

# ANNEX C

## Methodology for Estimating Emissions of CH<sub>4</sub>, N<sub>2</sub>O, and Ambient Air Pollutants from Stationary Combustion

### Estimates of CH<sub>4</sub> and N<sub>2</sub>O Emissions

Methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions from stationary combustion were estimated using IPCC emission factors and methods. Estimates were obtained by multiplying emission factors—by sector and fuel type—by fossil fuel and wood consumption data. This “top-down” methodology is characterized by two basic steps, described below. Data are presented in Table C-1 through Table C-5.

#### Step 1: Determine Energy Consumption by Sector and Fuel Type

Greenhouse gas emissions from stationary combustion activities were grouped into four sectors: industrial, commercial, residential, and electricity generation. For CH<sub>4</sub> and N<sub>2</sub>O, estimates were based upon consumption of coal, gas, oil, and wood. Energy consumption data were obtained from EIA’s *Annual Energy Review* (EIA 2001), and adjusted from higher to lower heating values by multiplying by 0.9 for natural gas and by 0.95 for coal and petroleum fuel. This is a simplified convention used by the International Energy Agency. Table C-1 provides annual energy consumption data for the years 1990 through 2000.

#### Step 2: Determine the Amount of CH<sub>4</sub> and N<sub>2</sub>O Emitted

Activity data for each sector and fuel type were then multiplied by emission factors to obtain emissions estimates. Emission factors were taken from the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997). Table C-2 provides emission factors used for each sector and fuel type.

### Estimates of NO<sub>x</sub>, CO, and NMVOC Emissions

For ambient air pollutants, the major source categories included were those identified in EPA (2001): coal, fuel oil, natural gas, wood, other fuels (i.e., bagasse, liquefied petroleum gases, coke, coke oven gas, and others), and stationary internal combustion, which includes emissions from internal combustion engines not used in transportation. EPA (2001) periodically estimates emissions of NO<sub>x</sub>, CO, and NMVOCs by sector and fuel type using a “bottom-up” estimating procedure. In other words, the emissions were calculated either for individual sources (e.g., industrial boilers) or for many sources combined, using basic activity data (e.g., fuel consumption or deliveries, etc.) as indicators of emissions. EPA (2001) projected emissions for years subsequent to their bottom-up estimates. The national activity data used to calculate the individual categories were obtained from various sources. Depending upon the category, these activity data may include fuel consumption or deliveries of fuel, tons of refuse burned, raw material processed, etc. Activity data were used in conjunction with emission factors that relate the quantity of emissions to the activity.

Table C-3 through Table C-5 present ambient air pollutant emission estimates for 1990 through 2000.

The basic calculation procedure for most source categories presented in EPA (2001) is represented by the following equation:

$$E_{p,s} = A_s \times EF_{p,s} \times (1 - C_{p,s}/100)$$

where,

E	=	emissions
p	=	pollutant
s	=	source category
A	=	activity level
EF	=	emission factor
C	=	percent control efficiency

The EPA currently derives the overall emission control efficiency of a category from a variety of sources, including published reports, the 1985 National Acid Precipitation and Assessment Program (NAPAP) emissions inventory, and other EPA databases. The U.S. approach for estimating emissions of NO<sub>x</sub>, CO, and NMVOCs from stationary combustion as described above is similar to the methodology recommended by the IPCC (IPCC/UNEP/OECD/IEA 1997).

**Table C-1: Fuel Consumption by Stationary Combustion for Calculating CH<sub>4</sub> and N<sub>2</sub>O Emissions (Tbtu)**

