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 inclusion of biofuels in motor fuel statistics. 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 third modification adjusts for consumption of bunker fuels, which refer to quantities of fuels used for international transportation estimated separately from U.S. totals. The fourth 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-223. Furthermore, waste fuels (e.g., MSW combustion) is not captured as part of the reference approach energy statistics. Therefore, waste fuels are not used in the comparison between the sectoral and reference approaches energy use in order to improve consistency between the reference and sectoral approaches in terms of estimation coverage. However, sectoral estimates for MSW combustion emissions are added to the reference approach in order to align CO_2 emissions comparisons across the two different approaches.

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-223 for 2022), 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-224. The resulting fuel type-specific energy data for 2022 are provided in Table A-225.

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-224.

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-225).[125] 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-226). This step differs from the Sectoral Approach in that emissions from both fuel combustion and non-energy uses are accounted for directly 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 separately in the Sectoral Approach.[126] 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).

[125] 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-226 for more specific source information.

[126] The emission scope of the reference and the sectoral approaches is the same since C emissions from NEU (i.e. C not excluded) are included in both approaches, the energy consumption covered by the sectoral approach includes both fuel consumption and NEU, which is reported under category 1.A.5 other, hence the scope of energy consumption under the sectoral approach is comparable with that under the reference approach without excluding NEU. To the extent it is indicated that NEU emissions are subtracted under the sectoral approach, it means that they are reported separately, not that they are not covered by the sectoral approach.

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 obtain total CO_2 emitted from fossil fuel combustion in million metric tons (MMT). The results are contained in Table A-226.

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. Note: fossil emissions from the combustion of municipal solid waste (MSW) including from tires are derived following the approach described in Annex 3.7 Incineration of Waste for both the reference and sectoral approaches, as there are no reference data available.

Differences in Total Amount of Energy Consumed

Table A-229 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 0.7 percent lower than the Sectoral Approach for 2022. The greatest differences lie in lower estimates for petroleum and coal consumption for the Reference Approach (2.0 percent and 0.6 percent, respectively) and higher estimates for natural gas consumption for the Reference Approach (0.7 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 (e.g., anthracite, bituminous).

- *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. Furthermore, Hydrocarbon Gas Liquids (HGL) is a blend of multiple paraffinic hydrocarbons: ethane, propane, isobutane, and normal butane, and their associated olefins: ethylene, propylene, isobutylene, and butylene, each with their own heat content. The heat content for HGL varies annually depending upon the components of the blend.

- *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 1a 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.

Table A-223: 2022 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	2,486	[1]	[1]	[1]			
	Bituminous Coal	270,526	[1]	[1]	[1]			
	Sub-bituminous Coal	273,618	[1]	[1]	[1]	367		
	Lignite	47,526	[1]	[1]	[1]	1,230		
	Coke		67	2,318	51			
	Unspecified Coal		6,313	85,956	(1,383)	18,128		1,405
Gaseous Fuels	Natural Gas (Million Cubic Feet)	35,861,012	3,024,160	6,903,902	(280,533)	404,491		49,747
	Still Gas (Thousand Barrels)		0	0	0			
Liquid Fuels (Thousand Barrels)	Crude Oil	4,347,377	2,292,673	1,305,317	(212,734)			
	HGL	2,165,567	63,602	879,446	18,097			2,380
	Other Liquids	0	404,923	163,234	2,375			
	Motor Gasoline	67	36,547	316,497	(577)	230,279		14,967
	Aviation Gasoline		423	0	55			
	Kerosene		118	2,719	(120)			80
	Jet Fuel		43,707	64,835	(759)		166,571	7,679
	Distillate Fuel		68,628	439,413	(11,140)	50	16,620	8,503
	Residual Fuel		73,643	40,205	4,969	7,000	51,722	8,835
	Naphtha for petrochemical feedstocks		4,562	0	(99)			
	Petroleum Coke		3,469	205,537	54	8,649		
	Other Oil for petrochemical feedstocks		1,177	14,244	(53)	1,240		
	Special Naphthas		5,044	0	(29)			
	Lubricants		17,853	34,765	374			172
	Waxes		2,117	1,655	52			
	Asphalt/Road Oil		21,534	6,187	1,592			
	Misc. Products		0	683	683			1

[1] Included in Unspecified Coal

Note: Parentheses indicate negative values.

