ANNEX 6 Additional Information

6.1. Global Warming Potential Values

Global Warming Potentials (GWPs) are intended as a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing—both direct and indirect effects—integrated over a period of time from the emission of a unit mass of gas relative to some reference gas (IPCC 1996). Carbon dioxide (CO_2) was chosen as this reference gas. Direct effects occur when the gas itself is a greenhouse gas. Indirect radiative forcing occurs when chemical transformations involving the original gas produce a gas or gases that are greenhouse gases, or when a gas influences other radiatively important processes such as the atmospheric lifetimes of other gases. The relationship between gigagrams (Gg) of a gas and teragrams of CO_2 equivalents (Tg CO_2 Eq.) can be expressed as follows:

$$\text{Tg}\,CO_2\ \text{Eq.} = (\text{Gg of gas}) \times (\text{GWP}) \times \left(\frac{\text{Tg}}{1{,}000\,\text{Gg}}\right)$$

Where,

Tg CO_2 Eq.	=	Teragrams of Carbon Dioxide Equivalents
Gg	=	Gigagrams (equivalent to a thousand metric tons)
GWP	=	Global Warming Potential
Tg	=	Teragrams

GWP values allow policy makers to compare the impacts of emissions and reductions of different gases. According to the IPCC, GWPs typically have an uncertainty of ±35 percent, though some GWPs have larger uncertainty than others, especially those in which lifetimes have not yet been ascertained. In the following decision, the parties to the UNFCCC have agreed to use consistent GWPs from the IPCC Second Assessment Report (SAR), based upon a 100 year time horizon, although other time horizon values are available (see Table A-266).

> *In addition to communicating emissions in units of mass, Parties may choose also to use global warming potentials (GWPs) to reflect their inventories and projections in carbon dioxide-equivalent terms, using information provided by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report. Any use of GWPs should be based on the effects of the greenhouse gases over a 100-year time horizon. In addition, Parties may also use other time horizons.*[99]

Greenhouse gases with relatively long atmospheric lifetimes (e.g., CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined. However, the short-lived gases such as water vapor, carbon monoxide, tropospheric ozone, other indirect greenhouse gases (e.g., NO_x and NMVOCs), and tropospheric aerosols (e.g., SO_2 products and black carbon) vary spatially, and consequently it is difficult to quantify their global radiative forcing impacts. GWP values are generally not attributed to these gases that are short-lived and spatially inhomogeneous in the atmosphere.

Table A-266: Global Warming Potentials (GWP) and Atmospheric Lifetimes (Years) of Gases Used in this Report

Gas	Atmospheric Lifetime	100-year GWP[a]	20-year GWP	500-year GWP
Carbon dioxide (CO_2)	50-200	1	1	1
Methane (CH_4)[b]	12±3	21	56	6.5
Nitrous oxide (N_2O)	120	310	280	170
HFC-23	264	11,700	9,100	9,800
HFC-32	5.6	650	2,100	200
HFC-125	32.6	2,800	4,600	920

[99] Framework Convention on Climate Change; FCCC/CP/1996/15/Add.1; 29 October 1996; Report of the Conference of the Parties at its second session; held at Geneva from 8 to 19 July 1996; Addendum; Part Two: Action taken by the Conference of the Parties at its second session; Decision 9/CP.2; Communications from Parties included in Annex I to the Convention: guidelines, schedule and process for consideration; Annex: Revised Guidelines for the Preparation of National Communications by Parties Included in Annex I to the Convention; p. 18. FCCC (1996)

HFC-134a	14.6	1,300	3,400	420
HFC-143a	48.3	3,800	5,000	1,400
HFC-152a	1.5	140	460	42
HFC-227ea	36.5	2,900	4,300	950
HFC-236fa	209	6,300	5,100	4,700
HFC-43-10mee	17.1	1,300	3,000	400
CF_4	50,000	6,500	4,400	10,000
C_2F_6	10,000	9,200	6,200	14,000
C_3F_8	2,600	7,000	4,800	10,100
C_4F_{10}	2,600	7,000	4,800	10,100
c-C_4F_8	3,200	8,700	6,000	12,700
C_5F_{12}	4,100	7,500	5,100	11,000
C_6F_{14}	3,200	7,400	5,000	10,700
SF_6	3,200	23,900	16,300	34,900

Source: IPCC (1996)

[a] GWPs used in this report are calculated over 100 year time horizon.

[b] The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Table A-267 presents direct and net (i.e., direct and indirect) GWPs for ozone-depleting substances (ODSs). Ozone-depleting substances directly absorb infrared radiation and contribute to positive radiative forcing; however, their effect as ozone-depleters also leads to a negative radiative forcing because ozone itself is a potent greenhouse gas. There is considerable uncertainty regarding this indirect effect; therefore, a range of net GWPs is provided for ozone depleting substances. The IPCC Guidelines and the UNFCCC do not include reporting instructions for estimating emissions of ODSs because their use is being phased-out under the Montreal Protocol (see note below Table A-267). The effects of these compounds on radiative forcing are not addressed in this report

Table A-267: Net 100-year Global Warming Potentials for Select Ozone Depleting Substances

Gas	Direct	Net_{min}	Net_{max}
CFC-11	4,600	(600)	3,600
CFC-12	10,600	7,300	9,900
CFC-113	6,000	2,200	5,200
HCFC-22	1,700	1,400	1,700
HCFC-123	120	20	100
HCFC-124	620	480	590
HCFC-141b	700	(5)	570
HCFC-142b	2,400	1,900	2,300
$CHCl_3$	140	(560)	0
CCl_4	1,800	(3,900)	660
CH_3Br	5	(2,600)	(500)
Halon-1211	1,300	(24,000)	(3,600)
Halon-1301	6,900	(76,000)	(9,300)

Source: IPCC (2001)

Parentheses indicate negative values.

Note: Because these compounds have been shown to deplete stratospheric ozone, they are typically referred to as ozone depleting substances (ODSs). However, they are also potent greenhouse gases. Recognizing the harmful effects of these compounds on the ozone layer, in 1987 many governments signed the Montreal Protocol on Substances that Deplete the Ozone Layer to limit the production and importation of a number of CFCs and other halogenated compounds. The United States furthered its commitment to phase-out ODSs by signing and ratifying the Copenhagen Amendments to the Montreal Protocol in 1992. Under these amendments, the United States committed to ending the production and importation of halons by 1994, and CFCs by 1996.

The IPCC has published its Fourth Assessment Report (AR4), providing the most current and comprehensive scientific assessment of climate change (IPCC 2007). Within this report, the GWPs of several gases were revised relative to the SAR and the IPCC's Third Assessment Report (TAR) (IPCC 2001). Thus the GWPs used in this report have been updated twice by the IPCC; although the SAR GWPs are used throughout this report, it is informative to review the changes to the GWPs and the impact such improved understanding has on the total GWP-weighted emissions of the United States. All GWPs use CO_2 as a reference gas; a change in the radiative efficiency of CO_2 thus impacts the GWP of all other greenhouse gases. Since the SAR and TAR, the IPCC has applied an improved calculation of CO_2 radiative forcing and an improved CO_2 response function. The GWPs are drawn from IPCC/TEAP (2005) and the TAR, with updates for those cases where new laboratory or radiative transfer results have been published. Additionally, the atmospheric lifetimes of some gases have been recalculated. Because the revised radiative forcing of CO_2 is about 8 percent lower than that in the TAR, the GWPs of the other gases relative to CO_2 tend to be larger, taking into account

revisions in lifetimes. However, there were some instances in which other variables, such as the radiative efficiency or the chemical lifetime, were altered that resulted in further increases or decreases in particular GWP values. In addition, the values for radiative forcing and lifetimes have been calculated for a variety of halocarbons, which were not presented in the SAR. Updates in some well-mixed HFC compounds (including HFC-23, HFC-32, HFC-134a, and HFC-227ea) for AR4 result from investigation into radiative efficiencies in these compounds, with some GWPs changing by up to 40 percent; with this change, the uncertainties associated with these well-mixed HFCs are thought to be approximately 12 percent.

