Gulf of Mexico OCS Oil and Gas Leasing Greenhouse Gas Emissions and Social Cost Analysis

Addendum to the Gulf of Mexico Lease Sales 259 and 261 Supplemental EIS and Technical Report – Corrected

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NOTE ABOUT THIS VERSION

This paper was originally published in October 2022 (document number BOEM 2022-056). Since publication of the original version, the Bureau of Ocean Energy Management (BOEM) has corrected two errors stemming from incorrect production volume inputs used in the Greenhouse Gas Life Cycle Energy Emissions Model. This version (February 2023) includes those corrections and updates to the associated text.

EXECUTIVE SUMMARY

This technical report summarizes the life cycle greenhouse gas (GHG) emissions estimated to result from a typical Gulf of Mexico (GOM) conventional energy lease sale. The report is additional documentation for the GOM Lease Sales 259 and 261 Supplemental Environmental Impact Statement and will also be used as a reference for ongoing GOM site-specific environmental reviews, including those associated with plan reviews.

The Bureau of Ocean Energy Management (BOEM) estimates GHG emissions and social costs associated with oil and natural gas leasing on the GOM Outer Continental Shelf (OCS) (the Leasing scenario)[1] and with potential energy market substitutes in the absence of leasing (the No Leasing scenario). Under the No Leasing scenario and without new OCS production, oil and gas demands may decrease but are not expected to entirely disappear; consumers would likely turn to other “substitute” sources.

This analysis categorizes GHG emissions estimates into 1) domestic full life cycle emissions (including exploration for hydrocarbon resources through consumption) and 2) emissions associated with a change in foreign oil consumption.

There are many uncertainties in estimating several decades of energy consumption and emissions, including uncertainty in prices, long-term consumption patterns, technological advances, and broad changes in U.S. and international energy policy. Because of these uncertainties, BOEM’s analyses do not integrate assumptions about changes in behavior and policies—such as the large-scale electrification of cars, aircraft, and heating and cooling systems—that could alter both consumption and substitution patterns. However, the Bureau is seeking ways to incorporate these recent developments into future analyses. Moreover, BOEM recognizes that there are gaps in certain elements of the analysis, particularly those associated with foreign emissions.

[1] For this analysis, BOEM used the mid-activity production scenario that was used for the 2017–2022 GOM Lease Sales 249, 250, 251, 252, 253, 254, 256, 257, 259, and 261 Final Multisale Environmental Impact Statement for modeling market response, GHG emissions, and social costs. This analysis assumes a start date of 2022 for the scenario.

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LIST OF ABBREVIATIONS AND ACRONYMS

BOE	barrels of oil equivalent
CCS	carbon capture and storage
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
E&D	exploration and development
EIA	Energy Information Administration
EIS	Environmental Impact Statement
GHG	greenhouse gas
GLEEM	Greenhouse Gas Life Cycle Energy Emissions Model
GOM	Gulf of Mexico
IEc	Industrial Economics, Inc.
IWG	Interagency Working Group on the Social Cost of Greenhouse Gases
kg	kilogram
MarketSim	Market Simulation Model
MMBOE	million barrels of oil equivalent
NDC	Nationally Determined Contributions
NEMS	National Energy Modeling System
N_2O	nitrous oxide
NPV	net present value
OCS	Outer Continental Shelf
OECM	Offshore Environmental Cost Model
SC-GHG	social cost of greenhouse gases
U.S.	United States
USEPA	U.S. Environmental Protection Agency

1 OVERVIEW

The Bureau of Ocean Energy Management (BOEM) estimates greenhouse gas (GHG) emissions and social costs for oil and gas leasing on the Gulf of Mexico (GOM) Outer Continental Shelf (OCS). This analysis encompasses emissions potentially resulting from the full life cycle of oil and gas exploration, development, production, and consumption; it also estimates emissions from use of energy substitutes in the absence of that leasing.

Anthropogenic emissions of GHGs are the main contributor to climate change. BOEM recognizes the global scope of the impacts of GHG emissions and the potential contributions of the effects of agency actions to global GHG concentrations.

This analysis expands on BOEM's previous analysis, *OCS Oil and Natural Gas: Potential Lifecycle Greenhouse Gas Emissions and Social Cost of Carbon* (Wolvovsky and Anderson 2016), which addressed domestic carbon emissions related to life cycle OCS oil and gas activity. In addition, BOEM considers the impact of the leasing and eventual production of OCS resources on foreign energy consumption and provides an overview of how OCS oil and gas leasing fits into the context of aggregate emissions, demand, and U.S. GHG reduction goals.

2 LIFE CYCLE GREENHOUSE GAS EMISSIONS

Life cycle refers to emissions from all activities related to the exploration, development, production, and consumption of a resource. For hydrocarbon resources, the activities are often grouped into three stages: upstream, midstream, and downstream (**Figure 1**). Upstream activities include exploration, development, and production, which are described in the exploration and development scenario.[2] Midstream activities are associated with refining, processing, storage, and distribution of fuels produced from leases issued via lease sales in the GOM. Finally, downstream activities are associated with consumption of those fuels.

[2] In order to generate estimates of anticipated future oil and gas production, BOEM develops oil and gas exploration and development (E&D) scenarios under a given leasing schedule. The E&D scenarios describe the development and production activities required to explore for, extract, and transport to market the anticipated oil and gas production.

Figure 1. Life cycle stages of greenhouse gas emissions

The activities associated with each stage would result in GHG emissions, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These GHG emissions would contribute to climate change globally. The analysis below quantifies projected GHG emissions that could occur under leasing (referred to as the Leasing scenario) and the subsequent consumption of produced fuels. This approach provides consistency with BOEM's previous GHG analysis (Wolvovsky and Anderson 2016). These projected GHG emissions serve as a proxy for assessing the potential contribution to climate change globally from OCS leasing.

The analysis also estimates GHG emissions associated with the No Leasing scenario. Under the No Leasing scenario, there would be no OCS lease sales. Thus, no upstream, midstream, or downstream activities associated with OCS oil and natural gas production stemming from a proposed lease sale would occur.

In the absence of leasing and production, demand for oil and gas would not disappear. Rather, it would be fulfilled from alternative sources, which BOEM refers to as substitute sources. This substitution does not occur on a 1:1 basis (a concept known as “perfect substitution”), because the lack of production from a proposed lease sale would correspond with an environment of slightly higher prices, which, in turn, would lead to a slightly lower demand. BOEM’s analysis of the No Leasing scenario thus reflects the energy sources estimated to substitute for oil and gas that would have been produced under the exploration and development scenario for a proposed lease sale. The No Leasing scenario life cycle GHG emissions are those generated from the substitute fuels that are produced or consumed domestically in the absence of a proposed lease sale. BOEM’s modeling suggests that the substitute fuels are primarily additional oil imports and domestic onshore natural gas.

The emissions analysis can be categorized into two components: 1) estimated GHG emissions resulting from domestically produced or consumed fuels, and 2) estimated GHG emissions when considering the shift in foreign oil consumption. BOEM can model domestic energy markets with sufficient reliability to estimate the energy substitutes consumed or produced domestically. However, global energy markets cannot be modeled to the same level of detail as the domestic energy sources. BOEM’s GHG analysis has been updated to include a newly developed quantitative analysis of the impact on foreign oil consumption. This update aligns with the court rulings in *Center for Biological Diversity v. Bernhardt*, Case No. 18-73400 (9th Cir. 2020) and, more recently, *Friends of the Earth v. Haaland*, Case No. 1:21-cv-02317-RC (D.D.C. 2022). The *Center for Biological Diversity* court stated, in part, that BOEM must provide a quantitative assessment of GHG emissions resulting from shifts in foreign consumption attributable to the proposed action or explain why such quantitative assessment could not be done. As a result, BOEM updated its analysis to consider the potential impacts of GHG emissions from the change in foreign oil consumption.

