ARMINES
CENTRE ENERGETIQUE ET PROCEDES – CEP

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1990 to 2010 Refrigerant inventories for Europe
Previsions on banks and emissions from 2006 to 2030 for the European Union

Executive Summary

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A00 – Executive summary

1. The aim of this study

- The aim of this study is twofold: it analyses the development of the refrigerant bank ("inventories") / demand / emissions from 1990 to 2010 and develops two scenarios on how this bank / demand / emissions could develop over the next 20 years until 2030.
- The "F-Gas Scenario" is based on the full implementation of the F-gas Regulation as well as on the introduction of lower GWP refrigerants and further improvements based on current market trends.
- The "F-Gas Plus Scenario" is a more ambitious scenario and is based on a more aggressive introduction of lower GWP refrigerants.
- Both scenarios provide an estimated assessment of the time frame and feasibility of introducing lower GWP refrigerants based on environmental compliance, affordability and safety whilst maintaining and/or improving energy efficiency as stipulated by the F-Gas Regulation. Consequently, they allow assessing the quantities of refrigerants (converted into CO_2 eq) required until 2030.
- The results show the maximum achievable demand and emission reduction until 2030 and can be used as a basis to establish phase-down schedules. However, it must be noted that the F-Gas Plus Scenario includes also "best non-available technologies" for which currently no feasibility studies have been carried out by product (OEM) manufacturers.

2. How to read this study

- This study considers both, already available ("best available technologies") and yet to be commercialised refrigerant options ("best non available technologies").
- Unless otherwise stated, the lower GWP options have been categorised as REF300, including refrigerants and their blends with average GWP values < 300 and as REF700, including refrigerants and their blends with average GWP values < 700.
- It is likely that industry will develop other energy efficient refrigerant solutions at varying GWP levels over the next few years. Therefore, the used GWP categories cannot be interpreted as suggested GWP cut-offs or bans.
- It should be noted that a phase-down scenario is based on both GWP and charges, therefore in the F-Gas and the F-Gas Plus Scenarios not only the GWP but also the charge needed to achieve at least the same energy efficiency and capacity have been taken into account for the best available technologies. For the best non-available technologies this has not been evaluated yet and needs further investigation.
- The market penetration rates of refrigerants have been determined taking into account energy efficiency, cost and safety aspects. They are based on current market trends in the F-Gas Scenario and on maximum technical feasibility (including technologies not yet available) in the F-Gas Plus Scenario.
- Both scenarios are based on achieving at least the same level of energy efficiency as with current HFC technologies.

- Due to time constraints, further analysis on energy efficiency has not been undertaken in the context of this study even though this aspect clearly plays a key role when choosing any refrigerant for a given application. For example, the energy efficiency requirements for most products (refrigeration, air conditioning and heat pumps) are increasing in the future due to the Eco-design and EPBD Directives and this may further limit the choice of refrigerants. Therefore, a follow-up study may be considered to analyse in detail the total greenhouse gas emissions including direct refrigerant emissions and indirect emissions due to energy consumption (Total Equivalent Warming Impact – TEWI).

3. The methodology

- The values used for the calculations are those of the 4th IPCC Assessment report in order to take into account latest scientific information.
- Refrigerant inventories for EU-27 follow the rules of IPCC guidelines for national greenhouse gas inventories. The method is "bottom-up", deriving the refrigerant quantities stocked in the installed bases (refrigerant bank) of the following six application sectors: domestic, commercial, industrial refrigeration, refrigerated transport, stationary air-conditioning / chillers and mobile air-conditioning.
- The inventories take into account all refrigerant types including CFCs, HCFCs, HFCs, hydrocarbons, ammonia and CO_2. Activity data are gathered from marketing studies, specialised publications, the RIEP database and international websites of UN or FAO.
- Emission factors are derived from real-life data such as refrigerant invoices for servicing and mandatory declarations by refrigeration and a/c system operators.
- The methodology for the future emission scenarios "F-Gas Scenario" and "F-Gas Plus Scenario" is based on modelling of the installed base of equipment and expected market growth.
- The modelling of the bank is based on the following key factors: Lifetime of equipment, refrigerant charge, emission rates, recovery efficiency at end of life, refrigerant in use, retrofits, markets and production of equipment.
- It should be noted that the definition of refrigerant demand can vary. One major factor is the integration of refrigerant included in pre-charged air-conditioning equipment imported into and exported from the EU. This study does not take into account these refrigerant charges for the calculation of demand but it does include them in the bank and emission data. Adaptation of figures can be envisaged in order to achieve direct comparability with other available studies.

