5. Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

Overview

Total U.S. Emissions of Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Carbon Equivalent)	46.8
Change Compared to 1999 (Million Metric Tons Carbon Equivalent)	2.0
Change from 1999 *(Percent)*	*4.5%*
Change Compared to 1990 (Million Metric Tons Carbon Equivalent)	17.1
Change from 1990 *(Percent)*	*57.8%*

In addition to the three principal gases (carbon dioxide, methane, and nitrous oxide), there are other gases that account for 2.5 percent of U.S. greenhouse gas emissions when weighted by global warming potential (GWP) (see box on page 58). These gases are engineered chemicals that occur on a very limited basis in nature.[75] Although they are more potent greenhouse gases and tend to have comparatively high GWPs, they are emitted in such small quantities that their overall impact is currently small.

The guidelines of the Intergovernmental Panel on Climate Change (IPCC) define three classes of these gases that "count" for emissions estimation: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). This chapter describes emissions sources and gives emissions estimates for HFCs, PFCs, and SF_6.

HFCs, PFCs, and SF_6 are emitted in small quantities, but they have disproportionate effects because of their large GWPs. PFCs and SF_6 have particularly high GWPs because of their scarcity in the atmosphere and long atmospheric lifetimes. SF_6 is the most potent of the greenhouse gases, with a GWP of 22,200. PFCs have GWPs in the range of 7,000 to 9,000. HFC-23 is the most potent of the HFCs, with a GWP of 12,000.[76]

Table 29 summarizes U.S. emissions of HFCs, PFCs, and SF_6 from 1990 to 2000, and Table 30 shows the corresponding emissions in million metric tons carbon equivalent. The U.S. Environmental Protection Agency (EPA) estimates total emissions of HFCs, PFCs, and SF_6 in 2000 at 46.8 million metric tons carbon equivalent—a 4.5-percent increase over 1999 emissions and a 57.8-percent increase over 1990 emissions.[77]

In summary, emissions of HFCs and PFCs are rising, and new data for SF_6 show a decline. In the case of HFCs, the rise in emissions reflects the use of HFCs as replacements for CFCs, whose use is being phased out under the Montreal Protocol because they damage the Earth's ozone layer. CFCs had been widely used as refrigerants, aerosol propellants, and foam blowing agents for many years, but with CFC production virtually ceasing by 1996, HFCs have been introduced into the market to fill the void in many key applications. The trend in HFC emissions is expected to accelerate in the next decade as HCFCs used as interim substitutes for CFCs are also phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol.

Emissions of PFCs and perfluoropolyethers (PFPEs) have also been rising since 1990 (although not as rapidly as HFC emissions), mainly because of the recent commercial introduction of new PFCs and PFPEs both as CFC substitutes and for use in various applications in the semiconductor manufacturing industry. New data for SF_6 show an overall decline in emissions, 41.4 percent since 1990, as opposed to previous years' estimations. The change is the result of lower estimates of emissions from electrical transmissions and distribution.[78]

[75]See Chapter 1, Table 1. Naturally occurring (pre-industrial) emissions of perfluoromethane (CF_4) were 40 parts per trillion. Their concentration had doubled by 1998.

[76]Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

[77]U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa/gov/globalwarming/ (preliminary extimates, 2001). Note that EIA calculates emissions in carbon-equivalent units using the GWP values published by the IPCC in 2001 in its Third Assessment Report, whereas the EPA uses the GWP values from the IPCC's 1996 Second Assessment Report (see box on page 58).

