

The rise and rise of fluorinated greenhouse gases as a share of global warming emissions

Summary of an Öko-Recherche study (including special remarks on commercial refrigeration), Frankfurt, June 2004, on behalf of Greenpeace

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Methodological remarks and data sources used in the study are given at the end of this summary.

1. Global warming impact of HFCs, CFCs, and HCFCs

HFCs are chlorine-free substitutes developed by the chemicals industry to replace ozone-depleting CFCs and HCFCs. These are hydrocarbons with fluorine (F) in the molecule. While CFCs/HCFCs contribute both to the destruction of the ozone layer and to global warming, HFCs are only a threat to the climate. Their impact is frequently underestimated, as only their current share in overall greenhouse gas emissions is considered.

2. The global 1.5% share of chlorine-free F-gases in total greenhouse gas emissions

Emissions of chlorine-free F-gases, which is the collective term for HFCs and two other groups of fluorinated greenhouse gases (SF₆ and PFCs), accounted for 1.5% of total direct greenhouse gas emissions in 2003. Carbon dioxide is the most important greenhouse gas, but methane and nitrous oxide also have considerable global warming impacts. Under the Kyoto Protocol on Climate Change, these three gases and the chlorine-free F-gases constitute the basket of gases whose emissions have to be reduced in order to mitigate climate change.

3. Globally, up to now HFCs have replaced CFCs/HCFCs by less than 30%

From recent studies within the scope of IPCC and UNEP, it emerges that up to now HFCs have replaced globally CFCs/HCFCs by less than 30%. Although the global warming impact of chlorine-containing F-gases is substantial, it is scarcely noticed or recorded because these gases are viewed almost exclusively from the angle of ozone depletion. Consequently, less than 30% of the actual global warming impact of all F-gases taken together, i. e. chlorine-containing (CFCs/HCFCs) as well as chlorine-free F-gases (most importantly HFCs), is accounted for.

4. Why the Kyoto Protocol disregards chlorine-containing F-gas emissions

Underestimating the climate impact of F-gas emissions has political, or better, practical reasons. F-gases containing chlorine (and bromine) have been deliberately excluded from the Kyoto Protocol as the latter may not interfere with the Montreal Protocol on ozone-depleting substances (CFCs/HCFCs). Such interference would be possible if climate protection measures - which according to the Kyoto Protocol are designed to curb emissions, not necessarily to eliminate them - were to be applied to chlorine-containing F-gases. A global step-by-step phase-out by 2040 has already been agreed on for CFCs/HCFCs.

5. World-wide transition from chlorine-containing to chlorine-free F-gas emissions

Chlorine-containing F-gases will continue to be used until 2040. Furthermore, the global rise of emissions of chlorine-containing F-gases is not expected to stop before 2050. Only then are today's emissions of CFCs/HCFCs expected to be overtaken by HFC emissions. Taken

historically, we are currently at an early stage of the world-wide transition from chlorine-containing to chlorine-free F-gas emissions.

6. Every existing CFC/HCFC application will be replaced by HFCs in the future

In the 1990s, a large number of applications of chlorine-containing F-gases were completely or significantly abandoned in favour of climate-friendly fluids or technologies (aerosols, solvents, fire extinguishers, foam blowing agents etc.). Refrigeration and air-conditioning remained the largest and most important sectors where a transition was made to HFCs. Today, almost two-thirds of all CFC, HCFC and HFC emissions arise from refrigerant applications. An additional 10% originate in the manufacture and use of insulating foams, which are themselves mainly used in connection with refrigeration (refrigeration appliances and cabinets, cold storage rooms, refrigerated vehicles etc).

In other words, every application running with CFCs/HCFCs today must be assumed to become an HFC application sooner or later.

7. Recalculation of chlorine-containing F-gases raises F-gas share up to global 4.1%

If today's total chlorine-containing F-gas emissions were recalculated to represent emissions from chlorine-free F-gases (HFCs) that will likely succeed them, the current global warming potential of F-gas emissions would represent not 1.5%, but 4.1% (rated with GWP 100yr) or 5.2% (rated with GWP 20yr) on a world-wide average.

