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 Annex 2.1 Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion. For example, the United Nations Framework Convention on Climate Change (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 Intergovernmental Panel on Climate Change (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." 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 carbon (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 Energy Information Administration (EIA) documents in order to obtain the necessary data on production, imports, exports, and stock changes.

It was necessary to modify 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-243.

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-243 for 2018), 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-244. The resulting fuel type-specific energy data for 2018 are provided in Table A-245.

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-244.

Step 3: Estimate Carbon Emissions

Once apparent consumption is estimated, the remaining calculations are similar to those for the "bottom-up" Sectoral Approach (see Annex 2.1 Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion). Potential CO_2 emissions were estimated using fuel-specific C coefficients (see Table A-245).[126] The C in products from non-energy uses of fossil fuels (e.g., plastics or asphalt) that is stored was then estimated and subtracted (see Table A-247). This step differs from the Sectoral Approach in that emissions from both fuel combustion and non-energy uses are accounted for in the Reference Approach. As a result, the Reference Approach emission estimates are comparable to those of the Sectoral Approach, with the exception that the NEU source category emissions are included in the Reference Approach and reported seperatly in the Sectoral 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 Annex 2.1 Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion).

Step 4: Convert to CO_2 Emissions

Because the *2006 IPCC 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

[126] 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-246 for more specific source information.

obtain total CO_2 emitted from fossil fuel combustion in million metric tons (MMT). The results are contained in Table A-246.

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 Annex 2.1 Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion and Annex 2.3 Methodology for Estimating Carbon Emitted from Non-Energy Uses of Fossil Fuels. 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 Common Reporting Format (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.

Differences in Total Amount of Energy Consumed

Table A-249 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 1.6 percent lower than the Sectoral Approach for 2018. The greatest differences lie in lower estimates for petroleum and coal consumption for the Reference Approach (3.4 percent and 1.7 percent, respectively) and higher estimates for natural gas consumption for the Reference Approach (0.4 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 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-250 summarizes the differences between the two methods in estimated C emissions.

As mentioned above, for 2018, the Reference Approach resulted in a 1.6 percent lower estimate of energy consumption in the United States than the Sectoral Approach. The resulting emissions estimate for the Reference Approach was 1.3 percent lower. Estimates of natural gas emissions from the Reference Approach are higher (0.5 percent), and coal and petroleum emission estimates are lower (2.3 percent and 2.1 percent, respectively) than the Sectoral Approach. Potential reasons for these differences may include:

- *Product Definitions.* Coal data are 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 (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-243: 2018 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	1,896	[1]	[1]	[1]			
	Bituminous Coal	357,226	[1]	[1]	[1]			
	Sub-bituminous Coal	340,007	[1]	[1]	[1]	367		
	Lignite	57,038	[1]	[1]	[1]	4,854		
	Coke		117	1,151	(204)			
	Unspecified Coal		5,954	115,632	(36,910)	3,606		1,963
Gas Fuels (Million Cubic Feet)	Natural Gas	30,481,655	2,888,847	3,607,418	(312,251)	349,812		55,000
Liquid Fuels (Thousand Barrels)	Crude Oil	4,011,521	2,835,491	747,540	7,163			
	Nat Gas Liquids and Liquefied Refinery Gases	1,594,813	71,953	584,596	(980)			4,005
	Other Liquids	0	469,808	186,963	9,874			
	Motor Gasoline	36,772	16,343	320,755	1,246	236,769		34,263
	Aviation Gasoline		72	0	(85)			
	Kerosene		616	1,560	475			411
	Jet Fuel		45,352	81,343	281		198,850	8,044
	Distillate Fuel		63,769	470,334	(5,476)	80	16,286	18,586
	Residual Fuel		77,166	117,265	(1,063)	9,000	66,417	20,195
	Naphtha for petrochemical feedstocks		6,445	0	545			
	Petroleum Coke		4,175	214,443	(620)	12,451		
	Other Oil for petrochemical feedstocks		1,410	0	(24)	1,240		
	Special Naphthas		4,688	0	269			
	Lubricants		15,838	38,504	1,934			172
	Waxes		1,943	1,554	(179)			
	Asphalt/Road Oil		13,876	9,238	5,321			
	Still Gas		0	0	0			
	Misc. Products		97	356	(11)			13,144

Note: Parentheses indicate negative values.
[1] Included in Unspecified Coal
Sources: Solid and Gas Fuels: EIA (2019a and 2019b); Liquid Fuels: EIA (2020).

