The Real Costs of Offshore Oil and Gas Leasing

A Review of BOEM's Economic Analysis for Its Proposed Five-Year Program

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Executive Summary

In July 2022, the Bureau of Ocean Energy Management (BOEM) released its proposed Outer Continental Shelf (OCS) oil and gas leasing program for 2023–2028.[1] In that proposed program, BOEM considers holding up to 11 lease sales over the next five years located in the Gulf of Mexico and the Cook Inlet program areas, while also considering the possibility of holding no lease sales during the planning period.[2]

BOEM recognizes that OCS oil and gas development exacerbates climate change, poses numerous environmental risks, and may have limited economic benefit as the nation transitions away from fossil-fuel energy.[3] However, its "current analysis finds that there are potential net benefits" of the 11 proposed sales, whereas "a National OCS Program with no lease sales for 2023–2028 would reduce net benefits as substitute energy sources increase to meet the largely unchanged energy demand."[4] BOEM recognizes uncertainty in its net benefits analysis and seeks comment, with a particular request for feedback of its analysis of substitute energy sources.[5]

This report provides comprehensive feedback on BOEM's net benefits analysis. **As the report details, BOEM vastly understates the environmental and social costs of OCS leasing by omitting key costs from its net benefits analysis such as climate damages from downstream greenhouse gas emissions and the costs of catastrophic oil spills. BOEM's modeling choices throughout its net benefits analysis understate environmental risk.**

For instance, while BOEM elsewhere recognizes that further OCS leasing would severely exacerbate climate change, its net benefits analysis consider climate change a *benefit* of OCS leasing due to numerous omissions. Similarly, although BOEM elsewhere acknowledges that the proposed program could plausibly lead to a catastrophic oil spill even larger than the Deepwater Horizon event, it completely ignores catastrophic oil spills in its net benefits analysis and instead quantifies them as a potential benefit of OCS leasing. While ignoring these substantial environmental and social costs from its net benefits analysis, BOEM's analysis overstates the potential benefits of OCS leasing through its hurdle price analysis and its consideration of energy security.

This report details crucial limitations in BOEM's net benefits analysis, offers suggestion for the agency to improve its analysis, and provides original modeling in several areas to identify how those improvements may affect the agency's results. **Our analysis calls into question BOEM's conclusion that OCS leasing is cost-justified, and offers extensive evidence suggesting that, if BOEM followed economic best practices, it may conclude that the costs of the proposed leasing exceed the benefits.**

Part I of this report critiques BOEM's substitution analysis, explaining that the agency's current analysis understates the potential climate impacts of OCS leasing by disregarding the likelihood that the United States and foreign nations will take additional actions to mitigate climate change. According to BOEM's net benefits analysis, the vast majority of the

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1 All documentation for the proposed program is available at https://www.boem.gov/oil-gas-energy/national-program/national-ocs-oil-and-gas-leasing-program-2023-2028.

2 Bureau of Ocean Energy Mgmt., 2023–2028 National Outer Continental Shelf Oil and Gas Leasing Proposed Program 4 (July 2022) [hereinafter "Proposed Program"].

3 *See generally id.* at 1–9.

4 *Id.* at 7.

5 *Id.* (requesting "potential data sources sufficient for BOEM's modeling that could help enhance the model and better reflect assumptions associated with a transitioning economy").

climate pollution that results from OCS leasing would still occur under a no-leasing scenario because substitute sources of oil and gas will take the place of the OCS production forgone. Yet as BOEM acknowledges, this finding is predicated on the assumption that the U.S. and other nations will remain heavily reliant on fossil fuels in the coming decades and fail to meet their international climate commitments, resulting in an abundance of substitute fossil-fuel sources.

BOEM can quantitatively model energy substitution under a range of future pathways, and by doing so, it would likely find that OCS leasing has far greater climate consequences than the agency currently acknowledges. This Part offers suggestions in response to BOEM's request for comments on improving the agency's substitution modeling to incorporate decarbonization pathways. It then presents the results of our original modeling, which finds that **total net greenhouse gas emissions from the proposed program (i.e. total emissions from the program minus total emissions from substitute energy sources) could roughly triple or quadruple under plausible assumptions about more aggressive decarbonization pathways**.