8. F-gas emissions are expressed by global warming potentials of HFCs

In this recalculation of all present-day F-gas emissions into emissions of chlorine-free F-gases, the CFCs/HCFCs are not rated with their own specific contribution to the greenhouse effect. If the global warming potential of these gases had been taken into account, the resulting global warming F-gas emissions would be much higher. This study calculates on the basis of the HFC type that will most likely be the substitute for each application of CFC or HCFC, based on past experience, e.g. HFC-134a or HFC-blends like R-404A, R-407C, R-410A. Their global warming potential (GWP) serves as the measure of the climate impact of F-gas emissions. The GWP values are expressed relative to CO₂ and calculated for a time horizon of 100 years.

9. Industrialised countries are responsible for 80% of all F-gas emissions

Following recent UNEP reports, 80% of emissions of HFCs, CFCs and HCFCs originate from industrialised countries. These include the USA, Europe with Russia, Japan and Australia. Only 20% of total F-gas emissions (chlorine-free plus chlorine-containing recalculated to chlorine-free F-gases) originate in developing countries, home to more than 80% of the world's population.

10. The F-gas share in industrialised countries is 6.2%, in developing countries it is 2.1%

In industrialised countries alone, the recalculated present-day F-gas emissions make up a share of 6.2% (GWP 100yr) of industrialised countries' overall greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide. (This represents 1.2 billion tons of CO₂ equivalent, expressed with GWP 100yr.) Developing countries' emissions total 2.1% (0.4 billion tons CO₂ equivalent.)

11. Fast growth of F-gas emissions in developing countries until 2050

Up to now, emissions of chlorine-free and chlorine-containing F-gases have simply been added mathematically. As mentioned above, this will last until 2050. But the world of 50

years hence will look very different from today. Developing countries will have industrialised to a considerable extent – like in east Asia, south Asia and South America. This will lead to greater output of greenhouse gases, especially CO₂. The 2050 share of developing countries' F-gas emissions depends on the growth rate of F-gas emissions compared to the growth rate of emissions of other greenhouse gases. As the use of F-gases best indicates the degree of industrialisation, F-gas emissions are assumed to grow even faster than CO₂ emissions over the next 50 years.

In industrialised countries, in contrast, a slight decrease of greenhouse gas emissions is likely, for F-gases as well as for the other three greenhouse gases. F-gas emissions of industrialised countries can thus be predicted to represent the same 6.2% share in overall global warming emissions by 2050 as in 2003. It should be noted that the 6.2% share by 2003 is a calculated figure whereas the same figure by 2050 will be genuine.

To guard against misunderstanding: the transformation of present-day chlorine-containing F-gas emissions to chlorine-free F-gas emissions is one process, and the general growth in F-gas emissions from 2003 onwards (as assumed for developing countries) is another. Both processes will run simultaneously over the next decades.

12. Developing countries will also reach 6.2% F-gas emission share by 2050

If an annual growth rate of 4% is assumed for developing countries' F-gas emissions and, based on the IPCC 2001 main scenarios (illustrative 'marker' scenarios), an annual growth rate of 2% is assumed for the other greenhouse gases (CO₂, methane, and nitrous oxide), F-gas emissions in developing countries will in 2050 reach the same 6.2% share of all greenhouse gas emissions as in industrialised countries.

13. Per capita emissions of developing countries at half the level of industrialised countries

According to this projection, by 2050 in absolute terms the overall greenhouse gas emissions from developing countries will be almost three times higher than those from industrialised countries (respectively, 50 and 17 billion tons CO₂ equivalent). The same ratio between developing and industrialised countries applies to F-gas emissions with 3 billion and 1 billion tons of CO₂ equivalent, respectively. Even in these circumstances, however, per capita emissions of both all greenhouse gases and F-gases alone in developing countries will still be only slightly greater than half the level of industrialised countries.

