Appendix A

Conversion Factors for Standard Units

This appendix has been prepared in consistent metric units based on the *Le Systéme International d'Unités* (SI). Some important features of the SI are summarized in this appendix along with a summary of factors to enable readers to convert to English units.

Table A.1. SI Derived Units

Quantity	Unit	Symbol
Energy, work, heat[a]	joule	J
Power, radiant flux	watt	W
Electric potential	volt	V
Electric resistance	ohm	R
Conductance	siemans	S
(a) An energy unit accepted for limited use is the kilowatthour (kWh). 1 kWh = 1,000 Wh = 3.6 MJ.		

Table A.2. SI Prefixes

Prefix	Symbol	Multiplication Factor
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}

Table A.3. SI Area and Mass Units

Quantity	Unit	Symbol
Area		
Square meter	1 m^2	m^2
Hectare	10,000 m^2	ha
Million hectares	10^6 ha	Mha
Mass		
Metric ton	10^3 kg	t
Gigagram	10^9 g	Gg
Million metric tons	10^6 t	Mt
Giga ton	10^9 t	Gt

Table A.4. Conversion of Metric Units to English Units

To convert from	to	multiply by
Basic units		
Area		
hectares (ha)	acres	2.471
Mass		
kilograms (kg)	pounds (mass)	2.205
metric tons (t)	short ton (2,000 lb)	1.102
gigagrams (Gg)	short ton (2,000 lb)	1.102×10^3
Energy		
kilojoules (kJ)	British thermal units (Btus)	0.9478
exajoules (EJ)	quad (10^{15} Btus)	0.9478
petajoules (PJ)	quad (10^{15} Btus)	0.9478×10^{-3}
Special Units		
Carbon		
kg carbon (kg C)	lb CO_2	8.084
Crop production		
metric t (corn)	bushel (56 lb)	39.37
metric t (soybeans)	bushel (60 lb)	36.74
metric t (wheat)	bushel (60 lb)	36.74
Crop yield		
kg/ha	lb/acre	0.8922
metric t/ha	short ton/acre	0.4461
metric t/ha (corn)	bushels (56 lb)/acre	15.93
metric t/ha (soybeans)	bushels (60 lb)/acre	14.87
metric t/ha (wheat)	bushels (60 lb)/acre	14.87

Appendix B

Emissions Factors

Table B.1. Factors: Carbon Coefficients and Assumptions

Fuel Type	Million Short Tons Carbon Dioxide per Quadrillion Btu	Million Metric Tons Carbon Dioxide per Quadrillion Btu[(a)]
Petroleum		
Motor Gasoline	77.7	70.5
LPG	69.1	62.7
Jet Fuel	77.9	70.7
Distillate Fuel	79.9	72.5
Residual Fuel	86.6	78.6
Asphalt and Road Oil[(b)]	84.2	76.4
Lubricants[(b)]	84.9	77.0
Petrochemical Feed	77.8	70.6
Aviation Gas[(b)]	77.7	70.5
Kerosene	77.9	70.7
Petroleum Coke[(b)]	109.2	99.1
Special Naphtha[(b)]	77.7	70.5
Other: Waxes and Miscellaneous[(b)]	84.2	76.4
Coal[(c)]		
Anthracite Coal	112.5	102.1
Bituminous Coal	101.5	92.1
Subbituminous Coal	105.0	95.3
Lignite	106.5	96.6
Natural Gas		
Flare Gas[(b)]	60.8	55.2
Natural Gas	58.2	52.8

(a) Assumes conversion of 1 quadrillion Btu = 1.0551 exajoules and fraction combusted = 99 percent.
(b) Emissions coefficients are EIA estimates based on underlying chemical composition of the product.
(c) Coal emissions factor is for 1990: varies by $\pm$0.2 percent in other years.
NA = not available.

