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-227. Furthermore, waste fuels (e.g., MSW combustion) is not captured as part of the reference approach. Therefore, waste fuels are not used in the comparison between the sectoral and reference approaches in order to improve consistency between the reference and sectoral approaches in terms of estimation coverage.

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-227 for 2020), 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-228. The resulting fuel type-specific energy data for 2020 are provided in Table A-229.

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-228.

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-229).[176] 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-230). 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.[177] 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).

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[176] 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-230 for more specific source information.

[177] 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-230.

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-233 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 1.2 percent lower than the Sectoral Approach for 2020. The greatest differences lie in lower estimates for petroleum and coal consumption for the Reference Approach (2.5 percent and 2.4 percent, respectively) and higher estimates for natural gas consumption for the Reference Approach (0.6 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. Additionally, the accounting of pentanes plus as a part of HGL is different between the approaches. The United States reports consumption of all HGL components (i.e., ethane, propane, isobutane, normal butane, ethylene, propylene, isobutylene, butylene, and pentanes plus) for both approaches, but in the Sectoral Approach, pentanes plus is accounted for separately from other HGL components whereas it is included in HGL in the Reference Approach. 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. HGL also includes pentanes plus. 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 of CO_2. Table A-234 summarizes the differences between the two methods in estimated C emissions.

As mentioned above, for 2020, the Reference Approach resulted in a 1.2 percent lower estimate of energy consumption in the United States than the Sectoral Approach. The resulting emissions estimate for the Reference Approach was 0.3 percent higher. Estimates of natural gas and petroleum emissions from the Reference Approach are higher (0.8 percent and 1.2 percent respectively), and coal emission estimates are lower (2.6 percent) 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.

Table A-227: 2020 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	2,372	[1]	[1]	[1]			
	Bituminous Coal	237,916	[1]	[1]	[1]			
	Sub-bituminous Coal	245,781	[1]	[1]	[1]	367		
	Lignite	49,365	[1]	[1]	[1]	1,221		
	Coke		162	683	440			
	Unspecified Coal		5,137	69,067	(3,616)	16,432		1,500
Gaseous Fuels	Natural Gas (Million Cubic Feet)	33,389,498	2,551,342	5,283,607	179,766	402,211		48,258
	Still Gas (Thousand Barrels)		0	0	0			
Liquid Fuels (Thousand Barrels)	Crude Oil	4,129,563	2,150,267	1,173,342	55,818			
	HGL	1,893,894	58,380	761,581	16,472			449
	Other Liquids	0	388,466	149,742	(20,369)			
	Motor Gasoline	(29,607)	38,758	264,282	(731)	207,745		14,671
	Aviation Gasoline		253	0	(31)			
	Kerosene		351	2,203	(135)			81
	Jet Fuel		54,787	35,296	(1,840)		99,222	6,096
	Distillate Fuel		79,789	434,353	21,105	47	18,019	12,285
	Residual Fuel		60,922	54,101	(347)	7,000	46,761	7,925
	Naphtha for petrochemical feedstocks		5,535	0	(123)			
	Petroleum Coke		2,940	190,054	(1,356)	9,375		
	Other Oil for petrochemical feedstocks		1,255	0	(55)	1,240		
	Special Naphthas		4,643	0	(166)			
	Lubricants		13,207	34,406	(2,984)			172
	Waxes		1,760	1,642	(171)			
	Asphalt/Road Oil		16,563	8,773	(311)			
	Misc. Products		14	477	(101)			449

[1] Included in Unspecified Coal
Note: Parentheses indicate negative values.
Sources: Solid and Gas Fuels: EIA (2021 and 2022a); Liquid Fuels: EIA (2022b).

