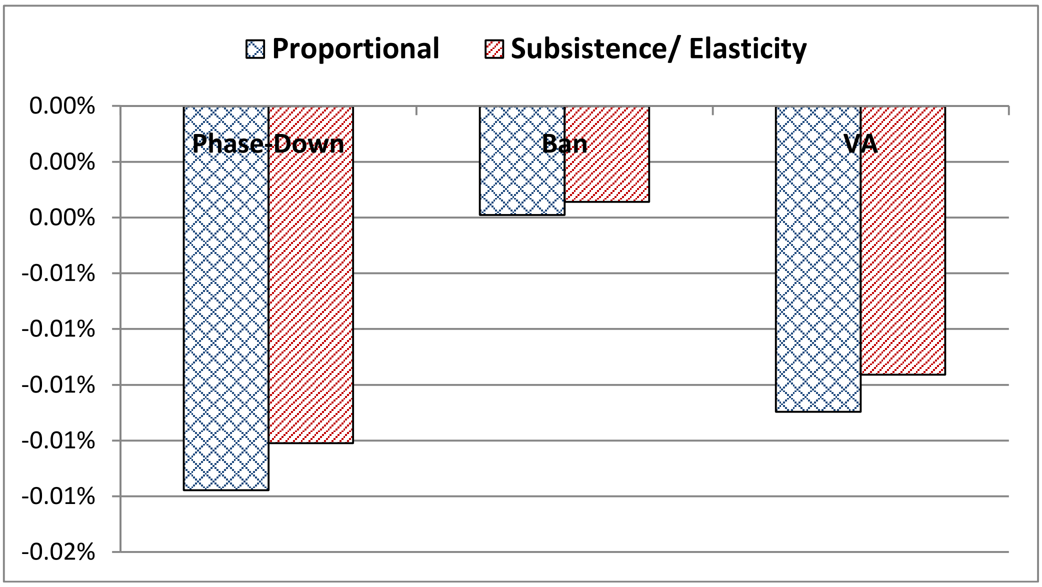

Fig. A_IX-2: Output effect of different assumptions on demand reduction by consumers

However, independent of the assumptions relating to the demand reaction, the overall effect remains about the same (see Fig. A_IX-3 below).

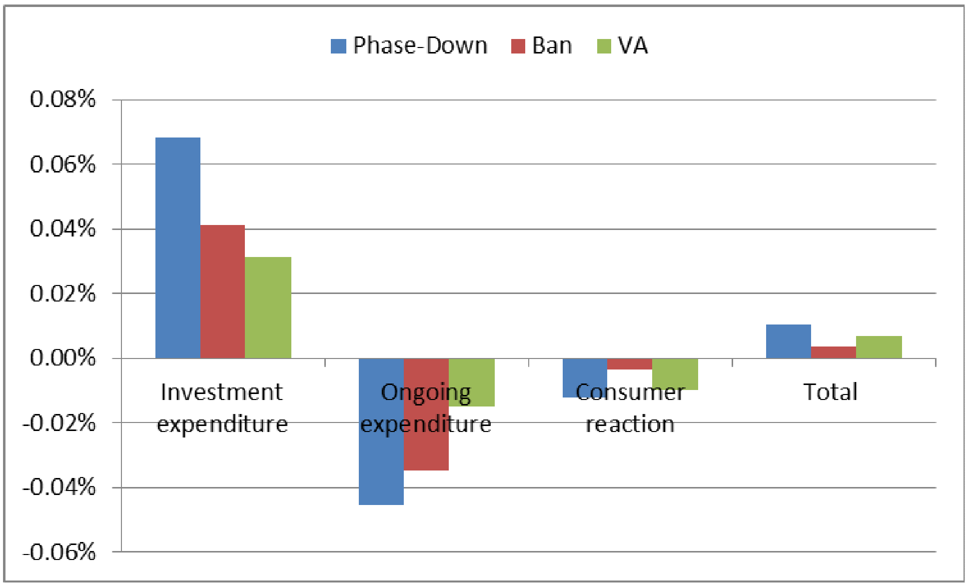

Fig. A_IX-3: Output effect for the different options under different assumptions on consumer reaction (as % of 2007 overall output)

The second sensitivity analysis estimates output effects sensitivity of reduced prices for unsaturated HFCs. The most notable effect occurs in the chemicals sector, for which the policy-induced change in investment is now negative for all three options, with the least negative effect on production activity occurring for Option D (Phase Down) (See Figure A_IX-4). This effect is due to the fact that under this assumption that conventional HFCs are more expensive than their replacements, meaning that less money flows into the chemicals/gases sector. Again, however, the overall picture remains very close to the base case (see Figure A_IX-5).

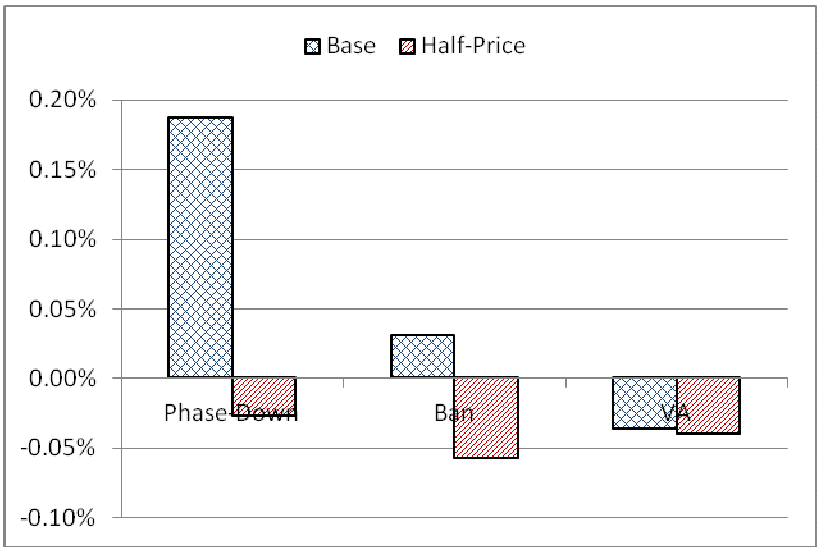

Fig. A_IX-4: Output effects of half-price scenario on the chemicals/gases sector (as % of 2007 sector output)

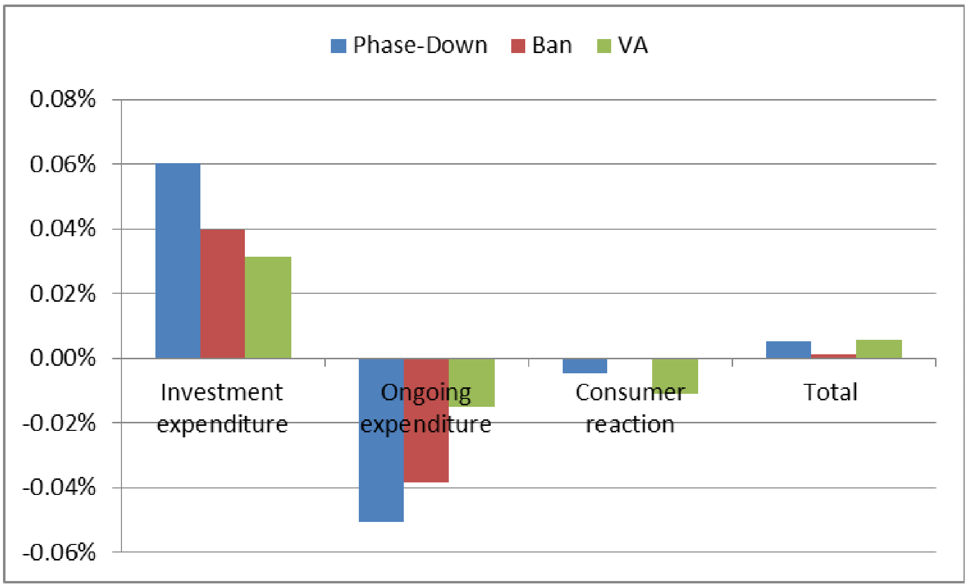

Fig. A_IX-5: Overall effects of a half-price scenario (as % of 2007 output)

ANNEX X: Mechanism for the Placement of HFCs on the EU Market

1. INTRODUCTION AND SUMMARY

The main concept for a phasedown mechanism entails defining a reduction pathway between the current and a future level for the placing of HFCs on the EU market.

In this annex, sub-options for mechanisms implementing the policy option to phasedown of the placing on the market of HFCs (option D) are developed and discussed. For each set of sub-options one option was chosen for further consideration.

In the chosen scope of the proposed phasedown mechanism, "placing on the market" (POM) refers to making available HFCs to the EU market (sold production + import) for the first time and is limited to HFC flows in bulk quantities, thus not accounting for HFCs contained in imported products or equipment. Exported bulk HFCs are not regarded as "placed on the market" if they are either directly exported by producers or exported by third parties when the quantities had been purchased for that purpose. The list of HFCs covered by the phasedown is almost identical to the list of HFCs covered by the current F-Gas Regulation: The list is amended by two additional HFCs (HFC-152 and HFC-161) for which the IPCC provided GWP values in its Fourth Assessment Report. The GWPs of the Fourth IPCC Assessment Report shall be used for the conversion of physical tonnes into CO_2 equivalents. No exemptions for HFC-using sectors are foreseen.

The limitation for the placing of HFCs on the EU market ("cap") for subsequent periods decreases over time. The proposed reduction schedule features a step-wise reduction, starting with a freeze at a baseline level in 2015, a first reduction step in 2016 and a final step down in 2030 reaching 29% of the baseline. The reduction steps are based on the expected feasibility of using alternative substances. Decisions on the additional reductions beyond 2030 should be made at a later stage, but well before 2030, taking into account new technological developments.

Under the reduction scheme, entities that place HFCs on the EU market have to hold rights to place HFCs on the market (quotas), expressed in tonnes of CO_2eq. The sum of these quotas should not exceed the defined maximum level for a respective year for the EU. The Commission allocates quotas to involved producers and importers, using a central database where quota accounts of all companies placing HFCs on the EU market are held. The allocation method chosen for further consideration is allocation by grandfathering, i.e. based on past activities. Quotas may be transferred between companies, but the transfer of unused quota at the end of a year to subsequent years is not allowed.

As under the present F-Gas Regulation, stakeholders annually report to the Commission and Member States on stocks, production, import and exports of regulated HFCs which allow the calculation of their respective placing of HFCs on the market. Reports above certain thresholds shall be subject to independent verification. Reporting on reclamation and destruction is enhanced.

Enforcement and compliance, beyond the administration of the quotas at EU level, follows the general responsibilities for the enforcement of EU legislation. MS would need to take measures in cases of non-compliance as part of the implementation of a revised F-Gas regulation to ensure that the HFC phasedown is implemented.

In order to ensure the integrity of the phasedown mechanism it is necessary to foresee complementary measures addressing the placing on the market of equipment pre-charged with HFCs. Already today the amounts of HFCs imported in equipment account for 11% of the overall EU demand and is expected to reach a share of 18% in 2030 if left unaddressed. Whereas for hermetically sealed systems bans of certain types of equipment are envisaged, for other systems a ban on pre-charging before importation should ensure that the quantities used for the first fill are captured by the phasedown.

2. SCOPE

2.1. Coverage of substances

Any mechanism limiting the placing on the market of HFCs needs to clearly define the substances controlled under such a scheme.

2.2. HFCs to be specified individually in a list

The current Regulation (EC) No 842/2006 defines the scope by means of a general definition[80] complemented by a list of individual substances in an annex in which the individual substances are grouped according to their chemical similarities. The Montreal Protocol and the Kyoto Protocol use a similar approach by listing the gases covered. Such a list of HFCs would be annexed to a regulation or decision in the same way as in the current F-Gas Regulation and for HFCs such a list could include the following chemical species as indicated in *Table A X-1*. This list includes all HFCs for which the IPCC has already provided an official GWP.

HFC-152 and HFC-161, which are included in *Table 1*, are not covered by the current F-Gas Regulation but should be included. These HFCs could become potential alternatives to other HFCs, in particular in preparations. Under the UNFCCC there is an agreement that new HFCs for which the Fourth IPCC Assessment Report has provided a GWP should be included in the future reporting of greenhouse gas emission inventories and also in emission reduction commitments of a second commitment period under the Kyoto Protocol[81]. For consistency in monitoring and reporting with the future modalities under the UNFCCC and the Kyoto Protocol, it is therefore recommended that all HFCs are included in such a list for which the IPCC has provided a GWP in its most recent assessment report.

In both amendment proposals to the Montreal Protocol that have currently been proposed, the scope of substances covers all HFCs as listed in *Table A_X-1*. In addition, two unsaturated HFCs, i.e. HFC-1234yf (GWP 4) and HFC-1234ze (GWP 6) are also included, which are not included in the Fourth IPCC Assessment Report and do not have an GWP determined under the UNFCCC.

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80 ‘Fluorinated greenhouse gass’ means hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) as listed in Annex I and preparations containing those substances, but excludes substances controlled under Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer. ‘Hydrofluorocarbon’ means an organic compound consisting of carbon, hydrogen and fluorine, and where no more than six carbon atoms are contained in the molecule.

81 Annex III to decision -/CP.17 on “the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention” and decision -/CMP.7 on “greenhouse gass, sectors and source categories, common metrics to calculate the carbon dioxide equivalence of anthropogenic emissions by sources and removals by sinks, and other methodological issues”

Table A_X-1 *List of HFC species and GWPs according to the IPCC 2nd Assessment Report (SAR), 3rd (TAR) and 4th Assessment Report (FAR)*

Industrial Designation or Common Name	Chemical Formula	Global Warming Potential for 100-year time horizon		
		SAR	TAR	FAR
Hydrofluorocarbons				
HFC-23	CHF_3	11,700	12,000	14,800
HFC-32	CH_2F_2	650	550	675
HFC-41	CH_3F	150	97	92
HFC-125	CHF_2CF_3	2,800	3,400	3,500
HFC-134	CHF_2CHF_2	1,000	1,100	1,100
HFC-134a	CH_2FCF_3	1,300	1,300	1,430
HFC-143	CH_2FCHF_2	300	330	353
HFC-143a	CH_3CF_3	3,800	4,300	4,470
HFC-152	CH_2FCH_2F			53
HFC-152a	CH_3CHF_2	140	120	124
HFC-161	CH_3CH_2F			12
HFC-227ea	CF_3CHFCF_3	2,900	3,500	3,220
HFC-236cb	$CF_3CF_2CH_2F$		1,300	1,340
HFC-236ea	$CF_3CHFCHF_2$		1,200	1,370
HFC-236fa	$CF_3CH_2CF_3$	6,300	9,400	9,810
HFC-245fa	$CHF_2CH_2CF_3$		950	1,030
HFC-245ca	$CH_2FCF_2CHF_2$	560	640	693
HFC-365mfc	$CH_3CF_2CH_2CF_3$		890	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$ or ($C_5H_2F_{10}$)	1,300	1,500	1,640

Despite the inconsistency with the proposed amendments, the scope of the phasedown mechanism should be limited to HFCs for which the IPCC has provided an 'official' GWP, as this is currently the major science-based process for such a determination. Otherwise it would be necessary to establish a parallel scientific process to assess the GWPs for new gases which seems beyond the mandate of the revision of the F-Gas Regulation.

The inclusion of unsaturated HFCs with a low GWP in the phasedown would only have a minor impact on the calculated future supply if expressed in CO_2eq. In the scenarios calculated for this report, the consumption of unsaturated HFCs totals approx. 216 kt CO_2eq in 2030. This is 0.16% of the total supply in 2030. The two unsaturated HFCs should be included in the reporting requirements under a revised F-Gas Regulation in order to ensure adequate monitoring and reporting of their production and consumption, also for the case an international HFC phasedown mechanism, including these substances, is agreed.

2.3. Considered alternative(s)

Beside an enumeration of the covered HFCs in a list, the alternative option considered was to include only HFCs above a certain (GWP) threshold. In view of ensuring consistency with current policy approaches and the initiatives at international level, but also to avoid uncertainties with regards to the determination of a GWP for a substance in question, the latter option has been discarded.

2.4. Coverage of mixtures/preparations

It is also necessary to define how substances that consist of mixtures of HFCs or mixtures of HFCs with other substances would be treated. A consistent treatment would mean that only the specific component of a mixture would fall under the scope of a phasedown mechanism if a controlled HFC component specified in the list is contained in the mixture. In terms of enforcing the regulation this means that the components of the mixtures are treated as individual substances and measures are needed to enable the identification of the components of such mixtures.

Such a rule would diverge from the current F-Gas Regulation that defines "preparations" as a mixture composed of two or more substances, at least one of which is a fluorinated greenhouse gas, except where the total GWP of the preparation is less than 150. However, it seems inconsistent to use a GWP threshold for preparations, but not in general for the scope of F-Gases.

2.5. Recovered, recycled and reclaimed HFC

Recovered, recycled and reclaimed HFC quantities should not be included in the scope of the phasedown mechanism in order not to offset efforts made according to Article 4 of the F-Gas Regulation which reduces the demand for virgin HFCs. This is also in line with the ODS Regulation, which excludes these quantities from controls of production.[82]

3. ACTIVITIES SUBJECT TO QUANTITATIVE RESTRICTIONS

The proposed HFC phasedown mechanism refers to the placing on the market of HFCs in the EU and is thus related to the supply of HFCs. "Placing on the market" is defined in the F-Gas Regulation (Article 2 point 7) as "the supplying of or making available to a third party within the Community for the first time, against payment or free of charge, […] and includes import into the customs territory of the Community".

3.1. HFCs in imported equipment

The phasedown mechanism follows the approach chosen under the Montreal Protocol for ozone depleting substances and reduces the availability of HFCs over time, in this way eliminating potential sources of future emissions. Whether measures on bulk substances alone would be sufficient to reach the intended emission reductions in the EU depends on the share of emission sources in the EU not covered by the mechanism in such a case. The supply of bulk HFC in the EU does not represent accurately the amount of substances which can potentially be emitted in the EU if there is a considerable amount of substances contained in imported pre-charged equipment. The first fill of such equipment is carried out in a third country and manufacturing emissions

[82] ODS Regulation: "No amount recovered, recycled or reclaimed shall be considered as production".

occur there. After import and installation of the equipment, use-phase and disposal emissions arise in the EU.

HFC quantities contained in pre-charged equipment already account for a significant share of HFCs on the European market in several sectors, such as mobile and stationary AC, and is projected to increase. Most relevant is the stationary AC sector (in particular smaller AC units such as single-splits and movables) for which high growth is projected (*Schwarz et al. (2011)*[9]. 75-90% of the split and multi-split air conditioners and small moveable systems are imported from outside the EU, in particular from Asia.

The ratio of HFCs in pre-charged equipment being imported to the EU relative to overall EU demand is currently 11% (18 Mt CO_2eq) and is projected to amount to a share of 18% or 31 Mt CO_2eq HFC supplied to the EU in the year 2030 (see *Table A_X-2* and *Figure A_X-1*).). Details on the sectoral distribution are provided in *Tables A_X-3* and *A_X-4*.

Table A_X-2 *Supply of HFCs in EU-27 (Mt CO_2eq) in the baseline scenario (F-Gas Regulation and MAC Directive in place; option A) in the period 2010-2050 – with and without pre-filled systems*

Year	2010	2015	2020	2030	2050
Supply for domestic fill/refill (supply)	152	141	140	139	143
Supply of HFCs in imported pre-filled systems	18	24	27	31	32
Total demand incl. pre-filled imported systems	170	165	167	170	174

Source: AnaFgas

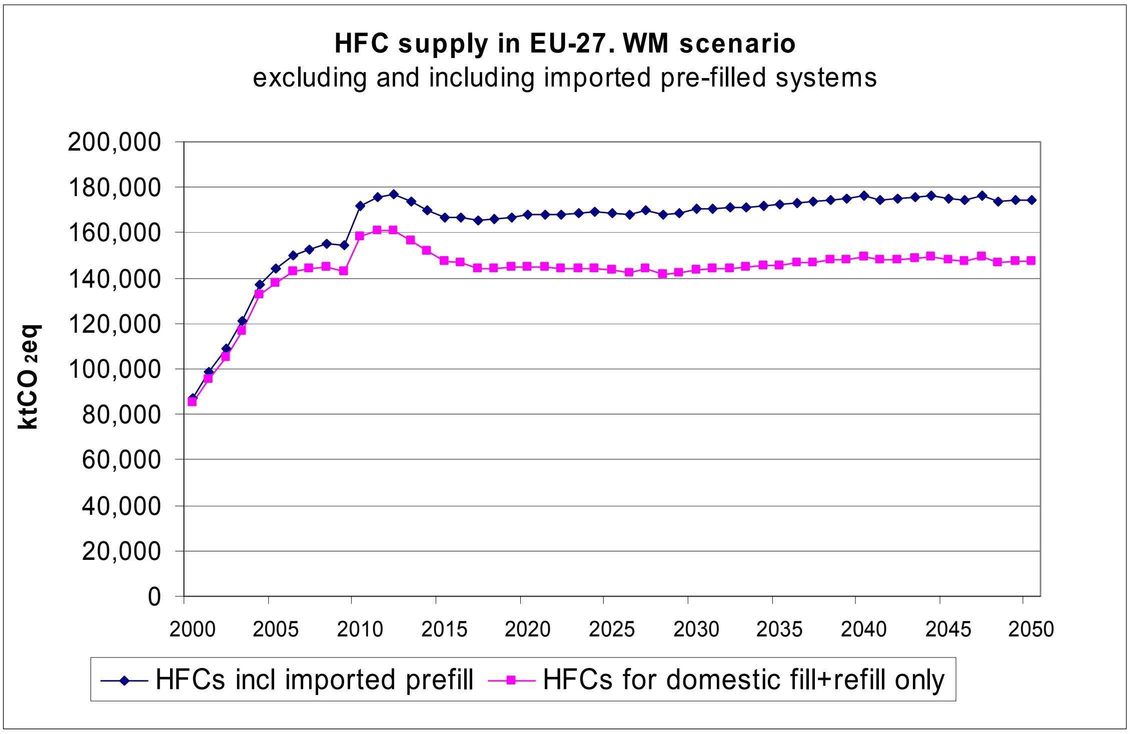

Fig. A_X-1: Supply of HFCs to EU-27 (kt CO_2eq) in the baseline (WM) scenario (F-Gas Regulation and MAC Directive in place; option A) in the period 2000-2050 with and without pre-charged systems

With regard to pre-charged equipment, two categories need to be distinguished:

– Hermetically sealed pre-charged equipment is filled during manufacture and sealed before import; refilling is not required. Only the import of moveable room air conditioners is quantitatively relevant. Other types of hermetically sealed pre-charged equipment are not imported in large quantities, e.g. commercial refrigeration systems, heat pumps, tumble-dryers and domestic refrigerators containing HFCs.

– Other pre-charged equipment, for example split-air conditioners, is usually filled with an initial charge during manufacture. This type of equipment needs in some cases to be topped up with refrigerant before use and possibly during service.

On the other hand, some quantities of HFCs supplied in the EU are not used and finally emitted in the EU but filled into equipment which is exported. Domestic first fill for export equipment is relevant with regard to mobile air conditioners of motor vehicles and medical aerosols (MDIs). XPS (extruded polystyrene) insulation boards blown using HFC-134a constitute an export stream of HFCs in products as well.

