ANNEX 4 IPCC Reference Approach for Estimating CO_2 Emissions from Fossil Fuel Combustion

It is possible to estimate carbon dioxide (CO_2) emissions from fossil fuel consumption using alternative methodologies and different data sources than those described in the Estimating Emissions from Fossil Fuel Combustion Annex. For example, the UNFCCC reporting guidelines request that countries, in addition to their "bottom-up" sectoral methodology, complete a "top-down" Reference Approach for estimating CO_2 emissions from fossil fuel combustion. Volume 2: Energy, Chapter 6: Reference Approach of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) states, "comparability between the sectoral and reference approaches continues to allow a country to produce a second independent estimate of CO_2 emissions from fuel combustion with limited additional effort and data requirements." (IPCC 2006). This reference method estimates fossil fuel consumption by adjusting national aggregate fuel production data for imports, exports, and stock changes rather than relying on end-user consumption surveys. The basic principle is that once C-based fuels are brought into a national economy, they are either saved in some way (e.g., stored in products, kept in fuel stocks, or left unoxidized in ash) or combusted, and therefore the C in them is oxidized and released into the atmosphere. Accounting for actual consumption of fuels at the sectoral or sub-national level is not required. The following discussion provides the detailed calculations for estimating CO_2 emissions from fossil fuel combustion from the United States using the IPCC-recommended Reference Approach.

Step 1: Collect and Assemble Data in Proper Format

To ensure the comparability of national inventories, the IPCC has recommended that countries report energy data using the International Energy Agency (IEA) reporting convention. National energy statistics were collected in physical units from several EIA documents in order to obtain the necessary data on production, imports, exports, and stock changes.

It was necessary to make a number of modifications to these data to generate more accurate apparent consumption estimates of these fuels. The first modification adjusts for consumption of fossil fuel feedstocks accounted for in the Industrial Processes and Product Use chapter, which include the following: unspecified coal for coal coke used in iron and steel production; natural gas, distillate fuel, and coal used in iron and steel production; natural gas used for ammonia production; petroleum coke used in the production of aluminum, ferroalloys, titanium dioxide, ammonia, and silicon carbide; and other oil and residual fuel oil used in the manufacture of C black. The second modification adjusts for the fact that EIA energy statistics include synthetic natural gas in coal and natural gas data. The third modification adjusts for the inclusion of ethanol in motor gasoline statistics. Ethanol is a biofuel, and net carbon fluxes from changes in biogenic carbon reservoirs in croplands are accounted for in the estimates for Land Use, Land-Use Change, and Forestry (see Chapter 6). The fourth modification adjusts for consumption of bunker fuels, which refer to quantities of fuels used for international transportation estimated separately from U.S. totals. The fifth modification consists of the addition of U.S. territories data that are typically excluded from the national aggregate energy statistics. The territories include Puerto Rico, U.S. Virgin Islands, Guam, American Samoa, Wake Island, and U.S. Pacific Islands. These data, as well as the production, import, export, and stock change statistics, are presented in Table A- 266.

The C content of fuel varies with the fuel's heat content. Therefore, for an accurate estimation of CO_2 emissions, fuel statistics were provided on an energy content basis (e.g., Btu or joules). Because detailed fuel production statistics are typically provided in physical units (as in Table A- 266 for 2013), they were converted to units of energy before CO_2 emissions were calculated. Fuel statistics were converted to their energy equivalents by using conversion factors provided by EIA. These factors and their data sources are displayed in Table A- 267. The resulting fuel type-specific energy data for 2013 are provided in Table A- 268.

Step 2: Estimate Apparent Fuel Consumption

The next step of the IPCC Reference Approach is to estimate "apparent consumption" of fuels within the country. This requires a balance of primary fuels produced, plus imports, minus exports, and adjusting for stock changes. In this way, C enters an economy through energy production and imports (and decreases in fuel stocks) and is transferred out of the country through exports (and increases in fuel stocks). Thus, apparent consumption of primary fuels (including crude oil, natural gas liquids, anthracite, bituminous, subbituminous and lignite coal, and natural gas) can be calculated as follows:

$$Apparent\ Consumption = Production + Imports - Exports - Stock\ Change$$

Flows of secondary fuels (e.g., gasoline, residual fuel, coke) should be added to primary apparent consumption. The production of secondary fuels, however, should be ignored in the calculations of apparent consumption since the C

contained in these fuels is already accounted for in the supply of primary fuels from which they were derived (e.g., the estimate for apparent consumption of crude oil already contains the C from which gasoline would be refined). Flows of secondary fuels should therefore be calculated as follows:

Secondary Consumption = Imports - Exports - Stock Change

Note that this calculation can result in negative numbers for apparent consumption of secondary fuels. This result is perfectly acceptable since it merely indicates a net export or stock increase in the country of that fuel when domestic production is not considered.