14. The 8.6% share of F-gas emissions over the 20-year period

A time horizon of 100 years is most commonly used to calculate the climate impact of F-gas emissions. For analysing short-term climate impacts (glacial retreat, decline in tropical rainfall, etc.) this medium-term time horizon is less suitable than the shorter time horizon of 20 years¹. The latter indicates that for a short period the climate impact of F-gases is even

¹ IPCC calculates for each greenhouse gas the climate impact with respect to CO₂ (GWP values) not only for the medium term (time horizon 100 years) but also for the short term (20 years) and the long term (500 years). The time horizons themselves are defined fairly arbitrarily with 20, 100 and 500 years. Scientifically seen, they are equivalent to each other. For political reasons, the Kyoto Protocol has decided to use the 100-year time horizon as the general standard. Therefore, the medium-term time horizon has acquired a privileged position. However, the choice of time horizon is a choice that depends upon issues such as the time-scales of the climate system and the emphasis on long-term versus short-term potential climate changes. If the policy emphasis is to help guard against the possible occurrence of potentially abrupt, non-linear climate responses in the relatively near future, then a choice of a 20-year time horizon would yield an index that is relevant to making decisions on appropriate greenhouse gas abatement strategies. In addition, if the speed of potential climate change is of greatest interest (rather than the eventual magnitude), then a focus on a shorter time horizon can be used.

higher relative to CO₂ than for a longer period. If the time horizon of 20 years is applied, the global warming potential of F-gases as well as of methane increases both absolutely and relative to the global warming emissions of carbon dioxide. Over a 20-year period, not only the calculative 2003 share but also the likely actual 2050 share of F-gas emissions rises to 8.6% (compared to 6.2% when rated with GWP 100yr).

It should be stressed that the two time horizons are equivalent from a scientific point of view.

15. The high global warming potential of F-gases makes their substitution important

The very high share of F-gas emissions in total greenhouse gas emissions (6.2% and 8.6%) can be reversed. It will come about only if current use and emission trends continue. If more attention is directed to curbing emissions in the future, by, inter alia, implementation of the industrialised countries' commitment under the Kyoto Protocol, or if climate-damaging F-gases in present-day applications are increasingly replaced by climate-friendly substances and technologies, F-gas measures could achieve considerable success in mitigating climate catastrophe.

16. The key role of refrigerants, especially in commercial refrigeration

Refrigeration and air-conditioning play a key part in the current and future development of F-gas emissions. According to recent investigations in preparation of a special IPCC report on F-gases, roughly 63% of world-wide F-gas emissions arise from leakage and irregular decommissioning of stationary and mobile refrigeration and air-conditioning equipment. Half these emissions are attributable to the largest subsector of refrigerant application: commercial refrigeration. This subsector represents such a large slice of emissions because of the wide use of refrigerant blends like 404A for freezing perishable food. This HFC blend has a particularly high global warming potential: over a 100-year period it is 3,500 times greater than that of CO₂. Containment of emissions or F-gas replacement by natural refrigerants is therefore of great importance in commercial refrigeration. The challenge of substituting fluorinated refrigerants grows with the size of the equipment. Replacement should thus start with smaller decentralised refrigeration units, which are usually industrially pre-fabricated. Although such so-called stand-alone equipment contains no more than 10% of refrigerants used world-wide in commercial refrigeration, the signalling of a partial F-gas phase-out should not be underestimated.

17. Refrigeration system types used in worldwide commercial refrigeration

Commercial refrigeration equipment types vary greatly in size, mainly depending on country and kind of shop. According to a recent UNEP report, commercial refrigeration equipment consists of three main system types.

- *Centralised systems* are installed in super- and hyper-markets. A wide range of refrigerating capacity is estimated to be installed in 340,000 such outlets. Here, the refrigerant charge varies from 100 kilos-2,000 kilos. The refrigeration system is installed in a machinery room and the refrigerant circulates between this and display cases in the sales area.
- *Condensing units* are typically installed in specialised shops. Their refrigerant charge varies between 1 and 5 kilos, and their estimated global number is around 32.5 million. The refrigerant of choice depends on the temperature range required. Both HFC-134a and HFC blend R-404A are preferred for medium temperatures, and R-404A for low temperatures. Due to safety concerns, HCs are not a common option for the charge amount normally present in condensing units.
- *Stand-alone equipment* includes integrated display cases, ice machines, vending machines, and an array of small equipment installed in stores or public areas. It is estimated that there

are more than 50 million units in this category world-wide. Refrigerant charges range between 0.2 and 1 kilo. HFC-134a is the dominant option at present.

