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## **DEVELOPMENT AND TRANSFER OF TECHNOLOGY**

### **WAYS AND MEANS OF LIMITING EMISSIONS FOR HYDROFLUOROCARBONS AND PERFLUOROCARBONS**

#### **Submissions from Parties and intergovernmental organizations**

##### **Note by the secretariat**

1. By its decision 13/CP.4, entitled "Relationship between efforts to protect the stratospheric ozone layer and efforts to safeguard the global climate system: issues related to hydrofluorocarbons and perfluorocarbons", the Conference of the Parties (COP) invited Parties, the relevant bodies of the Montreal Protocol, the IPCC, intergovernmental and non-governmental organizations to provide information to the secretariat, by 15 July 1999, on available and potential ways and means of limiting emissions of hydrofluorocarbons and perfluorocarbons, including their use as replacements for ozone-depleting substances (FCCC/CP/1998/16/Add.1).

2. The secretariat has received seven such submissions from Parties, one from an intergovernmental organization and nineteen from non-governmental organizations as at 18 August 1999. Submissions from Parties and intergovernmental organizations are included in this document. In accordance with the procedure for miscellaneous documents, these submission are attached and are reproduced in the language in which they were received and without formal editing.\*

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\* In order to make these submissions available on electronic systems, including the World Wide Web, these contributions have been electronically imported, scanned and/or retyped. The secretariat has made every effort to ensure the correct reproduction of the texts as submitted.

**FCCC/SBSTA/1999/MISC.6**

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3. The full text of all submissions, i.e. from Parties, intergovernmental organizations and non-governmental organizations, is available on the web site of the UNFCCC secretariat (<http://www.unfccc.de/program/wam/>). Computer diskettes with the submissions will be available for Parties at the eleventh session of the SBSTA.

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Technology and Economic Assessment Panel of the Montreal Protocol  
(Submission received 15 July 1999)

PAPER NO. 1: CANADA

**WAYS AND MEANS OF LIMITING EMISSIONS  
OF HFCs AND PFCs**

In response to decision 13/CP.4, Canada would like to submit the following views on ways and means of limiting emissions of HFCs and PFCs. Canada has chosen not to submit views on ways and means of limiting emissions of SF<sub>6</sub>, as recently requested by the UNFCCC Secretariat, since this was not part of the original COP-4 decision.

**Introduction**

Hydrofluorocarbons (HFC) and perfluorocarbons (PFC) are two classes of substances which are increasingly being used as substitutes for ozone-depleting substances (ODS) as these are phased-out under the provisions of the Montreal Protocol. HFCs and PFCs are potent greenhouse gases and contribute directly to climate change. Policies to limit the use of ODS, because of their effects on the ozone layer, are affecting the use patterns and the emissions of HFCs and PFCs. Similarly, policies restricting the use of HFCs and PFCs, because of their effect on the climate, could slow down the conversion or replacement of equipment using ODS. A holistic approach to the management of HFCs and PFCs and an appropriate balance of policy measures need to be considered in order to achieve the greatest benefit from both a climate change and ozone protection point of view.

**Current Canadian Approach**

Canada has been a strong supporter of the development and implementation of the Montreal Protocol and has actively promoted the goals of eliminating ODS and furthering ozone science. Canada has tracked its ODS consumption, as required under the Montreal Protocol, and has successfully phased out or is in the process of phasing out these substances, in some cases faster than required by the Protocol. In accordance with UNFCCC requirements, Canada has also tracked the increase in the use of HFCs and PFCs in order to properly inventory and report these emissions. By 2010, Canada's emissions of HFCs and PFCs are anticipated to increase to approximately 13 Megatonnes (Mt) of CO<sub>2</sub> equivalent, which would represent 2% of Canada's assigned Kyoto Protocol amount.

Canada is developing or has implemented a number of initiatives for dealing with emissions of HFCs and PFCs. These include:

- The National Action Plan for the Environmental Control of Ozone-Depleting Substances and their Halocarbon Alternatives, which has prompted the development of regulations at the provincial level which require recycling, recovery and reclamation of ODS and their halocarbon alternatives used as refrigerants, including HFCs and PFCs;

- The Federal Halocarbon Regulation (FHR) which harmonises regulations at Government of Canada installations and installations under federal jurisdiction with those developed at the provincial level. The FHR also goes further than provincial regulations by also prohibiting the use of HFCs and PFCs as solvents in Government of Canada installations and installations under federal jurisdiction beginning in 2005;

Under the 'Substances New to Canada' provisions of the Canadian Environmental Protection Act (CEPA), Environment Canada has identified a suspicion of toxicity for certain HFCs that have been subject to notification as new substances. As a consequence, the use of these new HFCs are now limited to applications where they replace ODSs.

Canada has also addressed process emissions of PFCs from aluminium smelters by encouraging voluntary initiatives within the aluminium industry.

### **Future Initiatives**

Since there are some existing HFCs that are not controlled as new substances, Environment Canada is planning the development of regulations which would limit the use of HFCs to the replacement of ODS. As part of the development of this regulation, an assessment will be conducted to establish the expected costs and benefits (environmental, economic and social) of this approach.

Additionally, Canada is assessing, through an expert panel, the potential and barriers for introduction of alternatives to ODS, including hydrocarbons, in the refrigeration and air conditioning sector. A multi-stakeholder working group is being considered to provide a forum for discussion of these issues.

### **Quantitative Assessment**

Through its National Climate Change Process (described to the Secretariat in various other submissions and interventions), Canada is conducting thorough assessments of the potential for emission reductions in various economic sectors. At present, the analysis and conclusions of this process are not complete.

PAPER NO. 2: FINLAND

**SUBMISSION BY FINLAND ON BEHALF OF THE EUROPEAN COMMUNITY  
AND ITS MEMBER STATES OF INFORMATION ON AVAILABLE AND  
POTENTIAL WAYS AND MEANS OF LIMITING HFC, PFC AND SF<sub>6</sub> EMISSIONS**

**1. Introduction**

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>) are used in a wide variety of applications ranging from aerosol cans to industrial refrigeration and electrical systems which may contain thousands of kilograms of these substances. The paper at hand describes the uses and emission sources of these gases within the European Union, and briefly discusses some of the options available for limiting emissions from these sources. The projected emission figures for 2010 quoted in section 2 are based on a "business-as-usual" scenario assuming the current level of regulation in the EU. The forecast also includes assumptions - which, as well as the uncertainties related to forecasts in general, should be kept in mind when reading the paper - regarding practice improvements and considerably decreased leakage as a result of "increased awareness" among fluorocarbon users (cf. March 1998).

**2. Description of the source categories**

There are several source categories in the EU where HFCs and PFCs are currently used or anticipated to be used in the near future: refrigeration and air conditioning equipment, foam blowing, aerosols, solvents and fire extinguishers. HFCs are also emitted from plants manufacturing these gases and as a by-product from HCFC-22 manufacture (HFC-23). PFCs (as well as HFC-23 and SF<sub>6</sub>) are also emitted from the manufacture of semiconductors. SF<sub>6</sub> is emitted from magnesium casting processes, gas insulated switchgear (GIS) and circuit breakers, as well as from SF<sub>6</sub> containing car tyres and insulated windows. Currently, the majority of HFC emissions originate from HCFC-22 manufacture, refrigeration and air conditioning systems, and the use of aerosols. Majority of PFC emissions originate from primary aluminium production.

*Refrigeration and Air Conditioning Equipment*

HFCs are used as refrigerants in replacing ozone depleting substances (CFCs and HCFCs) in domestic, commercial and industrial refrigeration applications. Also included in this source category are transport refrigeration, commercial and residential air conditioning, heat pumps and mobile air conditioning systems. The physical and thermodynamical properties of a refrigerant have an important influence on the performance of a refrigeration or air conditioning system. HFC-134a is widely used to replace CFCs in existing systems and in new refrigeration systems partly because, thermodynamically, it resembles CFC-12, traditionally one of the most extensively used refrigerant. For certain applications, where other refrigerants such as CFC-502 or HCFC-22 have been used, HFC-mixtures, such as

HFC-404A (a mixture of HFC-125, 134a and 143a), provide superior performance compared to HFC-134a and are increasingly being used to optimise performance, although they have higher GWPs than HFC-134a. New designs of refrigeration equipment may trigger a shift from some currently used mixtures to others.

Overall, the use of PFCs usually as a mixture is limited to a small number of refrigerant applications such as low-temperature refrigeration and as an easy-to-use "drop-in replacement" for certain existing CFC equipment. In some Member States the latter use is growing rapidly.

Considerable amounts of CFCs and HCFCs were still used in EU in 1995, implying a relatively low level of HFC emissions from refrigeration and air conditioning equipment. However, in 1995, refrigeration and air conditioning sector was the second largest emitter of HFCs within EU, accounting for approximately 10% of the total HFC emissions of 40.7 million tonnes CO<sub>2</sub> equivalent. A six-fold increase in emissions from refrigeration and air conditioning is anticipated by 2010, assuming the current level of regulation and even taking into account the increased awareness in the industry (March 1998). This is mainly due to the phase-out of ozone depleting substances and an increasing use of mobile air conditioning systems.

#### *Foam Blowing*

HFCs are mainly used or anticipated to be used in manufacturing closed cell foams for insulation purposes. Many of the manufacturers making polyurethane (PU), polyisocyanurate (PIR), polyethylene (PE), and extruded polystyrene (XPS) foams currently use HCFC based technologies. Revision of the current EU regulation 3093/94 on substances that deplete the ozone layer, however, is putting greater pressures on the foam industry to find alternative blowing agents for HCFCs. HFC emissions from foam blowing were estimated to be zero in 1995, but expected to rise to a level well over 10 million tonnes of CO<sub>2</sub> equivalent by 2010 (March 1998). Because a proportion of HFC used for blowing remains trapped inside the foam the anticipated use in 2010 should be much greater than the estimated emission for that year (which consists of emissions from the manufacture as well as emissions from already installed foams).

#### *Aerosols/Metered Dose Inhalers*

HFC-134a and HFC-227ea have been approved as propellants for metered-dose inhalers (MDIs) used to treat respiratory diseases such as asthma (UNEP 1998). Furthermore, HFCs (mainly HFC-134a, to a smaller degree HFC-152a) are used as propellants for one component polyurethane foam cans, which are used by craftsmen and other consumers. In this application, the HFC does not serve as a blowing agent or thermal insulant. Instead, the HFC is used as a propellant to dispense the foam from the can. Most of the propellant HFC is lost to the atmosphere at the time of application, the remainder being emitted after one year at the latest. For many countries this application constitutes a significant emission source for HFCs (e.g. for Germany more than half of total HFC emissions originate from this source). HFC-134a is also used in aerosols where flammability is of concern, i.e. aerosols used as freezing



sprays for electronics testing, freezing sprays for pipework isolation and air dusters used on electronic products such as computers. Whereas emissions from MDIs were zero in 1995, aerosols for other uses mentioned above contributed 3% of the total EU HFC emissions. A five-fold increase in emissions from general aerosols is expected, making it the fourth largest emitter by 2010 (March 1998).

#### *Solvents*

CFC-113 and methyl chloroform were previously used as solvents in electronic assembly production processes, precision cleaning, general metal degreasing and dry cleaning (UNEP 1992). Currently, there is one commercially available HFC alternative to CFC-113: HFC-43-10mee. Also, HFC-365mfc, considered for foam blowing, may prove efficient for solvent use (March 1998).

#### *Fire Extinguishers*

HFC-227ea and a mixture of HFC-134a and HFC-125 are used as halon replacements in fixed fire fighting systems. Some PFCs may also be suitable for fire fighting purposes. HFCs are estimated to replace approximately 20% and PFCs 1% of fixed halon-utilising systems since other fire fighting technologies, such as smoke detection systems, inert gas and water-based systems, are available in many applications. For portable extinguishers, HFCs are replacing halons only in some specialist applications, such as aircraft use. In 1995, there were no HFC emissions from fire fighting equipment, and the anticipated contribution of HFCs emitted from fixed systems to total EU HFC emissions by 2010 is only 0.3% (March 1998).

#### *Fugitive Emissions*

*Manufacture of HFCs, PFCs and SF<sub>6</sub>.* Fugitive emissions of a chemical occur during the production and distribution of a chemical. In 1995, fugitive HFC emissions were estimated at 0.2% of the total EU emissions of HFCs increasing to 0.8% by 2010 (March 1998). Fugitive emissions from SF<sub>6</sub> manufacture are estimated at approximately 0.2% of total quantity of SF<sub>6</sub> produced (IPCC 1999f). No estimates are available regarding the fugitive emissions of PFCs.

#### *By-Product Emissions*

*HCFC-22 manufacture.* Trifluoromethane (HFC-23) is generated as a by-product during the manufacture of HCFC-22. The HFC-23 is separated as a vapour from the HCFC-22, and, as an unwanted product in most cases, has been vented to the atmosphere. In some cases it may be captured for use or thermally destroyed. HCFC-22 is produced in a number of EU Member States with the total production amounting to approximately 128 000 tonnes in 1995 (IPCC 1999a). It should be noted that emissions from HCFC-22 manufacture does not necessarily correlate with the production figures since emission abatement technologies may be in place.

In 1995, HCFC-22 manufacture was the largest HFC emission source within EU, generating 85% of total emissions of HFCs. Many plants have made process changes in order to reduce

the generation of the unwanted by-product HFC-23, thus increasing the yield of HCFC-22. Also, EU regulations related to ozone depleting substances are anticipated to cause a substantial cut in HFC-23 emissions by 2010, at which point the contribution to total EU emissions would have shrunk to 15% (March 1998).

#### *Aluminium Production*

The majority of EU's PFC emissions are generated by the primary aluminium industry. The PFCs emitted are carbon tetrafluoride,  $\text{CF}_4$ , and carbon hexafluoride,  $\text{C}_2\text{F}_6$ . These two gases are formed during a phenomenon known as the Anode Effect (AE). The amount of PFCs formed depend primarily on the frequency and duration of the AE. The magnitude of PFC emissions from aluminium production range from 0.02 to 1.19 kg of  $\text{CF}_4$  per tonne aluminium produced, and 0.001 to 0.14 kg of  $\text{C}_2\text{F}_6$  per tonne aluminium produced. These emission factors vary considerably because they are process and smelter specific; also the uncertainties related to these factors are relatively high, typically of the order of 50% (IPCC 1997). Primary aluminium is produced in 8 EU Member States with total production of approximately 2.1 million tonnes in 1995 (Heijnes et al. 1999). As estimated by the European Aluminium Association, PFC emissions from aluminium production in 1995 were 6.8 million tonnes of  $\text{CO}_2$  equivalent (EAA 1999).

