Remarks on Emissions of Fluorocarbons
CFCs, HCFCs and HFCs

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Introduction

Several reports on emissions of fluorocarbons (CFCs, HCFCs and HFCs) have recently been published: AFEAS data on 2002 production and sales, IPCC/TEAP special report entitled Safeguarding the ozone layer and the global climate system, inventory data on greenhouse gas emissions published by the UNFCCC on the occasion of COP-10 and an inventory and forecast of refrigerant emissions in France for the year 2002.
The author displays certain figures published in these documents, analyses them and makes a few comments.

AFEAS data

AFEAS (Alternative Fluorocarbons Environmental Acceptability Study) collects data on production and sales of fluorocarbons (CFCs, HCFCs and HFCs) and has published them since 1976 (AFEAS, 2005). In comparing its own data with those of UNEP which are global, AFEAS considers that its figures comprise 40% of the production of CFCs, 73% of that of HCFCs and 97% of that of HFCs. Fluorocarbon manufacturers which do not exchange data with AFEAS belong to Article 5 countries such as India and China.

Analysis of data and graphics published by AFEAS (AFEAS, 2005) tends to prove that measures taken in order to protect the environment in this domain were successful:

- Sales of fluorocarbons are globally decreasing, with the exception of those of HFC-134a (Figure 1).

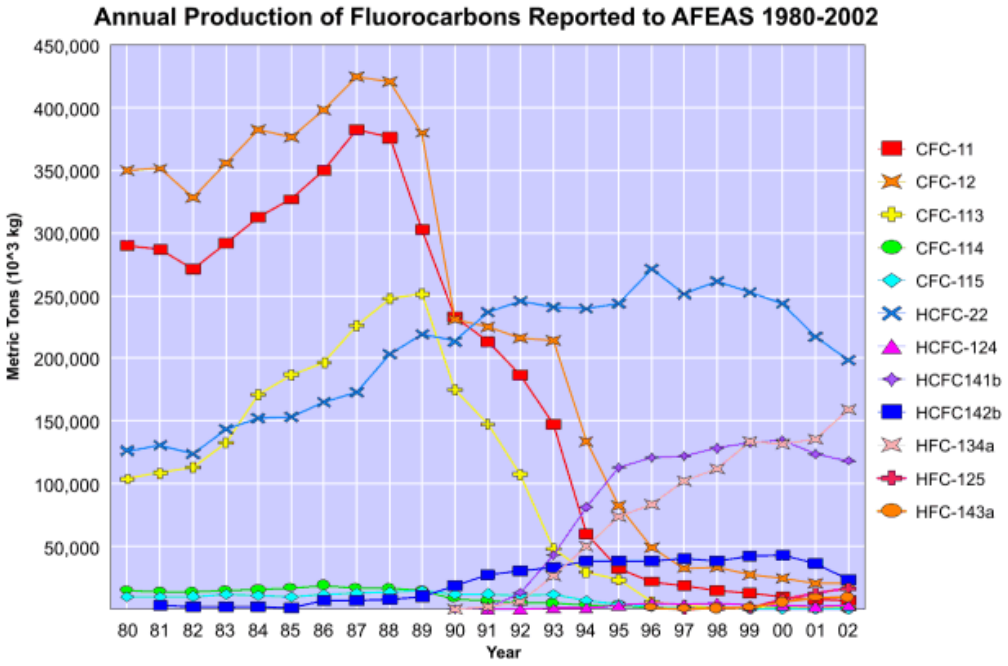

Figure 1. Annual production of fluorocarbons from 1980 to 2002

- The ODP-weighted production curve (Figure 2) has been continuously decreasing since 1988.