Table A-228: 2020 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				25.77		
	Lignite	12.87				12.87		
	Coke		20.35	24.97	20.35			
	Unspecified		25.00	25.97	20.86	23.47		25.14
Gaseous Fuels	Natural Gas (BTU/Cubic Foot)	1,037	1,025	1,009	1,037	1,037		1,037
	Still Gas (Million Btu/Barrel)		6.00	6.00	6.00		6.00	6.00
Liquid Fuels (Million Btu/Barrel)	Crude Oil	5.69	6.07	5.71	5.71		5.71	5.71
	HGL	4.19	4.19	4.19	4.19		4.19	4.19
	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 (2022a); Unspecified Solid Fuels: EIA (2011).

Table A-229: 2020 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	53.6						-	53.6
	Bituminous Coal	5,683.8						-	5,683.8
	Sub-bituminous Coal	4,212.7				9.5		-	4,203.2
	Lignite	635.1				15.7		-	619.4
	Coke	-	3.3	17.1	9.0			-	(22.7)
	Unspecified	-	128.4	1,793.8	(75.4)	385.6		37.7	(1,937.8)
Gaseous Fuels	Natural Gas	34,624.9	2,615.1	5,331.2	186.4	417.1		50.0	31,355.4
	Still Gas	-	-	-	-	-	-	-	-
Liquid Fuels	Crude Oil	23,501.3	13,043.5	6,698.6	318.7		-	-	29,527.6
	HGL	7,932.2	244.5	3,189.7	69.0		-	1.9	4,919.9
	Other Liquids	-	2,262.8	872.2	(118.6)		-	-	1,509.2
	Motor Gasoline	(149.6)	195.8	1,335.2	(3.7)		-	74.1	(1,211.1)
	Aviation Gasoline	-	1.3	-	(0.2)		-	-	1.4
	Kerosene	-	2.0	12.5	(0.8)		-	0.5	(9.3)
	Jet Fuel	-	310.6	200.1	(10.4)		563.7	34.6	(408.2)
	Distillate Fuel	-	464.8	2,530.1	122.9	0.3	105.0	71.6	(2,221.9)
	Residual Oil	-	383.0	340.1	(2.2)	44.0	294.0	49.8	(243.1)
	Naphtha for petrochemical feedstocks	-	29.0	-	(0.6)		-	-	29.7
	Petroleum Coke	-	17.7	1,144.9	(8.2)	56.5	-	-	(1,175.5)
	Other Oil for petrochemical feedstocks	-	7.3	-	(0.3)	7.2	-	-	0.4
	Special Naphthas	-	24.4	-	(0.9)		-	-	25.2
	Lubricants	-	80.1	208.7	(18.1)		-	1.0	(109.4)
	Waxes	-	9.7	9.1	(0.9)		-	-	1.6
	Asphalt/Road Oil	-	109.9	58.2	(2.1)		-	-	53.8
	Misc. Products	-	0.1	2.8	(0.6)		-	2.6	0.5
Total		**76,494.1**	**19,933.5**	**23,744.2**	**463.0**	**935.8**	**962.6**	**323.8**	**70,645.7**

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

Table A-230: 2020 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	0.05	28.28	5.6
	Bituminous Coal	5.68	25.43	530.0
	Sub-bituminous Coal	4.20	26.49	408.2
	Lignite	0.62	26.77	60.8
	Coke	(0.02)	25.60	(2.1)
	Unspecified	(1.94)	25.34	(180.0)
Gaseous Fuels	Natural Gas	31.36	14.43	1,658.9
	Still Gas	0.00	18.20	0.0
Liquid Fuels	Crude Oil	29.53	20.31	2,198.4
	HGL	4.92	18.53	334.4
	Other Liquids	1.51	20.31	112.4
	Motor Gasoline	(1.21)	19.27	(85.6)
	Aviation Gasoline	+	18.86	0.1
	Kerosene	(0.01)	19.96	(0.7)
	Jet Fuel	(0.41)	19.70	(29.5)
	Distillate Fuel	(2.22)	20.22	(164.7)
	Residual Oil	(0.24)	20.48	(18.3)
	Naphtha for petrochemical feedstocks	0.03	18.55	2.0
	Petroleum Coke	(1.18)	27.85	(120.0)
	Other Oil for petrochemical feedstocks	+	20.17	+
	Special Naphthas	0.03	19.74	1.8
	Lubricants	(0.11)	20.20	(8.1)
	Waxes	+	19.80	0.1
	Asphalt/Road Oil	0.05	20.55	4.1
	Misc. Products	+	0.00	0.0
Total				**4,707.7**