Next, the apparent consumption and secondary consumption need to be adjusted for feedstock uses of fuels accounted for in the Industrial Processes and Product Use chapter, international bunker fuels, and U.S. territory fuel consumption. Bunker fuels and feedstocks accounted for in the Industrial Processes and Product Use chapter are subtracted from these estimates, while fuel consumption in U.S. territories is added.

The IPCC Reference Approach calls for estimating apparent fuel consumption before converting to a common energy unit. However, certain primary fuels in the United States (e.g., natural gas and steam coal) have separate conversion factors for production, imports, exports, and stock changes. In these cases, it is not appropriate to multiply apparent consumption by a single conversion factor since each of its components has different heat contents. Therefore, United States fuel statistics were converted to their heat equivalents before estimating apparent consumption. Results are provided in Table A- 267.

Step 3: Estimate Carbon Emissions

Once apparent consumption is estimated, the remaining calculations are similar to those for the "bottom-up" Sectoral Approach (see Estimating Emissions from Fossil Fuel Combustion Annex). Potential CO_2 emissions were estimated using fuel-specific C coefficients (see Table A- 268).[1] The C in products from non-energy uses of fossil fuels (e.g., plastics or asphalt) was then estimated and subtracted (see Table A-270). This step differs from the Sectoral Approach in that emissions from both fuel combustion and non-energy uses are accounted for in this approach. Finally, to obtain actual CO_2 emissions, net emissions were adjusted for any C that remained unoxidized as a result of incomplete combustion (e.g., C contained in ash or soot). The fraction oxidized was assumed to be 100 percent for petroleum, coal, and natural gas based on guidance in IPCC (2006) (see Estimating Emissions from Fossil Fuel Combustion Annex).

Step 4: Convert to CO_2 Emissions

Because the IPCC reporting guidelines recommend that countries report greenhouse gas emissions on a full molecular weight basis, the final step in estimating CO_2 emissions from fossil fuel consumption was converting from units of C to units of CO_2. Actual C emissions were multiplied by the molecular-to-atomic weight ratio of CO_2 to C (44/12) to obtain total CO_2 emitted from fossil fuel combustion in million metric tons (MMT). The results are contained in Table A-269.

Comparison Between Sectoral and Reference Approaches

These two alternative approaches can both produce reliable estimates that are comparable within a few percent. Note that the reference approach *includes* emissions from non-energy uses. Therefore, these totals should be compared to the aggregation of fuel use and emission totals from Emissions of CO_2 from Fossil Fuel Combustion and Carbon Emitted from Non-Energy Uses of Fossil Fuels Annexes. These two sections together are henceforth referred to as the Sectoral Approach. Other than this distinction, the major difference between methodologies employed by each approach lies in the energy data used to derive C emissions (i.e., the actual surveyed consumption for the Sectoral Approach versus apparent consumption derived for the Reference Approach). In theory, both approaches should yield identical results. In practice, however, slight discrepancies occur. An examination of past CRF table submissions during UNFCCC reviews has highlighted the need to further investigate these discrepancies. The investigation found that the most recent (two to three) inventory years tend to have larger differences in consumption and emissions estimates occurring earlier in the time series. This is a result of annual energy consumption data revisions in the EIA energy statistics, and the revisions have the greatest impact on the most recent few years of inventory estimates. As a result, the differences between the sectoral and reference approach decrease and are resolved over time. For the United States, these differences are discussed below.

[1] Carbon coefficients from EIA were used wherever possible. Because EIA did not provide coefficients for coal, the IPCC-recommended emission factors were used in the top-down calculations for these fuels. See notes in Table A- 269 for more specific source information.

