Preparatory study for the Review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases

Working Document 1

- covering preliminary results from ongoing analysis (Tasks 1-3) -

September 2010

Content

1. Background information and objectives of the review

Regulation No 842/2006 on certain fluorinated greenhouse gases (F-gas Regulation) and Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles (MAC Directive) are key elements of the European strategy to comply with commitments for greenhouse gas (GHG) emission reductions. They address emissions of fluorinated greenhouse gases (F-gases) such as HFCs, PFCs and SF_6, which are controlled under the Kyoto Protocol and have a high global warming potential. Anticipated emission reductions through the F-gas regulatory framework including the F-gas Regulation and the MAC Directive were estimated to range around 23 million tonnes of CO_2 eq. by 2010 compared to Business-As-Usual.

The F-gas Regulation applies since 4 July 2007, with the exception of Article 9 and Annex II, which apply since 4 July 2006. The provisions of a Regulation are generally directly applicable in the Member States. However, the F-gas Regulation required Member States to implement certain provisions on training and certification and on penalties.

The review of EU legislation on F-gases is primarily driven by the regulation itself (Art 10): The Commission is required to publish a report based on the experience of the application of the regulation also assessing the need for further action in the light of the evolving policy context. Appropriate proposals for revision of the relevant provisions of the regulation shall be presented where necessary. Aspects for review are listed in Article 10(2).

To support the Commission in reviewing Regulation (EC) No 842/2006, a service contract is carried out by Öko-Recherche and partners since late December 2009. The main objectives of this work include:

- To review relevant markets and policies;
- To assess the effectiveness of the current EU F-gas policy in view of current and future climate change objectives;
- To assess the feasibility of emerging options for an international arrangement for HFCs and other F-gases;
- To identify technically feasible, effective, efficient and consistent options and recommendations for further EU action and to assess their impacts.

2. Methodology

2.1. Sources of information

The work undertaken so far has been based on various sources of information in order to cover the different needs for

- quantitative or qualitative data,
- historic data or trends and projections,
- data by sectors or countries,
- data for Europe, developed countries, developing countries or the world.

Existing and on-going studies and scientific articles serve as important sources of sectoral details and approaches, as well on global and regional concepts and trends. Major sources include UNEP TEAP reports, the IPCC Special Report on Safeguarding the Ozone Layer and the Global Climate System as well as the IPCC 4th Assessment Report.

General expertise on F-gases, their alternatives and sectoral expertise are available through Öko-Recherche and partners, who have long-term experience and archives on the use of F-gases and methodologies required for the analysis to be undertaken.

In order to gain date information on the status of implementation of the current F-gas regulatory framework in the Member States, a questionnaire was developed by Öko-Recherche and has been sent to the competent authorities in all EU-27 Member States. The responses are complemented and cross-checked with the latest national communications under the UNFCCC. In addition, national greenhouse gas inventory submissions by the Member States and the EU to the UNFCCC served as data input, in particularly CRF data were used for modelling purposes and are indicated in the model description.

For information on the view and status of implementation of the F-gas Regulation by industry, different questionnaires were designed for and sent to stakeholders from all industry sectors relying on F-gases. Non-governmental organisations provided their views and additional information through position papers.

Further information and feedback is sought from the Expert Group on Fluorinated Gases which comprises representatives of Member State public authorities and of civil society while input is also being provided by numerous other stakeholders from the beginning of the project onwards.

2.2 Approaches

An overview of F-gas policies and measures at international level, European level and for each of the EU-27 Member States and other countries is compiled and analysed. An investigation of possible interactions, complementarities or overlaps of the EU F-gas framework and other EU international legislation from various fields is undertaken in order to identify issues which might impact current and future emissions of F-gases.

This analysis is closely linked to the emission scenarios in EU-27, potentials for a future international arrangement on HFCs and the development of options for the review of the F-gas Regulation.

The model AnaFgas (Analysis of Fluorinated greenhouse gases in the EU-27) is a bottom-up stock model to derive consumption and emission scenarios for F-gases from the relevant sectors and sub-sectors for the EU-27 Member States. Detailed information on assumptions, simplifications and emission parameters are explained in the description of the model for each sector and sub-sector in the progress report, some information is annexed to this working document.

An ex-post analysis of the most important measures of the F-gas Regulation is carried out in order to examine

- to what extent the current EU F-gas policy and in particular the relevant provisions of the F-gas Regulation have been de facto implemented and practically realised in the EU-27 Member States;
- to what extent the relevant provisions have had, or are expected to have, an impact on emissions, should such an assessment can be made at this stage.

The outcome of this ex-post assessment of the impact of measures of the F-gas Regulation serves as input for the development of policy options, if necessary, for the review of the F-gas Regulation.

An assessment of emerging options for an international arrangement on HFCs is based on projections of HFC consumption in developed and developing countries in relevant sectors. Abatement options for each sector and costs of the options were identified. Based on this analysis, marginal abatement cost curves are established and show that consumption controls of HFCs can be carried out at negative or low positive costs. Proposals for control of consumption of HFCs are discussed and compared to the maximum technically feasible abatement potential.

3. Preliminary results

3.1. Review of F-gas markets and policies

3.1.1. F-gas markets

Montreal Protocol as main driver of worldwide HFC production

Since the phase-out of fully halogenated ozone-depleting substances (CFCs) under the Montreal Protocol in the early 1990s, global production and sales of HFC-134a had constantly increased, primarily to meet the demand from mobile air conditioning of cars . When the Montreal Protocol was extended to a production and consumption phase-out of HCFCs, further HFC types came on the market as blends in order to replace HCFC-22 as a refrigerant.

Sales of HFC refrigerant blends and thus the production of HFC-125, HFC-143a, and HFC-32 have significantly increased from 2000 onwards, first in Europe, not much later in Japan, and with some delay in the remaining industrialised countries including USA. Even in China, demand for blends containing HFC-125 and HFC-32 grew significantly, due to growing manufacturing for export of room air conditioners.

By far the largest application of HFCs is refrigeration and air conditioning (mobile and stationary), accounting for more than three-quarters of worldwide sales. Whereas the sectors of fire protection, solvents, aerosols, and to a lesser extent the foam sector[1] accounted for half of the ODS production in the 1980s, these sectors did not undergo an equivalent transition to HFCs but mostly conversion to hydrocarbons or not-in-kind technologies. Overall the market for HFCs has not matched the former size of the ODS market.

Global production and sales of HFC-134a stopped growing in 2004, and are decreasing until today. All growth in HFC markets since then has been driven by the demand for refrigerant blends which have already over-compensated the decrease in the market of HCFC-22 refrigerants[2].

The following graph (figure 1) illustrates the global course of F-gas consumption with and without chlorine over 40 years, showing the reverse trend for HCFCs and HFCs from the end of the 1990s. From 2000 onwards, the growth of HFCs is supported by components for refrigerant blends substituting HCFC-22, while the global consumption of HFC-134a is projected to remain unchanged.

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[1] In the foam sector; market introduction of HFC blowing agents substituting the prevailing HCFC-141b took a longer time than the introduction of the R-22 replacing refrigerants. HFC- 245fa and -365mfc started production first after 2000, when the advanced HCFC prohibition in Europe entered into force.

[2] In contrast, the sharp drop in the PU foam blowing agent HCFC-141b is not at all offset by new HFCs (HFC-245fa and -365mfc) as a consequence of the progress of natural blowing agents.

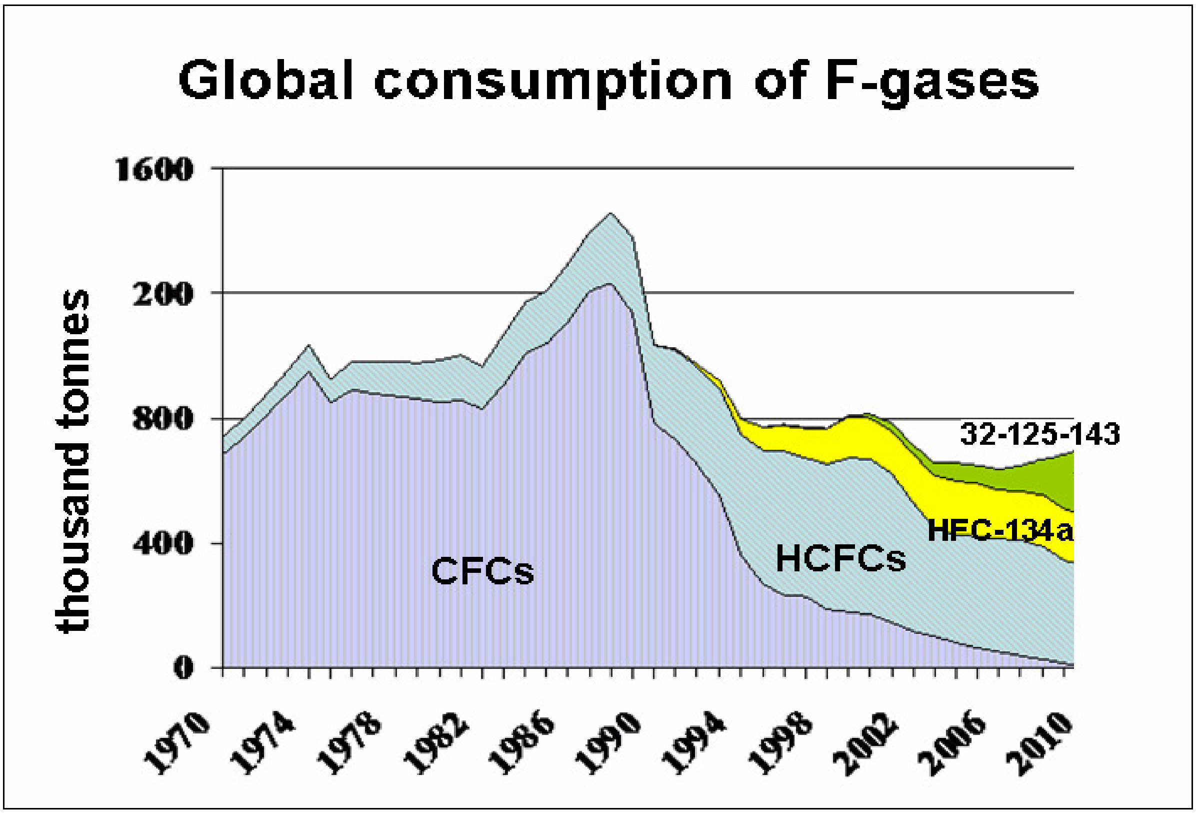

Figure 1: Global production and demand for fluorinated greenhouse gases including ozone-depleting fluorinated gases such as CFCs and HCFCs from 1970 to 2010. After 1990, CFCs show rapid decline, not offset by HCFCs. From 2000, HFCs replace HCFCs and maintain the overall consumption level. From 2004 onwards, the growth in HFC consumption is no longer driven by HFC-134a but by those HFCs that form R-22 substituting refrigerant blends. Over the four decades, refrigerants have become the most important F-gases. The quantities are presented in metric tons.

Reduced growth in F-gas demand

Since F-gases were included in the basket of greenhouse gases covered by the Kyoto Protocol in 1998, measures to improve containment, leak tightness and recovery have gained importance, and alterative fluids and not-in-kind technologies are increasingly discussed, developed and applied.

- Charges are being minimized. Growing numbers of equipment do not result in higher HFC-demand for filling and refilling.
- Higher awareness of personnel and technical measures improve leak tightness, and contribute to reductions of operating emissions. This decreases demand from the aftermarket.
- Recovery shows small, however already measurable results.
- Hydrocarbons, ammonia and CO_2 have penetrated into the sectors of refrigeration and stationary air conditioning, even outside of Europe.
- In Europe, several countries impede the use of F-gases through regulatory and fiscal measures (see section on policies). The EU legislative framework addressing F-gases from 2006 requires strict containment measures, and controls, and eventually bans the use of HFC-134a in the large sector of mobile air conditioning.

These measures have a direct impact upon the demand for HFCs. Such impact is more evident on HFC-134a which is not a key substitute to R-22 and therefore the demand for it is not greatly affected from the R-22 phase-out. In this context the reduction in the demand for HFC-134a is not considered a temporary phenomenon.

In the EU-27, the market for F-gases is still dominated by HFC-134a. The overview table 1 shows the high importance of this species.

Table 1: Sales of F-gases to the EU-27 market in 2007, by application, in kt

F-gas species	Application	kt
134a	Mobile air conditioning	25
	Commercial and industrial refrigeration	6
	Domestic refrigeration and appliances	2
	Transport refrigeration	1
	Stationary air conditioning (chillers)	1
	Refrigerant blends (407C, 404A)	3
	Foam (XPS, PU, OCF)	5
	MDI/Aerosols	9
	Total HFC-134a	*52*
32, 125, 143a	Blends for refrigeration	17
	Blends for stationary air conditioning	
245fa, 365mfc	PU Foam	10
	Solvent	2
227ea, 236fa	Fire protection/MDI	
SF_6	Switchgear	1.5
	Other SF_6 applications	0.5
PFC	Semiconductor Industry	0.5
Total F-gases		97

Source. Own estimates based on research in the scope of this study.

Table 1 shows that HFC-134a accounts for more than half of the total F-gas market (52 kt) in the EU. Mobile air conditioning (first fill and refill) is by far the most important single F-gas sector, accounting for half of the annual sales of HFC-134a (25 kt). Restrictions in the mobile air conditioning sector substantially impact the overall market of HFC-134a, even more so as neither foam nor general aerosols (~10 kt) form stable HFC sales areas.

Decline in EU F-gas sales 2007-2009

The first consequences of the regulatory measures to F-Gas demand occurred in Europe. Table 2 shows a decrease in sales of F-gases by 10% in 2009, which is not only a result of the economic crisis.

The sharp drop in sales of F-gases (SF_6) to magnesium casting industry from 31 tonnes to 8 tonnes indicates an impact of the use prohibition according to Art 9 of the F-gas Regulation. The decrease of F-gas sales to the foam sector is not only driven by the economic crisis but also by prohibition measures which ban placing on the market of one-component foam (Art 9, Annex II).

Table 2: Sales of F-gases by sectors in EU-27 (metric tonnes), 2007-2009, based on reported data (Art 6 of the F-gas Regulation).

Sectors	2007	2008	2009

	t	t	t
Refrigeration & Air Condition	64,600	64,176	60,000
Foams	14,578	10,664	11,799
Aerosols	9,545	11,614	8,572
Electrical equipment	1,568	2,386	1,384
Fire protection	685	598	735
Solvents	209	173	162
Semiconductor manufacture	129	312	184
Magnesium casting	31	8	7
Feedstock	9	2	2
Other or unknown	1,773	4,110	2,269
Total sales	**93,127**	**94,043**	**85,114**
HFC-134a only	*51,693*	*48,123*	*41,984*

Looking at the sales of HFC-134a only (bottom line), one can see that the demand for this F-gas type declined more sharply than the total F-gas demand in the period 2007-2009. Obviously, the general decrease of the F-gas demand was caused by HFC-134a.

Cutback of production capacities in the EU

The development of the HFC production capacities in Europe in 2005-2009 reflects the impact on the demand for HFC-134a from containment and legislative measures. At the same time, the R-22 phase-out, which is more advanced in Europe than in other world regions, is not completely compensated by domestic production of HFC components for R-22 replacing refrigerant blends.

In the period 2005-2009, half production plants for HFC-134a in Europe were closed (Italy, UK). As a consequence, the nominal capacity dropped from 55 kt to 30 kt. The closure of one HFC-134a plant also implied a decrease of the production of HFC-125, which had been captured as a by-product of the production of HFC-134a in this facility. During the same period, the number of facilities and production capacities for HFC-143a and HFC-32 remained unchanged. This stagnation is contrary to the global trend which shows for these HFC types (incl. HFC-32) overcompensation of the decline in the production of HCFC-22..

Two thirds of the plants which produced HCFC-22 for emissive end-uses (refrigerant, foam blowing) closed in the period 2005-2009, cutting the production capacity in Europe from 95 to 38 kt. In addition, some plants produce HCFC-22 for non-emissive use as feedstock for fluoropolymers (PTFE and PVDF), and are hence not affected by the HCFC phase out under ODS legislation. They continue production at a capacity of 90 kt.

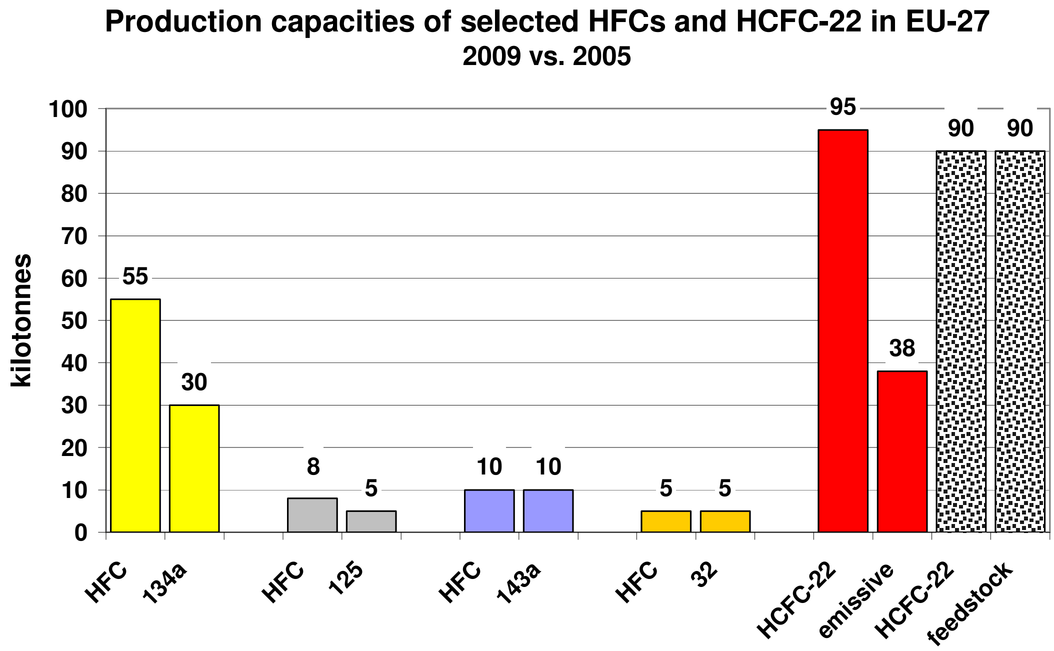

Figure 2: Production capacities for selected HFCs and HCFC-22 in EU-27. From 2005 to 2009 a sharp cutback in capacities took place for HFC-134a and HCFC-22 (emissive end-use only). The trend in the production of components of refrigerant blends in the EU does not mirror the decline in HCFC-22 production, contrary to the global trend in production and sales.

