BOEM 2025-041

The Greenhouse Gas Life Cycle Energy Emissions Model (GLEEM) 2025 Version

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Abbreviations and Acronyms

bbl	barrel(s) of oil
bcf	billion cubic feet
BOEM	Bureau of Ocean Energy Management
BTU	British Thermal Unit(s)
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EIA	Energy Information Administration
EPA	Environmental Protection Agency
°F	degree(s) Fahrenheit
gal	gallon(s)
GHG	greenhouse gas
GLEEM	Greenhouse Gas Life Cycle Energy Emissions Model
kg	kilogram(s)
MMcf	million cubic feet
N_2O	nitrous oxide
OCS	Outer Continental Shelf
OECM	Offshore Environmental Cost Model
scf	standard cubic feet
U.S.	United States

Abstract

The Bureau of Ocean Energy Management (BOEM) has updated its analytical model to estimate the combined upstream, midstream, and downstream greenhouse gas emissions for Outer Continental Shelf (OCS) oil and gas resources potentially consumed under the national oil and gas leasing program. This report describes the analytical model methodology for the Greenhouse Gas Life Cycle Energy Emissions Model (GLEEM).

The analytical model uses historical consumption patterns, emissions factors, and economic and production estimates, subject to several assumptions, as outlined in this report.

Citation

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1 Introduction

Greenhouse gases (GHGs) are emitted largely through the burning of fossil fuels for energy consumption. As noted in a recent U.S. Geological Survey article, “multiple and independent lines of evidence clearly show that the world has warmed during the past 150 years, especially during the past six decades, and that this warming is primarily attributable to human activities that emit GHGs into the atmosphere” (Terando et al. 2020).

The Bureau of Ocean Energy Management (BOEM), which is the federal agency responsible for authorizing oil and gas exploration, development, and production on the Outer Continental Shelf (OCS), currently analyzes air pollutant emissions through its Gulfwide Emissions Inventory (Wilson et al. 2019). To understand the entire life cycle of GHG emissions, BOEM developed a model, the Greenhouse Gas Life Cycle Energy Emissions Model (GLEEM), which focuses on GHG emissions from the subsequent onshore processing, storage, and distribution of oil and gas, known as “midstream emissions,” and the consumption of oil and gas products, or “downstream emissions.” The version of GLEEM described in this document is an update from the 2024 version of the model (Wolvovsky 2024).

The goal of this report is to describe the GLEEM methodology for estimating the range of potential future emissions that may result from oil, gas, and coal development. This includes all onsite operations, if a user has this information, associated with oil, natural gas, and coal leases (exploration, development, and production), processing (refining, storage, and coal processing), delivery of these products to the final consumer, and consumption of the oil, natural gas, and coal products. The report references coal—even though its development is not authorized by BOEM—because the GLEEM model has the capability to estimate the effects of coal leasing, as well as onshore oil and natural gas leasing, on greenhouse gas emissions.

Due to uncertainties inherent in today’s energy markets, the most appropriate use for the model presented in this paper is for examining a range of potential GHG emission outcomes. Among the more significant uncertainties are the amount of oil, gas, and coal resource potential from a given lease; anticipated future oil, natural gas, and coal production; types of products to be consumed in the future; and future GHG regulatory regimes of the federal government or states, which could alter consumer demand for these resources. These uncertainties limit the accuracy of modeling to estimate projected GHG emissions. Therefore, BOEM recommends that users apply a range of possible scenarios to better capture the wide range of possible emissions. Nonetheless, BOEM believes the results provided by GLEEM give a useful picture of the consequences for GHG emissions of energy exploration, development, production, and consumption.

BOEM strives to address uncertainties and other challenges moving forward by revisiting the methodology regularly; adjusting inputs to reflect more recent data (e.g., emissions factors, consumption patterns, etc.); and adding to, removing, or modifying the algorithms described in this paper to reflect new techniques. Reflecting that commitment to improvement, this paper updates the 2024 version.