Fuel/End-Use Sector	1990	1995	1996	1997	1998	1999	2000
<b>Coal</b>	<b>18,169</b>	<b>19,196</b>	<b>20,117</b>	<b>20,660</b>	<b>20,862</b>	<b>20,940</b>	<b>21,722</b>
Residential	62	53	54	58	44	47	47
Commercial	93	80	82	87	66	70	70
Industry	1,478	1,427	1,370	1,381	1,317	1,271	1,119
Electricity Generation	16,536	17,635	18,610	19,135	19,434	19,553	20,487
<b>Petroleum</b>	<b>11,655</b>	<b>11,277</b>	<b>11,941</b>	<b>12,186</b>	<b>12,199</b>	<b>12,376</b>	<b>12,067</b>
Residential	1,266	1,361	1,457	1,432	1,324	1,456	1,492
Commercial	907	715	741	705	665	672	723
Industry	8,152	8,382	8,858	9,056	8,857	8,895	8,657
Electricity Generation	1,329	819	885	993	1,354	1,352	1,195
<b>Natural Gas</b>	<b>18,230</b>	<b>21,087</b>	<b>21,475</b>	<b>21,522</b>	<b>20,871</b>	<b>21,146</b>	<b>22,233</b>
Residential	4,519	4,984	5,390	5,125	4,669	4,858	5,081
Commercial	2,698	3,117	3,250	3,310	3,098	3,130	3,425
Industry	6,963	7,743	8,052	7,966	7,366	7,279	7,250
Electricity Generation	4,050	5,243	4,783	5,122	5,737	5,880	6,477
<b>Wood</b>	<b>1,872</b>	<b>2,044</b>	<b>2,085</b>	<b>1,993</b>	<b>1,998</b>	<b>2,177</b>	<b>2,187</b>
Residential	581	596	595	433	387	414	433
Commercial	37	45	49	47	47	51	52
Industrial	1,254	1,402	1,441	1,513	1,564	1,711	1,702
Electricity Generation	NO						

Note: Totals may not sum due to independent rounding.  
NO (Not occurring)

**Table C-2: CH<sub>4</sub> and N<sub>2</sub>O Emission Factors by Fuel Type and Sector (g/GJ)<sup>1</sup>**

Fuel/End-Use Sector	CH <sub>4</sub>	N <sub>2</sub> O
<b>Coal</b>		
Residential	300	1.4
Commercial	10	1.4
Industry	10	1.4
Electricity Generation	1	1.4
<b>Petroleum</b>		
Residential	10	0.6
Commercial	10	0.6
Industry	2	0.6
Electricity Generation	3	0.6
<b>Natural Gas</b>		
Residential	5	0.1
Commercial	5	0.1
Industry	5	0.1
Electricity Generation	1	0.1
<b>Wood</b>		
Residential	300	4.0
Commercial	300	4.0
Industrial	30	4.0
Electricity Generation	30	4.0

<sup>1</sup> GJ (Gigajoule) = 10<sup>9</sup> joules. One joule = 9.486×10<sup>-4</sup> Btu

