

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.⁴⁰ Emissions of halogenated substances can be classified into two groups according to the accuracy with which their GWPs can be determined.

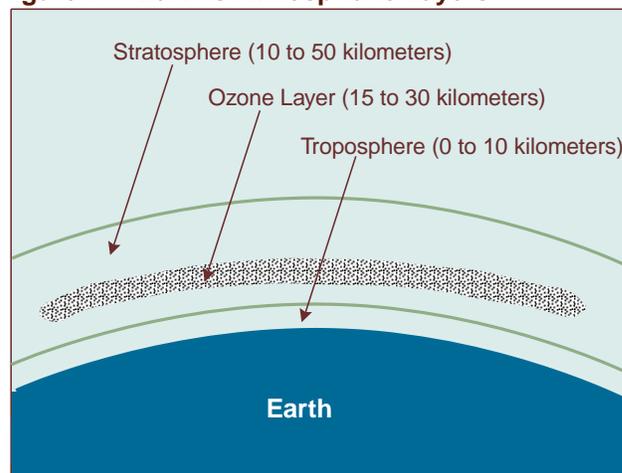
The first group consists of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other chlorine-containing gases. These compounds absorb infrared radiation at wavelengths that would not otherwise be absorbed, making them potent greenhouse gases with direct radiative forcing effects hundreds 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 14), 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 (SF₆). 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 SF₆ as greenhouse gases affected by its provisions.

Figure 14. Earth's Atmospheric Layers



Source: U.S. Environmental Protection Agency.

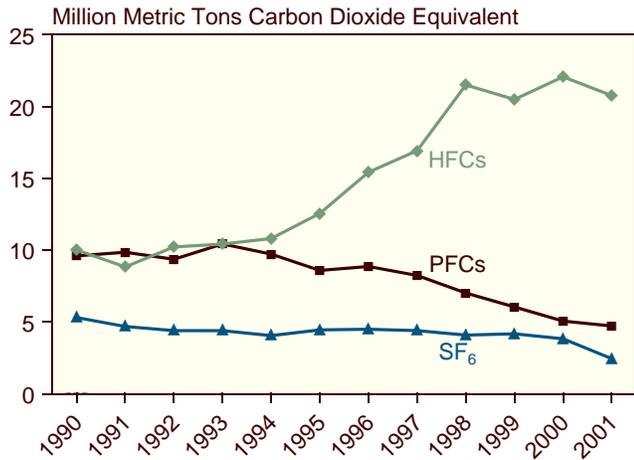
In 2001, U.S. emissions of HFCs, PFCs, and SF₆ were estimated to be 115.3 million metric tons carbon dioxide equivalent, a 26-percent increase over 1990 levels, primarily due to increases in HFC emissions.⁴¹ Emissions of HFCs, which are used as replacements for CFCs as blowing agents, refrigerants, solvents, and in automobile air conditioners, overall have been growing since 1990 (Figure 15). In turn, emissions of CFCs are decreasing, according to recent estimates published by the Energy Information Administration.⁴² PFCs are emitted as a byproduct of aluminum smelting and are used in semiconductor manufacturing as etchants and cleaning agents. Emissions of PFCs have remained relatively stable since 1990, and emissions of SF₆ have been declining.

⁴⁰Global 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.

⁴¹Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), web site www.eia.doe.gov/oiaf/1605/1605a.html.

⁴²Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), web site www.eia.doe.gov/oiaf/1605/1605a.html. Estimates of CFC, HFC, PFC, and SF₆ emissions are based on data obtained from the U.S. Environmental Protection Agency.

Figure 15. Estimated U.S. Emissions of HFCs, PFCs, and Sulfur Hexafluoride, 1990-2001



Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), Table 30, p. 71.

Projects Reported

For the 2001 data year, 33 entities reported on 58 projects that reduced emissions of halogenated substances, 1 less reporter and 5 fewer projects than were reported for 2000. Thirty-one of the 33 entities reporting in this category reported on 55 projects, 17 of which included direct reductions in SF₆ emissions. Three entities reported on projects with zero direct reductions in SF₆ emissions. Four entities reported on projects that included direct reductions of PFC emissions. One entity reported on a project to reduce emissions of HFC-134a (tetrafluoroethane) but provided no data on reductions for 2001. Eighteen of the 33 entities reporting in this category reported on projects that included reductions in emissions of PFCs (perfluoroethane and perfluoromethane).

