6. HFCs, PFCs, and Sulfur Hexafluoride

U.S. Emissions of HFCs, PFCs, and Sulfur Hexafluoride

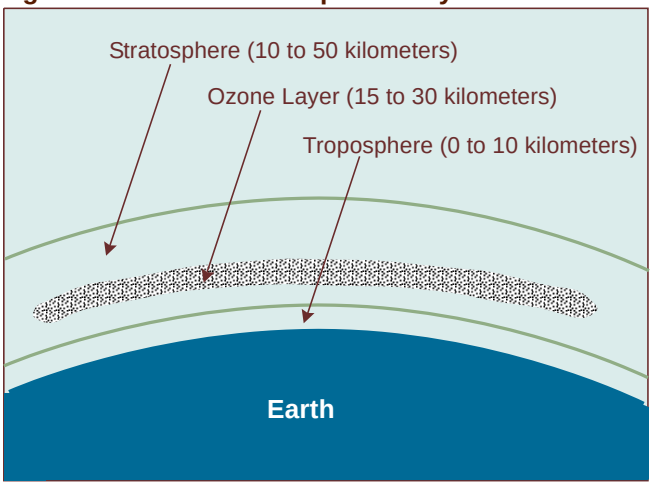
Halogenated substances are chemicals that have been engineered for a variety of industrial uses. Some are greenhouse gases with high global warming potentials (GWPs) as compared with carbon dioxide and, therefore, may have an effect on global climate disproportionate to the relatively small volumes emitted.[57] Emissions of halogenated substances can be classified into two groups according to the accuracy with which their GWPs can be determined.

The first group consists of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other chlorine-containing gases. These compounds absorb infrared radiation at wavelengths that would not otherwise be absorbed, making them potent greenhouse gases with direct radiative forcing effects hundreds or thousands of times greater than that of carbon dioxide. Because they contain chlorine, however, these substances also tend to destroy the ozone layer, located in the middle to upper stratosphere (Figure 13), which absorbs damaging ultraviolet radiation from the sun. Because ozone is a greenhouse gas, the reaction tends to offset the net warming effects of the chlorine-containing halogens to varying degrees. As a result, their effective GWPs are difficult to determine.

CFC production ceased in January 1996 in accordance with the Copenhagen Amendments to the Montreal Protocol (except for production of CFCs used in metered dose inhalers for asthma patients). In addition, all HCFC production is required to be phased out by 2030. The United Nations Framework Convention on Climate Change (UNFCCC) excludes from its provisions gases covered by the Montreal Protocol and, therefore, does not address CFCs and HCFCs.

The halogenated substances in the second group, which are the focus of this chapter, include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These compounds also absorb infrared radiation that would not otherwise be absorbed in the troposphere, and they have relatively high radiative forcing impacts. In contrast to the chlorine-containing halogenated substances, these compounds do not destroy ozone. Thus, their estimated GWPs, expressed in metric tons carbon dioxide equivalent, can be more accurately evaluated. The Kyoto Protocol to the UNFCCC explicitly lists HFCs, PFCs, and SF_6 as greenhouse gases affected by its provisions.

Figure 13. Earth's Atmospheric Layers



Source: U.S. Environmental Protection Agency.

In 2000, U.S. emissions of HFCs, PFCs, and SF_6 were estimated to be 171.6 million metric tons carbon dioxide equivalent, a 58-percent increase over 1990 levels, primarily due to increases in HFC emissions.[58] Emissions of HFCs, which are used as replacements for CFCs as blowing agents, refrigerants, solvents, and in automobile air conditioners, overall have been growing during the 1990s (Figure 14). In turn, emissions of CFCs are decreasing, according to recent estimates published by the Energy Information Administration.[59] PFCs are emitted as a byproduct of aluminum smelting and are used in semiconductor manufacturing as etchants and cleaning agents. In contrast, emissions of PFCs and SF_6 have remained relatively stable since 1990.

[57] Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), Table 6.7, pp. 388-389.

[58] Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), web site http://www.eia.doe.gov/oiaf/1605/1605a.html.

[59] Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), web site http://www.eia.doe.gov/oiaf/1605/1605a.html. Estimates of CFC, HFC, PFC, and SF_6 emissions are based on data obtained from the U.S. Environmental Protection Agency.