From comparison of the sales data (table 2) with the data on capacities (figure 2) it can be seen that the domestic F-gas production, which includes exports, is significantly lower than the domestic demand. Traditionally, demand is covered to a large extent by imports, most of all from USA. From 2005 to 2009, HFC sales in the EU have not decreased as sharply as the production capacities. Our conclusion is that the cutback in EU production capacities has its source in negative market expectations of the producers, who anticipate further decline.

HFC markets in North America, Japan, and Asia-Pacific

In other regions of the world, the market trends differ from those in Europe.

In USA the production of F-gases is more than twice as high as in Europe and the domestic demand is much larger, in particular for refrigeration and mobile air conditioning. Stationary air conditioning is also important and represents a strong market for HFC blends. The phase-out of HCFC-22 and transition to HFC blends is still in progress. Regulatory measures for containment or prohibition of F-gases currently do not exist. Alternative fluids and not-in-kind technologies do not yet attract such high interest as they do in Europe.

In Japan the phase-out of HCFCs follows a tight schedule similar to that in Europe. The market potential for HFC blends replacing R-22 is not fully exploited yet. Like the USA, Japan has a large sector of stationary air conditioning, which generates high demand. In contrast, the potential for the use of HFC-134a in mobile air conditioning is unlikely to increase. The position of the Japanese PU industry, which recently decided to waive HFCs in spray foam (the largest sub segment of foam in Japan)[3], is an expression of growing reservation towards HFCs.

The most evolving markets for F-gases in the future are the developing countries, in particular China. In China the use of HFC-134a in mobile air conditioning is still in its initial stages within the car industry. The stationary refrigeration sector is still ahead of HCFC-22 phase out and thus a transition to HFC blends. The large-scale production of room air conditioners for the domestic and the world market causes high demand for HFC blend components, in particular for HFC-32 and HFC-125 (for the production of the blend R-410A). In China an unknown but growing number of small plants emerges and represents increasing competition for the Western and Japanese chemical companies to meet this growing demand. In addition, natural refrigerants and foam blowing agents attract growing interest in developing countries.

From a global perspective, the foreseeable development in global F-gas markets is not consistent. On the one hand new demand arises, and on the other hand national and international regulatory measures, alternative fluids and not-in-kind technologies with better climate performance usually at low cost, reduce the demand potential.

It must be pointed out that even very strict regulatory measures on the use of F-gases, like the EU phase-out decision for HFC-134a from air conditioning systems in passenger cars do not necessarily imply reduction in demand for F-gases. The decline in the annual HFC demand by ca. 20 kt of HFC-134a in the EU-27 can possibly be compensated by new HFCs with low GWP, such as HFC-1234yf. An international agreement accepting the use of HFCs with low GWP would contribute to keep the world market for HFCs at comparably high level in terms of metric tonnes but would result in lower negative impact on the climate. In this point, commercial interests and climate protection seem to coincide.

[3] Japan Urethane Industries Institute (JUII): “Phase-out of hydro fluorocarbons (HFC) as a blowing agent of Polyurethane (PU) rigid spray foam for the residential building insulation” by the end of August, 2010; press release 26th January 2010.

3.1.2. F-gas policies and measures

The F-gas Regulation No 842/2006 and the MAC Directive 2006/40/EC were adopted in 2006. The subsequent review of policies at international and European level aims to explain the current political context and changes which might impact use and emissions of F-gases. Policies and measures at national level in EU-27 look at the national implementation of certain provisions of the F-gas Regulation and line out in which regard Member State policies are stricter than or additional to the F-gas Regulation.

International level

Multilateral environmental agreements

The EU has ratified international conventions, which impact use and emissions of F-gases while not addressing them exclusively.

The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol are covering HFCs, PFCs and SF_6 emissions since 1997. The Kyoto Protocol lays down national greenhouse gas emission reduction targets for developed countries (Annex I countries) until 2012, which also include F-gas emissions. The EU (EU-15) committed to reductions of GHG emissions by 8% below 1990 levels in the period 2008-2012.

While COP 15 failed to produce an international agreement involving binding GHG emissions reduction targets for the post-2012 period, most Annex I countries pledged quantifiable emission reductions under the Copenhagen Accord[4]. The EU pledged to reduce GHG emissions by 20% compared to 1990 levels and to cover 20% of energy consumption by renewables. The EU leaders also offered to increase the EU's emissions reduction to 30%, on condition that other major emitting countries in the developed and developing worlds commit to do their fair share under a global climate agreement. European policies addressing all types of GHG emissions including F-gases will hence need to be adapted in order to meet these new commitments.

Under the Vienna Convention, the Montreal Protocol on ozone depleting substances is closely linked to F-gases since the phase out of ozone depleting substances (ODS) results in increasing use of HFCs, which were designed as substitutes for the same sectors of application. Hence both conventions address the same sectors and interact strongly. It is currently being discussed to further link the work on HFCs done under the Kyoto and post-Kyoto regime and further phase out of ODS under the Montreal Protocol (see section on the feasibility on an international HFC agreement).

Market-based mechanisms

In the context of the Kyoto Protocol, three market-based mechanisms were established:

- International Emissions Trading (IET).
- The Clean Development Mechanism (CDM), which allows developed countries to finance projects avoiding greenhouse gas emissions in developing countries and receive credits for doing so. As of 1 August 2010, 22 CDM projects address emissions of HFC-23 and HFC-134a, 6 projects target PFC emissions and 11 projects refer to SF_6 emissions[5].

[4] UNFCCC 2009: Decision 2/CP15 Copenhagen Accord of 18 December 2009.

[5] UNEP Risoe: CDM/JI pipeline analysis and database. http://cdmpipeline.org/

- The Joint Implementation Mechanism (JI), which refers to projects in developed countries reducing net greenhouse gas emissions in another developed country in order to receive credits. As of 1 August 2010, 4 JI projects were addressing HFC emissions and 2 JI projects targeted PFC emissions.

Voluntary programmes and initiatives

International voluntary industry initiatives to reduce F-gas emissions include the commitment by the global semiconductor industry to achieve absolute reductions of combined PFC and SF_6 emissions of 10% by 2010 (baseline 1995), and the global agreement by aluminium industry to reduce PFC production emissions by 50% per tonne of production by 2020 (baseline 2006).

Initiatives such as “Refrigerants, Naturally!” and “The Natural Voice” provide platforms for companies committing to the use of natural refrigerants.

European level

Regulatory measures

In order to comply with the Kyoto Protocol, the European Commission identified and developed an EU strategy through the European Climate Change Programme (ECCP). A package consisting of the F-gas Regulation and the MAC Directive has been adopted in 2006 and is linked to expected emission reductions of 23 million tonnes CO_2 eq. compared to BAU by 2010.

The F-gas Regulation has been implemented by ten Commission Regulations adopted between December 2007 and April 2008[6] which established certain technical elements of the Regulation.

In the context of additional commitments for GHG emission reductions, a new stage of European climate and energy policy has been initiated when the so called “climate and energy package” was agreed in 2008. It comprises four legislative elements[7] and primarily aims at implementing the 20-20-20 targets agreed by the European Council for 2020:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

An important element is the revised Renewable Energy Directive 2009/28/EC, which lays down mandatory national targets for the Member States’ use of renewable energy in

[6] These include Commission Regulations 1493/2007, 1494/2007, 1497/2007, 1516/2007, 303/2008, 304/2008, 305/2008, 306/2008, 307/2008, 308/2008.

[7] The “climate and energy package comprises a revision of the 2003 Emissions Trading Directive (Directive 2009/29/EC), a Decision on sharing the effort of GHG emissions in the non-ETS sectors among Member States (Decision 406/2009/EC), a new and comprehensive Renewable Energy Directive (Directive 2009/28/EC), and a Directive on carbon capture and storage (CCS) (Directive 2009/31/EC).

electricity, heating, cooling and transport, which are adding up to 20% of the EU's total energy consumption by 2020 (see interactions).

Market-based mechanisms

The European Emissions Trading System (EU ETS) is a key element of European climate policy action and commenced operation in 2005. It currently only covers CO_2 emissions from installations performing specified activities. From 2013, the scope will be extended to other sectors and gases and will then also include PFC emissions from the aluminium sector. Other F-gases and/or sources of emissions are not currently addressed by the EU ETS.

Voluntary programmes and initiatives

The European semiconductor industry has agreed to a European emission reduction target in order to meet the global reduction target (1995-2010).

EU Member State level

Regulatory measures

Early national policy measures addressing F-gases were based on existing ODS legislation, which was extended to F-gases or applied to sectors relying on both ODS and F-gases. In France, recovery of CFCs, HCFCs and HFCs was mandatory from 1992 onwards[8]. In Sweden, personnel and companies had to be trained and accredited by the Swedish Board of Accreditation and Conformity Assessment (SWEDAC) since 1992. Since 1992, the Danish KMO system and the Dutch STEK system have been working on the prevention of emissions of all types of halogenated refrigerants and on training and certification of personnel and companies.

Following the commitments for reduction of GHG emissions under the Kyoto Protocol, the EU Burden Sharing Agreement of 1998[9] has redistributed the EU target among the Member States. Subsequently and in addition to European legislation, Member States have individually implemented their own measures addressing GHG emissions. Legislation on F-gas emissions entered into force in Denmark (March 2001) and Austria (December 2002) ahead of the EU-wide legislation.

As soon as the F-gas Regulation came into force, its provisions have been directly applicable in the Member States. Nevertheless, some requirements needed to be complemented by the Commission and some are subsequently being implemented at national level through national legislation by most Member States. Some Member States even decided to establish provisions under their national legislation which are stricter than the requirements of the F-gas Regulation with regard to scope and mechanisms of different measures.

[8] Decree of 7 December 1992.

[9] This agreement is based on an arrangement under Article 4 of the Kyoto Protocol whereby Annex I Parties can fulfil their emission targets jointly by pooling their individual emissions in a common 'bubble.' The EU (EU-15) has used this provision and sub-divided its target of -8% into differentiated targets for each Member State that take account of their different national circumstances.

Table 3: Status of provisions at national level in comparison to the F-gas Regulation (as of July 2010).

National legislation		National legislation under preparation
Provisions are not stricter than provisions set out by the F-gas Regulation	Provisions are stricter with regard to certain aspects than provisions set out by the F-gas Regulation	
Bulgaria, Cyprus, Lithuania, Romania, UK, Ireland	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden	Greece, Italy, Luxemburg, Latvia*

*) Information on national legislation is partly not available yet.

Measures stricter than the F-gas Regulation that have been imposed by national legislation include e.g.

- Lower charge thresholds: Equipment containing lower charges of F-gases than set out by the F-gas Regulation (3 kg) is subject to rules for containment in Denmark (minimum charge of 2.5 kg) and France (minimum charge of 2 kg).
- Mandatory leakage checks for mobile equipment (not required under the F-Gas Regulation): Leakage checks of certain types of mobile equipment are mandatory in Germany (refrigerated trucks containing charges of >3 kg of F-gases) and Sweden (refrigeration and AC systems installed on ships containing charges of >10 kg of F-gases).
- Maximum annual leakage rates for stationary equipment have been established in Germany (refrigeration and AC equipment; depending on charge and date of manufacture), Belgium (new equipment 5%) and Luxembourg (5%). No maximum leakage rates are established under the F-Gas Regulation.
- Minimum period of maintenance of equipment records applies in Czech Republic (5 years), France (5 years) and Germany (5 years). Electronic recording is mandatory in Slovakia.
- Registration of certain F-Gas containing equipment in a database for monitoring and enforcement purposes is mandatory in Hungary (cooling circuits), Slovenia (charges >3 kg of ODS or F-gases), Estonia (charges >3 kg of F-gases).
- Producer responsibility schemes requiring producers and suppliers of F-gases to take back recovered F-gases for further recycling, reclamation and destruction are in place in Sweden (legally binding since 2007) and Germany (legally binding since 2008).

Under the 2008 climate and energy package, new legally binding national targets for GHG emission reduction have been laid down through the Effort Sharing Decision 409/2009/EC. These national targets were set for the period 2013-2020 in order to contribute to the EU's overall reduction objective by 2020. They are based on the reference year 2005 and set the framework for further EU and national policy measures.

Market-based mechanisms

In addition to regulatory measures, several Member States established fiscal measures including taxes and/or tax refund schemes related to HFCs or F-gases, which represent a market-based instrument to incentivize lower emissions.

Such schemes are in place in Denmark (import of bulk F-gases and F-gases contained in products; based on CO_2-tax per tonne CO_2 eq.) and Slovenia (tax on import/ first placing on the market of F-gases with GWP >150 for production of equipment and/or maintenance needs). Similar systems are discussed in Poland (fees for consumption of F-gases by operators; refund on recovered quantities) and Sweden (tax on import/ production of HFCs).

Deposit schemes for used F-gases represent a market-based instrument to incentivize recovery. Such schemes are in place in Denmark and Sweden since the early 1990s. In Sweden, the system has been run by companies involved and anticipated later producer responsibility schemes.

Voluntary programmes and initiatives at national level

- Producers of refrigeration, air conditioning and heat pump equipment: Voluntary take-back schemes established by industry for end of life equipment such as commercial and industrial air conditioning systems (Greece, UK, Belgium), heat pumps (Belgium).
- Fire protection industry: Prior to the F-gas Regulation, voluntary agreements on monitoring, leak detection and containment processes were in place in the Netherlands (since 1999) and the UK (since 1994, renewed in 1997). The agreements were outdated by the F-gas Regulation.
- High voltage switchgear industry: Voluntary agreements addressing use and emissions of SF_6 exist in France (2005-2010), Germany (since 1996/ renewed in 2005), Spain (2008-2012).

Outside EU-27

Regulatory measures

Examples for legislation addressing use and emissions of F-gases:

- Switzerland: General ban of HFCs (except for HFC-152a), PFCs and SF_6, but exemptions for specific sectors such as solvents, foams, refrigerants, fire extinguishing agents and spray cans apply.
- Japan: Recovery of CFCs, HCFCs and HFCs from commercial refrigeration and air conditioning systems during servicing (since 2006) and at end of life (since 2002) in order to ensure proper destruction.
- USA: Proposals for domestic climate legislation currently pending Congress decision include the American Clean Energy and Security Act (formerly known as the Waxman-Markey bill) and the American Power Act (known as the Kerry-Lieberman discussion draft) and introduce cap and trade mechanisms. Both set out consumption caps on all HFCs and maximum allowable amounts of consumption. Reduction steps are relative to the baseline of average US consumption in the period 2004-2006 and differ between the proposals. Regulatory measures already in place include rules

established by the US EPA e.g. a final rule that establishes thresholds for GHG emissions that define when permits are required for new and existing industrial facilities (effective from January 2011) and a rule on mandatory reporting of GHG emissions, which refers *inter alia* to magnesium production (first reports 2012).

<u>Voluntary programmes and measures on national level</u>

- USA: Voluntary partnerships between industries and the Environmental Protection Agency address emissions of PFCs and SF_6 from aluminium, magnesium, semiconductor and electric power industries.
- Japan: Voluntary agreement of the Japanese Urethane Industry for a phase-out of HFCs as blowing agents of PU rigid spray foam for residential building insulation by end of August 2010. The Industrial Network for Fluorocarbon Recovery Promotion has encouraged recovery of fluorocarbon refrigerants during repair and maintenance of equipment since the mid 1990s.

3.1.3 Interactions of EU F-gas policies with other relevant policies

F-gas policies and existing and new policies in other areas might interact, overlap or complement each other. In order to identify issues to be taken into account in the development of possible review options, an analysis of current EU policies is ongoing.

Regulatory measures

Several interactions and possible areas of overlap between the legislation on F-gases and legislative acts from other fields can be identified (examples in figure 3). Certain interactions create synergies and are likely to result in reductions of F-gas emissions while others might have the potential to increase emissions. In some cases, such effects can be quantified and are integrated into the model AnaFgas. Other effects may not be quantifiable.