**Table C-3: NO<sub>x</sub> Emissions from Stationary Combustion (Gg)**

Sector/Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<b>Electricity Generation</b>	<b>6,045</b>	<b>5,914</b>	<b>5,901</b>	<b>6,034</b>	<b>5,956</b>	<b>5,792</b>	<b>5,566</b>	<b>5,691</b>	<b>5,628</b>	<b>5,128</b>	<b>4,763</b>
Coal	5,119	5,043	5,062	5,211	5,113	5,061	5,057	5,120	4,932	4,472	4,149
Fuel Oil	200	192	154	163	148	87	107	132	202	171	140
Natural gas	513	526	526	500	536	510	259	289	346	336	320
Wood	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Internal Combustion	213	152	159	160	159	134	143	150	149	151	154
<b>Industrial</b>	<b>2,754</b>	<b>2,703</b>	<b>2,786</b>	<b>2,859</b>	<b>2,855</b>	<b>2,852</b>	<b>2,864</b>	<b>2,814</b>	<b>2,768</b>	<b>2,840</b>	<b>2,924</b>
Coal	530	517	521	534	546	541	493	487	475	489	493
Fuel Oil	240	215	222	222	219	224	204	196	190	194	207
Natural gas	1,072	1,134	1,180	1,207	1,210	1,202	1,093	1,079	1,066	1,089	1,137
Wood	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other Fuels <sup>a</sup>	119	117	115	113	113	111	109	104	104	107	112
Internal Combustion	792	720	748	783	767	774	965	948	933	961	976
<b>Commercial</b>	<b>336</b>	<b>333</b>	<b>348</b>	<b>360</b>	<b>365</b>	<b>365</b>	<b>367</b>	<b>374</b>	<b>353</b>	<b>371</b>	<b>376</b>
Coal	36	33	35	37	36	35	31	32	34	34	34
Fuel Oil	88	80	84	84	86	94	87	88	73	72	73
Natural gas	181	191	204	211	215	210	224	229	220	240	244
Wood	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other Fuels <sup>a</sup>	31	29	25	28	28	27	24	25	26	25	26
<b>Residential</b>	<b>749</b>	<b>829</b>	<b>879</b>	<b>827</b>	<b>817</b>	<b>813</b>	<b>726</b>	<b>699</b>	<b>651</b>	<b>683</b>	<b>677</b>
Coal <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Fuel Oil <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Natural Gas <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wood	42	45	48	40	40	44	27	27	27	27	30
Other Fuels <sup>a</sup>	708	784	831	787	777	769	699	671	624	656	647
<b>Total</b>	<b>9,884</b>	<b>9,779</b>	<b>9,914</b>	<b>10,080</b>	<b>9,993</b>	<b>9,822</b>	<b>9,522</b>	<b>9,577</b>	<b>9,400</b>	<b>9,022</b>	<b>8,740</b>

IE (Included elsewhere)

NO (Not occurring)

<sup>a</sup> "Other Fuels" include LPG, waste oil, coke oven gas, coke, and non-residential wood (EPA 2001).<sup>b</sup> Coal, fuel oil, and natural gas emissions are included in the "Other Fuels" category (EPA 2001).

Note: Totals may not sum due to independent rounding.

**Table C-4: CO Emissions from Stationary Combustion (Gg)**

Sector/Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<b>Electricity Generation</b>	<b>329</b>	<b>317</b>	<b>318</b>	<b>329</b>	<b>335</b>	<b>338</b>	<b>363</b>	<b>376</b>	<b>379</b>	<b>367</b>	<b>380</b>
Coal	213	212	214	224	224	227	228	233	220	208	212
Fuel Oil	18	17	14	15	13	9	11	13	17	17	16
Natural gas	46	46	47	45	48	49	72	76	88	87	95
Wood	NO										
Internal Combustion	52	41	43	46	50	52	53	54	54	55	56
<b>Industrial</b>	<b>798</b>	<b>835</b>	<b>867</b>	<b>946</b>	<b>944</b>	<b>958</b>	<b>1,080</b>	<b>1,055</b>	<b>1,044</b>	<b>1,067</b>	<b>1,108</b>
Coal	95	92	92	92	91	88	100	99	96	99	100
Fuel Oil	67	54	58	60	60	64	49	47	46	47	50
Natural gas	205	257	272	292	306	313	308	308	305	308	327
Wood	IE										
Other Fuels <sup>a</sup>	253	242	239	259	260	270	317	302	303	309	322
Internal Combustion	177	189	205	243	228	222	306	299	294	303	308
<b>Commercial</b>	<b>205</b>	<b>196</b>	<b>204</b>	<b>207</b>	<b>212</b>	<b>211</b>	<b>130</b>	<b>133</b>	<b>130</b>	<b>135</b>	<b>137</b>
Coal	13	13	13	14	13	14	13	13	14	14	14
Fuel Oil	16	16	16	16	16	17	17	18	15	15	15
Natural gas	40	40	46	48	49	49	58	59	57	62	63
Wood	IE										
Other Fuels <sup>a</sup>	136	128	128	129	134	132	42	44	44	45	46
<b>Residential</b>	<b>3,668</b>	<b>3,965</b>	<b>4,195</b>	<b>3,586</b>	<b>3,515</b>	<b>3,876</b>	<b>2,364</b>	<b>2,361</b>	<b>2,352</b>	<b>2,359</b>	<b>2,515</b>
Coal <sup>b</sup>	IE										
Fuel Oil <sup>b</sup>	IE										
Natural Gas <sup>b</sup>	IE										
Wood	3,430	3,711	3,930	3,337	3,272	3,628	2,133	2,133	2,133	2,133	2,292
Other Fuels <sup>a</sup>	238	255	265	249	243	248	231	229	220	226	223
<b>Total</b>	<b>4,999</b>	<b>5,313</b>	<b>5,583</b>	<b>5,068</b>	<b>5,007</b>	<b>5,383</b>	<b>3,936</b>	<b>3,926</b>	<b>3,905</b>	<b>3,928</b>	<b>4,140</b>

