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12th Informatory Note on Fluorocarbons and Refrigeration

Fluorocarbons and global warming

The third Conference of the Parties to the Framework Convention of the United Nations on Climate Change (UNFCCC) will be held in Kyoto, Japan in next December. The goal of the conference, as defined by the "Berlin Mandate" during the first Conference of the Parties, in March 1995, is to adopt the terms of a regulatory protocol on greenhouse gases that would take effect after the year 2000. On the eve of this important conference, it seems appropriate to review the global warming impact of fluorocarbons (i.e., CFCs, HCFCs and HFCs), used, among other things, as refrigerants. Refrigeration and air-conditioning applications, which are the subject of this note, today account for 57% of total fluorocarbon sales. /1/

The two families of fluorocarbons

There are two types of fluorocarbons:

- those containing chlorine (CFCs and HCFCs) or bromine, which are regulated by the Montreal Protocol; production of CFCs (R11, R12, R502, etc.) has been prohibited in developed countries since 1995; production of HCFCs (R22, etc.) will be by the year 2030; the UNFCCC does not deal with CFCs or HCFCs.
- those containing neither chlorine nor bromine (HFCs); they are not regulated under the Montreal Protocol, but could be taken into consideration by UNFCCC in its deliberations; they include R134a, R404A, R407C.

In the event they are released into the atmosphere, these gases contribute to the greenhouse effect. "**Global Warming Potential**", or **GWP** describes certain properties of the substance in question, particularly its lifespan and its capacity to absorb infrared radiation. As an indication, the table below gives some examples of GWPs with a time-horizon of 100 years:

CFCs		**HCFCs**		**HFCs**			
Refrigerant	GWP	Refrigerant	GWP	Refrigerant	GWP	Refrigerant	GWP
CFC-11	3800	HCFC-22	1500	HFC-134a	1300	HFC 410A	1725
CFC-12	8100			HFC-404A	3260	HFC 507	3300
R502	5500			HFC-407C	1520		

Table 1 GWPs of some CFCs, HCFCs and HFCs

The GWP alone is not enough to determine the effect of a refrigerant on global warming; the quantities emitted into the atmosphere must also be considered. A second index, **TEWI** (**Total Equivalent Warming Impact**) better characterises the overall effect of fluorocar-bons on climate. For a given system, it is the total of the direct global warming impact, from emissions of refrigerant into the atmos-phere, and the indirect global warming impact, from the emissions produced in the production of electricity or in direct burning of fuel.

Measuring emissions

The ultimate goal of the UNFCCC is to "stabilise the greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system". Nevertheless, it requires the Parties to take inventories of, and to take measures against, only those greenhouse gases that are not regulated by the Montreal Protocol; it thus excludes CFCs and HCFCs. HFCs were only recently introduced to replace CFCs and HCFCs and to help implement the Montreal Protocol. Thus, in 1990, the UNFCCC's reference year, there were almost no HFC emissions or contribution to global warming from them. They can therefore only grow in the years to come. The corresponding fall in CFC and HCFC emissions should therefore be taken into account.

What is the current global warming impact of the different greenhouse gases?

Two approaches are possible for determining this.

The first approach consists of estimating the global warming impact from real ***concentrations*** of greenhouse gases measured in the atmosphere./2/ Thus, Table 2, which is based on data from the IPCC (Intergovernmental Panel on Climate Change) gives, in the first three columns, **radiative forcing** (or **enhanced greenhouse effect**) due to long-lived greenhouse gases, from the pre-industrial era to 1992.

The enhanced greenhouse effect from greenhouse gases emitted by man from 1750 to today corresponds to 2.45 Wm^{-2}. The radiative forcing of CFCs and HCFCs, estimated by the IPCC at 0.25 Wm^{-2}, thus accounts for 10.2% of total radiative forcing /2/.

The second approach consists in comparing annual ***emissions*** of different greenhouse gases by multiplying the quantities emitted by their respective GWPs. The quantities obtained are expressed in GWP-tonnes (or CO_2-tonne equivalent). This method shows that, thanks, among other things, to the Montreal Protocol, the proportion of fluorocarbons within total annual emissions has diminished rapidly over the past few years, declining from 14.6% in 1988 (the year of the highest level of emissions), to 9.3% in 1992 and 6.5% in 1995. /1/

Greenhouse gas	**1992**		**2020**		**2100**	
	Wm^{-2}	%	Wm^{-2}	%	Wm^{-2}	%
CO_2	1.56	63.7	2.62	70.1	5.90	75.8
CH_4	0.47	19.2	0.62	16.6	1.07	13.8
N_2O	0.14	5.7	0.23	6.1	0.52	6.7
CFC + HCFC + HFC	0.25	10.2	0.27	7.2	0.29	3.7
(just HFCs)	(0)	(0)	(0.04)	(1.0)	(0.21)	(2.7)
Miscellaneous	0.03	1.2	—	—	—	—
Total	**2.45**	**100.0**	**3.74**	**100.0**	**7.78**	**100.0**

Table 2 Radiative forcing of greenhouse gases in 1992 and forecasts for 2020 and 2100 (IS92a scenario).