Table A- 268: Comparison of GWPs and Lifetimes Used in the SAR, TAR, and AR4

	Lifetime (years)			GWP (100 year)			Difference (relative to SAR)			
Gas	**SAR**	**TAR**	**AR4**	**SAR**	**TAR**	**AR4**	**TAR**	**TAR (%)**	**AR4**	**AR4 (%)**
Carbon dioxide (CO_2)	50-200	5-200[a]	5-200[a]	1	1	1	NC	NC	NC	NC
Methane (CH_4)[b]	12±3	8.4/12[c]	8.7/12[c]	21	23	25	2	10%	4	19%
Nitrous oxide (N_2O)	120	120/114 [c]	120/114 [c]	310	296	298	(14)	(5%)	(12)	(4%)
Hydrofluorocarbons										
HFC-23	264	260	270	11,700	12,000	14,800	300	3%	3,100	26%
HFC-32	5.6	5.0	4.9	650	550	675	(100)	(15%)	25	4%
HFC-125	32.6	29	29	2,800	3,400	3,500	600	21%	700	25%
HFC-134a	14.6	13.8	14	1,300	1,300	1,430	NC	NC	130	10%
HFC-143a	48.3	52	52	3,800	4,300	4,470	500	13%	670	18%
HFC-152a	1.5	1.4	1.4	140	120	124	(20)	(14%)	(16)	(11%)
HFC-227ea	36.5	33.0	34.2	2,900	3,500	3,220	600	21%	320	11%
HFC-236fa	209	220	240	6,300	9,400	9,810	3,100	49%	3,510	56%
HFC-245fa	NA	7.2	7.6	NA	950	1,030	NA	NA	NA	NA
HFC-365mfc	NA	9.9	6.6	NA	890	794	NA	NA	NA	NA
HFC-43-10mee	17.1	15	15.9	1,300	1,500	1,640	200	15%	340	26%
Fully Fluorinated Species										
SF_6	3,200	3,200	3,200	23,900	22,200	22,800	(1,700)	(7%)	(1,100)	(5%)
CF_4	50,000	50,000	50,000	6,500	5,700	7,390	(800)	(12%)	890	14%
C_2F_6	10,000	10,000	10,000	9,200	11,900	12,200	2,700	29%	3,000	33%
C_3F_8	2,600	2,600	2,600	7,000	8,600	8,830	1,600	23%	1,830	26%
C_4F_{10}	2,600	2,600	2,600	7,000	8,600	8,860	1,600	23%	1,860	27%
c-C_4F_8	3,200	3,200	3,200	8,700	10,000	10,300	1,300	15%	1,600	18%
C_5F_{12}	4,100	4,100	4,100	7,500	8,900	9,160	1,400	19%	1,660	22%
C_6F_{14}	3,200	3,200	3,200	7,400	9,000	9,300	1,600	22%	1,900	26%
Others[d]										
NF_3	NA	740	740	NA	10,800	17,200	NA	NA	NA	NA

NC (No Change)
NA (Not Applicable)
[a] No single lifetime can be determined for CO_2. (See IPCC 2001)
[b] The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.
[c] Methane and nitrous oxide have chemical feedback systems that can alter the length of the atmospheric response, in these cases, global mean atmospheric lifetime (LT) is given first, followed by perturbation time (PT).
[d] Gases whose lifetime has been determined only via indirect means or for whom there is uncertainty over the loss process.
Note: Parentheses indicate negative values.
Source: IPCC (2001)

The choice of GWPs between the SAR, TAR, and AR4 has an impact on both the overall emissions estimated by the inventory, as well as the trend in emissions over time. To summarize, Table A-269 shows the overall trend in U.S. greenhouse gas emissions, by gas, from 1990 through 2011 using the three GWP sets. The table also presents the impact of TAR and AR4 GWPs on the total emissions for 1990 and for 2011.

Table A-269: Effects on U.S. Greenhouse Gas Emissions Using TAR, SAR, and AR4 GWPs (Tg CO_2 Eq.)

Gas	Trend from 1990 to 2011			Revisions to Annual Estimates (relative to SAR)			
				TAR	AR4	TAR	AR4
	SAR	TAR	AR4	1990		2011	
CO_2	504.0	504.0	504.0	NC	NC	NC	NC
CH_4	(52.7)	(57.7)	(62.7)	60.9	121.9	55.9	111.9
N_2O	12.6	12.0	12.1	(15.6)	(13.3)	(16.1)	(13.8)
HFCs, PFCs, and SF_6*	55.1	60.6	59.1	(2.2)	11.8	3.3	15.7
Total	**519.1**	**519.0**	**512.4**	**43.2**	**120.4**	**43.1**	**113.8**
Percent Change	**8%**	**8%**	**8%**	**0.7%**	**1.9%**	**0.6%**	**1.7%**

NC (No Change)
*Includes NF_3
Note: Totals may not sum due to independent rounding. Excludes sinks. Parentheses indicate negative values.

When the GWPs from the AR4 are applied to the emission estimates presented in this report, total emissions for the year 2011 are 6,816.1 Tg CO_2 Eq., as compared to 6,702.3 Tg CO_2 Eq. when the GWPs from the SAR are used (a 1.7 percent difference). Table A-270 provides a detailed summary of U.S. greenhouse gas emissions and sinks for 1990 through 2011, using the GWPs from the AR4. The percent change in emissions is equal to the percent change in the GWP; however, in cases where multiple gases are emitted in varying amounts the percent change is variable over the years, such as with substitutes for ozone depleting substances. Table A-271 summarizes the resulting change in emissions from SAR to AR4 GWPs for 1990 through 2011 including the percent change for 2011.

Table A-270: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks using the AR4 GWPs (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010	2011
CO_2	**5,108.8**	**6,109.3**	**6,032.9**	**6,128.6**	**5,944.8**	**5,517.9**	**5,736.4**	**5,612.9**
Fossil Fuel Combustion	4,748.5	5,748.7	5,665.8	5,767.7	5,590.6	5,222.4	5,408.1	5,277.2
Electricity Generation	1,820.8	2,402.1	2,346.4	2,412.8	2,360.9	2,146.4	2,259.2	2,158.5
Transportation	1,494.0	1,891.7	1,890.9	1,904.7	1,816.0	1,749.2	1,763.9	1,745.0
Industrial	848.6	823.4	848.1	844.4	802.0	722.6	780.2	773.2
Residential	338.3	357.9	321.5	341.6	347.0	337.0	334.6	328.8
Commercial	219.0	223.5	208.6	218.9	223.8	223.4	220.6	222.1
U.S. Territories	27.9	50.0	50.3	45.2	41.0	43.8	49.6	49.7
Non-Energy Use of Fuels	117.4	142.7	144.9	134.9	139.5	124.0	132.8	130.6
Iron and Steel Production & Metallurgical Coke Production	99.8	66.7	69.4	71.3	66.8	43.0	55.7	64.3
Natural Gas Systems	37.7	29.9	30.0	30.9	32.6	32.2	32.3	32.3
Cement Production	33.3	45.2	45.8	44.5	40.5	29.0	30.9	31.6
Lime Production	11.5	14.3	15.0	14.6	14.3	11.2	13.1	13.8
Incineration of Waste	8.0	12.5	12.5	12.7	11.9	11.7	12.0	12.0
Limestone and Dolomite Use	4.9	6.3	7.3	7.4	5.9	7.6	9.6	9.2
Ammonia Production	13.0	9.2	8.8	9.1	7.9	7.9	8.7	8.8
Cropland Remaining Cropland	7.1	7.9	7.9	8.2	8.6	7.2	8.4	8.1
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	3.5	4.9	4.1	3.4	4.4	4.3
Petrochemical Production	3.4	4.3	4.0	4.1	3.6	2.8	3.5	3.5
Aluminum Production	6.8	4.1	3.8	4.3	4.5	3.0	2.7	3.3
Soda Ash Production and Consumption	2.8	3.0	2.9	2.9	3.0	2.6	2.7	2.7
Titanium Dioxide Production	1.2	1.8	1.8	1.9	1.8	1.6	1.8	1.9
Carbon Dioxide Consumption	1.4	1.3	1.7	1.9	1.8	1.8	2.2	1.8
Ferroalloy Production	2.2	1.4	1.5	1.6	1.6	1.5	1.7	1.7
Glass Production	1.5	1.9	2.1	1.5	1.5	1.0	1.5	1.3
Zinc Production	0.6	1.0	1.0	1.0	1.2	0.9	1.2	1.3
Phosphoric Acid Production	1.5	1.3	1.2	1.2	1.1	1.0	1.1	1.2
Wetlands Remaining Wetlands	1.0	1.1	0.9	1.0	1.0	1.1	1.0	0.9
Lead Production	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.1	0.2	0.2