Part II details three other ways, apart from substitution modeling, through which BOEM understates the climate costs of OCS leasing, and offers suggestions to correct these limitations. First, while BOEM acknowledges in its environmental analysis that the proposed program would result in billions of dollars in climate damages, its net benefits analysis actually counts climate change as a benefit of the proposed program because it omits emissions from downstream consumption and focuses only on upstream emissions. While BOEM contends that such an omission is legally required, it is mistaken. In fact, as this Part and the accompanying report titled *Interior's Authority to Consider Downstream Emissions from Offshore Leasing* explain, the Outer Continental Shelf Lands Act permits BOEM to consider downstream emissions and case law does not compel otherwise. Accordingly, **BOEM should consider the full climate impacts of the proposed program, and not focus its net benefits analysis on a small subset of emissions that falsely implies that OCS leasing mitigates climate change.**

Besides its omission of downstream emissions, BOEM undercounts and undervalues greenhouse gas emissions in at least two other key ways. Second, this Part suggests that BOEM consider the potential for foreign reciprocity—that is, that other nations will reduce their fossil-fuel development if the United States does—and explains that by ignoring this impact, BOEM disregards an important climate benefit of the no-leasing alternative. And third, this Part suggests that BOEM apply higher valuations of the social cost of greenhouse gases, as the Interagency Working Group on the Social Cost of Greenhouse Gases has recommended. This Part presents our original analysis finding that **the climate costs of the proposed program alone may exceed the program's total benefits**.

Part III explains that BOEM's analysis overlooks a critical cost of OCS leasing by omitting the cost of catastrophic oil spills, and offers suggestions to improve BOEM's analysis in this area. This Part first suggests that BOEM include catastrophic oil spills in its net benefits analysis rather than entirely omit them from the analysis, as BOEM has sufficient data to include this potentially severe effect. It discusses how the possibility of a catastrophic oil spill is not especially unlikely, nor is it necessarily more uncertain than the economic impacts that BOEM does monetize in its net benefits analysis. This Part then explains that BOEM disregards important countervailing considerations, documented in peer-reviewed research and government reports, when it states that the likelihood and severity of oil spills have been declining. The Part concludes by offering recommendations for BOEM to improve its existing quantification of oil spills, finding that the monetized estimates that the agency presents are likely under-valuations for numerous reasons.

Part IV explains that BOEM's analysis of uncertainty—both through its consideration of option value and its hurdle price analysis—overlooks important environmental risks while applying flawed methodologies that bias the analysis in favor of leasing. In particular, this Part provides existing techniques that BOEM could use to quantify environmental and social cost uncertainties and incorporate into its option value analysis. This Part also critiques BOEM's hurdle price analysis—a key component of its consideration of uncertainty and option value—for ignoring economic best practices in a manner that renders the analysis deficient and inappropriately biases it to favor development. This Part calls for BOEM to rethink its hurdle price analysis while quantifying environmental and social cost uncertainties using well-developed methodologies. It also explains how the large number of currently undeveloped leases, which BOEM does not consider in its option value analysis, counsels in favor of delay by limiting the potential costs of not leasing at this time.

Part V criticizes BOEM's treatment of energy security as a benefit of OCS leasing, and explains that OCS leasing may in fact come at a cost to energy security. As this section explains, the very literature that BOEM cites does not support its conclusions and in fact suggests that expanded OCS leasing, by making the United States more dependent on fossil fuels, could make the nation less energy secure by increasing its sensitivity to oil price shocks.
A technical appendix at the back of this report describes some of the report's economic modeling and recommendations in further detail. It contains sections on substitution modeling (Appendix A), oil spills (Appendix B), and energy security (Appendix C).

All told, this report demonstrates that **BOEM's net benefits analysis omits most of the environmental and social costs of OCS development**, including the climate damages that would result under decarbonization pathways, downstream and midstream greenhouse gas emissions, the costs of catastrophic oil spills, and additional environmental and social cost uncertainties. **It concludes that there is extensive evidence that, properly considered, the costs of OCS leasing may exceed the benefits.**

I. BOEM's Substitution Analysis Ignores the Likelihood of Future Climate Mitigation, Which Suggests that Greenhouse Gas Emissions Attributable to OCS Leasing Are Far Greater than the Agency Recognizes