4. Key results

4.1. The Bank: 1990 to 2010

- **In EU-27, CO_2 eq emissions have decreased from 170 million tonnes in 1990 to 147 million tonnes in 2010** (Figure ES-2) despite more than a doubling of the refrigerant bank from 200,000 tonnes in 1990 to about 510,000 tonnes in 2010 (Figure ES-1) meaning an average market growth of 5% per annum. This is due to the accelerated phase-out of CFCs and HCFCs under the EU ODS Regulations and to the introduction of the EU F-Gas Regulation in 2006.

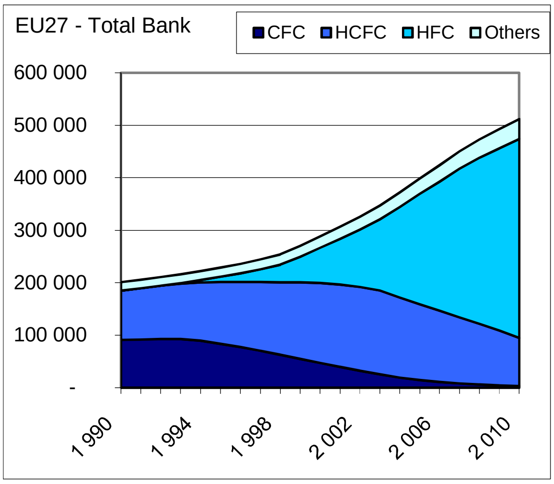

Figure ES 1-EU Refrigerant bank from 1990to 2010.

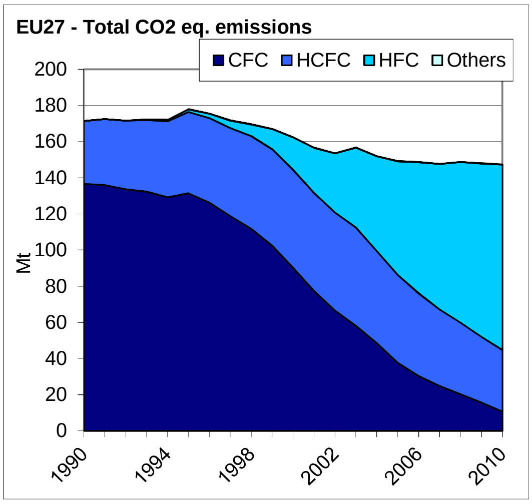

Figure ES 2-EU CO_2 eq. refrigerant emissions.

4.2. Emission scenarios: 2010 to 2030

- **Under both scenarios, F-Gas and F-Gas Plus, the refrigerant bank increases between 2010 and 2030 from approx. 510,000 tonnes to between 800,000 (F-Gas plus** - figure Es-4**) and 900,000 tonnes (F-Gas** Figure Es-3**)** (+ 60% to +75%). This increase is due to economic growth forecasted to be 2% in EU-15 and 4% in EU-new, refrigerant conversions in existing installations as well as the increase of heat pump and air conditioning use which is contributing to the total CO_2 emission reduction. The additional 15% reduction for the F-Gas Plus scenario can be achieved due to more stringent efforts on containment, end of life recovery and refrigerant charge reduction.