Table A-244: 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)		22.57						
	Anthracite Coal							
	Bituminous Coal	23.89						
	Sub-bituminous Coal	17.14				28.16		
	Lignite	12.87				12.87		
	Coke		20.42	24.29	20.42			
	Unspecified		25.00	25.97	20.86	127.91		25.14
Natural Gas (BTU/Cubic Foot)		1,036	1,025	1,009	1,036	1,036		1,036
Liquid Fuels (Million Btu/Barrel)	Crude Oil	5.71	6.06	5.72	5.72		5.72	5.72
	Nat Gas Liquids and Liquefied Refinery Gases	3.59	3.59	3.59	3.59		3.59	3.59
	Other Liquids	5.83	5.83	5.83	5.83		5.83	5.83
	Motor Gasoline	5.05	5.05	5.05	5.05	5.05	5.05	5.05
	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[a]		5.67	5.67	5.67		5.77	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

Sources: Coal and lignite production: EIA (1992); Coke, Natural Gas Crude Oil, NGL and Motor Gasoline: EIA (2019b); Unspecified Solid Fuels: EIA (2011).

[a] Jet fuel used in bunkers has a different heating value based on data specific to that source. When physical values are converted based on a combined heating value across all sources of jet fuel (as shown in Table 1.A(b) of CRF) it will not necessarily match jet fuel bunker data (as shown in Table 1.D of CRF).

Table A-245: 2018 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	42.8							42.8
	Bituminous Coal	8,534.1							8,534.1
	Sub-bituminous Coal	5,827.7				10.3			5,817.4
	Lignite	733.8				62.4			671.4
	Coke		2.4	28.0	(4.2)				(21.4)
	Unspecified		148.9	3,003.2	(770.0)	461.2		49.3	(2,496.2)
Gas Fuels	Natural Gas	31,579.0	2,961.1	3,639.9	(323.5)	362.4		57.0	30,918.2
Liquid Fuels	Crude Oil	22,889.7	17,191.6	4,276.7	41.0				35,763.7
	Nat Gas Liquids and Liquefied Refinery Gases	5,727.0	258.4	2,099.3	(3.5)			14.4	3,904.0
	Other Liquids		2,736.6	1,089.1	57.5				1,590.1
	Motor Gasoline	185.8	82.6	1,621.1	6.3			173.2	(1,185.8)
	Aviation Gasoline		0.4	(0.4)	(0.4)				1.2
	Kerosene		3.5	8.8	2.7			2.3	(5.7)
	Jet Fuel		257.1	461.2	1.6		1,146.8	45.6	(1,306.8)
	Distillate Fuel		371.5	2,739.7	(31.9)	0.5	94.9	108.3	(2,323.4)
	Residual Oil		485.1	737.2	(6.7)	56.6	417.6	127.0	(592.6)
	Naphtha for petrochemical feedstocks		33.8		2.9				31.0
	Petroleum Coke		25.2	1,291.8	(3.7)	75.0			(1,337.9)
	Other Oil for petrochemical feedstocks		8.2		(0.1)	7.2			1.1
	Special Naphthas		24.6		1.4				23.2
	Lubricants		96.1	233.5	11.7			1.0	(148.2)
	Waxes		10.8	8.6	(1.0)				3.1
	Asphalt/Road Oil		92.1	61.3	35.3				(4.5)
	Still Gas								
	Misc. Products		0.6	2.1	(0.1)			76.2	74.7
Total		**75,520.1**	**24,790.4**	**21,301.0**	**(984.7)**	**1,035.7**	**1,659.2**	**654.3**	**77,953.5**

