

## 6. Halogenated Substances

### U.S. Emissions of Halogenated Substances

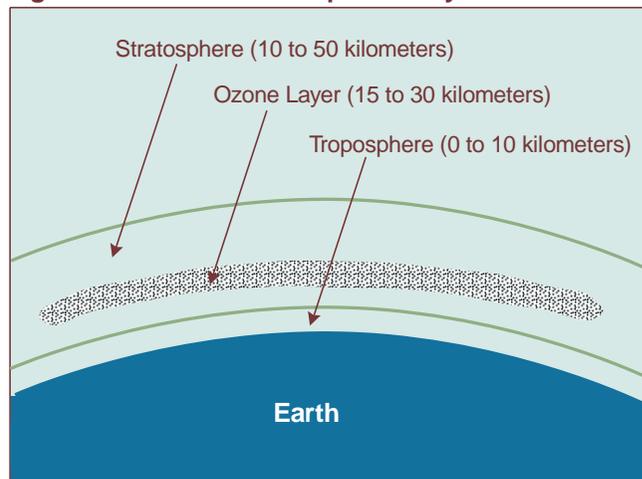
Halogenated substances are chemicals that have been engineered for a variety of industrial uses. Some are potent greenhouse gases and, therefore, may have an effect on global climate. Emissions of halogenated substances can be classified into two groups according to the accuracy with which their global warming potential (GWP) can be determined (for a discussion of GWPs, see Chapter 1).

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 15), which absorbs damaging ultraviolet radiation from the sun. Because ozone is a greenhouse gas, its destruction 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 second group of halogenated substances includes hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>). These compounds also absorb infrared radiation that would not otherwise be absorbed in the troposphere, and they have relatively

Figure 15. Earth's Atmospheric Layers



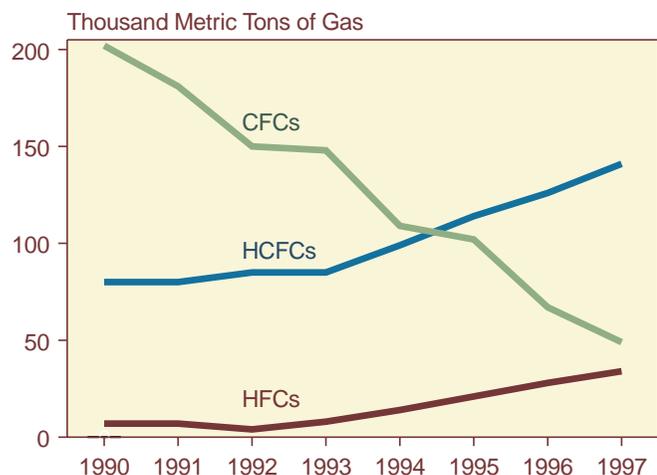
Source: U.S. Environmental Protection Agency, Stratospheric Protection Division, <http://www.epa.gov/spdpublic/index.html>.

high radiative forcing impacts. In contrast to the chlorine-containing halogenated substances, these compounds do not destroy ozone. Thus, their estimated GWPs, expressed in carbon dioxide equivalent, can be more accurately evaluated. The Kyoto Protocol to the UNFCCC explicitly lists HFCs, PFCs, and sulfur hexafluoride as greenhouse gases affected by its provisions.

In 1997, U.S. emissions of HFCs, PFCs, and sulfur hexafluoride were estimated to be 137.5 million metric tons carbon dioxide equivalent, a 68-percent increase over 1990 levels, primarily due to increases in HFC emissions.<sup>61</sup> Emissions of HCFCs and HFCs, which are used as replacements for CFCs as blowing agents, refrigerants, solvents, and in automobile air conditioners, are growing (Figure 16). In turn, emissions of CFCs are decreasing. Estimated PFC emissions as a byproduct of aluminum smelting rose in 1997 along with aluminum production. PFC use in semiconductor manufacturing as etchants and cleaning agents has also been growing. In contrast, emissions of sulfur hexafluoride have remained relatively unchanged.

<sup>61</sup>Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998), <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

**Figure 16. Estimated U.S. Emissions of CFCs, HCFCs, and HFCs, 1990-1997**



Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998).