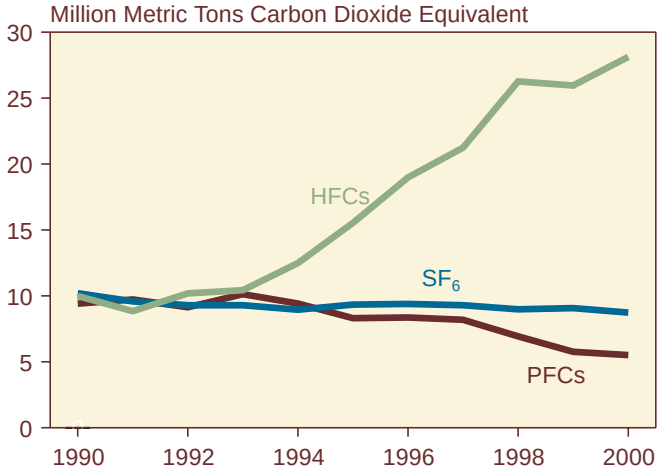
Projects Reported

For the 2000 data year, 29 entities reported on 44 projects that reduced emissions of halogenated substances, a 7-percent increase in the number of entities reporting and a 22-percent increase in the number of projects reported, as compared with the 1999 data year. For 2000, American Electric Power, Inc., reported a project in this category for the first time, as did Consolidated Edison of New York, Inc., a new reporter to the program. Both reported SF_6 reduction projects. Twenty of the 29 entities reporting in this category reported on 19 projects that included reductions in emissions, and 13 of the 20 project reports included direct reductions in SF_6 emissions. Another entity also reported direct reductions in SF_6 emissions but provided no data for 2000. Two entities reported on projects that included direct reductions of PFC emissions.

Other projects for 2000 included objectives to reduce HFC emissions. One entity reported a project with zero direct reductions in HFC-134a emissions, and a second entity reported on a project to reduce HFC-134a emissions but provided no data on reductions for 2000. A third entity reported on a project to reduce HFC-152a emissions but also provided no data on reductions for 2000. One entity reported on a project that included indirect reductions in SF_6 emissions, and one report unspecified reductions in SF_6 emissions on Form EIA-1605EZ.

Twenty-one of the 29 entities reporting for 2000 were electric utilities; two were aluminum smelters (Alcan Ingot's Sebree Aluminum Plant and Noranda Aluminum, Inc.); three were from the chemical and allied products industry (Allergan, Inc., the Dow Chemical Company, and Pharmacia & Upjohn Caribe, Inc.); one was from the transportation equipment industry (Pratt & Whitney North Berwick); one was a local government in New York State (Madison County Department of Solid Waste & Sanitation); and one was from the holdings and other investment office industry (CLE Resources).

Figure 14. Estimated U.S. Emissions of HFCs, PFCs, and Sulfur Hexafluoride, 1990-2000



Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), Table 30, p. 67.

Nineteen of the 21 electric utilities that reported projects in this category were participants in the Climate Challenge Program sponsored by the U.S. Department of Energy (DOE). Other voluntary programs with which the projects reported in this category were affiliated include the Climate Wise Recognition Program, the Voluntary Aluminum Industrial Partnership, and the Sulfur Hexafluoride Emissions Reduction Partnership for Electric Power Systems. In addition, all but one of the 29 entities that reported on projects to reduce emissions of halogenated substances used Form EIA-1605 to report their activities to the Voluntary Reporting Program. Pratt & Whitney North Berwick reported on Form EIA-1605EZ.

For 2000, emissions avoidance and recycling were the two most frequently reported project types (23 and 17 projects reported, respectively), followed by substitution of other chemicals (10 projects reported). Other types of projects reported for 2000 included the destruction of halogenated substances and the use of improved appliances. One general halogenated substance project reported on Form EIA-1605EZ, where the types of activities are not specified, was reported for 2000 (Table 21).

Direct reductions of HFCs, PFCs, and SF_6 emissions were reported by 16 entities for 19 projects, totaling 4,637,909 metric tons carbon dioxide equivalent (Table 22), and 3 entities each reported a project that included direct reductions of SF_6 but did not provide data for 2000. Also for 2000, one entity reported a project that included indirect reductions of SF_6 emissions totaling 81 metric tons carbon dioxide equivalent, and another entity reported unspecified reductions of SF_6 emissions (on Form EIA-1605EZ) that amounted to 20,744 metric tons carbon dioxide equivalent.

Emission Reductions by Gas

Reported project-level reductions of perfluoromethane and perfluoroethane in 2000 were lower than those reported for 1999 (Table 23), primarily because of the increased use of HCFCs and HFCs as replacements for CFCs. The largest GWP-adjusted reductions were reported for PFCs at 3,230,562 metric tons carbon dioxide equivalent (Table 22). Reported direct reductions of SF_6 emissions for 2000 increased by 811,888 metric tons

carbon dioxide equivalent (136 percent) and were almost 16 times the value reported for 1994 (Table 21). American Electric Power, Inc., reported for the first time in this category, and Consolidated Edison of New York, Inc., was a new reporter to the Program for 2000. These two entities together accounted for 57 percent of the increase in reported direct reductions of SF_6 emissions from 1999 to 2000.