Differences in Total Amount of Energy Consumed

Table A-272 summarizes the differences between the Reference and Sectoral approaches in estimating total energy consumption in the United States. Although theoretically the two methods should arrive at the same estimate for U.S. energy consumption, the Reference Approach provides an energy consumption total that is 2.0 percent lower than the Sectoral Approach for 2013. The greatest differences lie in lower estimates for coal and petroleum consumption for the Reference Approach (3.2 percent and 3.1 percent, respectively) and higher estimates for natural gas consumption for the Reference Approach (0.3 percent).

There are several potential sources for the discrepancies in consumption estimates:

- *Product Definitions.* The fuel categories in the Reference Approach are different from those used in the Sectoral Approach, particularly for petroleum. For example, the Reference Approach estimates apparent consumption for crude oil. Crude oil is not typically consumed directly, but refined into other products. As a result, the United States does not focus on estimating the energy content of the various grades of crude oil, but rather estimating the energy content of the various products resulting from crude oil refining. The United States does not believe that estimating apparent consumption for crude oil, and the resulting energy content of the crude oil, is the most reliable method for the United States to estimate its energy consumption. Other differences in product definitions include using sector-specific coal statistics in the Sectoral Approach (i.e., residential, commercial, industrial coking, industrial other, and transportation coal), while the Reference Approach characterizes coal by rank (i.e. anthracite, bituminous, etc.). Also, the liquefied petroleum gas (LPG) statistics used in the bottom-up calculations are actually a composite category composed of natural gas liquids (NGL) and LPG.
- *Heat Equivalents.* It can be difficult to obtain heat equivalents for certain fuel types, particularly for categories such as "crude oil" where the key statistics are derived from thousands of producers in the United States and abroad.
- *Possible inconsistencies in U.S. Energy Data*. The United States has not focused its energy data collection efforts on obtaining the type of aggregated information used in the Reference Approach. Rather, the United States believes that its emphasis on collection of detailed energy consumption data is a more accurate methodology for the United States to obtain reliable energy data. Therefore, top-down statistics used in the Reference Approach may not be as accurately collected as bottom-up statistics applied to the Sectoral Approach.
- *Balancing Item.* The Reference Approach uses *apparent* consumption estimates while the Sectoral Approach uses *reported* consumption estimates. While these numbers should be equal, there always seems to be a slight difference that is often accounted for in energy statistics as a "balancing item."

Differences in Estimated CO_2 Emissions

Given these differences in energy consumption data, the next step for each methodology involved estimating emissions of CO_2. Table A-273 summarizes the differences between the two methods in estimated C emissions.

As mentioned above, for 2013, the Reference Approach resulted in a 2.0 percent lower estimate of energy consumption in the United States than the Sectoral Approach. The resulting emissions estimate for the Reference Approach was 1.8 percent lower. Estimates of natural gas emissions from the Reference Approach are higher (0.3 percent), and coal and petroleum emission estimates are lower (3.4 percent and 2.0 percent, respectively) than the Sectoral Approach. Potential reasons for these differences may include:

- *Product Definitions.* Coal data is aggregated differently in each methodology, as noted above. The format used for the Sectoral Approach likely results in more accurate estimates than in the Reference Approach. Also, the Reference Approach relies on a "crude oil" category for determining petroleum-related emissions. Given the many sources of crude oil in the United States, it is not an easy matter to track potential differences in C content between many different sources of crude; particularly since information on the C content of crude oil is not regularly collected.
- *Carbon Coefficients.* The Reference Approach relies on several default C coefficients by rank provided by IPCC (IPCC 2006), while the Sectoral Approach uses annually updated category-specific coefficients by sector that are likely to be more accurate. Also, as noted above, the C coefficient for crude oil is more uncertain than that for specific secondary petroleum products, given the many sources and grades of crude oil consumed in the United States.

Although the two approaches produce similar results, the United States believes that the "bottom-up" Sectoral Approach provides a more accurate assessment of CO_2 emissions at the fuel level. This improvement in accuracy is largely

a result of the data collection techniques used in the United States, where there has been more emphasis on obtaining the detailed products-based information used in the Sectoral Approach than obtaining the aggregated energy flow data used in the Reference Approach. The United States believes that it is valuable to understand both methods.

