United States Department of the Interior

BUREAU OF OCEAN ENERGY MANAGEMENT
WASHINGTON, DC 20240-0001

Note To Readers

February 08, 2022

RE: Attached Memorandum (Capabilities of MarketSim and the OECM for the Estimation of GHG Emissions Impacts)

The attached memo, written by Industrial Economics, Inc. (IEc) at the request of BOEM, provides IEc's assessment of BOEM's ability to model a global response to OCS supply shocks and resulting GHG emissions. The assessment is limited to their knowledge of the models they support with BOEM and their expertise as consultants on energy economics. This is primarily focused on the Market Simulation Model (MarketSim), the Offshore Environmental Cost Model (OECM), and their research of the academic literature and industry data available to conduct a global estimate of GHG emissions. It does not include a detailed assessment of other GHG emissions models or analyses BOEM may have ongoing outside of those two models

IEc

MEMORANDUM | JUNE 13, 2021

TO Kristen Strellec and Charles Paris, BOEM

FROM Jason Price, IEc

SUBJECT Capabilities of MarketSim and the OECM for the Estimation of GHG Emissions Impacts

1. INTRODUCTION

Pursuant to recent court rulings and policy changes instituted by the new Administration, BOEM is seeking to enhance its capability to assess the greenhouse gas (GHG) emissions impacts associated with outer continental shelf (OCS) oil and gas development. In the *Center for Biological Diversity v. Zinke*, the Court of Appeals for the Ninth Circuit (the Court) ruled that BOEM must perform a quantitative analysis not only of the domestic GHG impacts associated with OCS oil and gas decisions, but also the corresponding foreign GHG impacts, including downstream emissions impacts (i.e., associated with the consumption of fossil fuels). The Court also stipulated that, in situations where a quantitative analysis is not possible, BOEM must explain more specifically why such an analysis is not possible.

Against this backdrop, the new Administration has also issued guidance related to the GHG impacts of policy decisions. Specifically, Section 5(a) of Executive Order 13990 states:

> *"It is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account. Doing so facilitates sound decision-making, recognizes the breadth of climate impacts, and supports the international leadership of the United States on climate issues. The "social cost of carbon" (SCC), "social cost of nitrous oxide" (SCN), and "social cost of methane" (SCM) are estimates of the monetized damages associated with incremental increases in greenhouse gas emissions."*

Similarly, Section 5(b) of Order 3399 issued by the Secretary of the Interior stipulates the following:

> *"Identifying important interactions between a changing climate and the environmental impacts of a proposed action in NEPA documents can help decision makers identify opportunities to reduce GHG emissions, improve environmental outcomes, and contribute to protecting communities from the climate crisis.*
>
> *When considering the impact of GHG emissions from a proposed action, Bureaus/Offices should use appropriate tools, methodologies, and resources available to quantify GHG emissions and compare GHG quantities across alternatives. When quantifying GHG emissions is not possible because tools, methodologies, or data inputs are not reasonably available, Bureaus/Offices will*

provide a qualitative analysis and the rationale for determining that a quantitative analysis is not warranted."

To comply with the Court's ruling and implement the policy changes specified above, BOEM seeks to better understand the capabilities of two of its models that, together, may inform the assessment of foreign GHG impacts as well as any GHG impacts not currently captured in BOEM assessments: the Market Simulation Model (MarketSim) and the Offshore Environmental Cost Model (OECM). MarketSim is a multi-market partial equilibrium energy market model that BOEM uses to (among other applications) assess the substitution effects associated with changes in OCS oil and gas production. The OECM is an Access-based model that assesses the environmental and social costs of an OCS exploration and development scenario (including GHG emissions impacts), net of the costs associated with the No Action Alternative.

Consistent with BOEM's objective of better understanding the GHG estimation capabilities of these models, the purpose of this memo is three-fold:

1) Assess the capabilities of MarketSim and the OECM for estimating the *full* GHG impacts associated with changes OCS oil and gas activity, making note of any structural or data-related limitations for both models.
2) Identify any limitations of the models that BOEM may feasibly address in the short term, either through minor modifications to one or both models or post-processing analyses that may be developed from model outputs.
3) For data and modeling limitations that are difficult or impossible to overcome, develop a more robust explanation of the underlying difficulties.

The sections that follow largely focus on these three elements. To provide context for the material presented for each of these items, however, this memo first describes the analytic and data requirements for developing a thorough and accurate assessment of the GHG impacts associated with OCS oil and gas activity.

2. REQUIREMENTS FOR FULL AND ACCURATE ACCOUNTING OF GHG IMPACTS

Production of oil and gas on the OCS may have wide-ranging effects across U.S. and foreign energy markets that result in changes to global GHG emissions. These GHG impacts may be related to fuel extraction (i.e., upstream effects), the processing and transportation of fuel (i.e., midstream effects), and fuel consumption (i.e., downstream effects). Because each of these effects may vary by energy source and/or location (e.g., U.S. versus non-U.S.), accurately capturing these GHG impacts requires a detailed understanding of both the energy substitution effects that result from OCS activity and the GHG emissions profiles associated with the production, processing & transportation, and consumption of individual energy sources.