18. The push for climate protection announced by food and beverage companies

Several large food and beverage companies have indicated that they will refrain from using HFCs within a few years where suitable alternatives are available. Coca Cola, Unilever and McDonald's, for example, own about 12 million beverage and ice cream vending machines between them. Implementing the measures they announce would significantly cut the global amount of fluorinated greenhouse gases in commercial stand-alone equipment, which is highly prone to leakage and, consequently, to global warming emissions.

Methodological Remarks

The data and projections presented in this summary are based on scientific assumptions described in long version of the study (in German). For the conclusions presented above, it is necessary to clarify four points:.

1. The 2002 data on global emissions of CFCs, HCFCs and HFCs (in addition to SF₆ and PFCs) and their sources is used as the starting point. This data has been collected sector by sector from specialised studies (e.g. on Refrigeration/Air-Conditioning, Foams etc.), most carried out recently within the scope of the upcoming IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System, which will be published in 2005. Additionally, special reports by several UNEP Technical Options Committees were evaluated. With the help of these reports and some additional information, the size and composition of total 2002 emissions of F-gases (chlorine-containing plus chlorine-free including PFCs and SF₆) could be assessed.
2. The 2001 Special Report on Emissions Scenarios (SRES) by the IPCC Working Group III was used to establish a time series until 2050 of non-F-gas greenhouse gas emissions. Historical data on 2000 could be drawn immediately from that (in kilo-tonnes and rated either with GWP 100yr or GWP20yr, with the GWP values originating from the IPCC Third Assessment Report 2001). Since the SRES contains four groups ("families") of emissions scenarios for the year 2050, with different results, it was attempted to minimise the bias in the scenario used by Oeko-Recherche by combining two of the four scenario groups (the 'illustrative marker' scenarios A1B and B1). Experts from the UNFCCC Secretariat were consulted on this procedure. In this way, "expected" emissions of Non-F-gas greenhouse gases CO₂, methane, nitrous oxide by 2050 were established, separated by industrialised (Annex I) countries and developing countries (non Annex I countries).
3. The most decisive step before relating F-gas emissions for 2050 to overall greenhouse gas emissions for the same year (in order to obtain the F-gas emission shares), is the projection of the F-gas emissions themselves. Assumptions can only be made regarding growth rates of F-gas emissions, since no reliable data is available. For industrialised countries a slightly negative growth rate is applied (-0.3%/yr). For developing countries, however, a positive growth rate of slightly more than 4%/yr is assumed. For these figures Oeko-Recherche is fully responsible, being aware that any forecasting for the year 2050 is speculative. The main difference of this study compared to others is that the projected growth rates do not only describe F-gases which are chlorine-free today, but the total of emissions of chlorine-containing and chlorine-free F-gases.
4. It should be noted that the significant growth of F-gas emissions from developing countries does not take into account any climate mitigating measures or political actions that may and should be taken in order to curb F-gas emissions.