Land Use, Land-Use Change, and Forestry (Sink)[a]	*(794.5)*	*(997.8)*	*(961.8)*	*(929.2)*	*(902.6)*	*(882.6)*	*(888.8)*	*(905.0)*
Wood Biomass and Ethanol Consumption[b]	*218.6*	*228.7*	*232.7*	*238.3*	*251.7*	*245.1*	*264.5*	*264.5*
International Bunker Fuels[c]	*103.5*	*113.1*	*114.1*	*115.3*	*114.3*	*106.4*	*117.0*	*111.3*
CH_4	**761.8**	**706.7**	**731.9**	**736.5**	**736.6**	**718.8**	**705.6**	**699.1**
Natural Gas Systems	192.0	189.3	200.7	200.5	194.6	179.5	171.0	172.3
Enteric Fermentation	158.0	163.0	165.8	168.8	168.3	167.3	165.8	163.5
Landfills	175.9	133.9	132.8	132.8	135.2	134.9	127.1	122.7
Coal Mining	100.1	67.7	69.3	68.9	79.9	83.7	86.2	75.3
Manure Management	37.5	56.6	57.2	62.3	61.3	60.1	61.7	62.0
Petroleum Systems	41.9	34.8	34.7	35.5	35.8	36.4	36.7	37.5
Wastewater Treatment	19.0	19.6	19.8	19.8	19.8	19.6	19.5	19.2
Forest Land Remaining Forest Land	3.0	9.6	21.1	17.1	10.3	6.8	5.6	16.9
Rice Cultivation	8.5	8.2	7.0	7.4	8.6	8.7	10.2	7.9
Stationary Combustion	8.9	7.9	7.3	7.6	7.8	7.4	7.5	7.5
Abandoned Underground Coal Mines	7.2	6.6	6.5	6.3	6.3	6.1	5.9	5.8
Petrochemical Production	2.7	3.7	3.8	3.9	3.4	3.4	3.7	3.7
Mobile Combustion	5.5	2.8	2.7	2.5	2.3	2.2	2.1	2.1
Composting	0.4	1.9	1.9	2.0	2.0	1.9	1.8	1.8
Iron and Steel Production & Metallurgical Coke Production	1.1	0.9	0.9	0.8	0.8	0.4	0.6	0.7
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2
Ferroalloy Production	+	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**331.0**	**342.3**	**354.5**	**361.5**	**336.2**	**325.6**	**330.6**	**343.1**
Agricultural Soil Management	219.1	228.3	233.8	242.5	235.9	233.4	235.0	237.6
Stationary Combustion	11.8	19.8	19.9	20.3	20.3	19.9	21.7	21.1
Mobile Combustion	42.3	35.5	32.5	27.9	24.5	21.8	19.9	17.8
Manure Management	13.8	16.4	17.2	17.3	17.1	17.0	17.1	17.3
Nitric Acid Production	17.5	16.3	15.9	19.0	16.2	13.5	16.1	14.9
Forest Land Remaining Forest Land	2.0	6.7	14.2	11.6	7.1	4.8	4.0	11.5
Adipic Acid Production	15.2	7.1	8.6	10.3	2.5	2.7	4.2	10.2
Wastewater Treatment	3.3	4.5	4.6	4.6	4.7	4.8	4.9	5.0
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	1.7	1.8	1.8	1.7	1.6	1.6
Settlements Remaining Settlements	0.9	1.4	1.4	1.5	1.4	1.3	1.4	1.4
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*1.0*	*1.0*	*0.9*	*1.0*	*1.0*
HFCs	**46.6**	**127.7**	**128.5**	**133.5**	**130.2**	**123.0**	**134.0**	**143.0**
Substitution of Ozone Depleting Substances[d]	0.3	107.4	110.6	111.6	112.6	115.9	125.5	133.7
HCFC-22 Production	46.1	20.0	17.5	21.5	17.2	6.8	8.0	8.8
Semiconductor Manufacture	0.2	0.3	0.3	0.4	0.4	0.3	0.5	0.4
PFCs	**24.3**	**7.9**	**8.0**	**9.8**	**8.6**	**6.0**	**7.8**	**9.2**
Semiconductor Manufacture	2.9	4.5	5.1	5.3	5.5	4.2	5.9	5.7
Aluminum Production	21.5	3.4	2.9	4.5	3.2	1.9	1.9	3.5
SF_6	**31.1**	**14.3**	**13.1**	**11.7**	**10.9**	**9.4**	**9.6**	**8.9**
Electrical Transmission and Distribution	25.4	10.6	9.4	8.4	8.2	7.7	7.4	6.7

Magnesium Production and Processing	5.2	2.8	2.7	2.5	1.8	1.0	1.2	1.3
Semiconductor Manufacture	0.5	0.9	0.9	0.8	0.8	0.7	1.0	0.9
Total	**6,303.6**	**7,308.4**	**7,268.8**	**7,381.5**	**7,167.3**	**6,700.7**	**6,924.0**	**6,816.1**

+ Does not exceed 0.05 Tg CO_2 Eq.
[a] The net CO2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Parentheses indicate negative values or sequestration.
[b] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals.
[c] Emissions from International Bunker Fuels are not included in totals.
[d] Small amounts of PFC emissions also result from this source.
Note: Totals may not sum due to independent rounding. Parentheses indicate negative values.

Table A-271: Change in U.S. Greenhouse Gas Emissions and Sinks Using SAR vs. AR4 GWPs (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010	2011	Percent Change in 2011
CO_2	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**
CH_4	**121.9**	**113.1**	**117.1**	**117.8**	**117.9**	**115.0**	**112.9**	**111.9**	**19%**
Natural Gas Systems	30.7	30.3	32.1	32.1	31.1	28.7	27.4	27.6	19%
Enteric Fermentation	25.3	26.1	26.5	27.0	26.9	26.8	26.5	26.2	19%
Landfills	28.1	21.4	21.2	21.3	21.6	21.6	20.3	19.6	19%
Coal Mining	16.0	10.8	11.1	11.0	12.8	13.4	13.8	12.0	19%
Manure Management	6.0	9.1	9.2	10.0	9.8	9.6	9.9	9.9	19%
Petroleum Systems	6.7	5.6	5.6	5.7	5.7	5.8	5.9	6.0	19%
Wastewater Treatment	3.0	3.1	3.2	3.2	3.2	3.1	3.1	3.1	19%
Forest Land Remaining Forest Land	0.5	1.5	3.4	2.7	1.7	1.1	0.9	2.7	19%
Rice Cultivation	1.4	1.3	1.1	1.2	1.4	1.4	1.6	1.3	19%
Stationary Combustion	1.4	1.3	1.2	1.2	1.3	1.2	1.2	1.2	19%
Abandoned Underground Coal Mines	1.2	1.1	1.0	1.0	1.0	1.0	0.9	0.9	19%
Petrochemical Production	0.4	0.6	0.6	0.6	0.5	0.6	0.6	0.6	19%
Mobile Combustion	0.9	0.5	0.4	0.4	0.4	0.4	0.3	0.3	19%
Composting	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	19%
Iron and Steel Production & Metallurgical Coke Production	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	19%
Field Burning of Agricultural Residues	+	+	+	+	+	+	+	+	19%
Ferroalloy Production	+	+	+	+	+	+	+	+	19%
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+	+	19%
Incineration of Waste	+	+	+	+	+	+	+	+	19%
International Bunker Fuels[a]	+	+	+	+	+	+	+	+	*19%*
N_2O	**(13.3)**	**(13.8)**	**(14.3)**	**(14.6)**	**(13.5)**	**(13.1)**	**(13.3)**	**(13.8)**	**(4%)**
Agricultural Soil Management	(8.8)	(9.2)	(9.4)	(9.8)	(9.5)	(9.4)	(9.5)	(9.6)	(4%)
Stationary Combustion	(0.5)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.9)	(0.9)	(4%)
Mobile Combustion	(1.7)	(1.4)	(1.3)	(1.1)	(1.0)	(0.9)	(0.8)	(0.7)	(4%)
Manure Management	(0.6)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(4%)
Nitric Acid Production	(0.7)	(0.7)	(0.6)	(0.8)	(0.7)	(0.5)	(0.6)	(0.6)	(4%)
Forest Land Remaining Forest Land	(0.1)	(0.3)	(0.6)	(0.5)	(0.3)	(0.2)	(0.2)	(0.5)	(4%)
Adipic Acid Production	(0.6)	(0.3)	(0.3)	(0.4)	(0.1)	(0.1)	(0.2)	(0.4)	(4%)
Wastewater Treatment	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(4%)
N_2O from Product Uses	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(4%)
Composting	(0.0)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(4%)
Settlements Remaining Settlements	(0.0)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(4%)
Incineration of Waste	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(4%)
Field Burning of Agricultural Residues	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(4%)