The substitution effects that result from OCS oil and gas production include consumers substituting between different forms of energy (including between an energy source and conservation), producers substituting production of one energy source for another in conjunction with consumer substitution (e.g., producers shifting from oil to gas production as demand shifts from oil to gas), and (for a given energy source) substitution

between different production sources (e.g., production of oil from conventional wells versus unconventional wells). For example, increased OCS oil production may lead to reduced energy conservation among U.S. consumers, reduced U.S. and non-U.S. *consumption* of natural gas, reduced U.S. and non-U.S. *production* of natural gas, and reduced production of oil from domestic onshore sources and non-U.S. sources. As this simple example illustrates, a full accounting of the substitution effects that affect global GHG emissions requires the following:

- ***Assess all major forms of energy:*** To capture the substitution effects associated with OCS oil and gas production, an analysis must include explicit representations of oil and gas markets, as well as the major substitutes for oil and gas. This would include electricity as well as coal.
- ***Assessment of energy markets on a global scale:*** Because OCS oil and gas production may affect energy markets in the U.S. as well as outside the U.S., a complete understanding of the substitution dynamics associated with OCS production requires the assessment of all major energy sources on a global scale. This includes assessment of both the consumption and production of each major energy source both within the U.S. and outside the U.S.
- ***Explicit representation demand-driven substitution effects:*** A global representation of each energy market is necessary but not sufficient for a full accounting of the substitution effects that affect GHG emissions. In addition to examining energy markets globally, an analysis must also include an explicit representation of how the market for one energy source affects demand for other energy sources, thereby causing shifts in consumption and production across energy sources. For example, this could involve the inclusion of cross-price elasticity parameters in the specification of demand for each energy source.
- ***Explicit representation of competition-driven substitution effects for a given energy source:*** Although the modeling of cross-price effects allows for the assessment of demand-driven substitution, substitution in energy markets also arises from competition between sources of supply for the same fuel. For example, a reduction in the oil price associated with increased OCS oil production may (among other effects) lead to reduced oil production from conventional onshore wells. To the extent that the GHG footprint of conventional onshore wells differs from that of OCS oil production, capturing this substitution effect is important for developing a full accounting of the net GHG emissions impacts associated with OCS oil and gas activity. More generally, a thorough analysis of the GHG impacts of OCS oil and gas activity must include an explicit representation of different production sources for the same fuel, if those production sources differ in terms of their GHG footprint.

In practical terms, the above conditions would imply modeling supply and demand for oil, gas, electricity, and coal separately for both the U.S. and non-U.S. markets, with cross-price effects or other mechanisms for capturing substitutability between energy sources.

In conjunction with projected substitution effects such as those described above, a thorough assessment of the GHG emissions impacts associated with OCS oil and gas activity requires detailed information on the GHG emissions profiles of OCS oil and gas and likely substitutes. This includes GHG emissions related to the following:

- ***Upstream, midstream, and downstream emissions for OCS oil and gas:*** This would include a full representation of the GHG emissions associated with all facets of OCS exploration and development, such as seismic surveys, drilling of exploration and development wells, the transport of personnel and supplies on support vessels and helicopters, the operation of platforms, and platform decommissioning. GHG emissions associated with midstream activities include emissions related to the transportation of oil and gas to different markets, distribution within a given market (e.g., delivery of refined petroleum to retail outlets), gas processing (e.g., to remove moisture prior to injection into a pipeline network), and petroleum refining. Downstream GHG emissions would include emissions associated with the consumption of OCS oil and gas, both in the U.S. and in foreign markets.
- ***Upstream, midstream, and downstream emissions of domestic substitutes for OCS oil and gas:*** The domestic substitutes for OCS oil and gas are diverse and include various categories of onshore oil (e.g., tight oil), onshore gas, and onshore coal. Assessing the net GHG impacts of OCS oil and gas exploration and development requires a full accounting of the upstream, midstream, and downstream GHG emissions associated with each of these substitute energy sources. This would include emissions associated with drilling onshore oil and gas wells; the extraction of coal from mine sites; transporting domestic oil, gas, and coal to market; distribution in local markets (in the U.S. and foreign countries); and consumption (again, both in the U.S. and foreign countries).
- ***Upstream, midstream, and downstream emissions of foreign substitutes for OCS oil and gas:*** The foreign substitutes for OCS oil and gas are also diverse with several sources of production. A comprehensive accounting of the net GHG impacts of OCS oil and gas development requires assessment of the emissions associated with the various upstream, midstream, and downstream emissions sources as specified above, but for the non-U.S. context. Because of the significant diversity in non-U.S. substitutes for OCS oil and gas, the use of composite GHG emissions information (e.g., an average emissions factor for non-U.S. oil production) would be appropriate in many cases.

