

# ANNEX R

## Ozone Depleting Substance Emissions

Ozone is present in both the stratosphere,<sup>1</sup> where it shields the earth from harmful levels of ultraviolet radiation, and at lower concentrations in the troposphere,<sup>2</sup> where it is the main component of anthropogenic photochemical “smog.” Chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs), along with certain other chlorine and bromine containing compounds, have been found to deplete the ozone levels in the stratosphere. These compounds are commonly referred to as ozone depleting substances (ODSs). If left unchecked, stratospheric ozone depletion could result in a dangerous increase of ultraviolet radiation reaching the earth’s surface. In 1987, nations around the world signed the *Montreal Protocol on Substances that Deplete the Ozone Layer*. This landmark agreement created an international framework for limiting, and ultimately eliminating, the production of most ozone depleting substances. ODSs have historically been used in a variety of industrial applications, including refrigeration and air conditioning, foam blowing, fire extinguishing, as an aerosol propellant, sterilization, and solvent cleaning.

In the United States, the Clean Air Act Amendments of 1990 provide the legal instrument for implementation of the *Montreal Protocol* controls. The Clean Air Act classifies ozone depleting substances as either Class I or Class II, depending upon the ozone depletion potential (ODP) of the compound.<sup>3</sup> The production of CFCs, halons, carbon tetrachloride, and methyl chloroform—all Class I substances—has already ended in the United States. However, large amounts of these chemicals remain in existing equipment,<sup>4</sup> and stockpiles of the ODSs are used for maintaining the equipment. In addition, U.S. regulations require the recovery of ODSs in order to minimize “venting” to the atmosphere. As a result, emissions of Class I compounds will continue, albeit in ever decreasing amounts, into the early part of the next century. Class II designated substances, all of which are hydrochlorofluorocarbons (HCFCs), are being phased out at later dates because they have lower ozone depletion potentials. These compounds serve as interim replacements for Class I compounds in many industrial applications. The use and emissions of HCFCs in the United States is anticipated to increase over the next several years as equipment that use Class I substances are retired from use. Under current controls, however, the production for domestic use of all HCFCs in the United States will end by the year 2030.

In addition to contributing to ozone depletion, CFCs, halons, carbon tetrachloride, methyl chloroform, and HCFCs are also potent greenhouse gases. However, the depletion of the ozone layer has a cooling effect on the climate that counteracts the direct warming from tropospheric emissions of ODSs. Stratospheric ozone influences the earth’s radiative balance by absorption and emission of longwave radiation from the troposphere as well as absorption of shortwave radiation from the sun.

The IPCC has prepared both direct GWPs and net (combined direct warming and indirect cooling) GWP ranges for some of the most common ozone depleting substances (IPCC 1996). See Annex Q for a listing of the net GWP values for ODS.

Although the IPCC emission inventory guidelines do not require the reporting of emissions of ozone depleting substances, the United States believes that no inventory is complete without the inclusion of these compounds. Emission estimates for several ozone depleting substances are provided in Table R-1.

---

<sup>1</sup> The stratosphere is the layer from the top of the troposphere up to about 50 kilometers. Approximately 90 percent of atmospheric ozone is within the stratosphere. The greatest concentration of ozone occurs in the middle of the stratosphere, in a region commonly called the ozone layer.

<sup>2</sup> The troposphere is the layer from the ground up to about 11 kilometers near the poles and 16 kilometers in equatorial regions (i.e., the lowest layer of the atmosphere, where humans live). It contains roughly 80 percent of the mass of all gases in the atmosphere and is the site for weather processes including most of the water vapor and clouds.

<sup>3</sup> Substances with an ozone depletion potential of 0.2 or greater are designated as Class I. All other substances that may deplete stratospheric ozone but which have an ODP of less than 0.2 are Class II.

<sup>4</sup> Older refrigeration and air-conditioning equipment, fire extinguishing systems, meter-dose inhalers, and foam products blown with CFCs/HCFCs may still contain ODS.