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Table A- 266: 2013 U.S. Energy Statistics (Physical Units)

Fuel Category (Units)	Fuel Type	Production	Imports	Exports	Stock Change	Adjustment	Bunkers	U.S. Territories
Solid Fuels (Thousand Short Tons)	Anthracite Coal	1,613	[a]	[a]	[a]			
	Bituminous Coal	444,601	[a]	[a]	[a]			
	Sub-bituminous Coal	467,577	[a]	[a]	[a]	367		
	Lignite	71,050	[a]	[a]	[a]	4,335		
	Coke		138	840	266			
	Unspecified Coal		8,906	117,659	(38,430)	2,556		1,653
Gas Fuels (Million Cubic Feet)	Natural Gas	24,273,568	2,883,355	1,572,413	(546,158)	295,505		48,028
Liquid Fuels (Thousand Barrels)	Crude Oil	2,717,876	2,821,480	48,968	(7,732)			
	Nat Gas Liquids and LRGs	951,057	66,290	170,941	(24,843)			2,628
	Other Liquids	0	480,460	130,881	7,371			
	Motor Gasoline	39,812	16,440	136,146	(16,235)	215,691		26,075
	Aviation Gasoline		25	0	(180)			
	Kerosene		334	2,256	127			946
	Jet Fuel		30,832	56,989	(2,437)		160,665	7,299
	Distillate Fuel		56,465	413,888	(7,266)	416	5,679	9,643
	Residual Fuel		82,173	132,152	4,193	14,000	60,409	17,745
	Naphtha for petrochemical feedstocks		11,050	0	(266)			
	Petroleum Coke		3,534	191,219	1,028	7,937		
	Other Oil for petrochemical feedstocks		2,383	0	162	1,240		
	Special Naphthas		3,796	0	34			
	Lubricants		11,565	26,697	403			172
	Waxes		1,931	2,003	(11)			
	Asphalt/Road Oil		9,635	9,251	(715)			
	Still Gas		0	0	0			
	Misc. Products		61	396	(38)			6,796

[a] Included in Unspecified Coal

Note: Parentheses indicate negative values.

Data Sources: Solid and Gas Fuels: EIA (2015); Liquid Fuels: EIA (1995-2014).

Table A- 267: Conversion Factors to Energy Units (Heat Equivalents)

Fuel Category (Units)	Fuel Type	Production	Imports	Exports	Stock Change	Adjustment	Bunkers	U.S. Territories
Solid Fuels (Million Btu/Short Ton)	Anthracite Coal	22.57						
	Bituminous Coal	23.89						
	Sub-bituminous Coal	17.14				28.16		
	Lignite	12.87				12.87		
	Coke		23.37	24.60	23.37			
	Unspecified		25.00	25.97	20.86	219.35		25.14
Natural Gas (BTU/Cubic Foot)		1,027	1,025	1,009	1,027	1,027		1,027
Liquid Fuels (Million Btu/Barrel)	Crude Oil	5.80	6.01	5.80	5.80		5.80	5.80
	Nat Gas Liquids and LRGs	3.71	3.71	3.71	3.71		3.71	3.71
	Other Liquids	5.83	5.83	5.83	5.83		5.83	5.83
	Motor Gasoline	5.06	5.06	5.06	5.06	5.06	5.06	5.06
	Aviation Gasoline		5.05	5.05	5.05		5.05	5.05
	Kerosene		5.67	5.67	5.67		5.67	5.67
	Jet Fuel		5.67	5.67	5.67		5.80	5.67
	Distillate Fuel		5.83	5.83	5.83	5.83	5.83	5.83
	Residual Oil		6.29	6.29	6.29	6.29	6.29	6.29
	Naphtha for petrochemical feedstocks		5.25	5.25	5.25		5.25	5.25
	Petroleum Coke		6.02	6.02	6.02	6.02	6.02	6.02
	Other Oil for petrochemical feedstocks		5.83	5.83	5.83	5.83	5.83	5.83
	Special Naphthas		5.25	5.25	5.25		5.25	5.25
	Lubricants		6.07	6.07	6.07		6.07	6.07
	Waxes		5.54	5.54	5.54		5.54	5.54
	Asphalt/Road Oil		6.64	6.64	6.64		6.64	6.64
	Still Gas		6.00	6.00	6.00		6.00	6.00
	Misc. Products		5.80	5.80	5.80		5.80	5.80

Data Sources: Coal and lignite production: EIA (1992); Unspecified Solid Fuels, Coke, Natural Gas and Petroleum Products: EIA (1995-2014).