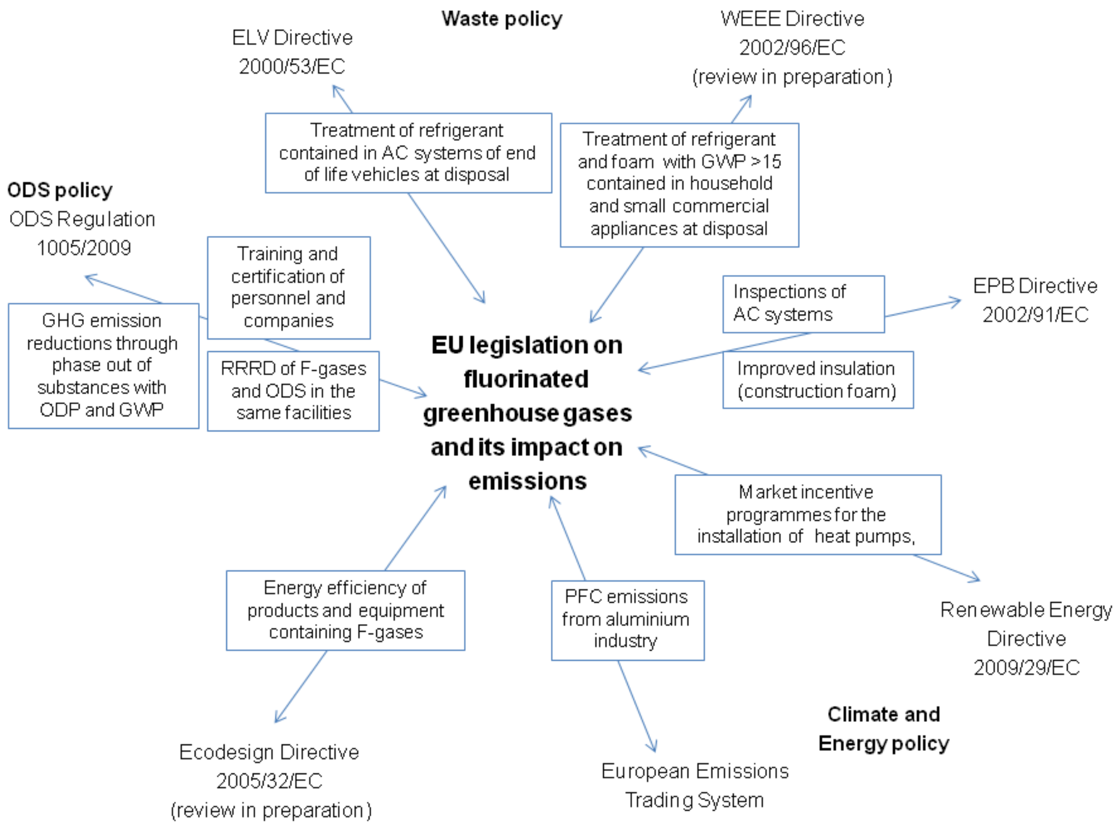

Figure 3: Interactions of regulatory measures from various policy fields and F-gas legislation with regard to impacts on emissions.

Interactions between legislation related to climate and energy and the F-gas legislation:

- The number of heat pumps installed, which has been rapidly growing in the entire EU-27 since 2003, is expected to continue increasing due to the promotion of renewables under the Renewable Energy Directive. Following the projection of the model AnaFgas, the annual installations over the entire EU is expected to grow from 1.3 million units in 2009 to 13 million units in 2030. As a result, HFC emissions from heat pumps will increase to 2.45 million t CO_2 eq.

- PFC emissions from the aluminium industry, which will be integrated into the EU-ETS from 2013, will support the introduction of technological improvements which are expected to reduce projected emissions by 1.3 million t CO_2 eq. until 2020.
- The EPB Directive could contribute in increasing use of HFCs (365mfc, 245fa) as foam blowing agents. However, natural blowing agents are known to provide the same energy performance as HFCs. Thus, this interaction is not expected to impact F-gas emissions in the long-term. Furthermore, inspections of AC systems >12 kW as required by the EPB Directive (Art 9) might also contribute in improving leak tightness irrespective of the charges. Yet this impact can hardly be quantified.
- The Ecodesign Directive addresses various products and equipment containing F-gases including refrigerating and freezing equipment (service cabinets, blast cabinets, walk-in cold rooms, chillers, remote condensing units, water dispensers, minibars, wine storage appliances, ice makers, dessert and beverage machines) (Lot 1), air-conditioning and ventilation (Lot 6), residential room air conditioning appliances (Lot 10), commercial refrigerators and freezers (Lot 12), household refrigerating appliances (Lot 13).

  Improvements of energy efficiency may influence the refrigerant charge size of systems, and thus the emissions. However, there is no specific trend identifiable in terms of whether the efficiency of a given system with a given refrigerant capacity will improve with more or less refrigerant mass.[10]

Areas of overlap between waste legislation and F-gas legislation:

- The treatment of refrigerants and to certain extent foams from certain domestic and small commercial appliances as required by the WEEE Directive is also addressed by provisions on RRRD of the F-gas Regulation (Art. 4). While the disposal emission factor of the sectors covered under the WEEE Directive will decrease as recovery efficiency increases, few quantitative data on the impact of this are available in EU-27.
- The treatment of refrigerants from mobile AC systems at end of life vehicles as required by the ELV Directive is also addressed by provisions on RRRD of the F-gas Regulation (Art 4). While the disposal emission factor of mobile AC will decrease as recovery efficiency increases, so far, no quantitative data on the impact of this are available.

Interactions between ODS legislation and F-gas legislation:

ODS legislation has effectively supported GHG emission reductions due to the phase out of substances which show both ozone depleting potential and global warming potential. At the

[10] Energy efficiency can be increased by use of larger conventional heat exchangers which typically contain greater refrigerant charge mass (due to increased internal volume), or alternatively by use of so-called mini channel heat exchangers which contain less refrigerant. The latter option, which is still more expensive, would benefit from higher refrigerant cost.

same time, the Montreal Protocol and related ODS legislation acted as main drivers for increased use of F-gases.

- General awareness raising and capacity development of personnel and companies through training and certification as usually the same companies deal with ODS and F-gases.
- Reclamation and destruction of ODS and F-gases take place in the same facilities. Reporting requirements for ODS destruction could be extended to F-gases in order to gain information on the effectiveness of provisions on F-gas recovery and recycling and related disposal emissions.

Further issues for consideration will be investigated in the course of the project.

3.2. Effectiveness of the current EU-F-gas policy

3.2.1. Description and documentation of the Model AnaFgas

The Model AnaFgas (Analysis of Fluorinated greenhouse gases in the EU-27) is a bottom-up stock model to derive consumption and emission scenarios for F-gases from the relevant sectors and sub-sectors for the EU-27 Member States[11]. It models consumption and emissions of HFCs, PFCs and SF_6 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 to manufacture and/or maintain equipment and products over time.

Datasets including quantitative and qualitative information from various sources (see the section on methodology) were compiled per sector and Member State and serve as basis for the model. The majority of emission estimates are derived from bottom-up approaches, i.e. by estimating emissions per sector through the use of underlying driving factors. These include annual changes in equipment stock, composition and charge of F-gases in the equipment, leakage emissions during equipment lifetime and on disposal. Some of these components are driven by other factors such as population development, GDP growth or technological changes. Based on these drivers annual emissions and banks are calculated for each year, sub sector and EU Member State.

AnaFgas makes use of market information to build an inventory of in-use stocks of the equipment in each of the end-uses (figure 4) in each country. These modelled stock inventories are maintained through the annual addition of new equipment/new F-gas quantities and the retirement of equipment after an appropriate number of years. Use-phase emissions and disposal emissions are estimated for each of the end-uses. In addition, in some sectors manufacturing emissions (e.g. hard foam, switch gear) or fugitive and by-product emissions (e.g. production of F-gases, production of primary aluminium) are estimated.

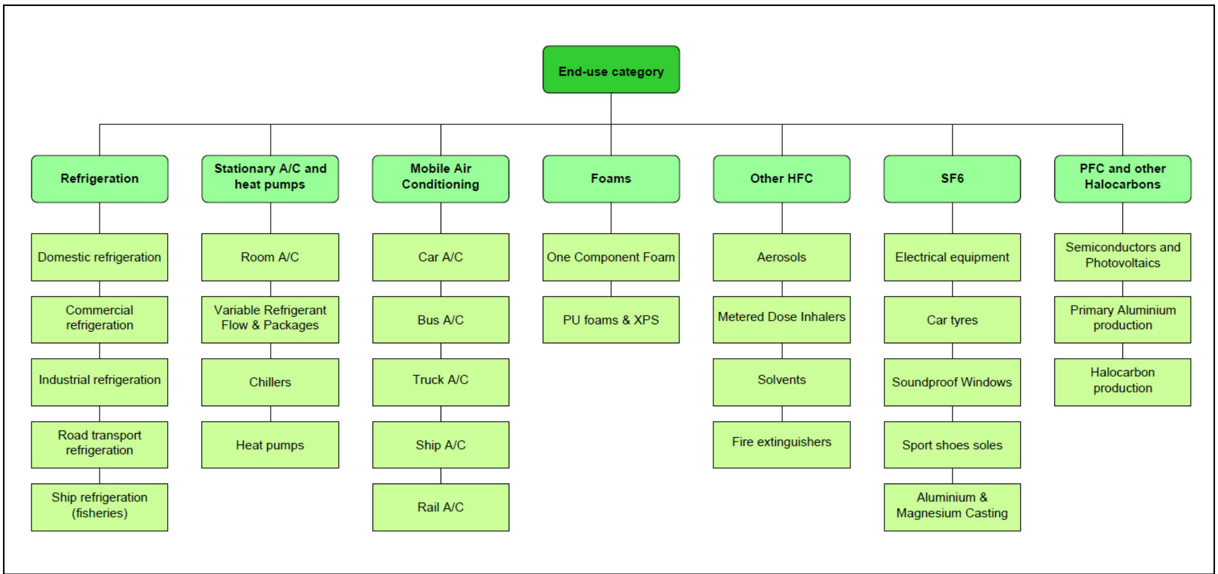

Figure 4: Schema of the sectors and sub-sectors covered by AnaFgas

[11] An ODS-Module is still under development and not part of this project.

Seven sectors with a total of 29 sub sectors are separately represented in the model (see Figure 4). In total 21 different F-gases are included in the model (12 HFCs, 7 PFCs, SF_6 and NF_3) and calculations can either be based on metric tonnes or global warming potential (GWP) (Table 4). In addition, the user can choose between the GWP included in the second, third or fourth IPCC Assessment Report (2^{nd}, 3^{rd}, 4^{th} AR). Emissions are calculated annually for all years between 1995 and 2050.

Table 4: List of gases and global warming potentials included in the model AnaFGas.

Industrial Designation or Common Name	Chemical Formula	GWP (100 yr)		
		2^{nd} AR	3^{rd} AR	4^{th} AR
Compounds				
404A	44% 125, 4% 134a, 52% 143a	3.260	3.784	3.922
407C	23% 32, 25% 125, 52% 134a	1.526	1.653	1.774
507	50%125, 50% 143a	3.300	3.850	3.985
410A	50% 32, 50% 125	1.725	1.975	2.088
Hydrofluorocarbons				
HFC-23	CHF_3	11.700	12.000	14.800
HFC-32	CH_2F_2	650	550	675
HFC-1234yf		4	4	4
HFC-125	CHF_2CF_3	2.800	3.400	3.500
HFC-134a	CH_2FCF_3	1.300	1.300	1.430
HFC-143a	CH_3CF_3	3.800	4.300	4.470
HFC-152a	CH_3CHF_2	140	120	124
HFC-227ea	CF3CHFCF3	2.900	3.500	3.220
HFC-236fa	$CF_3CH_2CF_3$	6.300	9.400	9.810
HFC-245ca	$CH_2FCF_2CHF_2$	560	640	693
HFC-245fa	$CHF_2CH_2CF_3$	--	950	1.030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	--	890	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1.300	1.500	1.640
Perfluorocarbons				
PFC-14	CF_4	6.500	5.700	7.390
PFC-116	C_2F_6	9.200	11.900	12.200
PFC-218	C_3F_8	7.000	8.600	8.830
PFC-318	$c\text{-}C_4F_8$	8.700	10.000	10.300
PFC-3-1-10	C_4F_{10}	7.000	8.600	8.860
PFC-4-1-12	C_5F_{12}	7.500	8.900	9.160
PFC-5-1-14	C_6F_{14}	7.400	9.000	9.300
Other fluorinated gases				
Sulphur hexafluoride	SF_6	23.900	22.200	22.800
Nitrogen trifluoride	NF_3	--	10.800	17.200

Results are shown in tabular and graphical form for each year in three different ways (see Figure 5):

1) emissions per chemical substance,
2) emissions per source, and
3) emissions per (sub-)sector.

Stationary A/C and Heat Pumps									
Country EU-27									
GWP Fourth AR		1995	2000	2010	2020	2030	2040	2050
Without measures								
Total by Gas	[kt CO2eq]	0.0	88.3	11 567.9	36 057.2	55 013.9	60 325.8	59 760.8
HFC 134a	[kt CO2eq]	0.0	37.8	2 167.8	4 149.5	4 130.8	4 549.8	4 488.5
HFC 143a	[kt CO2eq]	0.0	1.2	25.4	96.6	273.5	320.6	289.1
HFC 125	[kt CO2eq]	0.0	41.7	7 882.6	26 714.8	42 487.9	46 556.8	46 156.6
HFC 32	[kt CO2eq]	0.0	7.6	1 492.1	5 096.3	8 121.6	8 898.6	8 826.6
Total by Source	[kt CO2eq]	0.0	88.3	11 567.9	36 057.2	55 013.9	60 325.8	59 760.8
Lifetime Emissions	[kt CO2eq]	0.0	88.3	11 479.4	24 084.0	28 876.1	29 174.2	29 174.2
Disposal Emissions	[kt CO2eq]	0.0	0.0	88.5	11 973.2	26 137.8	31 151.6	30 586.6
Total by Sector	[kt CO2eq]	0.0	88.3	11 567.9	36 057.2	55 013.9	60 325.8	59 760.8
Room A/C	[kt CO2eq]	0.0	63.2	6 702.9	24 386.1	38 999.4	42 775.2	42 775.2
Variable Refrigerant Flow & Mu	[kt CO2eq]	0.0	0.0	1 500.9	3 634.4	4 406.4	4 770.5	4 770.5
Chillers	[kt CO2eq]	0.0	19.6	3 066.9	6 321.3	6 700.3	7 027.7	7 027.7
Heat Pumps	[kt CO2eq]	0.0	5.4	297.3	1 715.4	4 907.8	5 752.4	5 187.4

Figure 5: Model output by substance, source and sector.

The stock model requires input regarding the market growth for each of the end-uses, as well as a history of the market penetration of F-gases. For the purpose of projecting the use and emissions of F-gases into the future, AnaFgas incorporates the available information about probable evolutions of the end-use market, trends of F-gas substitution and trends of emission factors. It also requires assumptions on future growth trends in different areas such as population development, growth in transport (passenger and freight), change in social structure, consumer habits and lifestyle. Forecasts by EU institutions, Member States and IPCC TEAP Special report 2005[12] and the recent TEAP reports are included in the growth assumptions until 2050. For the projections until 2050 AnaFgas generally distinguishes between two different time periods:

1) Near future (5-10 years) is modelled on known policies and measures, technological changes, substitution patterns and expected changes in consumption patterns, and

2) distant future (until 2050) is based on a continuation of trends observed, external projections of driving forces such as GDP and population and follows a business as usual scenario; the model does not consider changes in technologies which are likely to happen in such a long timeframe.

AnaFgas contains three different scenarios to be able to assess the effect of existing and additional policies and measures:

1) **Without measures (WOM):** A counter-factual consumption and emission scenario for the EU-27 and each MS reflecting the situation that would must like have occurred since 1995 (baseline year for F-gases under the Kyoto Protocol) without the 2006 EU policy intervention (F-gas Regulation, MAC directive). National mitigation measures which existed prior to the F-gas regulation also are accounted in the WOM. The projected 2050 consumption and emission are based on sub-sector specific growth assumptions, which in most cases do not include technological change or introduction of alternative fluids (“frozen technology”). Often the consumption level of the last year, or the trend over the last years before enforcement of the European F-gas legislation

[12] IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorcarbons and Perfluorcarbons. 2005 Prepared by Working Group I and III of the Intergovernmental Panel on Climate Change, and the Technology and Economic Assessment Panel. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 488 pp.

is extrapolated to the future. Details are given in a sub sector specific model description.

2) **With measures (WM):** A scenario of actual or baseline consumption and emission trends for the period 1995-2050 taking into account the existing policies and measures to reduce F-gas consumption and emissions at EU-27 level and for each Member State. The 'with measures' scenario is based on the same underlying growth trends as the WOM scenario, but, following the assessment of the existing EU policy framework, varies those parameters of the estimation that are (or expected to be) influenced by the European legislation for the period during which this effect takes place. These parameters include leakage rates, recovery efficiency, prohibitions of use and the substitution of certain gases which would not have occurred without the policy intervention.

3) **With additional measures (WAM):** A scenario for the consumption and emission trends in the EU and Member States with possible additional measures to mitigate F-gas emissions. This scenario will be presented at a later stage of the project and is thus not included in subsequent explanations.

The difference between the WOM and the WM scenario shows the effectiveness of current legislation, most importantly Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases (F-Gas Regulation) and Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles and amending Council Directive 70/156/EEC (MAC Directive). The WAM scenario will help determine the emission reductions which could be achieved by additional policies and measures, e.g. through a revised F-gas regulation.

Figure 6 shows the difference between the without measures and the with measures scenarios for the example of the MAC Directive which refers to passenger cars. It shows the impact of the MAC Directive on the entire sector of mobile air conditioning, which includes in addition to passenger cars also trucks, buses, ships and railcars.

All of the parameters, drivers, assumptions and other input variables are based on EU-wide sources and trends. Where necessary and possible, this has been refined by Member State specific information. A detailed overview of the assumptions (gases, charges, equipment lifetime, emission factors and other measures) is given in annex.

AnaFgas is able to produce separate output for each Member State, for EU-15, EU-12 and EU-27.