Wetlands Remaining Wetlands	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(4%)
International Bunker Fuels[a]	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	*(4%)*
HFCs	**9.7**	**12.7**	**12.5**	**13.5**	**12.7**	**11.0**	**12.7**	**14.0**	**11%**
Substitution of Ozone Depleting Substances	(0.0)	8.5	8.8	8.9	9.1	9.6	10.9	12.1	10%
HCFC-22 Production	9.7	4.2	3.7	4.5	3.6	1.4	1.7	1.8	26%
Semiconductor Manufacture	0.045	0.1	0.1	0.1	0.1	0.1	0.1	0.1	26%
PFCs	**3.7**	**1.8**	**2.0**	**2.2**	**2.0**	**1.6**	**1.9**	**2.2**	**31%**
Semiconductor Manufacture	0.6	1.3	1.6	1.5	1.6	1.3	1.6	1.7	41%
Aluminum Production	3.0	0.5	0.4	0.6	0.5	0.3	0.3	0.5	18%
SF_6	**(1.5)**	**(0.7)**	**(0.6)**	**(0.6)**	**(0.5)**	**(0.5)**	**(0.5)**	**(0.4)**	**(5%)**
Electrical Transmission and Distribution	(1.2)	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(0.4)	(0.3)	(5%)
Magnesium Production and Processing	(0.3)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)	(0.1)	(0.1)	(5%)
Semiconductor Manufacture	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(5%)
Total	**120.4**	**113.1**	**116.7**	**118.3**	**118.6**	**114.1**	**113.7**	**113.8**	**1.7%**

NC (No change)
+ Does not exceed 0.05 Tg CO_2 Eq.
[a] Emissions from International Bunker Fuels are not included in totals.
Note: Totals may not sum due to independent rounding. Parentheses indicate negative values.

Table A-272 below shows a comparison of total emissions estimates by sector using both the IPCC SAR and AR4 GWP values. For most sectors, the change in emissions was minimal. The effect on emissions from waste was by far the greatest (17.8 percent in 2011), due the predominance of CH_4 emissions in this sector. Emissions from all other sectors were comprised of mainly CO_2 or a mix of gases, which moderated the effect of the changes.

Table A-272: Comparison of Emissions by Sector using IPCC SAR and AR4 GWP Values (Tg CO_2 Eq.)

Sector	1990	2005	2006	2007	2008	2009	2010	2011
Energy								
SAR GWP (Used in Inventory)	5,267.3	6,251.6	6,178.3	6,266.9	6,096.2	5,699.2	5,889.1	5,745.7
AR4 GWP, Updated	5,322.0	6,298.8	6,227.6	6,316.4	6,146.7	5,747.9	5,936.9	5,792.2
Difference (%)	1.0%	0.8%	0.8%	0.8%	0.8%	0.9%	0.8%	0.8%
Industrial Processes								
SAR GWP (Used in Inventory)	316.1	330.8	335.7	347.2	318.7	265.3	303.4	326.5
AR4 GWP, Updated	327.3	344.4	349.3	361.9	332.9	277.5	317.4	341.9
Difference (%)	3.5%	4.1%	4.1%	4.2%	4.4%	4.6%	4.6%	4.7%
Solvent and Other Product Use								
SAR GWP (Used in Inventory)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
AR4 GWP, Updated	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Difference (%)	-3.9%	-3.9%	-3.9%	-3.9%	-3.9%	-3.9%	-3.9%	-3.9%
Agriculture								
SAR GWP (Used in Inventory)	413.9	446.2	454.6	470.9	463.6	459.2	462.3	461.5
AR4 GWP, Updated	437.2	472.8	481.4	498.6	491.5	486.9	490.2	488.6
Difference (%)	5.6%	6.0%	5.9%	5.9%	6.0%	6.0%	6.0%	5.9%
Land Use, Land-Use Change, and Forestry								
SAR GWP (Used in Inventory)	(780.8)	(972.5)	(919.0)	(892.0)	(875.4)	(862.2)	(869.1)	(868.4)
AR4 GWP, Updated	(780.5)	(971.3)	(916.3)	(889.7)	(874.1)	(861.3)	(868.4)	(866.2)
Difference (%)	0.0%	-0.1%	-0.3%	-0.2%	-0.1%	-0.1%	-0.1%	-0.3%
Waste								
SAR GWP (Used in Inventory)	167.8	136.9	136.3	136.5	138.6	138.1	131.4	127.7
AR4 GWP, Updated	198.9	161.6	160.8	161.0	163.5	162.9	154.9	150.4
Difference (%)	18.5%	18.0%	18.0%	17.9%	17.9%	17.9%	17.9%	17.8%
Net Emissions (Sources and Sinks)								
SAR GWP (Used in Inventory)	**5,388.7**	**6,197.4**	**6,190.3**	**6,334.0**	**6,146.2**	**5,704.0**	**5,921.5**	**5,797.3**
AR4 GWP	**5,509.1**	**6,310.5**	**6,307.0**	**6,452.3**	**6,264.7**	**5,818.1**	**6,035.2**	**5,911.1**
Difference (%)	**2.2%**	**1.8%**	**1.9%**	**1.9%**	**1.9%**	**2.0%**	**1.9%**	**2.0%**

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values.

Overall, these revisions to GWP values do not have a significant effect on U.S. emission trends, as shown in Table A-273 and Table A-274.

Table A-273: Change in U.S. Greenhouse Gas Emissions and Sinks Using TAR vs. AR4 GWPs (Tg CO_2 Eq.)

Gas	1990	2005	2006	2007	2008	2009	2010	2011
CO_2	NC	NC	NC	NC	NC	NC	NC	NC
CH_4	60.9	56.5	58.6	58.9	58.9	57.5	56.4	55.9
N_2O	2.2	2.3	2.4	2.4	2.3	2.2	2.2	2.3
HFCs	8.8	12.2	11.9	12.6	11.7	9.7	10.4	10.9
PFCs*	4.4	1.2	1.2	1.5	1.2	0.9	1.0	1.4
SF_6	0.8	0.4	0.3	0.3	0.3	0.2	0.3	0.2
Total	**77.2**	**72.6**	**74.4**	**75.7**	**74.4**	**70.5**	**70.3**	**70.7**

NC (No change)
*Includes NF_3
Note: Totals may not sum due to independent rounding.

Table A-274: Change in U.S. Greenhouse Gas Emissions Using TAR vs. AR4 GWPs (Percent)

Gas/Source	1990	2005	2006	2007	2008	2009	2010	2011
CO_2	NC	NC	NC	NC	NC	NC	NC	NC
CH_4	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%
N_2O	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
HFCs	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Substitution of Ozone Depleting Substances	23.2%	10.6%	10.2%	10.4%	9.8%	8.5%	8.4%	8.2%
HCFC-22 Production[b]	3.3%	8.5%	8.4%	8.2%	8.0%	7.8%	7.5%	7.3%
Semiconductor Manufacture[c]	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%
PFCs	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%	23.3%
Semiconductor Manufacture[c]	22.4%	17.7%	17.6%	17.7%	16.9%	17.5%	15.3%	17.6%
Aluminum Production[a]	10.0%	13.1%	14.2%	13.2%	13.6%	15.3%	13.5%	15.0%
SF_6	24.2%	24.4%	24.2%	23.4%	22.9%	22.8%	21.5%	22.1%
Total	**1.2%**	**1.6%**	**1.6%**	**1.6%**	**1.7%**	**1.7%**	**1.7%**	**1.7%**

NC (No change)
[a] PFC emissions from CF_4 and C_2F_6
[b] HFC-23 emitted
[c] Emissions from HFC-23, CF_4, C_2F_6, C_3F_8, SF_6, and the addition of NF_3
Note: Excludes Sinks.

References

IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon , D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press. Cambridge, United Kingdom 996 pp.

IPCC (2001) Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change, J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, C.A. Johnson, and K. Maskell (eds.). Cambridge University Press. Cambridge, United Kingdom.

6.2. Ozone Depleting Substance Emissions

Ozone is present in both the stratosphere,[100] where it shields the earth from harmful levels of ultraviolet radiation, and at lower concentrations in the troposphere,[101] 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, sterilization, solvent cleaning, and as an aerosol propellant.

