PFCs, compounds containing carbon and fluorine only (**1**), are included in the fluorine containing gases ("F-Gases") of the Kyoto Protocol basket. PFC compounds are highly volatile, linear, branched chain or cyclic perfluorinated carbons (C1 up to C6, fully saturated); speciality gases CF4, C2F6, C3F8, c-C4F8, C4F10 and dielectric liquids C5F12, C6F14 (**2**)

PFC compounds listing:

Species	Code	Formula	GWP	Lifetime (y)	Boiling Point (°C)
Perfluoromethane	14	CF4	6500	50000	-128
Perfluoroethane	116	C2F6	9200	10000	-78
Perfluoropropane	218	C3F8	7000	2600	-37
Perfluorobutane	3-1-10	C4F10	7000	2600	-2
Perfluorocyclobutane	c-318	c-C4F8	8700	3200	-7
Perfluoropentane	4-1-12	C5F12	7500	4100	30
Perfluorohexane	5-1-14	C6F14	7400	3200	56

More information

Emission and uses

Natural geological emissions have been responsible for the PFCs that have accumulated in the atmosphere over a very long time. However, the largest current source is aluminium production, releasing CF4 and C2F6 as by-products.

With the phase-out of ozone depleting substances, PFCs have been introduced into several specialised applications. The low volume level of use is associated with the fact that PFCs are relatively expensive products and are only selected if they are absolutely necessary for performance, system efficiency or safety. The manufacturing cost of PFCs is related to high material costs and processes that have limited scope for scale-up; the cost of manufacturing is much less sensitive to scale than that of HCFCs and HFCs.

The industrial use is mainly linked to the electronics industry, as PFCs offer a unique combination of properties: they are inert, good dielectrics, non-flammable, non-toxic and compatible with a broad range of materials. Semiconductor manufacturing processes utilise PFC gases as a fluorine source for chemical vapour deposition chamber cleaning and specialised plasma etching. PFC liquids C5F12 and C6F14 are traditionally used as direct contact immersion cooling liquid for high power electronics, mainly as replacement for CFC-113, with required good dielectric characteristic at optimum material compatibility and thermal stability.

C3F8 has been developed as an inerting agent for a number of speciality refrigerant formulations. These formulations are primarily for use in existing CFC-based equipment and have a significant benefit of requiring the very minimum of retrofit adjustments. Whilst there are many new ODP-

free refrigerants available (mainly HFC-134a) which perform well in newly designed equipment, their use in existing equipment is limited due to the high cost of retrofit.
In summary, only niche market applications for PFCs have developed following the European CFC phase-out since 1995. Today, the market is already in mature status and the EC HCFC phase-out regulation (EC 2037/2000) will not have a significant impact on the inert PFC liquids.

Outlook

Primary aluminium manufacturing - PFC by-product emissions will decline due to already available process optimisation technologies.

Semiconductor manufacturing - the industry's goal for global PFC emission reduction will reduce the total emissions by 10% (MMTCE) by 2010 (baseline 1995). This goal is embraced by European semiconductor manufacturers (Memorandum of Agreement signed 1998) and is equivalent to a reduction of more than 95% for each electronic component made (**3**).

Refrigerant blends - use of C3F8 (in for example R-403A/B, R-412A) to render HCFC blends non-flammable will decline because HCFCs will discontinue by end 2009, as required by EC2037/2000. PFCs are also used in small amounts in specialist blends with HFCs but the quantities are small compared to releases from the semiconductor and aluminium industries.

(April 2003)

Quotes

1. International Union of Pure and Applied Chemistry (IUPAC) and Intl. Organisation for Standardisation (ISO) and IPCC guidelines.

2. European Fluorocarbon Technical Committee, et al, April 1999 and Japanese law no. 118 of 1998 as enforced April 8., 1999, Law Concerning the Promotion of the Measures to Cope with Global Warming.

3. World Semiconductor Council and EECA, Global PFC emission reduction goal, April 23, 1999