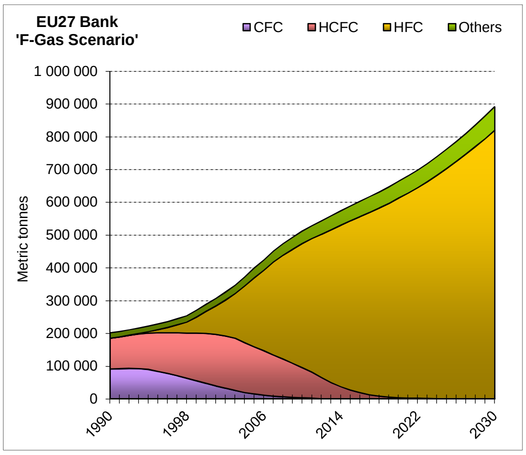

Figure ES 3- Overall refrigerant banks from 1990 to 2030-F-Gas Scenario.

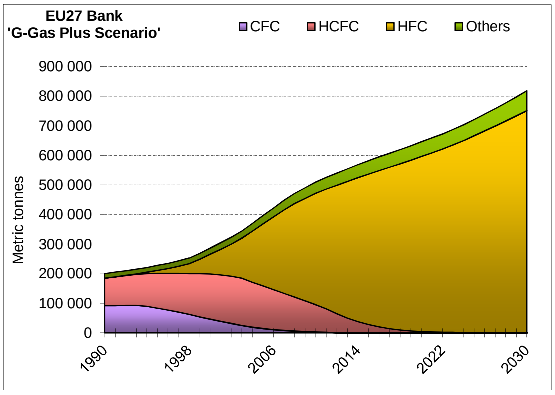

Figure ES 4- Overall refrigerant banks from 1990 to 2030-F-Gas Plus Scenario.

- **Despite the growing bank of refrigerants, CO_2 eq emissions significantly decrease under both scenarios: in the F-Gas Scenario from 147 million tonnes in 2010 to 124 million tonnes in 2030** (figure ES-5) **and to 57 million tonnes in the F-Gas Plus Scenario** (figure ES-6)**, meaning a reduction by respectively 15% or 60%.** The significantly higher reduction potential for the F-Gas Plus Scenario is due to further improved containment and an accelerated change from high GWP refrigerants to lower GWP refrigerants.

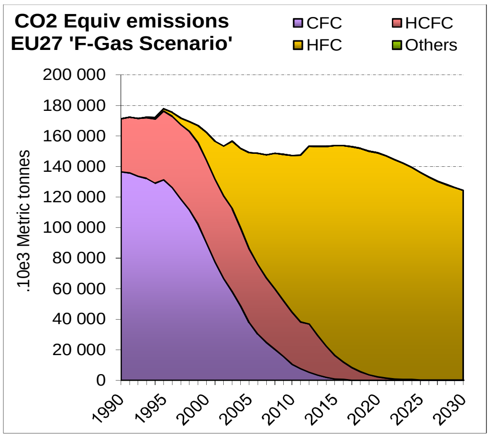

Figure ES 5-EU CO_2 eq. refrigerant emissions –F-Gas scenario.

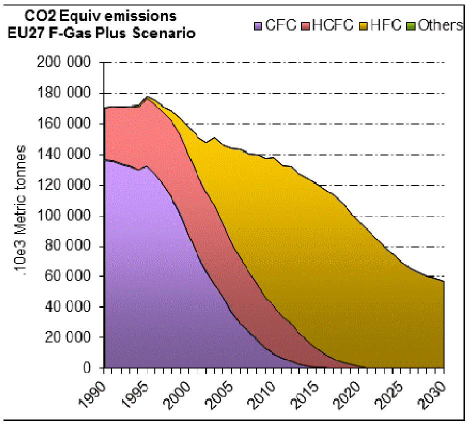

Figure ES 6- CO2 eq. refrigerant emissions –F-Plus Gas scenario.

4.3. HFC total demand: 2010 to 2030

- HFC total demand in this study takes into account refrigerant used for newly produced equipment in the EU, refrigerant used for topping up new installations and refrigerant used for servicing existing equipment.
- Both scenarios, F-Gas and F-Gas Plus**, lead to a significant reduction of the refrigerant demand in terms of CO_2 equivalents.** In the F-Gas Scenario, the refrigerant demand will decline by approx. 9% from 136 million tonnes to 124 million tonnes. **In the F-Gas Plus Scenario, the reduction will be more significant as the refrigerant demand will decrease to only 49 million tonnes, i.e. a reduction of more than 60%.**
- Improved recovery and recycling of refrigerants and the end of life of the equipment gives some flexibility and will further reduce the refrigerant demand.