Table A_X-3 presents in a more disaggregated way the sectorial figures on the HFC-using sectors affected by the proposed phasedown scheme. It indicates the HFC types mainly used, main replacement options and demand estimates for 2010 and 2030, including bulk substance plus imports of pre-charged systems and exports of prefilled systems. It also indicates the sectors in which imports or exports of equipment or products containing HFCs are relevant.

Table A_X-4 provides quantitative data on the sectorial demand in CO_2eq tonnes.

Table A_X-3 Sectoral demand of HFCs and shares of imported or exported equipment / products containing HFCs

Sector			HFCs used	Replacement options	HFC demand (ext2) [kt CO2eq] 2010	2030 baseline scenario	Growth 2030 vs. 2010	Pre-charged HFC equipment/ products	Import: share pre-charged of demand 2010	Export: share pre-charged of demand 2010	Remarks
Total					169,853	170,421	568				
	Refrigeration				60,557	55,265	-5,292				
		Domestic Refrigeration	HFC-134a	HC	3	0	-3	negl.	negl.	no	
		Commercial Refrigeration	HFC 134a; HFC 143a; HFC 125	HFC-1234yf; HC; CO2	36,320	34,867	-1,453	negl.	no	negl.	
		Industrial Refrigeration	HFC 134a; HFC 143a; HFC 125; HFC-32	NH_3	20,128	14,046	-6,082	negl.	no	negl.	
		Road transport Refrigeration	HFC 134a; HFC 143a; HFC 125	HFC-1234yf; HC; CO2	3,718	5,348	1,630	negl.	no	negl.	
		Shipping Refrigeration (fisheries)	HFC 134a; HFC 143a; HFC 125	NH_3	388	1,004	616	no	no	no	
	Stationary A/C and Heat Pumps				39,240	72,724	33,484				
		Room A/C moveables	HFC-32; HFC-125	HFC-1234yf; HC; CO2	2,391	6,980	4,589	yes	69%	negl.	
		Room A/C single split	HFC-32; HFC-125	HFC-1234yf; HC; CO2; HFC32	23,492	45,428	21,936	yes	50%	negl.	
		Rooftop	HFC-32; HFC-125	HFC-1234yf; HC; CO2	1,175	1,358	183	yes	22%	negl.	
		Variable Refrigerant Flow & Multisplit	HFC-32; HFC-125	HFC-1234yf; HC; CO2	2,618	5,187	2,570	yes	42%	negl.	
		Chillers (displacement)	HFC-134a; HFC-32; HFC-125	HFC-1234yf HC; CO2; NH_3	6,610	6,722	112	yes	4%	negl.	

Sector	HFCs used	Replacement options	HFC demand (ext2) [kt CO2eq]			Pre-charged HFC equipment/ products	Import: share pre-charged of demand 2010	Export: share pre-charged of demand 2010	Remarks
			2010	2030 baseline scenario	Growth 2030 vs. 2010				
Centrifugal chillers	HFC-134a	uHFCa, HC, H2O	567	605	38	no			
Heat Pumps	HFC-32; HFC-125	HFC-1234yf; HC; CO2; HFC32	2,386	6,443	4,057	negl.	no	negl.	
Mobile A/C			40,326	11,953	-28,373				
Car A/C	HFC-134a	HFC-1234yf	33,837	3,453	-30,384	yes	8%	10%	After 2017: No HFC import , export 100%
Bus A/C	HFC-134a	HFC-1234yf	1,918	1,870	-48	yes	3%	6%	
Truck A/C	HFC-134a	HFC-1234yf	3,532	4,688	1,155	yes	9%	11%	
Ship A/C	HFC-134a	NH_3, XP10	901	1,771	869	yes	4%	no	
Rail A/C	HFC-134a	CO2	137	171	35	no			
Foams			10,935	10,810	-125				
One Component Foam	HFC-134a	HC	255	311	56	negl.		negl.	
PU foam	HFC-365mfc; HFC-227ea; HFC-134a	HFC-1234ze; HC	6,128	5,947	-181	negl.		negl.	
XPS	HFC-134a; HFC-152a	HFC-1234ze; HC; CO2	4,553	4,553	0	yes	no	20%	only with HFC-134a (not 152a)
Other HFCs			18,795	19,668	873				
Aerosols	HFC-134a	HFC-1234ze	3,960	3,960	0	negl.	negl.	negl.	
Metered dose inhalers	HFC-134a; HFC-227ea		7,670	8,471	801	yes	negl.	50%	
Solvents	HFC-43-10mee		330	330	0	no			

Sector			HFCs used	Replacement options	HFC demand (ext2) [kt CO2eq]			Pre-charged HFC equipment/ products	Import: share pre-charged of demand 2010	Export: share pre-charged of demand 2010	Remarks
					2010	2030 baseline scenario	Growth 2030 vs. 2010				
		Fires extinguishers	HFC-227ea; HFC-23; HFC 236fa; HFC-125	FK-5-1-12	6,721	6,785	64	no			
		Aluminium & Magnesium Casting	HFC-134a		39	47	9	no			HFC-134a is replacement for SF6
		Semiconductor and Photovoltaics	HFC 23		76	76	0	no			
Note: a uHFC: unsaturated HFC											

Source: Estimates based on AnaFgas

HFCs: List of substances as in Table A X-1; GWPs of Fourth IPCC Assessment Report

Table A_X-4 *Sectoral demand of HFCs and unsaturated HFCs (uHFC) and shares of imported/exported equipment/products containing HFCs [GWP]*

Sector	HFC demand (ext2) [Mt CO2eq]					uHFC demand (ext 2) [Mt CO2eq]		Thereof import HFC pre-charged equipment [Mt CO2eq]			Thereof HFC refill imported pre-charged equipment. [Mt CO2eq]		Thereof export HFC pre-charged equipment [Mt CO2eq]		
	2010	2030 baseline (WM) scenario	Growth 2030 vs. 2010	2030 Phasedown (WAM scenario)	Red. potential 2030 WAM vs. WM	2030 WM scenario	2030 WAM scenario	2010	2030 WM scenario	2030 WAM scenario	2010	2030 WM scenario	2010	2030 WM scenario	2030 WAM scenario
Total	170	170	1	36	-134	0.1	0.3	18	31	0	8	16	9	9	8
Refrigeration	61	55	-5	9	-46	-	0.0	0	0	0	0	0	0	0	0
Stationary A/C and Heat Pumps	39	73	33	7	-66	-	0.1	15	30	0	8	15	0	0	0
Room A/C moveables	2.4	7.0	4.6	-	-7.0	-	0.0	1.7	4.8	-	0.6	1.6			
Room A/C single split	23.5	45.4	21.9	-	-45.4	-	0.1	11.7	22.7	-	6.3	11.3			
Rooftop	1.2	1.4	0.2	0.0	-1.3	-	0.0	0.3	0.3	0.0	0.1	0.1			
Variable Refrigerant Flow & Multisplit	2.6	5.2	2.6	0.2	-5.0	-	0.0	1.1	2.2	0.1	0.9	2.4			
Chillers (displacement)	6.6	6.7	0.1	0.3	-6.5	-	0.0	0.3	0.3	0.0					
Mobile A/C	40	12	-28	6	-6	0.1	0.1	3	1	0	0	1	4	4	4
Car A/C	33.8	3.5	-30.4	3.5	-	0.1	0.1	2.7	-	-			3.5	3.5	3.5
Bus A/C	1.9	1.9	-0.0	0.2	-1.7	-	0.0	0.1	0.1	0.0			0.1	0.1	0.0

Truck A/C	3.5	4.7	1.2	0.7	-4.0	-	0.0	0.3	0.4	0.1	0.4	0.8	0.4	0.5	0.1
Ship A/C	0.9	1.8	0.9	1.1	-0.6	-	-	0.0	0.1	0.0					
Foams	11	11	-0	4	-6	-	0.0	0	0	0	0	0	1	1	0
XPS	4.6	4.6	-	-	-4.6	-	0.0						0.9	0.9	-
Other HFCs	19	20	1	10	-9	-	0.0	0	0	0	0	0	4	4	4
MDI	7.7	8.5	0.8	8.5	-	-	-						3.8	4.2	4.2
Note: a uHFC: unsaturated HFCs: HFC-1234yf (GWP 4), HFC-1234ze (GWP 6)															

Source: Estimates based on AnaFgas; HFCs: List of substances as in TableA X- 1; GWPs of Fourth IPCC Assessment Report

3.2. Options for taking measures on pre-charged equipment

Without specific measures on HFCs in pre-filled equipment alongside a phasedown mechanism, these HFCs would be a continuously growing source of HFCs emissions in the EU.

As a first approach it was therefore considered to integrate quantities contained in pre-charged equipment in a phasedown regime. The high number of entities which would be covered by this extended scheme was one determining factor to discard this option. In 2010, 107 stakeholders were involved in production, import and export of bulk HFCs in quantities of more than 1 tonne/year.[83] For import and export of products and equipment containing HFCs, no reporting obligations exist so far. The numbers of producers, importers and exporters of pre-charged equipment can be estimated as shown in *Table A_X-5*. Whereas the number of producing firms of prefilled equipment is limited, the amount of distributors can only be estimated and is most likely high. The order of magnitude of affected importers and exporters could be thousands, depending on the thresholds for the application of the phasedown mechanism chosen.

Table A_X-5 *Estimates of producers and distributors of products or equipment containing HFCs*

2010	Third country based producers of systems for export into EU	EU based producers of systems for export to third countries	EU-based distributors of systems imported from third countries	EU based distributors of systems for export to third countries
XPS-134a	0	3	0	unknown
Air conditioned passenger cars	10	12	high number	unknown
Air conditioned lorries (N1-N3)	5	12	high number	unknown
Air conditioned buses	0	5	few	few
Stationary AC - Chillers	10	4	high number	< 10
Stationary AC - Excluding chillers	10	2	very high number	< 10
MDI	0	8	0	~ 30

Source: Estimates Öko-Institute

83 8 producers, 70 importers and 68 exporters submitted reports, some companies carry out two or all activities.

Hence, the inclusion of imports of pre-charged equipment would subject a presently unknown, high number of importers as stakeholders to the phasedown mechanism. Most of those importers would probably have rather small amounts of placements on the markets. Experiences from the EU ETS show that "small" participants often have little knowledge of the system and create a lot of problems in administering the system.

Furthermore, the market for HFCs in bulk is mature and stable with regard to the market players and shares. Under these conditions a reduction of the flexibility of this market, which would be the result of any phasedown mechanism, seems acceptable. But this would not be the case for an inhomogeneous market, like the one for the broad variety of HFC containing equipment, which has to be open for new entrants and innovative products. An inclusion of HFC contained in pre-charged equipment in the phasedown mechanism could in particular negatively impact on the market access for SMEs launching new types of equipment or extending current activities. Moreover, *importers* of equipment and products that shift towards alternatives would be able to transfer their allocated POMs and generate windfall profits. Consequently, since *domestic* producers of similar equipment and products do not receive POMs that could be used for providing windfall profits, they would be put at a price competitive disadvantage compared to importers.

Consequently, a direct inclusion of imports under the cap is not a good solution as it is discriminatory (as only importers would be subjected to a registration and reporting scheme, while domestic producers only experience possible price increases from the cap), difficult to administer and design in the absence of reliable data and given the potentially high number of entities to be regulated, and is likely to create perverse incentives and windfall profits. Furthermore, the flexibility of the inhomogeneous and dynamic market has to be preserved.

Therefore, other options for addressing imports of pre-charged equipment and products containing HFCs were considered alongside a phasedown mechanism for bulk substances. Possibilities include (i) to prohibit HFC imports contained in non-hermetically sealed equipment (i.e. require filling in the EU), and (ii) specific bans.

Imports of HFC contained in non-hermetically sealed pre-charged equipment (i.e. single-split, multi-split, rooftops) may be addressed by means of a ban on precharging of these kinds equipment. All non-hermetically sealed equipment used in the EU should be filled on their installation site with HFC quantities which were either produced in the EU or imported in bulk quantities, and are thus subject to the phasedown mechanism. Such a measure would apply to both domestically and foreign produced equipment equally and is therefore non-discriminatory. Equipment relying on HFCs would have to be imported or produced with a holding charge (e.g nitrogen) only. This measure would therefore also reduce possible emissions during transportation. By ensuring that HFCs fall under the phasedown cap, replacement of HFCs will be incentivised also for imported equipment. For equipment that no longer relies on HFCs the filling requirement ceases to apply.

The first fill during installation has the additional advantage that the risk of illegal installations by unqualified personnel resulting in high emissions, malfunctioning and loss of energy efficiency is greatly reduced.

As regards manufacturing costs, these are estimated to not exceed €0.50 per unit, including investments for additional equipment and labour costs, even when considering the most conservative assumption on the additional cost per unit (for split AC). Slightly higher costs for the user may occur for installing equipment where the phasedown cap has not yet triggered HFC replacement, for HFC equipment where topping up with gas is currently not necessary.

Hence, due to the high consistency with the phasedown measure (i.e. HFCs for use in Europe all covered by phasedown), stakeholder acceptance and flexibility (as opposed to bans) and potential to improve compliance with installation requirements, requiring on-site filling is the preferred option to address HFCs imported in non-hermetically sealed (RAC) equipment. This would cover 86% of the imported AC equipment refrigerant mass (data for 2008).

The use of HFCs in sealed equipment which have to be filled during the manufacturing process might become subject to specific bans as analysed in *Schwarz et al. (2011)*[9]. Such bans would affect imported equipment as well as domestically produced equipment and should in particular address, where possible, hermetically sealed systems (i.e AC movables), which represent 14% of imported refrigerant mass in AC equipment (data for 2008).

3.3. Export of products containing HFCs

The treatment of direct exports of products or equipment containing HFCs by producers or designated dealers is no issue for the environmental integrity of a phasedown system focused on the EU market, as emission from exported HFCs would occur outside the EU. However, exports of products containing HFCs previously placed on the EU market would be covered by a phasedown scheme and would reduce the quantities available for use in the EU. Thus, exporters of EU-produced products or equipment containing HFCs face a certain competitive disadvantage since the HFC needed for their products is included in the scope of a phasedown scheme. Sectors of concern are motor vehicles (including passenger cars, buses and lorries), metered dose inhalers (MDIs) and foams (HFC-134a-blown XPS insulation boards). HFCs used in these products/equipment fall under the phasedown measure so that there is a certain incentive to develop and use alternatives. For passenger cars the MAC Directive already limits the use of HFCs drastically so this is not an issue here. Extra cost due to HFC price will also be very small for all transport AC sectors.

An unknown high number of exporters is affected. However, a differentiation of HFCs to be used in production according to the destination of the final products is not practicable at the moment of the placing on the market of the HFCs, in particular when the substance is not directly purchased from a producer or importer. A crediting of exports, which could then be used for new production of HFCs or their import would, due to the high number of participants and transactions, render the system unmanageable.

3.4. Sectors covered

Based on the approach of the Montreal Protocol, all sectors relying on HFCs are covered by a phasedown mechanism. In this way, the phasedown could be established in the most flexible manner and would not inhibit innovation in particular areas.

The MAC Directive already represents an implementing measure for mobile AC in passenger cars and contributes to the overall phasedown. A sufficiently high tail supply should integrate sectors and applications which also in the future are likely to rely on HFCs in the period until 2030 and for which alternatives may face technical or economic constraints. Such a tail supply would need to include HFC quantities projected to be required for:

(3) MDIs;

(4) particular sectors where no technically feasible and safe alternatives are available such as technical aerosols, industrial refrigeration, XPS foams;

(5) Additional quantities for applications not known today or which today play a minor role but could possibly increase (e.g. ORC, specific heat pump applications, for example in tumble driers).

In one quantitatively minor case, an HFC phasedown leading to higher HFC prices on the domestic EU market would entail a perverse incentive: For magnesium foundries, HFC-134a (GWP FAR: 1430) is the replacement substance for SF_6 (GWP FAR 22800) as the protective agent for the melt. Smaller magnesium foundries that do not fall under the ban as defined in the F-Gas Regulation would receive a financial incentive not to switch the F-Gas. However, if the phasedown is accompanied by a ban of the use of SF_6 in small magnesium foundries, this perverse incentive would vanish.

It could be considered to establish exemptions from the phasedown of particular sectors or subsectors. It is, however, likely that this would cause considerable difficulties in defining the exact scope of such exemptions and would substantially increase the administrative burdens for all authorities and companies involved. Furthermore, exemptions would open up possibilities for fraud.

Feedstock use of HFCs is known in only one case: In one F-Gas manufacturing plant, HFC-23 (by-product) is not fully emitted or treated in an incineration device. Large shares of this by-production, ca. 400-500 tonnes per year, are used in the same plant for halon-1301 production. Halon-1301 serves as basic material for the manufacture of a broad-spectrum insecticide. It is not recommended to introduce any exemptions from the phasedown scope for HFCs used as feedstock, as these would concern only very singular cases which do not warrant an administrative complication of the system.

4. Reduction schedule for a phasedown for placing HFCs on the market

The proposed phasedown schedule has been developed on the basis of the bottom-up model (*AnaFgas*), assessing the future availability and pace of introduction of alternative technologies in all main sectors currently relying on HFCs. The scope of that assessment referred to the EU F-Gas demand including imported pre-charged equipment. The reduction scenario is established in a way that early retirement of equipment already in use does not count towards the reduction, while new equipment that is put into use after the old equipment has reached the end of its technical lifetime would fall under the cap. Therefore, the market has time to adjust to the new regulation and unforeseen costs for investors are not minimised.

It has to be acknowledged that a bottom-up technology-based model like *AnaFgas* can never fully catch all applications of F-Gases and arrive at the same values like the top-down sales statistic of the EU reporting. Amongst the number HFC sub-sectors not included in the model for lack of sufficient data are e.g. heat pump tumble dryers, water heating heat pumps, organic rankine cycle (ORC), thermometers, magnesium cover gas, semiconductor etching gas, and other applications which may not be known to the authors of the model. To account for such data gaps, inventory makers often use a “bottom-up surcharge” for “other” in the range of 10-20%.

Reporting under the F-Gas directive is restricted to bulk substances. Thus imports and exports of HFCs contained in pre-charged equipment is not accounted for. Reported sales 2010, i.e. approx. 192 Mt CO_2eq (based on FAR), are above the model values shown in Table A_X-4: in the latter case 152 Mt CO_2eq (FAR) are calculated for bulk supply to the EU in 2010 (HFC demand: 170 Mt CO_2eq minus import of HFC in pre-charged equipment: 18 Mt CO_2eq). This deviation of 26% is not surprising, not only because of the sectors not covered by the model, but also due to high 2010 figures which compensate for 2009 losses in the economic crisis. The *AnaFgas* model was developed in 2008 and primarily optimised to calculate emissions comparable to the emission inventories. Thus, 2010 demand effects were hardly foreseeable. The EU reporting system on F-Gases is still relatively new, and the demand of quality control in checking and aggregating the companies’ reports has proven to be very high. Thus, an overestimation in the reported EU figures is not impossible.

To compensate for the mentioned uncertainties the phase-out schedule calculated on the basis of the model has been up scaled to match the quantities reported under the F-Gas regulation; a precaution avoiding a shortage in supply for applications which are not (yet) replaceable.

In the following section the calculations of the demand with and without the inclusion of HFC contained in pre-charged equipment are illustrated, before in a second step the implications of the complementary measure (banning the placing on the market of non-hermetic equipment which already contains a HFC pre-charge) are included. Finally, the phase-out schedule is scaled up to ensure consistency with the top-down data derived from the reporting under the F-Gas regulation.

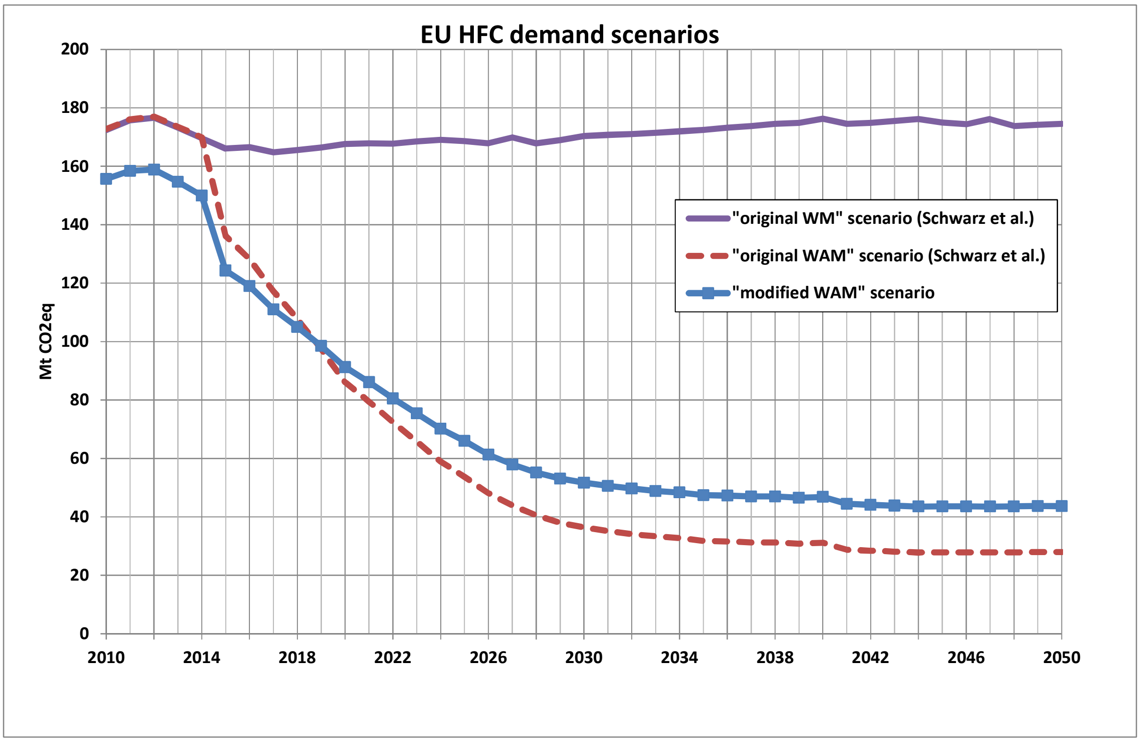

Fig. A_X-2: EU HFC demand scenarios

N.B.: For the original WM (baseline) and WAM (here: phasedown) scenarios, the term demand includes the first fill of pre-charged equipment imported into the EU. For the modified WAM scenario, the term demand does not includes the first fill of pre-charged equipment imported into the EU.

Source: Calculations based on Schwarz et al. (2011)[9]

Under the scenario which includes the quantities imported in equipment ("original WAM") the higher demand until around 2020 is generated by the first fill (carried our in the exporting country) which is accounted for under the phasedown. It is assumed that under this scenario the number of imported equipment decreases over the time as result of the mechanism.

Under the modified WAM scenario this incentive to switch to alternative technologies is missing and it is assumed that imports continue to increase (see *Table A_X-2*).[84] As a consequence the demand for HFCs for the servicing of such systems, carried out in the EU, is increasing and exceeds the overall demand calculated for the "original WAM" scenario.

In order to derive the total amount of virgin HFCs that needs to be placed on the market (POM) to fulfil the EU demand in the starting year, the estimated amounts of reclaimed

84 It must be noted that *Table A_X-2* does not reflect the impact of a phasedown scheme *without addressing HFCs in imported pre-charged equipment.* It is likely that that import shares would increase even more in this case.