Table 1 presents BOEM's overall GHG modeling approach. BOEM quantitatively considers the GHG emissions associated with domestically produced or consumed energy (**Table 4**). This analysis includes GHG emissions from production through consumption of OCS oil and gas under the Leasing scenario. The No Leasing scenario estimates include GHG emissions from the domestically consumed energy substitutes. A portion of these life cycle GHG emissions include upstream emissions from foreign production of energy that is imported and consumed domestically in the U.S. BOEM has also quantitatively estimated foreign downstream emissions associated with the increase in foreign oil consumption given the price decrease estimated to result from the Leasing scenario (**Table 5**). Although foreign oil consumption is expected to increase given this price decrease, foreign oil production would likely decrease, resulting in a decrease in upstream emissions. There would be changes in midstream emissions as well. At this time, BOEM does not quantify the changes in foreign oil's upstream and midstream emissions for reasons more fully described below. In response to the change in oil price, additional energy substitutions for foreign energy sources other than oil likely would occur, but these are complex and beyond BOEM's current modeling capabilities.

Table 1. BOEM's life cycle GHG modeling approach

Emissions Source	Quantifying GHG Emissions: Modeling Capability		
	Upstream	Midstream	Downstream
Domestically Produced or Consumed Energy			
Leasing: new OCS oil and gas production	Quantified (**Table 4**)	Quantified (**Table 4**)	Quantified (**Table 4**)
No Leasing: all domestically consumed substitutes (onshore, gross imports, renewables, reduced domestic demand)	Quantified (**Table 4**)	Quantified (**Table 4**)	Quantified (**Table 4**)
Non-U.S. Consumed Energy			
Foreign Oil Market Change	Under consideration but unavailable at this time	Under consideration but unavailable at this time	Quantified* (**Table 5**)
Substitutes for Oil in Foreign Markets (natural gas, coal, biofuels, renewables, reduced demand)	Not available at this time given available resources **	Not available at this time given available resources **	Not available at this time given available resources **

* Foreign oil consumption is not modeled as dynamically as domestic oil consumption. The Market Simulation Model's estimate of foreign oil consumption does not include cross-price effects. Also, foreign oil consumption double counts some exports of new OCS crude oil and petroleum exported to foreign markets. Those amounts are not disaggregated from the Greenhouse Gas Life Cycle Energy Emissions Model when it estimates midstream and downstream emissions from new OCS oil.
** Source: Price (2021)

This analysis is similar to the methodology BOEM first employed and published in Alaska's Cook Inlet Lease Sale 258 Draft Environmental Impact Statement (EIS) (BOEM 2021a). The initial GHG analysis included a quantification of GHG emissions from foreign consumption. Since then, BOEM published a second similar analysis as part of the *2023–2028 National OCS Oil and Gas Leasing Proposed Program* (2023–2028 Proposed Program) (BOEM 2022a). BOEM received comments on the Lease Sale 258 Draft EIS, and the comment period for the 2023–2028 Proposed Program analysis is open through October 6, 2022. BOEM continues to review and evaluate the comments and input from outside experts and the public to improve GHG analyses and methodologies.

One of the reasons BOEM did not previously prepare a quantitative analysis was the lack of information on foreign consumption of petroleum products. To address that data gap and prepare this quantitative analysis, BOEM used a single generic emissions factor, described below, in place of specific emissions factors for the different types of petroleum products consumed. BOEM is also working with outside experts on both short- and long-term efforts to refine and expand existing models and methodologies for deployment in future analyses.

The resulting analysis indicates that, when considering only emissions associated with domestic consumption and production, selection of the No Leasing scenario results in slightly lower GHG emissions than would be emitted under the Leasing scenario. When the analysis is expanded to also consider emissions from foreign energy markets, BOEM finds the No Leasing scenario still results in fewer GHG emissions. After estimating GHG emissions, BOEM then monetizes the social costs of those GHG emissions to estimate the Leasing scenario's incremental social cost of greenhouse gas emissions relative to the No Leasing scenario.

2.1 Life Cycle GHG Methodology

BOEM's life cycle greenhouse gas methodology was first described in Wolvovsky and Anderson (2016). The GHG model (now called the Greenhouse Gas Life Cycle Energy Emissions Model, or GLEEM) was developed to examine the life cycle GHG emissions associated with OCS oil and gas development activities both pre- and post-production. The scope of BOEM's life cycle greenhouse gas analysis includes all operations on the OCS associated with oil and gas leasing (i.e., exploration, development, and production). BOEM's life cycle greenhouse gas analysis relies on three BOEM models to estimate results: Market Simulation Model (MarketSim) (Industrial Economics Inc. 2021),[3] Offshore Environmental Cost Model (OECM) (Industrial Economics Inc. 2018a; 2018b),[4] and GLEEM (Wolvovsky 2021).[5] For a full description of these models, please refer to their documentation and associated reports, which are available on BOEM's website.

BOEM acknowledges that these models were developed for analysis at a national level, and there may be limitations on the scalability of the models to this regional analysis. However, the models incorporate a regional framework and specify assumptions by OCS planning area (e.g., Western and Central GOM Planning Areas) when applicable. The models represent the best science and methodology available for

[3] Available at https://www.boem.gov/oil-gas-energy/energy-economics/national-ocs-program.
[4] Available at https://www.boem.gov/oil-gas-energy/energy-economics/national-ocs-program.
[5] Available at https://www.boem.gov/environment/greenhouse-gas-life-cycle-energy-emissions-model.

estimating energy market impacts and substitution rates, which are important factors in the larger analysis and comparison of GHG emissions that could occur under the No Leasing scenario and the Leasing scenario.

When estimating emissions, BOEM's models quantify the three main GHGs: CO_2, CH_4, and N_2O. To provide a single metric for estimating an action alternative's emissions profiles, BOEM provides combined totals of all three GHG emissions in CO_2 equivalent, or CO_2e. This approach allows for a direct, aggregate comparison between emissions of pollutants with varying potentials to trap heat and different atmospheric lifespans. For example, 1 metric ton of CH_4 has an impact similar to 25 metric tons of CO_2. The analysis uses 100-year conversion factors developed by the U.S. Environmental Protection Agency (USEPA 2021a) (**Table 2**).

Table 2. Global warming potential (in metric tons)

Greenhouse Gas	CO_2	CH_4	N_2O
Global Warming Potential (CO_2e)	1	25	298

Source: USEPA (2021a)

BOEM evaluates life cycle GHG emissions assuming annual exploration, development, and production occur as estimated under a mid-activity production scenario.[6] To estimate the energy market substitutions that would occur in the No Leasing scenario, BOEM uses MarketSim. The substitute estimates are then used as inputs in the OECM and GHG Model (**Figure 2**).

[6] To generate estimates of anticipated future oil and gas production, BOEM develops oil and gas E&D scenarios under a given leasing schedule to describe the development and production activities required to explore for, extract, and transport to market the anticipated oil and gas production. BOEM develops these E&D scenarios for each program area and at three activity levels (low, mid, and high). For this analysis, BOEM uses the mid-activity production scenario that was also used for the analysis in the 2017–2022 GOM Lease Sales 249, 250, 251, 252, 253, 254, 256, 257, 259, and 261 Final Multisale EIS and 2018 GOM OCS Lease Sale Final Supplemental EIS.