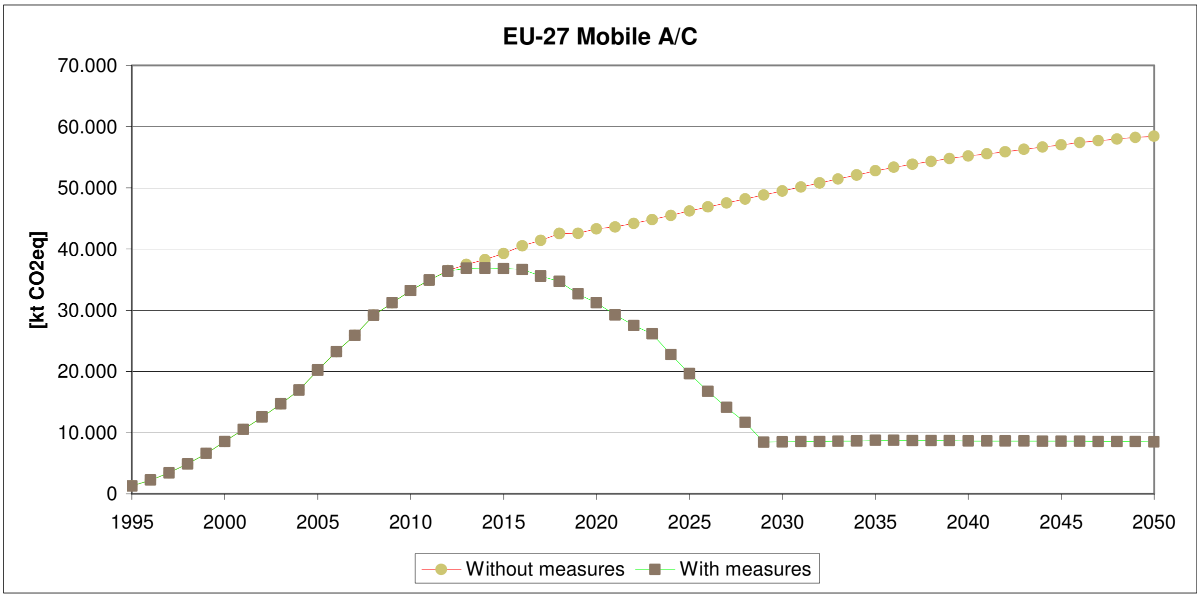

Figure 6: EU-27 emissions from mobile air-conditioning in the WOM and the WM scenario. The effect of the MAC Directive for passenger cars can clearly be seen in the curve split from 2011 onwards. From 2030 only HFC emissions from MAC systems in trucks, buses, ships and railcars arise, thus presenting the reduction potential from additional policy measures. (Remaining emissions from passenger cars are deemed of negligible size, compared with the current situation).

3.2.2. EU-27 emission scenarios

Currently the model includes the 'without measures' and the 'with measures' scenarios; the 'with additional measures' scenario will be developed at a later stage of the project.

Historic emissions included in the model have been compared to the national inventory submissions by Member States under the Kyoto Protocol (CRF data). Seven of the 29 sectors in AnaFgas are largely based on CRF data: domestic refrigeration, fire protection, solvents, semiconductor manufacture, primary aluminium production, production of halocarbons, and XPS foam.

The other sectors follow a different approach for which the CRF data could not be used straight forwardly for various reasons: CRF data is often too general, incomplete or not transparent enough. Additionally it is not of the same quality standard in all countries. Nevertheless CRF data represents the best available empirical information source on F-gas consumption and emissions in Member States. Despite the different approach followed for several sectors the overall output of the F-gas model is relatively close to overall output from the CRF data (table 5). The difference between the two data sets is lower than 5% in most years and well within the expected uncertainties of the Member State data and the model.

Table 5: Comparison of CRF data reported by Member States and the model output. GWP according to the 2nd IPCC Assessment Report.

kt CO_2 eq.	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
CRF	65,732	63,151	66,323	68,466	69,293	72,734	74,035	77,826	80,392
Model	62,674	60,021	66,373	68,019	70,912	74,725	77,965	83,459	92,094
Difference	4.7%	5.0%	-0.1%	0.7%	-2.3%	-2.7%	-5.3%	-7.2%	-14.6%

The steeper emission increase in the model, resulting in 14.6% higher values in 2008, results from higher growth rates for refrigerant banks in stationary refrigeration, and stationary and mobile air conditioning; in addition, the model includes disposal emissions from all Member States. A number of countries have not reported any disposal emissions, so far.

Total emissions and differences between the 'with measures' and the 'without measures' scenarios can be seen in Figure 7 and Figure 8.[13] The shape of the emission curves indicates the estimated/expected F-gas emission reduction potential although for the sectors primarily addressed through the containment provisions quantification is at this stage uncertain (see remarks on measurability of emission reduction through the F-gas Regulation in section 3.2.3). From 2008/2010 onwards the two curves distinctly split up.

In the WOM scenario projected emissions would almost double between 2010 and 2050, while in the WM scenario the increase is estimated to be no more than one fifth of this increase in the same time span.

Without measures (WOM) scenario

Without the EU legislation regarding fluorinated greenhouse gases, the total emissions would rise by 162% in the 2006-2050 periods. In 2006, when the F-gas Regulation and the MAC Directive entered into force, EU-27 emissions amounted to ca. 78 million t CO_2 eq[14]. They would increase to 205 million tons by 2050.

A particular steep rise would take place until 2020. The sectors of refrigeration (commercial, industrial, and transport refrigeration) and mobile air conditioning would contribute almost 30% each in 2020. Stationary air conditioning would contribute with 23% in 2020 to total F-gas emissions; this share increases to 29% by 2050. This means that refrigerants cause by far most of global warming F-gas emissions.

The other sectors like aerosols, solvents and fire extinguishers („other HFCs") together with foam blowing agents, which caused almost two-thirds of global warming emissions from halocarbons (CFCs, HCFCs) 20 years ago, currently play a minor role, compared to HFC refrigerants. Even under business-as-usual conditions (WOM scenario), emissions from these sectors would hardly rise in the future.

This statement also applies to emissions of SF_6, PFCs and emissions from the production of halocarbons. The latter causes amongst others by-product emissions of HFC-23. These emissions accounted for 50% of the total F-gas emissions in 2000. Due to abatement technologies and as a result of the legal prohibition of the production of HCFCs, after 2000 this emission source has become less important and will go on decreasing in importance.

[13] It must be noted that unlike emissions under UNFCCC reporting where the GWP of the 2nd IPCC Assessment Report are used, the data in this chapter is calculated with GWP values from the 4th IPCC Assessment Report. As a consequence, the amounts are nominally higher by approx. 10%.

[14] GWP according to the 4th IPCC assessment report

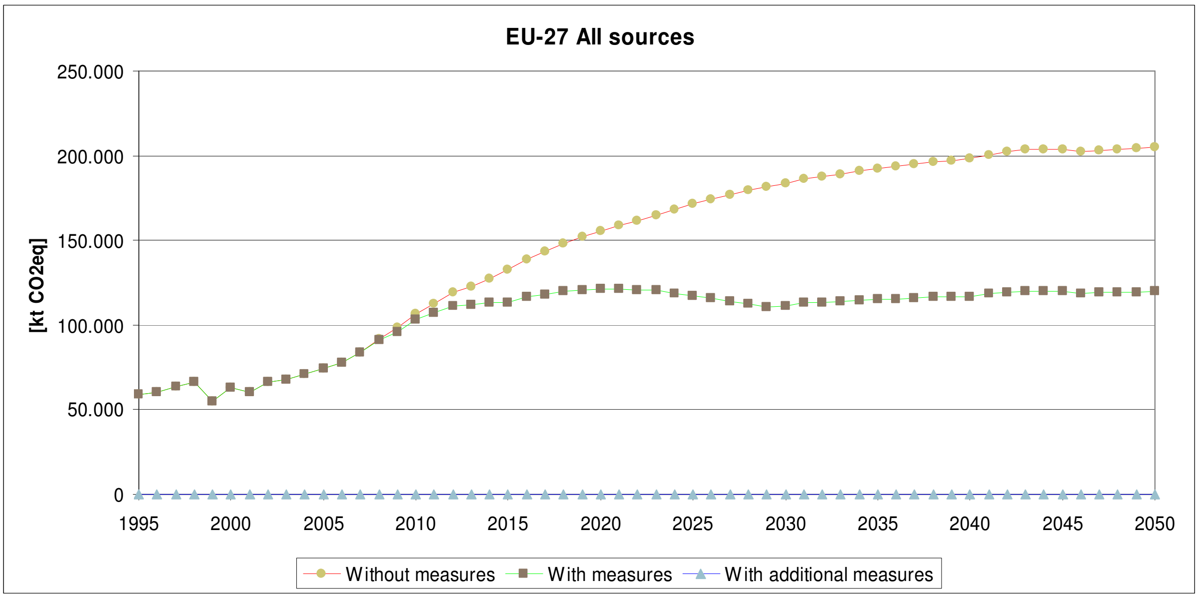

Figure 7: EU-27 emissions in the 'without measures' and the 'with measures' scenarios until 2050.

All sources								
Country EU-27 / GWP Fourth AR		1995	2000	2010	2020	2030	2040	2050
Without measures								
Total by Sector	[kt CO2eq]	58 869.4	62 674.8	106 468.3	155 512.9	183 601.0	198 139.8	204 802.9
Refrigeration	[kt CO2eq]	361.4	7 582.7	33 883.3	45 363.0	51 188.8	53 913.8	56 998.2
Stationary A/C and Heat Pump	[kt CO2eq]	0.0	88.3	11 567.9	36 057.2	55 013.9	60 325.8	59 760.8
Mobile A/C	[kt CO2eq]	1 304.4	8 549.6	33 202.1	43 311.8	49 483.9	55 219.0	58 456.2
Foams	[kt CO2eq]	9.1	294.7	4 032.6	4 949.2	5 895.3	6 613.6	7 316.0
Other HFCs	[kt CO2eq]	31.7	7 297.4	11 695.7	12 502.2	12 677.1	12 878.0	13 042.1
SF6	[kt CO2eq]	4 479.6	6 963.8	6 402.8	8 858.5	4 867.4	4 715.3	4 755.4
PFC and other Halocarbons	[kt CO2eq]	52 683.3	31 898.3	5 683.8	4 470.9	4 474.7	4 474.3	4 474.1
Total by Sector	[% of total]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Refrigeration	[% of total]	0.6%	12.1%	31.8%	29.2%	27.9%	27.2%	27.8%
Stationary A/C and Heat Pump	[% of total]	0.0%	0.1%	10.9%	23.2%	30.0%	30.4%	29.2%
Mobile A/C	[% of total]	2.2%	13.6%	31.2%	27.9%	27.0%	27.9%	28.5%
Foams	[% of total]	0.0%	0.5%	3.8%	3.2%	3.2%	3.3%	3.6%
Other HFCs	[% of total]	0.1%	11.6%	11.0%	8.0%	6.9%	6.5%	6.4%
SF6	[% of total]	7.6%	11.1%	6.0%	5.7%	2.7%	2.4%	2.3%
PFC and other Halocarbons	[% of total]	89.5%	50.9%	5.3%	2.9%	2.4%	2.3%	2.2%
With measures								
Total by Sector	[kt CO2eq]	58 869.4	62 674.8	103 450.6	121 183.1	111 285.1	116 711.2	119 647.4
Refrigeration	[kt CO2eq]	361.4	7 582.7	33 883.3	37 642.1	42 209.4	44 507.7	47 201.6
Stationary A/C and Heat Pump	[kt CO2eq]	0.0	88.3	11 567.9	27 396.7	38 968.1	41 713.7	41 431.2
Mobile A/C	[kt CO2eq]	1 304.4	8 549.6	33 202.1	31 218.1	8 518.5	8 653.5	8 540.3
Foams	[kt CO2eq]	9.1	294.7	2 425.1	2 984.5	3 495.1	3 959.8	4 382.1
Other HFCs	[kt CO2eq]	31.7	7 297.4	11 387.7	10 351.4	10 563.4	10 773.4	10 960.8
SF6	[kt CO2eq]	4 479.6	6 963.8	5 300.6	7 119.4	3 055.9	2 628.7	2 657.3
PFC and other Halocarbons	[kt CO2eq]	52 683.3	31 898.3	5 683.8	4 470.9	4 474.7	4 474.3	4 474.1
Total by Sector	[% of WOM]	100.0%	100.0%	97.2%	77.9%	60.6%	58.9%	58.4%
Refrigeration	[% of WOM]	100.0%	100.0%	100.0%	83.0%	82.5%	82.6%	82.8%
Stationary A/C and Heat Pump	[% of WOM]	-	100.0%	100.0%	76.0%	70.8%	69.1%	69.3%
Mobile A/C	[% of WOM]	100.0%	100.0%	100.0%	72.1%	17.2%	15.7%	14.6%
Foams	[% of WOM]	100.0%	100.0%	60.1%	60.3%	59.3%	59.9%	59.9%
Other HFCs	[% of WOM]	100.0%	100.0%	97.4%	82.8%	83.3%	83.7%	84.0%
SF6	[% of WOM]	100.0%	100.0%	82.8%	80.4%	62.8%	55.7%	55.9%
PFC and other Halocarbons	[% of WOM]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 8: EU-27 emissions by sector in the 'without measures' and the 'with measures' scenarios until 2050. Percentage values in the 'without measures' scenario are given relative to absolute emissions showing the contribution of the individual sectors to total emissions. Percentage values in the 'with measures' scenario are given relative to the 'without measures' emissions of the same sector, i.e. showing the emission reductions in the sectors compared to the no-policy intervention scenario.

With measures (WM) scenario

The WM projection calculates the relative emissions reductions until 2050 in relation to the WOM scenario, in consequence of the EU F-gas legislation from 2006, which includes the F-gas Regulation and the MAC Directive. Absolute emissions in 2050 will exceed emissions in 2006 by ca. 40,000 kt CO_2 eq. Nonetheless the absolute difference to the emissions in the WOM scenario is more than 85,000 kt CO_2 eq. in 2050, 42% of the emissions in WOM scenario in this year.

In the model AnaFgas, it is assumed that in all stationary refrigerant applications with higher charges than 3 kg, containment measures according to Art 3 of the F-gas Regulation lead to a decrease in the use-phase emission factors by 40% within the time span from 2010 to 2015; after, the emission factor is kept constant until 2050.

It must be pointed out that the reduction in the emission factor is no finding from the ex-post assessment of the existing EU policy framework. A possible reduction cannot yet empirically be measured, in 2010 (see section 3.2.3). It is an expected value which is considered to be likely on condition that the F-gas Regulation is fully implemented in the individual Member States in the affected F-gas application sectors and sub sectors in the EU.

The quantitative expectation of approx. 40% reduction is based on reports referring to the Dutch STEK system of regulation of ODS and HFCs, which is the model behind the key containment provisions of the F-gas Regulation. This system is reported to have cut the annual leakage rate in the Netherlands from more than 11% to less than 5%, within the same timeframe. It should be added that the authors of the IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System assume a reduction potential of similar size for the sectors of stationary air conditioning and refrigeration in their mitigation scenario for 2015.

In addition, enhanced recovery efficiency as a result of Art 4(1) is assumed to reduce disposal emission factors by ca. 33% from 2010 to 2015, in all stationary systems (irrespective of the refrigerant charge). In the sub sectors of fire protection and electrical switchgear, which are also subject to containment and/or recovery measures by Art 3 and/or Art 4(1), the same reduction effect is assumed for the two types of emission factors.

In the case of implementation and realization of the provisions of the F-gas Regulation, the growth in F-gas emissions from stationary refrigeration and air conditioning equipment can be substantially reduced in the 2010-2015 time spans. While in the WOM scenario the emissions from stationary refrigeration and air conditioning are projected to rise by 19 million t CO_2 eq., the 2010 emissions from refrigeration can be kept stable until 2015 and the growth in emissions from stationary air conditioning is limited to 7 million t CO_2 eq. by 2015 in the WM scenario. This means in effect relative emission savings from these sectors by 12 million t CO_2 eq. compared with the WOM scenario. The further relative emission reduction is projected be 17 million t CO_2 eq. resulting in a total relative reduction of 28 million t CO_2 eq. from 2010 to 2050 (figure 9).

Emission reductions by 2015 can be called the short-term reduction potential, and reductions by 2050 the long-term reduction potential of Art 3 and 4(1) of the F-gas Regulation, in stationary equipment containing F-gas refrigerants.

The emission reduction potential from Art 3, Art 4(1), Art 5 and Art 7 is still higher considering the impact on fire protection installations and electrical switchgear equipment. Emissions savings are projected to amount to 2.3 million t CO_2 eq. by 2015 and will not increase in the 2015-2050 period.