[78]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

Among the potential replacements, HFC-245fa appears to be the strongest contender.[108]

Honeywell is building a world-scale plant in Louisiana for the production of HFC-245fa which will become fully operational by July 2002. Semi-commercial quantities of the product will be available from the plant in the third quarter of 2000.[109] Honeywell is also developing blends that combine HFC-245fa with other materials to enhance its cost/performance ratio. To date, however, the foam blowing industry has failed to signal a clear preference for HFC-245fa or other alternatives. Instead, it continues to rely primarily on HCFC-141b while waiting to see which of the possible replacement candidates emerges as the preferred alternative.[110] For some applications, non-fluorochemical alternatives (e.g., hydrocarbons) have been identified.[111]

Perfluorocarbons (PFCs)

U.S. Emissions of Perfluorocarbons, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Carbon Equivalent)	8.7
Change Compared to 1999 (Million Metric Tons Carbon Equivalent)	-0.34
Change from 1999 *(Percent)*	*-3.7%*
Change Compared to 1990 (Million Metric Tons Carbon Equivalent)	-1.5
Change from 1990 *(Percent)*	*-14.4%*

*Less than 0.05 million metric tons.

PFCs are compounds composed of carbon and fluorine. PFC emissions are not regulated, although their high GWPs (5,700 for perfluoromethane [CF_4] and 11,900 for perfluoroethane [C_2F_6])[112] have drawn attention. PFCs are also characterized by long atmospheric lifetimes (up to 50,000 years); hence, unlike HFCs, they are essentially permanent additions to the atmosphere. The EPA estimates 2000 emissions of PFCs at 8.7 million metric tons carbon equivalent, slightly lower than 1999 emissions and 14.4 percent lower than 1990 emissions (Table 30).[113]

The principal quantifiable source of PFCs is as a byproduct of aluminum smelting created by the frequency and duration of anode effects during periods of process inefficiency. The EPA estimates U.S. emissions from aluminum production at 1,096 metric tons of perfluoromethane and 90 metric tons of perfluoroethane in 2000.[114] Reductions in primary aluminum production and efficiency improvements to reduce anode effects have reduced emissions of perfluoromethane and perfluoroethane since 1990 by 55 percent and 64 percent, respectively. Many of the efficiency improvements have been achieved as a result of the EPA's Voluntary Aluminum Partnership, which was launched in 1995. According to the U.S. Geological Survey, strong demand for aluminum in manufacturing passenger cars and light trucks is expected to increase overall consumption;[115] however, domestic aluminum production declined in 2000 due to high energy costs and subsequent smelter production cutbacks.[116]

Another source of PFC emissions is semiconductor manufacturing. Perfluoromethane and perfluoroethane are used as etchants and cleaning agents in semiconductor manufacturing. The United States consumed an estimated 800 tons of perfluoroethane and perfluoromethane in 1995.[117] For 2000, the EPA estimates emissions of perfluoromethane and perfluoroethane from semiconductor manufacturing at 286 metric tons and 431 metric tons of gas, respectively.[118] Both estimates are 4.6 percent lower than the corresponding estimates for 1999 emissions. It is difficult to assess trends in PFC emissions from the semiconductor industry. On the one hand, the continued rapid expansion of the worldwide semiconductor market may lead to increased PFC use and emissions. On the other hand, industry efforts to

[108]C. Boswell, "Hydrofluorocarbons Build with Transition Away from CFCs," *Chemical Market Reporter* (September 13, 1999).

[109]Honeywell, "Honeywell Set To Commercialize Non-Ozone-Depleting HFC-245fa Blowing Agent Product," News Release (March 27, 2000), web site www.genetron.com/applications/blowingagents/pdfs/blowing_agents_march27_2000.pdf.

[110]C. Boswell, "Hydrofluorocarbons Build with Transition Away from CFCs," *Chemical Market Reporter* (September 13, 1999).

[111]J. Ouellette, "Fluorocarbon Market Is Poised To Grow," *Chemical Market Reporter* (June 19, 2000).

[112]Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), p. 389.

[113]EIA calculates emissions in carbon-equivalent units using the GWP values published by the IPCC in 2001 in its Third Assessment Report, whereas the EPA uses the GWP values from the IPCC's 1996 Second Assessment Report (see box on page 58).

[114]U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, October 2001).

[115]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

[116]U.S. Geological Survey, Mineral Commodity Summaries (January 2001), web site http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/050301.pdf.

[117]"PFCs Can Be Recycled with New Technology," American Institute of Chemical Engineers, Press Release (March 12, 1997).

[118]U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, October 2001).