Sources: Solid and Gas Fuels: EIA (2024 and 2023b); Liquid Fuels: EIA (2023a).

Table A-224: 2022 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	25.50						
	Bituminous Coal	23.91						
	Sub-bituminous Coal	17.49				25.79		
	Lignite	13.14				12.87		
	Coke		21.45	24.35	21.45			
	Unspecified		25.00	25.97	20.86	25.67		25.14
Gaseous Fuels	Natural Gas (BTU/Cubic Foot)	1,036	1,025	1,009	1,036	1,036		1,036
	Still Gas (Million Btu/Barrel)		6.00	6.00	6.00		6.00	6.00
Liquid Fuels (Million Btu/Barrel)	Crude Oil	5.68	6.09	5.72	5.72		5.72	5.72
	HGL	4.21	4.21	4.21	4.21		4.21	4.21
	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		5.68	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
	Misc. Products		5.80	5.80	5.80		5.80	5.80

[a] Jet fuel used in bunkers has a different heating value based on data specific to that source.

Sources: Coal and lignite production: EIA (1992); Coke, Natural Gas Crude Oil, HGL, and Motor Gasoline: EIA (2024); Unspecified Solid Fuels: EIA (2011).

Table A-225: 2022 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	63.4						-	63.4
	Bituminous Coal	6,468.7						-	6,468.7
	Sub-bituminous Coal	4,785.5				9.5		-	4,776.0
	Lignite	624.5				15.8		-	608.6
	Coke	-	1.4	56.4	1.1			-	(56.1)
	Unspecified	-	157.8	2,232.4	(28.8)	465.3		35.3	(2,475.7)
Gaseous Fuels	Natural Gas	37,152.0	3,099.8	6,966.0	(290.6)	419.1		51.5	33,208.9
	Still Gas	-	-	-	-		-	-	-
Liquid Fuels	Crude Oil	24,710.5	13,950.9	7,467.7	(1,217.1)		-	-	32,410.7
	HGL	9,109.3	267.5	3,699.3	76.1		-	10.0	5,611.4
	Other Liquids	-	2,358.7	950.8	13.8		-	-	1,394.0
	Motor Gasoline	0.3	184.5	1,598.0	(2.9)		-	75.6	(1,334.6)
	Aviation Gasoline	-	2.1	-	0.3		-	-	1.9
	Kerosene	-	0.7	15.4	(0.7)		-	0.5	(13.6)
	Jet Fuel	-	247.8	367.6	(4.3)		945.6	43.5	(1,017.5)
	Distillate Fuel	-	399.8	2,559.6	(64.9)	0.3	96.8	49.5	(2,142.5)
	Residual Oil	-	463.0	252.8	31.2	44.0	325.2	55.5	(134.7)
	Naphtha for petrochemical feedstocks	-	23.9	-	(0.5)		-	-	24.5
	Petroleum Coke	-	20.9	1,238.2	0.3	52.1	-	-	(1,269.7)
	Other Oil for petrochemical feedstocks	-	6.9	83.0	(0.3)	7.2	-	-	(83.0)
	Special Naphthas	-	26.5	-	(0.2)		-	-	26.6
	Lubricants	-	108.3	210.8	2.3		-	1.0	(103.8)
	Waxes	-	11.7	9.2	0.3		-	-	2.3
	Asphalt/Road Oil	-	142.9	41.1	10.6		-	-	91.3
	Misc. Products	-	-	4.0	4.0		-	0.0	(7.9)
Total		**82,914.2**	**21,475.1**	**27,752.3**	**(1,470.3)**	**1,013.2**	**1,367.5**	**322.6**	**76,049.1**