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

Table A-246: 2018 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	4.4
	Bituminous Coal	8.53	25.41	795.0
	Sub-bituminous Coal	5.82	26.49	565.1
	Lignite	0.67	26.76	65.9
	Coke	(0.02)	31.00	(2.4)
	Unspecified	(2.50)	25.34	(231.9)
Gas Fuels	Natural Gas	30.92	14.43	1,636.1
Liquid Fuels	Crude Oil	35.76	20.31	2,662.7
	Nat Gas Liquids and LRGs	3.90	16.81	240.6
	Other Liquids	1.59	20.31	118.4
	Motor Gasoline	(1.19)	19.46	(84.6)
	Aviation Gasoline	+	18.86	0.1
	Kerosene	(0.01)	19.96	(0.4)
	Jet Fuel	(1.31)	19.70	(94.4)
	Distillate Fuel	(2.32)	20.17	(171.8)
	Residual Oil	(0.59)	20.48	(44.5)
	Naphtha for petrochemical feedstocks	0.03	18.55	2.1
	Petroleum Coke	(1.34)	27.85	(136.6)
	Other Oil for petrochemical feedstocks	+	20.17	0.1
	Special Naphthas	0.02	19.74	1.7
	Lubricants	(0.15)	20.20	(11.0)
	Waxes	+	19.80	0.2
	Asphalt/Road Oil	(+)	20.55	(0.3)
	Still Gas	0.00	18.20	0.0
	Misc. Products	0.07	20.31	5.6
Total				**5,320.0**

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

+ Does not exceed 0.005 QBtu or 0.05 MMT CO_2 Eq.

Sources: C content coefficients by coal rank from USGS (1998), PSU (2010), Gunderson (2019), IGS (2019), ISGS (2019), and EIA (2019a); natural gas C content coefficients from EPA (2010) and EIA (2019b); unspecified solid fuel and liquid fuel C content coefficients from EPA (2010).

Table A-247: 2018 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	124.7	31.00	3.87	0.10	2.1
Natural Gas	304.7	14.43	4.40	0.65	10.5
Asphalt & Road Oil	792.8	20.55	16.29	1.00	59.5
LPG	2,485.5	17.06	42.40	0.65	101.6
Lubricants	260.0	20.20	5.25	0.09	1.8
Pentanes Plus	104.8	19.10	2.00	0.65	4.8
Petrochemical Feedstocks	[1]	[1]	[1]	[1]	36.1
Petroleum Coke	0.0	27.85	0.00	0.30	0.0
Special Naphtha	86.5	19.74	1.71	0.65	4.1
Waxes/Misc.	[1]	[1]	[1]	[1]	0.7
Misc. U.S. Territories Petroleum	[1]	[1]	[1]	[1]	0.6
Total					**221.7**

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

Table A-248: 2018 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	1,196.0	2.1	1,1940.0	100.0%	1,1940.0
Petroleum	2,487.9	209.1	2,278.7	100.0%	2,278.7
Natural Gas	1,636.1	10.5	1,625.6	100.0%	1,625.6
Total	**5,320.0**	**221.7**	**5,098.3**		**5,098.3**

Note: Totals may not sum due to independent rounding.

Table A-249: Fuel Consumption in the United States by Estimating Approach (TBtu)[a]

Approach	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sectoral	**69,714**	**74,833**	**82,433**	**83,830**	**82,636**	**83,804**	**81,114**	**76,281**	**78,786**	**77,310**	**75,547**	**77,559**	**78,235**	**77,314**	**76,516**	**76,018**	**79,247**
Coal	18,072	19,187	21,748	22,187	21,833	22,067	21,753	19,231	20,267	19,071	16,827	17,452	17,370	15,041	13,783	13,379	12,771
Natural Gas	19,168	22,170	23,392	22,282	21,960	23,371	23,594	23,193	24,312	24,679	25,832	26,560	27,141	27,931	28,151	27,759	30,788
Petroleum	32,474	33,477	37,293	39,361	38,843	38,366	35,767	33,857	34,207	33,560	32,888	33,547	33,725	34,342	34,582	34,880	35,687