This 2025 version of the model, described in this document, also has a few minor changes compared to the 2024 version (Wolvovsky 2024). BOEM has updated the values used for fossil fuel production and consumption; emissions from refineries, natural gas systems, and coal processing; and processing gain.

2 Greenhouse Gas Emissions Methodology

The following analysis includes life cycle emissions from energy development, along with the substitution of sources for that energy under a "no leasing" scenario for the three GHGs that comprise more than 97% of all GHGs in the atmosphere: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The model estimates the emissions from exploration, development, production, transportation, processing (such as refining and storage), distribution, and consumption of energy products or their substitutes. It excludes emissions from secondary changes regarding these operations, such as oil and gas companies' office space, or changes in car manufacturing in response to changing market conditions. Additionally, emissions from fluorocarbons are not included because they are used in small quantities in refrigeration and circuit breakers and are not released intentionally as part of the oil, natural gas, and coal life cycle. Lastly, the model offers the option to evaluate emissions from replacement, which BOEM calls substitutions, under a "no lease" scenario.

The following four subsections detail the process for estimating GHG emissions. **Section 2.1** explains the data source for emissions released from onsite operations. **Section 2.2** describes the emissions released as part of processing and distribution. In **Section 2.3**, emissions resulting from consumption of oil, natural gas, and coal products are calculated using emissions factors and historical consumption patterns. Each calculation described in this section is performed three times, once each for CO_2, CH_4, and N_2O. **Section 2.4** describes the method for estimating emissions from substitute sources.

2.1 Emissions from Exploration, Development, Production, and Transport

The GLEEM greenhouse gas model estimates midstream and downstream GHG emissions. Onsite, or upstream, emissions must be estimated using other methods. BOEM uses the Offshore Environmental Cost Model (OECM) to calculate the GHG emissions associated with oil and gas activity occurring onsite (Industrial Economics Inc. 2018a; 2018b). The OECM estimates the monetized impact of typical activities associated with offshore production, including potential oil spills (other than catastrophic oil spills). As the basis for its calculations, the OECM uses economic inputs, resource estimates, expected exploration and development scenarios, and expected numbers of wells and associated production.

The OECM estimates GHG emissions from OCS operations associated with anticipated production. The OECM does not calculate onshore emissions associated directly with anticipated OCS production (e.g., onshore infrastructure). As described in **Section 2.4**, the OECM is also used to estimate GHG emissions from substitute energy sources that would replace forgone OCS production in the event of a decision for no leasing. The OECM reports a single total emissions number for each of the three major GHGs, as well as annualized upstream emissions of each of the three GHGs.

Equation 1:

$$PE_{onsite} = \sum PE_{equipment}$$

where

PE_{onsite} is total production emissions from onsite sources in metric tons

$PE_{equipment}$ are emissions from onsite operating equipment, such as from drilling wells, constructing platforms, delivering supplies, and transporting the resources to shore, in metric tons

2.2 Emissions from Processing, Storage, and Distribution

Generally, oil is refined into petroleum products for specific uses, such as jet fuel, kerosene, and motor gasoline. The ratio of expected oil production from given sites divided by total national crude oil inputs to refineries is used to scale emissions from refineries. Crude oil input data from 2024 (EIA 2025a) are used together with 2023 GHG emissions from refineries (USEPA 2025b). The same approach is used for natural gas storage and transmission; a ratio of production and national gas consumption in 2024 (EIA 2025a) is used to scale the Environmental Protection Agency's (EPA's) 2023 inventory (USEPA 2025b) of natural gas systems emissions. The same two data sets are also used to scale coal's post mining emissions. It is assumed emissions from these activities are in proportion to the amount of oil and gas that make their way through these facilities. Note that the EPA's emissions inventory only tracks CH_4 for coal. As a result, GLEEM does not account for CO_2 and N_2O emissions for coal in the midstream.