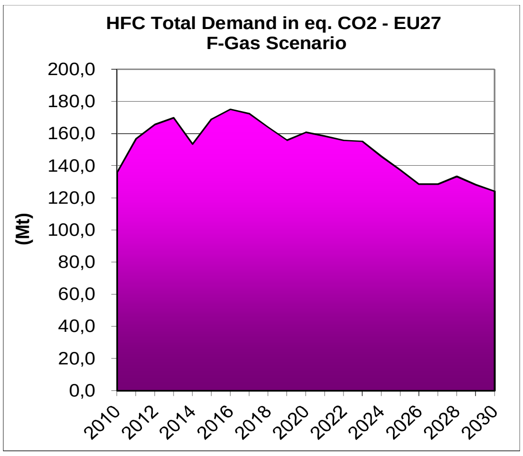

Figure ES-7 - CO_2 content of the annual HFC demand (2010 - 2030). F-Gas scenario.

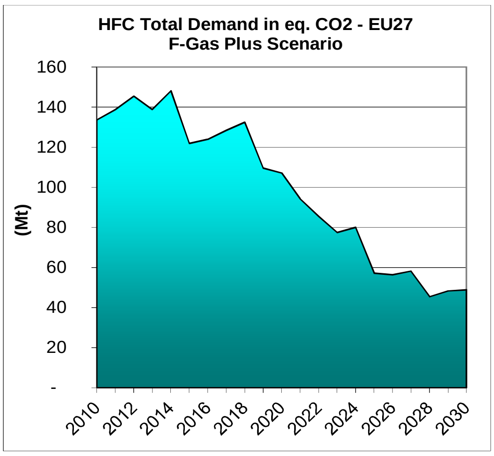

Figure ES-7 - CO_2 content of the annual HFC demand ((2010 - 2030).F-Gas Plus scenario.

5. Cost

- The cost associated with the implementation of the F-gas regulation is estimated at € 8.9 / t CO_2-eq, based on a full implementation in the EU-27 and on a total number of 228,000 technicians to be certified. In case of a higher number of technicians in the EU-27, this cost would increase. However, this does not take into account the cost benefits due to the preventive maintenance effect such as improved efficiency and guaranteed operation. The end of life refrigerant recovery policy is cost effective with a 2 €/t eq. CO_2 cost based on an average CO_2 eq. value of 1870 kg CO_2 / kg of refrigerant.
- The cost of conversion to lower GWP fluids has not been assessed in the context of this study. Since for example new Low GWP fluorinated compounds require more advanced chemistry, higher costs must be expected as was the case with the introduction of HFCs as replacements of ODSs. OEMs will face substantial upfront investment in the validation and adoption of new fluids. These costs can be mitigated if the new fluids emulate the existing fluids in terms of thermodynamic properties, capacity and material compatibility.

6. Conclusion

- The F-Gas Scenario shows that the F-Gas Regulation's containment principle as well as increased quality standards and evolving technology based on current market trends lead to a tangible reduction in refrigerant demand in terms of CO2 equivalent emissions.
- The sizeable difference between the F-Gas Scenario and the F-Gas Plus Scenario, however, shows that there is scope for additional measures that could complement the F-Gas Regulation.
- Reducing the quantity of HFC refrigerant placed on the market by restricting the amount of their CO2 eq. content via a phase-down scheme seems to be an effective measure to reduce significantly the climate impact of refrigeration, air-conditioning and heat pump equipment. A phase-down scheme leaves the choice open to choose the best suited refrigerant according to a given application, taking into account energy efficiency, safety, cost and environmental compliance as well as regional climate.
- It has to be underlined that lowering the GWP of refrigerants may require a re-assessment of the safety implications. New low GWP HFCs and also R-32 are mildly flammable; hydrocarbons are extremely flammable and require complementary assessments for their safe use. Other key properties are now under consideration and safety standards are in the process of being modified. In all cases, manufacturer liability remains a key parameter to decide whether a certain refrigerant can be used with confidence.