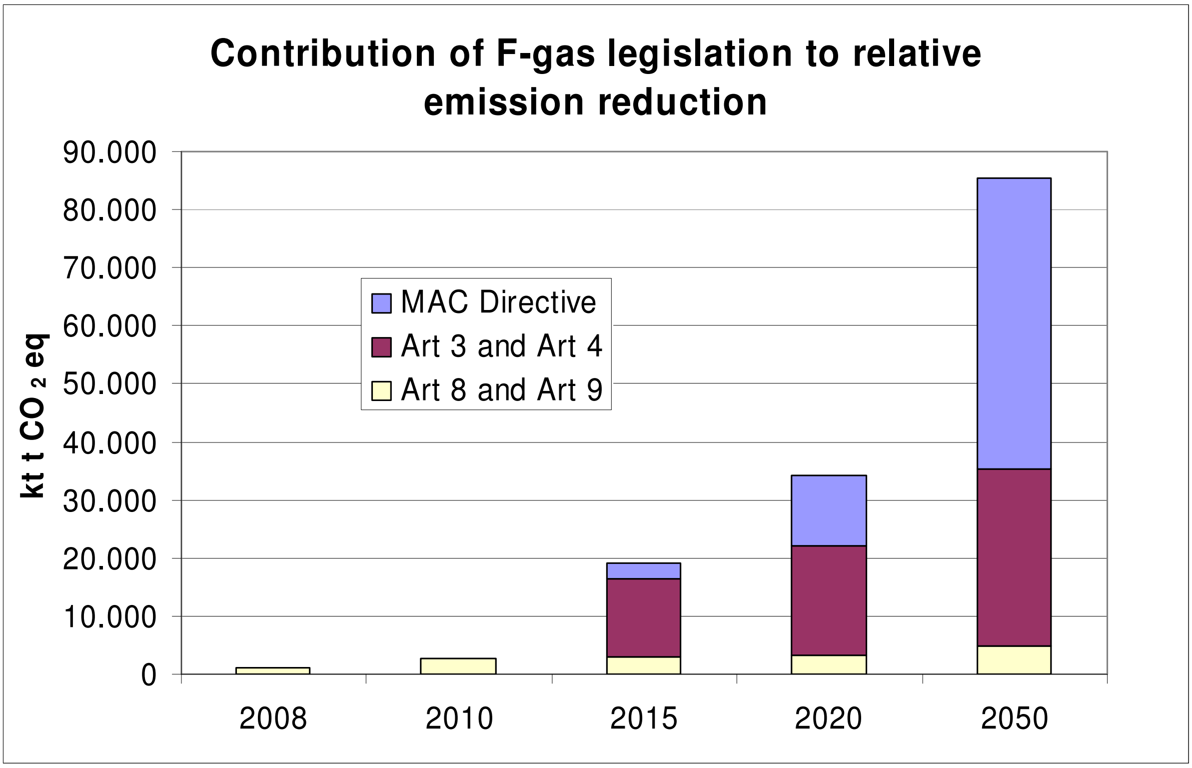

Figure 9: Contribution of containment/recovery measures of Art 3 and Art 4, prohibition measures of Art 8 and Art 9 and of the MAC Directive to the total F-gas emission reduction potential in selected years, in EU-27. In 2015 and 2020 measures according to Art 3 and 4 have the strongest effect. The MAC Directive contributes the most to emission reduction in 2050. Art 8 and 9 provisions show measurable effects already in 2008.

In addition to containment and recovery measures, the F-gas Regulation includes prohibition measures in some sectors applying F-gases. Art 8 and Art 9 (Annex II) interdict use or placing on the market for various applications of SF_6 like the magnesium industry, car tyres, soundproof glazing, and for HFC using sectors like one-component foam and novelty aerosols. The prohibitions entered into force already in the 2007-2009 periods. The last full years before these prohibition measures are mostly 2006 or 2007, for novelty aerosols it is the year 2008. As a consequence, an emission reduction effect can already be identified in 2008 for some SF_6 sub sectors and OCF. Some recent CRF reports already account for these sub-sector specific emission reduction effects and so does the model. The 2008 vs. 2006 emission reduction in the case of SF_6 applications subject to prohibition ranges at 0.65 million t CO_2 eq. and in the foam sector (OCF) at 0.24 million t CO_2 eq.

The full short-term reduction potential of OCF has been achieved by 2009 at 1.7 million t CO_2 eq. The long-term emission reductions will amount to almost 3 million t CO_2 eq. by 2050. OCF is the sub sector with the highest individual emission reduction potential from application of Art 8 or Art 9. From 2009 onwards, soundproof glazing, car tyres, and novelty aerosols will also cause significantly lower emissions.

F-gas legislation also applies to mobile equipment. From 2011 the MAC Directive prohibits the use of HFC-134a for air conditioning of passenger cars. By the end of 2017, systems in new vehicles are no longer allowed to be equipped with this refrigerant. The model AnaFgas takes into account the significant emission reduction in the mobile air conditioning sector subsequent to the HFC-134a phase-out from passenger cars. Considering the average lifetime of cars of 12 years, the full effect on emission reductions is expected to occur by 2030.

Emissions reductions through the MAC Directive begin in 2011 and will need several years to achieve full potential. In the model, HFC emissions from passenger cars will be almost completely cut to zero by 2029, causing relative emissions reductions of 50 million t CO_2 eq. by 2050. Remaining emissions will arise from other mobile sub-sectors like trucks, buses, ships, and railcars, which are not addressed effectively by the current policy[15].

Emission reduction by 2010: expectations and reality

In 2003, the European Commission's proposal for a Regulation to reduce emissions of fluorinated greenhouse gases[16] was expected to reduce the emissions of these gases by approx. 23 million t CO_2 eq. by 2010 (EU-15 only), i.e. from 98 million t CO_2 eq. until 2010 in a business as usual projection[17]to 75 million t CO_2 eq. by 2010 (GWP values of the 2nd IPCC AR). The WM scenario of the model AnaFgas estimates the 2010 emissions from the EU-15 (without the 12 new MS) to range at about 76.7 million t CO_2 eq. This value is not significantly higher than the 75 million t emission reduction target from 2003.

It must be pointed out that this relative emission reduction is at this point in time only to a small part a direct consequence of the F-gas Regulation. The directly measurable effect is only 2.5 million t CO_2 eq. and results from the prohibition measures of Art 8 and 9. However, an “indirect” effect must be taken into account which likely prevented an increase of the F-gas emissions to the projected amount of 98 million t CO_2 eq. in 2010. In anticipation of the impending political measures, numerous actors have made successful efforts to reduce leakage rates or replace F-gases by other substances or technologies, in stationary refrigerant application as well as in other sectors causing F-gas emissions.

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[15] In the model, the general provision of Art 4(3) for recovery by “appropriately qualified personnel” is not considered to impact quantitatively the disposal emission factor in mobile air conditioning.

[16] This proposal was a key element of the first phase of the European Climate Change Programme (ECCP), which was established in June 2000 to identify cost-effective reduction measures.

[17] European Commission: Climate Change: Commission tackles fluorinated gases. Press Release, 12 August 2003, IP/03/1155.

3.2.3. Ex-post assessment of the existing EU policy framework

The following ex-post assessment intends to investigate the impact of the individual measures in the existing F-gas policy framework on emissions by affected sectors and subsectors as well as the cost-effectiveness of the measures implemented. It is based on questionnaires submitted to the competent authorities in all EU Member States and to industry from all major sectors relying on F-gases, additional documents, relevant studies and further investigations.

Measurability of emission reduction of refrigerants caused by the F-gas Regulation

As shown in the previous section, emission reductions caused by prohibition measures of the F-gas Regulation are already reflected in the model AnaFgas for 2008 and in the recent CRF submissions of some Member States. It is a key question for the assessment of the effectiveness of the Regulation whether and to which extent reduction in use-phase emissions can be empirically verified in 2010 in those sectors affected by the containment measures. Therefore, various reporting and monitoring systems for F-gas consumption and emissions are evaluated with regard to the possibility to undertake calculations of emission factors. Emission factors are considered the appropriate indicator for effectiveness of the measures set out by the F-gas Regulation in terms of emission reductions.

- UNFCCC reporting by Member States (CRF data) is currently not suitable to indicate short-term changes of emissions from those sectors that are subject to the key containment provisions (Art 3) of the F-gas Regulation. This is first of all due to fact that the MS use constant emission factors which are updated only at intervals of several years.
- National surveys on refrigerant use (new fills and refills) in the Netherlands, Germany, and Austria are basically appropriate to reflect short-term changes in the amount of use-phase emissions. However, these surveys do not cover banks and thus do not allow identification of leakage rates (emission factors). Absolute emissions are not only affected by leak tightness but also by the bank which is influenced by a variety of factors like number of installations, charge sizes, share of alternative refrigerants, economic cycle, etc. The problem that banks are not included in surveys can be avoided in new monitoring systems which are currently being established in some new Member States. Time series sufficiently long for determination of leakage rate trends are not expected before 2013.
- Records from installations, which are mandatory under Art 3 of the F-gas Regulation, offer the possibility to establish and adjust emission factors over time and already in the near future. Systematic evaluation of records is hampered by the low level of compliance with the recording obligation and the hesitation of service companies and operators to release internal data to be analyzed within a central assessment. As a consequence, logbooks have rarely been evaluated in the Netherlands or in Sweden although the maintenance of records has been mandatory for more than 15 years.

As feasible monitoring approach, it is suggested to undertake a statistical sample survey over several years based on records of a large number of selected installations, instead of surveys on the total equipment stock. Installations and participating companies should be identical over a long time; the survey should be performed in the most important application sectors, in all EU Member States. In doing so, a reliable picture of the emission rates over time could be achieved. Even though this approach could not guarantee to be representative of absolute amounts of banks and emissions, the long-term trend in emission factors could be surveyed, indicating success or failure of the containment provisions of the F-gas Regulation.

The authors of this report hold the position that such a “slimmed” approach could also fulfil Art 6(4) of the F-gas Regulation which requests MS to establish reporting systems for the relevant sectors referred to in this Regulation, with the objective of acquiring, emission data.

In 2010, statements about the trends of leakage rates in major sectors covered under the F-gas Regulation cannot be verified through empirical data yet.

Implementation of certification requirements

The measures under the F-gas Regulation are binding and directly applicable in all EU Member States with the exception of the establishment or adaptation of training and certification requirements (Article 5(2)), and rules on penalties (Article 13(1)) which relied upon further implementation. Provisions on training and certification (Art 5) have been complemented by Commission Regulations 303/2008–308/2008 and needed to be implemented on Member State level. Rules on penalties for non-compliance with the measures in the Regulation also had to be implemented at Member State level.

Training, qualification and certification of personnel and companies involved in the handling of F-gases is a central aspect of the F-gas Regulation to reduce emissions of F-gases by prevention of leakages (i.e. leakage checking by certified personnel, Art 3(2)) and by putting in place appropriate arrangements for the proper recovery of F-gases (recovery by certified personnel, Art. 4(1) respectively by “appropriately qualified personnel”, Art. 4(3)).

According to Art 5(2), Member States had to establish or adapt their training and certification requirements for both companies and relevant personnel involved in installation, maintenance or servicing of the equipment and systems covered by Art 3(1) as well as for personnel involved in the activities provided for in the Articles 3 and 4 by July 2008. The Member States had to notify the Commission of their certification/attestation bodies as of January 2009. Interim certificates (personnel and companies) expire on 4 July 2010 for the fire protection sector and on 4 July 2011 for the SRAC/HP sector at the latest.

<u>Status of notification by sectors</u>

As of 30 April 2010:

- Refrigeration and air conditioning: 16 Member States provided final notification of their certification bodies for the SRAC/HP sector and of their attestation bodies for personnel recovering F-gases from AC systems in motor vehicles.
- Fire protection: 14 Member States had submitted final notification of the certification bodies
- High voltage switchgear: 13 Member States had submitted final notification of the certification bodies. Some Member States have decided to make use of the possibility of training and certification for this sector in other Member States.

- F-gas based solvents: 10 Member States provided final notification of their certification bodies. 16 Member States (AT, BE, BG, CY, CZ, EE, HU, IE, LT, LV, MT, NL, RO, SE, SI, and SK) declared that F-gas based solvents were not in use at the time. Two of them (AT, IE) explicitly decided not to identify training programmes and certification bodies according to (EC) No 306/2008, Art. 6(2). Use of F-gas based solvents is prohibited in DK.
- All sectors: 18 Member States had notified interim certification schemes.
- All sectors: 5 Member States had not yet notified neither interim nor final certification (Greece, Italy, Latvia, Malta, and Romania).

Looking at the status of implementation of Art 5(2) according to the notification obligations of the Member States, a delay of more than one year can be identified as of 30 April 2010. 11 out of 27 Member States (40%) have not yet notified the required certification and attestation systems for the most important stationary refrigeration, air-conditioning and heat pumps (SRAC/HP) sector and the mobile AC sector. These 11 Member States account for about 44% of the 2008 F-gas emissions from commercial refrigeration, industrial refrigeration and stationary air conditioning (calculated by the model AnaFgas). Final notification for the fire protection sector is lacking from 13 Member States, in high-voltage switchgear from 14 Member States, and with regard to recovery of F-gas based solvents from 16 Member States.

Training and certification systems by sectors

The organisational and institutional setup for training and certification differs widely between Member States and sectors in terms of timely implementation. This applies to both certification of personnel and company certification.

As of first quarter 2010,

- Stationary refrigeration and air conditioning: training and certification systems for personnel and companies have been in place in compliance with the F-gas Regulation (interim or final notification, national implementing provisions, availability of training centres within the Member State) in 16 Member States, in 3 Member States at least partially and in 8 Member States not yet.
- Mobile air conditioning: Training and attestation of personnel handling the recovery of F-gases from AC systems in motor vehicles in conformity with the F-gas Regulation was possible in at least 17 Member States.
- Fire protection sector: in 15 Member States training and certification systems were not yet finally established for various reasons.
- High voltage switchgear: 8 Member States had implemented all necessary provisions for training and certification in the HVS-sector. Certification abroad is of high importance for this sector.
- F-gas based solvents: In the solvent sector, only one operating training centre was identified.

Status of personnel and company certification by sectors

Reliable data are not yet available. The percentages indicated are based on estimates.

- Stationary refrigeration and air conditioning: The percentage of certified companies (interim and full) ranges below 30% (entire EU). It can be assumed that most Member States will not achieve full certification by July 2011.
- Mobile air conditioning: about 1/3 of the personnel has been certified.
- High voltage switchgear: about 1/3 of the personnel has been certified.

The identification of the reasons for the delay in implementing the requirements of Art 5(2) and associated problems has to consider the different conditions in the EU Member States. Examples include:

- Structural and cultural differences in the political-administrative systems of the Member States, which impact the priority given to the implementation of the F-gas Regulation.
- Different baseline conditions regarding the vocational training systems and the existence of certification systems in sectors at the time of entry into force of the F-Gas Regulation.
- Differences in the number of staff involved and companies concerned in the various sectors and Member States, and differences in the availability of training and examination bodies in the Member States.

In early 2010 the application of training and certification provisions is still in a transition from earlier systems to current requirements. It is characterized by

- Big differences between the Member States with regard to the implementation of the training and certification schemes;
- Coexistence of interim arrangements and training/certification in final accordance with F-gas Regulation;
- Difference in availability of training and certification facilities between the individual Member States. The availability inter alia depends on the particular certification needs in the country (number of persons / businesses);
- Different validity of certifications (temporary/permanent certificates) and high differences in costs of certification.

Containment measures (Art 3)

The extent to which containment measures according to Art 3 are consistently applied in the individual Member States and in the individual stationary applications of F-gases differs widely within EU-27.

<u>Frequency of leak checks by sectors</u>

- Stationary refrigeration and air conditioning: Leak checks according to Art 3(2) are not performed consistently in all Member States and sectors. Experts from industry note comparably high compliance of operators of large equipment and low compliance of operators of small equipment.

  In Member States, where regular leak checks have already been performed prior to the F-gas Regulation on the basis of technical standards, voluntary commitments, or legal obligations, the frequency of leak checks is higher compared to other Member States.

Industry stakeholders assume that since entry into force of the F-gas Regulation the frequency of leak checks has increased to some extent however with considerable differences between the individual Member States. Quantitative information that would substantiate this assumption, are not available.

- Fire protection: data is only available from associations and a few high-industrialised Member States (DE, IT, UK). A comparably high level of compliance is reported. Leakage checks have already been carried out for a long time on the basis of specific technical requirements (e.g. ISO 14520). An increase in the frequency of leak checks, specifically caused by the F-gas Regulation, is not reported by stakeholders.

<u>Leakage detection systems</u>

- Stationary refrigeration and air conditioning: Leakage detection systems according to Article 3 (3) have been installed rarely so far. Upgrading of older equipment with leak detection systems takes place to a small extent only. Only the cold storage industry claims satisfactory rates of installed leakage detection systems, which have already been in place over a long time period.
- Fire protection: The FPS-sector reports a high rate of installed leakage detection systems in UK (75%) and Germany (99%) (referring to installations erected after 4 July 2007). These high rates are related to the long-time experience of the industry with similar requirements prior to the F-gas Regulation.

<u>Record keeping and quality of records</u>

According to the information from the authorities, control authorities in more than half (16) of the Member States have randomly requested records from operators ("logbooks", usually in paper form, but often electronic) in the past few years. There is de facto no comprehensive evaluation of these records in the Member States.

- Stationary refrigeration and air conditioning: Industry communicates that not more than half of the operators keep records. The compliance level by SRAC sub-sectors and by geographic regions is similar to that of leakage checks: high percentages are typical of the industry, large supermarkets and large commercial applications, low percentages are typical of small enterprises and light commercial equipment. There is also a drop in the compliance level of record keeping from northern to southern Europe. The quality of records, where they exist, has been mentioned to lack accuracy.
- Fire protection: Prior to the F-gas Regulation, records have been kept in accordance with ISO 14520. Industry estimates that about half of the companies have changed to records meeting the requirements of the F-gas Regulation (transition phase).

<u>Awareness by sectors</u>

- Stationary refrigeration and air conditioning: According to the information from small and medium-sized contractors, as well as from large international service companies, as many as half of the operators do not know their obligations under the Regulation. A clear difference in awareness between large companies and operators of large plants (industry, large supermarkets, and large commercial applications) on the one hand and small companies and operators of small equipment on the other hand has been observed. Staff of specialized companies have better knowledge and higher awareness than staff from companies that work only occasionally in the SRAC/HP-sector (mechanical and electrical contractors). Furthermore, a clear north-south gradient concerning awareness is reported.

- Fire protection: Industry estimates that about two-thirds of the operators in the UK and DE know their obligations.