Table A- 268: 2013 Apparent Consumption of Fossil Fuels (TBtu)

Fuel Category	Fuel Type	Production	Imports	Exports	Stock Change	Adjustment	Bunkers	U.S. Territories	Apparent Consumption
Solid Fuels	Anthracite Coal	36.4							**36.4**
	Bituminous Coal	10,621.5							**10,621.5**
	Sub-bituminous Coal	8,014.3				10.3			**8,003.9**
	Lignite	914.1				55.8			**858.4**
	Coke		3.2	20.7	6.2				**(23.7)**
	Unspecified		222.7	3,055.8	(801.7)	560.7		41.6	**(2,550.6)**
Gas Fuels	Natural Gas	24,929.0	2,955.4	1,586.6	(560.9)	303.3		49.3	**26,604.7**
Liquid Fuels	Crude Oil	15,763.7	16,957.1	284.0	(44.8)				**32,481.6**
	Nat Gas Liquids and LRGs	3,532.2	246.2	634.9	(92.3)			9.8	**3,245.6**
	Other Liquids		2,798.7	762.4	42.9				**1,993.4**
	Motor Gasoline	201.5	83.2	689.2	(82.2)			132.0	**(190.2)**
	Aviation Gasoline		0.1	(0.9)	(0.9)				**1.9**
	Kerosene		1.9	12.8	0.7			5.4	**(6.3)**
	Jet Fuel		174.8	323.1	(13.8)		931.6	41.4	**(1,024.8)**
	Distillate Fuel		328.9	2,410.9	(42.3)	2.4	33.1	56.2	**(2,019.0)**
	Residual Oil		516.6	830.8	26.4	88.0	379.8	111.6	**(696.8)**
	Naphtha for petrochemical feedstocks		58.0		(1.4)				**59.4**
	Petroleum Coke		21.3	1,151.9	6.2	47.8			**(1,184.6)**
	Other Oil for petrochemical feedstocks		13.9		0.9	7.2			**5.7**
	Special Naphthas		19.9		0.2				**19.7**
	Lubricants		70.1	161.9	2.4			1.0	**(93.2)**
	Waxes		10.7	11.1	(0.1)				**(0.3)**
	Asphalt/Road Oil		63.9	61.4	(4.7)				**7.3**
	Still Gas								
	Misc. Products		0.4	2.3	(0.2)			39.4	**37.7**
Total		**64,012.7**	**24,547.1**	**11,998.9**	**(1,559.4)**	**1,075.7**	**1,344.5**	**487.6**	**76,187.7**

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

Table A- 269: 2013 Potential CO_2 Emissions

Fuel Category	Fuel Type	Apparent Consumption (QBtu)	Carbon Coefficients (MMT Carbon/QBtu)	Potential Emissions (MMT CO_2 Eq.)
Solid Fuels	Anthracite Coal	0.04	28.28	**3.8**
	Bituminous Coal	10.62	25.44	**990.8**
	Sub-bituminous Coal	8.00	26.50	**777.7**
	Lignite	0.86	26.65	**83.9**
	Coke	(0.02)	31.00	**(2.7)**
	Unspecified	(2.55)	25.34	**(236.9)**
Gas Fuels	Natural Gas	26.60	14.46	**1,410.1**
Liquid Fuels	Crude Oil	32.48	20.31	**2,418.4**
	Nat Gas Liquids and LRGs	3.25	16.91	**201.3**
	Other Liquids	1.99	20.31	**148.4**
	Motor Gasoline	(0.19)	19.46	**(13.6)**
	Aviation Gasoline	0.00	18.86	**0.1**
	Kerosene	(0.01)	19.96	**(0.5)**
	Jet Fuel	(1.02)	19.70	**(74.0)**
	Distillate Fuel	(2.02)	20.17	**(149.3)**
	Residual Oil	(0.70)	20.48	**(52.3)**
	Naphtha for petrochemical feedstocks	0.06	18.55	**4.0**
	Petroleum Coke	(1.18)	27.85	**(121.0)**
	Other Oil for petrochemical feedstocks	0.01	20.17	**0.4**
	Special Naphthas	0.02	19.74	**1.4**
	Lubricants	(0.09)	20.20	**(6.9)**
	Waxes	(0.00)	19.80	**(0.0)**
	Asphalt/Road Oil	0.01	20.55	**0.5**
	Still Gas		18.20	**-**
	Misc. Products	0.04	20.31	**2.8**
Total				**5,386.5**