## Projects Reported

For the 1997 data year, 21 entities reported on 30 projects that reduced emissions of halogenated substances—a 30-percent increase from 1996 in the number of projects reported and a 17-percent increase in the number of entities reporting. Seventeen of the reporting entities were electric utilities; two were aluminum smelters; and two were from the chemical and allied products industry and the electronics and other electrical equipment industry. Most (76 percent) of the entities participated in the Climate Challenge Program sponsored by the U.S. Department of Energy (DOE). Other voluntary programs in which the entities participated included the Climate Wise Recognition Program and the Voluntary Aluminum Industrial Partnership. All but one of the entities used the long form to report their activities to the Voluntary Reporting Program. Recycling and emissions

avoidance were the two most frequently reported project types (14 each), followed by substitution of other chemicals (7 projects reported). Other reported projects included the destruction of halogenated substances, the use of improved appliances, and general reduction activities (Table 14).

Thirteen projects reported reductions of HFCs, PFCs, and sulfur hexafluoride. In terms of GWP, the reported reductions are significant, totaling more than 4 million metric tons carbon dioxide equivalent in 1997 (Table 15).<sup>62</sup> GWPs were not calculated for CFCs and HCFCs.

## Emission Reductions by Gas

In terms of metric tons (non-GWP-weighted), overall reported reductions of halogenated substances in 1997 were lower than those reported for 1996 (Table 16), primarily because of the increased use of HCFCs and HFCs as replacements for CFCs. The largest reductions in metric tons of gas and in metric tons carbon dioxide equivalent were reported for PFCs. Reductions were reported for three CFCs, the greatest of which were for CFC-12, followed by CFC-11 and CFC-113. Reported reductions of sulfur hexafluoride have nearly tripled since 1995, and the number of reported projects has nearly doubled (see box on page 48). For 1997, net increases in emissions of HCFC-22, HCFC-123, HCFC-124, and HCFC-142b were reported, suggesting that the use of HCFCs is increasing as the use of CFCs declines.

## Perfluorocarbons

PFCs are emitted primarily during the aluminum smelting process when the amount of alumina in solution drops below the level necessary to drive the desired chemical reactions. In 1997, efforts by VANALCO, Inc., and Noranda Aluminum, Inc., to reduce PFC emissions were focused on controlling the amount of alumina in solution to avoid emissions by monitoring the process

**Table 14. Number of Projects Reported for Halogenated Substances, Data Years 1994-1997**

Project Type	1994	1995	1996	1997
General . . . . .	1	1	0	1
Reclamation: Recycling . . . . .	7	10	10	14
Reclamation: Destruction . . . . .	0	0	1	1
Substitution . . . . .	2	6	8	7
Emissions Avoidance . . . . .	3	6	8	14
Use of Improved Appliances . . . . .	0	1	1	1
Other Projects/Activities . . . . .	1	1	0	0
<b>Total Number of Projects . . . . .</b>	<b>15</b>	<b>22</b>	<b>23</b>	<b>30</b>

Note: Total number of projects may not equal the sum of project types as some projects are categorized as more than one project type.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ

<sup>62</sup>Global warming potentials from Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 121. A table of GWP values is included in Chapter 1 of this report.

**Table 15. Reported Reductions of Hydrofluorocarbon, Perfluorocarbon, and Sulfur Hexafluoride Emissions, Data Year 1997**

Gas	Emission Reductions Reported	
	Metric Tons of Gas	Metric Tons Carbon Dioxide Equivalent
HFC-134a . . . . .	-0.03	-42
Perfluoromethane . . . . .	482.00	3,133,000
Perfluoroethane . . . . .	58.34	536,730
Sulfur Hexafluoride . . . . .	23.28	553,387
<b>Reported Total . . . . .</b>	<b>NA</b>	<b>4,222,830</b>

NA = not applicable.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

**Table 16. Reported Reductions in Emissions of Halogenated Substances, Data Years 1994-1997 (Metric Tons of Gas)**

Gas	1994	1995	1996	1997
CFC-11 . . . . .	3.74	4.10	7.00	6.72
CFC-12 . . . . .	40.08	3,256.90	85.89	58.26
CFC-113 . . . . .	0.03	0.33	0.03	0.03
HCFC-22 . . . . .	1.00	0.26	2.69	-82.12
HCFC-123 . . . . .	0.61	-0.09	-0.16	-0.19
HCFC-124 . . . . .	NR	NR	NR	-0.91
HCFC-142b. . . . .	NR	-3,295.21	973.02	-162.81
Perfluoromethane . . . . .	465.77	437.00	486.12	482.00
Perfluoroethane . . . . .	45.78	42.50	48.34	58.34
HFC-134a . . . . .	-0.02	-0.03	-0.03	-0.03
HFC-152a . . . . .	NR	NR	126.96	0.00
Sulfur Hexafluoride . . . . .	3.76	8.74	-3.15	23.28