HFC need to be deducted from the modified WAM demand scenario. *Figure A_X-3* shows the comparison of demand and the calculated POM which is necessary to meet that demand for the modified WAM scenario.

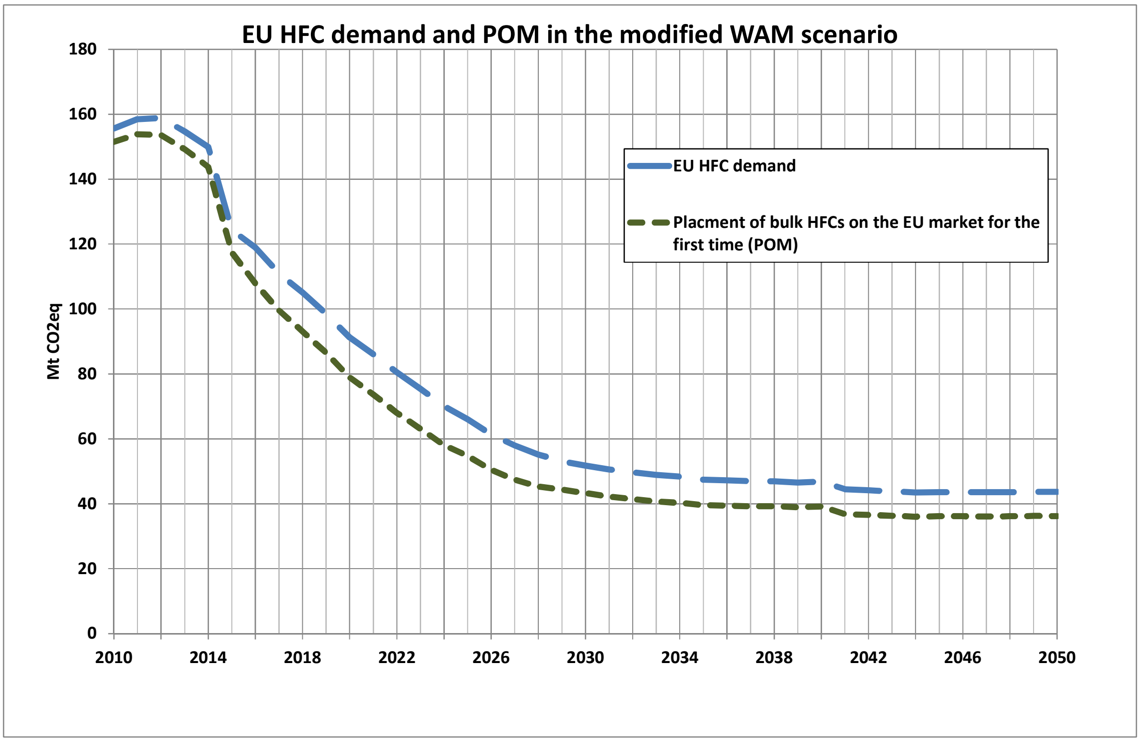

Fig. A X-3: Demand and POM in the modified WAM scenario

Source: Calculations based on AnaFgas

Reclaimed amounts are estimated by assuming that disposal emissions as calculated in the *AnaFgas* model are on average 50% of the F-Gas content at the end-of-life. The other half is estimated to be partly reclaimed (16%) and destroyed (34%).

The POM in the modified WAM scenario and the proposed phasedown steps are shown in *Figure A X-4.* The first limitation ("freeze") of the POM is suggested to take place in 2015. The first two reduction steps are designed to be above the calculated POM in order to grant more flexibility to ensure that companies have sufficient time to adapt: For the first reduction step in 2016 an additional margin of 10% of the model results for POM are added, for the second reduction step a margin of 5% is used. All later phasedown steps are designed to follow closely the technically feasible reduction of the modified WAM scenario. At present, the reduction schedule is defined up to 2030. Decisions on the pathway beyond 2030 should be made at later stage but well before 2030.

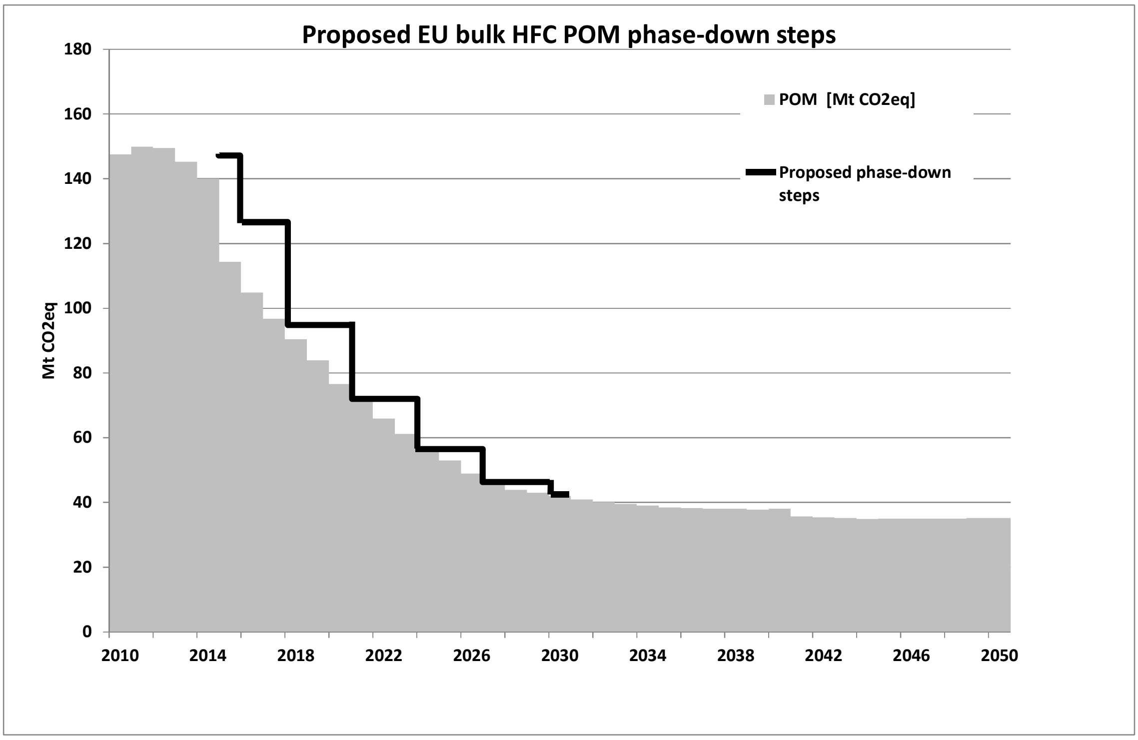

Fig. A_X-4: Phasedown steps (POM of bulk HFCs)

Source: Calculations based on AnaFgas

If the bulk phasedown is accompanied by measures on HFC imports contained in non-hermetically sealed equipment, a similar effect as explained for the difference between the original and the modified WAM scenarios is assumed: In the first years, a higher POM within the EU would be necessary in order to serve the additional demand for filling imported equipment. In later years (after 2020) a lower demand for HFCs can be expected, because for imported non-hermetic equipment the same rate of switching to alternatives to HFCs can be assumed as for domestically produced equipment.

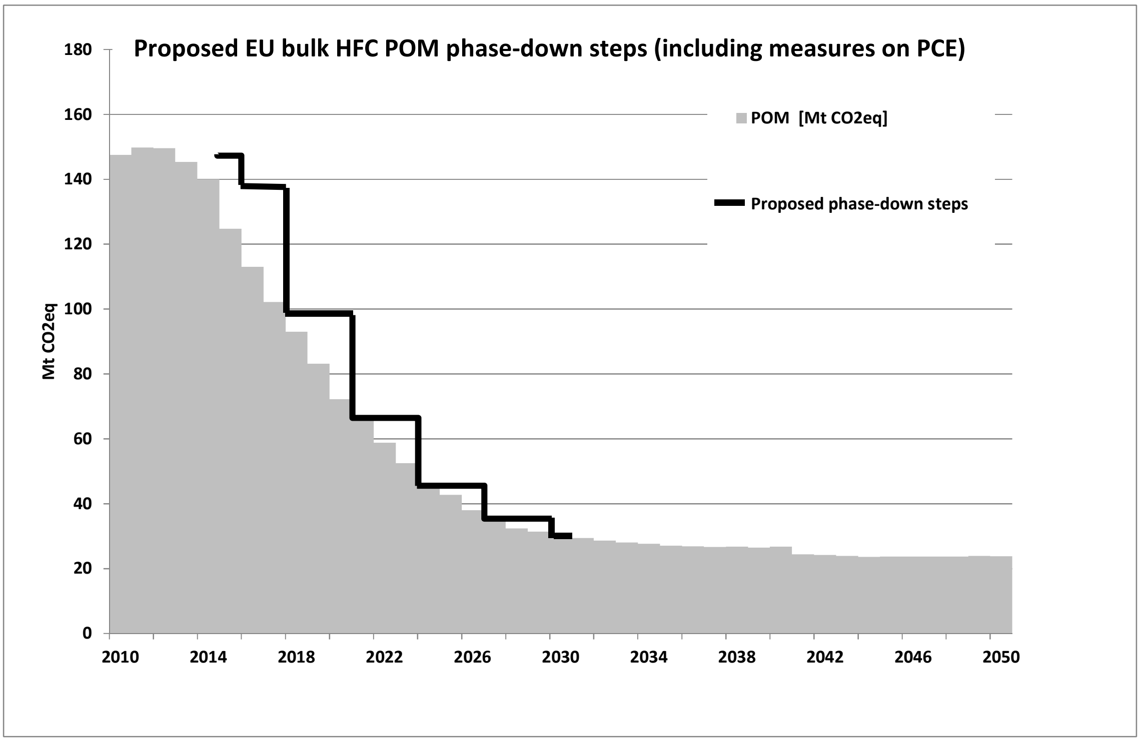

Fig. A_X-5: Phase-down steps (POM of bulk HFCs accompanied by measures on pre-charged equipment (PCE))

Source: Calculations based on AnaFgas

As mentioned above, the reduction schedule derived from the model needs to be scaled up by 26% in order to meet the level of EU reporting on HFCs. *Figure A_X-6* and *Table A_X-6* describe the scaled phasedown schedule, which should be proposed as basis for the phasedown mechanism under the revised regulation.

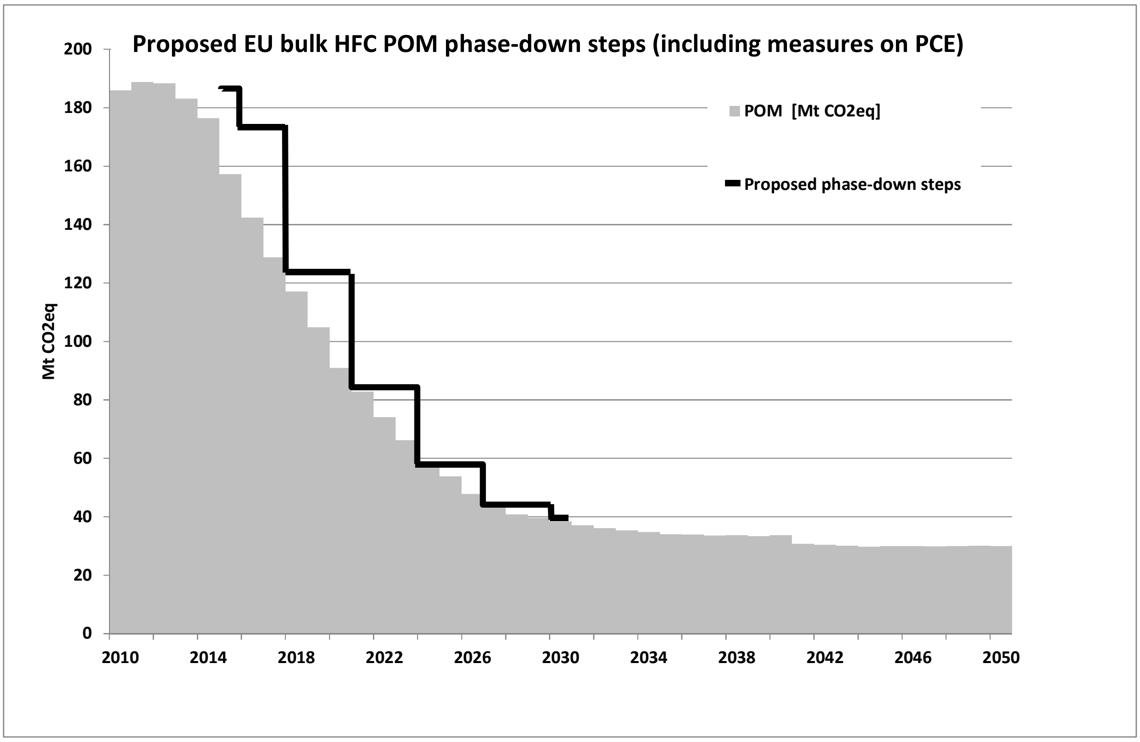

Fig. A_X- 6: Phasedown steps (POM of bulk HFCs accompanied by measures on pre-charged equipment (PCE)) (model results scaled to EU reporting levels)

Table A_X-6 *Key features of the proposed phasedown schedule, accompanied by measures on pre-charged equipment (model results scaled to EU reporting levels)*

	Proposed Reduction schedule		
Coverage	Bulk HFC placing on the market		
Baseline period	2008-2011		
Year of first control level	2015		
Proposed first control level	100%[a]		
Final phasedown level	21%[a]		
Year of final step down	2030		
Approximated Placing on the market for the first time of bulk HFCs in 2010 [a]	186 Mt CO_2eq		
Control schedule	Starting Year	POM Limit [Mt CO_2 eq]	Percentage of 2010[a]
	2015	186	100%
	2016	173	93%
	2018	123	63%
	2021	83	45%
	2024	58	31%
	2027	44	24%
	2030	38	21%

Note: [a] The final values for the POM of bulk HFCs in the 2008-2011 are not yet available. Thus, the percentages shown in this were calculated taking as a reference the *AnaFgas* model calculations for 2010 and have illustrative character only.

5. IMPLEMENTATION MECHANISM AND QUOTA ALLOCATION

In order to implement the established reduction schedule, the placing on the market of HFCs needs to be quantitatively restricted. The cap and corresponding quotas should be expressed in tonnes of CO_2 equivalents, rather than physical tonnes or kg of HFCs in order to adequately address the main objective of reducing greenhouse gas emissions. Using CO_2 equivalents also has the advantage that companies focussing their portfolio on low GWP gases have the highest benefits and the pressure to innovate is strongest for substances with particular high GWP.

All producers and importers of bulk HFCs falling under the scope of the mechanism have to hold quotas representing the right to place a certain amount of HFCs on the market. Consumers such as operators of equipment or maintenance and service companies will have no obligation under the scheme. To avoid disproportionate administrative burden, in particular for SMEs, a threshold should apply, comparable to the current threshold of one metric tonne of fluorinated gases currently applicable to the reporting requirements under Regulation (EC) No 842/2006. In view of the objective of the regulation to reduce the climate impact of F-Gas emissions, a CO_2 weighted threshold should be chosen, thus creating an additional incentive to prefer HFCs with lower GWPs. A value of 1 000 t CO_2eq would be for most HFCs (with GWPs above 1,000) slightly more stringent than the existing one (one metric tonne).

The reduction schedule refers to the EU consumption of bulk substances defined as production + imports – exports. Therefore, exported quantities do not count against the placing on the market quota.

5.1. Quota allocation – allocation through grandfathering or auctioning

The Commission establishes a central database for managing the allocation and use of quotas for individual companies (producers and importers). At the end of each year, the amount of HFCs placed on the market by each producer and importer has to be below or equal to the quota allocated to the company (expressed in CO_2eq). Compliance is assessed based on reports provided by the companies on the HFC quantities placed on the market for the respective year.

The quotas could either be sold via an auctioning system or distributed for free. The auctioning of quotas could have some advantages, as the generation of revenues and a high flexibility to react on market developments, also facilitating accessibility for new market players. An auctioning system would, however, require the development of an auctioning platform, providing the means of access to the auctioning process. The auctioning process would consist of various tasks including the registration of potential bidders, providing a platform and IT infrastructure, collecting bids, managing collateral, running the auction and ensuring payment and delivery. Even if the development and operation of the system would be outsourced, experience with the EU ETS shows that the supervision of the system would require a level of resources (either at Member States' or Commission level). Such a system would appear disproportionate to the size of the market addressed.

In addition, the structure of the market of bulk HFCs raises doubts about the appropriateness of an auctioning of HFC POM quotas. Already today the market is highly concentrated in the hands of very few suppliers. It can be expected that their market power would diminish the effectiveness of the pricing in the auctioning process and hamper the functioning of the market.

For these reasons the option of an auctioning system was discarded.

5.2. Grandfathering or allocation on demand

The allocation of quotas could either be organised on the basis of periodical requests declaring the expected, individual demand for a given time span, or by grandfathering based upon the past activity level, i.e. the amount of HFCs placed on the EU market by a participant during a base period multiplied with a reduction factor in order to meet the cap.

Under the previous regulations on ODS[85], the phase-out of these substances was implemented through quotas for the placing on the market of ODS allocated through grandfathering based on historic market shares. In a case where quotas for substances intended for an exempted use are subject to an EU-wide cap, the current ODS Regulation combines the grandfathering approach with a demand-based allocation mechanism.[86] For ODS intended for essential laboratory and analytical purposes it was deemed necessary to allow new entrants to benefit from this exemption, which is not limited in time. Since the HFC phasedown does not aim at a complete ban on HFCs (unlike the phase-out of ODS for other emissive uses), it is appropriate to follow the same combined approach as for the permanently exempted ODS uses.

An allocation mechanism which would only be based on a declaration of expected demands had been considered, but was discarded due to experiences acquired with the ODS quota system. Some companies seem to exaggerate their demand more than others and could receive a larger proportion of their real demand for free than others providing a more realistic estimate. Whilst declarations at the higher end of the expected demand are legitimate to prevent shortages in the upcoming allocation period. But massive over-declarations have the potential to disrupt the functioning of the allocation mechanism. As long as only a small proportion of the market would be concerned by this risk, certain specific allocation rules - as the ones adopted under the ODS regime[87] - can sufficiently mitigate the risk and ensure an adequate level of fairness of the system.

The grandfathering allocation scheme should, therefore, be complemented by a demand based allocation to new entrants. The necessary quotas can be reserved in a 'new entrants' reserve'. In view of the maturity of the market in bulk HFC a share of 5% of

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85 See Regulation (EC) No 2037/2000 on substances that deplete the ozone layer, OJ L 244, 29.9.2000, p. 1.

86 See Article 10 of Regulation (EC) No 1005/2009 on substances that deplete the ozone layer, OJ L 286, 31.10.2009, p. 1.

87 Commission Regulation (EU) No 537/2011 of 1 June 2011 on the mechanism for the allocation of quantities of controlled substances allowed for laboratory and analytical uses in the Union under Regulation (EC) No 1005/2009 on substances that deplete the ozone layer, OJ L 147, 2.6.2011, p. 4.

the historic baseline should be sufficient to satisfy the demand of new entrants. An option could be allowing new entrant to acquire a "historic" baseline in future years (e.g. after two full years of operation), which would also reduce the administrative effort linked with the recurring allocation processes. The reduction factor used should be identical to the one for allocation to incumbents.

If the sum of allocations based on expected demand and reduction factor was to surpass the amount in the reserve, all applicants would be entitled to an equal share of the reserve. If the reserve is not entirely used, the remaining quota could be distributed to eligible companies on a *pro-rata* basis.

5.3. Determination of the baseline

For individual companies the choice of the baseline for the grandfathering is an important distributional matter. The baseline should be representative for the activities of the majority of the participants. Given that the levels of activity of individual companies may fluctuate from one year to another due to both internal and external factors, the setting of a baseline based on an average of several years is regarded as fairer. Reporting data is available from 2007 onwards, excluding the first year(s) (as data quality tends to be lower when a reporting requirement is applied for the first time); a 3-year period (2009-2011) or a 4-year period (2008-2011) would is a viable option.

5.4. Treatment of exports

The treatment of exports in the calculation of the baseline has to be considered carefully. The cap is designed to represent the demand on the EU market only, so exports are excluded. Allocations could therefore exclude exports as well. Companies which mainly produce or import for the EU market will receive allocation for the physical placing on the domestic market only. If a company is only exporting bulk substances the allocation should be zero.

An alternative would be to base the allocation on the sum of production and imports without taking into account the exports. In this case exporting companies would be favoured above those selling mostly to the inland market, as they receive allocation for amounts that they will export and for which they have no need to hold a quota. As exports play a major role in the current F-Gas market, the allocation factor would seem rather low, because the sum of imports and production is by definition above the domestic supply. The latter alternative was therefore discarded.

5.5. Implementation and required data

Entities should be obliged to annually measure and report the quantities of HFCs placed on the market and to hold the corresponding quotas for doing so. Annual reporting reduces the risk that participating firms could place more substances on the market than they are entitled to.

The phasedown of placing HFCs on the EU market should be facilitated by a central database ensuring the accurate accounting, issuing, holding and deleting quotas. All participants in the phasedown (producers and importers) register in the database to open an account. The central database may be operated by the European Commission, as the number of players is limited and an implementation at Member States level is not necessary.

The following information would be recorded in the database:

- Accounts held by a company or physical person with contact information;
- Allocation of quotas to each participating undertaking;
- Transfers of quotas ("transactions") performed between the account holders. Payments and contracts for the transactions of allowances between companies are settled outside the registry system;
- Annual verified quantities of HFCs placed on the EU market by each account holder;
- Compliance status in regard to the last annual verification. If no verified quantities of HFCs placed on the market are reported by the deadline set, the accounts of these undertakings are blocked.

Part of the information would be available only to the account holder, the Commission and the competent authorities of the Member State concerned, but other information might be made available to the public. As the proposed phasedown mechanism has many similarities to the European ODS phase-out mechanism, the ODS database might be extended for that purpose.

The data requirements under a grandfathering system would include the domestic production, imports and exports of bulk substances. Data on production, purchases, sales, stock changes, imports and exports of bulk substances are currently reported under Commission Regulation (EC) No 1493/2007[88] for the years 2007 to 2010.

5.6. Transferability of quotas

If a company ceases its activities, its quota would be lost unless the closing company is entitled to transfer its quota to other market participants. Since the phasedown steps are calculated on the basis of the necessary supply to sectors for which alternatives to HFCs are not (fully) available, a reduction of the overall amount available HFCs should be avoided. The possibility of quota transfers between active producers or importers also offers the advantage of enabling market access for new entrants and to increase the flexibility for the holders of quota to satisfy additional demand occurring during an allocation period.

The transferability is an important element to compensate for the freeze of market shares of companies resulting from the chosen grandfathering approach for the quota allocation. The transferability would create a market value for the quota which should reflect the average marginal abatement costs across the sectors. The price signal would incentivise the reduction and substitution of the use of F-Gases, especially those with

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[88] Commission Regulation No 1493/2007 of 17 December 2007 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, the format for the report to be submitted by producers, importers and exporters of certain fluorinated greenhouse gass, OJ, 18.12.2007, L332, p. 7.

high GWP. The transferability of quotas between undertakings would enable the environmental objective of the HFC phasedown mechanism to be achieved in a more cost-effective manner.