+ 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: C content coefficients by coal rank from USGS (1998), PSU (2010), Gunderson (2019), IGS (2019), ISGS (2019), and EIA (2021); natural gas C content coefficients from EPA (2010) and EIA (2022a); unspecified solid fuel and liquid fuel C content coefficients from EPA (2010) and ICF (2020).

Table A-231: 2020 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	78.8	25.60	2.02	0.10	1.3
Natural Gas	663.0	14.43	9.57	0.63	22.0
Asphalt & Road Oil	832.3	20.55	17.11	1.00	62.4
HGL	2,656.5	16.82	44.68	0.63	102.6
Lubricants	227.7	20.20	4.60	0.09	1.5
Pentanes Plus	163.6	18.24	2.98	0.63	6.9
Petrochemical Feedstocks	[1]	[1]	[1]	[1]	28.9
Petroleum Coke	0.0	27.85	0.00	0.30	0.0
Special Naphtha	80.7	19.74	1.59	0.63	3.7
Waxes/Misc.	[1]	[1]	[1]	[1]	0.6
Misc. U.S. Territories Petroleum	[1]	[1]	[1]	[1]	0.0
Total					**229.9**

[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-232: 2020 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	822.4	1.3	821.1	100.0%	821.1
Petroleum	2,226.5	206.6	2,019.9	100.0%	2,019.9
Natural Gas	1,658.9	22.0	1,636.9	100.0%	1,636.9
Total	**4,707.7**	**229.9**	**4,477.8**		**4,477.8**

Note: Totals may not sum due to independent rounding.

Table A-233: Fuel Consumption in the United States by Estimating Approach (TBtu)[a]

Approach	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Sectoral	**69,631**	**74,684**	**82,541**	**83,918**	**78,676**	**77,091**	**76,263**	**75,726**	**79,001**	**78,136**	**71,468**
Coal	18,098	19,210	21,755	22,213	20,305	15,071	13,816	13,404	12,803	10,877	8,814
Natural Gas	19,173	22,173	23,395	22,283	24,313	27,932	28,153	27,742	30,815	31,904	31,175
Petroleum	32,361	33,301	37,391	39,422	34,058	34,088	34,294	34,580	35,383	35,356	31,479
Reference (Apparent)	**68,794**	**74,087**	**81,934**	**83,867**	**78,081**	**76,276**	**75,407**	**75,268**	**78,260**	**77,316**	**70,646**
Coal	17,598	18,591	20,964	22,013	19,659	14,826	13,580	13,137	12,568	10,698	8,600
Natural Gas	19,280	22,277	23,487	22,350	24,409	28,011	28,236	27,862	30,945	32,072	31,355
Petroleum	31,916	33,218	37,482	39,504	34,013	33,439	33,591	34,269	34,747	34,546	30,691
Difference	**-1.2%**	**-0.8%**	**-0.7%**	**-0.1%**	**-0.8%**	**-1.1%**	**-1.1%**	**-0.6%**	**-0.9%**	**-1.1%**	**-1.2%**
Coal	-2.8%	-3.2%	-3.6%	-0.9%	-3.2%	-1.6%	-1.7%	-2.0%	-1.8%	-1.6%	-2.4%
Natural Gas	0.6%	0.5%	0.4%	0.3%	0.4%	0.3%	0.3%	0.4%	0.4%	0.5%	0.6%
Petroleum	-1.4%	-0.2%	0.2%	0.2%	-0.1%	-1.9%	-2.1%	-0.9%	-1.8%	-2.3%	-2.5%

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

Note: Totals may not sum due to independent rounding.