Reference (Apparent)	**68,685**	**73,965**	**81,452**	**83,430**	**81,987**	**83,816**	**80,326**	**76,371**	**77,784**	**76,372**	**75,481**	**76,172**	**76,888**	**76,062**	**75,170**	**75,004**	**77,953**
Coal	17,573	18,567	20,957	21,986	21,534	21,577	21,391	19,243	19,620	18,756	16,642	17,097	17,210	14,796	13,547	13,112	12,548
Natural Gas	19,275	22,274	23,484	22,349	22,029	23,441	23,666	23,277	24,409	24,778	25,924	26,637	27,224	28,011	28,235	27,880	30,918
Petroleum	31,837	33,124	37,010	39,095	38,424	38,799	35,270	33,851	33,755	32,838	32,915	32,438	32,454	33,255	33,388	34,013	34,487
Difference	**-1.5%**	**-1.2%**	**-1.2%**	**-0.5%**	**-0.8%**	**0.0%**	**-1.0%**	**0.1%**	**-1.3%**	**-1.2%**	**-0.1%**	**-1.8%**	**-1.7%**	**-1.6%**	**-1.8%**	**-1.3%**	**-1.6%**
Coal	-2.8%	-3.2%	-3.6%	-0.9%	-1.4%	-2.2%	-1.7%	0.1%	-3.2%	-1.7%	-1.1%	-2.0%	-0.9%	-1.6%	-1.7%	-2.0%	-1.7%
Natural Gas	0.6%	0.5%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%
Petroleum	-2.0%	-1.1%	-0.8%	-0.7%	-1.1%	1.1%	-1.4%	0.0%	-1.3%	-2.2%	0.1%	-3.3%	-3.8%	-3.2%	-3.5%	-2.5%	-3.4%

Note: Totals may not sum due to independent rounding.

+ Does not exceed 0.05%.

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

Table A-250: CO_2 Emissions from Fossil Fuel Combustion by Estimating Approach (MMT CO_2 Eq.)[a]

Approach	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sectoral	**4,859**	**5,161**	**5,725**	**5,880**	**5,794**	**5,868**	**5,684**	**5,290**	**5,465**	**5,325**	**5,125**	**5,266**	**5,304**	**5,158**	**5,056**	**5,015**	**5,166**
Coal	1,718	1,822	2,070	2,120	2,082	2,105	2,075	1,835	1,934	1,820	1,607	1,667	1,658	1,438	1,317	1,279	1,222
Natural Gas	1,006	1,164	1,228	1,172	1,156	1,231	1,243	1,222	1,279	1,299	1,359	1,397	1,426	1,466	1,477	1,457	1,617
Petroleum	2,135	2,175	2,427	2,588	2,555	2,532	2,366	2,233	2,251	2,206	2,159	2,202	2,221	2,255	2,262	2,279	2,327
Reference (Apparent)	**4,791**	**5,128**	**5,678**	**5,887**	**5,778**	**5,883**	**5,648**	**5,327**	**5,404**	**5,277**	**5,144**	**5,180**	**5,224**	**5,086**	**4,980**	**4,957**	**5,098**
Coal	1,653	1,755	1,988	2,087	2,048	2,052	2,035	1,830	1,866	1,787	1,585	1,625	1,637	1,409	1,287	1,241	1,194
Natural Gas	1,013	1,171	1,233	1,176	1,160	1,235	1,247	1,227	1,285	1,305	1,365	1,402	1,431	1,471	1,482	1,464	1,626
Petroleum	2,125	2,203	2,457	2,624	2,569	2,596	2,366	2,270	2,253	2,185	2,194	2,153	2,156	2,206	2,211	2,252	2,279
Difference	**-1.4%**	**-0.6%**	**-0.8%**	**0.1%**	**-0.3%**	**0.3%**	**-0.6%**	**0.7%**	**-1.1%**	**-0.9%**	**0.4%**	**-1.6%**	**-1.5%**	**-1.4%**	**-1.5%**	**-1.2%**	**-1.3%**
Coal	-3.8%	-3.7%	-4.0%	-1.6%	-1.7%	-2.5%	-1.9%	-0.2%	-3.5%	-1.8%	-1.4%	-2.5%	-1.2%	-2.0%	-2.3%	-3.0%	-2.3%
Natural Gas	0.7%	0.6%	0.5%	0.3%	0.3%	0.3%	0.3%	0.4%	0.5%	0.5%	0.4%	0.3%	0.3%	0.3%	0.4%	0.5%	0.5%
Petroleum	-0.5%	1.3%	1.2%	1.4%	0.6%	2.5%	0.0%	1.6%	0.1%	-0.9%	1.7%	-2.2%	-2.9%	-2.2%	-2.3%	-1.2%	-2.1%

Note: Totals may not sum due to independent rounding

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