**Table R-1: Emissions of Ozone Depleting Substances (Gg)**

Compound	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<b>Class I</b>											
CFC-11	53.5	48.3	45.1	45.4	36.6	36.2	26.6	25.1	24.9	24.0	22.8
CFC-12	112.6	103.5	80.5	79.3	57.6	51.8	35.5	23.1	21.0	14.0	17.2
CFC-113	52.7	41.1	34.2	34.2	17.1	17.1	+	+	+	+	+
CFC-114	4.7	3.6	3.0	3.0	1.6	1.6	0.3	0.1	0.1	+	+
CFC-115	4.2	4.0	3.8	3.6	3.3	3.0	3.2	2.9	2.7	2.6	2.3
Carbon Tetrachloride	32.3	+	21.7	18.6	15.5	4.7	+	+	+	+	+
Methyl Chloroform	316.6	309.4	216.6	185.7	154.7	92.8	+	+	+	+	+
Halon-1211	1.0	1.1	1.0	1.1	1.0	1.1	1.1	1.1	1.1	1.1	1.1
Halon-1301	1.8	1.8	1.7	1.7	1.4	1.4	1.4	1.3	1.3	1.3	1.3
<b>Class II</b>											
HCFC-22	34.0	35.4	35.2	35.3	37.7	39.3	41.0	42.4	43.8	74.1	79.1
HCFC-123	+	+	0.1	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.1
HCFC-124	+	+	0.2	2.7	5.3	5.6	5.9	6.2	6.4	6.5	6.5
HCFC-141b	1.3	1.7	1.7	2.9	6.2	9.9	9.9	8.8	9.7	10.9	10.9
HCFC-142b	0.8	1.4	1.9	2.6	3.3	3.6	4.0	4.3	4.7	5.0	5.4
HCFC-225ca/cb	+	+	+	+	+	+	+	+	+	+	+

+ Does not exceed 0.05 Gg

## Methodology and Data Sources

Emissions of ozone depleting substances were estimated using two simulation models: the Atmospheric and Health Effects Framework (AHEF) and the EPA's Vintaging Model. AHEF contains estimates of U.S. domestic use of each of the ozone depleting substances. These estimates were based upon data that industry reports to the EPA and other published material. The annual consumption of each compound was divided into various end-uses based upon historical trends and research into specific industrial applications. These end-uses include refrigerants, foam blowing agents, solvents, aerosol propellants, sterilants, and fire extinguishing agents.

With the exception of aerosols, solvents, and certain foam blowing agents, emissions of ozone depleting substances are not instantaneous, but instead occur gradually over time (i.e., emissions in a given year are the result of both ODS use in that year and use in previous years). Each end-use has a certain release profile, which gives the percentage of the compound that is released to the atmosphere each year until all releases have occurred. In refrigeration equipment, for example, the initial charge is released or leaked slowly over the lifetime of the equipment, which could be 20 or more years. In addition, not all of the refrigerant is ultimately emitted—some will be recovered when the equipment is retired from operation.

The AHEF model was used to estimate emissions of ODSs that were in use prior to the controls implemented under the *Montreal Protocol*. This included CFCs, halons, carbon tetrachloride, methyl chloroform, and HCFC-22. Certain HCFCs, such as HCFC-123, HCFC-124, HCFC-141b, HCFC-142b, HCFC-225ca and HCFC-225cb, have also entered the market as interim substitutes for ODSs. Emissions estimates for these compounds were taken from the EPA's Vintaging Model.

The Vintaging Model was used to estimate the use and emissions of various ODS substitutes, including HCFCs. The model, named for its method of tracking the emissions of annual "vintages" of new equipment that enter into service, is a "bottom-up" model. It models the consumption of chemicals based on estimates of the quantity of equipment or products sold, serviced, and retired each year, and the amount of the chemical required to manufacture and/or maintain the equipment. The Vintaging model makes use of this market information to build an inventory of the in-use stocks of the equipment in each of the end-uses. Emissions are estimated by applying annual leak rates, service emission rates, and disposal emission rates to each population of equipment, as in the AHEF. By aggregating the emission and consumption output from the different end-uses, the model produces estimates of total annual use and emissions of each chemical. Please see Annex J of this Inventory for a more detailed discussion of the Vintaging Model.

## Uncertainties

Uncertainties exist with regard to the levels of chemical production, equipment sales, equipment characteristics, and end-use emissions profiles that are used by these models.