IE (Included elsewhere)

NO (Not occurring)

<sup>a</sup> "Other Fuels" include LPG, waste oil, coke oven gas, coke, and non-residential wood (EPA 2001).<sup>b</sup> Coal, fuel oil, and natural gas emissions are included in the "Other Fuels" category (EPA 2001).

Note: Totals may not sum due to independent rounding.

**Table C-5: NMVOC Emissions from Stationary Combustion (Gg)**

Sector/Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<b>Electricity Generation</b>	<b>43</b>	<b>40</b>	<b>40</b>	<b>41</b>	<b>41</b>	<b>40</b>	<b>44</b>	<b>47</b>	<b>50</b>	<b>50</b>	<b>51</b>
Coal	25	25	25	26	26	26	25	26	26	26	27
Fuel Oil	5	5	4	4	4	2	3	4	5	5	4
Natural gas	2	2	2	2	2	2	7	7	9	9	10
Wood	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Internal Combustion	11	9	9	9	9	9	9	10	10	10	10
<b>Industrial</b>	<b>165</b>	<b>177</b>	<b>169</b>	<b>169</b>	<b>178</b>	<b>187</b>	<b>162</b>	<b>160</b>	<b>159</b>	<b>162</b>	<b>169</b>
Coal	7	5	7	5	7	5	6	6	6	6	6
Fuel Oil	11	10	11	11	11	11	8	7	7	7	8
Natural gas	52	54	47	46	57	66	54	54	54	54	57
Wood	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other Fuels <sup>a</sup>	46	47	45	46	45	45	32	31	31	32	34
Internal Combustion	49	61	60	60	58	59	63	62	61	63	64
<b>Commercial</b>	<b>18</b>	<b>18</b>	<b>20</b>	<b>22</b>	<b>21</b>	<b>21</b>	<b>24</b>	<b>24</b>	<b>24</b>	<b>26</b>	<b>26</b>
Coal	1	1	1	1	1	1	1	1	1	1	1
Fuel Oil	3	2	3	3	3	3	3	3	3	3	3
Natural gas	7	8	9	10	10	10	13	13	12	14	14
Wood	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other Fuels <sup>a</sup>	8	7	7	8	8	8	8	8	8	9	9
<b>Residential</b>	<b>686</b>	<b>739</b>	<b>782</b>	<b>670</b>	<b>657</b>	<b>726</b>	<b>788</b>	<b>787</b>	<b>786</b>	<b>787</b>	<b>843</b>
Coal <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Fuel Oil <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Natural Gas <sup>b</sup>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wood	651	704	746	633	621	689	756	756	756	756	812
Other Fuels <sup>a</sup>	35	35	36	36	36	37	33	32	30	31	31
<b>Total</b>	<b>912</b>	<b>975</b>	<b>1,011</b>	<b>901</b>	<b>898</b>	<b>973</b>	<b>1,020</b>	<b>1,019</b>	<b>1,018</b>	<b>1,025</b>	<b>1,089</b>

IE (Included elsewhere)

NO (Not occurring)

<sup>a</sup> "Other Fuels" include LPG, waste oil, coke oven gas, coke, and non-residential wood (EPA 2001).<sup>b</sup> Coal, fuel oil, and natural gas emissions are included in the "Other Fuels" category (EPA 2001).

Note: Totals may not sum due to independent rounding.