It was generally communicated by industry stakeholders that operators' compliance and awareness of the requirements of the F-gas Regulation is highly dependent on enforcement by the authorities.

Impact of the provisions

Quantitative data regarding the impact of the containment requirements under Article 3 of the F-gas Regulation on total F-gas emissions is not yet available. This does not exclude potential mitigation effects from application of the containment measures according to Art.3. Such effects, however, cannot be quantified at present as necessary baseline data are missing. In addition, the time since entry into force of the F-gas Regulation is rather short and implementation is still in progress in many cases.

Recovery provisions (Art 4)

Article 4(1) covers stationary applications of refrigeration, air conditioning and heat pumps, equipment containing F-gas based solvents, stationary fire protection systems and fire extinguishers and high-voltage switchgear. The article applies to all equipment irrespective of the quantity of F-gases they contain. Recovery has to be done by certified personnel to ensure their recycling, reclamation or destruction (RRD). Similar provisions relate to refillable or non-refillable F-gas containers for transport or storage, which reach their end of life (Art 4(2). F-gases contained in other products and equipment, including mobile equipment (unless it is serving military operations) shall be recovered by appropriately qualified personnel to the extent that is technically feasible and does not entail disproportionate cost (Art 4(3)).

"Recovery", which must be executed by certified personnel in stationary installations, is carried out in the form of onsite recycling and as recovery for external RRD of the F-gas. Recovery for onsite recycling is performed by at least two thirds of the servicing companies in the SRAC-sector. It is also applied widely in the HVS equipment >52 kV. The recovered quantities for onsite recycling are not included in the reported data on recovery.

"Recovery" typically means the F-gas recovery for external RRD. The resulting quantities consist of F-gas removed during service/maintenance or of F-gas recovered at end of life before disposal.[18]

[18] In the IPCC Guidelines and in the model AnaFgas recovery relates to end-of-life only, irrespective of whether the following steps are carried out on site or in external facilities. The quantity which is not recovered at end of life is disposal emission. The disposal emission factor expresses the quantity of F-gases released to the atmosphere at end of life of equipment ("on disposal"). In the model AnaFgas a large number of sector specific disposal emission factors are used.

<u>Quantitative data by sectors</u>

- Stationary refrigeration and air conditioning: Quantitative data on F-gas recovered refrigerants which could be analysed hardly exists. Data from SNEFCCA and ADEME (France) show low recovery rates far below 10% of the annual refrigerant consumption. This confirms the general assumption that recovery before disposal is low and suggests a strong potential for F-gas emission reductions.

  Available data on recovery (France, UK) does show no or only a slight increase in recovered quantities of F-gases since 2006 (Table 6). The increase in refrigerant reclamation in UK is completely caused by HCFCs (R-22).

Table 6: Refrigerants recovered in France and UK, 2007-2009 (metric t)

	Refrigerants returned for reclamation/destruction	**2007**		**2008**		**2009**	
		t	%	t	%	t	%
France	HCFC/HFC (t)	500	*100*	550	*110*	660	*132*
UK	HCFC/HFC (t)	979	*100*	971	*99*	1207	*123*
	R-22 reclaimed (t)	205	*100*	210	*102*	522	*255*
	HCFC/HFC returned without R-22 (t)	774	*100*	721	*93*	685	*89*

- Fire protection: Recovery for recycling on site does not take place. In most cases containers with unused charges of extinguishing agents are returned to the manufacturers who subsequently carry out recovery and recycling of the F-gases.. Compiled data for this branch of industry are not available.
- High voltage switchgear: SF_6 is recovered from "closed systems" during the servicing of the equipment (on site recycling) and generally before disposal. Because of the long lifetime of the systems, recovery before disposal currently plays only a minor role compared to the SF_6-stock in equipment but will become more important as of 2010. Quantitative data from Germany show that the recovered quantity of SF_6 for reclamation/destruction has increased slightly from 2005 to 2009. In certain Member States such as France, Germany and the UK, co-operation between HVS manufacturers, utilities and SF_6 producers has been intense for many years now. The European SF_6-producer has established a reuse system in which HVS operators and utilities from many Member States participate. Commitments to reduce emissions have been laid down in a series of voluntary agreements (see section on national F-gas policies).
- F-gas based solvents: Industry could not provide data on recovery in this sector.

<u>Availability of reclamation and destruction facilities for F-gases</u>

The availability of reclamation and destruction facilities in the Member States and access to such facilities abroad is essential for the RRRD process. The survey shows that 12 of the EU-27 Member States do not have F-gas reclamation facilities in their territory. 15 Member States do not have any destruction facilities. This results in the need for pronounced cross border transport of used F-gases.

In the SRAC-sector, more recovered F-gas is reclaimed than destroyed. Reprocessing of HFCs is only done if sufficient quantities are available to make the process profitable. In countries with an F-gas market below 1,000 t/a (e.g. Austria), the amount of refrigerants returned for reclamation is considered to be too small to offer reclaim at lower prices than for virgin F-gases, especially HFC blends. In addition to the technical costs, costs for logistics (e.g. special cylinders and transport and administrative costs for hazardous waste) need to be taken into account. Reclamation is currently focusing on HCFC R-22.

Reporting requirements (Art 6)

The reporting system according to Art 6(1) of the F-gas Regulation is well-established. All large producers/importers/exporters fulfil their reporting obligation, the reported sales and production quantities of F-gases are well within acceptable statistical error range. The F-gas reporting system benefits from the preceding reporting system on ODS, which had been established seven years earlier for the majority of the present participants. Control and enforcement mechanisms seem to be not fully active at this point in time. Reporting of recycled, reclaimed, or destroyed quantities can be used to complete the picture of the overall RRRD quantities within the EU.

Importers and exporters are not obliged to report on F-gas quantities contained in equipment. The lack of information on these quantities might have serious consequences for the data quality and the assessment of the F-gas emission potential within the EU-27.

Table 7 shows that exports of F-gas contained in pre-charged equipment amounted to ca. 8,000 tonnes and imports of F-gas to about 8,700 tonnes in 2008. Imported quantities of F-gases contained in pre-charged equipment represent almost 13 % of the total import of bulk F-gases covered under reporting obligations. Export of F-gases contained in pre-charged equipment represents ca. 42% of the exported quantities reported.

Table 7: 2008 import and export of F-gases contained in pre-charged equipment, which is currently not covered under reporting obligations.

		Import		**Export**	
Sector	**F-gas**	**metric t**	**CO_2 eq (Mt)**	**metric t**	**CO_2 eq (Mt)**
Automotive	HFC-134a	1,694	2.20	2,389	3.11
Stat Air Con	R-410A	7,002	13.83	negl.	negl.
OCF	HFC-134a	0	0	2,100	1.99
MDI	134a, 227ea	0	0	3,135	4.15
Switchgear*	SF_6	negl.	negl.	460	10.21
Total		8,697	16.03	8,084	19.46

Source: Öko-Recherche survey 2010.

Although in metric tonnes, imports and exports in charged equipment balance each other almost, the consideration of pre-charged F-gases significantly shifts the composition of the emission potential by individual F-gas types. The distortion of the reported emission potential is evident when looking at the global warming potentials. A clear difference between import and export in 2008 was found which amounts to 3.4 million t CO_2 eq.

The estimation of potential F-gas emissions would improve significantly if F-gases contained in pre-charged equipment would be included in the reporting requirements.

A review option on whether to include F-gases contained in pre-charged equipment in the reporting obligations according to Art 6 will be discussed at a later stage of the project.

Cost assessment

The ex-post assessment of the current EU F-gas policy includes an assessment of the cost of implementation of the F-gas Regulation in the Member States and an assessment of the cost effectiveness of the reduction of emissions. The assessment of cost effectiveness is not included in the work undertaken so far as it relies on data concerning emission reductions caused by the measures of the EU F-gas legislation, which are not available at this stage for all measures. The cost effectiveness of measures to substitute HFC-134a in automotive A/C systems is examined at the international level in the context of a potential HFC agreement (see relevant report).

The costs for implementation of the current policy measures include:

- Public administrative costs (bureaucratic costs) for personnel certification and certificates of companies (Art 5), monitoring of the provisions of the Regulation and sanctioning of their infringements (enforcement) (Art. 13);
- Additional costs including expenditure of time for companies resulting from leakage control and documentation (Art. 3), recovery (Art 4), training and certification of personnel and companies (Art 5), reporting (Art 6) and labelling (Art 7).

One-time costs, e.g. for the establishment of certification schemes, and current costs, e.g. for operation of leak detection systems, must be distinguished.

To put the assessment on a broader basis, administrative costs and costs for companies resulting from the provisions of the F-gas Regulation from some Member States and industries have been determined so far. The ranges of public administrative costs seem to differ largely between Member States, and additional data still need to be collected.

One-time costs for certification courses range between ca. € 100 and over € 1,000, depending on sector and duration of the programme. Companies calculate the costs per person 2-5 times higher, accounting for absence from work, travel expenses, etc. Concern was raised about unequal costs as a result from validity differences of certifications.

Annual costs for leakage control are calculated with € 50–200 per installation/circuit. Annual costs for testing of leak detection devices were estimated to be about 120 € (fire protection sector). Additional costs for record keeping are estimated to be low but depend on whether documentation systems exist or not.

In general stakeholders consider the cost burden created by the F-gas Regulation to be within acceptable ranges. In the past, an average cost effectiveness per tonne of <20 € was assumed on the basis of the implementation costs of STEK-Regulation in the Netherlands and the assumption that emission reductions of 15 million t CO_2 eq. could be achieved by 2012 (Enviros 2003). In the course of this project it will be necessary to further verify whether such a scale is realistic.

Assessment of needs for clarification and simplification of the F-gas Regulation

An assessment of needs for clarification and simplification of the F-gas regulation was based on the following input:

- First, experience of the persons executing the application of the F-gas regulation in the Member States and individual industries has to be considered.

- Second, the assessment of the recent impacts of the F-gas regulation needs to be the basis of the assessment. Although a lot of information has been obtained so far, review and evaluation are currently ongoing.

Issues to consider further include for instance:

- Review of some definitions and terms (e.g. "operator", "disproportionate cost", "hermetically sealed systems", "container" and "non-refillable container", "equipment", "application"). Some general definitions seem to be different in ODS- and F-gas Regulation, irrespective of the objectives of both regulations.
- Addition of definitions (e.g. "application", "transport refrigeration systems").
- Review of some terms and provisions that may need to be specified, because they are too general (e.g. "leakage detection system"; the requirements of Art 6 (4)).
- Review of potential inconsistencies in some specifications (e.g. inconsistencies in the specification of work for technicians according to categories 1-4/SRAC sector).
- Review of the need and possibility of the clarification of regulations which are handled differently in different Member States, with the objective of harmonized application in the Member States (e.g. validity of certifications).

3.3. Feasibility of emerging options for an international emission reduction arrangement for HFCs and other F-gases

Within the assessment of the feasibility of emerging options for an international HFC arrangement, a bottom up model was developed providing aggregated Business as Usual (BAU) scenario for the future demand (consumption) for HFCs in industrialised countries (A2 countries) and developing countries (A5 countries), and each of the relevant sectors (Mobile AC, Domestic Refrigeration, Commercial Refrigeration, Refrigeration Transport, Industrial Refrigeration, Stationary Air Conditioning and Foam).

For each of the sectors abatement options (AOs) to reduce HFC consumption by replacing high GWP HFC applications with applications using low GWP alternatives were identified, and the applicability and the costs for introducing such options were analysed. In total 134 industrial abatement options (93 for refrigeration and AC, 41 for foam applications) were assessed separately for A2 and A5 countries, with special focus on their market penetration potential until 2015, 2020 and 2030.

Marginal abatement cost curves (MACCs) were established for abatement options

- on a global level,
- separately for A2 and A5 countries, and
- separately for each of the sectors.

For each of the sectors, the penetration potential of the most relevant abatement options in A2 and A5 is described in the report.

Based on the MACCs analysis, several abatement scenarios and their costs implications were developed.

This bottom up analysis was compared with the proposals on a control regime for HFCs under the Montreal Protocol submitted in 2010 by North America and Micronesia. For the different scenarios a ranking of options was undertaken.

The study started analysing key elements of an effective control regime under the Montreal Protocol and implications for a future regime on HFCs by specifically looking at substances to be included in a future regime, different baselines, aspects of a control regime, costs and funding options. The work undertaken so far comprises also an initial analysis of options for such a future international control regime.

In the course of this study, the analysis of the different proposals for a potential international regime will be developed further taking into account outcomes of upcoming international discussions and negotiations on the topic. Moreover, upcoming cross-conventional issues and additional elements related to internationally regulated HFC reduction will be considered in the course of further work.

3.3.1. Consumption of HFC in Business as Usual Scenario

The analysis of the BAU Scenario shows strong underlying demand for refrigerants and blowing agents in both A2 and A5 countries. World consumption of HCFCs and HFCs as market dominating refrigerants and blowing agents will grow from current 1.3 Gt CO_2 eq. annually to over 3 Gt CO_2 eq. by 2030 (Figure 10).

As stated above, the transition away from HCFCs is just about to start in developing countries and the demand for HFCs is expected to almost triple from current 0.7 Gt CO_2 eq. to over 2 Gt CO_2 eq. in 2030. In A2 countries demand will grow at a lower rate from currently 0.7 Gt CO_2 eq. to over 1 Gt in 2030.

Demand for refrigerants is largely driven by the air conditioning sector in A5 countries. Other sectors, such as industrial refrigeration, refrigerated transport and commercial refrigeration will also see substantial growth in A5.

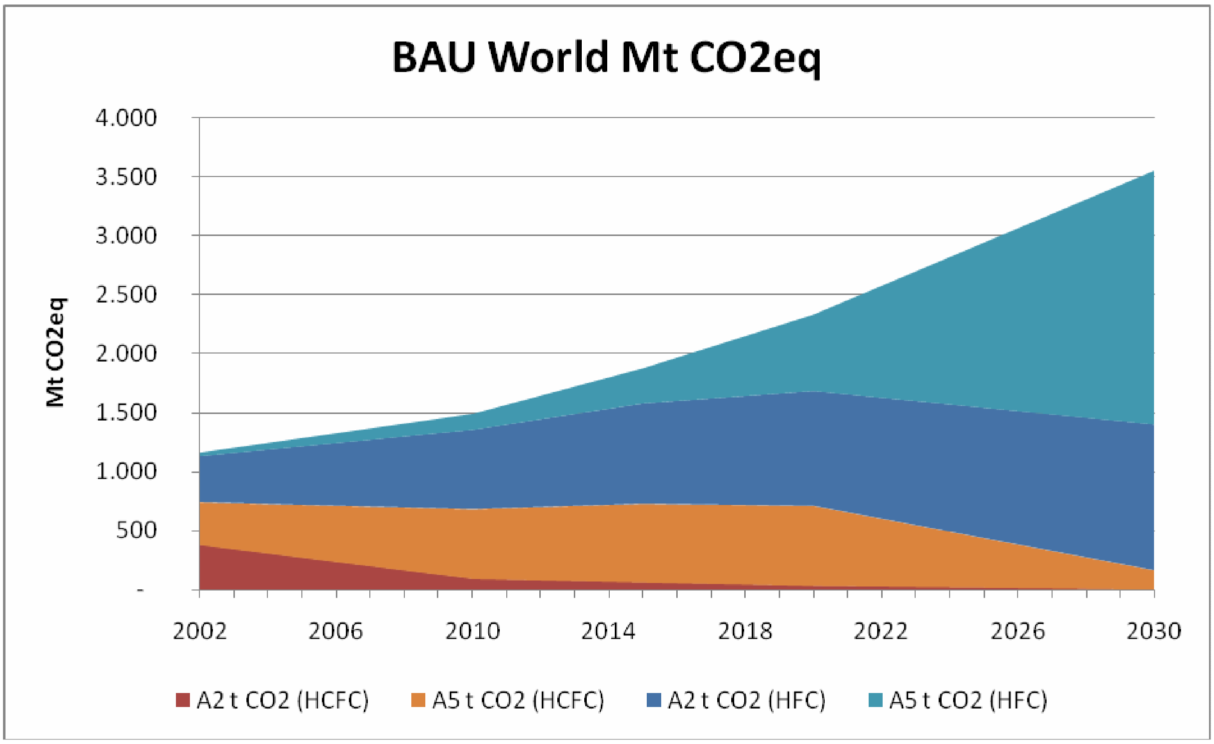

Figure 10: BAU consumption trend for A2 and A5 countries until 2030

So far, the Montreal Protocol controls ozone depleting substances (ODS), including CFCs and HCFCs. Under the control regime of the Montreal Protocol, the Parties decided on an accelerated phase out of HCFCs. To a large extent, Europe has completed this phase out. Most HCFCs have been replaced by HFCs but alternatives to HFCs, like hydrocarbons, CO_2 or ammonia have also been introduced, for example in domestic refrigeration (HC-600a). Outside Europe, the US still rely heavily on HCFCs and in A5 countries HCFC refrigerants and blowing agents are still the preferred choices.

In the BAU scenario A5 countries will change from the current use of 0.6 Gt CO_2 eq. of HCFCs and 0.1 Gt of HFCs to over 2 Gt CO_2 eq. of HFCs by 2030 due to the accelerated phase out of HCFCs under the Montreal Protocol. Given the life time of some equipment, e.g. the lifetime of chillers is assumed to range between 20 and 30 years, decisions on alternatives to HCFCs are taken today and will determine the consumption of HFCs by 2030. A5 countries, and to some extent A2 countries that have not completed the HCFC phase out, are facing the choice between HFCs, which are characterized by their high GWP, and alternatives to HFCs, which show low or no GWP.