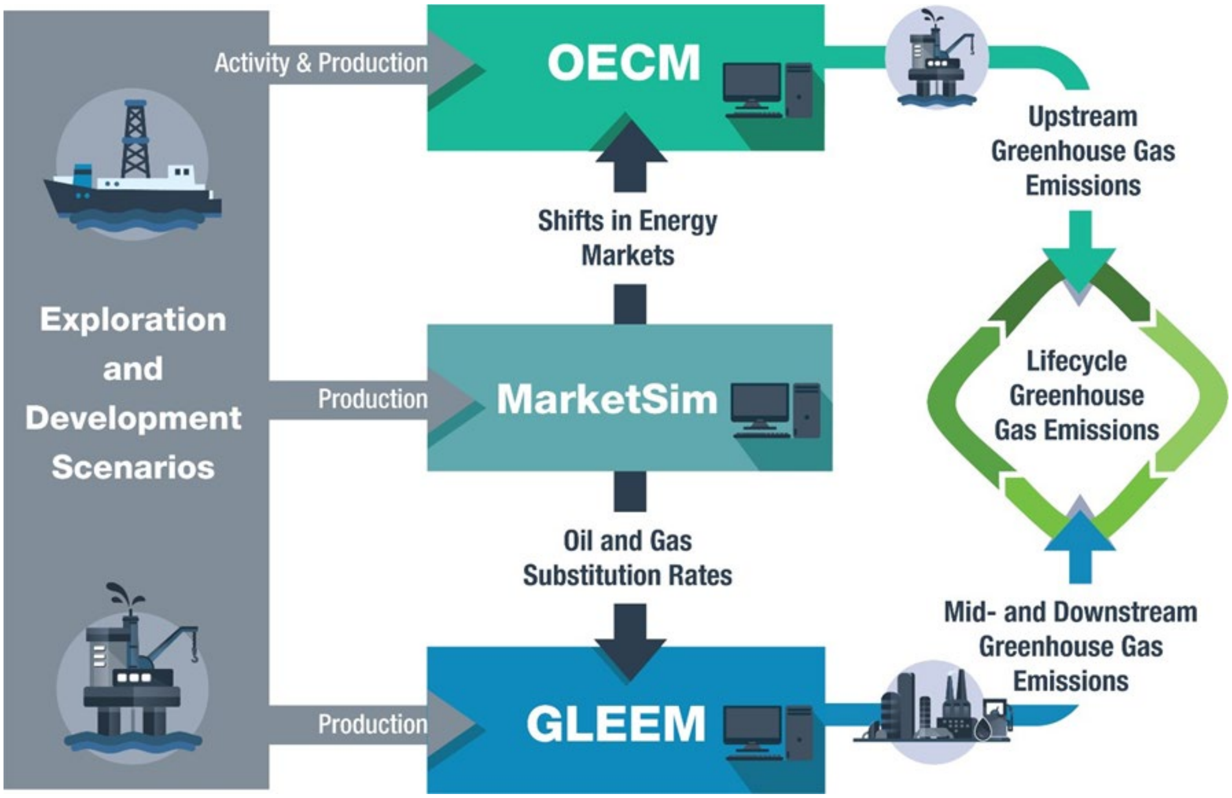

Figure 2. Illustration of BOEM's models and methodology

2.1.1 MarketSim Model

MarketSim is a Microsoft® Excel-based model for the oil, gas, coal, and electricity markets and is calibrated to a special run of the U.S. Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) from the *2020 Annual Energy Outlook* reference case (EIA 2020; Staub 2020). The model run includes no new OCS lease sales after 2022 so that BOEM can add in its lease sale schedule and estimates of anticipated production based on various OCS leasing scenarios.[7] MarketSim makes no assumptions about future technology or policy changes other than those reflected in the NEMS forecast (EIA 2020; Staub 2020).

BOEM continually evaluates its models to update them with the most recent available data. BOEM recently completed a review and update of its MarketSim model and documentation. The model was updated to include new elasticity values from the literature and an additional modeling category to directly incorporate onshore unconventional production (splitting from one generic onshore oil production category). MarketSim's elasticities and adjustment rates, which determine fuel substitution calculations, were evaluated and underwent a literature review by an outside contractor in 2021. These updates and additional details about how MarketSim models fuel substitutions across energy markets can be found in the MarketSim documentation (Industrial Economics Inc. 2021).

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7 NEMS projections, including production from new OCS leasing, are typically reported in the EIA's *Annual Energy Outlook*.

MarketSim uses estimated production from a proposed GOM lease sale and adds it to the baseline (the No Leasing scenario). MarketSim then evaluates a series of simulated price changes until each individual fuel market (i.e., coal, natural gas, oil, and electricity) reaches equilibrium, where supply equals demand. MarketSim uses price elasticities derived from NEMS runs, peer-reviewed studies, and input from experts to quantify the potential effects on prices, energy production, and consumption over a proposed GOM lease sale's period of production.

MarketSim's modeling of oil, natural gas, coal, and electricity for U.S. markets accounts for substitution between alternate fuel sources. It incorporates feedback effects among the markets for substitute fuels using cross-price elasticities between the fuels. For instance, additional natural gas production leads to reduced gas prices. With a reduced price, there is an increase in the quantity of gas demanded. The increase in natural gas quantity demand then decreases the demand for other fuels, like coal. The model also then considers the resulting decrease in the price of coal, which dampens the initial increase in the quantity of gas demanded. To better depict these substitutions, each fuel's demand is categorized into distinct sectors—i.e., residential, commercial, industrial, and transportation—each with its own-price and cross-price elasticity specific to each submarket. Additionally, each fuel is modeled for up to nine components of supply. For example, for the oil market, supply is modeled from domestic (lower 48) onshore conventional, domestic (lower 48) onshore unconventional, domestic (lower 48) offshore, Alaska onshore, Alaska offshore, biofuels, other, rest of world, and Canadian pipeline imports. This complexity allows MarketSim to simulate changes in energy prices and the resulting substitution effects between the various fuels in the presence of changes in OCS oil and gas production.

Table 3 shows the substitution of other energy sources as percentages of the Leasing scenario's forgone production of oil and gas under the No Leasing scenario. For example, the estimated production under the Leasing scenario is 1,133.6 million barrels of oil equivalent (MMBOE). Under the No Leasing scenario, MarketSim estimates that 45% of forgone production, or approximately 499.3 MMBOE, would be replaced by imports. In other words, 499.3 MMBOE of imports are estimated to be displaced by anticipated mid-activity level production under the Leasing scenario.

Table 3. Substitution of other energy sources under the No Leasing scenario

Substitute Energy Source	Percentage of Leasing Scenario Forgone Production*
Onshore production	33
Onshore oil	10
Onshore gas	22
Production from existing state/Federal offshore leases	1
Imports	45
Oil imports	44
Gas imports	1
Coal	1
Electricity from sources other than coal, oil, and natural gas**	2
Other energy sources***	6
Reduced demand	13

Notes: The percentages in this table represent the percent of forgone production that is replaced by a specific energy source (or in the case of reduced demand, the resulting reduced consumption rather than replacement) with the selection of the No Leasing scenario. The numbers can be interpreted as the percentage of anticipated production that would have been produced from the Leasing scenario if leasing had occurred (e.g., 33% by onshore production of oil and natural gas).

* Numbers may not sum due to rounding.

** Includes electricity from wind, solar, nuclear, and hydroelectric sources.

*** Includes primarily (roughly 80%) natural gas liquids, with the balance from biofuels, refinery processing gain, product stock withdrawal, liquids from coal, and "other" natural gas not captured elsewhere.

2.1.2 OECM and Upstream GHG Emissions Estimates

BOEM estimates upstream emissions of OCS oil and gas under the Leasing scenario and those of the energy substitutes under the No Leasing scenario using the OECM (Industrial Economics Inc. 2018a; 2018b). The OECM takes the level of exploration, development, and production activities estimated to occur from the Leasing scenario, as well as other outputs from MarketSim, to estimate the upstream GHG emissions from No Leasing scenario. The model also uses outputs from MarketSim to estimate the upstream emissions associated with the substitute energy sources (e.g., oil imports, onshore gas production) under the No Leasing scenario. MarketSim estimates differences in gross energy exports between the No Leasing scenario and the Leasing scenario. The range of activities[8] and their respective GHG emissions factors are available in the OECM's documentation (Industrial Economics Inc. 2018a; 2018b).

2.1.3 GLEEM: Midstream and Downstream GHG Emissions Estimates

GLEEM incorporates upstream emissions from the OECM and energy substitutions from MarketSim with additional information to generate the life cycle estimate. The model also includes additional calculations for the emissions associated with onshore processing (refining and storage), delivery of energy (i.e., oil, natural gas, or other energy substitutes) to the final consumer, and consumption of the

[8] The OECM estimates emissions from upstream activity, which includes (1) propulsion and auxiliary engines operated onboard vessels, (2) drilling operations, (3) platform operations including flaring, (4) helicopters and light aircraft, (5) use of above-ground pipelines, (6) construction (onshore and offshore), and (7) accidental oil spills and gas releases.

oil and gas products. GLEEM relies on the substitution estimates from MarketSim to estimate midstream and downstream emissions under the No Leasing scenario. GLEEM provides the annual emission estimates for the Leasing scenario and domestic midstream and downstream emission estimates for the No Leasing scenario. More details on GLEEM are available in the model documentation (Wolvovsky 2021).