Source: U.S. Department of Energy, Energy Information Administration. 1993. Table 11 in *Emissions of Greenhouse Gases in the United States 1985-1990*. DOE/EIA-0573. U.S. Government Printing Office, Washington, DC.

Appendix C

Adjusted Electricity Emissions Factors by State

Use of the State-Level Electricity Emissions Factors

The default emissions factors contained in this appendix are the simplest to use relative to other methods of calculating emissions. However, you should realize that these default factors will either underestimate or overestimate the actual emissions characteristics of any given power-generating equipment, as they represent the average emissions characteristics over a state. If available, you are encouraged to use emissions factors specific to your reported project, for example, a utility-specific factor that has incorporated actual fuel mix and dispatching modes.

For the purposes of the voluntary reporting program, and to retain flexibility and ease-of-use, Appendix C provides default state-level electrical emissions factors for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Three factors are given for each state: one for emissions from utility generation, one for emissions from nonutility generation, and one combined utility/nonutility. If you know the source for your electricity (that is, utility or nonutility), you may use the appropriate factor. If you do not know or if you use both utility and nonutility sources, you should use the combined factors for your state.

Table C.1. Adjusted Electricity Emissions Factors by State

		UTILITY		NUG		COMBINED			UTILITY	NUG	UTILITY	NUG	COMBINED	
REGION	STATE	CO2 Emissions Factor (short ton/MWh)	CO2 Emissions Factor (lbs/MWh)	Weighted CO2 Emissions Factor (short ton/MWh)	Weighted CO2 Emissions Factor (lbs/MWh)	CO2 Emissions Factor (short ton/MWh)	CO2 Emissions Factor (lbs/MWh)	CO2 Emissions Factor (metric ton/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)
New England	Connecticut	0.262	523	1.005	2010	0.358	715	0.324	0.037	0.290	0.005	0.052	0.0683	0.0104
	Maine	0.126	251	1.157	2314	0.483	966	0.438	0.000	0.351	0.000	0.054	0.1170	0.0180
	Massachusetts	0.711	1,422	0.824	1647	0.729	1459	0.662	0.118	0.184	0.021	0.056	0.1281	0.0266
	New Hampshire	0.340	680	1.283	2567	0.426	852	0.386	0.081	0.395	0.010	0.063	0.1077	0.0145
	Rhode Island	0.917	1,835	0.537	1074	0.546	1091	0.495	0.020	0.066	0.019	0.049	0.0644	0.0487
	Vermont	0.066	131	0.586	1173	0.080	159	0.072	0.011	0.182	0.003	0.030	0.0152	0.0041
Mid Atlantic	New Jersey	0.302	605	0.616	1232	0.387	774	0.351	0.065	0.097	0.015	0.051	0.0731	0.0241
	New York	0.493	986	0.763	1527	0.518	1036	0.470	0.076	0.186	0.018	0.048	0.0859	0.0208
	Pennsylvania	0.627	1,254	0.917	1835	0.643	1286	0.583	0.209	0.274	0.025	0.046	0.2128	0.0259
East-North Central	Illinois	0.432	865	0.814	1628	0.433	866	0.393	0.136	0.227	0.016	0.046	0.1360	0.0164
	Indiana	1.086	2,171	0.633	1267	1.086	2171	0.985	0.335	0.126	0.040	0.044	0.3346	0.0398
	Michigan	0.792	1,584	0.756	1511	0.788	1576	0.715	0.253	0.168	0.031	0.052	0.2450	0.0327