Given the small size of the market and to avoid disproportionate administrative burden, the transfers should be agreed bilaterally between entities registered in the central database. Any transfer should be notified to and be registered in this database.

5.7. Administrative costs for companies

For the allocation though grandfathering, total one-off costs to industry of 1.7 million Euros are estimated. One-off costs per company would range between approximately 0.4 and 60 thousand Euros, in average approximately 20 thousand Euros. Other costs are mainly related to the verification procedure, therefore an appropriate threshold for third party verification should be considered in order to avoid disproportionate burden in particular for SMEs. No annual costs would occur for the allocation of quotas, except for new entrants before they acquired a 'historic' reference baseline after a certain period of activities (e.g. two years).

6. MONITORING, REPORTING AND VERIFICATION

6.1. Reporting

Reporting provisions set out by Article 6 of the F-Gas Regulation and Commission Regulation (EC) No 1493/2007 allow an overview of the quantities of bulk F-Gases produced, imported and exported to/from the EU market. Reporting obligations apply to companies producing, importing or exporting F-Gas quantities and preparations >1 tonne and reports are to be submitted annually to the EU Commission and the competent authorities of the Member State concerned. The current reporting scheme under the F-Gas Regulation is basically suitable to retrospectively verify the bulk F-Gas uantities placed on the EU market. At present, F-Gases contained in products or equipment are not covered by the reporting obligation.

However, the reporting obligations under the current F-Gas Regulation would require some modifications in view of the HFC phasedown. The additional requirements concern the scope of substances and thresholds in terms of metric tonnes or tonnes of CO_2 equivalents produced, imported, exported, reclaimed or destroyed by stakeholders:

- All substances included in the phasedown regime need to be integrated in the reporting requirements. As discussed before, a *de minimis* rule should be foreseen. For the application of the phasedown mechanism a threshold of 1 000 t CO_2 equivalents of HFCs placed on the market per year is suggested. All production, import or export above that threshold should be reported. In addition, in order to enable an evaluation of the policy measures, any such activity involving more than 1 metric tonne should be reported, regardless of the before mentioned threshold of 1 000 t CO_2 equivalent.
- The unsaturated HFCs HFC-1234yf and HFC-1234ze are under discussion to be included in an amendment to the Montreal Protocol. Both substances are neither proposed to be included in the scope of the HFC phasedown nor covered in the

reporting obligation under the F-Gas Regulation. An inclusion of these substances in reporting obligations is thus not necessary in order to underpin an EU HFC phasedown, but it would be very useful to track the consumption of unsaturated substances for purposes of policy verification and evaluation. Such data would also strongly assist in explaining future HFC emission trends in the EU. In the case of an amended Montreal Protocol such a reporting obligation would also become necessary. Furthermore, concerns on the eco toxicity of breakdown products warrant a continuous monitoring of the quantities of unsaturated HFCs.

- An extension of the reporting requirement on imports and/or exports of HFCs contained in products or equipment – although not covered by the scope of the phasedown - would help monitor the effectiveness of the policy. A sufficiently high threshold should be foreseen to limit the administrative burden to the very high number of importers and exporters of such products or equipment.

- Recovered HFC quantities for re-use/recycling or reclamation are not counted within the scope of the HFC phasedown as POM means by definition the placement on the market "for the first time". However, estimated amounts of reclaimed HFCs were subtracted from the estimated demand of HFCs in order to calculate the cap for the overall quota to be placed on the market in a given year. Thus reclaimed HFC amounts are available to consumers beyond the POM cap. Therefore, a proper monitoring of reclaimed HFC amounts is important to monitor the performance of the phasedown mechanism.

  Reclaimed F-Gases are covered under the present reporting scheme of Art 6 F-Gas Regulation only for F-Gas producers, importers and exporters. Specialised HFC reclamation facilities are not yet covered and should be included in the reporting obligation.

- Destruction of F-Gases is covered under the present reporting scheme of Art. 6 F-Gas Regulation only for F-Gas producers, importers and exporters. Specialized destruction facilities are not covered. For the purpose of the POM phasedown scheme, there is no need to enhance reporting on destruction.

  In the case of an amended Montreal Protocol, full information on the destroyed amounts of HFCs might be needed and such a reporting obligation including specialised destruction facilities might become necessary. However, according to operators of destruction facilities, a reporting on destroyed HFC species by species is not at all feasible: Destruction facilities do not perform analyses to specify the components of these mixtures. According to operators, it is uncertain whether appropriate techniques are available, which would allow a determination of the specific HFC contents (and thus GWPs) of the destroyed quantities are available. At present, destruction facilities report to MS waste-management authorities the metric tonnes of an unspecified mix of HFCs, HCFCs and other refrigerants, only. A reasonably exact determination of the amount of HFCs destroyed expressed in CO_2 equivalents thus appears not to be possible.

- Direct exports by producers do not count against their quotas, since those substances are, by definition, not placed on the market. The same should apply to quantities which are purchased from a EU producer by an exporter, although this transaction would have to be considered as placing on the market. Both producer and exporter would have to specify the HFC amounts exported in the same allocation period.

Article 6 of the current F-Gas Regulation established reporting requirements for each producer, importer and exporter of fluorinated greenhouse gass, as well as destruction facilities, to the Commission and the same information shall be made available to the competent authority of the Member State concerned. The same procedure is suggested related to the extended reporting under an HFC phasedown mechanism. The Commission could also designate an entity to collect the reported information. The European Environment Agency (EEA) could be such an entity because the EEA will collect, assess and compile the submitted reports under the F-Gas Regulation and the ODS Regulation starting from 2012.

6.2. Verification

For an HFC phasedown mechanism it is essential to verify that participating undertakings do not place more HFCs on the EU market than the quantity for which they hold quotas.

Currently some checks on the reported data under the F-Gas Regulation are performed by the consultants who compile and assess the reported data for the Commission. However these checks are limited to rather obvious mistakes and do not deliver a clear answer whether the reported data is accurate. Measures for effective implementation and enforcement need to allow tracking of the quantities of individual HFC species and of HFC species in mixtures of substances on the EU market.

Especially if quotas are transferable and represent a monetary value to holders, a robust verification system should be established to ensure that the reported amounts of HFCs placed on the market are accurately reflecting the real amounts placed on the market.

A system of independent verification of the reports should be envisaged, complementing the supervision carried out by the competent authorities of the Member States as for other pieces of EU environmental legislation. It is assumed that reports might be verified rather easily by external business accountants, since the verification of production, imports and exports at company level concerns regular commercial transactions.

In order to reduce administrative burden, a certain threshold for low volume producers, importers and exporters should be introduced below which third party verification would not be demanded. Administrative costs could be further lowered with a verification system that does not require annual verification checks for all companies, but that checks the data reported for some of the companies each year. These checks could include some previous years. Thus each company may only be verified every 3 or 5 years. Such a system would still provide an incentive to report correctly because the likelihood that any fraud is discovered at some point in time would be high. The costs for such an independent verification system should be borne by companies.

An involvement of the customs authorities in the verification of reported imports and exports had been considered, as practiced under the ODS regulation. However, the trade in ODS requires a systematic licensing of each consignment which forms the basis for the checks carried out by the customs authorities. Unless required by an international agreement under the Montreal Protocol, a licensing system should not be envisaged for the HFC in order to reduce the administrative burden for the companies and authorities involved. Furthermore, the applicable customs codes do not (yet) distinguish between HFCs and other substances serving the same purposes. Based on the current HS code for HFCs (CN 2903 39), additional end-numbers for different HFC types in bulk would need to be established to allow customs verifying in spot checks the HFC types and quantities shipped across the EU border.

6.3. Compliance and enforcement

The following areas of infringements of provisions of an HFC phasedown mechanism would be particularly relevant for an enforcement and compliance system:

(1) The correct reporting of the amounts of HFCs placed on the EU market (production, imports, exports, imports in pre-filled equipment);

(2) The placement of HFCs on the market by a company shall not exceed the quotas available by the same company.

Member States are obliged to ensure that Union policies are implemented and can usually decide themselves on the means of enforcement. In this respect, controls and inspections play a crucial role. A legal instrument for a HFC phasedown should foresee that Member States shall lay down measures to ensure that the provisions have been implemented and potential consequences applicable to infringements of the provisions of a regulation for an HFC phasedown.

An infringement of reporting requirements could consist in a lack of reporting or in incorrect reporting. In the annual reporting cycle it would be registered if an undertaking does not submit a required annual report. If companies do not submit the required annual reports, Member States are required to take action to ensure compliance and sanction breaches of the legislation.

Incorrect reporting would be detected during the independent verification of the annual reports on the amounts of HFCs placed on the EU market and any excess of the allocated quotas mainly at EU level. To enable enforcement at Member State level, the Commission should inform Member States of any detected problems with the reporting or with the accuracy of the reported information as well as of the non-compliances with the individual quantitative limits.

Infringements with the reporting requirements detected by the independent verification could simply lead to a correction of the reported quantities if small corrections of errors occur. This could be implemented as part of the verification process and the correction should be transparently documented in the report of the independent verifiers. For major cases of misreporting specific penalties should be established at Member State level.

In addition to sanctions imposed by Member States for companies exceeding their allocated POM quotas, a reduction of the quota for these companies for the following year should be foreseen.

ANNEX XI: Schedule for the Introduction of Bans

Table A_XI-1 *Starting points for bans in policy option E*

Application	**Starting year of ban**
Commercial refrigeration (Stand-alone systems, Condensing units, Centralized systems)	2020
Industrial refrigeration	2030[89]
Transport refrigeration (Refrigerated trucks and trailers)	2030
Stationary AC (Moveable systems, single split systems, multi split/VRF systems, rooftop systems, displacement chillers)	2020
HFC-23 in fire protection	2015
Non-medical technical aerosols	2020
HFC-134a in XPS foam blowing	2015
SF_6 Magnesium die-casting <850 kg/ y and recycling of die casting alloys	2015
Mandatory destruction of HFC-23	2015

These starting points are based on the calculation of when 100% penetration rates can be reached in the different sectors (see Annex XVI).

89 Bans are possible earlier for larger industrial systems above a certain capacity. See also Becken et al. (2010)[4]

ANNEX XII: Analysis of Administrative Costs

1. METHODOLOGY

In this Annex, a transparent documentation of the estimation of administrative costs for the analysed policy options is provided. All administrative costs are to be understood as difference costs to policy option A (no policy change).

The employed methodology strictly follows the EU Impact Assessment guidelines[90]: For each policy option, a quantitative estimate of changes in **administrative costs and administrative burden** that may be incurred by stakeholders in implementing that policy option **in so far as activities to provide information are concerned**. The definition of administrative costs refers to the costs incurred by enterprises, the voluntary sector, public authorities or citizens in meeting legal obligations to provide information on their action or production, either to public authorities or to private parties. The term "information" is used in a broad sense, covering labelling, reporting, registration, monitoring and assessment needed to provide information as well as the transfer of information to public authorities and private parties (e.g. trade associations). Any other costs possibly incurred by stakeholders, i.e. not related to providing information, are not regarded as administrative costs. Administrative costs are to be understood on top of business-as-usual costs. Business-as-usual costs are the costs that currently result from the monitoring and reporting under the F-gas Regulation which would continue in the absence of new legislation.

Costs incurred by the Commission are similarly not included in the estimates for administrative costs.

For each policy option, all relevant and additional information requirements were first identified. To this end, the kind of information requirements/actions are defined as within or without the scope of administrative costs needed to be defined in detail. As the general concept, a normal functioning of the analysed policy options was assumed. For example, eventual judicial proceedings were not considered. As well, all further action by authorities or stakeholders to first establish a policy option, i.e. drafting or commenting on the final legal or contractual texts, was not considered.

For each identified information requirement, a concept was established for how to estimate specific cost per single action and overall costs for the EU-27. Data sources for specific costs include questionnaires to/interviews with stakeholders with experience in comparable information requirements as well as expert estimates. Specific cost data was multiplied with data on the number of affected stakeholders in order to arrive at absolute costs.

According to the guidelines, costs are distinguished as one-off costs and annually recurring costs. Furthermore, costs are differentiated as personnel costs, equipment costs and outsourcing costs. Equipment costs appeared to be not relevant for any of the considered options. For the estimation of personnel costs, first working time was

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90 http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_annex_en.pdf

estimated. In order to arrive at costs, the working time was multiplied with country specific and job-level specific tariffs for gross earnings. For activities assumed to be relevant for the considered policy options, the country-specific tariffs of job-level 2 "professionals" were used. These were considered to serve as a proxy for a probably applicable mix of job-levels 1 ("legislators, senior officials and managers"), 2 ("professionals") and 3 ("technicians and associate professionals"). Table A_XII-1 contains the used tariff data.

Table A_XII-1 *Overview of used country-specific tariffs*

Country specific tariffs – job level 2 ("Professionals")			
€ / h (2006)			
AT	38.75	IT	59.26
BE	35.25	LV	6.06
BG	2.24	LT	41.58
CY	20.29	LU	5.81
CZ	7.74	MT	13.21
DE	43.15	NL	35.19
DK	45.40	PL	10.37
EE	7.83	PT	19.32
EL	21.00	RO	5.97
ES	23.94	SE	40.47
FI	34.74	SI	18.75
FR	47.02	SK	5.19
HU	7.78	UK	49.75
IE	45.94		

Source: European Commission,, 2011

In the detailed questionnaires (see *Annex XIII*) to stakeholders for creating data on time/cost efforts, each information requirement was further disaggregated according to the guidelines into the following set of activities:

- Familiarising with the information obligation
- Training members and employees about the information obligations
- Retrieving relevant information from existing data
- Adjusting existing data
- Producing new data
- Designing information material (e.g. leaflet conception)
- Filling forms and tables (including recordkeeping)
- Holding meetings (internal/external with an auditor, lawyer etc.)
- Inspecting and checking (including assistance to inspection by public authorities)
- Copying (reproducing reports, producing labels or leaflets)
- Submitting the information to the relevant authority (e.g. sending it to the relevant authority)
- Filing the information
- Buying (IT) equipment & supplies (e.g. labelling machines) to specifically used to fulfil information obligations
- Other.

These activities were reflected in the questionnaire as appropriate for the individual questions. Not all types of activities were relevant for every question asked. Partly, the "other" category was further elaborated in order to adapt it to the specific question.

In the following sections, for each option and each information requirement, the cost estimates and data sources are documented.

2. POLICY OPTION A: NO POLICY CHANGE

Administrative costs are defined as difference costs to the application of present policies. Thus, no costs are assumed for this option.

3. POLICY OPTION B: VOLUNTARY AGREEMENTS

There are already voluntary agreements for fluorinated gases at international, European or Member State level. Therefore additional or enhanced voluntary agreements are considered as a policy option for reducing emissions of fluorinated gases in the EU. Voluntary agreements considered are identified in chapter 5.2.

According to the Communication on environmental agreements at Community level[91], environmental agreements or voluntary agreements should have quantified and staged objectives and should include a monitoring and reporting system for achieving the objectives. In this respect, Option B "Voluntary agreements" will cause an administrative burden for the participating business sectors in relation to the monitoring, reporting and verification of the reduction of F-Gas consumption.

Given that the concrete sectors and the objectives for voluntary agreements restricting the use of F-Gas in certain appliances would have been agreed between the relevant actors, it is assumed that no administrative costs will occur for the following steps:

- Identify the relevant actors in the sector for a voluntary agreement,
- Define reliable indicators to monitor compliance with objectives and (interim) targets including costs for research information and scientific and technological background data, and
- Define the objectives of the voluntary agreement and the baseline.

3.1. Overview of information requirements for the option of voluntary agreements

Table A_XII-2 gives an overview of information requirements which are necessary for voluntary agreements. Each line taken into account for the quantitative estimation of administrative cost is further explained in the following sections.

[91] European Commission 2002: Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions - Environmental Agreements at Community Level Within the Framework of the Action Plan on the Simplification and Improvement of the Regulatory Environment, COM(2002) 412 final of 17.7.2002.

Table A_XII-2 *Overview of information requirements for voluntary agreements*

Information requirements for voluntary agreements in policy option B						
No.	**Obligation**	**Frequency**	**Affected stakeholder group**		**Comment / Approach**	**Source of information**
			Type	**No.**		
VA01	Nominate monitoring institution & set up monitoring system	Once	Trade associations	6 VAs	The setting-up of VAs is neglected as defined not to be part of administrative costs.	
VA02	Annual report on HFC use	Once per year	Operators/producers of equipment/ products	No. of companies per VA	Use reporting efforts under F-Gas Regulation (PD 18).	Companies presently reporting acc. Art 6 F-Gas Regulation
VA03	Independent verification of HFC use reports / submission to trade association / monitoring institution	Assumption: 6 VAs	Operators/producers of equipment/ products	No. of companies per VA	Verification cost per company & year equal to verification cost of annual reports in phasedown option (PD19).	Companies presently reporting acc. Art 6 F-Gas Regulation
VA04	Annual monitoring report	Once per year	Trade associations/ Monitoring institutions	6 VAs	Cost per VA: Build on experience of existing VAs	Trade association having experience with VA, e.g. ESIA.
VA05	Check of monitoring reports	Once per year / of 6 VAs	COM	1	Is neglected as COM efforts are not included in administrative costs.	
VA06	Communication with stakeholders	Once per year	Trade associations/ Monitoring institutions	6 VAs	Cost per VA/year: Trade associations with VA experience estimate communication costs	Trade association having experience with VA, e.g. ESIA.

Information requirements for voluntary agreements in policy option B						
No.	Obligation	Frequency	Affected stakeholder group		Comment / Approach	Source of information
			Type	No.		
VA07	Communication with stakeholders	Once per year / on 6 VAs	COM	1	Is neglected as COM efforts are not included in administrative costs.	

3.2. Annual report on HFC use

The information obligation VA02 "Annual report on HFC use" determines the relevant costs for operators/producers of equipment/products containing HFC which fall within the scope of the respective voluntary agreement. In order to determine their administrative costs it will be referred to reporting efforts of a company under the F-Gas Regulation (Table A_XII-3).

Table A_XII-3 *Administrative burden per operator/producer: VA02 - Annual report on HFC use*

VA 02 - Annual report on HFC use		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
Annual		
55		506

Source: Öko-Institute estimate

Table A_XII-4 contains the estimated number of operators and producers falling under the scope of the relevant voluntary agreement.

Table A_XII-4 *Number of affected operators / producers per voluntary agreement: VA02 - Annual report on HFC use*

Number of affected operator / producers per voluntary agreement		
Voluntary Agreement	**No. of affected operators/ producers**	**Source**
Sub-option B-1: Voluntary agreements to phase-out HFCs in commercial refrigeration	ca. 20 (industrially manufactured stand- alone equipment) ca. 16 (large companies) ca.1000 (small companies for condensing units, centralized systems)	Ökoinstitute estimate
Sub-option B-2: Voluntary agreement to replace HFC-134a in XPS foams	13	See Schwarz et.al. 2011.[9]
Sub-option B-3: Voluntary agreement to replace HFC-23 in fire protection	30	Estimation of total number of EU based original equipment manufacturers, see Schwarz et.al. 2011[9], p. 235.
Sub-option B-4: Voluntary agreement for destruction of HFC-23 emissions from halocarbon production	1	Schwarz et al 2011[9], p.175
Sub-option B-5: Update of voluntary agreement with semiconductor industry related to PFCs, NF_3, HFC-23 and SF_6	19	19 Manufacturers are member of EECA (ESIA)
Sub-option B-6: Voluntary agreement to replace SF_6 and NF_3 in photovoltaic industry	8	See Schwarz et. al. 2011[9], p. 233.
Total amount	**1,107**	

Table A_XII-5 *Distribution of population in MS for EU-27 in %.*

Distribution of population in MS			
[% of EU-27]			
Belgium	2.19	Luxembourg	0.10
Bulgaria	1.49	Hungary	1.99
Czech Republic	2.09	Malta	0.08
Denmark	1.12	Netherlands	3.33
Germany	16.30	Austria	1.67
Estonia	0.26	Poland	7.61
Ireland	0.92	Portugal	2.13
Greece	2.25	Romania	4.27
Spain	9.21	Slovenia	0.42
France	12.62	Slovakia	1.08
Italy	12.12	Finland	1.08
Cyprus	0.22	Sweden	1.87
Latvia	0.44	United Kingdom	12.50
Lithuania	0.64	**EU-27**	**100.00%**

Source: www.weltbevölkerung.de, data from June 2011

As the distribution of affected companies in the EU-27 is not known, a weighted tariff based on the distribution of population in the EU-27 issued to calculate the personnel costs per company. Using the country specific tariffs for professionals (see *Table A_XII-1*) the thus weighted average tariff for the EU-27 is € 35.82 per hour.

In *Table A_XII-6* the administrative costs for producing annual reports on the use of HFC are shown. The figures are calculated for a number of 1,107 operators / producers affected by voluntary agreements, 55 hours personnel time and € 506 outsourcing costs per report / per company (cf. *Table A XII-3*) and on a weighted tariff for the EU-27 of € 36.

Table A_XII-6 *Overall administrative burden for all operators /producers in EU-27: VA 02 - Annual report on HFC use*

VA 02 - Annual report on HFC use			
Overall administrative burden for all operator/producer in EU-27			
[Thousand €] Annual			
Personnel costs	Equipment costs	Outsourcing costs	Total costs
2,192	0	560	2,752

In option B for the obligation VA 02 the overall annual costs to annually report on HFC use is estimated to be € 2.75 million.

3.3. Independent verification of HFC use reports / submission to trade association / monitoring institution

According to the information obligation VA03 operators and producers of equipment & products will have their annual reports on the use of HFC to be verified by independent organisation. Furthermore, they have to submit them to the relevant trade association and monitoring institution. As the verification cost per company / year is assumed to be equal to verification cost of annual reports in the phasedown option (Annex X), the respective specific burden estimated there will be used as a calculation basis.

Table A_XII-7 *Administrative burden per operator/producer: VA03 - Independent verification of HFC use reports*

VA03 - Independent verification of HFC use reports		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
25		6,183

Source: Analysis of questionnaires sent to F-Gas producers & importers (Annex XIII) & Öko-Institute estimate

In *Table A_XII-8* the administrative costs for operators and producers of equipment and products to verify the annual reports on the use of HFC by independent organisation are stated. The figures are calculated on a number of 1,107 operators / producers affected by voluntary agreements, 25 hours personnel time and € 6000 outsourcing costs per report / per company (cf. *Table A_XII-7*) and on a weighted tariff for the EU-27 of € 35.82 (as calculated for VA02).

Table A_XII-8 *Overall administrative burden for all operators /producers in EU-27: VA03 - Independent verification of HFC use reports / submission to trade association / monitoring institution*

VA 03 - Independent verification of HFC use reports / submission to trade association / monitoring institution			
Overall administrative burden for all operator/producer in EU-27			
[Thousand €] Annual			
Personnel costs	Equipment costs	Outsourcing costs	Total costs
973	-	6,844	7,818

In option B for the obligation VA03 the overall annual costs for independent verification of HFC use reports, the submission to trade association and monitoring institution is estimated to be € 7.8 million.

3.4. Annual monitoring report to EU

The assumption for obligation VA04 "Annual monitoring report" is that for each VA one industry association is responsible for collecting all the reports prepared by the associated members and produces an overall report once a year.

To estimate the costs for VA 04 a questionnaire listing the required action within VA 04 was sent to 31 associations. Six associations responded not to have any VA within their field of experience. Four industry associations reported administrative costs for a VA; no information was received by the other associations.