At present, funding under the MP still allows the conversion from ODS to HFCs. Although the funding plan provides additional incentives to change over to low GWP alternatives, without a clear control regime of HFCs, current incentives will not be sufficient to avoid strong growth of HFCs as projected in the BAU scenario. HFCs are still considered the easy drop in substitute whereas hydrocarbon and other alternatives require new product and production designs and manufacturing processes. Based on past experience, consumption of HFCs will eventually lead to significant emissions and represent a major driver for a further growth in global greenhouse gas emissions.

The analysis shows that abatement options are available within all key sectors currently consuming HCFCs and high GWP HFCs. In most sectors a significant proportion of consumption can be replaced by available technologies using low GWP alternatives at negative costs when looking at the full lifecycle of the product. Investment costs of low GWP alternatives are usually higher than the costs of high GWP applications. However, lower refrigerant costs and electricity consumption reduce the maintenance cost significantly. With some of the abatement options reaching significant market penetration and scale, marginal abatement costs will decrease over time. Applicability and, consequently, penetration rates will grow. Furthermore, the overall abatement potential will increase. Abatement options are most critical in sectors where most of the future demand will occur.

Overall, the analysis suggests that **ambitious consumption controls of HFCs can be carried out at negative or low positive costs.** Some technologies show negative cost, which means that they imply a net welfare gain from an overall economy viewpoint. Positive cost indicates a welfare loss. Classification of abatement technologies by costs results in the “marginal abatement cost curve” (MACC) shown in Figure 10. Accumulating the costs and benefits of all abatement options leads to the conclusion that a cost-effective transition to low GWP alternatives is feasible.

The abatement scenario is largely based on the in-depth bottom up analysis carried out by different experts and through various industry interviews. Assumptions for the different sectors are listed in annex. During the course of the project, further refining of the assumptions and data/results based on further discussions, inter alia in the context of steering group and expert group meetings will take place.

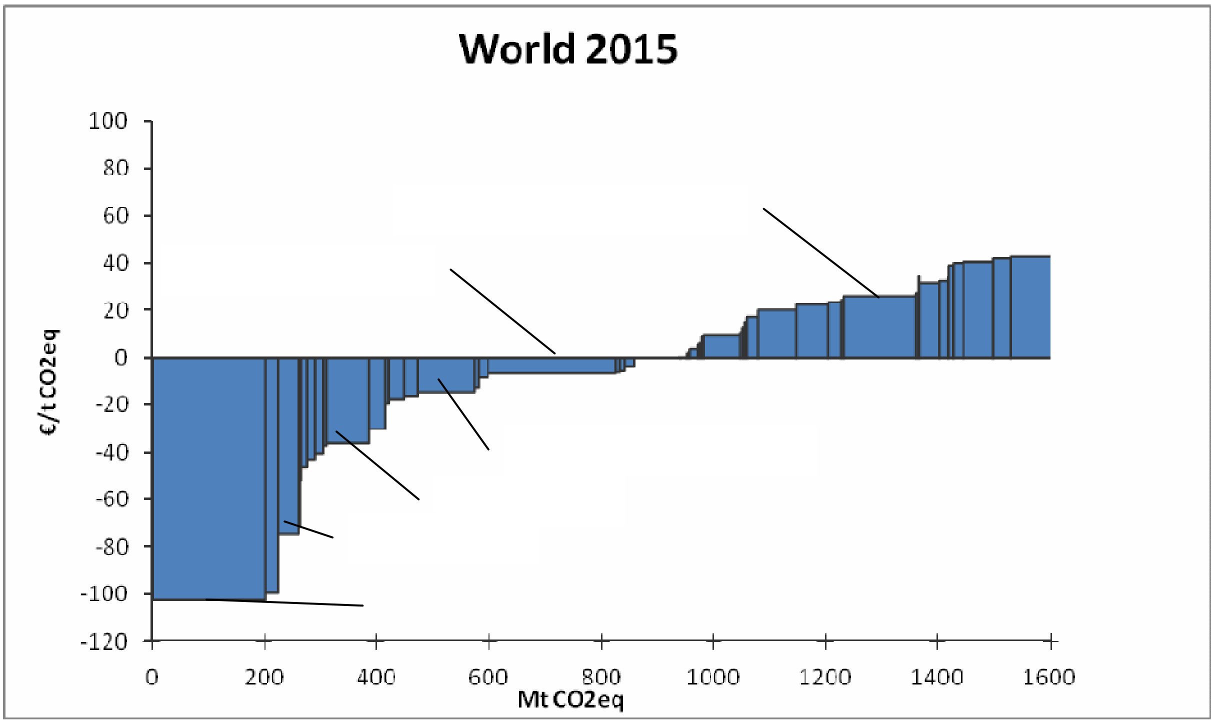

Figure 11: The table shows the MACCs across all sectors in A2/A5 (examples shown are only a selection out of 134 abatement options analysed).

Early phase in of low GWP alternatives will be most important in A5 countries, where major investments and purchases of new equipment will be made. Early change to low GWP alternatives will avoid double or triple conversion costs from HCFCs to HFCs or in some cases from CFCs to HCFCs to HFCs and finally to low GWP alternatives, and will allow low carbon technologies to grow significantly and reach their full economies of scale. In case the window of opportunity for the introduction of low GWP alternatives is missed now, servicing and refill of old equipment with high GWP substances will cause significant emissions in the near and distant future. The BAU scenario shows that servicing demand will reach almost 50% of future consumption for HFCs in 2020 and 2030.

Compared to the BAU scenario, significant emission reductions can be achieved though the given abatement technologies. Three scenarios with different threshold values are illustrated and compared with BAU (Figure 12):

RED	maximum technically feasible consumption reduction (regardless of costs)
MIT 0€	all abatement options with negative costs
MIT BE	Negative costs are used to balance out the positive cost. The cut-off is where the cumulated costs over all applied abatement options is zero. A2 and A5 countries are considered separately

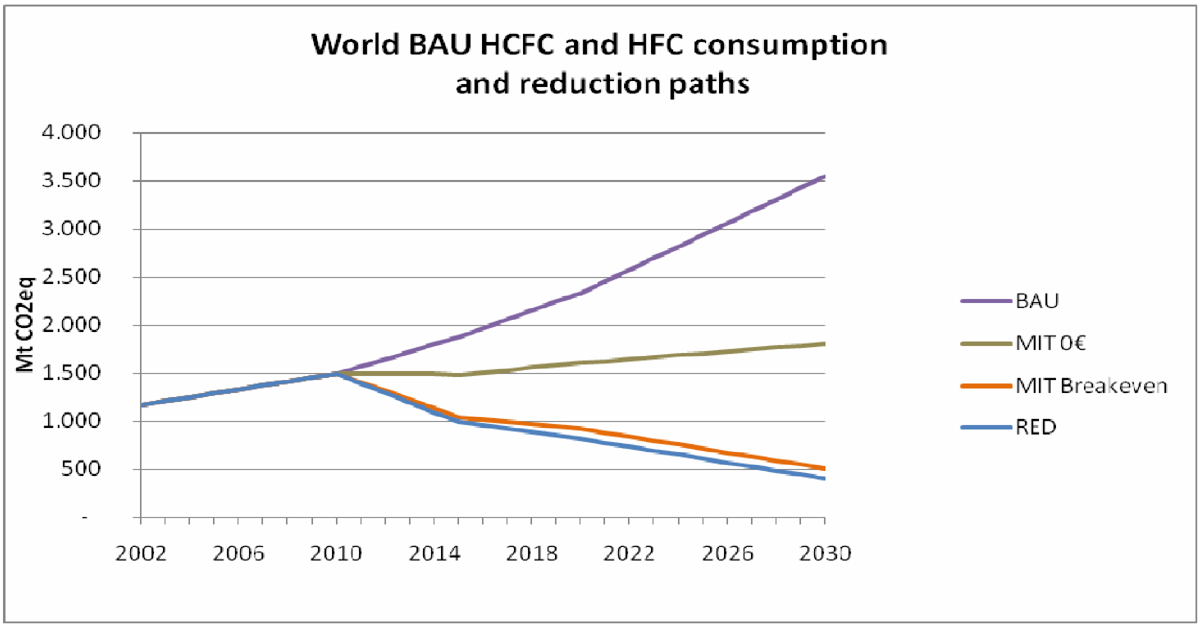

Figure 12: BAU and RED consumption trends until 2030

3.3.2. International Control Regime for HFCs

The Montreal Protocol has established a cost-effective approach by setting caps for consumption of ODS, which are gradually reduced and finally lead to phase out. If similar principles were applied to HFCs, large greenhouse gas emission reductions could be possible. Hence it is since 2009 being discussed to include HFCs in the Montreal Protocol regime.

In 2010 two proposals to control HFCs were submitted by the Federated States of Micronesia (FSM) and the North American countries US, Canada and Mexico (NA) building upon similar proposals submitted in the previous year. The key elements of the proposals are shown in tables 8 and 9, and are compared with possible features of the RED Scenario (maximum technically feasible abatement potential) developed in the context of this study.

Table 8: HFC reduction proposals for A2 countries.

Summary A2 countries	NA		FSM		RED	
Proposed Baseline	Combined HCFC and HFC consumption		Combined HCFC and HFC consumption		25% of HCFC baseline plus HFC consumption or 125% of HFC cons.	
Baseline years	2004-2006		2004-2006		2004-2006 combined or 2007-2009 HFCs only	
Year of first control level	2014		2013		2014	
Proposed First Control level (Freeze level)	90%		85%		85%	
Final phase down level	15%		10%		10%	
Year of final step down	2033		2030		2028	
Total baseline Mt CO2eq	769		769		647 or 753	
Control schedule	2014	90%	2013	85%	2014	85%
	2017	80%	2016	70%	2016	70%
	2020	70%	2019	55%	2019	50%
	2025	50%	2022	45%	2022	30%
	2029	30%	2025	30%	2025	15%
	2033	15%	2028	15%	2028	10%
			2030	10%		

In the RED scenario, an adjusted HCFC and HFC baseline reflects existing differences in the composition of HCFCs and HFCs and, therefore, helps mitigating distortions in the competitive playing field between the regions. Furthermore, it accounts for a fair distribution of allowable tail consumption between the regions.

Table 9: HFC reduction proposals for A5 countries.

Summary A5 countries	NA		FSM		RED	
Proposed Baseline	Combined HCFC and HFC consumption		HCFC consumption		HCFC consumption	
Baseline years	2004-2006		2007-2009		2005-2007	
Year of first control level	2017		2019		2015	
Proposed First Control level (Freeze level)	90%		85%		100%	
Final phase down level	15%		10%		10%	
Year of final step down	2043		2036		2040	
Total baseline Mt CO2eq	722		923		709	
Control schedule	2017	90%	2019	85%	2019	85%
	2021	80%	2022	70%	2022	72%
	2025	70%	2025	55%	2025	60%
	2029	50%	2028	45%	2028	50%
	2035	30%	2031	30%	2031	40%
	2043	15%	2034	15%	2034	30%
			2036	10%	2037	20%
					2040	10%

For phase down in A5 countries, the RED scenario suggests an earlier control level to limit the growth of HFCs until the first freeze, thereby promoting low GWP alternatives.

It is estimated that the proposals and the RED scenario would yield an accumulated reduction potential of 22-28 Gt CO_2 eq. by 2030 and 130-141 Gt CO_2 eq. by 2050, compared to BAU.

Table 10: Summary of possible HFC reduction of analyzed proposals.

Region	Proposal	2030	2050
Cumulating resulting reductions in Mt CO_2 eq.			
World			
	RED	28.023	141.635
	FSM	24.752	138.325
	NA	22.766	133.787
A2			
	RED	15.798	48.504
	FSM	13.710	46.174
	NA	11.210	42.673
A5			
	RED	12.225	93.131
	FSM	11.041	92.152
	NA	11.555	91.114

Figures 13 and 14 show the differences of the annual reduction of consumption as suggested by the two proposals (FSM, NA), and the RED scenario for comparison. Our analysis shows that the abatement steps suggested by the RED scenario are technically feasible for both A2 and A5 countries

With regard to A2 countries, an earlier phase down and lower tail consumption are included in the FSM proposal. For A5 countries, the FSM proposal suggests a comparably long grace period, followed by relatively steep cuts in consumption and low tail consumption.

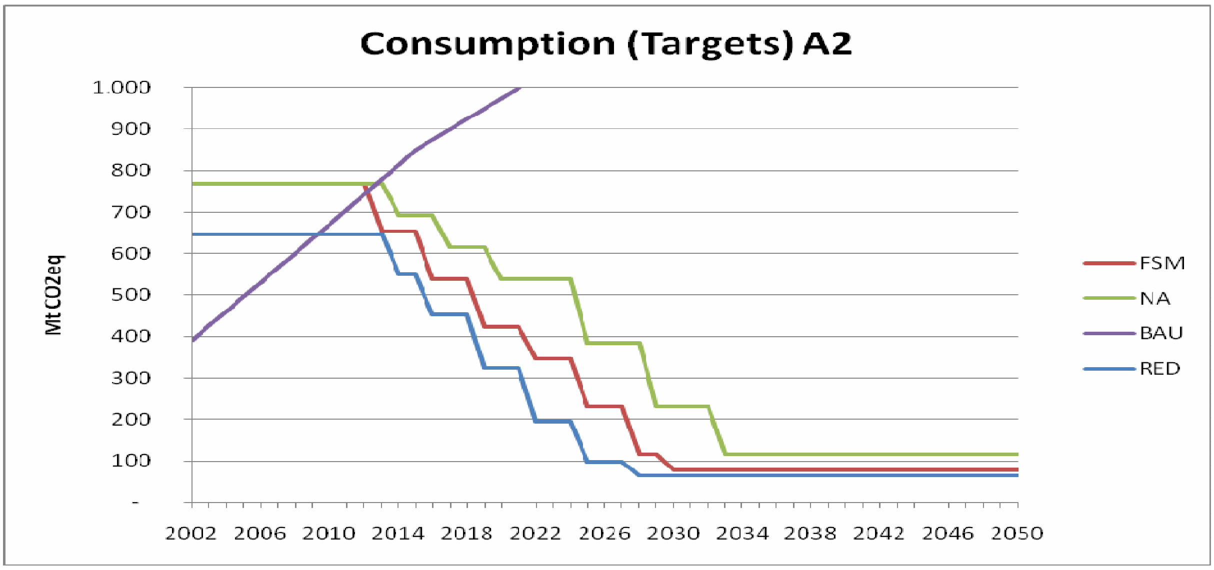

Figure 13: Proposed consumption targets for A2 countries

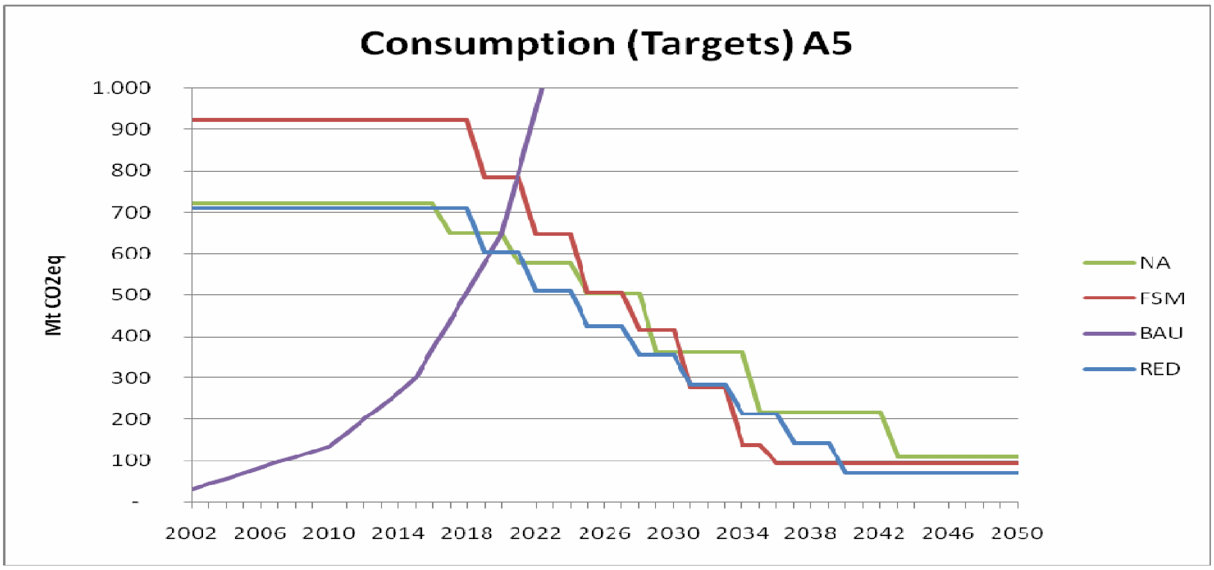

Figure 14: Proposed consumption targets for A5 countries

3.3.3. Substances

In principle, a new control regime would apply the principles of the CFC and HCFC phase out to HFCs. The NA and FSM proposals suggest including all HFC substances currently on the market under such a control regime.

Alternatively, HFC substances with a low or negligible GWP[19] could be excluded. In case that not all HFCs were covered by a control regime, the GWP would need to be sufficiently low in order to avoid substantial "leakage" effect given the strong demand in A5 countries.

Table 11 shows that consumption in 2050 could be as much as 5 times higher compared to the control regime suggested by the North American proposal, if a GWP threshold of 150 was introduced.

Table 11: Potential HFC consumption in 2050 under various GWP thresholds.