	Ohio	0.903	1,807	1.111	2222	0.904	1807	0.820	0.302	0.344	0.036	0.053	0.3020	0.0355
	Wisconsin	0.664	1,329	1.063	2125	0.671	1343	0.609	0.241	0.336	0.029	0.049	0.2430	0.0292
West-North Central	Iowa	0.842	1,685	0.943	1885	0.843	1686	0.765	0.288	0.319	0.034	0.040	0.2878	0.0342
	Kansas	0.852	1,703	0.513	1027	0.852	1703	0.773	0.239	0.055	0.030	0.047	0.2386	0.0302
	Minnesota	0.810	1,619	1.018	2035	0.814	1627	0.738	0.226	0.322	0.027	0.049	0.2278	0.0276
	Missouri	0.891	1,783	0.907	1815	0.891	1783	0.809	0.281	0.293	0.033	0.041	0.2814	0.0334
	Nebraska	0.644	1,288	N/A	N/A	0.644	1288	0.580	0.189	N/A	0.023	N/A	0.189	0.023
	North Dakota	1.152	2,303	0.794	1589	1.151	2303	1.045	0.319	0.222	0.038	0.041	0.3194	0.0376
	South Dakota	0.456	912	N/A	N/A	0.456	912	0.410	0.143	N/A	0.017	N/A	0.143	0.017
South Atlantic	Delaware	0.933	1,865	0.735	1470	0.928	1855	0.842	0.217	0.171	0.034	0.029	0.2161	0.0344
	District of Columbia	1.324	2,649	N/A	N/A	1.324	2649	1.192	0.048	N/A	0.005	N/A	0.048	0.005
	Florida	0.633	1,266	1.144	2288	0.647	1294	0.587	0.159	0.340	0.027	0.058	0.1640	0.0275
	Georgia	0.609	1,218	1.333	2665	0.610	1220	0.553	0.216	0.395	0.025	0.066	0.2160	0.0255
	Maryland	0.675	1,350	1.005	2011	0.678	1356	0.615	0.205	0.263	0.026	0.057	0.2051	0.0260
	North Carolina	0.650	1,300	1.138	2276	0.675	1350	0.612	0.222	0.371	0.026	0.050	0.2290	0.0276
	South Carolina	0.332	665	1.439	2878	0.344	688	0.312	0.110	0.447	0.013	0.070	0.1130	0.0136
	Virginia	0.488	977	1.101	2202	0.554	1107	0.502	0.163	0.336	0.022	0.053	0.1805	0.0253
	West Virginia	1.007	2,013	0.645	1290	1.003	2005	0.909	0.337	0.208	0.040	0.029	0.3356	0.0396
East-South Central	Alabama	0.683	1,367	1.258	2515	0.684	1369	0.621	0.227	0.358	0.027	0.068	0.2277	0.0271
	Kentucky	0.965	1,930	N/A	N/A	0.965	1930	0.869	0.323	N/A	0.038	N/A	0.323	0.038
	Mississippi	0.533	1,066	1.487	2973	0.537	1075	0.487	0.137	0.439	0.029	0.079	0.1382	0.0290
	Tennessee	0.667	1,334	1.066	2131	0.668	1335	0.606	0.226	0.342	0.027	0.050	0.2259	0.0266
West-South Central	Arkansas	0.642	1,284	1.293	2586	0.643	1286	0.584	0.182	0.364	0.025	0.073	0.1825	0.0250
	Louisiana	0.695	1,390	0.674	1348	0.694	1388	0.629	0.125	0.129	0.038	0.050	0.1248	0.0385
	Oklahoma	0.834	1,667	0.867	1735	0.836	1672	0.758	0.219	0.252	0.047	0.046	0.2211	0.0470
	Texas	0.798	1,596	0.576	1151	0.776	1552	0.704	0.172	0.087	0.041	0.048	0.1637	0.0413
Mountain	Arizona	0.399	797	1.140	2281	0.399	798	0.362	0.171	0.349	0.023	0.054	0.1709	0.0232
	Colorado	1.015	2,030	0.582	1164	1.000	2001	0.908	0.320	0.114	0.038	0.044	0.3137	0.0385
	Idaho	0.000	0	0.874	1748	0.134	269	0.122	0.000	0.261	0.000	0.046	0.0382	0.0067
	Montana	0.774	1,548	0.950	1899	0.777	1553	0.704	0.230	0.319	0.027	0.041	0.2317	0.0276
	Nevada	1.011	2,021	0.257	515	0.937	1875	0.850	0.268	0.029	0.037	0.024	0.2457	0.0360
	New Mexico	0.703	1,405	0.587	1174	0.703	1405	0.637	0.311	0.087	0.040	0.054	0.3111	0.0404
	Utah	0.996	1,991	0.494	988	0.995	1990	0.903	0.329	0.062	0.040	0.047	0.3283	0.0399
	Wyoming	1.097	2,194	0.633	1267	1.097	2194	0.995	0.334	0.149	0.039	0.043	0.3343	0.0393