Note: Emissions values are presented in CO_2 equivalent mass units using IPCC AR4 GWP values.
Data Sources: C content coefficients by coal rank from USGS (1998) and SAIC (2004); Unspecified Solid Fuels, EIA (1995-2014), Natural Gas and Liquid Fuels: EPA (1995-2014).
Note: Totals may not sum due to independent rounding.
Note: Parentheses indicate negative values.

Table A-270: 2013 Non-Energy Carbon Stored in Products

Fuel Type	Consumption for Non-Energy Use (TBtu)	Carbon Coefficients (MMT Carbon/QBtu)	Carbon Content (MMT Carbon)	Fraction Sequestered	Carbon Stored (MMT CO_2 Eq.)
Coal	119.6	31.00	3.71	0.10	2.0
Natural Gas	296.9	14.46	4.29	0.66	10.4
Asphalt & Road Oil	783.3	20.55	16.10	1.00	58.8
LPG	2,062.0	17.06	35.18	0.66	85.3
Lubricants	269.5	20.20	5.44	0.09	1.8
Pentanes Plus	45.4	19.10	0.87	0.66	2.1
Petrochemical Feedstocks	[a]	[a]	[a]	[a]	39.7
Petroleum Coke	0.0	27.85	0.00	0.30	0.0
Special Naphtha	96.5	19.74	1.90	0.66	4.6
Waxes/Misc.	[a]	[a]	[a]	[a]	0.9
Misc. U.S. Territories Petroleum	[a]	[a]	[a]	[a]	0.3
Total					**205.9**

[a] Values for Misc. U.S. Territories Petroleum, Petrochemical Feedstocks and Waxes/Misc. are not shown because these categories are aggregates of numerous smaller components.
Note: Totals may not sum due to independent rounding.

Table A-271: 2013 Reference Approach CO_2 Emissions from Fossil Fuel Consumption (MMT CO_2 Eq. unless otherwise noted)

Fuel Category	Potential Emissions	Carbon Sequestered	Net Emissions	Fraction Oxidized	Total Emissions
Coal	1,616.6	2.0	1,614.6	100.0%	1,614.6
Petroleum	2,359.9	193.5	2,166.3	100.0%	2,166.3
Natural Gas	1,410.1	10.4	1,399.7	100.0%	1,399.7
Total	**5,386.5**	**205.9**	**5,180.6**		**5,180.6**

Note: Emissions values are presented in CO_2 equivalent mass units using IPCC AR4 GWP values.
Note: Totals may not sum due to independent rounding.

Table A-272: Fuel Consumption in the United States by Estimating Approach (TBtu)[a]