3. CAPABILITIES OF MARKETSIM AND THE OECM FOR GHG IMPACT ASSESSMENT

MarketSim and the OECM, together, meet several but not all of the requirements described above for fully capturing the net GHG impacts associated with OCS exploration and development. We discuss the relevant capabilities and limitations of each model below.

MARKETSIM

BOEM relies on MarketSim to model the substitution effects that drive changes in global GHG emissions. Focusing on the first two requirements described above related to the assessment of substitution effects (i.e., assess all energy sources and examine each energy source on a global scale), MarketSim captures the types of energy that are the most likely substitutes for OCS oil and gas, though oil is the only energy source that it models on a global scale. As shown in Exhibit 1, which identifies the energy sources reflected in MarketSim and the model's geographic scope for each energy source, the model represents the U.S. markets for natural gas and coal, with imports and exports. As such, it does not capture (1) non-U.S. production of gas and coal consumed outside the U.S. or (2) non-U.S. consumption of natural gas or coal produced outside the U.S. Similarly, the model's treatment of electricity is limited to the U.S. market with net imports.

Where the model's structure allows, MarketSim captures demand-driven substitution effects relevant to the assessment of net GHG impacts, though MarketSim's representation of these effects is limited by the model's spatial scope for some energy sources. For U.S. demand of oil, gas, electricity, and coal, MarketSim includes cross-price elasticities in the specification of demand that allow the model to simulate shifts in U.S. demand from one energy source to another. For non-U.S. demand, however, MarketSim does not capture these substitution effects. Because MarketSim does not include a full representation of non-U.S. gas, coal, and electricity demand (i.e., it only captures non-U.S. demand for U.S. exports), it is not possible for the model to capture substitution in non-U.S. demand for these energy sources. For example, to the extent that new OCS oil production reduces oil prices, MarketSim cannot estimate the degree to which these reductions lead to reduced non-U.S. demand for natural gas and other oil substitutes, since the model does not simulate total non-U.S. demand for these fuels. While MarketSim does estimate total non-U.S. demand for oil, its specification of non-U.S. oil demand does not include cross-price elasticities to capture how non-U.S. demand for oil changes in response to other energy prices. Because MarketSim does not estimate total non-U.S. demand for gas, coal, or electricity, it also does not generate estimates of non-U.S. prices for these energy sources that would be necessary for cross-price oil demand calculations.[1]

[1] As described further below, modeling gas, coal, and electricity markets on a global scale would likely require the specification of prices by region for these energy sources.

EXHIBIT 1. LEVEL OF DETAIL AND SPATIAL SCOPE OF ENERGY PRODUCTION AND CONSUMPTION IN MARKETSIM

FUEL	OIL	GAS	ELECTRICITY	COAL
U.S. Production	• OCS production and six non-OCS sources modeled separately.	• OCS production and six non-OCS sources modeled separately.	• Electricity supply modeled for nine U.S. power production technologies.	• U.S. supply modeled as a single category.
U.S. Consumption	• Consumption modeled separately for four end-use sectors, plus electricity.	• Consumption modeled separately for four end-use sectors, plus electricity.	• Electricity demand modeled separately for five end-use sectors.	• Consumption modeled separately for the industrial sector, the electricity sector, and "other".
Foreign Production	• Non-U.S. (rest of world) estimated as single production category. • Pipeline imports from Canada estimated as portion of non-U.S. production but not integrated into model equilibration.	• Not modeled comprehensively. • Non-US production limited to U.S. gross pipeline imports and U.S. gross LNG imports.	• Not modeled comprehensively. • Modeling of non-U.S. supply limited to U.S. net imports of electricity.	• Modeling limited to production of coal imported into the U.S.
Foreign Consumption	• Specified as sum of (1) non-U.S. demand for U.S. crude oil, (2) non-U.S. demand for U.S. refined products, and (3) non-U.S. demand for non-U.S. oil.	• Not modeled comprehensively. • Non-US demand limited to demand for U.S. exports.	• Not modeled comprehensively. Reflected in estimates of U.S. net imports (see above)	• Modeling limited to foreign consumption of coal exported from the U.S.