Equation 2:

$$PE_{offsite} = R_{oil} \frac{Oil_{Production}}{Oil_{Total}} + SD_{ng} \frac{NG_{Production}}{NG_{Total}} + PM_{coal} \frac{Coal_{Production}}{Coal_{Total}}$$

where

$PE_{offsite}$ is total emissions from offsite processing in metric tons

R_{oil} is emissions from all oil refining onshore in metric tons, from

- Table 3-45—Crude Oil Transportation and Refining (USEPA 2025b)
- Table 3-47—Transportation and Crude Refining (USEPA 2025b)
- Table 3-49—Transportation and Crude Refining (USEPA 2025b)

$Oil_{Production}$ is oil expected to be produced in bbl

Oil_{Total} is total U.S. oil refinery inputs in 2023 (EIA 2025a) in bbl

SD_{ng} is emissions from storage and distribution of natural gas in metric tons, from

- Table 3-74—Processing, Transmission and Storage, Distribution (USEPA 2025b)
- Table 3-76—Processing, Transmission and Storage, Distribution (USEPA 2025b)
- Table 3-78—Processing, Transmission and Storage (USEPA 2025b)

$NG_{Production}$ is natural gas expected to be produced in millions of cubic feet (MMcf)

NG_{Total} is total U.S. natural gas consumption from 2023 (EIA 2025a) in MMcf

PM_{coal} is emissions from post mining processing of coal in metric tons, from

- Table 3-35—Post Mining Underground and Surface (USEPA 2025b)

$Coal_{Production}$ is coal expected to be produced in millions of short tons
$Coal_{Total}$ is total U.S. coal consumption from 2023 (EIA 2025a) in short tons

2.3 Emissions from Consumption

GLEEM assumes that U.S. markets consume all produced oil, natural gas, and coal (for details on this assumption, see **Section 3**). The EIA's 2024 national consumption reports (EIA 2025a) provide data on the types of petroleum products that Americans consume and the levels of consumption. The percent of total consumption by each product is generated by dividing the national consumption of each processed fuel type (e.g., motor gasoline) by the consumption of all fuels that start with the same raw material (e.g., oil).

Equation 3:

$$C_i = \frac{Fuel_i}{Fuel_{Total}}$$

where

C_i is a ratio consumption factor for end use of a petroleum or coal product
$Fuel_i$ is the national consumption for a processed fuel type (e.g., motor gasoline) (EIA 2025a)
$Fuel_{Total}$ is total national consumption of products made from the same raw material (e.g., oil) (EIA 2025a)

Tables 2-1 and 2-2 list the actual consumption levels and percent of total consumption for each petroleum and coal product quantified by the EIA (EIA 2025a). Because natural gas is not converted into multiple combustible products, it is not included in this step.

Table 2-1. U.S. 2024 oil consumption

Fuel Type	2024 Consumption (1,000s of barrels)	2024 Consumption (% of total)
Asphalt and Road Oil	134,320	1.82
Aviation Gasoline	4,015	0.05
Distillate Fuel Oil	1,429,340	19.31
Jet Fuel (Kerosene Type)	603,345	8.15
Kerosene	4,015	0.05
Propane	272,655	3.68
Propylene	100,740	1.36
Hydrogen Gas Liquids	905,930	12.24
Lubricants	30,295	0.41
Motor Gasoline	3,264,925	44.12
Petroleum Coke	92,345	1.25
Residual Fuel Oil	100,010	1.35
Other Oil	458,440	6.19

Source: EIA (2025a)
Note: 1 barrel is equal to 42 gallons.

Table 2-2. U.S. 2024 coal consumption

Fuel Type	2024 Consumption (1,000s of short tons)	2024 Consumption (% of total)
Commercial	594	0.14
Electric Power Sector	373,803	90.87
Industrial (Other)	21,444	5.21
Industrial (Coke Plants)	15,514	3.77

Source: EIA (2025a)

When oil is refined, the volume of product increases as a result of the addition of other ingredients used to make each petroleum product. This volume increase is called the processing gain. Currently, EIA estimates processing gain to be 5.9% across all petroleum products (EIA 2025b).