GWP Threshold	Proposal	0 *	> 30	>150
A2 (t CO_2 eq.)	NA	115.395.511	139.517.667	186.020.622
	FSM	76.930.340	101.615.610	200.356.687
A5 (t CO_2 eq.)	NA	108.302.163	236.006.291	496.894.456
	FSM	92.287.954	170.253.539	482.115.878
World (t CO_2 eq.)	NA	223.697.674	375.523.957	682.915.078
	FSM	169.218.294	271.869.148	682.472.566

*all HFC included in the allowable tail consumption

Additional considerations for the introduction of a GWP limit include:

- No scientific background exists for drawing a line between low and high GWP substances; a model classification proposed by TEAP is highly controversial among parties.
- Import controls for substances in A5, when reported under separate national codes and subheadings, distinguishing between controlled HFC and uncontrolled HFC and mixtures has high potential to lead to inconsistencies of reporting

To include all low GWP substances, low GWP HFC and low GWP non-HFCs in a control regime is not recommended, given complex implications where natural agents are used as technical gases or fuels. Introducing a minimum GWP for all substances is extremely complex and impractical.

[19] Key arguments for excluding HFCs with low GWP from the regime:

- To provide an incentive for the development of refrigerants below the threshold.
- To avoid additional administrative burden for regulation of such newly developed substances.
- To avoid the need for amending the MP with every new substance below threshold.
- To avoid unbalanced market interventions, by regulating low GWP HFCs but not natural refrigerants with comparable low GWPs.

3.3.4. Production and Consumption controls

The effectiveness of the Montreal Protocol is based on the principles of production and consumption controls. For introducing such control regimes, the following recommendations are provided.

Reporting/ synergies between the Kyoto and Montreal Protocol:

- Any control regime under the Montreal Protocol should be additional to the Kyoto Protocol in order to not undermine commitments and reporting requirements agreed under the Kyoto Protocol.
- Reporting should be undertaken both on the basis of emissions (CO2 eq. per tonne) similar to the previous Tier 1a[20] reporting under UNFCCC on potential emissions and in addition under the MP. (Production and consumption of HFC (export and import) will be reported under the MP) .This would include destruction of chemicals. An extension could include reporting of chemical containing products in import and exports as under previous Tier b. Reporting should be consistent and harmonized. HFC 23 reporting could be maintained as under UNFCCC

Production:

- Production of HFCs is shifting to A5 countries, especially to China. While the production of CFCs and HCFCs during their phase out was more equally distributed between A5 and A2, controls of HFC production could easily create trade distortions.
- Cuts in production need to be balanced with the demand in A2 (Europe) and the supply from A5 countries; unbalanced cuts of supply need to be avoided.

HFC-23:

- The proposals on HFC phase down include controls of HFC-23, which is generated as a by-product in the production of HCFC-22 for emissive uses (phased out under the Montreal Protocol) and feedstock. Feed stock production, process agents and emissions have, so far, not been funded under the MP. Such HFC-23 controls could be introduced either as an amendment to the existing HCFC controls or the newly proposed HFC controls. It needs to be taken into account that a decision on controls of HFC-23 may set precedence for further discussions of proposals on funding emissions, feedstock or process agent use, and needs to be reflected in formulating decisions.
- HFC-23 control should reflect and support the 30th OEWG proposal to update information on HCFC-22 production facilities, develop estimates of incremental costs associated with the collection and destruction of HFC-23 by-product emissions, and review options for the development and implementation of HFC-23 by-product control projects.

Consumption Controls, Baseline and Reduction Steps

[20] Tier 1a on potential emission included:
Production of chemical + Import of chemical in bulk – Export of chemical in bulk – Destruction of chemical = Sum (potential emission of chemical)

- **Baseline**: The selection of the baseline is essential to establish control steps and aggregated funding targets. For A2 countries both existing proposals suggest a combined HCFC and HFC baseline. As Europe has almost fully converted out of HCFCs, an HFC-only baseline or an adjusted baseline calculated as percentage of the allowable HCFC consumption would better acknowledge Europe's efforts of early phase out of HCFCs. For A5 with low or no consumption of HFCs, the use of an HCFC baseline is more appropriate, because of the non-availability of data. A lower baseline reduces aggregated funding requirements most effectively.
- **Freeze**: An early freeze level for A5 will avoid or reduce the possibility of converting from HCFCs to HFCs.
- **Reduction Steps:** Given the strong increase in demand for refrigeration and air conditioning in A5, early reduction steps are very important. In A5 countries HCFC phase out and HFC phase down could be harmonized in order to avoid a second conversion process.
- **Tail:** The allowable level of consumption should be fair and sufficient to meet the consumption needs of the countries. The level depends on the methodology applied for establishing the baseline.

3.3.5. Funding of the HFC Phase Down Scenario under the MLF

A phase down of HFC under the MP should include financial support through the MLF, based on accepted standards and procedures. There are a number of factors that influence the total cost of a funding regime under the MLF:

- The starting point which determines the aggregated funding baseline (generally based on the established consumption baseline)
- The eligibility criteria for funding established manufacturing capacities (e.g. cut-off-date)
- Availability and costs of alternatives and subsequently the thresholds for cost effectiveness of individual subsector phase down activities
- Phase in of HFCs under the HCFC phase out activities
- Arrangements for dealing with production phase down and by-product emissions of HFC-23

The various costs elements suggest an estimated total funding requirement for the HFC phase down of 5 to 11 billion Euros or ten replenishing periods with funding in the range of 500 to 1000 million[21] from freeze to 2050.

The lower range is calculated on the basis of historic cost effectiveness criteria of the MLF applied under the present HCFC phase out. The upper cost range is based on the experts' estimates of actual incremental costs for conversions in each subsector and take into

[21] Indicated costs levels are undiscounted and without consideration of exported consumption (not eligible for funding), which result in further reduce costs in the range of up to 20%.

consideration that some of the low GWP alternatives to HFCs (such as HC and CO_2) require more expensive transition and system changes similar to the approved HCFC guidelines.

4. Next steps

Based on these preliminary findings, as further developed inter alia with input from the Steering and Expert Groups supporting the review, possible options for review of Regulation (EC) No 842/2006 will be identified and developed, in the light of the following main objectives:

- To contribute to current or future climate change goals;
- To ensure compatibility with potential international commitments for HFCs, in particular under the Montreal Protocol;
- To upgrade existing legislation through clarification and enhancement of the effectiveness and efficiency.

An assessment of the likely economic, social and environmental impacts of all options identified will be undertaken and discussed within the coming months. The outcome of this impact assessment will lead to comprehensive recommendations for the review of the F-gas Regulation.

5. Annex

Assumptions underlying the model AnaFgas

Refrigeration

AnaFGas 1.2			**Refrigeration**				
			Domestic	Commercial	Industrial	Road transport	Ship (fisheries)
General assumptions							
	Gases concerned		HFC 134a	134a; 404A	404A	134a; 404A	404A
	Charges	kg	n.e.	n.e.	different for each sector	2.2 for vans; 6.5 for trucks and trailers	from 17 (medium vessels) to 8000 (fish factories converted
	Lifetime	years	15	Central systems: 12; condensing units: 15; hermetic units: 15	20 for ice rinks and other industry; 30 for all other sectors	8	40
WOM Scenario							
	Emission factors						
	EF Manufacturing	% / year	Country specific; Min: 0.6; Max: 5.0				
	EF Lifetime	% / year	Country specific; Min: 0.1; Max: 1.0	Central systems: 15; condensing units: 7; hermetic units: 1	10 for ice rinks, other industry and milk farms; 15 for all other sectors	30 for vans; 20 for trucks and trailers	40
	EF Disposal	% / year	50; SE: 5	Central systems: 30; condensing units: 50; hermetic units: 70	30	30	30
	EF By-product	% / year					
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)							
	Emission factors						
	EF Manufacturing	% / year					
	EF Lifetime	% / year		Central systems: 9; condensing units: 4.2; hermetic units: 1	6.7 for ice rinks, other industry and milk farms; 10 for all other sectors		
	EF Disposal	% / year	30; SE: 5	Central systems: 20; condensing units: 25; hermetic units: 35	20		
	Other Gases						
	Other Reduction measures						

Stationary A/C and heat pumps

AnaFGas 1.2			Stationary A/C and heat pumps			
			Room A/C	VRF & Packages	Chillers	Heat pumps
General assumptions						
	Gases concerned		407C; 410A	VRF: 410A; Packages: 407C; 410A	407C; 410A	404A; 407C; 410A
	Charges	kg	Moveables: 0.75; Split: 1.5	VRF: 13.5; Packages: 10.5	minichillers: 2; <100 kW: 10; >100 kW: 95; centrifugal: 700	2.7
	Lifetime	years	10	VRF: 13; Packages: 10	15	15
WOM Scenario						
	Emission factors					
	EF Manufacturing	% / year				
	EF Lifetime	% / year	5	5	7	3.5
	EF Disposal	% / year	70	30	30	70
	EF By-product	% / year				
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)						
	Emission factors					
	EF Manufacturing	% / year				
	EF Lifetime	% / year		3	4.2	
	EF Disposal	% / year	35	20	20	
	Other Gases					
	Other Reduction measures					

Mobile Air Conditioning

AnaFGas 1.2			Mobile Air Conditioning				
			Car A/C	Bus A/C	Truck A/C	Ship A/C	Rail A/C
General assumptions							
	Gases concerned		134a; 1234yf	HFC 134a	HFC 134a	HFC 134a	HFC 134a
	Charges	kg	1993: 0.943; decreasing until 2007 to: 0.625	1993: 12; decreasing until 2016 to: 10.4	N1:1993: 1.0; decreasing until 2016 to: 0.81; N2: 1.0; N2: 1.2	Cruise: 6400; Passenger: 520; Cargo+Container: 160	Rail: 18; Tram: 30; Metro: 10
	Lifetime	years	12	10	10	40	30
WOM Scenario							
	Emission factors						
	EF Manufacturing	% / year					
	EF Lifetime	% / year	10	15	N1:10; N2+N3: 15	40	8
	EF Disposal	% / year	70	30	70	30	30
	EF By-product	% / year					
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)							
	Emission factors						
	EF Manufacturing	% / year					
	EF Lifetime	% / year					
	EF Disposal	% / year					
	Other Gases		1234yf or CO2 in 2012, from 2017 on the only refrigerant				
	Other Reduction measures						

Foams

AnaFGas 1.2			**Foams**		
			One Component Foam	PU foam	XPS
General assumptions					
	Gases concerned		HFC 134a	HFC 365mfc, 245fa, 134a, 152a	HFC 134a, 152a
	Charges	kg	0,11	n.e.	n.e.
	Lifetime	years	1	50	50
WOM Scenario					
	Emission factors				
	EF Manufacturing	% / year	100	Default: 10 Sprayfoam 15	HFC 134a: 30; HFC 152a: 100
	EF Lifetime	% / year		Country specific or default: 1	HFC 134a: 0.75; HFC 152a: n.a
	EF Disposal	% / year		n.e.	n.e.
	EF By-product	% / year			
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)					
	Emission factors				
	EF Manufacturing	% / year			
	EF Lifetime	% / year			
	EF Disposal	% / year			
	Other Gases				
	Other Reduction measures		Prohibition of placing on the market except for safety standards		

Other HFCs

AnaFGas 1.2			Other HFC			
			Aerosols	Metered Does Inhalers	Solvents	Fire Extinguishers
General assumptions						
	Gases concerned		HFC 134a	HFC 134a, 227ea	HFC 43-10mee, 134a, C6F14, CF4	HFC 134a, 227ea, 23, 125, 236fa; C4F10
	Charges	kg	n.e.	80 g HFC / Person with Asthma using spray inhalers	n.e.	n.e.
	Lifetime	years	1	1	1	20
WOM Scenario						
	Emission factors					
	EF Manufacturing	% / year				
	EF Lifetime	% / year	100	100	100	Country and gas specific
	EF Disposal	% / year				1
	EF By-product	% / year				
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)						
	Emission factors					
	EF Manufacturing	% / year				
	EF Lifetime	% / year				Country specific reduction
	EF Disposal	% / year				0.5
	Other Gases					
	Other Reduction measures		Prohibition of placing on the market for novelty aerosols			Prohibition of placing on the market for PFC as of July 2007

SF$_6$

AnaFGas 1.2		**SF6**				
		Electrical Equipment	Car tyres	Soundproof Glazing	Sport Shoe Soles	Magnesium Casting Secondary Aluminium
General assumptions						
Gases concerned		SF6	SF6	SF6	SF6, C3F8	SF6; HFC 134a, 125
Charges	kg	n.e.	n.e.	n.e.	n.e.	n.a.
Lifetime	years	40	3	25	3	n.a.
WOM Scenario						
Emission factors						
EF Manufacturing	% / year	Country specific		33		Aluminium: 3.0-1.5; Magnesium: 100
EF Lifetime	% / year	Country specific		1		
EF Disposal	% / year	Germany: 1.5; other MS: 5	100	100	100	
EF By-product	% / year					
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)						
Emission factors						
EF Manufacturing	% / year					
EF Lifetime	% / year	Country specific reduction since 2008				
EF Disposal	% / year	1.5				
Other Gases						Since 2008: HFC 134a, 125, SO_2 in die casting > 850 kg
Other Reduction measures			No SF6 in car tyres as of July 2007	No SF6 in windows as of July 2008		No SF6 in large die casting as of 2008

PFCs and other Halocarbons

AnaFGas 1.2			**PFC and other Halocarbons**		
			Seminconductors and Photovoltaics	Primary Aluminium Production	Halocarbon Production
General assumptions					
	Gases concerned		SF6, HFC 23; CF4, C2F6, C3F8, c-C4F8	CF4, C2F6	HFC 23, 32, 125, 134a, 143a, 227ea, 365mfc,CF4, C4F10, C5F12, C6F14, SF6
	Charges	kg	n.a.	n.a.	n.a.
	Lifetime	years	n.a.	n.a.	n.a.
WOM Scenario					
	Emission factors				
	EF Manufacturing	% / year	absolute values		
	EF Lifetime	% / year			
	EF Disposal	% / year			
	EF By-product	% / year		CF4: 0.140 decreasing to 0.045 kg CF4/ t Al; C2F6: 0.014 decr. to 0.004 kg C2F6 / t Al	By-product and Fugitive Emissions: abs. values
Different values for WM Scenario (with linear interpolation from WOM value in year 2010 to WM value in 2015)					
	Emission factors				
	EF Manufacturing	% / year			
	EF Lifetime	% / year			
	EF Disposal	% / year			
	Other Gases				
	Other Reduction measures				

Assumptions underlying the analysis of an international HFC arrangement

Region	End use type	Type of appliance	Annual growth to 2015	Annual growth to 2020	Annual growth to 2030	Equipment lifetime [years]	Annual leakage rate	Inital Charge [kg]
A2	Mobile AC	Passenger cars	2,0%	2,0%	2,0%	12	14%	0,8
A2	Mobile AC	Buses	0,4%	0,4%	0,3%	12	15%	10,0
A2	Domestic refrigeration	Refrigerators + Freezers	4,3%	4,4%	4,0%	15	1%	0,2
A2	Commercial refrigeration	Centralized systems	1,5%	1,5%	1,5%	9	20%	325,0
A2	Commercial refrigeration	Condensing units	1,5%	1,5%	1,5%	13	15%	8,0
A2	Commercial refrigeration	Stand-alone equipment	3,0%	3,0%	3,0%	9	3%	0,4
A2	Refrigerated transport	Land	1,0%	1,0%	1,0%	12	15%	4,0
A2	Refrigerated transport	Ships (Containers)	3,0%	3,0%	3,0%	14	15%	4,5
A2	Industrial refrigeration		4,0%	4,0%	3,0%	30	12%	3162,5
A2	Stationary AC	Chillers small	1,0%	1,0%	1,0%	15	7%	35,0
A2	Stationary AC	Chillers large	1,0%	1,0%	1,0%	15	7%	200,0
A2	Stationary AC	Factory-sealed	-1,8%	-1,8%	-1,8%	10	5%	0,8
A2	Stationary AC	Split type	7,0%	4,0%	0,0%	10	5%	1,3
A2	Stationary AC	Multi-spilt	5,0%	3,0%	0,0%	10	5%	15,0
A2	Stationary AC	Ducted rooftop	-0,1%	-0,1%	-0,1%	10	5%	15,0
A2	Stationary AC	Heat pumps (water to water)	30,0%	25,0%	20,0%	10	5%	1,7
A5	Mobile AC	Passenger cars	6,0%	6,0%	6,0%	15	20%	0,6
A5	Mobile AC	Buses	1,2%	1,2%	1,5%	15	30%	8,0
A5	Domestic refrigeration	Refrigerators + Freezers	5,3%	5,1%	4,3%	20	2%	0,2
A5	Commercial refrigeration	Centralized systems	1,0%	1,5%	4,0%	20	35%	325,0
A5	Commercial refrigeration	Condensing units	4,5%	3,0%	1,5%	20	25%	4,0
A5	Commercial refrigeration	Stand-alone equipment	8,5%	8,5%	8,5%	14	3%	0,4
A5	Refrigerated transport	Land	10,0%	10,0%	10,0%	15	25%	4,0
A5	Industrial refrigeration		7,0%	7,0%	5,0%	30	12%	3162,5
A5	Stationary AC	Chillers small	6,0%	6,0%	6,0%	20	10%	35,0
A5	Stationary AC	Chillers large	6,0%	6,0%	6,0%	20	10%	200,0
A5	Stationary AC	Factory-sealed	-1,8%	-1,8%	-1,8%	15	10%	0,8
A5	Stationary AC	Split type	4,7%	4,7%	4,7%	15	10%	1,3
A5	Stationary AC	Multi-spilt	9,5%	9,5%	9,5%	15	10%	15,0
A5	Stationary AC	Ducted rooftop	3,0%	3,0%	3,0%	10	10%	15,0
A5	Stationary AC	Heat pumps (water to water)	65,0%	55,0%	45,0%	15	10%	1,7