Similar to MarketSim's treatment of substitution driven by demand-related cross-price effects, the model accounts for some, but not all, substitution effects arising from competition between different sources of supply for the same fuel. As indicated in Exhibit 1, MarketSim models U.S. oil and gas supply for six production sources each for oil and gas (other than new OCS production), with supply elasticities, adjustment rates, and calibration parameters specified separately for each source. The model also includes nine supply categories for U.S. electricity production. With this level of detail, MarketSim captures intra-fuel substitution for domestic oil, natural gas, and electricity. For U.S. coal production, however, MarketSim includes only one source of supply and therefore does not capture substitution between different supply sources (e.g., regions or mine types). MarketSim also does not capture substitution between different non-U.S. sources of gas, coal, or electricity, given that that model does not estimate total non-U.S. production of these energy sources. MarketSim does estimate total production of oil from non-U.S. sources, but the only categories of supply represented in the model are total non-U.S. oil imported into the U.S. via pipeline and all other non-U.S. production. MarketSim's representation of substitution between non-U.S. sources of production is therefore quite limited.

Based on the information presented above, Exhibit 2 summarizes the substitution effects relevant to developing a full accounting of net GHG impacts and describes the extent to which these effects are captured in MarketSim. The exhibit presents this information separately for demand-driven substitution and substitution related to competition between production sources for the same fuel/energy source.

Petroleum Refining

As described above, a comprehensive assessment of the net GHG impacts associated with OCS oil and gas leasing would reflect upstream, midstream, and downstream activity. In the context of the oil market, midstream activity includes emissions associated with petroleum refining. While virtually all oil is refined prior to use, understanding the degree to which OCS development affects the spatial distribution of refining is important for fully capturing the net GHG impacts of OCS development. Because refineries differ in terms of their energy efficiency and the technologies they use, the GHG footprint of refining is dependent on how oil is distributed across refineries in different countries. For example, not all refineries are equipped with catalytic cracking units that break large hydrocarbon molecules down into smaller, high-value molecules such as those in transportation fuels. These units are a significant source of GHG emissions for refineries equipped with this technology, as evidenced by the fact that catalytic cracking and reforming accounts for approximately 23 percent of the U.S. refining industry's CO_2e emissions.[2]

[2] U.S. EPA, Greenhouse Gas Reporting Program Industrial Profile: Petroleum Refineries Sector, September 2019, available at https://www.epa.gov/sites/production/files/2019-10/documents/petroleum_refineries_industrial_profile_9_25_2019.pdf.

EXHIBIT 2. SUMMARY OF SUBSTITUTION EFFECTS CAPTURED IN MARKETSIM

SUBSTITUTION TYPE	SUBSTITUTION EFFECT	MARKETSIM TREATMENT
Demand-Driven Substitution	U.S. substitution between fuels that may substitute for OCS oil and gas	MarketSim captures by including cross-price effects in U.S. demand equations for each energy source.
	Non-U.S. substitution between fuels that may substitute for OCS oil and gas.	Not captured by MarketSim for any energy sources.
Competition Between Energy Sources	Competition-driven substitution between different U.S. sources of a given fuel/energy source	Captured in MarketSim by modeling multiple U.S. production sources for a given fuel (except for coal), with separate supply elasticities, adjustment rates, and calibration parameters for each source.
	Competition-driven substitution between different non-U.S. sources of a given fuel/energy source	For oil, captured only by modeling pipeline imports of oil separately from other non-U.S. production, with separate supply elasticities, adjustment rates, and calibration parameters. For other energy sources, MarketSim does not capture competition between non-U.S. sources.
	Competition-driven substitution between U.S. and non-U.S. sources of a given fuel/energy source	Captured only for oil, with competition between individual types of U.S. sources and non-U.S. oil. For gas, coal, and electricity, limited to competition to meet U.S. demand: • ***Gas:*** competition between U.S. sources, pipeline imports, and LNG imports. • ***Electricity:*** competition between U.S. sources and "net imports" • ***Coal:*** competition between U.S. sources and imports

As currently designed, MarketSim is not capable of accurately informing the assessment of refining sector GHG emissions. The model treats oil as a homogenous commodity with all sources as perfect substitutes for each other, even though crude oils vary in their quality (e.g., heavy crude versus light crude). These differences in quality have implications for where crude oil is transported and refined and the specific petroleum products that can be produced from the oil. Maximizing the value obtained from heavy crude oils requires sophisticated refineries with cracking facilities such as those described above, which are more prevalent in the U.S. than in many other countries. Therefore, to capture the degree to which OCS activity affects GHG emissions from the global petroleum refining sector, MarketSim would need to account for the quality of different crude oils and the technological characteristics of the refining sector in the U.S. and in other countries. The model currently lacks this level of detail, as it includes no representation of crude oil quality and does not model the refining sector.

OECM

The OECM estimates the GHG emissions associated with a user-defined OCS oil and gas exploration and development (E&D) scenario net of impacts associated with the No Action Alternative. To generate these estimates, the model relies on activity data included in the E&D scenario (e.g., number of exploration wells drilled), outputs from MarketSim indicating the degree to which the new OCS production displaces the production of substitutes, and GHG emission factors included in the OECM.