#### *Semiconductor manufacture*

Fluorinated compounds are used by the semiconductor industry for cleaning chemical vapour deposition (CVD) chambers and for plasma (dry) etching. Six fully fluorinated compounds and one hydrofluorocarbon are used for these two purposes: tetrafluoromethane ( $\text{CF}_4$ ), hexafluoroethane ( $\text{C}_2\text{F}_6$ ), octafluoropropane ( $\text{C}_3\text{F}_8$ ), octafluorobutane ( $\text{C}_4\text{F}_{10}$ ), sulphur hexafluoride ( $\text{SF}_6$ ), nitrogen trifluoride ( $\text{NF}_3$ ) and trifluoromethane ( $\text{CHF}_3$ ). (IPCC 1999) Emissions of PFCs from this source are not well known because there is no common inventory method currently in use. It is estimated that approximately 50 tonnes of  $\text{SF}_6$  was used in Europe in 1995 by the semiconductor industry (Maiss & Brenninkmeijer 1998).

#### *Magnesium industry*

Molten magnesium and its alloys are volatile substances that oxidise explosively in air. Safe casting of molten magnesium thus require the use of a protective gas and  $\text{SF}_6$  is commonly used for this purpose. (IPCC 1999d) It is estimated that approximately 70 tonnes of  $\text{SF}_6$  was used in Europe in 1995 for blanketing molten magnesium (Maiss & Brenninkmeijer 1998).

#### *Electrical equipment*

$\text{SF}_6$  is used as an insulant in Gas Insulated Switchgear (GIS) and other electrical equipment, such as circuit breakers (IPCC 1999e). In 1995, a total purchased quantity of 1200 tonnes of  $\text{SF}_6$  for new installations is reported, of which 360 tonnes is accounted for by losses (Maiss & Brenninkmeijer 1998).

### *Other SF<sub>6</sub> sources*

Other European sources of SF<sub>6</sub> include car tyres and soundproof windows. In Germany, 130 tonnes of SF<sub>6</sub> was purchased in 1995 for filling tyres. Of this quantity, 112 tonnes was emitted (Schwarz & Leisewitz 1996). For soundproof windows, an estimated amount of 350 tonnes was used in Europe in 1995 (Maiss & Brenninkmeijer 1998). SF<sub>6</sub> is also used for laboratory purposes, in soles of sport shoes, as a tracer gas in air pollution and other atmospheric studies, and some other niche uses.

### **3. Ways and means of limiting emissions**

This chapter of the submission first addresses some general policy and strategy aspects related to limiting the emissions of HFCs, PFCs and SF<sub>6</sub>. Secondly, examples are given of measures which already have been adopted or are being planned by the individual Member States of the European Community. Finally, a description of options for emission reduction and limitation is included. The last part of this chapter follows the structure of the reporting format provided by the UNFCCC Secretariat.

The Council of the European Union, in Conclusions adopted in its Meeting on 16 and 17 June 1998 addressed the issue of new greenhouse gases as follows: *"The Council notes with concern the projected growth of some industrial gases with high global warming potential. In particular, it recognises the importance of further work on policies to limit and/or reduce emissions of HFCs, PFCs and SF<sub>6</sub>, particularly in the light of their inclusion within the Kyoto basket of gases. It stresses the role that common and co-ordinated policies could play alongside national measures in this area and invites the Commission to develop a framework covering all fields of production and use of these gases for emission limitation and/or reduction that can be further elaborated by Member States. This framework could include the following issues: improved monitoring of actual emissions, good housekeeping, action to reduce leakage, life-cycle management and recycling, reduction of used amounts by improving efficiency of cooling / heating / air-conditioning equipment, and substitution. The Council calls upon the Member States to put in place programmes to limit and/or reduce emissions of these gases, taking into account their global warming potential including, where appropriate, agreements with manufacturers and key users. In addition, The Council calls upon the Commission to pursue the development of environmentally sound and safe alternatives for HFCs, PFCs and SF<sub>6</sub>."*

There are various available options for emission reduction of HFCs, PFCs and SF<sub>6</sub>. These include e.g. substitution by alternative fluids (including substitutes with lower GWP, where appropriate) or not-in-kind technologies, prevention of leakages, process modifications, emission controls, labelling of products, and provisions for recovery and reuse or disposal.

Also a set of different implementation mechanisms for emission reduction options is available. These include legislation, voluntary agreements between industry and regulators, unilateral commitments by industry, government recommendations, information campaigns, and economic instruments. Also, encouragement of research and development can play a role.

The choice of any emission reduction strategy needs to take into account the specific situation of each (sub)sector of emission sources. In general, the combination of a reduction option

and the means to implement it has to be effective in actually reducing the emission. It also has to be practicable so that its implementation can be relatively simple. An evaluation of the economic impact of the proposed measure is useful for a comparison of cost-effectiveness of different strategies. Finally, any emission reduction strategy needs to be monitored for the evaluation of its success.

Attention also needs to be paid to the fact that HFCs and PFCs are used to replace ozone depleting substances. In certain applications HFCs, and to a lesser extent PFCs, may be the only technically and economically feasible alternatives to them for the time being. As a general principle, action taken to reduce HFC and PFC emissions should not undermine the efforts to phase out ozone depleting substances.

During the Tenth Meeting of the Parties to the Montreal Protocol the European Community and its Member States adopted, together with 25 other Parties, on 24 November 1998, a Declaration on Hydrochlorofluorocarbons (HCFCs), Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs). In this Declaration these Parties:

1. *“Call upon all bodies of the Montreal Protocol not to support the use of transitional substances (HCFCs) where more environmentally friendly alternatives or technologies are available;*
2. *Urge all Parties to the Montreal Protocol to consider all ODS replacement technologies, taking into account their total global-warming potential, so that the use of alternatives with a high contribution to global warming should be discouraged where other, more environmentally friendly, safe and technically and economically feasible alternatives or technologies are available.”*

In the European Union some Member States have created or are in the process of creating their national policies and measures towards reducing the emissions of new greenhouse gases. In addition, certain measures adopted to limit the emissions of ozone depleting substances, such as leakage control, also limit the emissions of HFCs and PFCs. Examples of measures limiting and/or reducing HFC, PFC and SF<sub>6</sub> emissions are listed below (the list is not exhaustive).

### ***Austria***

Planned and other measures:

- The Ministry of Environment is starting negotiation with the window producing industry to phase out SF<sub>6</sub> as a fill gas to produce sound absorbing windows.
- The Ministry of Environment together with the Association of Consumer Information is preparing a ECO-labelling system for insulation foam boards (PU/XPS foams) which will sign these boards as environmental friendly if they meet defined criteria developed by the ministry.
- In the production of magnesium SF<sub>6</sub> has been substituted as a protective gas by a mixture of SO<sub>2</sub> and N<sub>2</sub>.
- In foam cans for PU foams HFCs have been substituted as blowing agents by a mixture of propane, butane and dimethyl ether.

## ***Belgium***

### Planned and other measures:

- A national policy plan will be developed with measures to reduce and limit the emissions of HFCs and PFCs.

### Flemish Region

- Information system on ODS alternatives is being constructed.
- Certification programme for service and reparation technicians.
- Additional legislation for the use of ODS and HFCs and PFC in refrigeration and air conditioning.
- An inspection campaign on refrigerating systems is being carried out.

## ***Denmark***

### Measures already in place:

- The use of HFCs as fire extinguishing fluids is not allowed.
- According to The Refrigerant Sector Environment Scheme (KMO) only registered enterprises and / or individuals, who have the necessary knowledge and recovery equipment are allowed to purchase refrigerant.
- According to The Refrigerant Sector Environment Scheme (KMO) all refrigerants must be recovered and recycled, including HFCs.
- The National List of Undesirable Substances published in 1998, includes HFCs, PFCs and SF<sub>6</sub> as undesirable due to their greenhouse effect.
- According to national law Copenhagen community has adopted regulation entering into force by 1. July 1999 which requires leakage test for all larger refrigeration systems within the boundary of the municipality containing artificial refrigerants, i.e. CFC, HCFC, HFC and PFC. For HFC and PFC containing refrigeration systems the requirement is 2 checks per annum for systems containing less than 100 kg and 4 checks for systems containing more than 100 kg. For CFC and HCFC containing equipment the checks are more often. A number of municipalities are expected to use the possibility given by national legislation to adopt regulation of larger refrigeration systems containing artificial refrigerants, i.e. CFC, HCFC, HFC and PFC.

### Planned and other measures:

- A national greenhouse gas emission reduction strategy including HFCs, PFCs and SF<sub>6</sub> is under development. The first evidence is the inclusion of HFCs, PFCs and SF<sub>6</sub> to the National list of Undesirable Substances. For HFCs the political goal is a phase-out by 2006. Greenhouse warming (existing CO<sub>2</sub>-tax times GWP) taxes have been suggested for reaching the goal.
- An investigation was done on substitutes for potent greenhouse gases. The results

were published in 1999, showing the feasible alternatives and pointing out areas where research is needed.

### *France*

Measures already in place (applying to systems with more than 2 kg of refrigerant):

- A decree regarding refrigerant fluids contains an obligation to recover or destroy fluids when emptying or at disposal and requires that companies and their staff that handle these substances must be qualified.
- Another decree brings in an obligation to prevent leakage and check the system for leakages annually.
- Financial incentives for companies that collect refrigerant fluids.

Planned and other measures:

- A number of improvements to the above-mentioned decrees.
- Research and development regarding charge size minimisation, alternative fluids and improved energy efficiency.
- Discussions between industry (e.g. semiconductor, aluminium, electrical equipment, magnesium) and government regarding efficient means of limiting emissions.

### *Germany*

Measures already in place:

- Eco-labelling of HFC-free refrigerators.
- Incineration of HFC-23 from HCFC-manufacture.
- Ban of the use of HFCs as solvents pursuant to an ordinance.
- Declaration of the primary aluminium industry to reduce PFC emissions.
- Declaration of the manufacturers and users of SF<sub>6</sub> in electrical switching equipment and systems.
- Effects of the Thermal Insulation Ordinance on the reduction of SF<sub>6</sub> emissions of new windows.

### *Italy*

Measures already in place:

- Recovery and reuse of SF<sub>6</sub> from electrical equipment according to certain technical directives.
- A law bans the use of HFCs and PFCs in fire extinguishers.

Planned and other measures:

- Research in progress regarding safety and health problems related to HFC alternatives.
- Feasibility studies on centralised ammonia plants.
- A campaign to inform doctors and patients on the availability of alternatives to HFC-MDIs.

### *The Netherlands*

Measures already in place:

- Regulation regarding leakage from refrigeration systems (includes an objective of maximum loss of refrigerant per year: 0.1 - 1% of initial charge).
- national greenhouse gas emission reduction strategy including HFCs, PFCs and SF<sub>6</sub>.
- decision on voluntary reduction of HFC-23 from HCFC-22 manufacture is being implemented.
- The Netherlands Climate Policy Implementation Plan (announced by the government: improved monitoring of emissions; agreement on PFC reduction in the aluminium industry; agreements on reduction of HFC and PFC emissions from refrigeration and air conditioning, aerosols, foams, fire extinguishers and solvents; financial and fiscal support for emission reduction measures; etc.); the plan still has to be adopted by the Parliament.

### *Sweden*

Measures already in place:

The Refrigerants Order and the Swedish Code of Practice:

- Only accredited enterprises may install or conduct any service or maintenance of refrigeration systems.
- Material and design of refrigeration and air-conditioning system shall be such that leakage is minimized, maintenance is facilitated, refrigerant charge is minimized, refrigerants with smallest effect on ozone layer and climate is chosen.
- The refrigerants must be recovered or reclaimed for reuse or destruction.
- All equipment shall be subject to regular leak tests and controlled by accredited enterprises at least once a year.

The Swedish Fire Extinguisher Order

- Includes provisions for handling halons, HCFCs and HFCs (regular leak tests at least once a year, a record must be kept of leakages, only approved enterprises may handle fire extinguishing fluids, facilities containing more than 20 kg of fire extinguishing fluids must report annually to the Regional Authorities).

## ***United Kingdom***

Measures already in place:

- Statutory local air pollution guidance helping reduce SF<sub>6</sub> emissions and requires users to monitor use of SF<sub>6</sub>.
- Statutory pollution control resulted in significant reductions in PFC emissions from aluminium smelting.
- Statutory pollution control reduced HFC-23 emissions from main HCFC-22 production plant by 99%.
- Voluntary agreements between the government and the refrigeration, foam blowing, fire protection, aerosol, and mobile air conditioning sectors aiming to minimise emissions of HFCs.
- The voluntary agreement with fire protection sector also includes PFCs.

Planned and other measures:

- Discussion between government and industry on options for lowering SF<sub>6</sub> emissions from electrical equipment.
- Policy options for reducing PFC emissions in other than fire protection sectors.
- Review of effectiveness of voluntary agreements on HFCs/PFCs.

### **Way No.1**

<b>Name:</b>	Refrigerant conservation
<b>Type:</b>	Technology, leakage reduction in existing equipment Technology, recovery/recycling Technology, destruction Technology, improved system design Improved operation and maintenance procedures
<b>Sector:</b>	Refrigeration and air conditioning, all
<b>Gases affected:</b>	HFC-23, HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-143a, C <sub>3</sub> F <sub>8</sub>

**General description:** The scope for improved refrigerant conservation is considerable in reducing emissions of HFCs from refrigeration and air conditioning applications. Basic elements of refrigerant conservation include (UNEP 1998):

- properly design and install new equipment so as to minimise actual or potential leaks;
- leak-tighten existing systems so as to reduce emissions;
- improve service practices, including recovery, permitting continued system operation with reduced need to add refrigerant;
- make sure that refrigerant is recovered at system disposal.

**Examples of application:** Refrigerant conservation is particularly suitable for refrigeration applications where historical emission rates have been high or fairly high, such as medium



and large commercial refrigeration, refrigerated transport, mobile air conditioning, industrial refrigeration, and chillers.