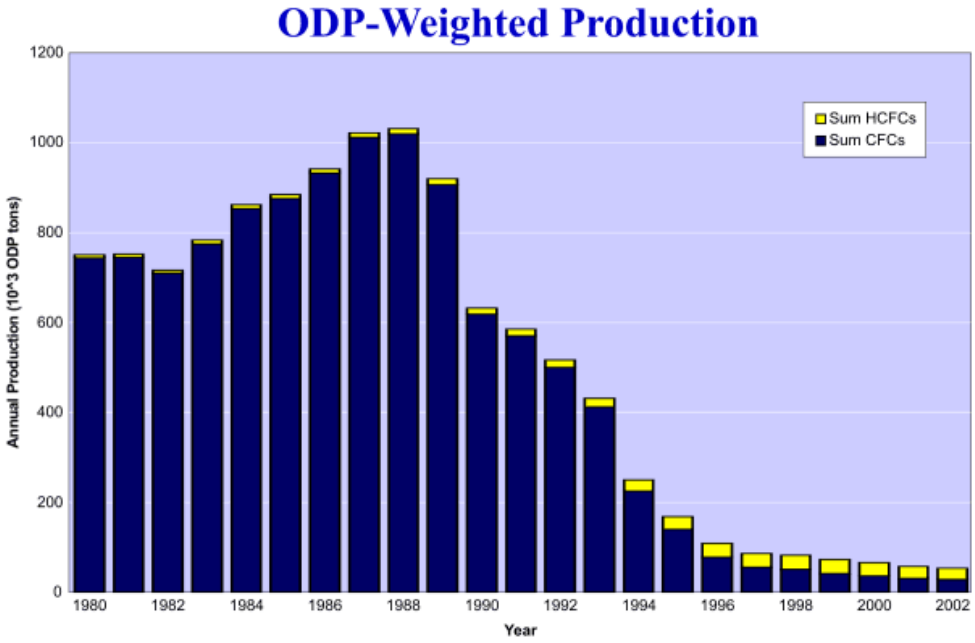

Figure 2. ODP-weighted production of CFCs and HCFCs over the period 1980-2002

- The GWP-weighted production of fluorocarbons (Figure 3) has been continuously decreasing since 1988.

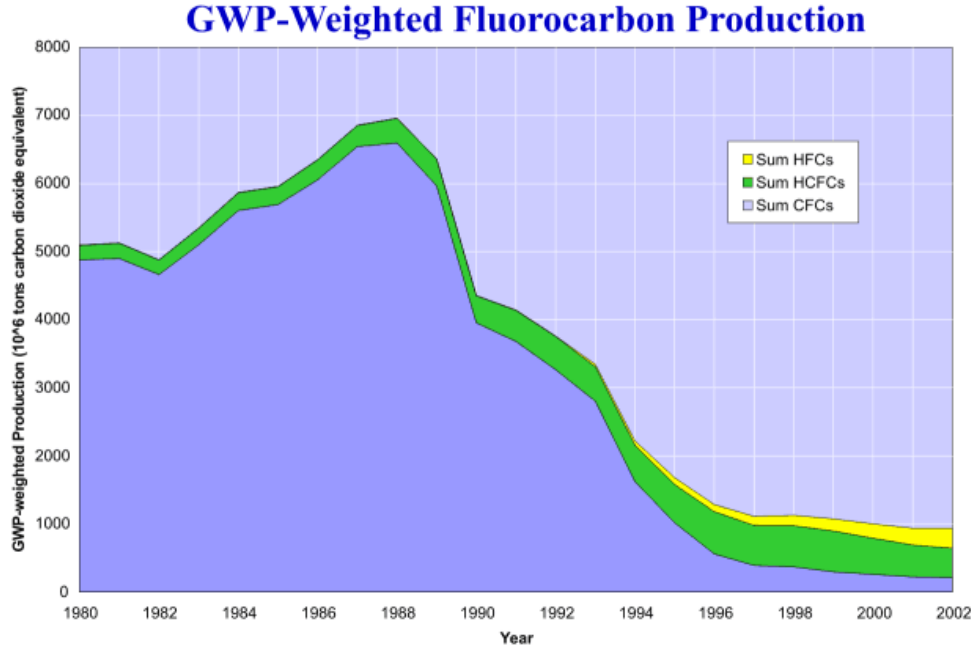

Figure 3. GWP-weighted production of CFCs, HCFCs and HFCs in Mt CO_2 eq. over the period 1980-2002