2.1.4 Foreign GHG Emissions Methodology

BOEM's foreign GHG emissions analysis estimates the change in foreign emissions resulting from price changes due to an increased supply associated with OCS production. Using the best available information, BOEM converts MarketSim's estimate of the change in global oil market demand between the Leasing and No Leasing scenarios and translates this difference into a change in GHG emissions. As described in the **Section 4**, foreign energy market simulations using MarketSim are necessarily more simplistic given limited information when compared to that available for the U.S. domestic energy markets. To arrive at a reasonable estimate for GHG emissions from foreign oil consumption under the No Leasing scenario relative to the Leasing scenario for a proposed lease sale, BOEM utilizes simplifying assumptions that allow for use of a broad foreign oil consumption estimate made by MarketSim and a generic GHG emissions factor published by the U.S. Environmental Protection Agency (USEPA). BOEM expects to make refinements to its analysis for upcoming OCS lease sales and post-lease activities.

As described above, under the No Leasing scenario, oil prices would be expected to be slightly higher due to the lower energy supply relative to the Leasing scenario. Oil is a global commodity, meaning any price changes likely would impact global production and consumption. MarketSim estimates changes in foreign oil production and consumption to determine a global equilibrium (the price where supply equals demand) for oil. MarketSim estimates the change in foreign consumption for each year of anticipated production.

GLEEM takes the annual change in foreign consumption and applies an emissions factor attributable to combusted oil. For this analysis, BOEM uses a single USEPA emissions factor called "Other Oil <401°F" (USEPA 2021a). This emissions factor is a miscellaneous factor used when the end petroleum product consumed is unknown. Typically, rather than using a single emissions factor, it would be preferable to use a range of emissions factors that correspond to the different end uses of petroleum products after oil refining. However, for this analysis, BOEM applies this emissions factor to all combusted oil due to a lack of information about the end petroleum products consumed in foreign markets. The consumption of oil and its end uses vary from country to country.

GLEEM's calculations for non-combustion uses of oil is based on the U.S. market as an approximation (Wolvovsky 2021). This approach is unlikely to change the results significantly, as the amount of oil used globally in non-combustion products is small.

Although the U.S. non-combusted oil products are used as a proxy for global non-combusted oil, taking a similar approach for emissions factors would likely produce less accurate results. For instance, in 2019, the most recent year for which data are available, about 20% of European Union oil was consumed as motor gasoline (Eurostat 2022), while in the U.S. that portion was more than double, i.e., approximately 45% of all oil was consumed as motor gasoline (EIA 2022). The different emissions factors for each type of fuel (USEPA 2021a) would likely result in significant changes in multiple ways. This variability applies to all countries around the world, including variability in oil product consumption within the European Union. Therefore, a U.S. consumption model would not apply to most other countries, and though these figures are available for the European Union, as well as some other countries, they are not available globally. As a result, BOEM has decided to use a generic emissions factor that does not corollate with specific oil products but that does give a reasonable approximation of emissions from oil consumed in other countries without introducing other uncertainties into the results.

2.2 Domestic Production and Consumption Life Cycle Greenhouse Gas Emission Estimates

Table 4 shows the estimates of life cycle GHG emissions of domestically consumed or produced energy for both the Leasing scenario and those of substitute energy sources under the No Leasing scenario.

Table 4. Domestic production and consumption life cycle GHG emissions (in thousands of metric tons)

	Upstream				Midstream and Downstream				Life Cycle			
	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O
Leasing	21,183	18,073	118	1	360,334	355,367	173	2	381,517	373,440	290	3
No Leasing	44,888	29,193	623	*	309,868	306,245	119	2	354,755	335,437	742	3
Difference	(23,705)	(11,119)	(505)	*	50,467	49,122	53	*	26,762	38,003	(452)	*

Note: Values rounded to nearest 1,000 metric tons.
* Values are between -0.5 and 0.5.

For the upstream portion of life cycle emissions, BOEM estimates about 21.2 million metric tons of CO_2e would be emitted due to Leasing scenario activities. The total emissions emitted from upstream activities associated with the energy substitutes in the No Leasing scenario are 44.9 million metric tons of CO_2e. BOEM's upstream emissions factors for OCS oil and gas, as well as for OCS substitutes like imports and onshore production, are based on emissions factors found in Table 5 of the OECM documentation (Industrial Economics Inc. 2018a). The No Leasing scenario results in roughly double the CO_2e emissions for upstream activities compared to those of the Leasing scenario, given that, collectively, the substitute energy sources have higher GHG emissions per unit of production (also known as "GHG intensity") compared to the forgone domestically produced OCS oil and natural gas of the Leasing scenario.

The upstream results from the model are supported by third-party, independent sources, as cited, and BOEM's research on GHG intensity of the OCS relative to other alternative oil and gas sources. GHG intensity of oil production is a volume-weighted ratio of GHGs emitted while producing a given unit of oil. For the year 2017, deepwater production in the U.S. GOM had an estimated GHG intensity of 11 kilograms (kg) per barrels of oil equivalent (BOE) (BOEM 2021b; BSEE 2021). Combined data from BOEM and Rystad show that 83% of GOM deepwater production is below Rystad Energy's estimated U.S. average GHG intensity of 12 kg/BOE, while 94% of GOM deepwater production is less than the global average of 18 kg/BOE (BOEM 2021b; BSEE 2021; Rystad Energy 2021a; 2021b). Although the methods and assumptions differ among various sources, the findings are similar. In general, the highest GHG intensive projects are those that seek heavy oil, those that flare or vent substantial amounts of natural gas, and those that are late in their life cycle. In contrast, GOM production is generally of a medium, less dense crude, and recent OCS leasing and development activities are occurring in deep water and are earlier in their life cycle. As described, deepwater GOM upstream oil and gas production is generally characterized as having some of the lowest GHG intensity of all oil production.

The Leasing scenario results in higher midstream and downstream emissions than the No Leasing scenario. This increase is due to slightly lower consumption and fuel switching away from OCS natural gas and oil under the No Leasing scenario. BOEM estimates that 360.3 million metric tons of CO_2e would be emitted from midstream and downstream activities associated with the Leasing scenario and 309.9 million metric tons of CO_2e would be emitted from midstream and downstream activities of substitute energy sources under the No Leasing scenario.

BOEM calculates that, under the No Leasing scenario, the absence of the production would result in slightly higher oil prices than under the Leasing scenario.[9] With the higher energy prices, MarketSim estimates that domestic energy demand (from all modeled energy sources over the entire 40-year period of OCS production) would be approximately 138.9 MMBOE (roughly 12.5%) lower in the No Leasing scenario when compared to the 1,133.6 MMBOE anticipated from new OCS production under the Leasing scenario. Specifically, MarketSim estimates U.S. demand to be lower by 31.4 million barrels of oil and 482.0 billion cubic feet of natural gas under the No Leasing scenario. Although oil and natural gas demand are expected to be lower in the No Leasing scenario, BOEM anticipates that there would be higher onshore production (largely natural gas) and imports (largely oil), in addition to higher coal consumption and production.

In conclusion, BOEM's modeling shows that life cycle emissions for domestic production and consumption between the Leasing and No Leasing scenarios are largely similar. When considering the full life cycle, the differences in emissions between the Leasing and No Leasing scenarios are marginal, and even small changes in the ratio of anticipated oil to natural gas production within the Leasing scenario and underlying assumptions within the models could lead to different results. The primary modeling assumptions affecting the results are elasticities, adjustment rates, differences in emission factors, and regional energy market differences. The interplay of all these variables, along with the ratio of oil versus natural gas production within the exploration and development scenario, is the main driver of the differences in GHG emissions estimates between the Leasing and No Leasing scenarios.

Elasticity, simply defined, is a mathematical value that expresses the percent change expected in one economic variable given a 1% change in another economic variable (e.g., supply, demand, or price). Adjustment rates are the limits MarketSim sets on how much of the long-term change estimated by the elasticity values can occur in 1 year. Collectively, elasticities and adjustment rates determine the change in supply and demand of alternative energy sources given a change in the anticipated production from the Leasing scenario. The changes in the alternative energy sources determine the substitution rates estimated by MarketSim. These substitution rates impact the GHG emissions for each portion of the GHG emissions life cycle, from upstream to downstream.