**Economic impact:** Conservation saves money because of the reduced need to add refrigerant. Well designed and optimally performing refrigeration system will also consume less power (money savings).

**Environmental impacts:** Refrigerant conservation reduces all refrigerant emissions thus decreasing adverse effects to the environment caused by different refrigerants. Well designed and optimally performing refrigeration system will also consume less power and thus contribute less to the indirect effect (CO<sub>2</sub> from power plants).

**Sources of additional information:** UNEP 1998. *1998 Report of the Technology and Economic Assessment Panel (Pursuant to Article 6 of the Montreal Protocol)*. United Nations Environment Programme, Ozone Secretariat.

### Way No. 2

**Name:** Refrigerant alternatives  
**Type:** Technology, substitution  
**Sector:** Refrigeration and air conditioning, all  
**Gases affected:** HFC-23, HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-143a, C<sub>3</sub>F<sub>8</sub>

**General description:** Several European manufacturers use isobutane in their refrigerators and freezers. In Germany, for instance, hydrocarbons represent nearly 100% of the market. Isobutane has the advantage of an insignificant GWP (approximately 20) compared to HFC-134a (approximately 1300).

Alternative fluids such as ammonia and hydrocarbons are also available for commercial refrigeration systems. Other possible alternatives include water, which can be used for refrigeration temperatures above 0 degrees C.

**Limitations:** The use of ammonia or hydrocarbons is not suitable for traditional large direct expansion systems due to safety concerns. These refrigerants require indirect refrigeration technology, such as secondary loop systems or distributed systems.

**Examples of application:** Large supermarkets in several EU countries have refrigeration systems utilising ammonia as a refrigerant. In Sweden, approximately 75 hydrocarbon-utilising supermarket refrigeration systems have been built since 1996 (Pedersen 1998). In some European countries, ammonia is now the standard in industrial refrigeration systems (e.g. food processing industry). Also, an industrial chiller based on water vapour compression has been built in Europe. It uses 30-40% less energy than the best available ammonia and HCFC/HFC technology. Some of the European car manufacturers have developed mobile air conditioning systems that utilise CO<sub>2</sub> as a refrigerant.

**Other remarks:** When assessing the use of alternative fluids in refrigeration equipment, the indirect effect due to energy use (the TEWI concept) should be taken into account.

**Sources of additional information:** Pedersen, P. H. 1998. *Muligheder for at reducere forbrug og emission af kraftige drivhusgasser (HFC'er, PFC'er og SF6)*. Dansk Teknologisk Institut, DTI Energi.

### Way No.3

**Name:** Refrigerant charge size reduction  
**Type:** Technology, other  
**Sector:** Refrigeration and air conditioning, all  
**Gases affected:** HFC-23, HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-143a, C<sub>3</sub>F<sub>8</sub>

**General description:** Charge size reduction in some refrigeration applications could dramatically reduce the emissions from these system. For instance, supermarket refrigeration systems have been dominated by so called direct expansion systems, where high pressure refrigerant from the machine room is circulated through the display cases located in the retail sales floor. Large supermarket systems may have thousands of metres of potentially leaky piping and very high refrigerant charges (AFEAS 1997). There are two commercially available technical options for reducing the charge size of large commercial refrigeration systems: secondary loop systems and distributed systems.

Secondary loop systems employ two separate heat transfer loops: one for the refrigerant and one for brine solution. The brine solution is circulated through the display cases using a pump. The refrigerant is contained within the primary loop in the machine room and does not enter the retail sales floor. A heat exchanger is required to cool the brine solution with the refrigerant. Because the refrigerant is no longer in the proximity of the customers, it is possible to use alternative fluids, such as ammonia. A number of supermarket installations with CO<sub>2</sub> as a secondary refrigerant have been installed with good results. Supermarket systems using ice-slurry (a mixture of water, ice and ethanol) are also installed in some European countries.

Distributed systems are another attempt to reduce the refrigerant emissions from commercial systems. This approach brings the compressors near the display cases they are servicing, thus reducing the length of piping. Commercially available systems employ a water loop to connect all of the compressor installations with a single cooling unit, which is required for the waste heat rejection.

**Other remarks:** The down side of these kind of systems is the thermodynamic penalty from using a heat exchanger, and the use of a pump for brine circulation, both of which add to the power consumption of the system. This penalty can be reduced by new developments in evaporating and melting secondary refrigerants.

A TEWI comparison of the three systems indicates that the GWP of alternative refrigerants for direct expansion systems has a significant effect on direct emissions. Moreover, the

results indicate that a significant reduction in TEWI could be achieved using either secondary loop or distributed systems (due to charge size reduction). The thermodynamic losses and pumping power requirements discussed above would, however, increase the energy consumption by 8 to 26% depending on the system in question. The overall reduction in TEWI would still be significant (AFEAS 1997).

**Sources of additional information:** AFEAS 1997. Energy and Global Warming Impacts of HFC Refrigerants and Emerging Technologies. Alternative Fluorocarbons Environmental Acceptability Study and US Department of Energy. Oak Ridge National Laboratory: Oak Ridge, Tennessee.

#### Way No. 4

**Name:** Alternative refrigeration technologies  
**Type:** Technology, other  
**Sector:** Refrigeration, domestic  
Refrigeration, heat pumps  
**Gases affected:** HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-143a, C<sub>3</sub>F<sub>8</sub>

**General description:** Alternative technologies that are commercially available include absorption technologies (in refrigerators and industrial heat pumps). The applicability of this type of system is often limited to applications where waste heat is available. In other applications the energy efficiency of this type of system is often poor. Thermoelectric refrigeration is another alternative technology used in some applications, e.g. small drink cooler cabinets. Both of these technologies, however, are unlikely to replace compression vapour refrigeration for the broader refrigeration market. Not-in-kind technologies may prove feasible in some applications.

#### Way No. 5

**Name:** Refrigerant recovery and disposal  
**Type:** Technology, recovery / recycling  
Technology, destruction  
**Sector:** Refrigeration and air conditioning, all  
**Gases affected:** HFC-32, HFC-125, HFC-134a, HFC-152a, HFC-143a, C<sub>3</sub>F<sub>8</sub>

**General description:** Large refrigeration and air conditioning systems may contain hundreds or thousands of kilograms of refrigerant, most of which may still be in the system at decommissioning. Correct recovery and disposal thus play a vital role in minimising end of life emissions from these systems. Recovery is applicable also to smaller systems, such as domestic refrigerator and freezers.

Refrigerant recovered from a refrigerating system can be returned to the same system after recycling. It may be necessary to reclaim the refrigerant before it can be reused in another system to make sure that the contaminant level will not damage the equipment or adversely affect its performance. In addition, used refrigerants may be destroyed. Chlorofluorocarbons

and other halogenated solvents are included in the list of hazardous waste (Council Decision 94/904/EC).

**Other remarks:** Efficient recovery and disposal of CFC and HCFC refrigerants is already required in the EU Council Regulation 3093/94 on substances that deplete the ozone layer. Certain Member States have the same provision in their legislation covering also HFCs.

### Way No. 6

**Name:** Alternative foam blowing agents  
**Type:** Technology, substitution  
**Sector:** Foam, all  
**Gases affected:** HFC-134a, HFC-152a, HFC-245fa, HFC-365mfc

**General description:** Hydrocarbons are currently widely used in polyurethane applications such as flexible faced laminate/boardstock and sandwich panels and appliance foam. Hydrocarbons are used in producing approximately 50% of the European polyurethane foam while the remaining half of the production is blown with HCFCs. Other alternative blowing agents such as water and CO<sub>2</sub> are used for the manufacture of packaging materials and cushioning. CO<sub>2</sub> is also suitable for XPS foam blowing: there are plants already in Europe manufacturing XPS with CO<sub>2</sub> as a blowing agent. HFC-134a is currently used as a blowing agent in manufacturing appliance insulation. Other HFCs suitable for polyurethane foams (HFC-245fa and HFC-365mfc) are not yet commercially available.

### Way No. 7

**Name:** Not-in-kind insulation materials  
**Type:** Technology, other  
**Sector:** Foam, all  
**Gases affected:** HFC-134a, HFC-152a, HFC-245fa, HFC-365mfc

**General description:** The current insulation market is dominated by such not-in-kind insulation materials as mineral wool and glass-fibre. These products are viable alternatives in some cases to polyurethane insulation although the insulation performance is poorer.

### Way No. 8

**Name:** Emissions reduction options for HFC-blown foams  
**Type:** Technology, leakage reduction in existing equipment; Technology, recovery / recycling; Technology, destruction; Technology, improved system design  
**Sector:** Foam, all  
**Gases affected:** HFC-134a

**General description:** There are a number of emissions reduction options available for different types of foam:

Phase of life	Potential reduction measure	Applicable to
Manufacture	Capture of vapour at “head”	XPS, PU/PF flex board
	Re-capture from scrap/trim	All foam types (esp. block)
Use	Better installation practice	All foam types
	Lower permeability facings	Flexibly-faced laminates
De-commissioning	Controlled removal procedures	All foam types
	Incineration facilities	All foam types

Also, some types of insulation materials are perfectly usable after de-commissioning for less demanding applications. So the importance of recycling and reuse should be stressed for this source category.

Way No. 9

**Name:** Reduction of HFC emissions from aerosols  
**Type:** Technology, substitution  
 Technology, other  
**Sector:** Aerosols, all  
**Gases affected:** HFC-134a, HFC-152a,

**General description:** In addition to alternative dispensing technologies for aerosols, such as pump sprays, there are three main alternative types of propellant to previously used HFCs (March 1998):

- hydrocarbons (HCs);
- dimethyl ether (DME);
- compressed gases (e.g. CO<sub>2</sub>, N<sub>2</sub>, compressed air, nitrous oxide).

The use of HFCs should be limited to applications where there are no other safe or practical options. It is also possible to substitute HFCs used as propellants in one component polyurethane foam cans. In several countries, HFCs are no longer used for this purpose. Otherwise, due to the highly emissive nature of aerosols, there are no feasible reduction options available (March 1998).

Metered dose inhalers: There are two main alternatives to CFC using MDIs: dry powder inhalers (DPIs) and MDIs using HFCs. Although alternatives are available (and being used extensively in some countries, e.g. DPIs in Sweden), not all patients can use them and have to rely on MDIs with a propellant (Pedersen 1998).

**Sources of additional information:**

- March 1998. *Opportunities to Minimise Emissions of Hydrofluorocarbons (HFCs) from the European Union*. March Consulting Group, UK.
- Pedersen, P. H. 1998. *Muligheder for at reducere forbrug og emission af kraftige drivhusgasser (HFC'er, PFC'er og SF6)*. Dansk Teknologisk Institut, DTI Energi.

**Way No. 10**

**Name:** Reduction of HFC emissions from solvents  
**Type:** Technology, substitution  
Technology, improved system design  
Improved operation and maintenance procedures  
**Sector:** Solvents, all  
**Gases affected:** HFC-43-10 mee

**General description:** Only in a few solvent applications where ozone depleting substances were traditionally used is industry currently considering the use of HFCs. Many other viable alternatives exist for most applications. If HFCs become more widely used as solvents, the available options for emissions reduction are to choose a solvent with the lowest possible GWP, to minimise evaporative losses by improved design of the solvent bath itself, and by allowing the product to drain before leaving the enclosure.

**Way No. 11**

**Name:** Reduction of HFC and PFC emissions from fire fighting  
**Type:** Technology, substitution  
Technology, other  
**Sector:** Fire extinguishers, fixed systems  
**Gases affected:** HFC-227ea, HFC-134a, HFC-125, C<sub>3</sub>C<sub>8</sub>

**General description:** Not-in-kind technologies (such as highly sensitive smoke detectors) are of significant importance in replacing fixed halon systems. Approximately 50% of the market that relied on fixed halon systems have moved to such technologies. Also, a large proportion of earlier halon users have moved to natural fluids such as nitrogen, CO<sub>2</sub> or water. HFCs and PFCs are mainly used as alternatives to halons in some specialist applications. Also, the majority of portable halon extinguishers are being replaced by such alternatives as CO<sub>2</sub>, foam or water (March 1998).

Emissions reduction options for those fixed fire fighting system that are based on HFCs include improved system design to minimise the number of false alarms, and better testing practices, which reduce the need to discharge a proportion of the charge during testing. Significant product development has led to new systems that have relatively low annual emission rates, ranging from 1 to 3% of the initial charge (March 1998).

**Sources of additional information:**

March 1998. *Opportunities to Minimise Emissions of Hydrofluorocarbons (HFCs) from the European Union*. March Consulting Group, UK.

Way No. 12

**Name:** Reducing HFC-23 emissions from manufacturing of HCFC-22  
**Type:** Technology, improved system design  
Technology, destruction  
End of pipe technology  
**Sector:** By-product emissions  
**Gases affected:** HFC-23

**General description:** Virtually all (98 - 99%) HFC-23 emissions from HCFC-22 manufacture occur at a certain point of the process: the condenser vent (IPCC 1999a). Other points where HFC-23 is emitted or may be emitted from the process include fugitive emissions from leaking compressors, valves and flanges; separation from the main product using scrubbers; and venting from the storage tank where the HFC-23 is recovered.

The fact that most of the emissions take place at the condenser vent makes it possible to capture efficiently most of the HFC-23 and pass it to incineration. This way, a reduction of up to 99% in the overall emissions can be achieved. It is estimated that the cost effectiveness of these measures would be very high (March 1998).

**Sources of additional information:**

March 1998. *Opportunities to Minimise Emissions of Hydrofluorocarbons (HFCs) from the European Union*. March Consulting Group, UK.

Way No. 13

**Name:** Reducing PFC emissions from primary aluminium smelting  
**Type:** Technology, improved system design  
Policy and measure, training of technicians  
**Sector:** Aluminium production  
**Gases affected:** CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>,

**General description:** Reduction in PFC emissions from primary aluminium smelting can be achieved by controlling the frequency and duration of anode effects (AEs). It is possible to reduce AEs by as much as 70%. The reduction can be achieved by computerised process controls, but also increasing employee awareness and training, and the development of team-based management approaches can play a vital role. These measures result not only in reduced PFC emissions but can also improve energy efficiencies and process stability, thereby reducing overall emissions associated with primary aluminium production.