Table A-234: 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
Sectoral	**4,843**	**5,142**	**5,737**	**5,881**	**5,442**	**5,114**	**5,009**	**4,966**	**5,118**	**4,979**	**4,463**
Coal	1,720	1,824	2,070	2,121	1,937	1,438	1,319	1,280	1,223	1,038	843
Natural Gas	1,007	1,164	1,228	1,172	1,279	1,462	1,470	1,446	1,606	1,662	1,624
Petroleum	2,116	2,154	2,439	2,587	2,226	2,214	2,220	2,240	2,290	2,278	1,997
Reference (Apparent)	**4,806**	**5,144**	**5,714**	**5,924**	**5,437**	**5,119**	**5,014**	**4,996**	**5,141**	**5,005**	**4,478**
Coal	1,655	1,756	1,987	2,089	1,870	1,413	1,291	1,244	1,197	1,021	821
Natural Gas	1,014	1,171	1,233	1,176	1,285	1,467	1,476	1,454	1,615	1,674	1,637
Petroleum	2,137	2,216	2,494	2,659	2,282	2,238	2,248	2,297	2,329	2,310	2,020
Difference	**-0.8%**	**+%**	**-0.4%**	**0.7%**	**-0.1%**	**0.1%**	**0.1%**	**0.6%**	**0.5%**	**0.5%**	**0.3%**
Coal	-3.8%	-3.7%	-4.0%	-1.5%	-3.4%	-1.8%	-2.1%	-2.8%	-2.1%	-1.6%	-2.6%
Natural Gas	0.7%	0.6%	0.5%	0.3%	0.5%	0.3%	0.4%	0.6%	0.6%	0.7%	0.8%
Petroleum	1.0%	2.9%	2.3%	2.8%	2.5%	1.1%	1.2%	2.5%	1.7%	1.4%	1.2%

+ Does not exceed 0.05 percent.

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

Note: Totals may not sum due to independent rounding.

References

EIA (2022a) *Monthly Energy Review, February 2022,* Energy Information Administration, U.S. Department of Energy. Washington, D.C. DOE/EIA-0035(2022/02).

EIA (2022b) *Petroleum Supply Annual*, Energy Information Administration, U.S. Department of Energy, Washington, D.C., Volume I. DOE/EIA-0340.

EIA (2021) *Annual Coal Report 2020,* Energy Information Administration, U.S. Department of Energy. Washington, D.C. DOE/EIA-0584(2020).

EIA (2011) *Annual Energy Review,* Energy Information Administration, U.S. Department of Energy, Washington, D.C. DOE/EIA-0384(2011).

EIA (1992) Coal and lignite production. *EIA State Energy Data Report 1992*, Energy Information Administration, U.S. Department of Energy, Washington, DC.

EPA (2010) Carbon Content Coefficients Developed for EPA's Mandatory Reporting Rule. Office of Air and Radiation, Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, D.C.

Gunderson, J. (2019) Montana Coal Sample Database. Data received 28 February 2019 from Jay Gunderson, Montana Bureau of Mines & Geology.

ICF (2020) Potential Improvements to Energy Sector Hydrocarbon Gas Liquid Carbon Content Coefficients. Memorandum from ICF to Vincent Camobreco, U.S. Environmental Protection Agency. December 7, 2020.

Illinois State Geological Survey (ISGS) (2019) *Illinois Coal Quality Database*, Illinois State Geological Survey.

Indiana Geological Survey (IGS) (2019) *Indiana Coal Quality Database 2018*, Indiana Geological Survey.

IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds.). Published: IGES, Japan.

Pennsylvania State University (PSU) (2010) Coal Sample Bank and Database. Data received by SAIC 18 February 2010 from Gareth Mitchell, The Energy Institute, Pennsylvania State University.

USGS (1998) *CoalQual Database Version 2.0*, U.S. Geological Survey.