[9] The average differences in price in the No Leasing scenario relative to the Leasing scenario over the 40 years of oil and natural gas production anticipated from a proposed GOM lease sale are $0.068 per billion barrels higher for oil, $0.006 per thousand cubic feet higher for natural gas, $0.001 per ton higher for coal, and $0.007 per kilowatt higher for electricity.

The varying emissions factors among the different energy sources, along with the amount of anticipated OCS oil and natural gas and their substitutes, also play a role in determining the results. For the upstream analysis, the OECM makes assumptions about the onshore regions adjacent to the 26 OCS planning areas and their reliance on imports versus existing onshore energy resources. These assumptions determine where substitute resources would come from or go to and the associated transport emissions from those substitute energy sources. Although these assumptions only affect the margins in upstream emissions between the Leasing and No Leasing scenarios, **Table 4** clearly illustrates the relatively significant role upstream emissions play in affecting the results between alternatives.

The midstream and downstream analysis results in equal, or lower, emissions rates for most substituted sources relative to those of OCS oil and natural gas. In particular, BOEM's MarketSim model indicates that, under a No Leasing scenario, oil is largely replaced by additional imports and domestic onshore oil production, with some reduced demand. A larger portion of forgone OCS natural gas is not replaced by alternative sources and represents reduced consumption. Further, zero-emissions energy sources (wind, solar, nuclear, and hydroelectric) substitute for natural gas in larger proportion than for oil. Although some coal substitution (which has higher emissions than OCS oil and natural gas) is possible domestically, its substitution rate is small relative to the combination of reduced demand and non-emitting sources of energy substitution rate.

Because natural gas energy substitutes in general have lower emissions profiles than the oil substitutes, the ratio of oil and gas production in an area can play a significant role in the margin of emissions between the Leasing and No Leasing scenario.

BOEM continues to review and evaluate the models and assumptions used in this analysis and will refine and update the methodology in future BOEM analyses.

2.3 Foreign Oil Consumption Greenhouse Gas Emission Estimates

MarketSim estimates that, as a result of the Leasing scenario, foreign oil consumption would increase by roughly 173.5 million barrels of oil in total above that of the No Leasing scenario over the 40-year period of estimated production. This difference represents 0.012% of the baseline foreign oil consumption of 1.4 trillion barrels under the No Leasing scenario during this time period. This comparison is provided for context only with regard to consumption and is not meant to characterize the relative impacts of the Leasing scenario's GHG emissions to those of the No Leasing scenario. **Table 5** presents the increase in GHG emissions attributable to the higher foreign consumption of oil under the Leasing scenario. Another way to view this is that the foreign oil consumption estimated under the No Leasing scenario is lower than under the Leasing scenario, leading to an estimated 66.8 million metric tons of CO_2e fewer GHG emissions under the No Leasing scenario.

Table 5. Change in foreign oil consumption GHG emissions under the Leasing scenario (in thousands of metric tons)

CO_2e	CO_2	CH_4	N_2O
66,769	66,537	3	1

Notes: Accounts for crude oil and petroleum product consumption only. Values rounded to nearest thousand metric tons.

2.4 Life Cycle Emissions Compared to Targets and Carbon Budgets

The Paris Agreement requires countries to set goals to help stabilize atmospheric GHG concentrations at a level that would limit anthropogenic interference with the climate system to keep the global average temperature increase to within 2°C, and preferably to within 1.5°C, of pre-industrial levels. These intermediate goals, which are on the pathway to global net-zero emissions, are referred to as Nationally Determined Contributions (NDCs) (United Nations Framework Convention on Climate Change 2015). The U.S. set its NDCs using domestic emissions from a base year of 2005. In 2005, U.S. net emissions were 6.68 billion metric tons of CO_2e (USEPA 2021b). The U.S. achieved its 2020 goal to reduce its net GHG emissions by 17% below 2005 levels, in part due to the coronavirus pandemic. Currently, the U.S. has established NDCs for 2025 and 2030, each with a two-percentage-point range (The White House 2021). **Table 6** lists the current emissions targets. The U.S. has an additional goal of net-zero emissions by 2050 (U.S. Department of State and U.S. Executive Office of the President 2021); this target is outside of the Paris Agreement framework.

Table 6. U.S. domestic GHG (CO_2e) reduction targets

Target Year	Target Net Reduction	Target Net Emissions (Current) of CO_2e (in billions of metric tons)
2025[a]	26 to 28%	4.94 to 4.81
2030[a]	50 to 52%	3.34 to 3.21
2050[b]	100%	0

Notes:
[a] Target submitted to the United Nations as part of the U.S. NDC.
[b] Target established outside of the Paris Agreement framework.

Table 7 compares the estimated emissions from the target year to the U.S. NDCs and shows the percentage of the target that is expected to be consumed under the Leasing and No Leasing scenarios. The percentages in **Table 7** likely show a worst-case scenario for years 2025 and 2030, as there is the potential for carbon capture and storage (CCS) to allow for higher emissions than the targets, while still achieving the NDCs. By 2050, to achieve the net-zero emissions target, all GHG emissions would have to be offset by removal of an equal CO_2e amount of GHGs from the atmosphere, including those resulting from any OCS development. As **Table 7** shows, the Leasing scenario is expected to release similar amounts of CO_2e compared to the No Leasing scenario.

Table 7. Comparison between GOM Leasing and No Leasing scenarios and U.S. emissions target reductions (CO_2e, in thousands of metric tons)

Target Year	Leasing CO_2e	Leasing % of U.S. Targets	No Leasing CO_2e	No Leasing % of U.S. Targets
2025	1,899	0.038% to 0.039%	1,293	0.026% to 0.027%
2030	14,625	0.438% to 0.456%	13,696	0.410% to 0.427%
2050	5,692	-	5,158	-

Notes: Percentages represent the amount of the U.S. targets that are estimated to be consumed by new leasing on the OCS or substitutions. Percentage of the 2050 targets consumed by OCS production, or its substitutes, is blank because by 2050 an equal amount of emissions would have to be removed from the atmosphere to achieve the net-zero emissions target. However, if the amount of emissions removed in 2050 is in fact less than the amount emitted, than any amount of emissions will exceed the U.S. target for 2050, up to 5,692 metric tons in amount.

Carbon budgets are different from NDCs set by governments in that they project the amount of global emissions that can be emitted before a certain amount of warming occurs. These budgets can be indexed to different global average temperature increases, but most focus on the 1.5^oC and 2^oC targets outlined in the Paris Agreement. Estimates of the remaining CO_2 emissions left in the global carbon budget vary, but they largely center around 1 trillion metric tons of CO_2 remaining (Friedlingstein et al. 2021; Intergovernmental Panel on Climate Change 2021).

Beyond seeking to reduce future emissions, another approach being aggressively pursued is CCS. This approach could effectively increase the carbon budget by capturing atmospheric or oceanic carbon before it would naturally be removed. The technology is relatively new, and though the OCS will likely play a role in CCS, efforts are currently in their infancy. With or without large-scale CCS projects, new emissions from OCS development or substitute sources of energy will count against the planet's carbon budget.

3 MONETIZED IMPACTS FROM GHG EMISSIONS

The social cost of CO_2, N_2O, and CH_4—together, the "social cost of greenhouse gases" (SC-GHG)—are estimates of the monetized damages associated with incremental increases in GHG emissions in a given year.

On January 20, 2021, President Biden issued Executive Order 13990 (86 FR 7037), *Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis*. Section 1 of Executive Order 13990 establishes an Administration policy to, among other things, listen to the science, improve public health and protect our environment, ensure access to clean air and water, reduce greenhouse gas emissions, and bolster resilience to the impacts of climate change. Section 5 of Executive Order 13990 emphasizes how important it is for Federal agencies to "capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account" and establishes an Interagency Working Group on the Social Cost of Greenhouse Gases (IWG). In February 2021, the IWG published *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide; Interim Estimates under Executive Order 13990* (IWG 2021b). This interim report updates previous guidance from 2016. The final report is still pending as of the date of this publication. BOEM is utilizing the interim

IWG estimates for this analysis; as IWG's estimates are refined and revised, BOEM may update the analysis herein as necessary.