IPCC/TEAP special report

The IPCC (Intergovernmental Panel on Climate Change) on behalf of the UNFCCC (United Nations Framework Convention on Climate Change) and TEAP (Technology and Economic Assessment Panel) on behalf of the Montreal Protocol, have produced a special report on Safeguarding the ozone layer and the global climate system: issues related to HFCs and PFCs.

Both IPCC and TEAP are recognized for the quality of their studies based on a scientific approach to issues.

The IPCC/TEAP published its report with a summary for policymakers in April 2005 (IPCC/TEAP, 2005). The value of this report lies in the fact that it provides global figures on radiative forcing, banks and emissions of not only HFCs but also ozone-depleting substances (ODS): CFCs and HCFCs. This is not the case at UNFCCC level, which does not deals with CFCs and HCFCs.

The main outcomes of this report are the following:

1. Radiative forcing of fluorocarbons (CFCs, HCFCs and HFCs) is evolving favourably (Table 1). The estimated radiative forcing in 2002 of 0.34 ± 0.3 $W.m^{-2}$ accounts for 14% of the radiative forcing of all greenhouse gases. IPCC/TEAP estimates that in 2015 the contribution of CFCs and HCFCs will decrease to 10% and that of HFCs be 1%. Radiative forcing is a particularly useful concept since it represents the additional greenhouse effect of manmade greenhouse gases from 1750 to today. It gives a clear picture of global warming. The rather slow decrease in radiative forcing of ODS is due to the very long lifetime of CFCs (100 years for CFC-12, 45 years for CFC-11).

   Table 1. Radiative forcing of fluorocarbons in 2002 and in 2015 expressed as a percentage of the radiative forcing of all manmade greenhouse gases

Substance	2002	2015
CFCs + HCFCs	14%	10%
HFCs	ε	1%
Total	14%	11%

2. Bank and emissions of fluorocarbons are given for the year 2002 and estimated for the year 2015 (Table 2). The bank is the total amount of substances contained in existing equipment, chemical stockpiles and foams. The bank of fluorocarbons in refrigeration and air-conditioning equipment, in heat pumps and in foams, that is 21 000 Mt CO_2 eq. is of the same order of magnitude as annual CO_2 emissions due to global fossil fuel burning (coal, petrol, gas), which represents 24 100 Mt CO_2 eq/y.

   The report also mentions that the total global amount of HFC-134a currently in the atmosphere is believed to be about equal to the amount in banks.

Table 2. Bank and emissions of fluorocarbons in 2002 and 2015

	Bank (Mt CO_2 eq.)		Emissions (Mt CO_2 eq./y)	
	2002	2015	2002	2015
CFCs	16 000	8 000	1 600	300
HCFCs	4 000	5 000	500	900
HFCs	1 000	5 000	400	1 200
Total	21 000	18 000	2 500	2 400

3. Emissions of fluorocarbons decreased from 7500 Mt CO_2 eq/y around 1990 to 2500 Mt CO_2 eq/y in 2002.

4. The estimate made by IPCC of the CFC bank in 2015 is 7000 Mt CO_2 eq/y in foams and 1000 Mt CO_2 eq/y in refrigeration and air-conditioning systems. One might as well say that plants will practically contain no more CFCs in 2015.

5. According to the IPCC/TEAP report, CFC emissions will considerably drop between 2002 and 2015 (Table 2). However, unlike emissions of CFCs, according to a "Business-As-Usual" (BAU) scenario, provisional emissions of HFCs should increase threefold. Consequently, emissions of CFCs, HCFCs and HFCs altogether, would not experience a significant decrease (2500 Mt CO_2 eq/y in 2002 and 2400 Mt CO_2 eq/y in 2015), which is disturbing. As a matter of fact, the amount of emissions prefigures the radiative forcing in the future. The BAU scenario assumes that all existing measures, including the Montreal Protocol and relevant national policies, will continue.