By allocating expected production proportionately based on the petroleum and coal products and incorporating oil processing gain, BOEM can apply EPA's emissions factors for GHG inventories (**Table 2-3**). These numbers represent the mass (in kilograms [kg]) of GHG emitted for every gallon (gal) of fuel type burned. These categories of petroleum products do not match up perfectly between EIA and EPA. In two cases (distillate and residual fuel oils), there are multiple EPA emission factors for a single EIA product category. In these instances, the amount of oil is split evenly among the possible emission factors. This difference does not have a major effect on the overall analysis because the emissions factors for the different distillate and residual fuel oil categories are similar. Lastly, BOEM matched EIA's category for petroleum coke with EPA's petrochemical feedstock emissions factors.

Table 2-3. Petroleum emission factors for greenhouse gas inventories (in kg/gal)

Fuel Type	CO_2	CH_4	N_2O
Asphalt and Road Oil	11.91	0.00047	0.00009
Aviation Gasoline	8.31	0.00036	0.00007
Distillate Fuel Oil #1	10.18	0.00042	0.00008
Distillate Fuel Oil #2	10.21	0.00041	0.00008
Distillate Fuel Oil #4	10.96	0.00044	0.00009
Jet Fuel (Kerosene Type)	9.75	0.00041	0.00008
Kerosene	10.15	0.00041	0.00008
Propane	5.72	0.00027	0.00005
Propylene	6.17	0.00027	0.00005
Other Liquid Petroleum Gases	5.68	0.00028	0.00006
Lubricants	10.69	0.00043	0.00009
Motor Gasoline	8.78	0.00038	0.00008
Petrochemical Feedstocks	8.88	0.00038	0.00008
Residual Fuel Oil #5	10.21	0.00042	0.00008
Residual Fuel Oil #6	11.27	0.00045	0.00009
Other Oil (> 401°F)	10.59	0.00042	0.00008

Source: USEPA (2025a)

Not every fuel type is burned; some oil and natural gas are used as an ingredient for non-combustible products such as fertilizer and petrochemicals. EIA (2025a) reports that 1,097,000 MMcf of natural gas, 1,342,470,000 bbl of oil, and 426,508 short tons of coal are not combusted. In these cases, the use of the products does not directly result in GHG emissions and therefore are excluded from GHG emissions estimates for consumption calculations. Emissions are still calculated for these products in **Section 2.2**.

Thus, the estimation for emissions from consumption of oil is a summation of the emissions from each distinct petroleum product that is combusted.

Equation 4:

$$CE_{oil} = (PG + 1) * CP_{oil}(1 - NC_{oil}) * \sum_{i=1}^{n} [C_i * EF_i]/1{,}000$$

where

CE_{oil} is total emissions from oil consumption in metric tons
PG is the percent processing gain
CP_{oil} is oil expected to be produced in gal
NC_{oil} is the proportion of oil that is not combusted
C_i is the consumption factor for end use of a petroleum product (ratio, see **Equation 3**)
EF_i is the emission factor for a petroleum product in kg/gal

i refers to each of the petroleum products listed in **Table 2-3**
1,000 converts kg to metric tons

Natural gas is not refined into distinct combustible products, and there is no processing gain; moreover, there is only a single product to assess, even though natural gas is used in different markets. USEPA (2025b) provides a single set of emission factors for natural gas (**Table 2-4**).

Table 2-4. Natural gas emission factors for greenhouse gas inventories (in kg/MMcf)

Emission Factor	CO_2	CH_4	N_2O
Natural Gas	54,440	1.03	0.100

Source: USEPA (2025b)

This makes the natural gas estimation straightforward:

Equation 5:

$$CE_{ng} = CP_{ng}(1 - NC_{ng}) * EF_i / 1{,}000$$

where

CE_{ng} is total emissions from natural gas consumption in metric tons
CP_{ng} is natural gas produced and consumed in MMcf
NC_{ng} is the proportion of natural gas that is not combusted
EF_i is the emission factor for natural gas in kg/MMcf
1,000 converts kg to metric tons

Coal is processed into multiple combustible products, and there is no processing gain. USEPA (2025b) provides emission factors for coal (**Table 2-5**).