Figures shown in *Table A_XII-9* are the resulting average hours necessary for an industry association to prepare an annual monitoring report for the Commission.

Table A_XII-9 *Administrative burden per association: VA 04 – Annual monitoring report*

VA04 - Annual monitoring report to EU		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
68	-	3,500

Source: Analysis of questionnaires sent to trade associations

Due to the low response no outliers were identified.

In *Table A_XII-10* for each possible voluntary agreement within the policy option B the affected European Industry Association(s) and the number of associated national member associations or associated companies is given.

Table A_XII-10 *Industry Associations affected by Voluntary Agreements*

Industry Associations affected by Voluntary Agreements		
Voluntary Agreement	**Affected Association**	**No. of associated Members/Companies**
Sub-option B-1: Voluntary agreements to phase-out HFCs in commercial refrigeration	ASERCOM (Association of European Refrigeration Component Manufacturers)	16
Sub-option B-2: Voluntary agreement to replace HFC-134a in XPS foams	EXIBA (European Extruded Polystyrene Insulation Board Association)	9
	ISOPA (European Diisocyanate & Polyol Producer Association)	8
	PU Europe (Polyurethane (PUR/PIR) Insulation Industry)	11
Sub-option B-3: Voluntary agreement to replace HFC-23 in fire protection	EUROFEU (The European Committee of the Manufacturers of Fire Protection Equipment and Fire Fighting Vehicles)	18
Sub-option B-4: Voluntary agreement for destruction of HFC-23 emissions from halocarbon production	EFCTC (Association of fluorocarbon producers)	1[92]
Sub-option B-5: Update of voluntary agreement with semiconductor industry related to PFCs, NF_3, HFC-23 and SF_6	European Semiconductor Industry Association (EECA)(ESIA)	19

92 So far only one facility for destruction of HFC-23 emissions from halocarbon production in Europe exists. Therefore the administrative costs for a voluntary agreement are negligible.

Industry Associations affected by Voluntary Agreements		
Voluntary Agreement	**Affected Association**	**No. of associated Members/Companies**
Sub-option B-6: Voluntary agreement to replace SF_6 and NF_3 in photovoltaic industry.	EPIA (European Photovoltaic Industry Association)	240

Based on a number of 8 European industry associations who would be engaged in 6 voluntary agreements the overall annual costs for producing an annual monitoring report are estimated in *Table A_XII-11*. As the European industry associations are generally located in Brussels (Belgium) the weighted tariff for professionals of € 35.25 per hour for Belgium is used.

Table A_XII-11 *Overall administrative costs for European industry associations affected by Voluntary Agreements*

VA04 - Annual monitoring report to EU			
Overall administrative cost in EU 27			
Personnel costs	Equipment costs	Outsourcing costs	Total cost
[Thousand €] annual			
19.1	-	28.0	47.1

In option B for the obligation VA04 the overall annual costs for producing an annual monitoring report are estimated at approximately € 47,000.

3.5. Communication with stakeholders

The obligation VA06 within a voluntary agreement addresses the administrative efforts per year of a European industry association to communicate with other stakeholders (Member States, industry, NGOs, etc.) concerning the voluntary agreement.

The administrative effort is based on the figures received from questionnaires sent to industry associations which are having experiences with voluntary agreements.

Table A_XII-12 states that the average time needed per European industry association to communicate with stakeholders is 139 hours.

Table A_XII-12 *Administrative burden per association: VA06 – Communication with stakeholders*

VA06 – Communication with stakeholders		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
139	4,563	-

Source: Analysis of questionnaires to industry associations experienced with VAs in the field of F-Gases

Based on a number of 8 European industry associations who would be engaged in 6 voluntary agreements, the overall annual costs to produce an annual monitoring report are estimated in *Table A_XII-13*. As the European industry associations are generally located in Brussels (Belgium) the weighted tariff for professionals of € 35.25 per hour for Belgium is used.

Table A_XII-13 *Overall administrative costs for European industry associations affected to communicate with stakeholders – VA06*

VA06 - Communication with stakeholders			
Overall administrative cost in EU 27			
Personnel costs	Equipment costs	Outsourcing costs	Total cost
[Thousand €] annual			
39.2	36.5	-	75.7

In option B for the obligation VA06 the overall annual costs to communicate with stakeholders are estimated to be approximately 76,000 Euros.

3.6. Summary of administrative costs of voluntary agreements

The estimation of the overall annual administrative costs in the EU-27 for the policy option B "Voluntary Agreements" is stated in *Table A_XII-14*.

Table A_XII-14 *Overall annual administrative costs in the EU-27 for the policy option B, Voluntary Agreements*

Summary administrative cost phase-down (annual)					
Overall administrative cost in EU 27					
	Information requirement	Personnel cost	Equipment Cost	Outsourcing cost	**Total Cost**
		[Thousand €] annual			
VA02	Annual report on HFC use	2,196	-	560	**2,756**
VA03	Independent verification of HFC use reports	973	-	6,844	**7,818**
VA04	Annual monitoring report to EU	19	-	28	**47**
VA06	Communication with stakeholders	39	37	-	**76**
	Total annual	**3,228**	**37**	**7,432**	**10,697**

Approximately 73% of the estimated annual costs of 10.7 million €/year is due to independent verification of reported HFC use.

4. POLICY OPTION C: EXTENDED SCOPE OF CONTAINMENT MEASURES

For this policy option, no administrative costs were assumed.

5. POLICY OPTION D: ESTABLISHMENT OF QUANTITATIVE LIMITS FOR PLACING CERTAIN F-GASES (HFCS) ON THE EU MARKET (PHASEDOWN)

5.1. Overview of information requirements for the phasedown option

Table A_XII-15 gives an overview of information requirements occurring in the phasedown option. Each line taken into account for the quantitative estimation of administrative costs is further explained in the following sections. *Table A_XII-16* contains a shortlist of those information requirements quantitatively assessed.

For the present assessment of administrative cost, any administrative efforts related to the complementary measures on pre-charged equipment have not be assessed. Such efforts would occur for Member States and would not be identical to the efforts assessed for policy option E (bans) as a different set of stakeholders would need to be controlled.

Table A_XII-15 *Overview of information requirements in the phasedown option*

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	**Information requirement**	**Frequency**	**Affected stakeholders**		**Comment / Approach**	**Source of information**
			Group	**No**		
PD01	Set-up of F-Gas data base	Once	COM	1	COM efforts are not to be included in Impact Assessment.	
PD02	Operation of F-Gas data base	Permanent	COM	1	COM efforts are not to be included in Impact Assessment.	
PD03	Registration in F-Gas data base	Once	Producers & importers above CO2eq threshold	80	Experience of ODS actors, cost per company	ODS companies
PD04	Submission of verified baseline report	Once	Producers & importers above CO2eq threshold	80	Only transfer of information as data is available from the reports under the F-Gas regulation	Own estimate
PD05	Verification of baseline report	Once	Producers & importers above CO2eq threshold	80	Cost per year taken from annual report verification cost PD19 below	PD19
PD06	Check of verified baseline report + allocation decision	Once	COM	1	COM efforts are not to be included in Impact Assessment.	
PD07	Transfer of baselines	Once	Producers & importers above CO_2eq threshold (mainly in the case of mergers & acquisitions)	10	*Not regarded as information requirement. Flexibility option offering a business opportunity.*	

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	Information requirement	Frequency	Affected stakeholders		Comment / Approach	Source of information
			Group	No		
PD08	Adjustment of baselines for allocation reflecting baseline transfers (mergers & acquisitions)	Yearly, cases depend on mergers & acquisitions	COM	1	COM efforts are not to be included in Impact Assessment.	
PD09	Allocation to new entrants + check of verified reports of future HFC use	4 times a year, cases depend on the number of new entrants	COM	1	COM efforts are not to be included in Impact Assessment.	
PD10	Set up of auctioning platform	Once	COM	1	*Not considered for chosen phasedown option - relevant for auctioning system only.* COM efforts are not to be included in Impact Assessment.	
PD11	Auction of rights to POMs	Regular (6 times per year)	COM	1	*Not considered for chosen phasedown option - relevant for auctioning system only.* COM efforts are not to be included in Impact Assessment.	
PD12	Auction of rights to POMs	Regular (6 times per	Producers & importers above	80	*Not considered for chosen phasedown option - relevant for auctioning system*	Own estimate

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	**Information requirement**	**Frequency**	**Affected stakeholders**		**Comment / Approach**	**Source of information**
			Group	**No**		
		year), entities participating 3 times only	CO_2eq threshold		*only.* Cost per company & auction: Only conservative estimate of time technically needed to place the bids. Business strategy not to be included!	
PD13	Transfer of rights to POMs	5x times per year per participating entity = 400	Producers & importers above CO2eq threshold	80	*Not regarded as information requirement. Rather a/ business opportunity* Cost per transfer: Only conservative estimate of time technically needed to place the bids. Business strategy not to be included!	Own estimate
PD14	Definition of eligibility criteria for verifiers	Once	MS	27 MS	*Not counted as administrative costs: Part of legislative procedure*	
PD15	*Deleted*					
PD16	Definition of eligibility criteria for verifiers	Once	COM	1	*Not counted as admin costs: Part of legislative procedure.* Same cost as for one MS. COM efforts are not to be included in	

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	Information requirement	Frequency	Affected stakeholders		Comment / Approach	Source of information
			Group	No		
					Impact Assessment.	
PD17	*Deleted*					
PD18	Report (Art 6) on placing on the market, import & export+ reclamation, recycling & destruction	Once per year	Producers, importers & exports above one tonne.	100	***Baseline***: Not to be counted as administrative cost, obligation of existing F-Gas regulation	Companies presently reporting under Art 6 F-Gas Regulation
PD18b	Additional reporting on exports on behalf of producers	Once per year	Selected producers& exporters	~15	*Not regarded as information requirement. Flexibility option offering a business opportunity.*	
PD19	Verification of reporting & submission to MS or central authority	Once per year	Producers & importers above CO_2eq threshold + exporters wishing to benefit	30	Concerns only HFC reports, no HFO reports Data source: estimates by Companies presently reporting und Art 6 F-Gas Regulation; reduction to 30% due to assumed higher threshold for verification needs	Companies presently reporting under Art 6 F-Gas Regulation
PD19b	Verification for additional reporting on exports on behalf of producers	Once per year	Selected exporters	~10	*Not regarded as information requirement. Flexibility option offering a business opportunity.*	

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	**Information requirement**	**Frequency**	**Affected stakeholders**		**Comment / Approach**	**Source of information**
			Group	**No**		
PD20	*Deleted*					
PD21	*Deleted*					
PD22	*Deleted*					
PD23	Introduce compliance system at MS level	Once	MS	27	No relevant additional effort compared to present F-Gas Regulation considered.	
PD24	Check of compliance	Once per year	COM	1	*MS are informed by COM on compliance issues.* COM efforts are not to be included in Impact Assessment.	
PD25	Impose penalties in case of non-compliance	Once per year	MS	27	*Not counted for admin costs: Assumption: companies comply*	
PD26	*Deleted*					
PD27	*Deleted*					
PD28	*Deleted*					
PD29	Deduct non-compliance	Once per year	COM	1	*Negligible!*	

Overview of information requirements in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	**Information requirement**	**Frequency**	**Affected stakeholders**		**Comment / Approach**	**Source of information**
			Group	**No**		
	amounts from next allocation to non-compliant actor				COM efforts are not to be included in Impact Assessment.	
PD30	Reporting on reclamation and destruction	Once per year	Specialised reclamation and destruction facilities	65	Let facilities estimate cost for HFC / blend-specific reporting Not necessarily needed for the phasedown. However, advisable. Necessary in case of amended Montreal Protocol.	Specialised reclamation facilities

Table A_XII-16 *Shortlist of information requirements quantitatively assessed for administrative costs in the phasedown option*

Shortlist on quantitatively assessed administrative costs in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	**Obligation**	**frequency**	**Affected stakeholders**		**Comment / Approach**	**Source of information**
			Group	**No.**		
PD03	Registration in F-Gas data base	once	Producers & importers above CO2eq threshold	80	Experience of ODS actors, cost per company	ODS companies
PD04	Submission of verified baseline report	once	Producers & importers above CO_2eq threshold	80	Only transfer of information as data is available from the reports under the F-Gas regulation	Own estimate
PD05	Verification of baseline report	once	Producers & importers above CO_2eq threshold	80	Cost per year taken from annual report verification cost PD19 below	PD19
PD19	Verification of reporting & submission to MS or central authority	Once per year	Producers & importers above CO_2eq threshold + exporters wishing to benefit	30	Concerns only HFC reports, no HFO reports Data source: estimates by Companies presently reporting und Art 6 F-Gas Regulation; reduction to 30% due to assumed higher threshold for verification needs	Companies presently reporting under Art 6 F-Gas Regulation
PD30	Reporting on reclamation and destruction	Once per year	Specialised reclamation and destruction facilities	65	Let facilities estimate cost for HFC / blend-specific reporting Not necessarily needed for the phasedown. However, advisable.	Specialised reclamation facilities

Shortlist on quantitatively assessed administrative costs in the policy option on quantitative limits for placing on the market of HFCs (phasedown)						
No	Obligation	frequency	Affected stakeholders		Comment / Approach	Source of information
			Group	No.		
					Necessary in case of amended Montreal Protocol.	

5.2. PD03 - Registration in F-Gas database

All stakeholders intending to place HFCs on the markets above a threshold of 1 kt CO_2eq need to register in a database operated by the European Commission. This is a one-off cost.

The effort is estimated to be comparable to the registration to the Commission's database on production, import and export of ozone depleting substances (ODS)[93]. Thus, companies currently involved in the ODS phase-out scheme were addressed to gather information on specific costs.

The number of affected entities is estimated at 80, based on experiences with the present reporting under the F-Gas Regulation (Art 6). This is a conservative estimate as the number includes entities which presently exclusively deal with PFCs and SF_6 and thus would not be affected by the HFC phasedown scheme.

Information on the distribution of entities to Member States is available, as well as based on experience with the present reporting under the F-Gas Regulation (Art 6). As this data includes exporters, the percentage per country is used as a proxy (*Table A_XII-17*).

[93] http://ec.europa.eu/clima/policies/ozone/ods/index_en.htm

Table A_XII-17 *Distribution of entities placing HFCs on the EU market between Member States*

Distribution of entities placing HFCs on the EU market between MS			
[% of EU-27]			
AT	-	IT	10.3%
BE	7.5%	LV	-
BG	3.7%	LT	3.7%
CY	1.9%	LU	-
CZ	1.9%	MT	1.9%
DE	11.2%	NL	3.7%
DK	0.9%	PL	4.7%
EE	2.8%	PT	1.9%
EL	2.8%	RO	1.9%
ES	8.4%	SE	2.8%
FI	1.9%	SI	1.9%
FR	7.5%	SK	-
HU	3.7%	UK	11.2%
IE	1.9%	**EU-27**	**100.0%**

Source: European Commission 2011: Confidential Report on F-Gases 2010

The distribution between Member States in combination with the country-specific tariffs as shown in *Table A_XII-1* leads to a weighted average tariff of 32.55 €/h.

Table A_XII-18 shows the evaluation of the questionnaires. Three answers were received. Thus, no outliers could be identified. Estimates for equipment cost and outsourcing costs were summarised as outsourcing costs. Figures shown are the resulting averages.

Table A_XII-18 *Administrative burden per entity: PD 03 - Registration in F-Gas data base*

PD03 - Registration in database		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
once (one-off)		
68		155

Source: Analysis of questionnaires sent to ODS stakeholders

Table A_XII-19 shows the resulting overall cost (one-off) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-19 *Overall administrative costs for EU-27: PD03 - Registration in F-Gas database*

PD03 - Registration in database			
Overall administrative cost in EU-27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] once (one-off)			
177.1	0.0	12.4	189.5

5.3. PD04 - Submission of verified baseline report

As the basis for the allocation of rights to POMs in the analysed grandfathering system, undertakings intending to place HFCs on the market need to submit a baseline report covering their respective activities in the base period. The necessary data are assumed to be easily available to the undertakings, as these data had to be reported in previous years according to Art 6 of the F-Gas Regulation. Concerning the specific administrative burden per company, a conservative estimate of two person-days (16 hours) is made. Time needed would concern gathering, combination, internal checks of the data, the filling of tables and submission of the report. Efforts for the verification of the report are estimated separately below in 5.4 (PD05 – Verfication of baseline report).

Table A_XII-20 *Administrative burden per entity: PD04 - Submission of verified baseline report*

PD 04 - Submission of verified baseline report		
Administrative burden per entity		
Once (one-off)		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
16	-	-

This requirement would apply to the same set of involved stakeholders as in PD03 above (chapter 5.2), i.e. undertakings that place HFCs on the market above a threshold of 1 kt CO_2eq. Thus, the same estimated number of affected entities in the EU-27 (80 undertakings) and the same EU-wide weighted tariff of 32.55 €/h is used here in order to calculate overall cost for EU-27, as well.

Table A_XII-21 shows the resulting overall costs (one-off) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-21 *Overall administrative costs for EU-27: PD04 - Submission of verified baseline report*

PD04 - Submission of verified baseline report			
Overall administrative cost in EU-27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] once (one-off)			
41.7	0.0	0.0	41.7

5.4. PD05 - Verification of baseline report

Baseline reports for the allocation of quotas in a grandfathering system (as described in chapter 5.3 above) need to be verified. The estimate for the specific burden for reporting companies are based on estimates which were collected among F-Gas reporting companies regarding the additional external verification of an annual report on production, import and export (as presently required under the F-Gas Regulation). Those specific costs are multiplied by three in order to take into account that the baseline report would cover not one single year but a series of three years.

Table A_XII-22 *Administrative burden per entity: PD05 - Verification of baseline report*

PD05 - Verification of baseline report		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
once (one-off)		
74	0	18 000

This requirement would apply to the same set of stakeholders involved in PD03 – Registration in F-Gas database (chapter 5.2), i.e. undertakings that place HFCs on the market above a threshold of 1 kt CO_2-eq. Thus, the same estimated number of affected entities in the EU-27 (80 undertakings) and the same EU-wide weighted tariff of 32.55 €/h is used here in order to calculate the overall costs for EU-27 as well.

Table A_XII-23 shows the resulting overall costs (one-off) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-23 *Overall administrative costs for EU-27: PD 05 - Verification of baseline report*

PD05 - Verification of baseline report			
Overall administrative cost in EU-27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] once (one-off)			
192	-	1 440	1,632

5.5. PD18 - Report (Art. 6) on placing on the market, import & export, reclamation, recycling & destruction

The administrative effort of undertakings presently reporting according to Art 6 of the F-Gas regulation is not to be considered as administrative costs within the phasedown policy option. However, reporting undertakings were asked to estimate their respective efforts in order to be able to estimate potentially more precisely the implications of a change of scope of the reporting obligation.

Table A_XII-24 shows the evaluation of the questionnaires. 24 answers were received. Seven outliers could be identified and discarded from the analysis. Estimates for equipment cost and outsourcing costs were summarised as outsourcing costs: Partly, undertakings use external consultants to help prepare their reporting. Few undertakings report one-off equipment costs for IT. In order to estimate annual costs for this assessment, 20% of the average equipment costs were interpreted as annual outsourcing costs. Figures shown in Table A_XII-24 are the resulting averages.

Table A_XII-24 *Administrative burden per entity: PD18 - Reporting acc. Art 6 F-Gas Regulation*

PD18 - Reporting acc. Art 6 F-Gas Regulation		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
55		506

Source: Analysis of questionnaires sent to F-Gas producers & importers

This requirement applies to the same set of involved stakeholders as in PD03 – Registration in F-Gas database (chapter 5.2), i.e. undertakings that place HFCs on the market. Thus, the same estimated number of affected entities in the EU-27 (80 undertakings) and the same EU-wide weighted tariff of 32.55 €/h is used here in order to calculate the overall costs for EU-27 as well.

Table A_XII-25 shows the resulting overall costs (annual) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-25 *Overall administrative costs for EU-27: PD 18 - Reporting according to Art 6 F-Gas Regulation*

PD18 - Reporting acc. Art 6 F-Gas Regulation			
Overall administrative cost in EU-27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] annual			
144.2	0.0	40.5	184.7

5.6. PD 19 – Verification of Reporting & submission to MS or central authority

The annual reporting by undertakings needs to be verified. Thus, reporting undertakings were asked to estimate the costs of a verification of an annual report by an external business accountant.

Table A_XII-26 shows the evaluation of the questionnaires. 15 answers were received. Two outliers could be identified and discarded from the analysis. Estimates for equipment costs and outsourcing costs were summarised as outsourcing costs: Figures shown in *Table A_XII-26* are the resulting averages.

Table A_XII-26 *Administrative burden per entity: PD 19 - Verification of Reporting acc. Art 6 F-Gas Regulation*

PD19 - Verification of Reporting acc. Art 6 F-Gas Regulation		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
25		6 183

Source: Analysis of questionnaires sent to F-Gas producers & importers (Annex XIII)

This requirement would in principle apply to the same set of involved stakeholders as in chapter 5.2 (PD 03 – Registration in F-Gas database), i.e. undertakings that place HFCs on the market. However, due to the assumption of a higher threshold for verification needs, the number of affected entities in the EU-27 is estimated as 30 undertakings. The same EU-wide weighted tariff of 32.55 €/h as for PD 03 is used here in order to calculate the overall costs for the EU-27 as well.

Table A_XII-27 shows the resulting overall costs (annual) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-27 *Overall administrative costs for EU-27: PD 19 - Verification of Reporting acc. Art 6 F-Gas Regulation*

PD19 - Verification of Reporting acc. Art 6 F-Gas Regulation			
Overall administrative cost in EU 27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] annual			
24.0	-	185.5	209.5

5.7. PD 30 – Reporting on reclamation and destruction

In order to improve monitoring and data availability, an obligation for reclamation and destruction facilities to report reclaimed and destroyed F-Gas quantities should be introduced. Table A_XII-28 gives an overview of specialised reclamation and destruction facilities in EU-27.

Table A_XII-28 *Number of reclamation and destruction facilities in the EU-27*

	Number of reclamation facilities	Number of destruction facilities
AT	0	0
BE	3	1
BG	2	0
CY	0	0
CZ	5	1
DE	3	5[b]
DK	0	2
EE	0	0
EL	1[a]	0
ES	4	0
FI	0	1
FR	5	3
HU	3	2
IE	0	0
IT	3	3
LT	1[a]	0
LU	0	0
LV	0	0
MT	0	0
NL	3	0
PL	1	1
PT	0	0
RO	1	1
SE	1	2
SI	0	0
SK	0	0
UK	5	2
Total	41	24

[a] License since March 2010 (Greece) and June 2010 (Lithuania)

[b] One company with 4 facilities referred to as 1 facility (only 1 out of the 4 facilities is operating).

Source: Schwarz et al. (2011)[9]

For destruction, quantities are already monitored and reported to authorities under the waste legislation and thus are readily available in most cases. The data submitted, however, cannot be specified for particular HFC types or types of blends since mixtures of different HFCs, HCFCs and other refrigerants are usually delivered for destruction. Destruction facilities do not perform analyses to specify the components of these mixtures. According to operators, it is uncertain whether appropriate techniques are available, which would allow a determination of the specific HFC contents (and thus GWPs) of the destroyed quantities are available. Therefore, it remains unknown to date whether the data available are sufficiently specific for monitoring purposes under the phasedown option, even more in the case of monitoring requirements for an amended Montreal Protocol.