Table C.1. (cont'd)

REGION	STATE	UTILITY		NUG		COMBINED			UTILITY	NUG	UTILITY	NUG	COMBINED	
		CO2 Emissions Factor (short ton/MWh)	CO2 Emissions Factor (lbs/MWh)	Weighted CO2 Emissions Factor (short ton/MWh)	Weighted CO2 Emissions Factor (lbs/MWh)	CO2 Emissions Factor (short ton/MWh)	CO2 Emissions Factor (lbs/MWh)	CO2 Emissions Factor (metric ton/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)	Weighted N20 Emissions Factor (lbs/MWh)	Weighted CH4 Emissions Factor (lbs/MWh)
Pacific Contiguous	California	0.287	573	0.593	1186	0.378	756	0.343	0.004	0.123	0.027	0.042	0.0392	0.0315
	Oregon	0.097	195	1.309	2618	0.118	235	0.107	0.039	0.400	0.009	0.066	0.0448	0.0102
	Washington	0.138	276	0.915	1831	0.153	306	0.139	0.043	0.241	0.006	0.055	0.0461	0.0069
Pacific Non-Contiguous	Alaska	0.000	1	0.834	1667	0.016	31	0.014	0.173	0.201	0.091	0.049	0.1732	0.0907
	Hawaii	0.700	1,399	0.943	1886	0.757	1514	0.687	0.042	0.248	0.005	0.036	0.0888	0.0120
	U.S. Mean	0.648	1,296	0.896	1792	0.646	1291	0.586	0.179	0.245	0.026	0.050	0.1872	0.0291

Methodology Used to Develop Electricity Emissions Factors by State

C.1 Utility CO_2 Emissions Factors

To arrive at the carbon dioxide emissions factors in pounds per megawatt hour (lb/MWh), for each state, carbon dioxide emissions for 1992 in thousand short tons were converted to pounds (short tons multiplied by 2,000 pounds), then divided by 1992 net generation in million kilowatt hours (10^6 kWh). (Since these factors are principally for use by consumers of electricity, gross generation is not used.) The resultant value was then multiplied by 1,000 to convert pounds per kilowatt hour to pounds per megawatt hour. Because transmission and distribution losses have not been included, the emissions factors are considered conservative.

Example: State of Wisconsin

CO_2 Emissions = $30{,}867 \times 10^3$ short tons

= $30{,}867 \times 10^3$ short tons • 2,000 lb = $61{,}734 \times 10^6$ lb

Net Generation = $46{,}464 \times 10^6$ kWh

CO_2 Emission Factor = $61{,}734 \times 10^6$ lb/$46{,}464 \times 10^6$ kWh = 1,329 lbs/MWh

Source: DOE/EIA 1994, Table 46, third column, Electric Utility CO_2 Emissions in thousand short tons and Table 12, first column, Electric Utility Net Generation in million kilowatthours.

C.2 Utility Methane and Nitrous Oxide Emissions Factors

The utility weighted non-CO_2 emissions factors were calculated by assigning representative technologies to each energy source. These representative technologies for each energy source were compiled from 1992 information collected by the Energy Information Administration. The emissions factors (in pounds per megawatt hour), developed by NREL (1993), DOE (1991), WAPA (1994), and IPCC (1991), for these technologies were multiplied by the 1992 net generation (in millions of kilowatt hours) to give pounds of methane and nitrous oxide emissions. Finally, the pounds of methane and nitrous oxide emissions from each energy source were added and the sum divided by the total net generation. (See the example below, computing the nitrous oxide emissions factor for the state of Wisconsin.)