The OECM captures a broad range of GHG emissions impacts associated with a user-defined E&D scenario and the corresponding No Action Alternative. The model, however, is not comprehensive in its accounting of GHG impacts. In some cases, this is due to MarketSim not providing the OECM with the inputs required to estimate the change in GHG emissions from a certain type of emissions source. For other GHG effects, MarketSim generates the inputs that would be required by the OECM, but the OECM was not designed to estimate these GHG impacts. Exhibit 3 identifies the specific GHG impacts that the OECM captures and those that it does not capture. The exhibit presents this information separately by energy source (i.e., OCS oil and gas versus substitutes) and phase in the production-consumption lifecycle (i.e., upstream, midstream, and downstream emissions).

EXHIBIT 3. SUMMARY OF OECM CAPABILITIES FOR SPECIFIC GHG IMPACTS

ENERGY SOURCE	PHASE	GHG IMPACTS CAPTURED	GHG IMPACTS NOT CAPTURED
OCS Oil & Gas	Upstream[1]	• The OECM includes a thorough accounting of the GHG emissions associated with upstream emissions for a user-defined E&D scenario. This includes emissions associated with seismic surveys; exploration well drilling; development well drilling; FPSO construction en route to the site; FPSO installation at the site; the construction of offshore platforms, subsea structures, and pipelines; the operation of production platforms and FPSOs; support vessels and helicopters traveling between shore bases and production sites; FPSO removal; and platform decommissioning.	• No upstream GHG impacts excluded. The OECM includes a thorough accounting of upstream GHG impacts for OCS oil and gas.
	Midstream	**Transportation of OCS Oil and Gas** • For oil, the OECM captures GHG emissions related to (1) transporting oil to shore via tugs and barges, (2) transporting OCS oil from Alaska to the West Coast, and (3) transporting exported oil (crude and refined products) via tanker.	**Transportation of OCS Oil and Gas** • The OECM does not capture GHG emissions associated with the domestic transportation of OCS oil or gas once it has reached shore. This includes transportation via transmission pipelines, distribution pipelines (in the case of natural gas), and land-based tanker transport (mostly applicable to oil). • For natural gas, the OECM does not estimate transportation-related GHG emissions associated with changes in exports. **Processing of OCS Oil and Gas** • The OECM does not estimate GHG emissions related to petroleum refining. • The model also does not estimate emissions related to the processing of natural gas (e.g., to remove liquids from gas prior to injecting into pipelines).
	Downstream	• The OECM itself does not estimate emissions related to the consumption of OCS oil and gas. BOEM, however, has estimated the change in consumption-related emissions for U.S.-based consumption based on emission factors not included in the OECM.	• Consumption-related GHG emissions not estimated by the OECM, but BOEM has estimated emissions related to changes in U.S. fuel consumption. Neither the OECM nor analyses conducted by BOEM outside the model have estimated non-U.S. GHG emissions related to consumption.

ENERGY SOURCE	PHASE	GHG IMPACTS CAPTURED	GHG IMPACTS NOT CAPTURED
Substitutes for OCS Oil & Gas	Upstream[1]	**U.S. Production** • GHG emissions estimated for the domestic production of substitutes for OCS oil and gas, including onshore oil, conventional onshore gas, unconventional onshore gas, and onshore coal. **Non-U.S. Production** • For non-U.S. oil and gas, the OECM estimates GHG emissions related to the production of oil and gas imported into the U.S. via pipeline and oil and gas imported into the U.S. via tanker.	**U.S. Production** • No GHG impacts excluded. **Non-U.S. Production** • The OECM does not estimate changes in GHG emissions associated with the production of foreign oil or natural gas consumed outside the U.S. MarketSim, however, does generate data that would allow for the estimation of these emissions for oil. • The OECM does not estimate changes in GHG emissions related to any changes in foreign coal production.
	Midstream	**Fuel Transportation** • For oil, the OECM captures GHG impacts associated with changes in the transport of exports and imports.[2] • For natural gas, the OECM captures changes in GHG emissions associated with tanker imports.	**Fuel Transportation** • The OECM does not capture GHG emissions associated with the domestic land-based transportation of U.S. substitutes for OCS oil or gas. This includes transportation via transmission pipelines, distribution pipelines (in the case of natural gas), land-based tanker transport (mostly applicable to oil), or rail (coal and onshore oil only). • Similarly, the model does not capture non-U.S. GHG emissions associated with the land-based distribution of OCS oil and gas substitutes. • The OECM also does not capture changes in GHG emissions related to the import or export of coal. **Processing of Oil and Gas** • The OECM does not estimate GHG emissions related to petroleum refining. • The model also does not estimate emissions related to the processing of natural gas (e.g., to remove all liquids prior to injecting into pipelines).
	Downstream	• The OECM itself does not estimate emissions related to the consumption of any fuels. BOEM, however, has estimated the change in consumption-related emissions for U.S.-based consumption based on emission factors not included in the OECM.	• Consumption-related GHG emissions not estimated by the OECM, but BOEM has estimated emissions related to changes in U.S. fuel consumption. Neither the OECM nor analyses conducted by BOEM outside the model have estimated non-U.S. GHG emissions related to consumption.