Reclamation is carried out by few entities, notably gas distributors already reporting to authorities under the F-Gas Regulation. Reclaimed quantities are very low so far, since the technical process is complex and costly.

Questionnaires on the administrative effort required for reporting of F-Gases by reclamation and destruction facilities have been sent out but few responses have been received to date. Therefore, expert interviews were undertaken via telephone, but estimates of the administrative burden are preliminary at this stage.

Based on the assumption that data on reclaimed HFCs quantities (specific by HFCs) and on destroyed refrigerant mixes (including HFCs) are readily available within the undertakings, the additional effort for reporting to the Commission is conservatively estimated at one person-day (eight hours).

Table A_XII-29 *Administrative burden per entity: PD 30 – Reporting of F-Gases by reclamation/ destruction facilities not yet covered by reporting obligations*

PD 30 – Reporting of F-Gases by reclamation/ destruction facilities		
Administrative burden per entity		
Annual		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
8	0	0

In order to estimate a weighted average for tariffs, for each Member State, the number of destruction and reclamation facilities as shown in *Table A_XII-28* is divided by the EU-27 total. The result is given in *Table A_XII-30*.

Table A_XII-30 *Distribution of EU-27 destruction and reclamation facilities between Member States*

Distribution of EU-27 destruction and reclamation facilities between MS			
[% of EU-27]			
AT	-	IT	9.2%
BE	6.2%	LV	1.5%
BG	3.1%	LT	-
CY	-	LU	-
CZ	9.2%	MT	-
DE	12.3%	NL	4.6%
DK	3.1%	PL	3.1%
EE	-	PT	-
EL	1.5%	RO	3.1%
ES	6.2%	SE	4.6%
FI	1.5%	SI	-
FR	12.3%	SK	-
HU	7.7%	UK	10.8%
IE	-	**EU-27**	**100.0%**

Source: Calculated from Schwarz et al. (2011)[9]

The number of affected facilities is 65 (*Table A_XII-28*). The multiplication of Member State-specific tariffs (*Table A_XII-1*) by the distribution to Member States leads to a weighted EU-27 average tariff of 33.29 €/h.

Table A_XII-31 shows the resulting overall costs (annual) in the EU-27 taking into account administrative burden per entity, the weighted tariff per hour, and the number of affected entities.

Table A_XII-31 *Overall administrative costs for EU-27*

PD30 - Reporting on reclamation and destruction			
Overall administrative cost in EU-27			
Personnel costs	Equipment Costs	Outsourcing costs	Total Cost
[Thousand €] annual			
17.3	0.0	0.0	17.3

5.8. Summary of administrative cost of the phasedown option

Table A_XII-32 and *Table A_XII-33* summarise the one-off costs and annual cost estimates for the phasedown option:

Table A_XII-32 *Summary of the one-off cost in the EU-27 for the phasedown option*

Summary administrative cost phasedown (one-off)					
Overall administrative cost in EU-27					
	Information requirement	Personnel cost	Equipment Cost	Outsourcing cost	**Total Cost**
		[Thousand €] once (one-off)			
PD03	Registration in data base	177	-	12	**190**
PD04	Submission of verified baseline report	42	-	-	**42**
PD05	Verification of baseline report	192	-	1,484	**1,676**
	Total one-off	**411**	**-**	**1,496**	**1,907**

Table A_XII-33 *Summary of annual costs in the EU-27 for the phasedown option*

Summary administrative cost phasedown (annual)					
Overall administrative cost in EU-27					
	Information requirement	Personnel cost	Equipment Cost	Outsourcing cost	**Total Cost**
		[Thousand €] annual			
PD19	Verification of Reporting acc. Art 6 F-Gas Regulation	24	-	185	**209**
PD30	Reporting on reclamation and destruction	17	-	-	**17**
	Total annual	**41**	**-**	**185**	**227**

In order to compare both cost categories, the one-off cost can be converted into annuities for 18 years (2013–2030) using an interest rate of 8%. Under these conditions, the total one-off cost would correlate to € 203,000 per year. The total annualised administrative costs for industry incurred by the phasedown option would amount to approximately € 430,000 per year. About 90% of these costs are induced by the verification of annual reports and the baseline report.

However it should be noted that the cost estimated for the reporting of destruction of HFCs would cover the reporting of metric tonnes of an unspecified mix of HFCs, HCFCs and other refrigerants, only. A reasonably exact determination of the amount of HFCs destroyed expressed in CO_2 equivalents is not possible on this basis.

6. POLICY OPTION E: REGULATORY BANS

– Policy option E refers to the introduction of regulatory bans for certain open and closed applications containing fluorinated greenhouse gass as well as the mandatory destruction of HFC-23 from halocarbon production.

In section 5.5 in the main part the included bans are listed.

An overview of the information requirements in policy option E is given in Table A_XII-34 covering the following obligations:

- Cooperation with audits & inspection by public authorities - B01,
- Carry out audits / inspections - B02,

- Report on implementation to Commission - B03 and
- Check the verification reports - B04.

Given that the concrete sectors, gases, timelines of bans on the use of F-Gas in certain appliances would have been settled by the Commission beforehand, it is assumed that no administrative costs will occur for these steps. Furthermore the policy option is based on the assumption that there are no exemptions from a ban. This assumption is due to the fact that the management of exemptions would entail administrative costs for both undertakings and the Commission, inter alia covering the application process, legal assessment, granting or rejection of an exemption. However, such costs will not be treated as administrative costs, as it is not imposed on undertakings to apply for an exemption.

Administrative costs regarding obligation B01 are not collected from the stakeholder and will not be assessed, as the enforcement would probably consist in checking samples of imported/produced marketed products. Checking the verification reports (obligation B04) will not be included in the administrative costs of the option as that will be done by the Commission and thus can be neglected following the impact assessment guidelines.

6.1. Overview of information requirements for the ban option

Table A_XII-34 gives an overview of information requirements which are necessary for regulatory bans. Each line taken into account for the quantitative estimation of administrative cost is further explained in the following sections.

Table A_XII-34 *Overview of information requirements regarding regulatory bans*

Administrative costs of regulatory bans						
No.	**Obligation**	**Frequency**	**Affected stakeholder group**		**Comment / Approach**	**Source of information**
			Type	**No.**		
B01	Cooperation with audits & inspection by public authorities	Depends on enforcement by MS: Assumption is once per year	Producers, importers of equipment/prod ucts	~1250	Is neglected as enforcement would probably consist in checking samples of imported/produced marketed products.	
B02	Carry out audits / inspections	Once per year. No of inspections per year: No of producers/impor ters (B01).	MS authorities	27 MS	Build on European experience in bans and own estimations: Unit of specific cost (cost per controlled entity)	
B03	Report on implementation to COM	Once pear year	MS authorities	27 MS	Cost per MS based on experience with Art. 26 ODS reports.	ODS competent authorities
B04	Check verification reports	27 reports once per year	COM	1	Is neglected as COM efforts are not included in administrative costs.	

6.2. B02 - Carry out audits/inspections

Member States are required to enforce the bans established. Therefore, the costs for enforcement activities such as audits or inspections at relevant companies are of interest. In general, inspections are carried out by relevant authorities whereas audits are normally conducted by independent experts on behalf of the companies for quality control.

National legislation on F-Gases in France requires companies holding certificates ("attestation de capacité"; mandatory since 4 July 2009) to become audited by external bodies every 5 years. Such audits aim at the control of personnel certification, data monitoring and data verification within the company and are hence rather comprehensive and cannot be compared to measures ensuring compliance with a particular ban. Due to the legal requirement, all certified companies in France need to take audits.

Within an inspection campaign, not all companies active in a particular sector are controlled, but particular measures are enforced at random samples.

Despite these differences between the general nature of audits and inspections, it is estimated that the efforts to be made by companies for preparation and support are comparable. As officials investigate the cases chosen, the costs for an inspection carried out by authorities are considered to be lower than cost for an audit undertaken by contracted external auditors.

Questionnaires have been sent out to three authorities in Member States where bans of HFCs in certain products or general bans have been in place for some time. Only one answer has been received (from Denmark).

It should be noted that costs for inspections to enforce bans largely depend on the degree of detail such investigations are aiming at. For example, in Austria control of ODS bans in aerosols carried out in the 1990s included not only checks of the labels and company data, but also costly and time consuming chemical analyses by means of particular equipment. Bans of HFCs, in particular applications, have not been controlled in recent years.[94]

With regard to ODS refrigerants, checks of equipment logbooks to enforce bans of the use of virgin ODS are not known to date. Such bans are enforced by means of registration and control of F-Gas importers and distributors.

Thus, estimates of administrative costs for one inspection are based on their own estimates for an inspection of the ban of the use of HFCs in stationary equipment. It is assumed that official environmental and/or chemical inspectors undertake an on-site visit at one particular company. The inspection includes the check of the logbooks and servicing information, the filling in forms and tables and filing the information. No chemical analyses of products/equipment are carried out.

Based on a combination of the above-mentioned assumptions and the response of Denmark authorities who estimated to need 65 hours for carrying out one

[94] Telephone conversation with Austrian EPA, 22.12.2011.

audit/inspection the following estimates on the administrative burden per entity is provided in *Table A_XII-35*.

Table A_XII-54 *Administrative burden per entity: B02 – Carry out audits/ inspections*

B 02 – Carry out audits/ inspections		
Administrative burden per entity		
Annual		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
20	0	0

Table A_XII-36 *Number of affected companies with closed application within the areas of a regulatory ban: B02 – Carry out audits/inspections*

Area of a regulatory ban (closed application)	**No. of companies in EU-27 placing the equipment on the market: EU producers & Importers**	**Source**
Commercial refrigeration (Stand-alone systems, Condensing units, Centralized systems).	ca. 20 (industrially manufactured stand-alone equipment) ca. 16 (large companies) ca. 1000 (small companies for condensing units, centralized systems)	Ökoinstitute estimate
Industrial refrigeration	ca. 100	Ökoinstituteestimate
Transport refrigeration (Refrigerated trucks and trailers),	12	See Schwarz et. al. 2011[9], p. 233.
Stationary AC (Moveable systems, single split systems, multi split/VRF systems, rooftop systems, displacement chillers)	10 (Producers) ca. 20 (Importers of OEM)	Ökoinstitute estimate
HFC-23 in fire protection	30	Estimation on total number of EU based original equipment manufacturers, see Schwarz et.al. 2011[9], p. 235.
Total amount	**ca. 1,200**	

Table A_XII-37 *Number of affected companies with open applications within the areas of a regulatory ban: B02 – Carry out audits/inspections*

Area of a regulatory ban **(open application)**	**No. of producing companies in EU-27**	**Source of information**
XPS 134a foam blowing	13	See Schwarz et.al. 2011.[9]
SF_6 in Magnesium die-casting <850 kg/y and recycling of die casting alloys	19	See Schwarz/Gschrey 2009[95], p. 18.
Mandatory destruction of HFC-23.	1	Schwarz et al. (2011)[9], p.175
Technical aerosols	ca. 20	Ökoinstitute estimate
Total amount	**53**	

Table A_XII-38 shows the resulting overall annual costs in the EU-27, taking into account a time of 20 hours for the carrying out audits/ inspections per company (cf. *Table A_XII-35*)), the weighted tariff of 36 €/hour for EU-27 (as calculated in chapter 3.2 of this annex) and 1250 affected companies (sum of Table A_XII-36 and Table A_XII-37).

Table A_XII-38 *Overall administrative costs for EU-27: B02 – Carry out audits/ inspections*

B02 - Carry out audits / inspections			
Overall administrative cost in EU 27			
Personnel costs	Equipment costs	Outsourcing costs	Total cost
[Thousand €] annual			
895,6	-	-	895,6

95 Schwarz/Gschrey (Öko-Recherche): Service contract to assess the feasibility of options to reduce emissions of SF6 from the EU non-ferrous metal industry and analyse their potential impacts.

6.3. B 03 – MS reports on implementation

Obligation B03 "MS reports on implementation" envisages that competent authority in each Members State shall report to the Commission on the implementation of regulatory bans in their Member State. It is assumed that the effort is comparable to the administrative efforts necessary to report to the Commission on the implementation of ODS under Art. 26 ODS Regulation.

A questionnaire listing the required action within B03 was sent to 27 competent authorities in the Members States in charge of the ODS regulation. Answers from 10 Member States were received. Figures shown in *Table A_XII-39* are the resulting average hours necessary to report on the implementation to EU under Art. 26 of the ODS Regulation.

Table A_XII-39 *Administrative burden per MS: B03 - MS reports on implementation to EU*

B03 - MS reports on implementation		
Administrative burden per entity		
Time [hours]	Equipment costs [€]	Outsourcing costs [€]
annual		
306	-	4,542

Source: Analysis of questionnaires sent to MS competent authorities for ODS (Annex XIII)

Figures shown in Table A_XII-40 are the resulting minimum and maximum hours necessary to report on the implementation to EU under Art. 26 of the ODS Regulation.

Table A_XII-40 *Minimum and maximum administrative burden for the interviewed MS: B03 - MS reports on implementation to EU*

B03 - MS reports on implementation to EU	
Minimum and maximum administrative burden for the interviewed MS	
Time [hours], annual	
Minimum	Maximum
16	1,000

Source: Analysis of questionnaires sent to MS competent authorities for ODS (Annex XIII)

Two outliers were identified and removed from the analysis. One MS did not state any costs for reporting under Art. 26 ODS, one MS did not quantify the administrative costs and one MS stated 610 hours for reporting under Art. 26 ODS which is five times the average administrative burden.

Only one Member State of the seven reported to have equipment costs of € 2,250 necessary for the reporting under Art. 26 ODS regulation and therefore will be evaluated as an outlier not be included in the following analysis.

Table A_XII-41 shows that the resulting overall annual costs in the EU-27 is € 334.7 taking into account administrative burden per MS of 212 hours per report/once a year and the average tariff per hour for professionals in the EU-27 of € 26. The overall outsourcing costs are estimated to be € 122.6.

Table A_XII-41 *Overall administrative costs for EU-27: B03 - MS reports on implementation to EU*

B03 - MS reports on implementation			
Overall administrative cost in EU 27			
Personnel costs	Equipment costs	Outsourcing costs	Total cost
[Thousand €] annual			
212.0	-	122.6	334.7

The following comments given by the interviewed Member States are important inter alia for the transferability of the administrative costs from reporting under Art. 26 ODS to a possible reporting under F-Gas Regulation in option E:

In Federal States (e.g. Germany) the administrative burden may vary between federal states. According to competent authorities in Germany no additional equipment or outsourcing is required and the administrative burden is rather low because authorities can often produce the required information from their collected enforcement data. Other kinds of information might take considerably longer to collect.

In small countries administrative efforts in this field are not very complicated and comprehensive, e.g. everything in relation with reporting (Article 26) is carried out by one person over approximately 4 months (as part of regular work) in cooperation with stakeholders who provide data. However, it is believed that costs and workload will increase significantly if Member States will have to report on the use of F-Gases.

Following the assessment of the French competent authority the reporting of the MS according to Article 26 ODS is not an administrative burden. Nevertheless, the French competent authority believes that Article 26 ODS is not the most appropriate one to be included in the revision of the Regulation 842/2006. Instead a similar reporting mechanism (that includes production and destruction) according to Article 27 ODS

Regulation should be included in the revision of the F-Gas Regulation and should be extended to pre-charged equipment as such information is necessary to any phasedown scenario of the production and consumption of F-Gases.

6.4. Summary of administrative cost of the ban option

The overall estimation of the annual administrative costs in the option E "Regulatory ban on certain open and closed uses of HFC" is given in *Table A_XII-42*.

Table A_XII-42 *Annual administrative costs of the ban option*

Summary administrative cost phase-down (annual)					
Overall administrative cost in EU 27					
	Information requirement	Personnel cost	Equipment Cost	Outsourcing cost	**Total Cost**
		[Thousand €] annual			
B02	Carry out audits / inspections	896	-	-	**896**
B03	MS reports on implementation	212	-	123	**335**
	Total annual	**1,108**	**-**	**123**	**1,230**

ANNEX XIII: Questionnaire assessing Administrative Costs of Stakeholders

1. INTRODUCTION

Regulation (EC) No 842/2006 on certain fluorinated greenhouse gass ("F-Gas Regulation"), supplemented by 10 implementing Commission Regulations, aims at reducing emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) (collectively referred to as "F-Gases", all of which are controlled as greenhouse gass under the Kyoto Protocol) in the European Union, through a series of measures along two tracks of action:

- Avoiding F-Gases in some applications in which more environmentally superior alternatives were already cost-effective. Measures include use and marketing restrictions.
- Reduce leakages from equipment containing F-Gases. Measures comprise: labelling of equipment containing F-Gases, training and certification of personnel and companies handling this type oF-Gases, containment and proper recovery.

Article 10 of the F-Gas Regulation requires the European Commission to publish a report in 2011 based on the experience of its application and, if necessary, present proposals for revision of the relevant provisions of the Regulation.

On 26 September 2011 the Commission completed a review of the application, effects and adequacy of the F-Gas Regulation and issued a report[96], drawing from the results of an analytical study (Schwarz et al. (2011)[9].

In parallel, the European Commission has contracted a consortium including Öko-Institut, Öko-Recherche and HEAT International for support for the impact assessment of a possible legal proposal to revise the F-Gas Regulation. In the context of that contract several options for policy measures to revise the F-Gas Regulation in order to further reduce European emissions are elaborated and subjected to an impact assessment. As a part of that impact assessment, this questionnaire shall serve to help assessing the administrative costs which would be incurred by enterprises and public authorities in meeting additional legal obligations to provide information on their action or production, as required by a possible revision to the F-Gas Regulation, either to public authorities or to private parties.

Please note that this questionnaire is circulated in parallel to, but is, however, independent from the stakeholder consultation[97] which the Commission has launched regarding its above mentioned report of 26 September 2011. In case you wish to communicate to the Commission your opinions and arguments concerning any type of policy options to revise the F-Gas regulation, we kindly ask you to use that stakeholder consultation forum for that purpose. The evaluation of this questionnaire will not

[96] http://ec.europa.eu/clima/policies/F-Gas/docs/report_en.pdf
[97] http://ec.europa.eu/clima/consultations/0011/index_en.htm

include any general comments but will be restricted to the dimension of administrative cost connected to the range of policy options presented below.

2. GENERAL GUIDANCE TO THE USERS

The attached questionnaire is meant to underpin the Impact Assessment undertaken by the European Commission as part of the revision of the Regulation (EC) No. 842/2006 on certain fluorinated greenhouse gass. The aim of the questionnaire is to elicit a quantitative estimate of changes in **administrative costs and administrative burden** that may be incurred by stakeholders in implementing the requirements of a revised Regulation **in so far as activities to provide information are concerned**. The term "information" is used in a broad sense, covering labelling, reporting, registration, monitoring and assessment needed to provide information as well as the transfer of information to public authorities and private parties (e.g. trade associations). Any other cost possibly incurred to stakeholders, i.e. not related to providing information, is not subject to this questionnaire.

The variety of possible information requirements identified in this questionnaire is representative of a range of possible policy orientations, but they do not reflect the Commission's views at this stage.

In order to facilitate both filling in and evaluation of the questionnaire, we have implemented the questionnaire as an Excel worksheet.

Please complete the questions in the attached Excel worksheet in as much detail as possible and return your response by *//date//* to *//contact//,* using the e-mail-address *//E-mail//*. If you have any queries about the questionnaire, please also contact us using the E-Mail-address above.

In the Excel worksheet specific questions are asked focusing

– on stakeholders' **experience** on administrative cost for meeting information requirements which are comparable to those that might become relevant depending on policy options chosen for a potential revision of the F-Gas Regulation, or

– on stakeholders' **expectations** on administrative cost for meeting information requirements that might become relevant depending on policy options chosen for a potential revision of the F-Gas Regulation.

For better readability the questions are printed in section 3below of this document, as well.

The addressees of the questionnaire are kindly asked to indicate the time needed to fulfil an information obligations differentiated by a set of activities. According to the EU Impact Assessment guidelines[98] different types of required actions are categorized as follows:

[98] http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_annex_en.pdf

- Familiarising with the information obligation
- Training members and employees about the information obligations
- Retrieving relevant information from existing data
- Adjusting existing data
- Producing new data
- Designing information material (e.g. leaflet conception)
- Filling forms and tables (including recordkeeping)
- Holding meetings (internal/external with an auditor, lawyer etc.)
- Inspecting and checking (including assistance to inspection by public authorities)
- Copying (reproducing reports, producing labels or leaflets)
- Submitting the information to the relevant authority (e.g. sending it to the relevant authority)
- Filing the information
- Buying (IT) equipment & supplies (e.g. labelling machines) to specifically used to fulfil information obligations
- Other

These activities are reflected in the questionnaire as appropriate for the individual questions. Note that not all types of activities are relevant for every question asked. Whilst the basic data requirements from the questionnaire are fixed, a “comments/assumptions” section has been included to allow participants to provide further explanation of the estimates.

It must be emphasised that the Commission places great importance on determining numerical values for the costs and benefits of proposals, wherever possible. Therefore, the addressees are urged to provide their best estimates of staff-days and/or cost data.

The questions related to the administrative burden include the following elements:

- **Staff-hours**: the number of hours spent by staff of your company / institution fulfilling the requirement as defined in the question;
- **Consultancy costs**: fees for work done by external consultants;
- **Capital costs**: for software or other items purchased to fulfil information requirements.

The questionnaire allows for insertion of staff-days and/or cost data. Please clearly indicate which is being used by adding ‘days’ or ‘€’ (or other currency) in relevant cells. In case it is not possible to provide a fix numerical value, please provide an estimated range of staff days/costs and explain your estimate in the “comments/assumptions” column.