3.1 Uncertainty in Computing Social Costs

The IWG provides impact estimates evaluated at three different discount rates (5%, 3%, and 2.5%) (IWG 2021b). The guidance includes three sets of SC-GHG values—one each at the 5%, 3%, and 2.5% discount rates and the average level of damage—and a fourth set at the 3% discount rate and the 95th percentile of damages.[10]

The different discount rates and their assumption of a statistical level of damages represent uncertainty within SC-GHG estimates. With higher discount rates, future damages are more discounted and less significant in the total estimated costs. Because damages from GHG emissions are long term, higher discount rates lead to lower estimates of the SC-GHG. This trend is evident when comparing the SC-GHG at a 2.5% discount rate versus 5% discount rate, both at average statistical damages.

The assumption of a statistical level of damages plays a significant role in capturing uncertainty. IWG (2021b) contains frequency distributions that show uncertainty in the quantified parameters defining the damage functions of the three models used to estimate the sets of SC-GHG values. The magnitude of uncertainty reflected in the distribution of damages is evident by comparing the average and 95th percentile values of the 3% discount rate models. There are additional sources of uncertainty that are not, at this time, quantified in these estimates. For example, the damages associated with ocean acidification are not included in any of the three climate models. Uncertainty around those impacts is thus not captured within the SC-GHG but may be captured qualitatively within BOEM's analysis.

3.2 Methodology for Estimating the Social Cost of Greenhouse Gas Emissions

IWG (2021b) SC-GHG estimates represent the monetary value of the net harm to society associated with adding a metric ton of GHG to the atmosphere in any given year. This SC-GHG estimated value is specific to a given year and increases through time as the harm in later years leads to greater damages given the compounding nature of GHG emissions and their relationship to an increasing Gross Domestic Product (IWG 2021a). The SC-GHG estimates represent the value of the future stream of damages associated with a given metric ton of emissions discounted to the year of emission.

BOEM uses the IWG's annual SC-GHG estimates for each of the three GHGs to compute the Leasing and No Leasing scenarios social cost estimates. The total SC-GHG is then discounted back to a net present value using the same discount rate as the SC-GHG. Next, the net present value for the three GHGs are aggregated to derive the total SC-GHG for the Leasing and No Leasing scenarios under the specific discount rate and statistical damage assumptions for that set of SC-GHG values. BOEM provides an estimate for each of these cases.

[10] The models used to assess damages from an additional metric ton of GHG perform tens of thousands of simulations as to how that metric ton of emissions would work its way through the underlying assumptions. The model arrives at a distribution of probable damages, based on one estimate for each of those tens of thousands of runs. The SC-GHG at the 95th percentile suggests that 95% of the simulations are at or below the SC-GHG estimate. The average statistical values suggest that they are the average of all values simulated.

A detailed example of the calculation is provided below.

The IWG estimates SC-GHG through 2050. BOEM extrapolated for future years using the growth rate for the final 5 years available using the equation

$$\left(\frac{2050\ SC - GHG\ value}{2045\ SC - GHG\ value}\right)^{\frac{1}{5}}$$

The IWG presents the SC-GHG estimates in 2020 dollars. BOEM has inflated these social cost estimates to 2022 dollars based on the assumed start date of leases issued from a proposed 2022 lease sale.[11] **Table 8** provides examples of the IWG SC-GHG values at the 3% discount rate and average statistical damages assumption inflated to 2022 dollars for the first year of GHG upstream emissions (2023), the peak year of upstream GHG emissions (2027), and the last year of upstream GHG emissions (2064).

The inflated annual IWG estimates of SC-GHG are applied to the annual emissions estimate for each of the three GHGs. **Table 8** shows an example of the calculation for select years of upstream emission estimates for the Leasing scenario. Note that the first and last year do not have CH_4 emissions, and the last year does not have N_2O emissions, because those GHGs are not associated with the activities taking place in those years.

Table 8. Example of domestic upstream GHG emissions in select years (for Leasing scenario)

Year	**SC-GHG Estimates*** *2022 $/Metric Ton (at 3% discount rate, average damages)*			**GHG Emissions** *(in thousands of metric tons)*			**Social Cost of GHG Emissions** *2022 $ (millions)*		
	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O
2023	1,663	56	20,169	-	226.66	0.01	-	12.59	0.18
2027	1,855	60	21,957	5.01	1,082.24	0.03	9.29	64.83	0.60
2064	4,100	105	42,651	-	0.54	-	-	0.06	-

Source: IWG (2021b)

The above calculation is performed for every year of GHG emission. To arrive at a net present value (NPV) of social costs, the annual amounts are then discounted back to the year of analysis using the same discount rate used by IWG (2021b) for the SC-GHG estimate (in this example, 3%).

The NPVs for each of the GHGs are aggregated to arrive at an estimated social cost for each discount rate and statistical damage assumption recommended by the IWG. This process is repeated for every component of the emissions life cycle for both the Leasing scenario emissions and those from substitutes under the No Leasing scenario.

[11] Inflated using the Gross Domestic Product Chain-type Price Index from EIA (2021).

3.3 Social Cost of Greenhouse Gas Results

For the reasons described below, BOEM presents the results of its SC-GHG analysis separately—one for the SC-GHG resulting from domestic production, production of imports, and domestic consumption, and another for those resulting from a shift in foreign oil consumption.

3.3.1 Domestic Production and Consumption Life Cycle

Using the methodology described above, **Table 9** estimates the social cost of the emissions expected from domestic production and consumption in the life cycle analysis for the Leasing and No Leasing scenarios, respectively. Under each of the domestic SC-GHG cases, the social costs of emissions are higher under the Leasing scenario than the No Leasing scenario. For example, at 3% discount rate and an average level of statistical damages, the Leasing scenario would result in costs of approximately $990 million when considering domestically produced and consumed OCS oil, natural gas, and their substitutes alone.

Table 9. Incremental change in domestic production and consumption life cycle social cost of GHG emissions (2022 $, billions)

Discount Rate	Statistical Damages	Leasing	No Leasing	Incremental
5.0%	Average	$4.16	$4.01	$0.15
3.0%	Average	$16.77	$15.78	$0.99
2.5%	Average	$25.72	$24.07	$1.65
3.0%	95th Percentile	$51.00	$47.72	$3.28

Notes: Values are rounded to nearest $10 million. A positive value is a cost. A negative value is a benefit. Incremental SC-GHG represents the difference between the Leasing scenario and the No Leasing scenario. A positive incremental value suggests costs are lower under the No Leasing scenario and higher under the Leasing scenario.

3.3.2 Foreign Oil Consumption

BOEM followed the same process described above to calculate the social cost of emissions resulting from increased foreign consumption of oil under the Leasing scenario (**Table 10**). **Table 10** does not account for the cost of GHG emissions from shifts in foreign energy market consumption of other substitute fuel sources, nor the upstream or midstream GHG emissions from any foreign energy market substitutes, for the reasons discussed below.

Table 10. Change in social cost of GHG emissions from the shift in foreign oil consumption associated with the Leasing scenario

Discount Rate	Statistical Damages	Incremental Value of SC-GHG from Leasing Relative to No Leasing Scenarios *(2022 $, billions)*
5.0%	Average	0.71
3.0%	Average	2.91
2.5%	Average	4.47
3.0%	95th Percentile	8.87

Notes: Values are rounded to nearest $10 million. Values presented are incremental costs of the Leasing scenario GHG emissions from an increase in foreign oil consumption relative to the No Leasing scenario.

4 GLOBAL LIFE CYCLE GREENHOUSE GAS ANALYSIS

In this analysis, BOEM estimates emissions associated with the anticipated increase in foreign oil consumption resulting from of a representative GOM lease sale. The foreign GHG emissions estimates (**Table 5**) are based only on changes in foreign oil consumption and are not as comprehensive as the estimates of life cycle emissions from domestic production or consumption (**Table 4**). BOEM recognizes that there are additional market responses and impacts that cannot be quantified at this time (**Table 1**); however, these are considered qualitatively in this section.