Hydrofluorocarbons

HFCs are used as replacements for ozone-depleting substances such as CFCs. U.S. emissions of HFCs were estimated at 103 million metric tons carbon dioxide equivalent in 2000, a 181-percent increase over 1990 levels.[60] HFCs are used to replace CFCs as blowing agents, in automobile air conditioners and refrigerators, and in other manufacturing applications, where emissions result from system leaks. In the semiconductor industry, HFCs are also used in plasma etching and chemical vapor deposition processes. HFC-23 is a byproduct of HCFC-22 manufacturing. One entity, Commonwealth Edison, reported a project with zero direct reductions of HFC-134a (tetrafluoroethane) emissions in 2000. Another entity, Dow Chemical, reported on a project that included a direct reduction in HFC-134a emissions in 2000 but provided no data on the amount of the reduction.

Perfluorocarbons

The principal source of PFC emissions is aluminum smelting. PFCs are produced during aluminum production when the alumina content of the electrolytic bath falls below critical levels required by the electrolytic effect. The resulting electrical upset in the reduction cell is manifested as a rapid voltage increase. The gases formed accumulate at the anode of the reduction cell (hence the name "anode effect"). PFCs are also used in some semiconductor manufacturing processes and, consequently, may be emitted from fabrication plants.

Table 21. Number of Projects Reported for Halogenated Substances, Data Years 1994-2000

Project Type	1994	1995	1996	1997	1998	1999	2000
General	1	1	0	1	0	0	1
Reclamation: Recycling	7	10	10	14	15	15	17
Reclamation: Destruction	0	0	1	1	0	1	1
Substitution	2	6	8	7	8	9	10
Emissions Avoidance	3	6	8	14	17	16	23
Use of Improved Appliances	0	1	1	1	1	1	1
Other Projects/Activities	1	1	0	0	0	0	0
Total Number of Projects	**15**	**22**	**23**	**30**	**35**	**36**	**44**

Note: Project totals may not equal sum of components because some projects may be counted in more than one category.
Sources: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

Table 22. Reported Reductions of Hydrofluorocarbon, Perfluorocarbon, and Sulfur Hexafluoride Emissions, Data Year 2000

	Emission Reductions Reported					
	Metric Tons of Gas			Metric Tons Carbon Dioxide Equivalent		
Gas	Direct	Indirect	Unspecified[a]	Direct	Indirect	Unspecified[a]
HFC-134a	0	—	—	0	—	—
HFC-152a	—	—	—	—	—	—
Perfluoromethane	469	—	—	2,675,552	—	—
Perfluoroethane	47	—	—	555,010	—	—
Sulfur Hexafluoride	63	*	1	1,407,347	81	20,744
Total	**NA**	**NA**	**NA**	**4,637,909**	**81**	**20,744**

[a]Unspecified reductions represent quantities reported on Form EIA-1605EZ, which does not distinguish between direct and indirect emission reductions.
*Less than 0.5 metric tons.
NA = not applicable. — = none reported.
Sources: Energy Information Administration, Form EIA-1605 and EIA-1605EZ. Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), Table 6.7, pp. 388-389.

[60]Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), web site http://www.eia.doe.gov/oiaf/1605/1605a.html.

For 2000, two companies (Alcan Ingot's Sebree Aluminum Plant and Noranda Aluminum, Inc.) reported reductions in emissions of PFCs totaling 3,230,562 metric tons carbon dioxide equivalent, which accounted for 70 percent of total reported project-level direct reductions in emissions of PFCs, HFCs, and SF_6 in 2000 (Table 22). During 2000, efforts by Noranda to reduce PFC emissions were focused on controlling the amount of alumina in solution to avoid anode effects and monitoring the process more closely to stop or correct them expeditiously. Noranda reported the larger individual reductions between the two projects in this category for 2000. According to Noranda's report, perfluoromethane emissions were reduced by 2,696,100 metric tons carbon dioxide equivalent and perfluoroethane emissions by 559,300 metric tons carbon dioxide equivalent.