Table 2-5. Coal emission factors for greenhouse gas inventories (in kg/short tons)

Emission Factor	CO_2	CH_4	N_2O
Mixed (Commercial Sector)	2,016	0.235	0.034
Mixed (Electric Power Sector)	1,885	0.217	0.032
Mixed (Industrial Coking)	2,468	0.289	0.042
Mixed (Industrial Sector)	2,116	0.246	0.036

Source: USEPA (2023b)

The coal consumption is estimated using the following equation:

Equation 6:

$$CE_{coal} = CP_{coal}(1 - NC_{coal}) * \sum_{i=1}^{n} [C_i * EF_i] * 0.907185$$

where

CE_{coal} is total emissions from coal consumption in metric tons
CP_{coal} is coal produced and consumed in short tons
NC_{coal} is the proportion of coal that is not combusted
C_i is the consumption factor for end use of a petroleum product (ratio, see **Equation 3**)
EF_i is emission factor for coal in kg/short ton
0.907185 converts short tons to metric tons

Finally, total emissions, in metric tons, from each scenario can be summed as E_{total}:

Equation 7:

$$E_{total} = PE_{offsite} + PE_{onsite} + CE_{oil} + CE_{ng} + CE_{coal}$$

where

E_{total} is total emissions from each scenario in metric tons
$PE_{offsite}$ is total emissions from offsite processing in metric tons
PE_{onsite} is total emissions from onsite production in metric tons
CE_{oil} is total emissions from oil consumption in metric tons
CE_{ng} is total emissions from natural gas consumption in metric tons
CE_{coal} is total emissions from coal consumption in metric tons

2.4 Emissions from Energy Substitutes

To evaluate the difference between new leasing versus a “no leasing” scenario, GLEEM estimates the GHG emissions that would otherwise be released from the other sources of energy used in the United States. In addition, under a “no leasing” scenario, there would be some degree of energy conservation.

For changes in energy consumption patterns, GLEEM uses inputs derived from an energy market simulation model, MarketSim (Industrial Economics Inc. 2021). MarketSim simulates end-use domestic consumption of energy and then estimates the substitution rates for oil and natural gas. GLEEM’s substitution algorithms estimate the quantity of oil, natural gas, and coal required to meet those substitution rates based on expected production from the leases. The main model (described in **Sections 2.1, 2.2, and 2.3**) is then processed a second time using the substituted energy quantities.

GLEEM assumes that nuclear, biofuels, solar, and wind sources have negligible GHG emissions at the midstream and downstream phases, because the emissions are small by unit (Industrial Economics Inc. 2018a; 2018b).

To determine fuel quantities for the “no leasing” scenario, the first step is to convert all the expected production into the same unit, British thermal units (BTUs); see **Appendix A** for conversion factors. Next, fuel quantities are calculated for oil (**Equation 8**), natural gas (**Equation 9**), and coal (**Equation 10**).

Equation 8:

$$CS_{oil} = CP_{oil} * S_{oil} + CP_{ng} * S_{ng} + CP_{coal} * S_{coal}$$

where

CS_{oil} is the total substituted oil in BTUs
CP_{oil}, CP_{ng}, *and* CP_{coal} are expected production for oil, natural gas, and coal (in BTUs)
S_{oil}, S_{ng}, *and* S_{coal} are the substitution rates for oil, natural gas, and coal expected to be replaced by oil from other sources

Equation 9:

$$CS_{ng} = CP_{oil} * S_{oil} + CP_{ng} * S_{ng} + CP_{coal} * S_{coal}$$

where

CS_{ng} is the total substituted natural gas (in BTUs)
CP_{oil}, CP_{ng}, *and* CP_{coal} are expected production for oil, natural gas, and coal (in BTUs)
S_{oil}, S_{ng}, *and* S_{coal} are the substitution rates for oil, natural gas, and coal expected to be replaced by natural gas from other sources