Way No. 14

<b>Name:</b>	Reducing PFC, HFC and SF <sub>6</sub> emissions from semiconductor manufacturing
<b>Type:</b>	Technology, improved system design Improved operation and maintenance procedures
<b>Sector:</b>	Semiconductors manufacturing
<b>Gases affected:</b>	CF <sub>4</sub> , C <sub>2</sub> F <sub>6</sub> , C <sub>3</sub> F <sub>8</sub> , c-C <sub>4</sub> F <sub>8</sub> , SF <sub>6</sub> , HFC-23

**General description:** PFCs are emitted from semiconductor manufacturing processes. Listing of potential reduction options for this source is difficult. This is due to the complexity of the production process and the rapid rate at which processes change in this dynamic industry. It has been reported, though, that efforts to develop ways to measure these emissions are being undertaken by industry leaders throughout the world (IPCC 1999c).

**Sources of additional information:**

IPCC 1999c. "Expert Group Meeting on Good Practice in Inventory Preparation - Industrial Processes and New Gases: PFC, HFC, and SF<sub>6</sub> Emissions from Semiconductor Manufacturing (DRAFT)". IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories.

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IPCC (1999b.)

*Expert Group Meeting on Good Practice in Inventory Preparation - Industrial Processes*



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*Expert Group Meeting on Good Practice in Inventory Preparation - Industrial Processes and the New Gases: Sulphur Hexafluoride (SF<sub>6</sub>) Emissions from Magnesium*. IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories.

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*Expert Group Meeting on Good Practice in Inventory Preparation - Industrial Processes and the New Gases: SF<sub>6</sub> from Electrical Equipment and Other Uses (Draft)*. IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories.

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PAPER NO. 3: KENYA

**POTENTIAL WAYS AND MEANS OF LIMITING EMISSIONS OF  
HYDROFLUOROCARBONS AND PERFLUOROCARBONS**

Kenya notes that a number of alternatives for Ozone-depleting substances have been accepted and adopted by the Parties to Montreal Protocol. These substances include Hydrofluorocarbons (HFCs) which have zero Ozone Depleting Potential (ODP) and Hydrochlorofluorocarbons (HCFCs) which even though have negligible ODP, have some ODP nonetheless. HCFCs are therefore being used on the interim basis and are to be phased out by 2030 in the developed countries and by 2040 in the developing countries. In view of global warming potentials of HCFCs earlier phase out dates are currently being negotiated by the meeting of the Parties to the Montreal Protocol.

Both HFC and HCFC have high global warming potentials (GWPs).

It is to be noted that Montreal Protocol allows a certain level of production of controlled substances (about 15%) ostensibly for basic domestic needs of the developing countries. This allowance encourages continuous production of these Ozone Depleting Substance (ODSs). The developed countries have also remained passive to the export of equipment that are designed to use, contain, or depend on CFCs and it can therefore be stated that they have encouraged continued use of ODSs.

HFCs and HCFCs are costly, are not readily available and the non-availability of technical know-how on their handling and service etc. have acted as disincentive for their adoption. Therefore, their use has not yet taken strong root. However, these substances can be phased out and replaced with hydrocarbons (HC) on which current indications are that they are better alternatives due to their availability and low cost. HC do not also deplete the Ozone layer or cause global warming. However, since HC are flammable, consideration should be taken to improve safety aspects in using them as alternatives to ODS.

Perfluorocarbons are alternatives to ODS used as alternative solvents. They do cause global warming. For this reason, they can also be replaced with other non-ozone depleting alternatives that are listed by the Protocol.

The Montreal Protocol provision for increased production of ozone depleting substances, except where it is for essential use as defined by the Protocol, should be reviewed. This is a little area where the developed countries could face the litmus test in transfer of technology.

We note that control of emission of ODS, or alternatives to ODS known to have GWPs, remains to be the priority of the Montreal Protocol. Since some of these ODS are listed in Annex A to the Kyoto Protocol, it is recommended that Technical Options Committee of the Montreal Protocol and the SBSTA of the UNFCCC should form a joint working group or Task force to establish ways and means of limiting emissions of these ODSs with GWPs.

PAPER NO. 4: NEW ZEALAND

**RELATIONSHIP BETWEEN EFFORTS TO PROTECT THE STRATOSPHERIC OZONE LAYER AND EFFORTS TO SAFEGUARD THE GLOBAL CLIMATE SYSTEM: ISSUES RELATED TO HYDROFLUOROCARBONS AND PERFLUOROCARBONS**

New Zealand welcomes submissions by Parties and other bodies providing information on potential ways and means of reducing emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), and thanks the Secretariat for facilitating technical submissions through the provision on an electronic common reporting format.

Given the importance of ensuring multilateral environmental agreements are implemented in a coherent and complementary manner, New Zealand considers that particular emphasis should be placed on information relating to the interface between the Montreal Protocol and the Kyoto Protocol ie. on the use of HFCs and PFCs as replacements for ozone-depleting substances. The primary focus at this stage should be on facilitating the implementation of the Kyoto Protocol and Montreal Protocol in a mutually reinforcing fashion.

Technical information on ways and means of reducing emissions from other sources will be extremely valuable to the long-term implementation of the Kyoto Protocol. Information we have available at this stage is contained in New Zealand's Second National Communication.

PAPER NO. 5: NORWAY

**WAYS AND MEANS TO LIMIT EMISSIONS OF HFCS**

**Submission from Norway, August 1999**

The Conference of the Parties in its decision 13/CP.4 invited Parties to provide information on measures to abate emissions of HFCs and PFCs to the UNFCCC Secretariat. In this submission we only provide information on HFCs, since no analysis regarding ways or means to limit emissions on PFCs or SF<sub>6</sub> has been carried out. Our submission concentrates on technical options to reduce HFC emissions, but there is ongoing work in Norway regarding the means and instruments for reduction of these emissions. Please note that this is preliminary information, and that we will submit the information using the required Internet form as soon as possible.

The Norwegian Pollution Control Authority conducted a study in 1997 on reductions in the use of HFCs, with an analysis of possible measures and their related costs (SFT 97:32, Reductions in the use of HFC. Measures and costs). The measures were directed towards the use of HFCs as refrigerants, foam blowing agents, solvents and fire extinguishing agents. The assessed measures are shown in the table below. Reductions and costs are calculated for 2010, and both investment and maintenance costs are taken in account. The emissions reductions are calculated as CO<sub>2</sub>-equivalents, and they are also given as a percentage to the total estimated projection for the use of HFC in 2010 (1799 ktonnes of CO<sub>2</sub>-equivalents).

Considerable uncertainty is related to many of the elements in the analysis. The uncertainty related to consumption/reductions and costs are estimated to about 30 %. However, the relative values (% , NOK/tonne) are not very sensitive to errors in the absolute values.

**Measures to abate HFC emissions in Norway**

	Emission reduction in 2010		Yearly costs	
	%	1000 tonn CO <sub>2</sub>	Mill. NOK	NOK/tonne CO <sub>2</sub>
<b>Household refrigeration:</b> Transition to hydrocarbons as refrigerant in household refrigeration	0.1	1.4	1.6	1100
<b>Commercial refrigeration:</b> Reduced leakage of refrigerant from plants	13.5	242	60.8	250
Recovery of refrigerant from condemned small plants	3.2	58	25.9	450
Recovery of refrigerant from condemned medium sized plants	4.7	85	8.8	100
Recovery of refrigerant from condemned large plants	1.8	32	0.8	30
Use of HFC-134a as refrigerant in plants for cooling purposes	13.5	243	0.4	0
Transition to hydrocarbons as refrigerant in small plants	1.7	31	13.3	400
Transition to NH <sub>3</sub> as refrigerant in large plants for cooling purposes	5.6	100	7.4	70
Transition to NH <sub>3</sub> as refrigerant in industrial and commercial freezing-plants	9.1	163	24.0	150
<b>Mobile air conditioning:</b> Recovery of refrigerant from air conditioners in cars	1.4	25	10.2	410
<b>Foam blowing:</b> Transition to pentane/CO <sub>2</sub> as blowing agent for rigid PUR	3.4	61	1.8	30
Transition to HFC-152a as blowing agent for extruded polystyrene	8.7	156	6.8	40
<b>Solvents:</b> Avoid the use of HFC/PFC in vapour cleaning processes	0.6	10	0	0
<b>Fire extinguishing equipment:</b> Avoid the use of HFC/PFC as fire extinguishing agent	0.7	12	0	0

PAPER NO. 5: SUDAN

**AVAILABLE AND POTENTIAL WAYS AND MEANS OF LIMITING  
EMISSIONS OF HFCS AND PFCS, INCLUDING THEIR USE AS  
REPLACEMENTS FOR ODSS**

**Steps:**

First step towards this target is to develop and adopt a national communications by the so called “Enabling activities” which may involve the followings:

**1. National Capacity building**

Activities:

- Facilitate international cooperation, information exchange and dissemination.
- Training of industry managers, plant engineers, technicians, national consultants, policy makers, regulation authorities and other target groups.

**2. Raising public awareness on climate change issues:**

Activities:

- Print media ( news and press)
- Radio and TV programs
- Meetings, seminars, workshops, group briefings, and lectures
- Any other awareness raising campaigns and dissemination activities.

**3. Effective legislations and enforcement:**

We will largely rely on existing legal framework (with the necessary amendments and modifications) but are prepared to take some administrative measures to accelerate the process of emissions reduction and are also prepared to issue necessary rules and regulations (if the scheduled program is endangered by adverse developments).

**4. Implementation of demonstration projects in different industry sub- sectors and locations in the country:**

Adoption of industrial abatement options:

- Facilitate the transfer of new efficient production technologies and cleaner production techniques.
- Establish a common methodology for mitigation assessment and practice in its applications.

5. **Implement environmental management systems:**

- Environmental auditing
- Environmental reporting
- Environmental impact assessment

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PAPER NO. 6: UNITED STATES OF AMERICA

**AVAILABLE AND POTENTIAL WAYS AND MEANS OF LIMITING EMISSIONS OF HYDROFLUOROCARBONS AND PERFLUOROCARBONS**

For many years, the United States has worked with other nations to phase out chlorofluorocarbons under the Vienna Convention and its Montreal Protocol because these substances deplete the Earth's stratospheric ozone layer. While we have made great strides, that phase out is far from complete. For example, only this year are developing countries required to freeze production of CFCs. Significant further efforts on many fronts will be required if the stratospheric ozone layer is to recover, as projected, by about the middle of the next century.

In this regard, HFCs are critical substitutes for CFCs. Their development and use has enabled and continues to enable nations to cease using ozone depleting substances and join the global effort to protect the stratospheric ozone layer. Their continued availability and use remains critical to this effort.

At the same time, HFCs, as well as PFCs and SF<sub>6</sub>, are potent greenhouse gases with very long resident times in the atmosphere. For this reason, the Kyoto Protocol, which has not yet entered into force, includes these gases in the basket from which developed country Parties will meet their commitments to limit and reduce emissions of greenhouse gases in the period 2008-12.

How those commitments are met will depend on the individual choices of Annex I Parties. The Kyoto Protocol provides each Annex I Party with discretion to determine the strategy most appropriate in its national circumstances.

In light of existing commitments under the U.N. Framework Convention on Climate Change, the United States has been working with industry for some time to promote efforts to reduce emissions of HFCs, as well as PFCs and SF<sub>6</sub>. We are pleased herewith to make a seven-part submission on "Ways and Means of Limiting Emissions of Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur hexafluoride (SF<sub>6</sub>)," as invited by Decision 13/CP.4 in FCCC/CP/1998/16/Addendum 1.

This submission discusses on-going voluntary and regulatory programs of the U.S. Environmental Protection Agency to reduce emissions of these gases. Please note that, while sections 608 and 609 of the Clean Air Act require recycling and/or recovery of HFCs used in refrigeration and air conditioning. Congress has not enacted legislation creating general authority to regulate HFCs.

Our submission is being made via facsimile and electronically to ensure its receipt. It consists of seven parts, exclusive of this letter:

- I. Voluntary Partnership for Aluminum (PFCs)
- II. Voluntary Partnership for Electric Utilities (SF6)
- III. Voluntary Partnership for Magnesium (SF6)
- IV. Voluntary Partnership for Semiconductors (PFC, HFCs, SF6)
- V. Technology process optimization and destruction for HFC-23 byproduct of HFCF-22 manufacture
- VI. Sec. 608 and 609 of the Clean Air Act Recycling and Emissions Reduction Program
- VII. Sec. 612 of the Clean Air Act Significant New Alternatives Policy (SNAP) Program

**Name:** Voluntary Aluminum Industrial Partnership (VAIP)  
**Type:** Policy and Measure, voluntary agreement  
**Category:** Aluminum Production  
**Gases affected:** Perfluorocarbons

**General Description:** In 1995, the United States Environmental Protection Agency (EPA) and 11 out of the nation’s 12 primary aluminum companies teamed up, with the assistance of The Aluminum Association, to create the Voluntary Aluminum Industrial Partnership (VAIP). The main goal of this partnership is to reduce PFC emissions while increasing the efficiency of aluminum production. The VAIP sets company-specific PFC emission reduction targets and includes periodic reporting of progress achieved toward those emissions reduction goals. As of June 1999, 11 of the 12 U.S. primary aluminum producers have joined the VAIP and set company-specific emission reduction targets jointly with EPA. As shown in Table 1, VAIP partner companies represent about 94% of U.S. production capacity. While each company’s emissions reduction goal is tailored to site-specific conditions, the overall program goal is to reduce PFC emissions from VAIP partners by 45% from 1990 levels by the year 2000, assuming that production levels in 2000 will be similar to those in 1990. This is equivalent to reducing about 8 million metric tons of carbon dioxide emissions annually.

**Table I. VAIP Partners and Portion of 1996 National Production Capacity**

<b>Company</b>	<b>% of Total</b>
Aluminum Company of America (Alcoa)*	34%
Alumax, Inc.*	14%
Reynolds Metals, Inc.	11%
Kaiser Aluminium & Chemical Co.	7%
Century Aluminum Co.	5%
Noranda, Inc.	5%
Southwire Co.	4%
Alcan Aluminum Corp.	4%
Columbia Falls Aluminum	4%
Goldendale Aluminum Co.	4%
Vanalco	3%
Northwest Aluminum	2%
<b>Total</b>	<b>94%</b>

\* Alcoa purchased Alumax, Inc. in 1998. *Source:* Aluminum Statistical Review for 1996 [6]. Total 1996 capacity = 4,201,000 tons. Totals may not sum due to independent rounding.