NR = not reported.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

more closely. Noranda reported the greatest individual reductions among projects in this category: 473 metric tons of perfluoromethane and 47 metric tons of perfluoroethane emissions were avoided in 1997. VANALCO contributed 10 metric tons of PFC reductions via reductions in anode effects. Advanced Micro Devices, Inc., reduced PFC emissions by 10 metric tons by substituting octofluoropropane (perfluoropropane), which has a lower GWP than perfluoroethane and is needed in lesser quantities, for perfluoroethane. In total, PFC reductions reported for 1997 amounted to nearly 3.7 million metric tons carbon dioxide equivalent. EPA sponsors the Voluntary Aluminum Industrial Partnership, which seeks to reduce emissions of PFCs, carbon tetrachloride, and sulfur hexafluoride during primary aluminum processing. In 1997, VANALCO and Noranda reported participation in the program.

## Hydrofluorocarbons

HFCs are used as replacements for ozone-depleting substances such as CFCs. U.S. emissions of HFCs were estimated at 76.3 million metric tons carbon dioxide equivalent in 1997, a 112-percent increase over 1990 levels.<sup>63</sup> HFCs 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 used in plasma etching and chemical vapor deposition processes. HFC-23 is a byproduct of HCFC-22 manufacturing.

Two HFC projects reported to the Voluntary Reporting Program resulted in a net increase in emissions of 126 metric tons, equivalent to more than 17,700 metric tons of carbon dioxide. EPA works with the semiconductor industry to reduce HFC emissions.

<sup>63</sup>Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998), p. 54, <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

## Greenhouse Gas Profile: Sulfur Hexafluoride Emission Reduction Projects

Electric utilities use sulfur hexafluoride as an insulator for circuit breakers, switch gear, and other electrical equipment. Sulfur hexafluoride is also used in magnesium manufacturing as a cover gas and in certain semiconductor production processes. Emissions from these uses result from leaky breakers and other transforming equipment (in the case of electrical equipment) and from certain semiconductor production processes. Overall, U.S. sulfur hexafluoride emissions have remained relatively unchanged since 1990. Although national emissions of sulfur hexafluoride are relatively low, its high GWP (23,900) makes it a potent greenhouse gas. Therefore, even small reductions are significant.

For the 1997 data year, eight electric utilities reported a total of 23 metric tons of sulfur hexafluoride reductions, equivalent to more than 556,000 metric tons of carbon dioxide. The increase in reported reductions resulted mainly from projects reported by Texas Utilities Electric Company, Duquesne Light Company, Tucson Electric Power Company, and GPU, Inc.:

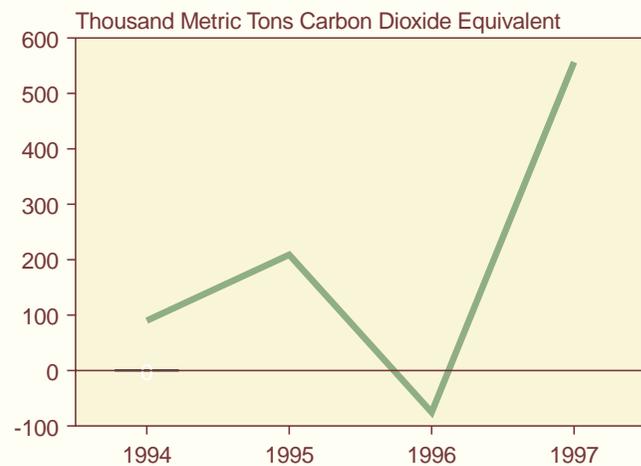
- Texas Utilities reported a program in 1997 to identify and repair leaking circuit breakers. The program reduced sulfur hexafluoride emissions by 9 metric tons, or slightly more than 200,000 metric tons carbon dioxide equivalent.
- Duquesne Light Company reported sulfur hexafluoride reductions of nearly 6 metric tons, the equivalent of 143,000 metric tons of carbon dioxide, through its replacement of gaskets to reseal leaky breaker and bus joints.
- Tucson Electric reported a sulfur hexafluoride recycling project that reduced emissions by nearly 3.5 metric tons of sulfur hexafluoride, the equivalent of nearly 82,000 metric tons of carbon dioxide. In addition to repairing or replacing leaky equipment, Tucson Electric recovered sulfur hexafluoride during maintenance and implemented strict work practices to avoid emissions.