Equation 10:

$$CS_{coal} = CP_{oil} * S_{oil} + CP_{ng} * S_{ng} + CP_{coal} * S_{coal}$$

where

CS_{coal} is the total substituted coal in BTUs
CP_{oil}, CP_{ng}, *and* CP_{coal} are expected production for oil, natural gas, and coal (in BTUs)
S_{oil}, S_{ng}, *and* S_{coal} are the substitution rates for oil, natural gas, and coal expected to be replaced by coal from other sources

Table 2-6 provides the conversion rates of the different fuels.

Table 2-6. Oil, natural gas, and coal conversions to BTUs

Fuel	Conversion	Units Converted to BTUs
Oil	5,800	1,000s of barrels
Natural Gas	1,032	MMcf
Coal	20,387	short tons

Source: Whitney et al. (2009)

After converting the oil, natural gas, and coal back into their standard units (bbl, scf, and short tons, respectively), midstream and downstream emissions are calculated using the method described in **Sections 2.2 and 2.3**. BOEM currently uses the OECM to estimate upstream emissions from substitute energy sources described above. These substitute energy sources that result in estimates of upstream GHG emissions include onshore oil, gas, and coal production, as well as production and transportation of energy imports.

3 Key Assumptions

GLEEM makes several assumptions, some of which may reduce its accuracy. The principal variables in this estimation are the production estimates of oil, natural gas, and coal, and the underlying uncertainty in these estimates has a profound impact on overall accuracy. Other critical assumptions also affect the GHG emission estimates and are as follows:

1) *Engines used for production, processing, and consumption of oil and gas will not become more efficient, and oil and gas will remain a primary energy source.*

Historically, engines have become increasingly efficient but have remained dependent on fossil fuels. Efficiency improvements are made to meet the need for greater fuel economy and to meet government regulations; these improvements could alter the fuel type or quantity used to generate power. Similar changes could impact other types of products, such as plastics and fertilizers, by altering not only the amount used, but also the portion consumed by each sector. For example, motor gasoline remains the largest petroleum product consumed in the United States, ranging between 39% and 47% of each barrel of petroleum product consumed since 1950. As battery technology continues to improve, plug-in electric vehicle prices may continue to drop (Lutsey and Nicholas 2019), increasing the share of electric vehicles and reducing the percent of oil used for motor gasoline. However, as the U.S. electrical grid is increasingly dependent on natural gas, such shifts could increase demand for natural gas.

Figure 3-1 shows how consumption patterns of oil have changed in the past, including the rise of jet fuel and motor gasoline use and the contraction of residual fuel oil use. Despite these longer-term shifts, petroleum products maintain a reasonable level of continuity from year to year.

Without a definitive method of estimating consumption markets for the production life of a given project, it is impossible to predict how consumption will change. Using 2024 data still provides a useful approximation of consumption, because these patterns have not radically changed over the short term. Longer-term trends could be incorporated by keeping GLEEM up to date with consumption patterns. The 2020 COVID pandemic is a useful case study in these changes; despite the sharp change to American's behavior during the pandemic (and by extension consumption of petroleum products), the ratio of petroleum products did not change more than in other years, despite a drop in overall consumption.

Efficiency is likely to continue to improve, meaning less fuel will be required to generate the same amount of energy. These changes to engine efficiency also affect the calculations in estimating emissions from exploration, development, production, processing, storage, and distribution. This assumption equally impacts both the evaluation of expected production and energy substitution, thereby still allowing direct comparison of emissions.