One entity also reported a project with zero reductions of PFC emissions.

Twenty-seven of the 33 entities reporting projects that reduced emissions of halogenated substances for 2001 were electric utilities; two were aluminum smelters (Alcan Primary Metals Group–Sebree Works and Noranda Aluminum, Inc.); one was from the electronic equipment industry (Lucent Technologies, Inc.); and one was a local government in New York State (Madison County Department of Solid Waste & Sanitation).

Nineteen of the 27 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 Voluntary Aluminum Industrial Partnership, the Energy Star Programs, Rebuild America, and the Sulfur Hexafluoride Emissions Reduction Partnership for Electric Power Systems.

For 2001, emissions avoidance and recycling were the two most frequently reported project types (23 and 16 projects reported, respectively), followed by substitution of other chemicals (6 projects reported) and the destruction of halogenated substances (1 project reported). Reductions in PFC emissions were also reported for 19 post-consumer waste recycling projects in which aluminum was one of the materials collected and recycled (Table 21).

Direct reductions of HFC, PFC, and SF₆ emissions were reported by 20 entities for 22 projects, totaling 6,081,957 metric tons carbon dioxide equivalent (Table 22), and 1 entity reported a project that included direct reductions of HFC emissions but did not provide data for 2001. Also for 2001, 14 entities reported on projects that included indirect reductions of PFC emissions totaling 34,400 metric tons carbon dioxide equivalent, and another

Table 21. Number of Projects Reported on Form EIA-1605 for Halogenated Substances, Data Years 1994-2001

Project Type	1994	1995	1996	1997	1998	1999	2000	2001
General	0	1	0	1	0	0	0	0
Reclamation: Recycling	7	10	10	14	15	15	18	16
Reclamation: Destruction	0	0	1	1	0	1	1	1
Substitution	1	5	7	7	8	9	9	6
Emissions Avoidance	3	6	8	13	17	16	23	23
Use of Improved Appliances	0	1	1	1	1	1	1	0
Other Projects/Activities	1	1	0	0	0	0	0	0
PFC Reductions from Materials Recycling . .	0	0	0	4	7	10	20	19
Total Number of Projects	13	21	22	33	42	46	63	58

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

entity reported indirect reductions of SF₆ emissions that amounted to 81 metric tons carbon dioxide equivalent.

Emission Reductions by Gas

Reported direct reductions of PFC emissions totaled 3.6 million metric tons carbon dioxide equivalent and accounted for the highest percentage (59 percent) of direct reductions in emissions of halogenated substances reported for 2001. This reflects an increase over the amounts reported for 2000 (Table 23), primarily because of the increased use of HCFCs and HFCs as replacements for CFCs. Reported direct reductions of

SF₆ emissions for 2001 increased by 1.4 million metric tons carbon dioxide equivalent (76 percent) from those reported for 2000 and were almost 30 times the value reported for 1994 (Table 23). Consolidated Edison of New York, Inc., Southern Company, and TXU together accounted for 71 percent of the total reported direct reductions in SF₆ emissions for 2001 and 29 percent of the total reported direct reductions of HFCs, PFCs, and SF₆ emissions combined.

Hydrofluorocarbons

HFCs are used as replacements for ozone-depleting substances such as CFCs. U.S. emissions of HFCs were

Table 22. Reductions of Hydrofluorocarbon, Perfluorocarbon, and Sulfur Hexafluoride Emissions Reported on Form EIA-1605, Data Year 2001

Gas	Emission Reductions Reported			
	Metric Tons of Gas		Metric Tons Carbon Dioxide Equivalent	
	Direct	Indirect	Direct	Indirect
HFC-134a.....	0	—	0	—
HFC-152a.....	—	—	—	—
Perfluoromethane.....	523	5	2,982,917	29,115
Perfluoroethane.....	52	*	623,896	5,205
Sulfur Hexafluoride.....	111	*	2,475,144	81
Total.....	NA	NA	6,081,957	34,400

*Less than 0.5 metric tons.

NA = not applicable. — = none reported.

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.