Example: Weighted N_20 Emissions Factor for the State of Wisconsin for 1992

Technology	Net Generation (10^3 MWh)	N_20 Emissions Factor (lbs/MWh)	Estimated N_20 Emissions (thousand lbs)
Coal - Pulverized	32,741	0.34	11,131.94
Nuclear/Other	11,207	0.00	0.00
Hydroelectric	2,123	0.00	0.00
Wood - Steam Turbine	133	0.55	73.15
Municipal Solid Waste - Steam Turbine	16	0.55	8.80
Gas - Steam Turbine	173	0.00	0.00
Gas - Combustion Turbine	15	0.24	3.6
Oil - Steam Turbine	53	0.00	0.00
Oil - Combustion Turbine	2	0.276	0.55
Total	46,464		11,218.04

Weighted N_20 Emissions Factor for State of Wisconsin for 1992:

$[(11{,}218.04 \times 10^3 \text{ lbs of } N_20)/(46{,}464 \times 10^6 \text{ kWh})] \bullet 10^3 \text{ kWh/MWh} = \underline{0.241 \text{ lbs/MWh}}$

Sources: DOE/EIA 1994, Tables 13, 14, and 15; Energy Information Administration, Monthly Power Plant Report (Form EIA-759); WAPA 1994; DOE 1991; NREL 1993; IPCC 1991.

C.3 Nonutility CO_2 and Non-CO_2 Weighted Emissions Factors Calculation

The weighted emissions factors for nonutility generators were calculated as outlined above for utility non-carbon dioxide emission factors, based on "bottom-up" (technology) methodology. The emissions factors for each technology are listed in the Emissions Factors for Selected Technologies table below.

Deliveries data in millions of kilowatt hours were used to account for sales, interchanges, and exchanges of electric energy with utilities and other nonutilities.

Source: DOE/EIA 1994, Tables 79 and 82.

Emissions Factors for Selected Technologies

Technology	CO_2 Emissions Factor (lbs/MWh)	N_2O Emissions Factor (lbs/MWh)	CH_4 Emissions Factor (lbs/MWh)
Coal - Pulverized	1,970	0.34	0.04
Nuclear/Other	0.00	0.00	0.00
Hydroelectric	0.00	0.00	0.00
Wood Waste Biomass Boiler	3,400	0.55	0.14
Municipal Solid Waste Boiler	3,747	0.55	0.02
Gas - Steam Turbine	968	0.00	0.05
Gas - Combustion Turbine	1,560	0.24	0.16
Gas- Combined Cycle	952	0.063	0.015
Oil - Steam Turbine	1,452	0.00	0.002
Oil - Combustion Turbine	2,150	0.276	0.021
Oil- Combined Cycle	1,330	0.268	0.013
Renewables	0.00	0.00	0.00

Sources: WAPA 1994; DOE 1991; NREL 1993; IPCC 1991.

C.4 Combined Emissions Factors

To calculate combined CO_2, N_2O, and CH_4 utility/nonutility factors, the sum of utility and non-utility CO_2 emissions was divided by the sum of utility and nonutility generation.

C.5 References

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Appendix D

Conversion of Carbon to Carbon Dioxide Emissions

Conversion of Carbon to Carbon Dioxide Emissions

Many times project analysis starts with data on the carbon content of fuels or the release of carbon from sinks. This means that the analysis may end with a result expressed in terms of carbon emissions or carbon capture. However, the EPAct 1605(b) voluntary reporting program requires that reports be expressed in terms of greenhouse gases—that is, carbon dioxide.