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.[102] 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,[103] and stockpiles of the ODSs, as well as material recovered from equipment being decommissioned, are used for maintaining the existing equipment. As a result, emissions of Class I compounds will continue, albeit in ever decreasing amounts, for many more years. Class II designated substances, all of which are HCFCs, have been, or are being, phased out at later dates than Class I compounds because they have lower ozone depletion potentials. These compounds served, and in some cases continue to 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 continue for several decades as equipment that use Class I substances and Class II 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; overall, stratospheric ozone has a warming effect.

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 6.1, Global Warming Potential Values, 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 A- 275.

Table A- 275: Emissions of Ozone Depleting Substances (Gg)

Compound	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Class I														
CFC-11	29.0	12.1	12.7	12.7	12.6	12.7	12.4	12.2	12.2	11.1	9.9	8.6	8.3	7.8
CFC-12	108.7	65.9	32.9	26.8	21.7	17.2	12.9	9.0	6.4	5.9	4.9	4.0	3.6	3.1

[100] 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.

[101] 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.

[102] Substances with an ozone depletion potential of 0.2 or greater are designated as Class I. All other designated substances that deplete stratospheric ozone but which have an ODP of less than 0.2 are Class II.

[103] Older refrigeration and air-conditioning equipment, fire extinguishing systems, meter-dose inhalers, and foam products blown with CFCs/HCFCs may still contain ODS.

CFC-113	59.4		11.5		+	+	+	+	+	+	+	+	+	+	+	+
CFC-114	5.4		1.1		+	+	+	+	+	+	+	+	+	+	+	+
CFC-115	8.9		6.8		4.2	3.8	3.4	3.0	2.6	2.1	1.6	1.1	0.7	+	+	+
Carbon Tetrachloride	4.3		0.9		+	+	+	+	+	+	+	+	+	+	+	+
Methyl Chloroform	222.5		72.1		+	+	+	+	+	+	+	+	+	+	+	+
Halon-1211	1.6		1.6		1.1	0.9	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Halon-1301	1.6		1.6		1.5	1.5	1.5	1.5	1.5	1.4	1.3	1.1	0.9	0.8	0.7	0.6
Class II																
HCFC-22	49.3		57.2		72.0	74.6	77.6	79.2	81.4	82.2	84.6	85.6	87.3	87.7	84.2	83.0
HCFC-123	+		0.3		0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
HCFC-124	+		1.3		1.5	1.6	1.6	1.6	1.6	1.6	1.5	1.6	1.6	1.6	0.7	0.7
HCFC-141b	1.0		4.0		7.0	6.7	5.6	4.0	4.1	4.2	4.3	5.5	6.9	8.4	8.7	9.0
HCFC-142b	2.1		3.6		2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.7	2.5	1.1	1.2
HCFC-225ca/cb	+		+		+	+	+	+	+	+	+	+	+	+	+	+

+ Does not exceed 0.5 Gg.

Methodology and Data Sources

Emissions of ozone depleting substances were estimated using the EPA's Vintaging Model. 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. 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 3.8, Methodology for Estimating HFC and PFC Emissions from Substitution of Ozone Depleting Substances, 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. Please see the ODS Substitutes section of this report for a more detailed description of the uncertainties that exist in the Vintaging Model.

References

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6.3. Sulfur Dioxide Emissions

Sulfur dioxide (SO_2), emitted into the atmosphere through natural and anthropogenic processes, affects the Earth's radiative budget through photochemical transformation into sulfate aerosols that can (1) scatter sunlight back to space, thereby reducing the radiation reaching the Earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., stratospheric ozone, by providing surfaces for heterogeneous chemical reactions). The overall effect of SO_2-derived aerosols on radiative forcing is believed to be negative (IPCC 2007). However, because SO_2 is short-lived and unevenly distributed through the atmosphere, its radiative forcing impacts are highly uncertain. Sulfur dioxide emissions have been provided below in Table A-276.

The major source of SO_2 emissions in the United States is the burning of sulfur containing fuels, mainly coal. Metal smelting and other industrial processes also release significant quantities of SO_2. The largest contributor to U.S. emissions of SO_2 is electricity generation, accounting for 60 percent of total SO_2 emissions in 2011 (see Table A-277); coal combustion accounted for approximately 92 percent of that total. The second largest source was industrial fuel combustion, which produced 18 percent of 2011 SO_2 emissions. Overall, SO_2 emissions in the United States decreased by 59 percent from 1990 to 2011. The majority of this decline came from reductions from electricity generation, primarily due to increased consumption of low sulfur coal from surface mines in western states.

Sulfur dioxide is important for reasons other than its effect on radiative forcing. It is a major contributor to the formation of urban smog and acid rain. As a contributor to urban smog, high concentrations of SO_2 can cause significant increases in acute and chronic respiratory diseases. In addition, once SO_2 is emitted, it is chemically transformed in the atmosphere and returns to earth as the primary contributor to acid deposition, or acid rain. Acid rain has been found to accelerate the decay of building materials and paints, and to cause the acidification of lakes and streams and damage trees. As a result of these harmful effects, the United States has regulated the emissions of SO_2 under the Clean Air Act. The EPA has also developed a strategy to control these emissions via four programs: (1) the National Ambient Air Quality Standards program,[104] (2) New Source Performance Standards,[105] (3) the New Source Review/Prevention of Significant Deterioration Program,[106] and (4) the sulfur dioxide allowance program.[107]

Table A-276: SO_2 Emissions (Gg)

Sector/Source	1990	2000	2005	2006	2007	2008	2009	2010	2011
Energy	**19,628**	**13,797**	**12,634**	**11,568**	**10,991**	**9,573**	**7,800**	**7,800**	**7,800**
Stationary Combustion	18,407	12,849	11,541	10,612	10,172	8,891	7,167	7,167	7,167
Mobile Combustion	793	632	889	750	611	472	455	455	455
Oil and Gas Activities	390	287	181	182	184	187	154	154	154
Waste Combustion	38	29	24	24	24	23	24	24	24
Industrial Processes	**1,307**	**1,031**	**831**	**818**	**807**	**795**	**798**	**798**	**798**
Chemical Manufacturing	269	307	228	230	230	231	222	222	222
Metals Processing	659	284	159	167	176	184	158	158	158
Storage and Transport	6	5	3	3	4	4	2	2	2
Other Industrial Processes	362	372	327	318	308	298	324	324	324
Miscellaneous*	11	64	114	102	89	77	91	91	91
Solvent Use	**+**	**1**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Degreasing	+	+	+	+	+	+	+	+	+
Graphic Arts	+	+	+	+	+	+	+	+	+
Dry Cleaning	NA	+	+	+	+	+	+	+	+
Surface Coating	+	+	+	+	+	+	+	+	+
Other Industrial	+	1	+	+	+	+	+	+	+
Non-industrial	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agriculture	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste	**+**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Landfills	+	1	1	1	1	1	1	1	1
Wastewater Treatment	+	+	+	+	+	+	+	+	+

[104] [42 U.S.C § 7409, CAA § 109]
[105] [42 U.S.C § 7411, CAA § 111]
[106] [42 U.S.C § 7473, CAA § 163]
[107] [42 U.S.C § 7651, CAA § 401]

Miscellaneous Waste	+		+		+	+	+	+	+	+	+
Total	**20,935**		**14,830**		**13,466**	**12,388**	**11,799**	**10,368**	**8,599**	**8,599**	**8,599**

Source: Data taken from EPA (2005) and disaggregated based on EPA (2003).
* Miscellaneous includes other combustion and fugitive dust categories.
+ Does not exceed 0.5 Gg
NA (Not Available)
Note: Totals may not sum due to independent rounding.

Table A-277: SO_2 Emissions from Electricity Generation (Gg)

Fuel Type	1990		2000		2005	2006	2007	2008	2009	2010	2011
Coal	13,808		9,620		8,680	7,846	7,459	6,300	4,718	4,718	4,718
Petroleum	580		428		458	414	393	332	249	249	249
Natural Gas	1		157		174	157	149	126	94	94	94
Misc. Internal Combustion	45		54		57	52	49	41	31	31	31
Other	NA		78		71	64	61	51	38	38	38
Total	**14,433**		**10,338**		**9,439**	**8,532**	**8,111**	**6,851**	**5,131**	**5,131**	**5,131**

Source: Data taken from EPA (2009 and 2010) and disaggregated based on EPA (2003).
Note: Totals may not sum due to independent rounding.