In developing the global life cycle GHG analysis, BOEM consulted with the contracted developer of MarketSim, Industrial Economics, Inc. (IEc)[12] to assist in refining and expanding its analysis. Through this expert review, IEc extensively evaluated BOEM's approach to estimating the change in emissions associated with the shift in foreign energy consumption. However, given the model's current capabilities and limitations, IEc acknowledged that MarketSim would not allow a complete estimation of global life cycle GHG emissions at this time.

According to IEc, the model would need demand-driven and competition-driven substitution effects for all global major energy forms as well as upstream, midstream, and downstream emissions profiles for OCS oil and gas and domestic and foreign substitutes (Price 2021). To derive these substitution effects, the model requires a detailed global baseline energy forecast that includes multiple categories of supply, demand, and prices at a regional level. IEc indicated they were unaware of any such existing forecasts with the required level of detail that have been published by a major organization. IEc suggested that, in theory, BOEM could develop its own projections of foreign supply, demand, and prices based on less detailed forecasts, but doing so would "require a number of assumptions that would introduce significant uncertainty into MarketSim's results" (Price 2021).

Currently, MarketSim estimates total non-U.S. demand for oil, but its specification of non-U.S. oil demand does not include cross-price elasticities that would capture how non-U.S. demand for oil

[12] IEc is a consulting firm that engages on a wide variety of projects including economics, public policy, and natural resource management.

changes in response to other energy prices. Similarly, the model does not capture how non-U.S. demand for oil substitutes changes in response to oil prices. MarketSim also does not capture non-U.S. production of gas and coal consumed outside the U.S. or non-U.S. consumption of gas or coal produced outside the U.S. A comprehensive accounting of all these effects would require a significant expansion of MarketSim in scope and complexity, as well as the development of baseline supply and demand projections beyond what is included in the EIA's *Annual Energy Outlook*.

Given the extensive data requirements and limitations, BOEM determined that, for this analysis, the Bureau could reasonably quantify the GHG emissions from foreign consumption of oil (for downstream only, as presented in **Section 2.3**). However, BOEM continues to evaluate options to improve methodologies to estimate upstream and midstream emissions from foreign oil production for use in future analyses.

Evaluating the foreign energy market qualitatively, the price decreases for oil under the Leasing scenario would be felt beyond U.S. borders given that oil is a globally traded commodity. The substitutions (i.e., natural gas, coal, biofuels, and renewables) discussed earlier for the domestic energy market also occur in the foreign markets in response to the decrease in the price of oil, but at different rates within each country or region depending on their energy infrastructure and market.

4.1 Foreign Oil Life Cycle Change: Upstream

In its research, IEc found existing data that would allow BOEM to estimate the upstream emissions associated with the production of non-U.S. oil consumed outside of the U.S (Price 2021). However, at this time, BOEM has not quantified the associated emissions, as the Bureau continues to explore the necessary assumptions required to reliably estimate these foreign upstream emissions.

Using MarketSim's existing calculations, BOEM estimates that crude oil production in foreign markets would be higher under the No Leasing scenario than the Leasing scenario. To estimate the emissions associated with this increase in production, BOEM would need information on where the increase in oil production is coming from and the relative GHG intensity of different foreign oil markets. For comparison, in the domestic analysis, foreign upstream emissions estimated for oil imported to the U.S. is more specific because BOEM has data on its trading partners and constructs a weighted average to estimate emissions based on the volume of imported oil the U.S. consumes. BOEM could use a generic factor to translate the increase in emissions under the No Leasing scenario but prefers not to overestimate the impact nor skew the results.

BOEM continues to review relevant data sources that would allow for quantifying emissions from the estimated change in foreign oil production in future analyses. In the interim, the best available and credible information suggests that the changes in foreign oil production would increase GHG emissions under the No Leasing scenario and potentially mitigate (decrease) some of the increased GHG emissions under the Leasing scenario. However, even when combined with other potentially offsetting sources of emissions from foreign energy substitutes currently not quantified under the No Leasing scenario, mitigating changes in foreign oil production would not overcome the full magnitude of increased GHG emissions under the Leasing scenario, and the Leasing scenario would still result in increased GHG emissions when compared to the No Leasing scenario.

4.2 Foreign Oil Life Cycle Change: Midstream

According to IEc, estimating midstream emissions resulting from the change in oil consumption would also introduce several new complexities, as the GHG emissions associated with activities such as refining differ based on the quality of crude oil and the technological capabilities of different refining sectors. Given these complexities and limited data availability, BOEM considers these impacts qualitatively in this section. Unlike foreign upstream emissions, the models provide no direct estimates for the foreign midstream. However, it is reasonable to qualitatively conclude that midstream emissions would increase under the Leasing scenario given the increase in consumption.

Under the Leasing scenario, foreign production is expected to decrease, and foreign oil consumption is projected to increase. Increased consumption must be met with increases in midstream activities, either from the U.S. or other foreign markets. Although some of the midstream refining occurs in the U.S. and is exported to foreign markets, not all of the increase in midstream processes is accounted for in BOEM's estimate of new OCS oil refined in the U.S. and exported. BOEM does not account for the midstream transportation and storage activities or the refining that takes place abroad. The vast majority of the midstream emissions due to the increased consumption is unaccounted for and would represent an increase under the Leasing scenario or, alternatively, a decrease under the No Leasing scenario.

4.3 Substitutes for Oil in Foreign Markets

To understand the complexities and limitations of estimating substitutes and their emissions in foreign markets, it is useful to provide context from BOEM's domestic analysis. The inputs for BOEM's domestic GHG model are based on the best available and most credible information. They are illustrative of the range and depth of data necessary to credibly conduct a full quantitative analysis of changes in foreign GHG emissions. BOEM's MarketSim model adopts assumptions from the EIA (the primary Federal government entity on energy statistics and analysis) and from economics literature cited in the model documentation. These assumptions help BOEM estimate where the likely substitute sources of oil and gas would come from (i.e., oil and gas production from state submerged lands, onshore domestic production, and international imports) and the other types of energy sources that would be utilized to balance demand and supply (i.e., coal, biofuels, nuclear, and renewable energy). Accurately estimating this mix of substitute energy sources is important because each substitute energy source has a different life cycle GHG emissions profile over the course of its production, transportation, refining, and/or consumption.

A main factor in considering the impact of the change in foreign oil consumption is identifying the other energy sources that would be replaced with oil consumption given an oil price reduction. These sources vary throughout the world. In some areas, oil may replace coal, and the emissions associated with the oil consumption increase would be expected to bring a reduction in global emissions as a result of the Leasing scenario. However, it is unlikely that coal would substitute for oil on such a scale as to fully compensate for the decrease in emissions from lower foreign oil consumption under the No Leasing scenario relative to the Leasing scenario. Instead, other areas may rely more heavily on natural gas, biofuels, nuclear, or renewable energy, all of which have a lower GHG intensity than oil. In these cases, the shift to oil leads to a net increase in emissions, though the net change in emissions would still not be as large as that estimated in **Table 5**. The degree to which various energy substitutes might replace forgone oil consumption in foreign energy markets under the No Leasing scenario is uncertain, but it is appropriate to acknowledge that substitution would certainly occur and mitigate a portion of the decreased emissions that would result from forgone foreign oil consumption.

IEc highlighted the complexities and wide range of data required to consider these substitutions. IEc found that the incremental emissions associated with the full life cycle for all energy sources other than oil produced and consumed in foreign markets cannot be quantified without making significant assumptions and are more appropriately addressed qualitatively. Though oil is a global commodity, the regional nature of gas, coal, and electricity would require MarketSim to consider regional price differences and calculate regional equilibriums for these other fuels. IEc characterized the necessary updates to create this global-regional analysis as “a major challenge.” Furthermore, regarding the necessary underlying data that would be required to support a model if built, IEc stated the following:

> We are unaware of any existing forecasts published by EIA, the International Energy Agency, or other organizations that include this level of detail. In the absence of such a forecast, BOEM could develop its own based on less detailed forecasts that may be available, but this would likely require a number of assumptions that would introduce significant uncertainty into MarketSim’s results (Price 2021).