- GPU reported reductions of nearly 2 metric tons of sulfur hexafluoride emissions, equivalent to more than 40,000 metric tons of carbon dioxide, from maintenance and replacement of sulfur hexafluoride charged breakers.

A net increase in sulfur hexafluoride emissions of just over 3 metric tons, equivalent to 75,000 metric tons of carbon dioxide, was reported in 1996 (see figure), due in part to an increase in emissions from a reported transmission and distribution facility maintenance program.

In early 1999, the U.S. Environmental Protection Agency (EPA) launched the Sulfur Hexafluoride Partnership for Electric Power Systems, a voluntary partnership with the electric power industry to pursue technically and economically feasible activities to reduce sulfur hexafluoride emissions. EPA's main role is as a clearinghouse for technical information on successful reduction methods and a repository for data on sulfur hexafluoride emission reductions. Participants in the program receive recognition for their achievements. There were 50 charter members.

### Reported Reductions in Sulfur Hexafluoride Emissions, Data Years 1994-1997



Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

## Chlorofluorocarbons

U.S. emissions of CFCs have decreased from 202,000 metric tons in 1990 to 49,000 metric tons in 1997,<sup>64</sup> as U.S. production ceased in compliance with the Copenhagen Amendments to the Montreal Protocol and usage declined. A reflection of this decline can be seen in decreased sizes reported for projects that reduced CFCs. The Dow Chemical Company, for example, reported reductions of nearly 550 metric tons of CFCs from a refrigeration systems conversion project in 1996. By the end of that year, Dow had phased out its use of CFCs as blowing agents to manufacture foams; therefore, no reductions were reported from this project for 1997. Similarly, several refrigerator recycling and replacement programs operating in previous years have been discontinued, resulting in fewer reported CFC-12 reductions. Overall reported CFC reductions were down by 30 percent from 1996 levels in 1997.

Reported projects that reduced CFC emissions included recycling CFCs from refrigerators, chillers, coolers, and air conditioners and/or replacing CFCs with other, non-ozone-depleting substances. Dow reported reducing CFC emissions by 54 metric tons by converting existing CFC refrigerant systems to non-CFC refrigerant systems, achieving the largest reductions of CFCs among 1997 reporters. Tucson Electric Power Company installed a variety of systems to reduce or avoid emissions of CFCs from its chillers, including a refrigeration recovery system that prevents CFC emissions during repairs.

## Hydrochlorofluorocarbons

National emissions of HCFCs increased by 12 percent in 1997, as they were used increasingly to replace CFCs as solvents, as blowing agents for foams, and in refrigerator applications. According to EPA estimates, the use and emissions of HCFCs in these applications are expected to increase over the next several years before production of all HCFCs is phased out by 2030.<sup>65</sup>

In 1997, four projects reduced HCFC-22 emissions by 0.35 metric tons. HCFC-22 was the only member of the HCFC group of gases for which reported projects achieved reductions in 1997. Baltimore Gas and Electric Company and New England Electric System Company reported reductions of HCFC-22 from refrigerator recycling projects. Tennessee Valley Authority and Tucson Electric Power Company reported reductions of HCFC-22 from replacing and recycling air conditioners. The emission reductions reported for these four projects were offset, however, by projects reported by several other entities that involved net increases in HCFC emissions. The effect of all projects reported for 1997 on HCFC emissions was a net increase of 246 metric tons (Table 16).

<sup>64</sup>Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*, DOE/EIA-0573(97) (Washington, DC, October 1998), p. 61, <http://www.eia.doe.gov/oiaf/1605/1605a.html>.

<sup>65</sup>U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1996*, EPA 236-R-98-006 (Washington, DC, March 1998), Annex K, <http://www.epa.gov/globalwarming/inventory/1998-inv.html>.