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6.4. Complete List of Source Categories

Chapter/Source	Gas(es)
Energy	
Fossil Fuel Combustion	CO_2
Non-Energy Use of Fossil Fuels	CO_2
Stationary Combustion (excluding CO_2)	CH_4, N_2O, CO, NO_x, NMVOC
Mobile Combustion (excluding CO_2)	CH_4, N_2O, CO, NO_x, NMVOC
Coal Mining	CH_4
Abandoned Underground Coal Mines	CH_4
Natural Gas Systems	CH_4
Petroleum Systems	CH_4
Incineration of Waste	CO_2, CH_4, N_2O
Industrial Processes	
Titanium Dioxide Production	CO_2
Aluminum Production	CO_2, CF_4, C_2F_6
Iron and Steel Production	CO_2, CH_4
Ferroalloy Production	CO_2, CH_4
Ammonia Production	CO_2
Urea Consumption for Non-Agricultural Purposes	CO_2
Cement Production	CO_2
Lime Production	CO_2
Limestone and Dolomite Use	CO_2
Soda Ash Production and Consumption	CO_2
Glass Production	CO_2
Carbon Dioxide Consumption	CO_2
Phosphoric Acid Production	CO_2
Petrochemical Production	CH_4, CO_2
Silicon Carbide Production and Consumption	CH_4, CO_2
Lead Production	CO_2
Zinc Production	CO_2
Adipic Acid Production	N_2O
Nitric Acid Production	N_2O
Substitution of Ozone Depleting Substances	HFCs, PFCs[a]
HCFC-22 Production	HFC-23
Semiconductor Manufacture	HFCs, PFCs, SF_6[b]
Electrical Transmission and Distributing	SF_6
Magnesium Production and Processing	SF_6
Solvent and Other Product Use	CO, NO_x, NMVOC
N_2O Product Usage	N_2O
Agriculture	
Enteric Fermentation	CH_4
Manure Management	CH_4, N_2O
Rice Cultivation	CH_4
Field Burning of Agricultural Residues	CH_4, N_2O
Agricultural Soil Management	N_2O, CO, NO_x
Land Use, Land-Use Change, and Forestry	
CO_2 Flux	CO_2 (sink)
Cropland Remaining Cropland	CO_2
Settlements Remaining Settlements	N_2O
Forestland Remaining Forestland	CH_4, N_2O
Wetlands Remaining Wetlands	CO_2, N_2O
Waste	
Landfills	CH_4
Wastewater Treatment	CH_4, N_2O
Composting	CH_4, N_2O

[a] Includes HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-236fa, CF_4, HFC-152a, HFC-227ea, HFC-245fa, HFC-4310mee, and PFC/PFPEs.
[b] Includes such gases as HFC-23, CF_4, C_2F_6, SF_6.

6.5. Constants, Units, and Conversions

Metric Prefixes

Although most activity data for the United States is gathered in customary U.S. units, these units are converted into metric units per international reporting guidelines. Table A- 278 provides a guide for determining the magnitude of metric units.

Table A- 278: Guide to Metric Unit Prefixes

Prefix/Symbol	Factor
atto (a)	10^{-18}
femto (f)	10^{-15}
pico (p)	10^{-12}
nano (n)	10^{-9}
micro (μ)	10^{-6}
milli (m)	10^{-3}
centi (c)	10^{-2}
deci (d)	10^{-1}
deca (da)	10
hecto (h)	10^{2}
kilo (k)	10^{3}
mega (M)	10^{6}
giga (G)	10^{9}
tera (T)	10^{12}
peta (P)	10^{15}
exa (E)	10^{18}

Unit Conversions

1 kilogram	=	2.205 pounds		
1 pound	=	0.454 kilograms		
1 short ton	=	2,000 pounds	=	0.9072 metric tons
1 metric ton	=	1,000 kilograms	=	1.1023 short tons

1 cubic meter	=	35.315 cubic feet
1 cubic foot	=	0.02832 cubic meters
1 U.S. gallon	=	3.785412 liters
1 barrel (bbl)	=	0.159 cubic meters
1 barrel (bbl)	=	42 U.S. gallons
1 liter	=	0.001 cubic meters

1 foot	=	0.3048 meters
1 meter	=	3.28 feet
1 mile	=	1.609 kilometers
1 kilometer	=	0.622 miles

1 acre	=	43,560 square feet	=	0.4047 hectares	=	4,047 square meters
1 square mile	=	2.589988 square kilometers				

To convert degrees Fahrenheit to degrees Celsius, subtract 32 and multiply by 5/9

To convert degrees Celsius to Kelvin, add 273.15 to the number of Celsius degrees

Density Conversions[108]

Methane	1 cubic meter	=	0.67606 kilograms
Carbon dioxide	1 cubic meter	=	1.85387 kilograms

Natural gas liquids	1 metric ton	=	11.6 barrels	=	1,844.2 liters
Unfinished oils	1 metric ton	=	7.46 barrels	=	1,186.04 liters
Alcohol	1 metric ton	=	7.94 barrels	=	1,262.36 liters
Liquefied petroleum gas	1 metric ton	=	11.6 barrels	=	1,844.2 liters
Aviation gasoline	1 metric ton	=	8.9 barrels	=	1,415.0 liters
Naphtha jet fuel	1 metric ton	=	8.27 barrels	=	1,314.82 liters
Kerosene jet fuel	1 metric ton	=	7.93 barrels	=	1,260.72 liters
Motor gasoline	1 metric ton	=	8.53 barrels	=	1,356.16 liters
Kerosene	1 metric ton	=	7.73 barrels	=	1,228.97 liters
Naphtha	1 metric ton	=	8.22 barrels	=	1,306.87 liters
Distillate	1 metric ton	=	7.46 barrels	=	1,186.04 liters
Residual oil	1 metric ton	=	6.66 barrels	=	1,058.85 liters
Lubricants	1 metric ton	=	7.06 barrels	=	1,122.45 liters
Bitumen	1 metric ton	=	6.06 barrels	=	963.46 liters
Waxes	1 metric ton	=	7.87 barrels	=	1,251.23 liters
Petroleum coke	1 metric ton	=	5.51 barrels	=	876.02 liters
Petrochemical feedstocks	1 metric ton	=	7.46 barrels	=	1,186.04 liters
Special naphtha	1 metric ton	=	8.53 barrels	=	1,356.16 liters
Miscellaneous products	1 metric ton	=	8.00 barrels	=	1,271.90 liters

Energy Conversions

Converting Various Energy Units to Joules

The common energy unit used in international reports of greenhouse gas emissions is the joule. A joule is the energy required to push with a force of one Newton for one meter. A terajoule (TJ) is one trillion (10^{12}) joules. A British thermal unit (Btu, the customary U.S. energy unit) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2 Fahrenheit.

1 TJ =
- 2.388×10^{11} calories
- 23.88 metric tons of crude oil equivalent
- 947.8 million Btus
- 277,800 kilowatt-hours

Converting Various Physical Units to Energy Units

Data on the production and consumption of fuels are first gathered in physical units. These units must be converted to their energy equivalents. The conversion factors in Table A-279 can be used as default factors, if local data are not available. See Appendix A of EIA's *Annual Energy Review 2009* (EIA 2010) for more detailed information on the energy content of various fuels.

[108] Reference: EIA (2007)

Table A-279: Conversion Factors to Energy Units (Heat Equivalents)

Fuel Type (Units)	Factor
Solid Fuels (Million Btu/Short ton)	
Anthracite coal	22.573
Bituminous coal	23.89
Sub-bituminous coal	17.14
Lignite	12.866
Coke	24.8
Natural Gas (Btu/Cubic foot)	**1,026**
Liquid Fuels (Million Btu/Barrel)	
Motor gasoline	5,218
Aviation gasoline	5.048
Kerosene	5.670
Jet fuel, kerosene-type	5.670
Distillate fuel	5.825
Residual oil	6.287
Naphtha for petrochemicals	5.248
Petroleum coke	6.024
Other oil for petrochemicals	5.825
Special naphthas	5.248
Lubricants	6.065
Waxes	5.537
Asphalt	6.636
Still gas	6.000
Misc. products	5.796

Note: For petroleum and natural gas, *Annual Energy Review 2009* (EIA 2010). For coal ranks, *State Energy Data Report 1992* (EIA 1993). All values are given in higher heating values (gross calorific values).