The primary approach for reducing PFC emissions from aluminum smelting in this time frame is to reduce the frequency and duration of anode effects to the extent that is technically and economically practical. Previous studies have established that PFCs are only emitted during the occurrence of anode effects. In general, PFC emissions for a given

level of aluminum production increase with increases in the frequency and/or duration of anode effects. U.S. PFC emissions from aluminum production are estimated to have declined by roughly 2 MMTCE in 1997, as compared to 1990 levels. This decline was both due to reductions in domestic aluminum production and actions taken by the VAIP partners to reduce the frequency and duration of anode.

### **Ways and Means of Reducing Emissions**

The types of activities instituted at the company level to reduce PFC emissions from aluminum smelting can be divided into three categories: best management practices, technical initiatives, and research initiatives.

- **Best Management Practices.** These activities are considered good operating practices and are instituted at some level in all smelters worldwide. Activities that comprise best management practices include: educating employees on practices that reduce the frequency and duration of anode effects; supplying employees the tools to monitor alumina concentrations; and holding regular employee involvement team meetings of help to identify, develop and implement anode effect, voltage, and energy reduction measures.
- **Technical Initiatives.** These initiatives involve the use of state-of-the-art technologies, which are best available technologies that have a proven track record in actual production environments. The state-of-the-art PFC emission reduction technologies that are being used in many countries include computerized anode effect suppression systems that reduce anode effect duration and point feed systems that control alumina feed.
- **Research Initiatives.** Many countries are engaged in research and development activities that will lead to the development of advanced technologies and practices that are expected to have a significant impact on PFC emissions in the next 10 to 20 years. A long-term industry initiative that is being pursued aggressively through government-industry research and development efforts in several countries is the development of the non-consumable inert anode. These inert anodes do not utilize carbon, thereby eliminating the source of carbon for PFC and CO<sub>2</sub> generation during aluminum production. This technology also promises to reduce the energy required to produce a ton of aluminum significantly, thereby reducing energy related CO<sub>2</sub> emission as well. In the United States, R&D efforts from a joint program between the aluminium industry and the U.S. Department of Energy do not anticipate a commercially viable inert anode design for 10-15 years.

**Economic impact:** One of the assumptions behind VAIP is that by reducing PFC emissions and increasing efficiency, primary aluminum producers are saving money or, at least, reducing emissions in a cost-effective manner.

**Timing issues:** The VAIP partners have committed to emission reductions of 2.2 MMTCE by the year 2000, and are well on their way to meeting that goal.

### **Examples of Application:**

**The Alcan Ingot**, Sebree Aluminum Plant began to realize reductions of calculated PFC's in May 1998. These reductions were accomplished through the use of a computer-based "demand feed" system which optimizes the alumina feed rate into the aluminum reduction cells, thereby reducing "anode effects" and the resulting liberation of PFCs. Alcan-Sebree has spent \$1.6 million to-date installing the equipment. The reductions of calculated PFC emissions have been dramatic. Typical values prior to May 1998 were 0.30 to 0.40 kg CF<sub>4</sub> / MT Al. whereas the emissions since that date are calculated to be at 0.16 kg CF<sub>4</sub> / MT Al. **Alcoa** has made excellent progress toward the year 2000 Voluntary Aluminum Industrial Partnership goal with a reduction in anode effects by almost 70% from the 1990 baseline. Currently Alcoa is pursuing both near term strategies and longer term, breakthrough strategies for making further decreases in emissions of polyfluorinated carbon compounds (PFCs). For the near term continuing emphasis is being placed on reducing the frequency of occurrence of anode effects through increased attention to work practices and sharing of best practices across Alcoa's international primary aluminum operations. Looking toward the longer term, Alcoa is participating in a joint research program at MIT with US EPA and other US aluminum producers to better understand the fundamentals of PFC generation with an objective of reducing emissions when anode effects occur, or, eliminating anode effects altogether. Other research in a program with US Department of Energy is being conducted at the Alcoa Technical Center on new inert materials to replace the carbon anodes that produce the PFCs during anode effects.

**Century Aluminum's** efforts to improve process control and reduce anode effect frequency through refined computer feed control and a better-educated workforce. Today's workforce is being armed with key information and accurate process control to quickly react to feed and operational issues. Enhanced stability and efficiency of its operation will result in improved cell-related emissions at Century Aluminum.

**Columbia Falls Aluminum Company** has installed a computerized anode effect suppression system to reduce PFC emissions. This system, which is activated at a preset voltage, significantly reduces anode effect duration. Columbia Falls is also investigating the optimum alumina feed rate to reduce anode effects. In addition to reducing PFC emissions, the company expects these activities to reduce emissions of other gases as well.

**Goldendale Aluminum Company** has taken several actions to reduce anode effect frequency during the past couple of years. An employee involvement team regularly meets to identify, develop, and implement anode effect, voltage, and energy reduction measures. The team developed a predictive anode effect suppression program using the cell line computer system. Testing has shown an anode effect decrease, and the program has been implemented plant-wide. Goldendale expects that reducing anode effects will also reduce energy consumption and lower cell line emissions.

**Kaiser Aluminum** is pursuing two main approaches for reducing PFC emissions: educating employees on both operating practices for reducing the frequency and duration of anode effects and on the environmental impacts of anode effects; and continuing to

refine feed control strategies used by the computer system that manages cell operations. This combination of activities has proven effective for Kaiser and will produce benefits in addition to reducing PFC emissions. For example, the cost of the latest control strategy upgrade was offset significantly by the reduction in anode effect minutes per ton of aluminum produced.

**Noranda Aluminum, Inc.** has reduced PFC emissions by improving its computer control systems. For example, in 1983, Noranda adopted a new control system that significantly reduced anode effects on a potline that began operation in that year. As a result of upgrades and continual improvement in potline operations, Noranda has reduced anode effects by more than 70 percent since 1990. In addition to reducing PFC emissions, these upgrades have improved energy efficiencies and process stability.

**Northwest Aluminum Company** installed a computerized anode effect suppression system to reduce anode effect times. Northwest has also been investigating the optimum alumina feed rate to reduce anode effects. In addition to reducing PFC emissions, Northwest Aluminum expects these activities will reduce power consumption and other gas emissions.

**NSA - A Division of Southwire** has continually improved computer control systems and control programs to minimize the frequency and duration of anode effects, and thereby reduce PFC emissions. In addition to reducing PFC emissions, these efforts improve cell efficiency and reduce energy consumption, thereby reducing all emissions associated with primary aluminum production.

**Reynolds Metals Company's** commitment to environmental responsibility has been a core value for the company since its founding in 1919. Today, social responsibility, which includes environmental performance, is one of Reynolds' six Corporate Values by which the company manages its worldwide businesses. Since 1970, the company has decreased anode effect events by 42 percent at its operating U.S. reduction plants. Reynolds is continuing its research on anode effects to achieve further improvement, and has also instituted the AWARE program, a company-wide employee involvement program to prevent pollution.

**Vanalco, Inc.** completed computerization of its potlines in the late 1980s and implemented anode effect suppression control. In 1995, upgraded computer hardware allowed more sophisticated control of anode effects. The focus of the effort has been to prevent pollution by installation and optimization of computer control systems which tightly regulate the amount of alumina in solution to avoid anode effects, promptly identify anode effects when they occur and correct them as soon as possible. Vanalco made a commitment under VAIP in 1995 to reduce PFC emissions by 60% from a 1990 baseline level by the year 2000 as measured by anode effect frequency. Vanalco's five potlines, which are the oldest operating potlines in the United States, had an average of 1.81 anode effects per pot-day during the 1990 baseline year. The control system was implemented plant-wide six months ago. Since that time anode effect frequency has been reduced to 0.52 anode effects per pot-day which constitutes a 71% reduction.

**Regional Availability:** Not applicable

**Source of additional information:**

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**Link to more information:**

VAIP Home Page -- <http://yosemite.epa.gov/methane/home.nsf/pages/vaip>  
The Aluminum Association – <http://www.aluminum.org/>.

**Name:** SF<sub>6</sub> Emissions Reduction Partnership for Electric Power Systems  
**Type:** Policy and Measure, voluntary agreement  
**Category:** Electrical Insulation  
**Gases affected:** Sulfur Hexafluoride (SF<sub>6</sub>)

**General Description:** The SF<sub>6</sub> Emissions Reduction Partnership for Electric Power Systems, begun in early 1999, is one of the newest voluntary initiatives sponsored by EPA. SF<sub>6</sub> is a gaseous dielectric used by the electric power industry in circuit breakers, gas-insulated substations, and switchgear. SF<sub>6</sub> is also a greenhouse gas that contributes to global climate change. The partnership works with the electric power industry to pursue technically and economically feasible actions aimed at minimizing SF<sub>6</sub> emissions and reducing the threat of global climate change.

The electric power industry uses a significant percentage of the 6,500 to 7,500 metric tons of SF<sub>6</sub> produced worldwide each year. Ideally, none of this gas would be emitted to the atmosphere, either directly from operating equipment or as a result of losses due to maintenance and/or recycling activities. In practice, however, there are significant emissions from these sources. Estimates place 1997 U.S. emissions of SF<sub>6</sub> at 7 million metric tons of carbon equivalent (MMTCE). While not all emissions are attributable to the electric power industry, a significant percentage are.

The SF<sub>6</sub> Emissions Reduction Partnership for Electric Power Systems will not only benefit the environment, but also the bottom-line. SF<sub>6</sub> is a relatively expensive gas, therefore reducing emissions saves money. This cost saving opportunity, combined with the environmental concerns, has prompted many in the industry to take steps to reduce emissions. EPA's new voluntary program is intended to compliment and build upon those actions, creating a valuable opportunity for industry and EPA to work together to achieve common goals.

Electric power companies that join the partnership sign a Memorandum of Understanding (MOU) which details the roles of both EPA and the Partner to reduce emissions. The MOU was developed by EPA with significant industry input. Drafts of the MOU were shared with a variety of utilities as well as industry trade associations and comments were incorporated into the final agreement.

### **EPA and Partner Responsibilities**

Under the agreement, EPA will:

- Act as a clearinghouse for technical information on successful strategies to reduce SF<sub>6</sub> emissions;
- Provide partners with recognition for their achievements in reducing SF<sub>6</sub> emissions;
- Serve as a credible repository for data on the emissions reduction achievements of the partners; and



- Work to obtain commitments from all electric power system operators to join the partnership.

Partners agree to, where possible:

- Estimate SF<sub>6</sub> emissions during a starting year between 1990 and 1998;
- Annually inventory emissions of SF<sub>6</sub> using an emissions inventory protocol;
- Establish a strategy for replacing older, leakier pieces of equipment;
- Implement SF<sub>6</sub> recycling;
- Ensure that only knowledgeable personnel handle SF<sub>6</sub>, and
- Submit annual progress reports.

The first year's worth of partner reports will be submitted in the early 2000.

Partners can reduce emissions by replacing older, leakier units with new, tighter units, improving their recycling techniques (e.g., using gas recycling carts), and repairing leaky equipment.

Partners in the SF<sub>6</sub> Emissions Reduction Partnership for Electric Power Systems (alphabetical by state):

City Light, Water & Cable (Paragould, AR)  
Athens Electric Department (Athens, AL)  
Salt River Project (Phoenix, AZ)  
Wellton-Mohawk Irrigation and Drainage District (Wellton, AZ)  
Kings River Conservation District (Fresno, CA)  
PG & E Corporation (San Francisco, CA)  
Silicon Valley Power (Santa Clara, CA)  
Connecticut Light and Power Company (Berlin, CT)  
Northeast Utilities Services Company (Hartford, CT)  
Town of Wallingford (Wallingford, CT)  
Florida Power and Light Company (Juno Beach, FL)  
Fort Pierce Utilities Authority (Fort Pierce, FL)  
Southern Company (Atlanta, GA)  
Crisp County Power Commission (Cordele, GA)  
Muscatine Power and Water (Muscatine, IA)  
Commonwealth Edison (Chicago, IL)  
Big Rivers Electric Corporation (Henderson, KY)  
Southwestern Electric Power Company (Shreveport, LA)  
Commonwealth Electric (Wareham, MA)  
Western Massachusetts Electric Company (West Springfield, MA)

Bangor Hydro-Electric Company (Bangor, ME)  
Central Maine Power Company (Augusta, ME)  
Maine Public Service Company (Presque Isle, ME)  
City of Monroe (Monroe, NC)  
City of Rocky Mount (Rocky Mount, NC)  
Hastings Utilities (Hastings, NE)  
Grand Island Utilities Department (Grand Island, NE)  
North Atlantic Energy Service Corporation (Seabrook, NH)  
Public Service Company of New Hampshire (Manchester, NH)  
Consolidated Edison Company of New York, Inc. (New York, NY)  
Rochester Gas & Electric (Rochester, NY)  
American Electric Power (Columbus, OH)  
Cinergy Services, Inc., on behalf of The Cincinnati Gas & Electric Company and PSI Energy, Inc. (Cincinnati, OH)  
FirstEnergy Corporation (Akron, OH)  
OG&E Electric Services (Oklahoma City, OK)  
Bonneville Power Administration (Portland, OR)  
Columbia River PUD (St. Helens, OR)  
Eugene Water & Electric Board (Eugene, OR)  
Duquesne Light Company (Pittsburgh, PA)  
GPU Energy (Reading, PA)  
The Memphis Light, Gas & Water Division (Memphis, TN)  
El Paso Electric Company (El Paso, TX)  
Reliant Energy - HL & P (Houston, TX)  
San Antonio City Public Service Board (San Antonio, TX)  
Texas Municipal Power Agency (Bryan, TX)  
Texas Utilities Electric Company (Dallas, TX)  
West Texas Utilities (Abilene, TX)  
Central Vermont Public Service Corporation (Rutland, VT)  
PUD No. 1 of Pend Oreille County (Newport, WA)  
Manitowoc Public Utilities (Manitowoc, WI)  
Menasha Electric and Water Utilities (Menasha, WI)  
Consolidated Water Power Company (Wisconsin Rapids, WI)  
Village of Prairie du Sac (Prairie du Sac, WI)  
Wisconsin Electric Power Company (Milwaukee, WI)

**Impacts on ozone depletion:** None

**Impacts on global warming:**

Estimated emissions of SF<sub>6</sub> from the utility sector were 7 MMTCE in 1998.