3. QUESTIONNAIRE ADDRESSING COMPANIES WITH EXPERIENCE UNDER THE ODS REGULATION

- Registration in database

Obligation option PD03		Registration in data base			
	Addressed stakeholders:	Stakeholders with experience in registration in the EU ODS database			
	Answering entity based in:				
	Frequency of obligation:	Once			
	specific question:	What was your administrative effort for registration with the ODS data base?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		Once	**Once**	**Once**	
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				
7	Filling forms and tables				
9	Inspecting and checking (including assistance to inspection by public authorities)				
11	Submitting the information (sending it to the designated recipient)				
12	Filing the information				
14	Other				

4. QUESTIONNAIRE ADDRESSING RECLAMATION AND/OR DESTRUCTION FACILITIES CURRENTLY NOT COVERED BY REPORTING OBLIGATIONS

- Reporting of F-Gases by reclamation and/or destruction facilities

Obligation option PD30		Reporting of F-gases by reclamation and/or destruction facilities			
	Addressed stakeholders:	Reclamation and/or destruction facilities for F-gases currently not covered by reporting obligations			
	Answering entity based in:				
	Frequency of obligation:	Annual			
	Specific question:	What would be your administrative effort for annual reporting of reclamation and/or destruction of used F-gases by type?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		Annual	**Annual**	**Annual**	
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				Monitor F-gas quantities for reclamation by F-gas type
7	Filling forms and tables				
9	Inspecting and checking (including assistance to inspection by public authorities)				
10	Copying (reproducing reports, producing labels or leaflets)				
11	Submitting the information (sending it to the designated recipient)				
14	Other				

5. QUESTIONNAIRE ADDRESSING MS AUTHORITIES WITH EXPERIENCE IN F-GAS BANS

- Carry out audits/inspections

Obligation option B02		Carry out audits/ inspections			
Addressed stakeholders:		Authorities in Member States			
answering entity based in:					
Frequency of obligation:		Annually			
specific question:		Could you please estimate your administrative effort for carrying out **one** audit/inspection in order to enforce bans on fluorinated gases?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		Annually	**Annually**	**Annually**	
No.	Description of required action(s)				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				e.g. identifying and choosing relevant companies, scheduling of audit/inspection, preparing background information documents
7	Filling forms and tables				
9	Inspecting and checking (including assistance to inspection by public authorities)				
11	Submitting the information (sending it to the designated recipient)				
12	Filing the information				
13	Buying (IT) equipment & supplies				
14	Other				e.g. travel to onsite inspections

6. QUESTIONNAIRE ADDRESSING MS COMPETENT AUTHORITIES UNDER THE ODS REGULATION

- Report on implementation of EU legislation to the Commission

Obligation option B03		Report on implementation of EU legislation to the Commission			
	Addressed stakeholders:	MS competent authorities under the ODS regulation			
	Answering entity based in:				
	Frequency of obligation:	once			
	Specific question:	What was your administrative effort to report on the implementation of the ODS regulation to the Commission (Art. 26)?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		once	**once**	**once**	
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				
6	Filling forms and tables				
7	Holding meetings				
8	Submitting the information (sending it to the designated recipient)				
9	Filing forms and tables				
10	Other				

7. QUESTIONNAIRE ADDRESSING COMPANIES CURRENTLY FALLING UNDER REPORTING REQUIREMENT IN THE F-GAS REGULATION

- Annual report on the placing of F-Gases on the EU market

Obligation option PD18		Annual companies' reports on the placing on the market of F-Gases			
	Addressed stakeholders:	Companies currently reporting under the F-Gas regulation			
	Answering entity based in:				
	Frequency of obligation:	annually			
	Specific question:	What were your companies efforts for an (annual) report under the current F-Gas regulation?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		annually	**annually**		
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				
7	Filling forms and tables				
8	Holding meetings				
11	Submitting the information (sending it to the designated recipient)				
12	Filing the information				
14	Other				

- Verification of a report on the placing of F-Gases on the EU market

Obligation option PD19		Verification of a report on activity data in a given year			
Addressed stakeholders:		Companies currently reporting under the F-Gas regulation			
Answering entity based in:					
Frequency of obligation:		Annually			
Specific question:		How would you estimate your additional effort and cost to have your F-Gas report verified by an independent expert (e.g. by accounting consultants or EMAS verifier)?			
		Administrative burden per entity			
		Time (hours)	Equipment costs [€]	Outsourcing costs [€]	Remarks
		Annually	Annually	Annually	
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Filling forms and tables				
5	Submitting the information (sending it to the designated recipient)				
6	Other				
7	- Expenses for external verifiers				
8	- Assistance/support to external verifiers				

8. QUESTIONNAIRE ADDRESSING TRADE ASSOCIATIONS EXPERIENCED WITH A VOLUNTARY AGREEMENT (VA)

- Annual monitoring report

Obligation option VA04		**Annual monitoring report**			
Addressed stakeholders:		Industry/trade associations experienced with a voluntary agreement (VA)			
Answering entity based in:					
Frequency of obligation:		Annually			
Specific question:		What were your administrative efforts for an (annual) report to national or EU authorities under the voluntary agreement you have been involved in?			
		Administrative burden per entity			
		Time (hours)	**Equipment costs [€]**	**Outsourcing costs [€]**	**Remarks**
		Annually	**Annually**		
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				
7	Filling forms and tables				
8	Holding meetings				
11	Submitting the information (sending it to the designated recipient)				
12	Filing the information				
14	Other				

- Communication with stakeholders

Obligation option VA06		Communication with stakeholders			
	Addressed stakeholders:	Industry/trade associations experienced with a voluntary agreement (VA)			
	Answering entity based in:				
	Frequency of obligation:	Annually			
	Specific question:	What were your administrative efforts per year for communication with stakeholders concerning the voluntary agreement you have been involved in?			
		Administrative burden per entity			
		Time (hours)	Equipment costs [€]	Outsourcing costs [€]	Remarks
		Annually	Annually		
No.	Description of required action(s)				
1	Familiarising with the information obligation				
2	Training members and employees about the information obligations				
3	Retrieving relevant information from existing data				
4	Adjusting existing data				
5	Producing new data				
6	Designing information material (leaflet conception…)				
8	Holding meetings				
10	Copying (reproducing reports, producing labels or leaflets)				
11	Submitting the information (sending it to the designated recipient)				
12	Filing the information				
13	Buying (IT) equipment & supplies				
14	Other				

ANNEX XIV: Macroeconomic Analysis of F-Gas Policies with *GEM-E3*

1. METHODOLOGY

The *GEM-E3* model is an applied general equilibrium model[99]. The main feature of a general equilibrium model is capturing the price induced effects of policies, including substitution in commodity demand as well as shifts in trade behaviour. As *GEM-E3* evaluates emissions of all Kyoto-gases including fluorinated greenhouse gass, and as it is allows imposing taxes on these pollutants, the model captures the interactions between the economy, energy system, and interactions for the major world regions linked though endogenous bilateral trade flows. The current version of the model is based on the GTAP 7 database with the base year 2004. IPTS (JRC) performed the model calculations. The emissions follow historical paths up 2010 (based on the UNFCCC inventory of EEA of 2011). For fluorinated greenhouse gass the baseline emission path is in line with the "with measures" (WM) scenario of *Schwarz et al. (2011)*[9] after 2010 (option A). In *GEM-E3* emissions of HFC are accounted in the production stage, i.e. are allocated to the producers of HFC which is mainly the chemical sector. As HFC emissions are allocated to this sector, the cost of employing abatement technologies also are allocated to these sectors. The estimates of the abatement cost functions are based on the IIASA database.[100]

2. SCENARIOS

The scenarios implement the reductions of HFC as a trading system over all emission sources. HFC emissions are allocated to the producers of HFC, i.e. mainly the chemical sector. Therefore the scenarios implement emission trading at upstream, i.e. production, level. The emission reduction targets for 2030 are given in the *Table A_XIV-1* below. The scenarios differ in the way F-Gas emission rights are allocated: for free, or being sold through auctioning. Impacts would also depend on whether the non-European countries also impose reduction targets on HFC, i.e. whether the European policy is unilateral or not. An overview over the scenario settings is given in the table below. The model assesses the impacts of the two (strongest) options, D (Phase down) and option E (Ban), with the strongest impact (in terms of emission reduction and costs). The emission reductions for 2030 are consistent with the expected reduction in emissions in 2030 of option D and E in the main text.

Table A_XIV-1: HFC emission reduction targets compared to 2006

	2030
EU-Option D	62%
EU-Option E	45%

99 For a detailed model description see: www.GEM-E3.net

100 Hoglund-Isaksson et al. (2010). "Potentials and costs for mitigation of non-CO2 GHG emissions in the European Union until 2030." IIASA, Laxenburg. Report to the European Commission. http://ec.europa.eu/clima/policies/package/docs/non_co2emissions_may2010_en.pdf

Scenario 1 examines the case of allocation of permits with no passing on of the costs in the case of unilateral EU action. The scenario Group 1-W allows for costs pass-on, i.e. even if the permits are allocated for free, firms include the (market) value of permits into the output price. Group 2 implements full auctioning of F-Gas allocations (the right to place F-Gas on the market). In the full auctioning case, the income of auctioning F-Gas is assumed to be recycled into the economy by decreasing social security contributions paid by employers reducing labour costs. All cases are implemented for option D and E.

Table A_XIV-2 *Scenario overview*

Group		Unilateral
1	EU	Allocation of permits (grandfathering) No passing on
	Non-EU	No actions
1-W	EU	Allocation of permits (grandfathering) Passing on permit costs
	Non-EU	No actions
2	EU	Auctioning of permits
	Non-EU	No actions

3. DETAILED RESULTS

The table A_XIV-3 below show the possible impacts on GDP in 2030 for options D and E. While the GDP impacts differ across scenarios and between options D and E, they are small in all cases.

Table A_XIV-3 *GDP impacts in 2030 (% change compared to baseline)*

	D	E
Allocation – no passing on	-0.006	-0.003
Cost passing on	-0.012	-0.007
Auctioning	-0.008	-0.004

In case emission permits are allocated for free and their value is not included in the output price (Group 1), the GDP loss increases with the emission reductions. The GDP impact is therefore bigger in option D than E. In the case of unilateral European policy and the (opportunity costs of) grandfathered permits included into the output price (cost pass-through), the GDP losses becomes more pronounced but are still small: As the value of the permits further increases the output price, the loss in competitiveness leads to an further increase of imports and decrease of exports. The effect is smaller for option E since the permit price is lower. In case of full auctioning of HFC permits GDP losses are smaller than in the costs pass-through case. If these revenues are used to decrease social security contributions paid by employers they decrease the cost of labour. This exercises a positive effect on the whole economy as labour prices decrease.

The impacts on employment are shown in the following tables. Clearly, the impacts are small and either positive or negative. They would be the most negative in case the additional direct costs were passed through into higher prices. If permits to place F-Gases on the market would be auctioned and the revenues used to reduce labour costs the impact on employment would be positive. Note that the table does not take into account that importers of F-Gases are affected by the proposed options D and E as well. As a result the negative impacts on the number of jobs in the EU could be smaller (and less negative or even positive) as well since importers would also be faced with an increase in prices.

Table A_XIV-4: *Employment impacts in 2030 (number of jobs)*

	D	E
No cost passing on	-1.600	-1.000
Cost passing on	-15.800	-11.600
Auctioning	5.400	4.000

The impact on the level of production in the different sectors is shown in the Table A_XIV-5. As the abatement policy is implemented in an upstream manner, i.e. the producers of HFC are obliged to hold emission permits for HFCs sold, the chemical sector which is the main producers of HFC, is directly affected by the policy. The table shows the change in the production level of this sector compared to the business-as-usual (reflecting current legislation, option A). In general the effects on production are small. With the explanations given above, the results show the same pattern as the GDP results. Production decreases as domestic production is substituted by imports. In the case of auctioning the price of chemical products further increases and, thus, production decreases further. In the case of auctioning this effect is less pronounced (see i.e option D) since auctioning revenues are used to reduce labour costs. The double dividend of labour cost decrease also has a small positive effect on the chemical sector. The output losses might in reality be lower since importers of F-Gas (be it in bulk or included in products) are also affected to a certain degree by the options D & E since they are partially included. Modelling this would require detailed data on the production and trade flows of specific goods which is not available.

Besides the effect that the price change of chemical products affects the whole economy via intermediate demands, sector other than chemical production are affected mainly by abatement investment. Table A_XIV-5 shows for option D and E the detailed results indicating that in particular the electric goods, transport equipment, other equipment and metals sectors would see an increase in output. For option E similar but smaller impacts occur.

Table A_XIV-5 *Change in sectoral output in 2030 for option D and E (% change to baseline)*

	Option D			Option E		
	No cost passing on	Cost-passing on	Auction	No cost passing on	Cost-passing on	Auction
Chemical	-0.13	-0.35	-0.34	-0.06	-0.22	-0.22
Electricity	-0.01	-0.02	-0.02	-0.01	-0.01	-0.01
Coal	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Market services	0.00	0.00	0.00	0.00	0.00	0.00
Non-market services	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00
Energy Intensive	0.00	0.00	0.01	0.00	0.00	0.01
Consumer goods	0.01	0.02	0.02	0.00	0.01	0.01
Agriculture	0.01	0.02	0.02	0.01	0.01	0.02
Construction	0.01	0.01	0.01	0.00	0.00	0.00
Gas	0.01	0.04	0.04	0.00	0.02	0.02
Metals	0.02	0.04	0.04	0.01	0.04	0.04
Other equipment	0.02	0.05	0.05	0.02	0.02	0.03
Transport Equipment	0.02	0.04	0.04	0.01	0.02	0.03
Electric Goods	0.04	0.06	0.07	0.02	0.04	0.04

The implications for competiveness in terms of trade flows are shown in Table A_XIV-6 for the exports and Table A XIV-7 for the imports. Apart from the chemical sector, which experiences a small reduction in exports of 0.16% to 0.43% in option D and -.07 to 0.27% in option E, the impacts on exports in all other sectors are small, but positive. The auctioning tends to favour more labour-intensive sectors (e.g. non-market services) since auction revenues are assumed to be used to reduce labour costs but the effect does not differ significantly from the cost passing on in terms of exports.

Table A_XIV-6: *Change in exports in 2030 in all sectors for options D and E (% change to baseline)).*

	Option D			Option E		
	No cost passing on	Cost-passing on	Auction	No cost passing on	Cost-passing on	Auction
Chemical	-0.16	-0.43	-0.43	-0.07	-0.27	-0.27
Electricity	0.01	0.02	0.01	0.01	0.02	0.01
Energy Intensive	0.01	0.02	0.03	0.01	0.01	0.02
Transport	0.01	0.02	0.03	0.00	0.01	0.02
Construction	0.01	0.03	0.03	0.01	0.02	0.02
Metals	0.02	0.06	0.06	0.01	0.04	0.04
Consumer goods	0.02	0.05	0.05	0.01	0.03	0.04
Market services	0.02	0.04	0.04	0.01	0.03	0.03
Oil	0.02	0.04	0.04	0.01	0.03	0.02
Transport Equipment	0.02	0.04	0.05	0.01	0.03	0.03
Agriculture	0.03	0.07	0.07	0.03	0.04	0.05
Electric Goods	0.03	0.06	0.06	0.01	0.02	0.01
Non-market services	0.03	0.07	0.07	0.01	0.04	0.05
Other equipment	0.03	0.07	0.07	0.01	0.04	0.04
Gas	0.05	0.17	0.15	0.02	0.10	0.09
Coal	0.07	0.06	0.06	0.08	0.07	0.07

For the imports there is a more or less opposite trend compared to the exports, but impacts are much smaller. The chemical sector, construction, transport equipment and electric goods see an increase in imports. In the chemical sector this is mainly due to the increase in production costs compared to the other countries. In the other sectors the increases might also be due to increase in domestic output. With cost passing on of the (implicit) F-gas price in output prices the effects are slightly higher. Note that this is also since *GEM-E3* uses an upstream approach, i.e. energy, the chemical sector, are directly affected by the policy and in addition imports and export react to (production) price changes (see Annex XV for details).

Table A_XIV-7 *Change in imports in 2030 in all sectors for options D and E (% change to baseline (option A))*

	Option D			Option E		
	No cost passing on	Cost-pass on	Auction	No cost passing on	Cost-pass on	Auction
Chemical	0.01	0.01	0.02	0.00	0.01	0.01
Electricity	-0.01	-0.01	-0.01	0.00	-0.01	-0.01
Energy Intensive	-0.01	-0.02	0.02	-0.01	0.00	-0.01
Transport	0.00	-0.01	0.00	0.00	-0.01	0.00
Construction	0.01	0.01	0.01	0.00	0.00	0.00
Metals	0.00	-0.01	0.01	0.00	-0.01	0.00
Consumer goods	-0.01	-0.03	-0.02	0.00	-0.02	-0.01
Market services	-0.01	-0.03	-0.02	0.00	-0.02	-0.01
Oil	-0.02	-0.05	-0.05	-0.01	-0.03	-0.03
Transport Equipment	0.01	0.01	0.01	0.01	0.00	0.01
Agriculture	-0.01	-0.02	-0.02	0.00	-0.01	-0.01
Electric Goods	0.02	0.01	0.02	0.01	0.00	0.01
Non-market services	0.00	0.00	0.00	0.00	0.00	0.00
Other equipment	0.00	-0.01	0.01	0.00	-0.01	0.00
Gas	-0.01	-0.03	-0.03	-0.01	-0.02	-0.02
Coal	-0.01	-0.02	-0.02	0.00	-0.01	-0.01

The impact on the consumer price index is given in the following table for the various options. This is the median price effect across the EU countries included the model for 2030. The table shows that there is no significant impact across thee EU countries included in the model for 2030. This is true for option D and E quite irrespective of passing through of costs or auctioning of F-Gas rights.

Table A_XIV-8 *Change in market prices in 2030 for options D and E (% change to baseline).*

	Option D			Option E		
	No cost passing on	Cost-pass	Auction	No cost passing on	Cost-pass on	Auction
Market prices	0.00	-0.01	-0.01	0.00	0.00	-0.01

ANNEX XV: Differences between the EmIO-F and the GEM-E3 model

The two macro-economic models, EmIO-F and *GEM-E3*, show the same broad picture: the GDP, output as well employment effects of the proposed measures of F-Gas abatement are small. However, the model results differ in some minor points due to the different methodologies used. The main methodological differences relate to i) the model type (Input/Output model vs. Computable General Equilibrium model) and thus different treatment of international trade as well as production and consumer behaviour, ii) the implementation of the policy scenarios as upstream or mid-stream shocks.

More explicitly, some of the minor differences can be explained as follows. The chemical sector shows slightly positive reactions in EmIO-F for option D, while it shows somewhat much stronger reactions in *GEM-E3*, either positive or negative. The different behaviour of the models is because EmIO-F uses a mid-stream approach to F-Gas abatement, i.e. the F-Gas content of products is directly affected by the policy. This implies that changes in F-Gas related policies affect all production activities that require F-Gases or replacement substances independent of whether F-Gases are actually emitted or contained and recycled or emitted at a later state. Thus a much larger spectrum of sectoral activities than just the chemicals sector is affected by the policy change. EmIo-F accounts for the changes in investment and running costs operators of equipment containing F-Gases or manufacturers using F-Gases in the production process phase. In contrast, *GEM-E3* uses an upstream approach, i.e. the producers of F-Gases (the chemical sector) are directly affected by the policy.

Moreover, the input-output model (EmIO-F) assumes fixed coefficient production functions and holds the share between imports and exports for production and consumption constant across all simulations. In contrast, in *GEM-E3* production functions are formulated in a more flexible way allowing for price-induced substitution away from products which have become more expensive. Furthermore, imports and exports are also price sensitive in *GEM-E3,* i.e. depend on the imposed policy measures. Thus the chemical sector is negatively affected in the unilateral case. In a multilateral case such as the one where importers were to be included in the system Europe might gain competitiveness compared to countries outside Europe and, consequently, may increases production and exports.

There some differences in the impact of the F-gas policies across the various sectors as obtained with the two models. General trends and magnitude of effects are however similar, e.g. the sectors that deliver machinery/equipment and their suppliers (metals, metal products) show positive impacts in both models. A further difference between the models is the way in which government revenues of the imposed policy, i.e. the income of auctioning F-gas rights, is recycled (or used). In EmIO-F the government recycles revenue in a static way i.e. according to (historical) spending patterns contained in the Input-Output table. In contrast, *GEM-E3* recycles auction revenues by reducing social security costs paid by employers thus generating a dynamic employment effect since labour costs are reduced.

Annex XVI: State and potential of technology in the different sectors

This annex describes the technical feasibility of using replacement substances in sectors currently relying on F-Gases. This analysis is based on Schwarz et al.[9] and focuses on HFCs as the most important group of F-Gases and where most of the replacement potential is found.

1. COMMON TECHNOLOGY BY SECTORS

Common technology used in the different F-Gas sectors and subsectors at global scale is listed in an overview table (Table A_XVI-1) and includes conventional F-Gas technology and established alternative (halogen-free) technology.

HCFC technology listed is today used for new products and equipment only in developing countries and servicing of existing systems in developed countries. By quantity, the most important HCFC used today is HCFC-22 (GWP 1,810; ODP 0.05). HCFC technology still represents the state of technology of new and existing products and equipment in developing countries. In the USA, new HCFC equipment was sold widely until the end of 2010. In Europe, HCFC equipment is becoming more and more outdated technology but still exists to some extent. Only reclaimed HCFCs may be used for servicing needs of existing equipment and new virgin HCFCs must not be placed on the market any more (Regulation (EC) No 1005/2009).

HFC technology is widely applied in all refrigeration, AC, foam, aerosol and fire protection subsectors and can be considered state of technology in Europe and other developed countries. The most important HFCs used today include HFC-134a (GWP 1,430) and the blends R404A (GWP 3,922) and R410A (GWP 2,088).[101]

Technologies not relying on HFCs, PFCs, or SF_6 but on alternative substances with low GWP are also common and widely used in some sectors and subsectors such as domestic refrigeration, industrial refrigeration, certain subsectors of commercial refrigeration and stationary AC, foams, aerosols, solvents as well as the fire protection sector.

SF_6 (GWP 22,800) is used, amongst others, in electrical switchgear and non-ferrous metal industry. SF_6-free alternatives are used to some extent for medium-voltage switchgear. In the non-ferrous metal industry, which refers to the magnesium industry in EU-27, the use of SF_6 has been banned in large die casting facilities (annual SF_6 quantities used >850 kg) by the F-gas Regulation (Article 8). Small die casting facilities (annual SF_6 quantities used <850 kg) today partly rely on SF_6 but also introduced other technologies, such as the use of HFC-134a (GWP 1,430, which is considerably lower compared to the GWP of SF_6) or SO_2.

[101] If not otherwise stated, the GWP values in this report are from the 4th IPCC Assessment Report (2007).

Table A_XVI-1: State of technology in F-Gas sectors (excluding unsaturated HFCs)

Sector	Conventional F-gas technology	Established alternative technology
Domestic refrigeration	- HFC-134a	- HC-600a
Commercial refrigeration		
Centralized systems	- HCFC-22 - R404A, R407C - HFC-134a	- R744 in LT-cascade systems - R744 for MT and LT - R290, R1270 or R717 with secondary loop systems, sometimes R744 LT-cascade systems
Condensing units	- HCFC-22 - R404A, R410A - HFC-134a	
Stand alone units	- CFC-12 - HFC-134a - R404A	- R744 for a ice cream freezers and beverage vending machines - HC (hydrocarbon, mainly R290, sometimes R600a) for bottle coolers and LT cabinets, etc.
Industrial refrigeration	- HCFC-22 - R404A, R407C	- ammonia (R717) - ammonia and CO_2 cascade
Transport refrigeration		
Reefer containers	- HFC-134a - R404A	
Road refrigerated transport	- HFC-134a - R404A, R410A, R407C	
Fishing vessels	- HCFC-22 - R404A	- ammonia (R717) - ammonia and CO_2 cascade
Stationary AC	- HCFC-22 - R410A, R407C - HFC-134a (chillers) - R404A (chillers)	- R290 (room AC, chillers, heat pumps) - R717 (large chillers) - R744 (heat pumps)
Mobile AC		
Road vehicles	- HFC-134a - CFC-12	- hydrocarbons (service only) (R744 in prototypes)
Ships and rail	- HFC-134a	
Foam	- HFC-152a, HFC-134a - HFC-245fa - HFC-365mfc/227ea - HCFC-141b, HCFC-142b - HCFC-22	- hydrocarbons (pentanes) - organic solvents/CO_2 - water-CO_2
Fire protection	- HFC-227ea - HFC-236fa - HFC-23 - HFC-125	- water, water mist, dry chemical, foam aerosols; - CO_2 - inert gases
Aerosols; OCF (excl. MDI)	- HFC-152a - HFC-134a	- hydrocarbons - dimethylether
Medium voltage secondary switchgear	- SF_6	- solid insulation
Non-ferrous metal industry (Mg industry)	- SF_6 - (HFC-134a)	- SO_2 - HFC-134a

N.B. LT = Low Temperature; MT = Medium Temperature

2. THE MARKET POTENTIAL OF ABATEMENT TECHNOLOGY

2.1. Selection of sector abatement options

For each sector relying on HFCs today, cost-effective and technically feasible abatement solutions were identified and qualitatively and quantitatively compared to the sector-typical conventional HFC technology as reference.