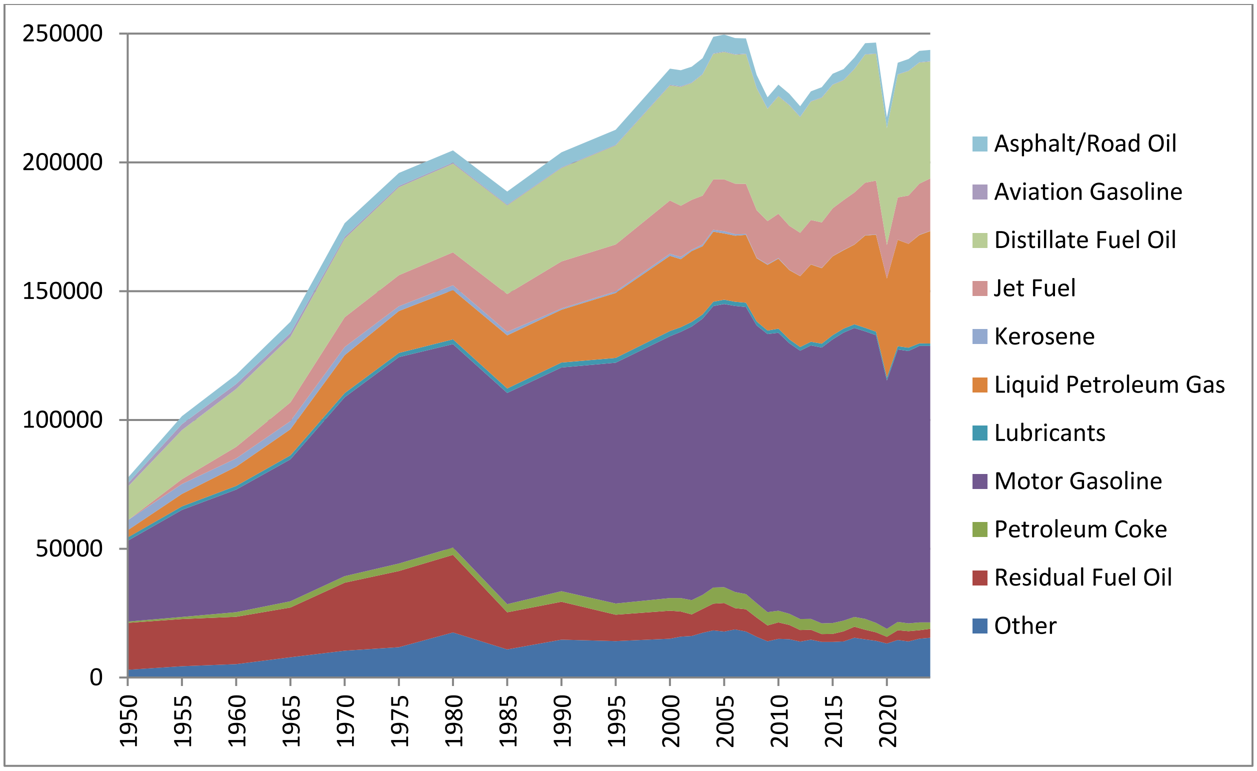

Figure 3-1. Historical U.S. consumption of petroleum products for 1950–2024 (in thousands of bbl)

Source: EIA (2025a)

2) All resources produced on leases are processed and consumed.

GLEEM assumes all resources entered into the model will be discovered, produced, processed, and consumed. In reality, some resources are lost, either by not being brought to production, or through inefficiencies at various stages of processing and distribution or other incidents, such as spills. These results assume that all resources reach a customer and are consumed with perfect efficiency. This assumption ensures emissions will not be underestimated. GLEEM accounts for products that are not combusted as part of their use.

3) "Other" oils, distillate fuel oil, and residual fuel oil are approximated.

There are several places where EIA's consumption categories do not match EPA's emissions factors. EIA lumps pentanes, petrochemical feedstocks, naphtha-type jet fuel, still gas, waxes, and crude oil into a single "Other" category, and these categories are matched with EPA's "Other Oil (> 401°F)" emissions factors. Similarly, EPA has two emissions factors for "Residual Fuel Oil" and three for "Distillate Fuel Oil," but EIA reports distillate and residual fuel oils broadly. As a result, it is assumed there is equal consumption for each emissions factor, with half of the residual fuel oil using each emission factor and a third of the distillate oil for the three emission factors. These assumptions slightly reduce GLEEM's accuracy. See **Table 2-1** for both residual and distillate fuel oil emission factors.