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6.6. Abbreviations

AAPFCO	American Association of Plant Food Control Officials
ABS	Acrylonitrile butadiene styrene
ACC	American Chemistry Council
AEDT	U.S. FAA Aviation Environmental Design Tool
AFEAS	Alternative Fluorocarbon Environmental Acceptability Study
AFV	Alternative fuel vehicle
AGA	American Gas Association
AHEF	Atmospheric and Health Effect Framework
AISI	American Iron and Steel Institute
ANL	Argonne National Laboratory
APC	American Plastics Council
API	American Petroleum Institute
APTA	American Public Tranpsortation Association
AR4	IPCC Fourth Assessment Report
ARI	Advanced Resources International
ASAE	American Society of Agricultural Engineers
ASTM	American Society for Testing and Materials
BCEF	Biomass conversion and expansion factors
BEA	Bureau of Economic Analysis, U.S. Department of Commerce
BLM	Bureau of Land Management
BoC	Bureau of Census
BOD	Biological oxygen demand
BOD5	Biochemical oxygen demand over a 5-day period
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BOF	Basic oxygen furnace
BRS	Biennial Reporting System
BTS	Bureau of Transportation Statistics, U.S. Department of Transportation
Btu	British thermal unit
C	Carbon
C&EN	Chemical and Engineering News
CAAA	Clean Air Act Amendments of 1990
CAPP	Canadian Association of Petroleum Producers
CARB	California Air Resources Board
CBI	Confidential business information
CEFM	Cattle Enteric Fermentation Model
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CH_4	Methane
CHP	Combined heat and power
CIGRE	International Council on Large Electric Systems
CKD	Cement kiln dust
CMA	Chemical Manufacturer's Association
CMOP	Coalbed Methane Outreach Program
CMR	Chemical Market Reporter
CNG	Compressed natural gas
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COGCC	Colorado Oil and Gas Conservation Commission
CRF	Common Reporting Format
CRM	Component ratio method
CRP	Conservation Reserve Program
CTIC	Conservation Technology Information Center
CVD	Chemical vapor deposition
CWNS	Clean Watershed Needs Survey
d.b.h	Diameter breast height
DE	Digestible energy
DESC	Defense Energy Support Center-DoD's defense logistics agency

DFAMS	Defense Fuels Automated Management System
DHS	Department of Homeland Security
DM	Dry matter
DOC	Degradable organic carbon
DOC	U.S. Department of Commerce
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EAF	Electric arc furnace
EF	Emission factor
EFMA	European Fertilizer Manufacturers Association
EJ	Exajoule
EGR	Exhaust gas recirculation
EIA	Energy Information Administration, U.S. Department of Energy
EIIP	Emissions Inventory Improvement Program
EOR	Enhanced oil recovery
EPA	U.S. Environmental Protection Agency
ERS	Economic Research Service
EVI	Enhanced Vegetation Index
FAA	Federal Aviation Administration
FAO	Food and Agricultural Organization
FCCC	Framework Convention on Climate Change
FEB	Fiber Economics Bureau
FERC	Federal Energy Regulatory Commission
FGD	Flue gas desulfurization
FHWA	Federal Highway Administration
FIA	Forest Inventory and Analysis
FIADB	Forest Inventory and Analysis Database
FIPR	Florida Institute of Phosphate Research
FQSV	First-quarter of silicon volume
FTP	Federal Test Procedure
g	gram
GCV	Gross calorific value
GDP	Gross domestic product
Gg	Gigagram
GHG	Greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GRI	Gas Research Institute
Gg	Gigajoule
GSAM	Gas Systems Analysis Model
GWP	Global warming potential
ha	Hectare
HBFC	Hydrobromofluorocarbon
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HDDV	Heavy duty diesel vehicle
HDGV	Heavy duty gas vehicle
HDPE	High density polyethylene
HFC	Hydrofluorocarbon
HFE	Hydrofluoroethers
HHV	Higher Heating Value
HMA	Hot Mix Asphalt
HTF	Heat Transfer Fluid
HTS	Harmonized Tariff Schedule
HWP	Harvested wood product
IBF	International bunker fuels
IC	Integrated Circuit
ICAO	International Civil Aviation Organization
IDB	Integrated Database
IEA	International Energy Association

IFO	Intermediate Fuel Oil
IISRP	International Institute of Synthetic Rubber Products
ILENR	Illinois Department of Energy and Natural Resources
IMO	International Maritime Organization
IPAA	Independent Petroleum Association of America
IPCC	Intergovernmental Panel on Climate Change
ITC	U.S. International Trade Commission
ITRS	International Technology Roadmap for Semiconductors
JWR	Jim Walters Resources
KCA	Key category analysis
kg	Kilogram
kWh	Kilowatt hour
LDDT	Light duty diesel truck
LDDV	Light duty diesel vehicle
LDGT	Light duty gas truck
LDGV	Light duty gas vehicle
LDPE	Low density polyethylene
LEV	Low emission vehicles
LFG	Landfill gas
LFGTE	Landfill gas-to-energy
LHV	Lower Heating Value
LKD	Lime kiln dust
LLDPE	Linear low density polyethylene
LMOP	EPA's Landfill Methane Outreach Program
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas(es)
LTO	Landing and take-off
LULUCF	Land use, land-use change, and forestry
MC	Motorcycle
MCF	Methane conversion factor
MCFD	Thousand cubic feet per day
MDI	Metered dose inhalers
MECS	EIA Manufacturer's Energy Consumption Survey
MGO	Marine gas oil
MJ	Megajoule
MLRA	Major Land Resource Area
mm	Milimeter
MMBtu	Million British thermal units
MMCF	Million cubic feet
MMCFD	Million cubic feet per day
MMS	Minerals Management Service
MMTCE	Million metric tons carbon equivalent
MODIS	Moderate Resolution Imaging Spectroadiometer
MoU	Memorandum of Understanding
MOVES	U.S. EPA's Motor Vehicle Emission Simulator model
MPG	Miles per gallon
MRV	Monitoring, reporting, and verification
MSHA	Mine Safety and Health Administration
MSW	Municipal solid waste
MT	Metric ton
MTBE	Methyl Tertiary Butyl Ether
N_2O	Nitrous oxide
NA	Not available
NACWA	National Association of Clean Water Agencies
NAHMS	National Animal Health Monitoring System
NAICS	North American Industry Classification System
NAPAP	National Acid Precipitation and Assessment Program
NARR	North American Regional Reanalysis Product
NASF	National Association of State Foresters
NASS	USDA's National Agriculture Statistics Service
NC	No change

NCV	Net calorific value
NE	Not estimated
NEI	National Emissions Inventory
NEMA	National Electrical Manufacturers Association
NEU	Non-Energy Use
NEV	Neighborhood Electric Vehicle
NGL	Natural gas liquids
NIR	National Inventory Report
NLCD	National Land Cover Dataset
NMVOC	Non-methane volatile organic compound
NOx	Nitrogen oxides
NPRA	National Petroleum and Refiners Association
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
NSCEP	National Service Center for Environmental Publications
NSCR	Non-selective catalytic reduction
NSPS	New source performance standards
NWS	National Weather Service
OAP	EPA Office of Atmospheric Programs
OAQPS	EPA Office of Air Quality Planning and Standards
ODP	Ozone depleting potential
ODS	Ozone depleting substances
OECD	Organization of Economic Co-operation and Development
OEM	Original equipment manufacturers
OMS	EPA Office of Mobile Sources
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OTA	Office of Technology Assessment
OTAQ	EPA Office of Transportation and Air Quality
PAH	Polycyclic aromatic hydrocarbons
PCC	Precipitate calcium carbonate
PDF	Probability Density Function
PECVD	Plasma enhanced chemical vapor deposition
PET	Polyethylene terephthalate
PET	Potential evapotranspiration
PEVM	PFC Emissions Vintage Model
PFC	Perfluorocarbon
PFPE	Perfluoropolyether
POTW	Publicly Owned Treatment Works
Ppbv	Parts per billion (10^9) by volume
Ppm	Parts per million
Ppmv	Parts per million(10^6) by volume
Pptv	Parts per trillion (10^{12}) by volume
PRP	Pasture/Range/Paddock
PS	Polystyrene
PSU	Primary Sample Unit
PU	Polyurethane
PVC	Polyvinyl chloride
PV	Photovoltaic
QA/QC	Quality Assurance and Quality Control
QBtu	Quadrillion Btu
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RMA	Rubber Manufacturers' Association
RPA	Resources Planning Act
SAE	Society of Automotive Engineers
SAGE	System for assessing Aviation's Global Emissions
SAN	Styrene Acrylonitrile
SAR	IPCC Second Assessment Report
SCR	Selective catalytic reduction