6. The IPCC/TEAP report considers that in 2015, according to a BAU scenario, HFC emissions would represent 7% of all greenhouse gases, i.e. 1200 Mt CO_2 eq/y in comparison with 17 000 Mt CO_2 eq/y. This figure is very high. IPCC/TEAP considers that we can and must reduce emissions of HFCs (mitigation scenario) by 60%.

7. The report considers that the costs of reduction of emissions are in the range of 0 to 300 US$ per tonne of CO_2 emission reduction, depending on the application. If we retain an average cost of 50 US$/t CO_2, the total cost of reduction of emissions for the refrigeration and air-conditioning (mobile and stationary) industry, according to the mitigation scenario, would be 36 billion US$ (720 Mt CO_2 eq. multiplied by 50 US$/t CO_2). Does the industry have the resources and the will to proceed with such an investment?

UNFCCC data

In December 2004, COP-10 (Conference of Parties) of the UNFCCC in Buenos Aires provided an opportunity to hand out to delegates the most recent figures on emissions of greenhouse gases covered by this convention and, from now on, governed by the Kyoto Protocol (Table 3).

Table 3. Annual emissions of greenhouse gases (in Mt CO_2 eq/y) for Annex I countries of the UNFCCC, in 1990 and 2015

	1990	2002	Change 1990-2002
Non-EIT* countries (24)	12 756	13 831	+ 8.4%
EIT* countries(16)	5 617	3 382	- 39.8%
Annex I countries (40)	18 376	17 212	- 6.3%
Combustion of fuels		24 102**	

*EIT: Countries with Economies In Transition **Source: IEA

In addition UNFCCC published in October 2004, a summary of information available from in-depth reviews of national communications from Parties included in Annex I to the convention (developed countries and EITs).
It contains, in particular, data on fluorocarbons.

These data call for a few comments:

1. Looking at Table 3, we may consider that the situation is satisfactory, given that the 40 Annex I countries, the only ones that have to comply with stringent commitments, reduced their emissions by 6.3% in 2002, in comparison with 1990. However this good figure is the consequence of the economic downturn in Eastern European countries, especially during 1990-1994. In these countries, emissions of GHGs decreased by 39.8%. Therefore, this figure hides the 8.4% increase in GHG emissions in the 24 non-EIT country economies. In addition, all the indicators prove that it will be extremely difficult to comply with the objective of minus 5% during the commitment period 2008-2012 in comparison with 1990, especially when one takes into consideration the fact that the economies of EIT countries have been expanding since 2001.

2. The emission figures provided by UNFCCC differ from those of AFEAS. As an example, AFEAS estimates of emissions of HFC-134a in 2002 are 139 Mt CO_2 eq, and UNFCCC, according to the national inventories, calculates an amount of 83.6 Mt CO_2 eq. This demonstrates that analysis of figures on emissions of fluorocarbons involves a great deal of uncertainty.

3. National inventories have been improved by countries year after year. In the first years, the column on fluorinated gases was not completed, except by a few countries. Today, 37 out of 40 countries have sent their figures on F-gases to the secretariat. These successive updates have finally doubled the level of HFC-emissions values. The globalization of emissions of HFCs, PFCs and of SF_6 makes it difficult to extract the HFC values alone.

4. The analysis of the tables provided by UNFCCC makes it possible to illustrate emissions of fluorinated gases as shown in Table 4.