Table 23. Reductions in Emissions of Halogenated Substances Reported on Form EIA-1605 by Type of Reduction, Data Years 1994-2001 (Metric Tons of Gas)

Gas and Reduction Type	1994	1995	1996	1997	1998	1999	2000	2001
HFC-134a								
Direct.....	**	**	**	**	-1	-1	0	—
Indirect.....	—	—	—	—	—	—	—	—
HFC-152a								
Direct.....	—	—	127	0	0	0	—	—
Indirect.....	—	—	—	—	—	—	—	—
Perfluoromethane								
Direct.....	466	431	486	482	507	498	470	523
Indirect.....	—	—	—	1	1	1	5	5
Perfluoroethane								
Direct.....	46	42	48	48	52	49	47	52
Indirect.....	—	—	—	*	*	*	1	*
Sulfur Hexafluoride								
Direct.....	4	8	-3	23	28	27	63	111
Indirect.....	—	*	—	*	*	*	*	*

*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, Form EIA-1605.

estimated at 77 million metric tons carbon dioxide equivalent in 2001, a 110-percent increase over 1990 levels.⁴³ 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. The Tennessee Valley Authority, reported on a project that included direct reductions of HFC-134a, but for which no reduction data have been available since 1998.

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.

For 2001, two companies (Alcan Primary Metals Group—Seabee Works and Noranda Aluminum, Inc.) reported reductions in emissions of PFCs totaling 3,604,919 metric tons carbon dioxide equivalent, which accounted for 59 percent of total reported project-level direct reductions in emissions of PFCs, HFCs, and SF₆ in 2001 (Table 22). During 2001, 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. According to Noranda’s report, perfluoromethane emissions were reduced by 2,616,300 metric tons carbon dioxide equivalent and perfluoroethane emissions by 547,400 metric tons carbon dioxide equivalent. Alcan reported direct reductions in perfluoromethane emissions totaling 365,011 metric tons carbon dioxide equivalent and direct reductions in perfluoroethane emissions totaling 76,208 metric tons carbon dioxide equivalent. Additionally, City Public Service and Los

Angeles Department of Water and Power reported materials recycling projects (see box in Chapter 5, page 53) that included direct reductions of PFC emissions totaling 1,895 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 SF₆ during primary aluminum processing. For 2001, both Alcan 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 SF₆ can play a disproportionate role in U.S. contributions to climate change.⁴⁴

For 2001, 16 companies—including Consolidated Edison of New York, Inc., Southern Company, FirstEnergy Corporation, TXU, and Southern California Edison—claimed direct reductions in SF₆ emissions that totaled 2,475,144 metric tons carbon dioxide equivalent, accounting for 41 percent of the total reported project-level direct reductions in emissions of PFCs, HFCs, and SF₆ (Table 22).

All of the largest reductions in SF₆ emissions reported for 2001 were direct emission reductions. Consolidated Edison of New York, Inc., reported the largest single reduction in SF₆ emissions for 2001 at 1,081,872 metric tons carbon dioxide equivalent, followed by the Southern Company (421,800 metric tons), TXU (257,125 metric tons), and FirstEnergy Corporation (167,057 metric tons). These four project-level claims of emission reductions combined to account for 78 percent (1,927,854 metric tons carbon dioxide equivalent) of total reported project-level direct reductions of SF₆ emissions for 2001 and 32 percent of total project-level direct emission reductions claimed for HFCs, PFCs, and SF₆ combined (Table 24).

⁴³Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), web site www.eia.doe.gov/oiaf/1605/1605a.html.

⁴⁴Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), web site www.eia.doe.gov/oiaf/1605/1605a.html.

Table 24. Largest Project-Level Direct Reductions of Sulfur Hexafluoride Emissions Reported on Form EIA-1605 by Reporter, Data Year 2001

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	
Consolidated Edison Company of New York, Inc. . . .	48.7	1,081,872	17.8
Southern Company	19.0	421,800	6.9
TXU	11.6	257,125	4.2
FirstEnergy Corporation	7.5	167,057	2.7
Southern California Edison Co.	6.0	132,681	2.2
American Electric Power, Inc.	4.4	97,678	1.6
FPL Group	4.1	91,566	1.5
PG&E Corporation	3.8	83,384	1.4
NiSource/NIPSCO	2.3	50,349	0.8
Tucson Electric Power Company	1.9	41,226	0.7
Niagara Mohawk Power Corporation	1.6	35,829	0.6
City Public Service	0.3	7,522	0.1
Reported Total	111.5	2,475,144	40.7

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.