SF<sub>6</sub> is a highly potent greenhouse gas. Over a 100-year period, SF<sub>6</sub> is 23,900 times more effective at trapping infrared radiation than an equivalent amount of carbon dioxide (CO<sub>2</sub>). SF<sub>6</sub> is also a very stable chemical, with an atmospheric lifetime of 3,200 years. As the gas is emitted, it accumulates in the atmosphere in an essentially undegraded state for many

centuries. Thus, a relatively small amount of SF<sub>6</sub> can have a significant impact on global climate change.

**Other environmental impacts:** None.

**Economic impact (cost):** No specific information yet on cost of emissions reductions efforts. However, SF<sub>6</sub> is a very expensive gas and one of the operating assumptions underlying the partnership is that there are cost-effective opportunities to reduce emissions.

**Timing issues:** There has been significant research into drop-in substitutes for SF<sub>6</sub>, especially in larger voltage applications, but no substitutes which work as well as SF<sub>6</sub> have been found.

**Examples of application:** None yet.

**Sources of additional information (what and where):**

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The tracking and reporting scheme implemented under the SF<sub>6</sub> Partnership will help partners avoid contributing to the atmospheric build-up of long-lived chemicals, and enable companies to document early contribution to the prevention of global climate change.

**Name:** SF<sub>6</sub> Emission Reduction Partnership for the Magnesium Industry  
**Type:** Policy and measure, voluntary agreement  
**Category:** Magnesium production  
**Gases affected:** SF<sub>6</sub>

**General description:** The U.S. Environmental Protection Agency (EPA) develops and fosters cooperative partnerships with a wide range of industries to reduce U.S. emissions of greenhouse gases. One such voluntary partnership is the SF<sub>6</sub> Emission Reduction Partnership for the Magnesium Industry. Started in 1998, this partnership seeks to reduce the U.S. magnesium industry's emissions of the potent greenhouse gas, sulfur hexafluoride (SF<sub>6</sub>).

The magnesium industry employs SF<sub>6</sub> to prevent the rapid oxidation and burning that occurs when the molten metal directly contacts air. A continuous flow (and subsequent release) is required to maintain a protective layer of gas at the melt surface. SF<sub>6</sub>, an odorless and non-toxic gas, has been the industry standard for melt protection for more than 20 years. However, the industry has recognized that continued emission of this long-lived, extremely potent greenhouse gas is a costly and unsustainable business practice and has begun to work with EPA to reduce emissions and evaluate control technologies.

In response to this environmental concern, EPA has launched a new initiative to assist the industry in its effort to reduce SF<sub>6</sub> emissions. As a voluntary partner, an individual magnesium producer or casting company signs a memorandum of understanding (MOU) with EPA committing to annually report their emissions of SF<sub>6</sub> and take cost-effective and technically feasible actions aimed at reducing those emissions. EPA works together with its industry partners to review and evaluate emission reduction strategies and technologies, promote technical information sharing by preparing annual reports and hosting technical conferences, record and verify the partner's progress, and provide positive public recognition for the partners' achievements.

The MOU encourages partners to follow a pollution prevention approach to reduce SF<sub>6</sub> emissions. This approach, as outlined in the United States Pollution Prevention Act of 1990, presents a hierarchy of emission reduction options that includes source reduction of SF<sub>6</sub> by reducing leaks and assuring appropriate cover gas concentrations and flow rates, substitution of SF<sub>6</sub> with a more environmentally benign chemical, capture and reuse of SF<sub>6</sub>, and lastly, destruction of the chemical before release to the environment. Many companies have already implemented various cost-effective source-reduction efforts including regular inspection and maintenance of the gas distribution system, installation of central cover gas blending equipment, and analysis of cover gas concentration and distribution at the molten metal's surface. In addition, a small group of magnesium companies are currently evaluating the technical feasibility and occupational safety concerns associated with installing either SF<sub>6</sub> capture/recycle systems or SO<sub>2</sub>-based alternative cover gas systems.

While the casting technologies of magnesium producers are distinctly different from those of casting companies, both rely heavily on SF<sub>6</sub> to provide crucial melt protection. Seven of the approximately forty companies that produce and cast magnesium in the U.S. have

joined EPA as partners. As of June 21, 1999, the following companies have signed MOUs with EPA:

- Acme Die Casting
- Chicago White Metal Casting
- Del Mar Die Casting
- Diemakers
- Hyatt Die Cast & Engineering Corporation
- Magnesium Products of America
- Spartan Light Metal Products

Several more companies are expected to join the partnership this year.

**Impacts on ozone depletion:** None

**Impacts on global warming:** The U.S. magnesium industry's 1997 SF<sub>6</sub> emissions are estimated to have been approximately 3 million metric tons of carbon equivalent (MMTCE).

**Other environmental impacts:** Careful consideration must be given to potential environmental "trade-offs" when evaluating emissions control technologies for this or any industry. The magnesium industry's use of SO<sub>2</sub> should be carefully evaluated to fully understand the increased occupational health and safety risks and the chemical's impact on regional air quality (e.g., acid rain concerns).

**Economic impact (cost):** EPA's voluntary partnership aims to reduce SF<sub>6</sub> emissions by identifying and implementing emission reduction strategies and technologies that are both technically feasible and cost effective for the individual partner companies.

**Timing issues:** The magnesium industry's production and casting equipment represent a significant capital investment and have service life spans of roughly 15 to 30 years.

**Examples of application:** The following technical papers discuss alternative cover gas options and capture/recycle technology respectively.

Gjestland and Magers, "Progress to Eliminate SF<sub>6</sub> as a Protective Gas in Magnesium Diecasting," *Conference Proceedings for IMA's Magnesiumguss Abnehmerseminar & Automotive Seminar*, October 1, 1998.

Li et al, "Capture and Recycle: A New Option for Emission Reduction of SF<sub>6</sub> in Magnesium Melting," *Air Liquide Discussion Paper*, June 1999.

**Regional availability or applicability:** Certain SF<sub>6</sub> abatement technologies require significant inputs of water and energy and may not be suitable for all geographical locations.

**Other remarks:** EPA plans to support the International Magnesium Association's (IMA) study to identify suitable substitute chemicals. The IMA committee organizing the research effort held its first planning meeting in June 1999 at the IMA's annual conference in Rome, Italy.

**Sources of additional information** (what and where):

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**Name:** U.S. Voluntary PFC Emission Reduction Partnership for Semiconductors  
**Type:** Policy and measure, voluntary agreement  
**Category:** Semiconductors manufacturing  
**Gases affected:** HFC-23; CF4; C2F6; C3F8; SF6 and NF3\*

\*The Semiconductor industry uses NF3 which has been identified as a greenhouse gas with a 100-year GWP = 8,000 and atmospheric life of 740 years (Molina et al, Geophysical Research Letters, Vol. 22, 1873-6 (1995)) but is not yet listed by the IPCC.

**General description:** In 1996, the U.S. Environmental Protection Agency (EPA) joined with semiconductor manufacturers to form the *PFC Emission Reduction Partnership for the Semiconductor Industry*. The voluntary partnership aims to reduce emissions of atmospherically long-lived perfluorocompounds from semiconductor manufacturing. Companies joining the Partnership have agreed to work to reduce their emissions by considering the viability of pollution prevention techniques such as process optimization, source reduction, substitute chemicals, recovery/recycling, and abatement. This Partnership is an important step in the U.S. effort to control emissions of long-lived, greenhouse gas emissions.

The semiconductor industry uses HFC-23, CF4, C2F6, C3F8, SF6, and NF3 in two important production processes--plasma etching thin films and plasma cleaning chemical vapor deposition (CVD) tool chambers. These chemicals are critical to current manufacturing methods because they possess unique characteristics when used in a plasma that currently cannot be duplicated by alternatives. There are no known zero-GWP substitutes for these chemical in these applications. The industry's technical reliance on high GWP gases has increased significantly in the past several years. This reliance is expected to increase due to rapid industry expansion to meet growing demand for semiconductor devices, and ever increasing complexity of semiconductor devices which require increased PFC use. However, voluntary action through the U.S. semiconductor partnership and global industry collaboration through the World Semiconductor Council is expected to result in significant reductions in emissions by 2010.

The U.S. voluntary partnership is implemented through a Memorandum of Understanding (MOU) which details the roles of both EPA and the Partner to reduce emissions. The MOU was developed in collaboration with the U.S. Semiconductor Industry Association (SIA). Partners agree to estimate PFC emissions beginning in 1995; estimate annual emissions using an emissions inventory protocol; submit annual progress reports; and set technically feasible, cost-effective emission reduction targets. EPA acts as a clearinghouse for technical information on successful strategies to reduce PFC emissions; provides partners with recognition for their achievements in reducing PFC emissions; serves as a repository for data on the emissions reduction achievements of the partners; and pursues commitments from all manufacturers operating in the U.S. to join the partnership. The tracking and reporting scheme implemented under the *Semiconductor Partnership* enables participants to document their early contribution to the prevention of global climate change.

In 1998 Japan became the first country to establish PFC emission reduction goals for the semiconductor industry. In that same year, IBM became the first U.S. semiconductor manufacturer to publically announce a comprehensive climate goal including a target for PFC emissions reduction. These actions energized industry to think globally and to use goals to motivate suppliers and customers to support climate protection.

Generally, process tools consume from 15-60% of influent PFCs depending on the chemical used and the process application (etch or CVD). PFC emissions vary depending on a number of factors: gas used, type/brand of equipment used, company-specific process parameters, number of PFC-using steps in a production process, generation of PFC by-product chemicals, and whether abatement equipment has been implemented. Product manufacture and production processes and, consequently, emissions vary widely from fab to fab. To further reduce emission levels, process optimization, alternative chemicals, capture/recycling and effluent abatement are all being considered. The size of wafers being processed in a semiconductor fabrication facility (fab) and the fab's design and age also have a major impact on PFC emissions reduction technology applicability. Existing fabs may have insufficient infrastructure and space to implement some emission reduction technologies. For new and planned fabs, purchasing state of the art process equipment that optimizes PFC use and employs alternative chemistries is expected to be the best option.

The *U.S. Semiconductor Partnership* is complemented by global action by the semiconductor industry to reduce PFC emissions. The World Semiconductor Council is coordinating a global initiative to reduce emissions which includes participation of companies in Europe, Japan, Korea, Taiwan and the United States. At their third meeting in Fuiggi, Italy in April 1999, the World Semiconductor Council (WSC) agreed to reduce PFC emissions by at least 10 percent below 1995 levels (1997 for Korea) by 2010. The WSC emission reduction goal will result in significant benefits to the climate and demonstrates the effectiveness of voluntary action by industry and governments. The WSC was formed in 1996 to address market access issues and promote industry cooperation on economic, trade and environmental concerns that face the global semiconductor industry. Through the WSC, the semiconductor industry is working together to develop, evaluate and share information on emission reduction techniques, provide a common message to equipment and chemical suppliers on the need to minimize emissions, and to set measurable emission reduction goals. The WSC includes the Semiconductor Industry Association (SIA) of the United States, the European Electronic Component Manufacturers Association (EECA), the Electronic Industries Association of Japan (EIAJ), the Korea Semiconductor Industry Association (KSIA), and the Taiwan Semiconductor Industry Association (TSIA). WSC members produce over 90 percent of the world's semiconductors. EPA and the Japan Ministry of International Trade and Industry (MITI) have actively supported and encouraged the WSC agreement.

Semiconductor industry actions to reduce emissions are outlined as follows:

1980s PFCs identified as effective etch and plasma cleaning chemicals

1990s PFCs identified as potent greenhouse gases



- 1996 U.S. EPA forms voluntary PFC emission reduction partnership  
EPA and MITI organize Japan PFC Pathfinder Meeting  
Voluntary partnerships organized in Japan and Europe
- 1998 Japan announces PFC emission reduction goals for electronics industry  
Voluntary partnership organized in Korea  
1<sup>st</sup> International PFC Emission Reduction Conference, Monterey, California  
World Semiconductor Council cites PFCs as top environmental challenge
- 1999 World Semiconductor Council commits to global emission reduction goal  
Voluntary partnership organized in Taiwan

**U.S. Voluntary Partners:**

Advanced Micro Devices  
American Microsystems (AMI)  
Burr-Brown  
Cherry Semiconductor  
Digital Equipment  
Dominion Semiconductor  
Eastman Kodak  
Hewlett-Packard  
Hitachi Semiconductor  
IBM  
Intel  
LSI Logic  
Lucent Technologies  
Micron Technology  
Motorola  
National Security Agency  
National Semiconductor  
NEC Electronics  
Philips electronics  
Rockwell Semiconductor Systems  
Sony Semiconductor  
ST Microelectronics  
Texas Instruments  
VLSI Technology

**Impacts on ozone depletion:** none

**Impacts on global warming:** In 1997, U.S. emissions of PFCs from the U.S. semiconductor industry at 1.3 million metric tons of carbon equivalent (MMTCE).

**Other environmental impacts:** None identified

**Economic impact (cost):** With the possible exception of some process optimization, reducing emissions of PFCs in semiconductor manufacture generally requires significant investment. Cost varies with emission reduction method used and the unique circumstances of the individual fabrication facility, e.g. space constraints, age of existing equipment, testing and trials needed to implement emission reduction technology, etc. The coordination efforts of the World Semiconductor Council with chemical suppliers and equipment manufacturers plus the global commitment to an emission reductions target is expected to lower the overall cost of reducing emissions for all manufacturers while maximizing the benefits to the environment.

**Timing issues:** This industry is characterized by rapid technology innovation that is developed through arduous multi-year process design and equipment development procedures. Changes to manufacturing techniques generally require significant lead time and close coordination with equipment and chemical suppliers. Actions taken by the World Semiconductor Council will help ensure cost-effective global implementation of technically feasible emission reductions in existing and next generation semiconductor manufacturing methods.