The conversion of quantities of carbon to quantities of carbon dioxide is simple. The atomic weight of carbon is 12. The atomic weight of oxygen is 16. Hence, the molecular weight of carbon dioxide (carbon dioxide) is 44 (one atom of carbon, 12, plus two atoms of oxygen, 32). This means that 12 grams (or pounds or tons) of carbon released as carbon dioxide is associated with 44 grams (or pounds or tons) of carbon dioxide. Therefore, the conversion from carbon released to carbon dioxide emissions can be expressed as follows:

$$\text{Weight of } CO_2 = 44/12 \text{ weight of carbon} = 3.67 \text{ weight of carbon}$$

Appendix E

Reportable Greenhouse Gases for Which Global Warming Potentials Have Been Developed

Reportable Greenhouse Gases for Which Global Warming Potentials Have Been Developed

A Global Warming Potential (GWP) is a measure, or index, of the impact that each gas has on global warming relative to the effect that carbon dioxide has. So, for example, if a kilogram of a certain gas has a GWP of 2, that kilogram of that gas is expected to have twice as much effect on global warming as a kilogram of carbon dioxide. Using GWPs helps decision-makers (for example, in utilities or industry) and policymakers put different greenhouse gases on an equivalent scale to perform a wide variety of analyses:

- performing cost-benefit analyses of various candidate projects to reduce greenhouse gas emissions
- assessing the relative contributions of the many human activities contributing to greenhouse gas emissions
- comparing (and ranking) climate effects from competing technologies and energy uses, including consideration of different energy policies
- developing approaches to minimize the impact of human activities on the climate system
- comparing the global climate change contributions of various countries
- functioning as a signal to policymakers for encouraging some activities and discouraging others
- determining approaches most appropriate for industries and governments to meet commitments to help reduce the radiative forcing on climate from increasing concentrations and emissions of greenhouse gases.

Several factors affect the GWP value for any particular gas. Gases that have large immediate warming effects (instantaneous radiative forcing) will generally have higher GWPs. However, the effects of greenhouse gases are realized over a period of time, so the second important factor in calculating a GWP is the length of time the gas stays in the atmosphere (atmospheric lifetime). Generally, gases with longer atmospheric lifetimes will have higher GWPs than gases with shorter lifetimes. Finally, some gases interact with other gases in the atmosphere (indirect effects) to either increase or decrease the impact of the gases.

The GWPs listed in Table E.1 were developed recently for the Intergovernmental Panel on Climate Change (IPCC 1994). This list will replace GWPs developed previously (IPCC 1990, 1992); as the science continues to evolve, the gases and the values will likely be revised again. Because of the difficulty in modeling the interactions of the various gases, these GWPs do not include indirect effects except where noted. (See, for example, methane.)

Table E.1 actually contains three sets of GWPs, each set calculated over a different time period. The GWP calculated for 20 years provides a comparison of the effects of gases in the relatively near future. In contrast, the 500-year index will give a relatively higher GWP values to long-lived gases than the 20-year GWP values.

As you use these GWPs, remember the limitations of such a measure. First, for most gases the GWPs do not account for indirect effects. So, for example, while CFC-11 appears to be 5,000 times as potent a greenhouse gas as carbon dioxide over the short term, its indirect effects may entirely negate its direct effects. This possibility is not reflected in the GWP index. Second, the modeling of atmospheric chemistry is rapidly changing. These GWPs are significantly different from those used by the IPCC two years ago, and they will probably be revised again. Third, these GWPs rest on an assumption that the background concentration of carbon dioxide is stable and that the atmospheric system is in equilibrium. This assumption is clearly unrealistic, though it helps to provide consistency in making assessments.