Approach	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sectoral	**69,724**	**74,941**	**82,559**	**81,135**	**81,933**	**82,332**	**83,964**	**83,926**	**82,758**	**83,981**	**81,282**	**76,490**	**79,048**	**77,543**	**75,703**	**77,723**
Coal	18,072	19,187	21,748	21,121	21,192	21,625	21,893	22,187	21,833	22,067	21,753	19,231	20,267	19,071	16,827	17,498
Natural Gas	19,184	22,170	23,392	22,466	23,163	22,561	22,623	22,282	21,960	23,371	23,594	23,193	24,312	24,679	25,832	26,528
Petroleum	32,468	33,585	37,418	37,548	37,578	38,145	39,448	39,457	38,964	38,543	35,936	34,066	34,470	33,794	33,044	33,697
Reference (Apparent)	**68,730**	**74,018**	**81,524**	**80,676**	**81,431**	**81,724**	**83,600**	**83,495**	**82,061**	**83,899**	**80,398**	**76,455**	**77,916**	**76,492**	**75,268**	**76,188**
Coal	17,573	18,567	20,957	20,710	20,797	21,081	21,735	21,986	21,534	21,577	21,391	19,243	19,620	18,756	16,483	16,946
Natural Gas	19,276	22,274	23,484	22,535	23,238	22,630	22,690	22,349	22,029	23,441	23,666	23,277	24,409	24,778	25,924	26,605
Petroleum	31,882	33,177	37,083	37,431	37,395	38,013	39,175	39,160	38,498	38,881	35,341	33,935	33,886	32,958	32,861	32,637
Difference	**-1.4%**	**-1.2%**	**-1.3%**	**-0.6%**	**-0.6%**	**-0.7%**	**-0.4%**	**-0.5%**	**-0.8%**	**-0.1%**	**-1.1%**	**0.0%**	**-1.4%**	**-1.4%**	**-0.6%**	**-2.0%**
Coal	-2.8%	-3.2%	-3.6%	-1.9%	-1.9%	-2.5%	-0.7%	-0.9%	-1.4%	-2.2%	-1.7%	0.1%	-3.2%	-1.7%	-2.0%	-3.2%
Natural Gas	0.5%	0.5%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.3%
Petroleum	-1.8%	-1.2%	-0.9%	-0.3%	-0.5%	-0.3%	-0.7%	-0.8%	-1.2%	0.9%	-1.7%	-0.4%	-1.7%	-2.5%	-0.6%	-3.1%

[a] Includes U.S. territories. Does not include international bunker fuels.

Note: Totals may not sum due to independent rounding.

Table A-273: CO_2 Emissions from Fossil Fuel Combustion by Estimating Approach (MMT CO_2 Eq.)[a]

Approach	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sectoral	**4,858**	**5,169**	**5,734**	**5,657**	**5,697**	**5,750**	**5,857**	**5,886**	**5,802**	**5,879**	**5,695**	**5,303**	**5,481**	**5,339**	**5,131**	**5,277**
Coal	1,719	1,823	2,071	2,011	2,022	2,066	2,093	2,121	2,083	2,106	2,076	1,835	1,935	1,820	1,607	1,671
Natural Gas	1,007	1,164	1,227	1,178	1,215	1,183	1,189	1,172	1,156	1,230	1,242	1,221	1,277	1,297	1,357	1,395
Petroleum	2,133	2,182	2,435	2,468	2,460	2,501	2,575	2,593	2,562	2,543	2,376	2,247	2,269	2,222	2,167	2,212
Reference (Apparent)	**4,792**	**5,132**	**5,683**	**5,654**	**5,697**	**5,738**	**5,883**	**5,891**	**5,782**	**5,888**	**5,653**	**5,333**	**5,414**	**5,284**	**5,124**	**5,181**
Coal	1,654	1,756	1,988	1,967	1,976	2,002	2,065	2,087	2,049	2,053	2,036	1,832	1,868	1,789	1,573	1,615
Natural Gas	1,013	1,170	1,233	1,182	1,220	1,188	1,194	1,176	1,160	1,235	1,247	1,226	1,283	1,303	1,363	1,400
Petroleum	2,126	2,206	2,462	2,505	2,501	2,548	2,625	2,627	2,573	2,600	2,370	2,275	2,262	2,193	2,188	2,166
Difference	**-1.4%**	**-0.7%**	**-0.9%**	**-0.1%**	**0.0%**	**-0.2%**	**0.4%**	**0.1%**	**-0.3%**	**0.1%**	**-0.7%**	**0.6%**	**-1.2%**	**-1.0%**	**-0.1%**	**-1.8%**
Coal	-3.8%	-3.7%	-4.0%	-2.2%	-2.3%	-3.1%	-1.3%	-1.6%	-1.7%	-2.5%	-1.9%	-0.2%	-3.4%	-1.8%	-2.1%	-3.4%
Natural Gas	0.6%	0.6%	0.5%	0.3%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0.5%	0.5%	0.4%	0.3%
Petroleum	-0.3%	1.1%	1.1%	1.5%	1.7%	1.9%	1.9%	1.3%	0.4%	2.3%	-0.3%	1.3%	-0.3%	-1.3%	1.0%	-2.0%

[a] Includes U.S. territories. Does not include international bunker fuels.

Note: Totals may not sum due to independent rounding.