Notes:
1. For the purposes of this memo, upstream emissions do not include GHG emissions associated with the production of electricity. Because these emissions are largely related to the combustion (i.e., consumption) of fossil fuels, GHG emissions related to electricity production are treated as downstream emissions.
2. Emissions related to oil exports are included here and above for OCS oil and gas, the model does not distinguish between exports of OCS oil exports of oil from other domestic sources.

SYNTHESIS OF MARKETSIM AND OECM CAPABILTIES AND LIMITATIONS

The capabilities and limitations of MarketSim and the OECM as described above show that, together, the models capture many though not all of the net GHG emissions impacts resulting from OCS oil and gas development. The models' assessment of these effects, however, is more robust for domestic GHG emissions than non-U.S. emissions. Domestically, the models provide thorough estimates of upstream GHG emissions impacts related to OCS oil and gas activities as well as upstream GHG emissions related to domestic substitutes for OCS oil and gas. Progressing downstream from exploration, development, and production, the models' capabilities for estimating domestic GHG emissions diminishes. At midstream (i.e., transportation and processing), the models capture GHG emissions related to the transportation of OCS oil to coastal facilities and the transportation of OCS oil from the Alaska region to West Coast ports. The models similarly capture transportation-related emissions associated with changes in imports and exports of both oil and natural gas. Midstream and downstream GHG emissions not captured by the models domestically include emissions related to pipeline transportation (e.g., methane emissions from natural gas pipelines), transportation of fuels via truck or rail, fuel processing and refining, and the consumption of OCS oil and gas and substitutes.

For non-U.S. GHG emissions, the models' capabilities are limited to the estimation of GHG emissions associated with the production of oil and gas imported into the U.S., marine transportation of oil and gas imports, and the transportation of U.S. oil exports for consumption outside the U.S. The models do not capture upstream GHG emissions associated with changes in non-U.S. production of OCS substitutes for consumption outside the U.S. Because MarketSim treats oil as a global market, the model generates outputs that would allow for the estimation of these emissions as they relate to oil. The resulting estimates, however, would not reflect substitution between oil and other fuels, since MarketSim does not include cross-price effects in its specification of non-U.S. energy demand. Similar to the models' treatment of U.S. emissions, they also do not capture non-U.S. GHG emissions related to fuel processing, distribution, or consumption.

4. SHORT-TERM APPROACH FOR ADDRESSING LIMITATIONS IN GHG EMISSIONS ESTIMATION

Many of the limitations described above related to the estimation of GHG emissions with MarketSim and the OECM may be at least partially addressed in the short term with minor changes to the models or through the post-processing of model results. These changes, presented in order of upstream, midstream, and downstream emissions, are as follows:

1. ***GHG emissions related to the production of non-U.S. oil consumed outside of the U.S.:*** The data necessary to estimate these emissions are already available within MarketSim and the OECM. The volume of non-U.S. oil consumed outside the U.S. may be calculated within MarketSim or through post-processing calculations as total non-U.S. oil production minus U.S. gross imports of oil, both of which are estimated by MarketSim. The GHG emissions associated with the

production of this oil may be estimated using the OECM's emissions factors for the production of oil imported into the U.S. via tanker. This would be a straightforward addition to the OECM or, in the short term, could be estimated outside the model.

2. ***GHG emissions related to petroleum refining:*** In the short term, BOEM may estimate changes in GHG emissions related to petroleum refining by applying global average GHG emissions factors for the refining sector to the estimated change in global oil production associated with a given E&D scenario, net of the No Action Alternative. While this approach would capture refining emissions related to the overall level of refining activity resulting from an E&D scenario, it would not capture changes in GHG emissions associated with changes in the distribution of refining activity (e.g., between refineries with catalytic cracking and those without this technology). If BOEM chooses to implement this change, this would be an important limitation to note in the documentation of the GHG emissions analysis.

3. ***GHG emissions from processing of domestically produced natural gas:*** Because MarketSim already estimates the net change in domestic natural gas production associated with an E&D scenario, capturing GHG emissions associated with natural gas processing would simply involve applying emission factors to the U.S. natural gas production estimates generated by MarketSim. These emission factors could be derived from historical gas production data and EPA data on natural gas processing emissions.[3] This could be implemented through a minor change/addition to the OECM or by performing calculations outside the model.