4) Processing gain is equal across all petroleum products.

Although all refined oil products have a processing gain, it is not the same for each product. Currently, EIA (2025b) estimates processing gain as 5.9% for all oil products. GLEEM applies this value to all oil products due to lack of available information as to the processing gain of individual fuels.

5) All products are consumed domestically.

Emissions from exported fuels are not accounted for in GLEEM. In 2024, total exports were small compared to the volumes consumed domestically (EIA 2025a). This assumption slightly underestimates the emissions from transportation of these products to other countries. Additionally, because there is a single product for natural gas, the emission factors do not vary if they are consumed overseas. However, oil and coal are consumed in a variety of products with a range of emissions factors, and there is some loss in accuracy for petroleum and coal products consumed overseas, as other countries do not consume these products in proportions identical to the United States. Even with the loss of accuracy, approximating global emissions from oil and coal using the United States as the example provides an estimation of national oil and coal consumption. Future increases in exports may require changes in future iterations of the model.

6) Products are consumed in the same proportions as products from all national sources.

Oil and coal from a particular lease are refined into specific products, and those products are not necessarily in the same proportions as oil and coal mined from all sources nationally. This assumption is necessary if the user lacks information about their specific leases. If more specific information is available about the type of products oil and coal are refined into, GLEEM can be adjusted to accommodate such information. See **Section 2.3** and the user guide for details.

7) Coal transport emissions are not modeled.

At the current time, it is not possible to model coal transport to processing facilities or from those facilities to the final customer. Coal transport emissions are not accounted for in the consumption calculations because this amount could vary widely as coal increasingly becomes a regional method of generating energy and is not always transported by coal power. A user estimating coal consumption could eliminate this factor by incorporating these emissions as part of the upstream emissions rather than the midstream emissions, where they actually take place.

4 Conclusion

Future changes in policy, supply and demand, shifting economic circumstances, or technological advances could substantially change various parts of this model. As a result, BOEM anticipates making annual updates to keep the consumption inputs up to date and to add or modify algorithms as new information—or changes in the processing of oil, natural gas, and coal—alter the climate change impacts of these resources.

Additionally, it is recommended that users model multiple scenarios to develop a broad range of possible outcomes for understanding the range of possible outcomes on oil, natural gas, and coal projects, which can last decades. Users should model energy at the highest level possible, as GLEEM is intended to evaluate emissions from the U.S. energy sector as a whole. Finally, it is recommended that results be rounded to at least the nearest 1,000 metric tons for each pollutant to avoid suggesting a higher degree of accuracy than actually exists in GLEEM.

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Appendix A: Unit Conversions

Table A-1. Conversion factors used within the model

Unit	Conversion
1 kilogram (kg)	1,000 metric tons
1 metric ton	0.907185 short tons
1 barrel (bbl)	42 gallons
1 million barrels (mmbbl)	1,000,000 barrels (bbl)
1 thousand cubic feet (mcf)	1,000 standard cubic feet (scf)
1 million cubic feet (MMcf)	1,000,000 standard cubic feet (scf)
1 billion cubic feet (bcf)	1,000,000,000 standard cubic feet (scf)
1 barrel of oil equivalent (boe)	5,620 standard cubic feet (scf) gas
1 barrel of oil (bbl)	5,800,000 British Thermal Units (BTUs)
1 cubic foot natural gas	1,029 British Thermal Units (BTUs)
1 short ton coal	20,387,000 British Thermal Units (BTUs)

Table A-2. Global warming potential (in metric tons)

Greenhouse Gas	100 Year Global Warming Potential (CO_2e)
CO_2	1
CH_4	30
N_2O	273

Source: Table 7.15 of Intergovernmental Panel on Climate Change (2021)

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