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

Table A-226: 2022 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	0.06	28.28	6.6
	Bituminous Coal	6.47	25.43	603.1
	Sub-bituminous Coal	4.78	26.49	463.8
	Lignite	0.61	26.80	59.8
	Coke	(0.06)	31.00	(6.4)
	Unspecified	(2.48)	25.34	(230.0)
Gaseous Fuels	Natural Gas	33.21	14.43	1,757.3
	Still Gas	0.00	18.20	0.0
Liquid Fuels	Crude Oil	32.41	20.31	2,413.1
	HGL	5.61	18.51	380.9
	Other Liquids	1.39	20.31	103.8
	Motor Gasoline	(1.33)	19.27	(94.3)
	Aviation Gasoline	+	18.86	0.1
	Kerosene	(0.01)	19.96	(1.0)
	Jet Fuel	(1.02)	19.70	(73.5)
	Distillate Fuel	(2.14)	20.22	(158.8)
	Residual Oil	(0.13)	20.48	(10.1)
	Naphtha for petrochemical feedstocks	0.02	18.55	1.7
	Petroleum Coke	(1.27)	27.85	(129.6)
	Other Oil for petrochemical feedstocks	(0.08)	20.17	(6.1)
	Special Naphthas	0.03	19.74	1.9
	Lubricants	(0.10)	20.20	(7.7)
	Waxes	+	19.80	0.2
	Asphalt/Road Oil	0.09	20.55	6.9
	Misc. Products	(0.01)	0.00	0.0
Total				**5,081.6**

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

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

Sources: Carbon content coefficients by coal rank from USGS (1998), PSU (2010), Gunderson (2019), IGS (2019), ISGS (2019), and eCFR (2024); natural gas carbon content coefficients from EPA (2010) and EIA (2024); unspecified solid fuel and liquid fuel carbon content coefficients from EPA (2010) and ICF (2020).

Table A-227: 2022 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	46.7	31.00	1.45	0.10	1.2
Natural Gas	654.2	14.43	9.44	0.72	24.8
Asphalt & Road Oil	916.1	20.55	18.83	1.00	68.7
HGL	2,758.8	16.82	46.39	0.72	121.8
Lubricants	125.4	20.20	2.53	0.09	0.9
Pentanes Plus	0.0	18.24	0.00	0.72	0.0
Petrochemical Feedstocks	[1]	[1]	[1]	[1]	25.0
Petroleum Coke	0.0	27.85	0.00	0.30	0.0
Special Naphtha	82.4	19.74	1.63	0.72	4.3
Waxes/Misc.	[1]	[1]	[1]	[1]	0.8
Misc. U.S. Territories Petroleum	[1]	[1]	[1]	[1]	0.0
Total					**247.4**

[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.

Note: Totals may not sum due to independent rounding.

Table A-228: 2022 Reference Approach CO_2 Emissions from Fossil Fuel Consumption (MMT CO_2 Eq.)

Fuel Category	Potential Emissions	Carbon Sequestered	Net Emissions	Fraction Oxidized	Total Emissions
Coal	897.0	1.2	895.8	100.0%	895.8
Petroleum	2,427.4	221.4	2,206.0	100.0%	2,206.0
Natural Gas	1,757.3	24.8	1,732.5	100.0%	1,732.5
Total	**5,081.6**	**247.4**	**4,834.3**	**-**	**4,834.3**

Note: Totals may not sum due to independent rounding.

Table A-229: Fuel Consumption in the United States by Estimating Approach (TBtu)[a]