References used in study

- AFEAS (Alternative Fluorocarbons Environmental Acceptability Study), Production, Sales and Calculated Emissions of Fluorocarbons through 2001, AFEAS, Arlington, U.S.A., 2003, available at www.afeas.org.
- Ashford, P. (Caleb Management Services, Bristol, UK) and M. Jeffs (European Isocyanate producers Association (ISOPA), Brussels, Belgium), Development of Emission Functions for Foams and their Use in Emissions Forecasting, The Earth Technology Forum, Washington DC, 2004.
- Campbell, N.; Technical, Pesticide, Convenience, and Novelty Aerosol Products; Proceedings of the "Joint IPCC/TEAP expert meeting on options for the limitation of emissions of HFCs and PFCs"; Energieonderzoek Centrum Nederland (ECN), Petten, 1999.
- Harnisch, J., O. Stobbe, D. de Jager (Ecofys), Abatement of Emissions of Other Greenhouse Gases: "Engineered Chemicals", by order of the IEA Greenhouse Gas R&D Programme, Utrecht, Feb. 2001.
- Harnisch, J. and N. Höhne, Comparison of Emissions Estimates Derived from Atmospheric Measurements with National Estimates of HFCs, PFCs and SF₆, ESPR – Environ Sci & Pollut Res 9 (5) 315 – 320 (2002).
- Harnisch, J., N. Höhne, M. Koch, S. Wartmann (Ecofys), W. Schwarz (Öko-Recherche), W. Jenseit und U. Rheinberger (Öko-Institut), P. Fabian, A. Jordan, Risiken und Nutzen von fluorierten Treibhausgasen in Techniken und Produkten unter besonderer Berücksichtigung der stoffintrinsic Eigenschaften, Forschungsvorhaben im Auftrag des Umweltbundesamtes (UBA), Berlin Fachgebiet III 1.4, Abschlußbericht, 14. November 2003.
- IPCC First Assessment Report. Scientific Assessment of Climate change – Report of Working Group I. JT Houghton, GJ Jenkins and JJ Ephraums (Eds). Cambridge University Press (pp 365) 1990.
- Radiative Forcing of Climate Change 1994b. Report to IPCC from the Scientific Assessment Working Group (WG I), Ch. 5 (Pre-publication version).
- IPCC 1994a: Radiative Forcing of Climate Change. The 1994 Report of the Scientific Assessment Working Group of IPCC. Summary for Policymakers, pp 28.
- Intergovernmental Panel on Climate Change, IPCC (2001): Climate Change 2001. Third Assessment Report. Cambridge University Press.
- IPCC-SRES (IPCC Special Report on Emissions Scenarios) Illustrative/Marker Scenarios (version 1.1, July 2000), Six different scenarios for The World and four regions: OECD90 (OECD member states as at 1990), REF (Central and Eastern Europe and Newly Independent States of the former Soviet Union), ASIA (Asia excluding the Middle East), ALM (Africa, Latin America and Middle East): A1, A2, B1, B2, A1FI, A1T. http://sres.ciesin.org/final_data.html und <http://www.grida.no/climate/ipcc/emission/data/allscen.htm>.
- Midgley, P. and A. McCulloch; Production, sales and emissions of halocarbons from industrial sources; in 'Reactive halogen compounds in the atmosphere' edited by P. Fabian and O. Singh, Handbook of Environmental Chemistry, pp. 155-190, Springer-Verlag, Berlin, 1999.
- Palandre, Lionel, Assaad Zoughaib, Denis Clodic, L. Kuijpers; Estimation of the world-wide fleets of refrigerating and air-conditioning equipment in order to determine forecasts of refrigerant emissions, The Earth Technology Forum, Washington DC, April 2003.
- Palandre, L., D. Clodic, L. Kuijpers, Ecole des Mines de Paris, Centre for Energy Studies, Paris, France and Technical University, TDO, Eindhoven (NL), HCFCs and HFCs emissions from the refrigerating systems for the period 2004 – 2015, The Earth Technology Forum, Washington DC, April 2004.
- UNEP (United Nations Environment Programme), Production and Consumption of Ozone Depleting Substances under the Montreal Protocol, 1986-2000, Ozone Secretariat, UNEP, Nairobi, 2002a.

UNEP (United Nations Environment Programme); 2002 Report of the Aerosols, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee (ATOC); Nairobi 2002b.

UNEP (United Nations Environment Programme); 2002 Report of the flexible and rigid foams technical options committee; Foams Technical Options Committee, Nairobi, March 2003a.

UNEP (United Nations Environment Programme); 2002 Report of the Technology and Economic Assessment Panel; HCFC Task Force Report, Nairobi, May 2003b.

UNEP (United Nations Environment Programme); 2002 Report of the Halons Technical Options Committee (ATOC); Nairobi 2003c.

UNEP (United Nations Environment Programme); 2002 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC); Nairobi, January 2003d.

UNFCCC; Rahmenübereinkommen der Vereinten Nationen über Klimaänderungen, Vereinte Nationen, Genf, 1992. <http://unfccc.int/resource/docs/convkp/convger.pdf>.