This comparative analysis was guided by the following main criteria:

- Energy consumption.
- Safety
- Maximum reduction potential of CO_2-weighted HFC use and emissions.
- Cost effectiveness (expressed in abatement cost of €/t CO_2 eq).

2.2. Energy efficiency

Energy consumption was an essential selection criterion. After the preliminary identification of alternative options only those options **that show at least equivalent energy performance as the reference HFC technology were considered further**. This criterion is important because additional energy consumption would negatively impact the total climate performance of a system (TEWI) up to the point where reductions of direct F-gas emissions by replacement of HFCs could be offset by additional CO_2 emissions from energy production (indirect emissions).

In several cases a standard abatement solution might not be able to achieve the same or better energy performance as the reference option in any climatic region due to low thermodynamic performance. This applies e.g. to indirect refrigeration or AC systems even if they use efficient refrigerants such as propane (R-290) or unsaturated HFCs (HFC-1234yf). In some of those cases, the energy consumption of direct HFC systems can be matched with the indirect use of gases if additional technical measures (e.g. larger heat exchanger surface) are implemented. Such technical optimisation increases, however, the investment cost of the abatement option. In the foam sector poorer insulation performance of alternative blowing agents must be compensated by increased foam thickness, which likewise raises the cost compared to HFC based technology. In those cases an abatement option is considered in the analysis but with the additional investment costs accounted.

Therefore, **the comparative analyses include only abatement options when these can, with or without technical optimisation, require equal or less energy for operation**.

2.3. The concept of penetration rates

Existing and future market penetration is a key parameter for the calculation of the consumption and emission reduction potential of any technical alternative to current HFC technology.

The penetration rate is defined as the maximum market potential of a technical choice (i.e. abatement option) to replace new products or equipment relying upon HFCs in a particular sector. Penetration rates are given for each abatement option based on technical feasibility to replace existing HFC technology by a specific alternative technology. A penetration rate of 30% in 2015 means that 30% of the new HFC units installed in 2015 could potentially be replaced by units of this particular abatement option.

However, any abatement option is rarely universally applicable to a sector. Thus, maximum market penetration for replacement of current HFC technology in a specific sector in 2015, 2020, 2025 or 2030 can only be met by aggregation of two or more abatement options.

2.4. Constraints to market penetration

Limitations of each abatement option are due to safety, cost and/or efficiency implications, and further parameters. It is therefore necessary to consider the use of each relevant abatement option for a specific sector within the context of the various limiting factors.

– Safety constraints

The application of refrigerants[102] is generally controlled by national regulations, such as those dealing with the use of hazardous substances, buildings and so on. Generally such regulations are non-specific in terms of how refrigerants can be applied and aim towards "safe use". However, in many countries, safety standards and codes of practice are available which are more specific in the manner by which refrigerants are applied; noting also that such standards and codes are often not legally mandatory but are considered as "best practice".

Many of the currently used F-Gas refrigerants have a safety classification of lower-toxicity/no flame propagation (i.e., class "A1"). This means that they can be applied within most situations without consideration of quantity limitations. However, many abatement solutions are flammable or have higher toxicity or both (typically "A2", "A3" and "B2" classifications), which results in limitations in terms of the quantity of refrigerant permitted within different locations. As such, where standards specifically limit certain technical abatement options in particular locations, this can impact on the penetration rate.

As an example, R717 (class B2) is not permitted to be used in direct systems, so the maximum penetration for room air conditioners would be 0%, whilst R290 (class A3) can be used in direct systems provided the charge size is below a certain quantity. Thus, the penetration would be more than 0% but less than 100% because it would not ordinarily be possible to use R290 in systems that require a large charge.

Whilst safety standards may partially or wholly restrict certain abatement options from being used in certain locations, it is possible to redesign systems in order to ensure the refrigerant is kept within an alternative location or reduce the quantity of refrigerant in a system. This may be applicable where two refrigerant circuits are used instead of one, or an indirect system is employed instead of a direct system.

– Efficiency constraints

As mentioned above, it was a basic principle for the analysis that any abatement option considered should not risk offsetting refrigerant-related emissions reduction by consuming more energy. Furthermore, in many countries, there are – or will be – minimum efficiency standards for e.g. room AC systems. Therefore abatement options can only be considered

[102] Penetration rates are assessed not only for refrigerant using systems but also for fire protection equipment, foams, and aerosols. Refrigerants, however, are by far the largest application of HFCs.

where systems would achieve at least the same level of efficiency. In general, most of the abatement options under consideration can already provide at least the same level of efficiency as the existing refrigerants.

In cases, where abatement options have a poorer efficiency than the existing HFC technology when used in comparable systems, additional materials and components may be required to bring the efficiency up to the required level, and these may incur costs. In particular, where indirect systems are used instead of direct systems and the construction is such that efficiency may be lost, increases in exchanger surface areas, for example, may be necessary to achieve the target level.

However, in some cases abatement options may not be able to achieve the required efficiency level (even with optimization), in which case the penetration rate would be limited.

As an example, the abatement option transcritical use of CO_2 (which is more energy efficient than most HFC systems in geographical zones with moderate climate could be used in AC systems within temperate climates. The penetration could reach 100% there, but in hot climates the ideal cycle efficiency of CO_2 (R744) would still be below the minimum efficiency of such air conditioners and therefore the penetration would be 0%. In the current analysis the penetration rate would be reduced according to share of moderate and hot climates. As an example, for Europe the penetration rate would be halved compared to the technical maximum because CO_2 systems are energetically superior north of the Alps but inferior south of the Alps.

– Cost constraints

In principle any technically feasible abatement option can be used for any application, provided unlimited funds are available to implement it. However, the market may not accept products at considerably higher cost (price) than existing products. The cost implication of using different abatement options which may be affected by several different parameters, including safety requirements, desired efficiency, system complexity and special materials. Therefore it is important to establish situations where abatement options may result in excessively high cost such that the penetration potential of that abatement options would be limited.

– Availability of materials and components

Some parts are specific to certain refrigerants, e.g. compressors. Whilst it is feasible to use, e.g. R744/CO_2 in rooftop air conditioners, no suitable compressors are currently available. Reciprocating compressors normally used for commercial refrigeration could be applied but the efficiency would be much lower than the equivalent (scroll) compressors that an R22 system may use. Another example is electrical components for flammable refrigerant systems. HC chillers need to use “protected” electrical devices to avoid ignition of a leak but certain components e.g. low flow switches are not available, except for maybe oil rig applications which would lead to overly high costs for use in refrigeration and AC applications. Today not every system could be build with each of the abatement options using “off the shelf” parts and the systems would need to be improvised, which could lead to high costs and/or low efficiency.

– Availability of refrigerants and blowing agents

Whilst hydrocarbons, CO_2, ammonia or water are available in sufficient quantities, newly developed unsaturated HFCs are not yet commercially available of the necessary scale today. However, these gases show promising prospects for replacement of conventional HFCs and hence unsaturated HFCs are included in the comparative analyses in this study wherever possible.

This applies particularly to HFC-1234yf (refrigerant) and, to minor extent, HFC-1234ze[103] (foam blowing agent, aerosol propellant, refrigerant). The penetration rates of HFC-1234yf will still be low by 2015, which is the first year for which production at large scale is announced. As the market availability can be assumed to develop over time, the accurate quantitative assessment of the penetration rates is key condition for the estimation of the HFC reduction potential in the period until 2030.

– System complexity and design know-how

Systems running on ODS, HFCs and HFC blends are of similar complexity and design. In contrast, design and construction of a refrigeration or AC system running on flammable refrigerants or transcritical CO_2 systems require additional knowledge and training. Therefore, design engineers and technicians need to acquire additional know-how in order to install abatement technology properly.

2.5. Determination of penetration rates

In estimating the maximum potential penetration rate, several factors are considered. For each of the constraints considered above, the proportion (χ) for each constraint (i) – in terms of refrigerant quantity, not necessarily number of systems – of the sector that could not accommodate the specific abatement option due to each is estimated.

These factors are estimated for the year 2030, which should therefore account for both (i) anticipated technical developments and (ii) market maturity. For example, where charge size limits are a limiting factor, it can be assumed that research and development efforts over the next 20 years will reduce specific charge sizes (kg/kW) to below today's lowest values, or that system components for certain abatement options are widely available such that the product development and small production scale costs have been eliminated from the purchase price.

Thus, the overall maximum penetration rate is estimated from $1 - \max\{\chi_i\}$.

i.e., the maximum possible penetration under business-as-usual should be based on the maximum proportion of a sector unable to accommodate the abatement option for any of the given constraints. For each abatement option the proportions (χ) are based on expert knowledge of the characteristics of the systems and equipment, system design characteristics, requirements of safety standards, technology requirements, etc. and coupling these with characteristics of the refrigerants under consideration.

103 Honeywell, the manufacturer of HFC-1234ze, stated that in 2011 HFC-1234ze was "commercially available". It should be noted that by May 2011 this unsaturated HFC was produced at a "small-scale production facility". In May 2011 the company announced to triple the capacities (Honeywell News Release, May 12, 2011).

Whilst the constraints detailed above are mechanistic, another constraint may be included to account for the “willingness” of the market to adopt a given abatement option, which may be a function of the additional considerations necessary to suitably apply a particular abatement option. These considerations may include having to get special training for technicians, interpretation of complicated standards and so on. Using this approach the maximum penetration rate could be scaled down.

Whilst the maximum penetration rate detailed above represents the best estimate for 2030, the penetration rates for the intermediate dates – 2015, 2020 and 2025 – are obtained from interpolation between the current status (i.e., penetration of each abatement option in 2010) and the 2030 penetration, but also accounting for the typical lifetime of the equipment within the sub sector.

It must be noted here that there is no generally accepted methodology for the determination of penetration rates, and that the rates are subjective and with uncertainties. Evidently, nobody can exactly forecast and quantify the technical development in the coming 20 years. The penetration rates for the numerous individual technical solutions rely on the best knowledge of the project experts. The assessment is inter alia a result of detailed literature study, and of intensive discussion with the industries concerned[104].

2.6. Combination of penetration rates (“penetration mix”)

It should be pointed out that in reality a sector may comprise a number of different abatement options. The mix of different technical solutions cannot necessarily be represented by the maximum penetration values for each abatement option since the same constraints that apply to one abatement option may apply to another (for example, flammability, etc). Therefore the maximum penetration rate of each abatement option for any one sector is the maximum penetration rate of any one of the abatement option within each of the groups listed in Table A_XVI-2 (refrigerants only). The groups represent the abatement option that are dominated by the same constraints and which are hence mutually exclusive.

For example, the penetration rates of two flammable refrigerant abatement options in direct systems cannot be added since flammability is the same limiting factor. However, the penetration rates for Group 1/2 and Group 4 can be added since Group 4 abatement option could be applied where it would be impossible to use Group 1 or 2.

[104] For example see “Remark on the replacement potential of hydrocarbon refrigerants in split room air conditioners” following the Data Input Sheet “Stationary AC – single split type” in annex IV which explains in detail the penetration rate assessment for room air conditioners with R-290. Room air conditioners with R-290 are the abatement technology with the highest individual HFC reduction potential in the study. It should be noted that the assumptions for the relevant variables of R-290 room air conditioners are in line with the draft Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans.

Table A_XVI-2: Classification of abatement options by limiting factors

Group 1 **Highly flammable**	R600a R290/R1270
Group 2 **Flammable**	Unsaturated HFC R717
Group 3 **Moderate ambient only**	R744
Group 4 **Indirect operation** **Highly efficient**	R290/R1270 + R744 cascade R717 + R744 cascade HC + evaporation secondary (e.g. R744) Unsaturated HFC+ evaporation secondary (e.g. R744)
Group 5 **Indirect operation** **Normal efficiency**	HC + liquid secondary R717 + liquid secondary Unsaturated HFC+ liquid secondary
Group 6 **Poor performance, high cost**	Air cycle Liquid absorption Solid adsorption

The first objective for each sector is the identification of those technically feasible alternative technologies that provide highest possible emission or demand reduction potential. The cost of these technologies is not the primary but the secondary selection criterion, which determines the order of different alternative options in the mix. From this it follows that abatement options relying upon low or no GWP technologies are the preferred choice. However, solutions with GWP which are lower than the ones used today, such as blends of HFCs with unsaturated HFCs (GWP ~700) or substances like HFC-32 (GWP 675) are also considered for the assumed penetration mix, if such solutions, in a given year, are either the only alternative to high-GWP HFCs, or can further increase the reduction potential of low-GWP options. According to our analysis, only in few sectors (passenger ship air AC, room AC <12 kW, and heat pumps[105]) inclusion of such solutions could increase the reduction potential of the low-GWP options to achieve the highest possible reduction effect until 2030. In all other sectors, the combination of low-GWP solutions alone represented the highest possible reduction potential.

[105] In the sub sectors of room air conditioners <12 kW (movable and single split systems) the additional reduction effect from inclusion of HFC-32 lasts only until 2029 because in 2020 the penetration mix of low-GWP technologies has reached 100% (lifetime 10 years).

2.7. Key abatement options by sectors

– Refrigeration and AC subsectors

In most refrigeration subsectors (Table A_XVI-3) the penetration mix of abatement options can reach 100% in or before 2030. Exemptions include the industrial refrigeration sector and refrigeration in fishing vessels.

Table A_XVI-3: Key abatement options in the refrigeration sectors and their aggregated market penetration potential in 2030

Refrigeration and AC	Key abatement options	Market penetration of abatement options (penetration mix) in 2030 (%)
Domestic refrigeration	R600a CO_2 (R744) R1234yf	95(100*) 5 0
Commercial refrigeration		
Centralized systems	R290 indirect + CO_2 cascade R290 + CO_2 + CO_2 cascade CO_2	90 10 0
Condensing units	R290 direct R290 indirect CO_2	40 30 30
Stand-alone units	R290 direct CO_2	85 15
Industrial refrigeration		
Small equipment	NH_3	95
Large equipment	NH_3	95
Transport refrigeration		
Refrigerated trucks	R290 direct CO_2	80 20
Refrigerated vans	CO_2 HFC-1234yf	50 50
Reefer containers	CO_2	100
Fishing vessels	NH_3 + CO_2 cascade	95

** 100% market potential of hydrocarbon refrigerant (R-600a) is assumed already for 2015.*

In many AC subsectors (Table A_XVI-4), the penetration mix of abatement options can reach 100% in or before 2030.

Table A_XVI-4: Key abatement options in the stationary and mobile AC sectors and their combined market penetration potential in 2030

AC	Key abatement options	Market penetration of abatement options (penetration mix) in 2030 (%)
Stationary AC		
Moveable AC	R290 direct	40
	CO_2	20
	HFC-1234yf	40
Single split AC	R290 direct	40
	CO_2	15
	HFC-1234yf	45
Multi split AC	R290 indirect	70
	CO_2	30
	HFC-1234yf	0
Rooftop AC	R290 indirect	65
	CO_2	35
	R290 + evaporating secondary (CO_2)	0
Small chillers	R290 direct	60
	CO_2	20
	NH_3	20
Large chillers	R290 direct	15
	CO_2	0
	NH_3	60
	R718	25
Centrifugal chillers	R290	20
	HFC-1234ze	50
	R718	30
Heat pumps	R290 direct	60
	CO_2	20
	HFC-1234yf	20
Mobile AC – road vehicles		
Passenger cars (incl. trucks)	HFC-1234yf	(100)
	R744	(100)
	HC indirect	0
Buses	HFC-1234yf	100
	R744	0
	HC indirect	0

Mobile AC – ships and rail vehicles[106]		
Passenger ships	Blends w unsat HFCs	90
Cargo ships	NH_3-brine	90
	Blends w unsat HFCs	10
Rail vehicles	R744	60

[106] Abatement options for ships and rail vehicles have been assessed for Europe only but not for the remaining A2 countries and for A5 countries, due to very limited data availability.

– Foam subsectors

In all foam subsectors (Table A_XVI-5), current HFC blowing agents could be substituted by abatement options in or before 2030.

Table A_XVI-5: Key abatement options in the foam subsectors and their combined market penetration potential in 2030

Foam blowing agents	Key abatement options	Market penetration of abatement options (penetration mix) in 2030 (%)
Insulation foams of PU and XPS for the construction sector		
Sandwich panels with metal facings, continuous (CME)	HC Unsaturated HFC	90 10
Sandwich panels with metal facings, discontinuous (DIP)	HC Unsaturated HFC	90 10
Sandwich panels with flexible facings, boardstock (CFF)	HC Unsaturated HFC	90 10
Spray foam (SPR)	Unsaturated HFC H_2O-CO_2	50 50
XPS Foam Boards (XPS)	HC incl. organic solvent+CO_2 Unsaturated HFC	85 15
PU Foam for refrigeration applications and integral skin		
Domestic refrigeration (DOR)	HC	100
Commercial refrigeration (COR)	HC Unsaturated HFC	50 50
Refrigerated trucks, reefer containers (RTRU)	HC Unsaturated HFC	90 10
Integral foams (INT)	H_2O Unsaturated HFC	50 50

– Fire protection and technical aerosols

Table A_XVI-6 includes technical aerosols[107] (excluding MDI[108]) and the fire protection sector. In fire protection, the key abatement option could fully substitute the use of HFC-23 (GWP 14,800) as fire extinguishing agent in or before 2030. The use of HFC-227ea, in contrast, can be replaced in most but not all applications.

With regard to technical aerosols, it is estimated that the market penetration potential of unsaturated HFCs will cover 95% of the applications.

Table A_XVI-6: Key abatement options in the aerosol and fire protection sectors and their market penetration potential in 2030

Fire protection **Technical aerosols**	**Key abatement options**	**Market penetration of abatement options (penetration mix) in 2030 (%)**
Fire protection		
Equipment with HFC-227ea	FK 5-1-12	90
Equipment with HFC-23	FK 5-1-12	100
Technical aerosols	Unsaturated HFCs	95

[107] There is currently no definition of technical aerosols in the legal text. FEA (Fédération Européenne des Aerosols) suggests the following definition: Technical aerosols are aerosol dispensers used in maintenance, repair, cleaning, testing, disinsecting, manufacturing, installation and other applications where a non-flammable formulation is required for safety reasons. (Communication to Öko-Recherche, 15 May, 2011). This definition also separates novelty aerosols from “technical” aerosols.

[108] HFCs are used in Metered-Dose Inhalers for the treatment of asthma and other respiratory diseases. Health aspects related to the application of MDIs as compared to potential abatement technology need specific investigation.

– Electrical switchgear and magnesium die casting

Since in magnesium die casting large facilities (SF_6 use >850 kg/y) already were required to substitute the use of SF_6, alternative options for small facilities are readily available and could reach full market penetration earlier than 2030. In the switchgear sector SF_6 is currently the only technical solution for voltage >52 kV. Below 52 kV, for the so-called medium voltage, SF_6 or air is used at the interface between high and medium voltage (primary level); at the interface between medium and low voltage (secondary level) SF_6 clearly dominates the market (ca. 98%) but solid insulation is technically possible today.

Table A_XVI-7: Key abatement options in the electrical medium-voltage secondary switchgear and magnesium casting sectors and their market penetration potential in 2030

Other sectors	**Key abatement options**	**Market penetration of abatement options (penetration mix) in 2030 (%)**
Medium voltage secondary switchgear	Solid insulation	40
Magnesium die casting and recycling	HFC-134a, SO_2	100

Annex XVII: Assessment of indirect impacts on sales

Table A_XVII.1 Increase in sales compared to baseline (Investments) by subsector (million €/year)

	B	C	D	E
Domestic Refrigeration	0	0	2	0
Commercial hermetics	81	0	81	71
Condensing units	753	0	753	602
Centralized systems	774	0	774	714
Industrial Ref small	0	0	67	5
Industrial Ref large	0	0	499	39
Refrigerated Vans	0	0	18	0
Refrigerated Trucks	0	0	142	17
Fishing vessels	0	0	6	0
Cargo ship AC	0	0	3	0
Passenger ship AC	0	0	0	0
Bus AC	0	0	35	0
Truck AC	0	0	2	0
Moveable AC systems	0	0	7	7
Split AC systems	0	0	158	158
Multi split AC systems	0	0	70	61
Rooftop AC systems	0	0	67	67
Chillers	0	0	339	339
Centrifugal chillers	0	0	3	0
Fire protection 227ea	0	0	5	0
Fire protection 23	0	0	0	0
Aerosols	0	0	0	0
XPS-152a	3	0	3	0
XPS-134a	0	0	3	0
PU other	0	0	3	0
HFC-23 by-product	0	0	0	0
SUM	**1611**	**0**	**3039**	**2080**

Table A_XVII.2. Change in sales in 2030 if increased investment costs (and other costs) are fully passed on to consumers (%)

	B	C	D	E
Condensing units commercial refrigeration	0.3%	0.0%	-0.3%	-0.3%
Centralized Systems Commercial Refrigeration	1.8%	0.0%	-1.8%	-1.8%
BUS AC	0.0%	0.0%	-0.8%	0.0%
Trucks and trailers AC	0.0%	-0.4%	-0.1%	0.0%
Single Split Room AC	0.0%	0.0%	-0.6%	-0.6%
Multi split AC	0.0%	0.0%	-0.3%	0.0%
Industrial refrigeration large	0.0%	0.0%	0.5%	0.5%
Chillers	0.0%	0.0%	-0.1%	-0.1%

Table A_XVII.3. Reduction in sales (investments) compared to Table A_XVII.1. Second-order effects in million Euros.

	B	C	D	E
Domestic Refrigeration				
Commercial hermetics				
Condensing units	-2.44	0.00	-2.44	-1.91
Centralized systems	-13.6	0.0	-13.7	-12.7
Industrial Ref small				
Industrial Ref large	0.0	0.0	2.6	0.2
Refrigerated Vans				
Refrigerated Trucks				
Fishing vessels				
Cargo ship AC				
Passenger ship AC				
Bus AC	0.0	0.0	-0.3	0.0
Truck AC	0.0	0.0	0.0	0.0
Moveable AC systems				
Split AC systems	0.0	0.0	-1.0	-1.0
Multi split AC systems	0.0	0.0	-0.2	0.0
Rooftop AC systems				
Chillers	0.0	0.0	-0.5	-0.5
Centrifugal chillers				
Fire protection 227ea				
Fire protection 23				
Aerosols				
XPS-152a				
XPS-134a				
PU other				
HFC-23 by-product				
SUM	-16.0	0.0	-15.5	-15.9
Impact main sectors	**-1.0%**	**0.0%**	**-0.6%**	**-0.8%**

Table A_XVII.3 shows the reduction in sales. E.g for option D sales of condensing units would go up by 753 million per year in 2030 (Table A_XV.1). As a result of the increase in costs demand would be 2.44 million lower and the net increase in sales would be smaller (753 minus 2.44 million €). The impact for the main sectors would be a second order reduction in the increase in sales of 1% or less. The sectors represent 87 to 95% of the total change in sales.