4. ***GHG emissions related to domestic pipeline transport of natural gas:*** To estimate these emissions, it would be reasonable for BOEM to assume that all natural gas delivered to U.S. customers and consumed in the U.S. is transported through the nation's natural gas pipeline network. Based on this assumption, MarketSim's estimates of the net change in U.S. natural gas consumption under a given E&D scenario, and historical emissions data for natural gas pipeline GHG emissions per trillion cubic feet of U.S. gas consumption, it would be possible to generate estimates of the change in GHG emissions from U.S. gas pipelines. This approach would require no changes to MarketSim and would be straightforward to implement in the OECM or outside the model.

5. ***GHG emissions associated with the tanker transport of natural gas exports:*** Together, MarketSim and the OECM include much of the information necessary to estimate GHG emissions associated with the tanker transport of natural gas exports. As designed, MarketSim estimates natural gas exports under each user-specified E&D scenario and under the No Action Alternative, and the OECM includes emission factors for LNG tankers (to estimate import-related emissions). To estimate export-related LNG tanker emissions, this information would need to

[3] See U.S. EPA, 2011-2019 Greenhouse Gas Reporting Program Industrial Profile: Petroleum and Natural Gas Systems, available at https://www.epa.gov/sites/production/files/2020-11/documents/subpart_w_2019_industrial_profile.pdf.

be integrated with (1) an assumed distribution between pipeline exports of natural gas and LNG exports and (2) an assumed travel distance for gas exported via tanker. Both of these assumptions could be developed from Energy Information Administration data on U.S. gas exports by country, which show pipeline exports to Canada and Mexico and tanker exports to various other countries.[4]

6. ***GHG emissions from U.S. fuel consumption:*** U.S. emissions related to the consumption of oil, natural gas, and coal would be straightforward to calculate in the OECM or outside the model. As a starting point, the OECM could use the estimated change in fuel consumption generated by MarketSim for each fuel. As described above, MarketSim's consumption estimates for each fuel reflect cross-price effects between fuels and therefore reflect demand-related substitution between fuels. To estimate GHG emissions associated with the projected changes in consumption, the OECM (or BOEM staff performing calculations outside the model) could apply fuel-specific emission factors for the combustion of each fuel. For CO_2, these emission factors generally do not depend on the type of device using the fuel; CO_2 emissions from the combustion of fossil fuels are simply reflective of the amount of fuel consumed and the carbon content of the fuel.

7. ***GHG emissions from non-U.S. fuel consumption:*** In the short term, BOEM could develop a partial accounting of the GHG emissions impacts associated with changes in non-U.S. fuel consumption. With respect to non-U.S. *oil* consumption, based on MarketSim's estimated changes in non-U.S. oil demand and GHG emission factors for oil consumption, the OECM (or BOEM staff working outside the model) could estimate these consumption-related emissions. Relying on the estimated change in non-U.S. oil demand rather than the change in U.S. exports would ensure that the estimates reflect substitution between U.S. oil and non-U.S. oil (i.e., the competition-related substitution described in Section 2 above). However, because MarketSim does not capture cross-price effects in non-U.S. demand, this approach would not reflect the degree to which foreign consumption of other fuels declines with increased oil consumption. Estimates generated from this approach would therefore overestimate the total GHG impacts of an increase in non-U.S. oil consumption.

   For gas and coal, it would not be feasible in the short term to fully capture the GHG emissions impacts associated with changes in non-U.S. consumption. As described above, MarketSim does not model total non-U.S. demand for these fuels but instead models U.S. exports and imports. However, it would be feasible in the short term to capture the GHG emissions impacts associated with other countries' consumption of gas and coal exported by the U.S. Similar to the other consumption-related GHG emissions described above, the OECM (or BOEM staff working outside the model) could estimate these emissions by applying fuel-specific emission factors to the estimated exports of gas and coal. An important limitation of this approach is that it would not capture the degree to which foreign

[4] U.S. EIA, U.S. Natural Gas Exports and Re-Exports by Country, available at https://www.eia.gov/dnav/ng/ng_move_expc_s1_a.htm.

consumption of U.S. gas or coal exports leads to reduced non-U.S. consumption of other fuels. This approach would therefore overstate the total consumption-related GHG impact associated with U.S. gas and coal exports.

The changes outlined above would capture many of the GHG impacts not currently captured by MarketSim and the OECM, though several important types of GHG impacts would remain outside the scope of the model's capabilities. These would include, but would not be limited to, the following:

- GHG emissions associated with the production of foreign gas and coal consumed outside the U.S.
- GHG emissions from the processing of natural gas produced outside the U.S.
- Emissions associated with shifts in refining activity between refineries with differing GHG intensity.
- GHG emissions associated with fuel distribution of petroleum products or coal in the U.S. or other countries.

In addition, as noted above, the potential model modifications outlined here would not address the GHG implications of non-U.S. energy consumers substituting between energy sources.