SEC	Securities and Exchange Commission
SEMI	Semiconductor Equipment and Materials Industry
SF_6	Sulfur hexafluoride
SICAS	Semiconductor International Capacity Statistics
SNAP	Significant New Alternative Policy Program
SNG	Synthetic natural gas
SOC	Soil Organic Carbon
SSURGO	Soil Survey Geographic Database
STMC	Scrap Tire Management Council
SULEV	Super Ultra Low Emissions Vehicle
SWANA	Solid Waste Association of North America
SWDS	Solid waste disposal sites
TA	Treated anaerobically (wastewater)
TAM	Typical animal mass
TAME	Tertiary amyl methyl ether
TAR	IPCC Third Assessment Report
TBtu	Trillion Btu
TDN	Total digestible nutrients
TFI	The Fertilizer Institute
Tg	Teragrams
Tg CO_2 Eq.	Teragrams carbon dioxide equivalent
TIGER	Topologically Integrated Geographic Encoding and Referencing survey
TJ	Terajoule
TLEV	Traditional low emissions vehicle
TMLA	Total Manufactured Layer Area
TRI	Toxic Release Inventory
TSDF	Hazardous waste treatment, storage, and disposal facility
TVA	Tennessee Valley Authority
UDI	Utility Data Institute
UFORE	U.S. Forest Service's Urban Forest Effects model
UG	Underground (coal mining)
U.S.	United States
U.S. ITC	United States International Trade Commission
UEP	United Egg Producers
ULEV	Ultra low emission vehicle
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAA	U.S. Aluminum Association
USAF	United States Air Force
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VAIP	EPA's Voluntary Aluminum Industrial Partnership
VKT	Vehicle kilometers traveled
VMT	Vehicle miles traveled
VOCs	Volatile organic compounds
VS	Volatile solids
WFF	World Fab Forecast (previously WFW, World Fab Watch)
WGC	World Gas Conference
WIP	Waste in place
WMO	World Meteorological Organization
WMS	Waste management systems
WW	Wastewater
WWTP	Wastewater treatment plant
ZEVs	Zero emissions vehicles

6.7. Chemical Formulas

Table A-280: Guide to Chemical Formulas

Symbol	Name
Al	Aluminum
Al_2O_3	Aluminum Oxide
Br	Bromine
C	Carbon
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
CF_4	Perfluoromethane
C_2F_6	Perfluoroethane, hexafluoroethane
c-C_3F_6	Perfluorocyclopropane
C_3F_8	Perfluoropropane
c-C_4F_8	Perfluorocyclobutane
C_4F_{10}	Perfluorobutane
C_5F_{12}	Perfluoropentane
C_6F_{14}	Perfluorohexane
CF_3I	Trifluoroiodomethane
$CFCl_3$	Trichlorofluoromethane (CFC-11)
CF_2Cl_2	Dichlorodifluoromethane (CFC-12)
CF_3Cl	Chlorotrifluoromethane (CFC-13)
$C_2F_3Cl_3$	Trichlorotrifluoroethane (CFC-113)*
CCl_3CF_3	CFC-113a*
$C_2F_4Cl_2$	Dichlorotetrafluoroethane (CFC-114)
C_2F_5Cl	Chloropentafluoroethane (CFC-115)
$CHCl_2F$	HCFC-21
CHF_2Cl	Chlorodifluoromethane (HCFC-22)
$C_2F_3HCl_2$	HCFC-123
C_2F_4HCl	HCFC-124
$C_2FH_3Cl_2$	HCFC-141b
$C_2H_3F_2Cl$	HCFC-142b
$CF_3CF_2CHCl_2$	HCFC-225ca
$CClF_2CF_2CHClF$	HCFC-225cb
CCl_4	Carbon tetrachloride
$CHClCCl_2$	Trichloroethylene
CCl_2CCl_2	Perchloroethylene, tetrachloroethene
CH_3Cl	Methylchloride
CH_3CCl_3	Methylchloroform
CH_2Cl_2	Methylenechloride
$CHCl_3$	Chloroform, trichloromethane
CHF_3	HFC-23
CH_2F_2	HFC-32
CH_3F	HFC-41
C_2HF_5	HFC-125
$C_2H_2F_4$	HFC-134
CH_2FCF_3	HFC-134a
$C_2H_3F_3$	HFC-143*
$C_2H_3F_3$	HFC-143a*
CH_2FCH_2F	HFC-152*
$C_2H_4F_2$	HFC-152a*
CH_3CH_2F	HFC-161
C_3HF_7	HFC-227ea
$CF_3CF_2CH_2F$	HFC-236cb
$CF_3CHFCHF_2$	HFC-236ea
$C_3H_2F_6$	HFC-236fa
$C_3H_3F_5$	HFC-245ca
$CHF_2CH_2CF_3$	HFC-245fa
$CF_3CH_2CF_2CH_3$	HFC-365mfc

$C_5H_2F_{10}$	HFC-43-10mee
CF_3OCHF_2	HFE-125
CF_2HOCF_2H	HFE-134
CH_3OCF_3	HFE-143a
$CF_3CHFOCF_3$	HFE-227ea
$CF_3CHClOCHF_2$	HCFE-235da2
$CF_3CHFOCHF_2$	HFE-236ea2
$CF_3CH_2OCF_3$	HFE-236fa
$CF_3CF_2OCH_3$	HFE-245cb2
$CHF_2CH_2OCF_3$	HFE-245fa1
$CF_3CH_2OCHF_2$	HFE-245fa2
$CHF_2CF_2OCH_3$	HFE-254cb2
$CF_3CH_2OCH_3$	HFE-263fb2
$CF_3CF_2OCF_2CHF_2$	HFE-329mcc2
$CF_3CF_2OCH_2CF_3$	HFE-338mcf2
$CF_3CF_2CF_2OCH_3$	HFE-347mcc3
$CF_3CF_2OCH_2CHF_2$	HFE-347mcf2
$CF_3CHFCF_2OCH_3$	HFE-356mec3
$CHF_2CF_2CF_2OCH_3$	HFE-356pcc3
$CHF_2CF_2OCH_2CHF_2$	HFE-356pcf2
$CHF_2CF_2CH_2OCHF_2$	HFE-356pcf3
$CF_3CF_2CH_2OCH_3$	HFE-365mcf3
$CHF_2CF_2OCH_2CH_3$	HFE-374pcf2
$C_4F_9OCH_3$	HFE-7100
$C_4F_9OC_2H_5$	HFE-7200
$CHF_2OCF_2OC_2F_4OCHF_2$	H-Galden 1040x
$CHF_2OCF_2OCHF_2$	HG-10
$CHF_2OCF_2CF_2OCHF_2$	HG-01
CH_3OCH_3	Dimethyl ether
CH_2Br_2	Dibromomethane
CH_2BrCl	Dibromochloromethane
$CHBr_3$	Tribromomethane
$CHBrF_2$	Bromodifluoromethane
CH_3Br	Methylbromide
CF_2BrCl	Bromodichloromethane (Halon 1211)
$CF_3Br(CBrF_3)$	Bromotrifluoromethane (Halon 1301)
CF_3I	FIC-13I1
CO	Carbon monoxide
CO_2	Carbon dioxide
$CaCO_3$	Calcium carbonate, Limestone
$CaMg(CO_3)_2$	Dolomite
CaO	Calcium oxide, Lime
Cl	atomic Chlorine
F	Fluorine
Fe	Iron
Fe_2O_3	Ferric oxide
FeSi	Ferrosilicon
H, H_2	atomic Hydrogen, molecular Hydrogen
H_2O	Water
H_2O_2	Hydrogen peroxide
OH	Hydroxyl
N, N_2	atomic Nitrogen, molecular Nitrogen
NH_3	Ammonia
NH_4^+	Ammonium ion
HNO_3	Nitric acid
NF_3	Nitrogen trifluoride
N_2O	Nitrous oxide
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate radical
Na	Sodium

Na_2CO_3	Sodium carbonate, soda ash
Na_3AlF_6	Synthetic cryolite
O, O_2	atomic Oxygen, molecular Oxygen
O_3	Ozone
S	atomic Sulfur
H_2SO_4	Sulfuric acid
SF_6	Sulfur hexafluoride
SF_5CF_3	Trifluoromethylsulphur pentafluoride
SO_2	Sulfur dioxide
Si	Silicon
SiC	Silicon carbide
SiO_2	Quartz

* Distinct isomers.