Table 4. Emissions of HFCs, PFCs and of SF_6 in 1990, 1995 and 2002 in Mt CO_2 eq/y (according to UNFCCC tables)

	1990	1995	2002	Change 1990-2002
HFCs	73.2	120.9	182.4	+ 150%
PFCs	86.5	75.5	59.8	- 30%
SF_6	50.7	62.6	35.9	- 30%
Total	210.4	259.0	278.1	+ 32%

When analysing these data, a lack of homogeneity appears. In particular, several countries, including Japan, Poland and Czech Republic, have not provided the secretariat with values for the year 1990. Consequently, the 1990-2002 change is overestimated.

5. In 2002, according to these values, HFCs represented 1.1% of all greenhouse gases. Fluorinated gases altogether (HFCs, PFCs and SF_6) represented 1.7% of total GHG emissions.

Market and emissions of fluorocarbons in France

The Ecole des Mines de Paris published in August 2004 the figures on the market, bank and emissions of fluorocarbons in France for the year 2002. The results are summarized in Tables 5 and 6.

Table 5. Sales of CFCs, HCFCs and HFCs in France in 1995 and 2002 (in tonnes)

	CFCs + HCFCs + HFCs (tonnes)	HFCs (tonnes)	Use	Quantity (tonnes)
1995	9459	956		
2002	11 634	6931	New equipment	4200
			Maintenance	2731

Table 6. Key figures on fluorocarbons in France in 2002

Designation	Quantity (tonnes)
Bank	43 665
Market	11 633
New equipement	4410
Maintenance	5706
Emissions	7801
Recovery	between 600 and 1300

These data call for a few comments:

1. One may reasonably wonder why sales of fluorocarbons have kept on increasing since 1995. The increase of 2175 tonnes between 1995 and 2002 (23% of the market in 1995) is equivalent to the increase in sales of HFCs for mobile air conditioning.

2. However, why are we seeing, in other fields of refrigeration and air conditioning, stabilization of sales and not a decrease? What is the true impact of policies and measures that have been implemented for many years: improvement in containment, recovery and recycling of refrigerants, reduction of refrigerant charge in refrigeration systems, in particular with the use of secondary refrigerants, increased use of natural refrigerants — HC-600a in domestic refrigeration, ammonia and CO_2 (cascade) in industrial refrigeration and use of not-in-kind technology instead of the vapour-compression cycle? Is what is said different from reality?

3. It is often said that the energy-related indirect impact of refrigeration systems is preponderant with regards to the overall impact on climate. This is true. However, don't we focus too much on energy efficiency to the detriment of the direct impact due to emissions of refrigerants? In addition, measures taken in order to reduce energy consumption are insufficient. LCCP (Life Cycle Climate Performance) has not yet been standardized and the TEWI concept is not currently used to compare various technical solutions. It is mainly used, in fact, as a convincing argument. If we reflect a little bit further, today we are not capable of quantifying CO_2 emissions due to energy consumption in refrigeration plants, because such consumption is not individually itemized. Hence, we are not able to assess progress or drifts in this domain.

4. Fluorocarbon emissions in France accounted for 17% of the total refrigerant bank in refrigeration plants in 2002. This figure is far too high and demonstrates that there is considerable room for progress in terms of containment and recovery, which implies the need to achieve significant progress in the fields of training and raising the awareness of practitioners.

5. The recovery level is only approximately 1000 tonnes in comparison with emissions of 8000 tonnes. Very large amounts of emissions could therefore be avoided if recovery was really used at servicing, maintenance and end-of-life levels.

6. It would be fruitful to analyse in other countries whether the French figures are a general trend.

Conclusion

Figures and graphics published by AFEAS show spectacular progress in the use of fluorocarbons regarding the impacts on the ozone layer and global warming. A contrario, when recent reports of IPCC/TEAP, UNFCCC and the Ecole des Mines de Paris are analysed, it is noticeable that disturbing trends can be perceived, which are quite different from what is generally presented. The difficulty encountered to reach the objectives of the Kyoto Protocol will, undoubtedly, require profound changes in practices by 2008 in the fields of refrigeration and air conditioning.

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