**Regional availability or applicability:** An estimated 90% of global semiconductor manufacture is working to meet the emission reduction target agreed under the World Semiconductor Council.

**Other remarks:** The U.S. government coordinates with and supports actions taken by the World Semiconductor Council to implement a 10% absolute emission reduction strategy from 1995 baseline (1997 for Korea) by the year 2010.

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**Name:** HFC-23 Emission Reduction from HCFC-22 Manufacture  
**Type:** Technology, Process optimization and destruction  
**Category:** By-product emissions of HFC-23  
**Gases affected:** HFC-23

**General description:** Manufacturers of HCFC-22 in the United States are voluntarily working to reduce emissions HFC-23 emissions which are generated as a by-product of HCFC-22 manufacture. In collaboration with U.S. manufacturers, the U.S. Environmental Protection Agency conducted a study of demonstrated and innovative techniques to reduce emissions of HFC-23 from the industrial process used to produce HCFC-22. The following outlines the outcome of that study. This study reflects the experience of the United States; availability of emission reduction technology and/or opportunities for emission reduction may differ in other countries.

### **Emission Points<sup>1</sup>**

The major emission point for HFC-23 is the condenser vent where most plants discharge it to the atmosphere after separation from the HCFC-22. Approximately 98 to 99 percent of the HFC-23 that is generated is emitted at this point.

There are several minor emission points for HFC-23. It may also be emitted as fugitive emissions from leaking compressors, valves, and flanges. However, there is a strong incentive to prevent leaks because of the potential for loss of valuable product (HCFC-22), and any leaks can usually be repaired quickly and effectively. Two U.S. plants have a formal leak detection and repair program, and their results show that fugitive emissions of HFC-23 from leaks is less than 300 kg/yr. HFC-23 can also be emitted when it is removed with the aqueous phases from caustic and water scrubbers used in the process. However, only a small quantity of HFC-23 is removed by this mechanism because HFC-23 has a low solubility in water, its vapor phase concentration is low, and the volumes of aqueous streams that are used is small. Some HFC-23 is removed with the HCFC-22 product, and this may be subsequently emitted depending on the fate of the HCFC-22 product. Plants have specifications on the concentration of HFC-23 allowed in the product, and these limits are a fraction of a percent. Consequently, removal with the product also accounts for only a very small portion of the HFC-23 that is generated.

One U.S. plant captures some HFC-23 for special applications, and a potential emission source is the vent from the storage tank after the HFC-23 is recovered by condensation at high pressures and low temperatures. The storage tank is kept refrigerated and vents through a refrigerated condenser. Any emissions from this operation are limited to brief venting events when the system must be vented to remove noncondensibles to avoid excessive pressure buildup. These storage tank emissions are very low because of the use of a refrigerated condenser as an emission control device and infrequent venting of noncondensibles.

### **Factors Affecting Emissions<sup>2,3</sup>**

There are a number of factors that affect halogen exchange of chlorine to fluorine and thus affect the generation of HFC-23 in the reactor, such as catalyst concentration, catalyst deactivation, temperature, pressure, and feed rates. One of the most important is catalyst life and catalyst activity. Another important variable is the reflux rate and the composition of the reflux because this also affects the concentrations of the compounds in the reactor. In general, higher catalyst concentrations, pressures, temperatures, and the amount of HCFC-22 refluxed to the reactor will increase the amount of HFC-23 produced.

### **Opportunities to Reduce Hfc-23 Emissions**

#### **Process Optimization<sup>3</sup>**

Process optimization focuses on the operating conditions that affect the generation and emission of HFC-23 and to determine the optimum conditions that minimize the quantity of HFC-23 produced. The HCFC-22 production process is relatively old (over 30 years) and has been extensively researched. All of the U.S. plants have studied their process in detail and already have insight into optimum conditions for producing HCFC-22. In general, process changes that reduce the amount of HFC-23 that is generated in the reactor also increase the yield of HCFC-22 (which can decrease production cost). The optimum operating conditions dictated by the economics are not necessarily the same conditions that minimize HFC-23 generation and may involve balancing the cost of lower yields with the value (profit) of HCFC-22.

Optimization is accomplished through controlled experimentation and evaluation of the operating parameters that affect the generation of HFC-23. Different statistical approaches are available for designing the program and evaluating the results. An important component is the accurate measurement of the quantity of HFC-23 that is generated under the different operating conditions. Over the years, some U.S. plants have reduced the generation of HFC-23 from 3 to 4 percent of HCFC-22 to approximately 1.5 to 2 percent. Process optimization and minor process modifications are expected to provide the most cost-effective opportunities for HFC-23 reduction because they are the least expensive to implement. This approach is most applicable for plants that are generating HFC-23 at a rate of 3 to 4 percent or more of the HCFC-22.

#### **Equipment Modifications<sup>3</sup>**

Equipment modifications include modifying or replacing existing equipment to improve the process, especially with respect to the operation of the reactor or the separation of products and by-products. One U.S. plant identified a process modification that has been demonstrated in a full scale application. This involved the installation of additional equipment to the reactor's reflux system, which reduced the amount of HCFC-22 that was returned to the reactor. Less HFC-23 was generated because less HCFC-22 was available for overfluorination. This project resulted in a 25 percent reduction in the quantity of HFC-23 generated and improved the yield of HCFC-22 at a capital cost of \$15,000 per

annual metric ton of HFC-23 reduced. Another U.S. plant installed a new and larger reactor that was operated under conditions somewhat different from the one it replaced. The ratio of HFC-23:HCFC-22 was lower for this new reactor because of a change in the reaction dynamics under operating conditions that produced less HFC-23.

### **Thermal Oxidation**

Thermal oxidation is a demonstrated technology for the destruction of halogenated organic compounds. For the relatively concentrated HFC-23 vent stream and its low flow rate, thermal oxidation is a cost-effective option that oxidizes the HFC-23 to CO<sub>2</sub>, HF, and water. If the HF is not to be emitted with the combustion gases, it must be scrubbed with water or an alkaline solution and removed as a sludge.

One U.S. plant installed a thermal oxidizer that operates at about 1,300°C with a residence time of 0.75 seconds. Figure 2 is a schematic representation of the entire process, including treatment of the combustion gases. When HFC-23 is oxidized, the off gases that are generated contain HF. Fortunately, HF is very water soluble and is easily scrubbed using water or alkaline solution. In most applications, a single scrubber could be used to achieve removals on the order of 95 to 99 percent. However, this facility is equipped with a series of scrubbers that achieves over 99.9 percent removal of HF. The first phase of scrubbing occurs with a once-through water quench, followed by a packed column scrubber (countercurrent flow of gas and water), and finally a caustic scrubber. Wastewater is sent to the wastewater treatment plant where it is neutralized. The wastewater treatment plant was designed to treat wastewater from the emission control devices on the oxidizer and other waste acid streams in the plant.<sup>4</sup>

Another feature of this operation is the use of gas holders that are used as the feed vessels for the oxidizer. The gas holders provide excess storage capacity in the event that maintenance or repairs must be performed on the oxidizer. Consequently, during normal operation the waste gases do not have to be bypassed to the atmosphere and can be accumulated for destruction later.

A series of emission tests conducted using standard sampling and analysis methods showed that over 99.996 percent of the HFC-23 was destroyed and that emissions were less than 0.0001 kg/hr. The plant monitors the operation of the oxidizer on a continuous basis to ensure it is operating properly with a monitoring system that has a continuous display (both electronic and a hard copy from the strip chart recorder). The parameters that are monitored as part of the permit conditions to show continuous compliance include the combustion temperature (must be over 1,260°C), oxygen out of the combustion chamber (must be at least 2 percent), quench water flow rate (208 L/minute, minimum), pH of the scrubber solution (minimum of 7), and maximum scrubber solution density (1.1 g/mL). If the temperature or oxygen fall below the minimum values, the flow of waste feed material to the oxidizer is stopped until the problem is corrected. In addition, the plant monitors several other parameters as part of normal operation (such as CO content as an indicator of complete combustion).<sup>4</sup>

The participating companies provided estimates of total installed capital costs on the order of \$1 to \$3 million. The lower end of the range is based on estimates to install a unit in another application (at another plant), and the upper end is a worst case high spot estimate assuming a rather large unit, special materials of construction, sophisticated instrumentation and monitoring, and a new wastewater treatment system to manage the HF scrubber water.<sup>3</sup>

A German company (Uhde GmbH, a member of the Hoechst group) is marketing a thermal oxidation process for halogenated organics that uses pure oxygen and hydrogen for oxidation (rather than air and natural gas common in conventional thermal oxidation). The process is designed to recover a 50-percent solution of HF for sale as a product.<sup>5</sup>

### **Pyrolysis**

Pyrolysis processes are designed to use high temperatures in the absence of oxygen to fracture or transform the HFC-23 molecule into more useful compounds that can be used as chemical feedstocks. A process to convert HFC-23 to tetrafluoroethylene (TFE) and hexafluoropropylene (HFP), both valuable feedstocks for producing synthetic polymers, was demonstrated commercially by the Pennwalt Chemicals Corporation in the 1960s and was abandoned shortly thereafter. The conversion is described in the patent as requiring temperatures of 900 - 1,100°C, and the product composition is affected by the pressure, temperature, and residence time. Higher pressures and temperatures produce more olefins, and lower ones increase the yield of TFE and HFP.<sup>6</sup>

A 1989 DuPont patent describes a process for producing TFE from HFC-23. The HFC-23 is contacted with a hot gas, preferably argon, at over 1,700°C followed by rapid cooling of the reaction mixture in less than one second to a temperature of 500°C. The patent claims yields of TFE in excess of 60 percent.<sup>7</sup>

### **Catalytic Hydroreduction<sup>8</sup>**

Catalytic hydroreduction has been demonstrated for the C-Cl bond, but attempts to reduce the C-F bond have been more difficult. This process uses hydrogen, high temperatures, and a catalyst to reduce HFC-23 (CHF<sub>3</sub>) to methane (CH<sub>4</sub>) and HF. The methane can be used to fuel the reactor, and a concentrated solution of HF could be recovered for reuse (theoretically). Potential advantages to conventional thermal oxidation include more complete destruction and less potential for the formation of toxic by-products.

A variation of the complete reduction to methane described above is partial reduction, leaving some chlorine or fluorine atoms bonded to the carbon to produce a useful compound. The literature indicates that studies have been conducted on the conversion of CFCs to HCFCs or HFCs using hydrogen, high temperatures, and a metal catalyst. Most of the reports are either patents or brief articles in Japanese journals. The reports claim to have demonstrated the hydrogenolysis of C-Cl in the laboratory, but there are few reports of C-F hydrogenolysis. However, a DuPont paper reports large yields of CH<sub>3</sub>CF<sub>3</sub> from

$\text{CCl}_2\text{FCF}_3$  under conditions of relatively low ratios of hydrogen to  $\text{CCl}_2\text{FCF}_3$ . Researchers at Yale report removal of some of the fluorine atoms from cyclic perfluoroalkanes, which are normally highly unreactive, by reaction with sodium oxalate at 230 °C. The reaction yields perfluoroarenes, which are valuable chemical intermediates. There is no indication that any of these processes have been demonstrated for HFC-23.

### **Conversion to $\text{CBrF}_3$ (Halon 1301)<sup>3</sup>**

A historical use of HFC-23 has been bromination to produce  $\text{CBrF}_3$ , which was used in fire extinguishers. Halon 1301 has been phased out under the Montreal Protocol and is no longer an option for reducing HFC-23 emissions.

### **Capture of Hfc-23 for Other Applications<sup>3</sup>**

There are some uses of HFC-23 that may make it economical for HCFC-22 producers to recover HFC-23 for sale. These include uses as a low temperature refrigerant, an etchant gas, and as a fire extinguishant. If these alternative uses do not result in emissions of the HFC-23, they may be considered opportunities for reducing emissions.

### **Miscellaneous<sup>3</sup>**

Some innovative ideas offered by researchers are related to reversing the reaction that produces HFC-23 after the HFC-23 has been separated from the product. If the conditions and catalyst could be found to reverse the reaction, the HFC-23 could be used to produce HCFC-22. Alternatively, if the reaction that produces HFC-23 could be reversed or slowed in the reactor (e.g., by increasing the reactor concentration of HFC-23), the rate at which it is generated would be reduced. However, there is no indication that either of these is practical or possible. A simplified mathematical model of the process indicates that the thermodynamics strongly favour the formation of HFC-23, and the thermodynamics of the reverse reaction are very unfavourable.

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**Impacts on ozone depletion:** None

**Impacts on global warming:** The U.S. estimated 1997 emissions of HFC-23 from this source at MMTCE.

**Other environmental impacts:** Thermal oxidation (incineration) has been demonstrated to be very effective in the destruction of halogenated organic compounds. The major concern with respect to HFC-23 by-products is the formation of acid gases (such as HCl and HF), which are easily controlled by water or alkaline scrubbers. HFC-23 vapor stream is concentrated and the concentration should be consistent over time. Proper design is important, especially with respect to adequate temperature and residence time, good mixing in the burner, and quenching the hot off gases to minimize re-combination reactions. The oxidizer needs to be designed, operated, and tested to demonstrate performance and compliance with any national, state and local regulations. Careful monitoring of the oxidizer on a continuous basis will ensure that it continues to operate within design specifications as demonstrated during the initial performance (emission sampling and analysis) tests.

**Economic impact (cost):** Process optimization is technically proven, currently available and cost-effective for plants that are generating HFC-23 at a rate of 3-4% or more of HCFC-22.

Estimates of total installed capital costs for incineration in the United States on the order of US\$1 - 3 million. Cost of incineration is directly affected by the sophistication of the design, especially with respect to materials of construction, instrumentation, off gas treatment, and wastewater treatment. The cost can vary widely depending on the type of incinerator that is installed. The upper end is a worst case high spot estimate assuming a rather large unit, special materials of construction, sophisticated instrumentation and monitoring, and a new wastewater treatment system to manage the HF scrubber water. Costs will be lower if an existing wastewater treatment system can be used to neutralize the



relatively small volume of wastewater produced. Cost effectiveness can be improved if there are other vent streams that could be routed to the incinerator for destruction.