In summary, BOEM's domestic production and consumption analysis estimates the emissions associated with the production of energy substitutes under the No Leasing scenario, but BOEM's foreign GHG emissions quantitative analysis is limited to only the foreign downstream (consumption) of oil. Missing from the foreign emissions impacts are changes in foreign oil’s upstream and midstream emissions associated with the downstream consumption. However, BOEM is considering suggested methodologies that would allow for foreign oil’s higher upstream emissions to be captured under the No Leasing scenario. Moreover, though foreign oil consumption is lower in the No Leasing scenario, foreign energy substitutes likely would be higher, because elevated oil prices can result in fuel switching to other fuels (e.g., coal, natural gas, biofuels, renewables) and a small reduction in overall energy demand. Because the quantifiable foreign analysis is not comprehensive, domestic production and consumption emissions are not directly comparable to the foreign estimates. Therefore, BOEM is not providing a combined quantitative estimate of domestic and foreign emissions because it would be potentially misleading to add them together.

BOEM is investigating methods to incorporate the global upstream emissions and estimate the full life cycle of foreign energy substitutes other than oil. However, as discussed earlier in **Section 4**, even if the unaccounted-for reductions in GHG emissions from foreign oil’s upstream activities and the full life cycle of all other foreign substitute fuel sources were to be quantified in the No Leasing scenario, global GHG emissions would still be higher with leasing than without new leasing. The unquantified reductions would not be high enough to offset the increase in GHG emissions resulting from the increase in foreign oil consumption associated with new leasing, because oil has higher emissions than all other substitute energy sources except coal. Moreover, downstream emissions account for the majority of the life cycle emissions, meaning most of the foreign GHG emissions have already been quantified in this analysis.

5 AREAS OF UNCERTAINTY IN MODELING INPUTS

BOEM's GHG emissions and social cost analysis is subject to uncertainty regarding several key variables. As shown in the preceding tables, domestic consumption and production emissions associated with the Leasing scenario and those associated with the energy substitutes under the No Leasing scenario are fairly similar. BOEM recognizes the importance of understanding and considering the trade-offs of different policy decisions; several factors and inherent differences in model assumptions lead to differences in results. Among the primary factors are those related to elasticities, adjustment rates, and ratio of anticipated OCS oil versus OCS natural gas. The interplay of the different elasticities for oil versus natural gas and their substitutes with the ratio of oil versus natural gas production is the main driver of the differences in emissions between OCS oil and natural gas and their substitutes.

This section focuses on the two key variables in the analysis and the importance of those assumptions in the final results: 1) elasticities and adjustment rates and 2) anticipated activity and production, specifically the ratio of anticipated OCS oil versus natural gas. Lastly, BOEM acknowledges the uncertainty in results derived from using model inputs that are based on current policies and technological capabilities, which would change under a net-zero emissions future.

5.1 Elasticities and Adjustment Rates

Elasticities and adjustment rates within MarketSim are integral to the GHG emissions results, and there is inherent uncertainty within the values used by the model.

Elasticities are used to determine the amount of fuel switching, which is the change in demand and supply between alternate energy sources in response to the price change driven by the anticipated production of OCS oil and natural gas. Elasticity measures the percentage change of one economic variable in response to a change in another variable. It is often used to estimate a change in supply or demand given a change in price (**Figure 3**). Additionally, there are cross-price elasticities that describe the response consumers have to a particular energy source given a change in price of a substitute energy source.

$$\text{Supply Elasticity} = \frac{\text{\% Change, Quantity Supplied}}{\text{\% Change, Price of Supply}} \Rightarrow \text{\% Change, Price of Supply} = \frac{\text{\% Change, Quantity Supplied}}{\text{Supply Elasticity}}$$

Figure 3. Illustration of supply elasticity

Along with elasticities, MarketSim also includes an adjustment rate variable. Given that the elasticities are long-term elasticities, BOEM uses adjustment rates to limit the amount an energy source's quantity supplied or demanded can shift in any year. Elasticities and adjustment rates together determine the change in supply and demand of substitute energy sources, given a change in the anticipated production from the Leasing scenario. The changes in substitute energy sources, primarily determined by the elasticities and adjustment rates, determine the substitution rates estimated by MarketSim. In turn, these substitution rates impact GHG emissions rates for each portion of the GHG emissions life cycle, from upstream to downstream.

BOEM continually evaluates its models to update them with the most recent available data. BOEM completed a review and update of its MarketSim model and documentation in November 2021 (Industrial Economics Inc. 2021). The updated model includes new elasticity values from peer-reviewed literature and expert sources, as well as two new baseline oil supply categories of conventional onshore (lower 48) and unconventional onshore (lower 48) oil production.

5.2 Anticipated Activity & Production: Oil and Gas Ratios

Another model input that drives results and has an element of uncertainty is anticipated activity and production. The amount of production and associated activities (exploration, development, and decommissioning) drive upstream emissions from the Leasing scenario. However, the ratio of anticipated OCS oil to OCS natural gas production is the major driver for the substitutions analysis and, subsequently, the No Leasing scenario and incremental life cycle emissions. Chapter 5 of the *Draft Economic Analysis Methodology for the 2023–2028 National Outer Continental Shelf Oil and Gas Leasing Program* discusses BOEM's process for estimating anticipated production (BOEM 2022b).

Changes in the ratios of production of oil versus natural gas lead to different substitution rates and, consequently, different GHG emissions results. Oil and natural gas have different own-price supply and demand elasticities, as well as different cross-price elasticities with substitute energy sources. **Table 3** shows the substitution rates for oil and natural gas. Furthermore, each OCS planning area has different volumes of anticipated oil versus natural gas production. Therefore, GHG emissions estimates vary among areas depending in part on their proportion of oil to natural gas production.

5.3 Changes in Current Laws and Policies

As noted above, substitution analysis is impacted by significant uncertainty given that it is an indicator of changes in energy markets. MarketSim uses as its baseline the *Annual Energy Outlook* (EIA 2020), which is based only on current policies and laws and does not assume regulations will be implemented to achieve net-zero emissions by 2050. If additional climate policies are put into place, there could be major changes in future energy markets and corresponding changes in how oil supply reduction may impact the markets. Alternatively, if major international supplies of oil are no longer available, the importance of OCS oil may increase, and substitutions could then have even broader implications.

BOEM is considering ways to incorporate U.S. climate commitments and future climate scenarios into the emissions modeling analysis. The changes in producer and consumer behavior patterns and policy changes that could help in achieving net-zero energy emissions are largely beyond the scope of BOEM's authority, but the Bureau recognizes the need to continually seek the best available information for our analyses and to address the policy mandates adopted under the Paris Agreement and established by the President for the Nation.

6 SUMMARY

BOEM's analysis of GHG life cycle emissions resulting from OCS lease sales indicates that domestic emissions from the No Leasing scenario are similar to those of the Leasing scenario given that energy market substitutes would replace large portions of domestic production under the Leasing scenario. As shown in the paper, slightly more domestic emissions are expected under the Leasing scenario in comparison to the No Leasing scenario. Global emissions under the Leasing scenario are anticipated to be even larger when considering the impact of changes in foreign oil consumption (**Table 5**). Although BOEM's analysis includes quantification of GHG emissions from foreign oil consumption, lack of needed information precludes quantification of foreign oil's upstream and midstream emissions and foreign substitutes' full life cycle emissions at this time. However, as discussed in **Section 4**, such estimates would not be expected to change BOEM's conclusion that more global GHG emissions would occur under the Leasing scenario.

BOEM's quantitative and qualitative GHG analyses together represent the best available approach for comparison of GHG emissions from the Leasing and No Leasing scenarios and serve as a proxy for evaluating and comparing impacts to climate change under both scenarios.

Nonetheless, BOEM continues its review and study of these issues and will update the foreign life cycle analysis as new data and methodologies become available. BOEM includes the global component in this analysis as an initial methodology using the most credible information currently available and will continue to review and refine the methodology moving forward.

7 REFERENCES

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U.S. Department of the Interior

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. The bureau promotes energy independence, environmental protection, and economic development through responsible management of these offshore resources based on the best available science.