5. DIFFICULTIES OF ADDRESSING SELECT LIMITATIONS

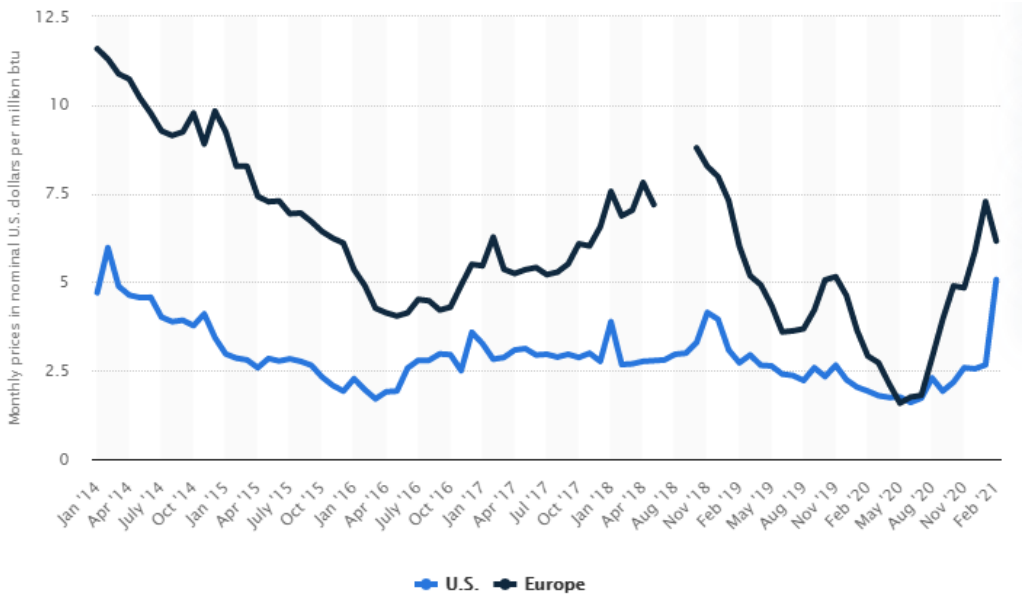
To address some of the GHG impacts not captured, or only partially captured, by the short-term changes outlined above, BOEM would need to overcome a number of analytic obstacles. In particular, developing a *full* accounting of GHG emissions impacts related to non-U.S. energy production and consumption would require a significant expansion of MarketSim in terms of both its scope and complexity, with all energy sources modeled globally. This would not be as simple as expanding the model's treatment of gas, coal, and electricity to match its treatment of oil. While oil is a truly global market, other energy sources are more regionalized, with prices differing significantly between regional markets in some cases. For example, U.S. natural gas prices have historically been much lower than European prices, as shown in Exhibit 4 below. Similarly, electricity prices in different regions depend on the generating technologies used in those areas and the local price of fuels used to produce electricity.

Due to these regional differences in energy markets, MarketSim would need to model the markets for these energy sources regionally rather than as a global market. This would represent a major challenge, as it would involve re-designing the model to simultaneously calculate an equilibrium price for each region and energy source while also accounting for trade between regions and substitution between energy sources within each region. With this level of complexity, MarketSim would potentially need to be redeveloped in a platform other than Excel.

Another potential complication of including this additional detail in the model is that it would require a detailed baseline energy market forecast that includes multiple categories

of supply, demand, and prices at the regional level.[5] 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.

EXHIBIT 4. U.S. AND EUROPEAN NATURAL GAS PRICES



Source: Statista USA, https://www.statista.com/statistics/673333/monthly-prices-for-natural-gas-in-the-united-states-and-europe/

Accurately capturing changes in GHG emissions from the global petroleum refining sector would also pose a number of challenges. As described above, maximizing the value obtained from lower quality, heavy crude oils requires sophisticated refineries with cracking facilities that can break large hydrocarbon molecules down into smaller, high-value molecules such as those in transportation fuels. Increased production of OCS oil could lead to shifts in the type of refinery where some crude oils are refined, leading to changes in GHG emissions from the refining sector.

To account for these dynamics in MarketSim, BOEM would need to include a representation of the global refining sector in the model and link it with MarketSim's specification of the crude oil market. This would involve segmenting the crude oil market into crude oils of varying quality (ideally while maintaining the model's existing detail on different sources of crude oil), accounting for differences in the technological capabilities of the refining sector in different regions (e.g., the U.S. versus the rest of the world), and modifying MarketSim to simulate the allocation of crude oil between different types of refineries (or regional refining sectors) based on changes in crude production. Together,

[5] Ideally, such a forecast would also preserve the existing detail in the model for U.S. production and consumption.

these changes would represent a significant expansion of the model and a reorganization of its representation of the global oil market. In addition, building this capability into the model would require baseline data on the mix of crude oils used by refineries with different technologies (i.e., those with catalytic cracking and reforming units and those without this technology), both in the U.S. and abroad. While such data may be available for the U.S., the availability of these data for other countries/regions is unclear.