Alcan Ingot, meanwhile, reported direct increases in perfluoromethane emissions (20,549 metric tons carbon dioxide equivalent) and perfluoroethane emissions (4,290 metric tons carbon dioxide equivalent). For 1999, Alcan Ingot reported direct reductions in perfluoromethane emissions totaling 64,838 metric ton carbon dioxide equivalent and direct reductions in perfluoroethane emissions totaling 13,542 metric tons carbon dioxide equivalent. The U.S. Environmental Protection Agency sponsors the Voluntary Aluminum Industrial Partnership, which seeks to reduce emissions of PFCs, carbon tetrachloride, and SF_6 during primary aluminum processing. For 2000, both Alcan Ingot and Noranda reported participation in the program.

Sulfur Hexafluoride

Sulfur hexafluoride is used as an insulator for circuit breakers, switch gear, and other electrical equipment and as a cover gas in magnesium smelting. It is also emitted during the aluminum smelting process. It has a very high GWP—22,200 times the warming effect of carbon dioxide per ton emitted. Therefore, even small amounts of SF_6 can play a disproportionate role in U.S. contributions to climate change.[61]

Table 23. Reported Reductions in Emissions of Halogenated Substances by Type of Reduction, Data Years 1994-2000
(Metric Tons of Gas)

Gas and Reduction Type	1994	1995	1996	1997	1998	1999	2000
HFC-134a							
Direct	**	**	**	**	-1	-1	0
Indirect	—	—	—	—	—	—	—
Unspecified[a]	—	—	—	—	—	—	—
HFC-152a							
Direct	—	—	127	*	0	0	—
Indirect	—	—	—	—	—	—	—
Unspecified[a]	—	—	—	—	—	—	—
Perfluoromethane							
Direct	466	431	486	482	507	498	469
Indirect	—	—	—	—	—	—	—
Unspecified[a]	—	—	—	—	—	—	—
Perfluoroethane							
Direct	46	43	48	48	52	49	47
Indirect	—	—	—	—	—	—	—
Unspecified[a]	—	—	—	10	—	—	—
Sulfur Hexafluoride							
Direct	4	8	-3	23	28	27	63
Indirect	—	*	—	*	*	*	*
Unspecified[a]	—	—	—	—	—	—	1

[a]Unspecified reductions represent quantities reported on Form EIA-1605EZ, which does not distinguish between direct and indirect emission reductions.
*Greater than zero but less than 0.5 metric tons of gas.
**Greater than -0.5 but less than zero metric tons of gas.
— = none reported.
Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

[61]Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001), web site http://www.eia.doe.gov/oiaf/1605/1605a.html.

For 2000, 14 companies—including Allegheny Energy, Inc., Baltimore Gas & Electric, Consolidated Edison of New York, Inc., GPU, Inc., Southern Company, and TXU—claimed direct reductions in SF_6 emissions that totaled 1,407,347 metric tons carbon dioxide equivalent, accounting for 30 percent of the total reported project-level direct reductions in emissions of PFCs, HFCs, and SF_6 (Table 22).

The Southern Company reported the largest single reduction in SF_6 emissions for 2000 at 377,400 metric tons carbon dioxide equivalent, followed by Consolidated Edison of New York, Inc. (353,202 metric tons), TXU, Inc. (236,714 metric tons), and GPU, Inc. (142,648 metric tons). These four project-level claims of emission reductions combined to account for 79 percent (1,109,964 metric tons carbon dioxide equivalent) of total reported project-level direct reductions of SF_6 emissions for 2000 and 24 percent of total project-level direct emission reductions claimed for HFCs, PFCs, and SF_6 combined (Table 24).

Table 24. Largest Reported Project-Level Reductions of Sulfur Hexafluoride Emissions by Reporter, Data Year 2000

Reporter	SF_6 Direct Emission Reductions Reported		Percent of Total Reported Direct Reductions of HFCs, PFCs, and SF_6 Emissions
	Metric Tons of Gas	Metric Tons Carbon Dioxide Equivalent	
Southern Company	17.0	377,400	8.1
Consolidated Edison Company of New York, Inc.	15.9	353,202	7.6
TXU	10.7	236,714	5.1
GPU, Inc.	6.4	142,648	3.1
American Electric Power, Inc.	4.8	105,533	2.3
NiSource/NIPSCO	2.2	49,745	1.1
Allegheny Energy, Inc.	2.0	44,911	1.0
Tucson Electric Power Company	1.9	41,931	0.9
PG&E Corporation	1.8	40,864	0.9
Niagara Mohawk Power Corporation	0.5	10,231	0.2
First Energy Corporation	0.2	4,169	0.1
Reported Total	**63.4**	**1,407,347**	**30.3**

Note: Totals may not equal sum of components due to independent rounding.

Sources: Energy Information Administration, Form EIA-1605. Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), Table 6.7, pp. 388-389.