Approach	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Sectoral	**69,697**	**74,607**	**82,491**	**83,639**	**78,461**	**76,973**	**76,170**	**75,492**	**78,792**	**77,804**	**71,121**	**75,316**	**76,576**
Coal	18,098	19,210	21,755	22,213	20,305	15,069	13,817	13,405	12,802	10,876	8,815	10,081	9,437
Natural Gas	19,147	22,148	23,372	22,267	24,297	27,941	28,154	27,716	30,815	31,913	31,271	31,391	32,984
Petroleum	32,452	33,249	37,363	39,159	33,859	33,962	34,200	34,371	35,175	35,015	31,036	33,844	34,155
Reference (Apparent)	**68,875**	**74,191**	**82,013**	**83,987**	**78,283**	**76,461**	**75,559**	**75,416**	**78,437**	**77,555**	**70,972**	**75,187**	**76,049**
Coal	17,733	18,757	21,157	22,219	19,876	15,003	13,725	13,301	12,715	10,838	8,750	9,907	9,385
Natural Gas	19,255	22,252	23,465	22,334	24,394	28,021	28,237	27,836	30,945	32,081	31,450	31,607	33,209
Petroleum	31,887	33,182	37,392	39,434	34,012	33,437	33,596	34,279	34,776	34,636	30,772	33,673	33,455
Difference	**-1.2%**	**-0.6%**	**-0.6%**	**0.4%**	**-0.2%**	**-0.7%**	**-0.8%**	**-0.1%**	**-0.5%**	**-0.3%**	**-0.2%**	**-0.2%**	**-0.7%**
Coal	-2.0%	-2.4%	-2.8%	0.0%	-2.1%	-0.4%	-0.7%	-0.8%	-0.7%	-0.4%	-0.7%	-1.7%	-0.6%
Natural Gas	0.6%	0.5%	0.4%	0.3%	0.4%	0.3%	0.3%	0.4%	0.4%	0.5%	0.6%	0.7%	0.7%
Petroleum	-1.7%	-0.2%	0.1%	0.7%	0.5%	-1.5%	-1.8%	-0.3%	-1.1%	-1.1%	-0.8%	-0.5%	-2.0%

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

Note: Totals may not sum due to independent rounding.

Table A-230: CO_2 Emissions from Fossil Fuel Combustion by Estimating Approach (MMT CO_2 Eq.)[a]

Approach	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Sectoral	**4,864**	**5,155**	**5,757**	**5,882**	**5,442**	**5,122**	**5,019**	**4,965**	**5,120**	**4,972**	**4,452**	**4,778**	**4,803**
Coal	1,720	1,824	2,070	2,121	1,937	1,438	1,319	1,280	1,222	1,038	843	964	903
Natural Gas	1,005	1,162	1,226	1,172	1,278	1,463	1,470	1,444	1,605	1,661	1,627	1,634	1,717
Petroleum	2,126	2,155	2,447	2,576	2,214	2,207	2,216	2,228	2,279	2,260	1,970	2,167	2,171
MSW	13	14	13	13	13	14	14	13	13	13	13	12	12
Reference (Apparent)	**4,828**	**5,171**	**5,746**	**5,957**	**5,470**	**5,149**	**5,042**	**5,022**	**5,170**	**5,038**	**4,514**	**4,844**	**4,847**
Coal	1,669	1,773	2,007	2,109	1,891	1,430	1,304	1,259	1,210	1,034	835	944	896
Natural Gas	1,012	1,169	1,232	1,176	1,284	1,468	1,476	1,452	1,615	1,673	1,640	1,649	1,733
Petroleum	2,135	2,215	2,494	2,659	2,282	2,238	2,247	2,297	2,331	2,318	2,027	2,238	2,206
MSW	13	14	13	13	13	14	14	13	13	13	13	12	12
Difference	**-0.7%**	**0.3%**	**-0.2%**	**1.3%**	**0.5%**	**0.5%**	**0.5%**	**1.2%**	**1.0%**	**1.3%**	**1.4%**	**1.4%**	**0.9%**
Coal	-3.0%	-2.8%	-3.0%	-0.6%	-2.4%	-0.6%	-1.1%	-1.6%	-1.0%	-0.4%	-0.9%	-2.1%	-0.8%
Natural Gas	0.7%	0.6%	0.5%	0.3%	0.5%	0.3%	0.4%	0.6%	0.6%	0.8%	0.8%	0.9%	0.9%
Petroleum	0.4%	2.8%	1.9%	3.2%	3.1%	1.4%	1.4%	3.1%	2.3%	2.6%	2.9%	3.3%	1.6%
MSW	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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

Note: Totals may not sum due to independent rounding.

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