**Name:** U.S. Environmental Protection Agency, Clean Air Act, Title VI, sections 608 and 609 Recycling and Emissions Reductions Programs  
**Type:** Policy and measure, regulation  
**Category:** Refrigeration (all categories)  
**Gases affected:** HFC-134a and any other ODS substitutes used in refrigeration and air conditioning

**General description:** Under section 608 of the U.S. Clean Air Act, beginning in 1995, the venting of refrigerants that substitute for ozone-depleting refrigerants are prohibited. Specifically, the prohibition bans venting any refrigerant that is a substitute for an ODS during the servicing or disposing of any appliance that contains that refrigerant. Section 609 of the Clean Air Act also mandates the recovery and recycling of all refrigerants used in motor vehicle air-conditioning systems.

**Impacts on ozone depletion:** Recycling at servicing and disposal can reduce emissions from air-conditioning and refrigeration equipment by 50-95%, depending on the specific type of equipment.

**Impacts on global warming:** Compliance with the statutory prohibition on venting ODS substitutes in stationary and commercial equipment, coupled with private incentives to recover and recycle refrigerants, is expected to result in reduced emissions of 5.6 MMTCE in 2000, and 22.3 MMTCE in 2005. In addition, the recapturing of HFC-134a during the servicing of motor vehicle air-conditioners is estimated to reduce emissions by 4.3 MMTCE in the year 2000 and by 5.2 MMTCE in 2005.

**Other environmental impacts:** None identified

**Economic impact (cost):** Recapture of refrigerants generally requires that facilities invest in equipment that can recover the refrigerant. The refrigerant is then either recycled (purified) at the same location, using portable recycling equipment, or is sent by the facility to a reclaimer.

**Timing issues:** Under the Clean Air Act, the venting prohibition has been in place for all sectors since 1995. The recycling requirement for refrigerant in motor vehicle air-conditioning systems has been in place since January, 1998.

**Examples of application:** See above.

**Regional availability or applicability:** Required throughout the United States.

**Other remarks:** None

**Sources of additional information (what and where):** U.S. EPA, Stratospheric Protection Division, Wash., DC

**Link to more information:** <http://www.epa.gov/ozone/title6/609/609.html> and <http://www.epa.gov/ozone/title6/608/608.html>

**Name:** U.S. Environmental Protection Agency, Clean Air Act Title VI, section 612 Significant New Alternatives Policy (SNAP) program  
**Type:** Policy and measure, regulation  
**Category:** Refrigeration (all categories), fire extinguishers (fixed systems and portable extinguishers), aerosols (industrial), and solvents (precision, electronics, and metal cleaning)  
**Gases affected:** HFC-23, HFC-32, HFC-134a, HFC-227ea, HFC-236fa, HFC-152a, HFC-125, HFC-4310mee, C3F8, C6F14, C4F10, C5F12, C6F12, C7F16, C8F18, C5F11NO, C6F13NO, C7F15NO, C8F16, SF6

**General description:** Section 612 of the Clean Air Act directs EPA to place limits on the use of certain substitutes for ozone-depleting substances where the Agency determines that other existing alternatives “reduce overall risk to human health and the environment.” EPA refers to this program as the Significant New Alternatives Policy (SNAP) program. SNAP regulates within the following industrial use sectors: Refrigeration and air conditioning; foam blowing; solvents cleaning; fire suppression and explosion protection; tobacco expansion; adhesives, coatings, & inks; aerosols; and sterilants. These sectors comprise the principal United States industrial sectors that historically consumed large volumes of ozone-depleting compounds.

In determining whether the use of substitutes for various industrial end-uses is acceptable, EPA compares the risks associated with the substitute to risks associated with continued use of ozone-depleting substances, and to use of various other available substitute substances and techniques.

To develop the list of unacceptable and acceptable substitutes for various end-uses, the EPA must assess and compare the “overall risks to human health and the environment” posed by use of substitutes, and this assessment must be performed in the context of particular applications. To conduct this overall examination, EPA must consider a wide range of health and environmental factors. EPA requires submitters provide the following information for review and determination:

- Name and description of the substitute
- Physical and chemical information
- Substitute applications (end-uses)
- Process description
- Ozone-depletion potential (ODP)

- Global warming potential (GWP)
- Toxicity data
- Environmental fate and transport
- Flammability
- Exposure data
- Environmental release data
- Replacement ratio for a chemical substitute
- Required changes in technology
- Cost of substitute
- Availability of substitute
- Anticipated market share

Under SNAP, EPA has restricted use of blends containing PFCs or HFC-23 in refrigeration end-uses where no other substitutes exist that pose lower environmental risk. PFC containing blends have been listed as acceptable only in very low temperature refrigeration systems and banned from all other refrigeration applications. EPA has listed as unacceptable PFC containing blends in 15 out of 16 refrigeration and air conditioning end-uses. No subsequent submissions for PFC containing blends have been submitted to EPA. Because of their high global warming potential and the availability of alternatives that pose less risks to the environment, EPA has restricted the use of two HFCs (134a and 152a) as refrigerants in self-chilling beverage can technology.

EPA has restricted the use of PFCs in fire suppression and solvents cleaning by listing last resort language: “where other alternatives are not technically feasible due to performance or safety requirements:

- a) because of their physical properties or chemical properties, or
- b) where human exposure to the extinguishing agents may result in failure to meet applicable use conditions.”

Under SNAP, SF<sub>6</sub> is listed as unacceptable in aerosol and all fire suppression end-uses, except for use as a discharge agent in military applications and in civilian aircraft

**Impacts on ozone depletion:** SNAP approved alternatives have resulted in reductions of approximately 1.2 million ODP-weighted tons of CFCs, halons, and other ozone-depleting substances.

**Impacts on global warming:** By the year 2000, the SNAP program is expected to result in reduction of approximately 45 million metric tons of carbon equivalent (MMTCE).

**Other environmental impacts:** Reduced workplace exposure to potentially toxic chemicals.

**Economic impact (cost):** SNAP restrictions only apply to alternatives for which other

substitutes are available that pose less or no risk to human health and the environment. Therefore, there are no costs to affected industry associated with the SNAP program.

**Timing issues:** The final rule creating the SNAP program was promulgated in 1994. Since then, EPA has published 10 Notices of Acceptability and 6 Final Rulemakings. EPA has reviewed approximately 175 substitutes for 50 different end-uses within the SNAP sectors. Over 90% of these substitutes were found acceptable with a variety of restrictions.

**Examples of application:** All new cars use SNAP-approved HFC-134a; self-chilling cans that use CO<sub>2</sub> are being developed in lieu of cans that would otherwise emit 134a or 152a into the atmosphere.

**Regional availability or applicability:** United States

**Other remarks:** none

**Sources of additional information (what and where):** Stratospheric Ozone Protection Hotline at 1-800-296-1996 or 1-301-614-3390

**Link to more information:** <http://www.epa.gov/ozone>

PAPER NO. 8: TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL  
OF THE MONTREAL PROTOCOL

**ACTIVITIES OF THE TEAP TASK FORCE ON HFCS AND PFCs**

In November 1998, the Conference of the Parties to the Framework Convention on Climate Change (FCCCC/CP/1998/L. 7) invited organisations, including the relevant bodies of the Montreal Protocol, "...to provide information by July 15, 1999 on available and potential ways and means of limiting emissions of hydrochlorocarbons and perfluorocarbons, including their use as replacements for ozone depleting substances." In November 1998, the Parties to the Montreal Protocol in Decision X/16 requested the Technology and Economic Assessment Panel (TEAP) to provide such information to the FCCC.

On behalf of the TEAP Task Force on HFCs and PFCs, I am pleased to submit the enclosed relevant information. The information consists of a collection of 1998-1999 TEAP publications, a bibliography of TEAP publications from 1989 to present, and a bibliography of publications that are unlikely to be submitted by other organisations that have been invited to supply you with information. It also includes a list of web sites where additional information can be obtained.

TEAP is mindful that the FCCC Secretariat is likely to receive hundreds of pages of submissions of such relevant technical information from national and regional governments, industry and environmental NGOs, and other individuals and organisations. Therefore, TEAP has concentrated on its own publications and on publications that are less likely to be supplied from other organisations. TEAP would welcome a summary of all submissions and could respond with additional relevant technical information that may be overlooked by other respondents to this call for information.

In August 1999, TEAP and the IPCC will provide the FCCC Secretariat with proceedings of the Petten "Joint IPCC/TEAP Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs."

In October 1999, the TEAP Task Force on HFCs and PFCs will complete and assessment of the implication to the Montreal Protocol of the inclusion of HFCs and PFCs in the Kyoto Protocol. At that time, copies of the TEAP assessment will be provided to the FCCC Secretariat.

**The TEAP Task Force on HFCs and PFCs made available to the secretariat hard copies of the following documents:\*\***

1. Bibliography of Relevant Information on HFCs and PFCs
2. Web sites Containing Relevant Information on HFCs and PFCs
3. Database of natural refrigerant literature (computer diskette)
4. Montreal Protocol on Substances that Deplete The Ozone Layer - 1998 Report of the Technology and Economic Assessment Panel (Pursuant to Article 6 of the Montreal Protocol)
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## 2. Web sites Containing Relevant Information on HFCs and PFCs

SITE	DESCRIPTION	Type <sup>1</sup>
<a href="http://cwis.nyu.edu/pages/mathmol/">cwis.nyu.edu/pages/mathmol/</a>	MathMol (Mathematics and Molecules) Home Page	5
<a href="http://kulde-nett.skarland.no">kulde-nett.skarland.no</a>	KULDE-Nett – Kulde-bransjens utgangspunkt	2
<a href="http://www.afeas.org">www.afeas.org</a>	Alternative Fluorocarbons Environmental Acceptability Study	5
<a href="http://www.airah.org.au">www.airah.org.au</a>	Australian Institute of Refrigeration, Air-Conditioning, and Heating (Inc.)	2
<a href="http://www.aircondition.com">www.aircondition.com</a>	Automotive Air Conditioning Information Server	4
<a href="http://www.akb.dk">www.akb.dk</a>	Autoriserede Klefirmaers Branchforening	5
<a href="http://www.ari.org">www.ari.org</a>	Air-Conditioning and Refrigeration Institute	2
<a href="http://www.ashrae.org">www.ashrae.org</a>	American Society of Heating, Refrigerating and Air-Conditioning Engineers	2
<a href="http://www.autofrost.com">www.autofrost.com</a>	Autofrost R406a R414 a Home Page	4
<a href="http://www.baltaircoil.com">www.baltaircoil.com</a>	Baltimore Aircoil	4
<a href="http://www.bcse.org">www.bcse.org</a>	The Business Council for Sustainable Energy	2
<a href="http://www.bfs-kaelte-klima.com">www.bfs-kaelte-klima.com</a>	Bundesfachschule	4
<a href="http://www.carrier.com/HomePage">www.carrier.com/HomePage</a>	Carrier – World Leader in Air Conditioning, Heating and Refrigeration Systems	4
<a href="http://www.cci-promotor.de">www.cci-promotor.de</a>	Die CCInternet im Promotor Verlag	4
<a href="http://www.climatenetwork.org">www.climatenetwork.org</a>	Climate Network Europe	3
<a href="http://www.davidsuzuki.org">www.davidsuzuki.org</a>	The David Suzuki Foundation	3
<a href="http://www.dow.com/heattrans">www.dow.com/heattrans</a>	Dow Chemical Heat Transfer	4
<a href="http://www.edf.org">www.edf.org</a>	Environmental Defense Fund	3

<sup>1</sup> Organisation Types:

- 1 – Government and Intergovernmental
- 2 – Associations
- 3 – ENGOs
- 4 – Industry
- 5 – Academic and Research

www.eeb.org	European Environment Bureau	3
www.enme.umd.edu/ceee	Center for Environmental Energy Engineering	5
www.epa.gov/ozone	Environmental Protection Agency Stratospheric Ozone Division	1
www.fiz-karlsruhe.de/peu/peuger.html	Projektgruppe Energie und Umwelt	5
www.foe.org	Friends of the Earth	3
www.frigorbox.it	FRIGOR-BOX Home Page	4
www.gartner-refrig.com	Gartner Refrigeration & Mfg., Inc.	4
www.genetron.com	Allied Signal Inc. Genetron	4
www.greenpeace.org	Greenpeace	3
www.gtz.de/proklima/index.html	PROKLIMA: The Ozone Depleting Substances Phase Out Project in German Technical Cooperation	2
www.he.afrl.af.mil/hes/hest/default.html	Air Force Research Laboratory Human Effectiveness Directorate Operational Toxicology Branch	1
www.iea.org	International Energy Agency	1
www.iifir.org	International Institute of Refrigeration	2
www.ilkdresden.de	Institut für Luft und Kältetechnik	5
www.ipac.com	International Pharmaceutical Aerosol Consortium	2
www.lawton.co.uk/clients/care	Calor CARE	4
www.mannlib.cornell.edu:10000/hmv1/watrsoil/surf.htm	Water Surface Tension	5
www.mmm.com/market/industrial/fluids/refheat.html	3M Specialty Fluids Heat Transfer	4
www.mst.dk/publica/01000000.htm	Report on potent greenhouse gases by Danish EPA	1
www.ngdc.noaa.gov/paleo/perspectives	NOAA Handbook on Global Warming	1
www.nist.gov	National Institute of Standards and Technology	1
www.nist.gov/srd	NIST Standard Reference Data Products Catalog	1
www.nrdc.org	Natural Resources Defense Council	3
www.osar.odessa.ua	Odessa State Academy of Refrigeration	5
www.ozone.org	Ozone Action	3
www.paft.org	Programme for Alternative Fluorocarbon Toxicity Testing	5

<a href="http://www.panda.org">www.panda.org</a>	World Wide Fund for Nature	3
<a href="http://www.rismed.com/Millennia.html">www.rismed.com/Millennia.html</a>	MILLENNIA, the Freon replacement	4
<a href="http://www.teap.org">www.teap.org</a>	Technology and Economic Assessment Panel	1
<a href="http://www.teriin.org">www.teriin.org</a>	Tata Energy Research Institute	5
<a href="http://www.ttc.nrc.ca">www.ttc.nrc.ca</a>	Thermal Technology Centre	5
<a href="http://www.worldwatch.org">www.worldwatch.org</a>	Worldwatch Institute	3
<a href="http://www.wri.org">www.wri.org</a>	World Resources Institute	3

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