Table E.1. Direct Global Warming Potentials[(a)]

Species	Chemical Formula	Atmospheric Lifetime (years)	Global Warming Potential (Time Horizon)		
			20 years	**100 years**	**500 years**
CO_2	CO_2	(b)	1	1	1
CFCs					
CFC-11	$CFCl_3$	50±5	5000	3900	1400
CFC-12	CF_2Cl_2	102	8000	8300	4000
CFC-13	$CClF_3$	640	8700	12100	13800
CFC-113	$C_2F_3Cl_3$	85	5100	4900	2200
CFC-114	$C_2F_4Cl_2$	300	7000	9100	7900
CFC-115	C_2F_5Cl	1700	6300	9100	12400
HCFCS, etc.					
HCFC-22	CF_2HCl	13.3	4300	1600	500
HCFC-123	$C_2F_3HCl_2$	1.4	310	90	30
HCFC-124	C_2F_4HCl	5.9	1500	470	140
HCFC-141b	$C_2FH_2Cl_3$	9.4	1800	620	190
HCFC-142b	$C_2F_2H_3Cl$	19.5	4300	2000	600
HCFC-225CA	$C_3F_5HCl_2$	2.5	590	180	50
HCFC-225CB	$C_3F_5HCl_2$	6.6	1800	570	170
Carbon Tetrachloride	CCl_4	42	2000	1400	480
Methyl Chloroform	CH_3CCl_3	5.4±0.4	360	110	30
Bromocarbons[(f)]					
H-1301	CF_3Br	65	6300	5500	2100
Other					
HFC-23	CHF_3	390	9500	12700	12400
HFC-32	CH_2F_2	6	1900	570	180
HFC-43-10mee		20.8	3400	1600	490
HFC-125	C_2HF_5	36.0	5000	3200	1100
HFC-134	$C_2H_2F_4$	11.9	3200	1160	350
HFC-134a	CH_2FCF_3	17.7	3800	1700	510
HFC-152a	$C_2H_4F_2$	1.5	440	130	40
HFC-143a	$C_2H_3F_3$	55	5300	4300	1600
HFC-227ea	C_3HF_7	43.0	4800	3300	1100

Table E.1. (cont'd)

Species	Chemical Formula	Atmospheric Lifetime (years)	Global Warming Potential (Time Horizon) 20 years	100 years	500 years
HFC-236fa	$C_3H_2F_6$	265	6200	7900	6500
HFC-245ca	$C_3H_3F_5$	1.0	300	90	30
HFC-245ca	$C_3H_3F_5$	9.2	2400	790	240
Chloroform	$CHCl_3$	0.55	20	5	1
Methylene chloride	CH_2Cl_2	0.41	30	10	3
Sulfur hexafluoride	SF_6	3200	9300	13600	19500
Perfluoromethane	CF_4	50000	2700	4000	6100
Perfluoroethane	C_2F_6	10000	6100	9000	13500
Perfluorocyclo-butane	$c\text{-}C_4F_8$	3200	6100	8900	12800
Perfluorohexane	C_6F_{14}	3200	5600	8900	17800
Methane[(c)]	CH_4	12-18[(d)]	56-110	19-43	9-16
Nitrous oxide	N_2O	121	290	320	170
Trifluoroiodo-methane	CF_3I	<0.005	<6	<<1	<<<1
Carbon monoxide[(e)]	CO	months	+	+	+
Nonmethane hydrocarbons[(e)]	NMHCs	days to months	+	+	+
Nitrous oxides[(e)]	NO_x	days	+	+	+

(a) Referenced to the AGWP for the Bern carbon cycle model CO_2 decay response and future CO_2 atmospheric concentrations held constant at current levels (based on IPCC 1994 and WMO 1994).
(b) Decay of CO_2 is a complex function of the carbon cycle.
(c) Includes direct and indirect components.
(d) Includes the dependence of the residence time on CH_4 abundance.
(e) GWPs for indirect effects involving emissions from short-lived gases are particularly difficult to evaluate, though the sign of these three types is expected to be positive.
(f) You may report other halogenated substances, such as H-1211 and H-2402, that are not listed in this table and for which the IPCC has not developed an estimate of global warming potential.

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