Assumptions to the Annual Energy Outlook 2023: Energy-Related Carbon Dioxide

March 2023

Independent Statistics and Analysis
U.S. Energy Information Administration

www.eia.gov
U.S. Department of Energy
Washington, DC 20585

The U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy (DOE), prepared this report. By law, our data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Government. The views in this report do not represent those of DOE or any other federal agencies.

Table of Contents

Table of Tables

Energy-Related Carbon Dioxide

Overview

The *Annual Energy Outlook 2023* (AEO2023) projects fossil fuel-related carbon dioxide (CO_2) emissions by fuel and by sector and industrial activities that capture carbon in products, such as the manufacturing plastics. The AEO2023 reflects this captured carbon in the CO_2 factors (the amount of CO_2 emitted per unit of energy consumed) for fossil fuel inputs (feedstocks). We adjust these CO_2 factors based on our estimates of how much carbon remains in the product instead of how much carbon is released into the atmosphere. We assume some nonfuel uses of fossil fuels capture all carbon inputs but other nonfuel uses emit some CO_2 during production. The amount of carbon captured and the amount of CO_2 released during nonfuel use of fossil fuels are not reported separately, but industrial sector emissions reflect these net values.

Fuel use

CO_2 emissions from fuel use depend on the carbon content of the fossil fuel, the fraction of the fuel combusted, and the amount of the fuel consumed. The chemical composition of most fossil fuels is relatively stable over time, resulting in little to no change in their carbon factors. Some fuel categories have greater variability. For example, coal is reported as a single fuel type. However, if the underlying coal ranks that make up the coal category change, the carbon factor for coal can also change over time.

The product of the CO_2 coefficient at full combustion and the combustion fraction yields an adjusted CO_2 emission factor for each fossil fuel, whether it is used solely for its energy content or for nonfuel purposes. We express the emission factors in millions of metric tons of CO_2 emitted per quadrillion British thermal units (quads) of energy use. We multiply the adjusted emission factors by the energy consumption of the fossil fuel to project CO_2 emissions.

For fuel uses of energy, we assume all of the carbon is oxidized, so the combustion fraction is equal to 1.0 (in keeping with international convention). Some products, such as petroleum coke, have both fuel and nonfuel uses, and we adjust their combustion fraction accordingly. Lubricants are not used for their energy value, but we assume that half of the lubricants consumed are combusted (therefore emitted) and that half are not.

Nonfuel use

For some product categories, such as asphalt and road oil, we assume that a product captures all carbon in nonfuel, or non-combustion, uses. As a result, the carbon emissions factor is zero. For other fossil fuel inputs, such as those for petrochemical feedstocks, some CO_2 is emitted during production, and some carbon is stored in a final product (and not emitted into the atmosphere). Rather than having a 1.0 combustion fraction, these fossil fuel inputs have a fraction that reflects the reduced CO_2 emissions because of the carbon captured in the petrochemical product. Combustion fractions for fossil fuel categories that are mixes of fuel and nonfuel uses are in Table 1.

Biogenic inputs

When calculating CO_2 emissions for motor gasoline, we omit the direct emissions from renewable blending stock (ethanol). Similarly, we omit direct emissions from biodiesel from our reported CO_2

emissions. By international convention, we consider any CO_2 emitted by biogenic energy sources, such as biomass and alcohols, to be balanced by the CO_2 sequestration that occurred during production. As a result, we assume net emissions of CO_2 from biogenic energy sources are zero. To illustrate the potential for these emissions in the absence of any offsetting sequestration—as might occur under related land-use changes leading to deforestation—we calculate and report the CO_2 emissions from biogenic fuel use separately, although these values are not included in total or sectoral emissions estimates.

Assumed CO_2 coefficients at full combustion, the combustion fractions, and the adjusted CO_2 emission factors we used for AEO2023 are in Table 1.

Table 1. CO_2 emissions factors

million metric tons of CO_2 per quadrillion British thermal units

Fuel type	CO_2 coefficient at full combustion	Combustion fraction[a]	Adjusted emission factor
Petroleum			
Propane used as fuel	62.88	1.0	62.88
Propane used as feedstock	62.88	0.2	12.58
Ethane used as fuel	59.58	1.0	59.58
Ethane used as feedstock	59.58	0.2	11.92
Butane used as fuel	64.75	1.0	64.75
Butane used as feedstock	64.75	0.2	12.95
Isobutane used as fuel	64.94	1.0	64.94
Isobutane used as feedstock	64.94	0.2	12.99
Natural gasoline (pentanes plus) used as fuel	66.88	1.0	66.88
Natural gasoline (pentanes plus) used as feedstock	66.88	0.2	13.38
Motor gasoline (not including ethanol)	70.66	1.0	70.66
Jet fuel	72.23	1.0	72.23
Distillate fuel (not including biodiesel)	74.14	1.0	74.14
Residual fuel	75.09	1.0	75.09
Asphalt and road oil	75.35	0.0	0.0
Lubricants	74.07	0.5	37.03
Petrochemical feedstocks	70.27	0.41	28.81
Kerosene	73.19	1.0	73.19
Petroleum coke (industrial)	102.12	0.956	97.59
Petroleum coke (electric power)	102.12	1.0	102.12
Petroleum still gas	66.73	1.0	66.73
Other industrial[b]	48.89	1.0	48.89
Coal			
Residential and commercial	96.10	1.0	96.10
Metallurgical	93.87	1.0	93.87
Coke	113.67	1.0	113.67
Industrial other[c]	95.81	1.0	95.81
Electric power[d]	95.77	1.0	95.77
Natural gas			
Used as fuel	52.91	1.0	52.91
Used as feedstock	52.91	0.464	24.57
Biogenic energy sources[e]			
Biogenic waste	89.65	1.0	89.65
Ethanol	74.07	1.0	74.07

Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023*; National Energy Modeling System run: ref2023.d020623a

[a] For feedstocks, the combustion fraction includes process emissions as well as inputs that might be combusted onsite.

[b] *Other industrial petroleum* includes industrial lubricants, special naphtha (solvents), and miscellaneous products such as sulfur.

[c] *Industrial other coal* is for process heat other than the manufacture of raw steel (metallurgical coal).

[d] The National Energy Modeling System specifies emission factors for coal used for electric power generation by coal supply region and types of coal, so the average carbon dioxide (CO_2) content for coal varies throughout the projection period. The electric power value of 95.77 shown here illustrates a typical coal-fired emission factor.

[e] We include biogenic sources for informational purposes, but we do not count them in total CO_2 emissions.