Forecasts for 2020 and 2100: the IS92a scenario of the IPCC

What does the future hold in store? The IPCC has studied six scenarios. The one chosen as the most realistic was the IS92a scenario, which assumes an "average" increase, with a population of 11.3 billion in the year 2100 (up from the current level of 5.9 billion) and economic growth of 2.9% per year till 2025, then 2.3% per year till 2100 /3/. This scenario takes into account the gradual decrease in CFC and HCFC levels, following the implementation of the Montreal Protocol and the successive Copenhagen and London amendments, but does not allow for measures limiting greenhouse gas emissions that could be taken in the framework of the UNFCCC.

Table 2 gives the radiative forcing values that result from scenario IS92a./2/ The share of all fluorocarbons (CFCs, HCFCs, HFCs) in radiative forcing would fall from 10.2 to 3.7% from 1992 to 2100, as a result of lower concentrations of CFCs and HCFCs in the atmosphere and of the gradual decline in new emissions. The share of just the HFCs, which are replacing chlorinated fluorocarbons, would rise from 0 to 2.7%, given the hypothetical emission levels that are discussed below. /3/.

Further improvements: containment, recovery, qualification, alternative technologies

This "average" scenario of the IPCC assumes HFC emissions of about 1,800,000 tonnes in 2100 /3/, an estimate that is highly uncertain, given the unpredictability of consumption levels and leaks and the long time scale. (What might we think of similar forecasts made at the end of the last century on the year 2000!) Nevertheless, other experts estimate that emissions in 2100 will more likely total 600,000 tonnes /4/ /5/, or about 1% of radiative forcing and not 2.7%. **There are several factors pointing to this lower estimation**, including:

- the trend toward lower refrigerant charges in plant designs, spurred by the higher costs for HFCs than for CFCs and HCFCs;
- the increasingly common (and, in developed countries, generally mandatory) practice of recovering refrigerant during maintenance, repairs and scrapping;
- advances in containment of fluid in circuits;
- the development of alternative technologies in some applications /6/;
- the growing use of zero-GWP refrigerants, like ammonia and hydrocarbons, in other applications /7/;
- the efforts of a number of countries in certifying servicemen who work on the refrigerating circuit;

These factors should eventually lead to a reduction in future fluorocarbon emissions, currently estimated at 650,000 tonnes (and most of which are CFCs and HCFCs) /1/.

An overall approach: direct and indirect effect and TEWI

This note would not be complete if it were to deal only with the **"direct" impact** on global warming from greenhouse gases used in refrigeration, and if the **"indirect" impact** were ignored /8/. Refrigerating and air-conditioning plants run on electricity, gasoline or diesel (e.g., in vehicle air-conditioning and refrigerated transport), or even natural gas (in some heat pumps). In plants running on electricity (the most common type), the indirect global warming impact comes from the CO_2 emissions of the thermal power plants that produce the electricity by burning fossil fuels. Refrigeration and air-conditioning account for 10 to 20% of total electricity consumption in developed countries, i.e., about 2 to 4% of current greenhouse-gas emissions on the basis of 0.65 kg CO_2/kWh. Those refrigerating and air-conditioning units that do not run on electricity, but on gasoline or diesel fuel, emit CO_2 directly (e.g., about 0.2% of greenhouse-gas emissions for vehicle air-conditioning). Research on **TEWI** has shown that this should turn around in the future, since for most applications global warming impact will be greater from energy consumption than from HFC emissions.

Current and future technological advances for improving the energy efficiency of refrigerating systems will play a decisive role in reducing the greenhouse effect. The COP (coefficient of performance) of refrigerating plants is generally considered to have risen over the last 30 years from 2.5 to 3.3 for temperature differences of 30°C, thus bringing energy consumption down by 25% /8/. Given current research and development efforts, it can reasonably be assumed that the average COP will rise to 4.0 or 4.5 by the year 2020, thus raising energy efficiency by another 25%.

In Conclusion

According to IPCC hypotheses, the share of direct responsibility of CFCs, HCFCs and HFCs in global warming (all applications included) will decline gradually up till the year 2100, from 10.2% of total radiative forcing today to 3.7% in 2100 (including 2.7% for HFCs). However, projections of HFC demand by application, and current advances in plant design and maintenance suggest that HFCs' share should drop to around 1% by 2100, while that of CFCs and HCFCs will be close to zero.

Note that the indirect global warming impact of refrigeration and air-conditioning plants is estimated at 2 to 4%. Advances are called for in this area, as well.

The IIR has been working in this area and **recommends**:

- that CFC and HCFC emissions not covered in the UNFCCC inventories be nonetheless included in any trend analysis of refrigeration's impact on global warming;
- that a more sector-by-sector approach be adopted for refrigeration and air-conditioning, taking into account both the direct and indirect global warming impacts of plants;
- that measures for confinement, recovery and reduction of refrigerant quantities in installations be encouraged, in order to reduce the direct global warming impact, since this remains higher that the direct impact, which is estimated at 2 to 4%; therefore, priority should be given to applications with a high leakage potential (e.g., automobile air-conditioning, and supermarket refrigeration);
- that the importance given to energy efficiency in plants be commensurate with their indirect global warming impact.

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