BOEM relies on its net benefits analysis to support its OCS leasing program. A critical component of this analysis is its assessment of energy substitution. In that analysis, BOEM analyzes what alternative energy sources OCS production will displace and the extent to which OCS production will increase total consumption of oil and gas. This allows the agency to compare the effects of OCS leasing in each region against a baseline of what would occur if there were no OCS leasing in each region during the planning period. According to BOEM's analysis, OCS production from the proposed program would primarily displace alternative sources of oil and gas, thereby limiting its overall climate and environmental impact.[6]

But BOEM recognizes that its substitution analysis may be incomplete and likely understates the climate impacts of the proposed program, because it "assumes that current policies and trends continue and does not account for any major shift in energy consumption patterns."[7] The agency further recognizes that "as the U.S. adapts to meet its climate goals, major changes could greatly alter demand for oil and gas and, thus, any forgone OCS oil would likely not be replaced to the same extent that it is currently."[8] BOEM requests public comment on improving its substitution analysis to incorporate the possibility that the United States and other nations engage in deep decarbonization over the coming years and decades. This Part offers suggestions to BOEM on this front.

First, the Part outlines several reasons why BOEM should not rely on its existing substitution analysis. The Part explains that BOEM's analysis is outdated, in tension with published literature, and as BOEM recognizes, fails to account for likely future actions to mitigate climate change that could reshape the energy sector. Next, this Part offers detailed suggestions for BOEM to improve its substitution modeling to incorporate decarbonization pathways—either by adopting a new model or by making changes within its existing model: the Market Simulation Model (known as MarketSim).

This Part illustrates how some of these changes within MarketSim could affect the agency's results. It presents several illustrative model runs showing, under decarbonization pathways, OCS production is likely to displace renewables far more than BOEM's analysis finds and displace oil, gas, and coal far less than under BOEM's current analysis. Our illustrative model runs find that under potential decarbonization pathways, total net emissions from the proposed program (including lifecycle domestic emissions and emissions from increased foreign consumption) could be about three or four times higher than BOEM's analysis currently finds.

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[6] Proposed Program, *supra* note 2, at 5-50 fig.5-15. BOEM also finds that 9% of new OCS production under the proposed program would replace other non-coal energy sources such as renewables, 8% would replace reduced consumption, 1% would replace coal, and less than 1% would replace production from existing OCS leases. *Id.*

[7] *Id.* at 5-46.

[8] *Id. See also id.* at 5-52 to -56 (recognizing that there would likely be less substitution to other sources of oil and gas—and therefore greater climate impacts from OCS leasing—under a net-zero pathway).

Before delving into all of these critiques, however, the Part begins with a brief overview of MarketSim, which offers context for the ensuing discussion.

MarketSim: An Overview

MarketSim is BOEM's energy market model. It is a relatively simple partial-equilibrium model that projects U.S. energy markets out seven decades, to 2093.

MarketSim models the demand of four energy resources—coal, natural gas, oil, and electricity—at the national scale by four domestic sectors: residential, commercial, industrial, and transportation. Demand, coal production, and electricity production are modeled at the national scale (with some consideration of imports and exports), while oil and natural gas supply are modeled within the United States at fairly aggregate spatial scales (e.g., Alaska, Lower 48).

The model also captures renewables by modeling the supply of nuclear, hydro, wind, and solar energy, though this modeling is less detailed than the model's assessment of fossil fuels. In addition, the model captures international supply and demand of oil along with U.S. imports and exports of other fossil fuels. But the model is primarily domestic-focused and does not capture international markets in the same detail.

In total, MarketSim has 29 supply elasticities (by energy type, region, and production technology) and 44 own-price and cross-price demand elasticities (by energy type, region, and sector). Some elasticities are drawn from the literature. When estimates were unavailable in the literature, BOEM in numerous cases derived these parameters from the National Energy Modeling System (NEMS), which is the U.S. Energy Information Administration's (EIA) energy market model. In other cases, BOEM solicited elasticity parameters from expert input. MarketSim's elasticities are exogenous and do not change over time.

MarketSim draws its quantity and price parameters mostly from the "reference case" from EIA's 2020 version of the Annual Energy Outlook (AEO), which is the output of NEMS.[9] As discussed further below, the EIA reference case projects future quantities and prices of different energy sources assuming that current (at the time of the forecast) policies remain in place and no new policies are implemented.

To assess how OCS leasing will affect the energy market and, ultimately, greenhouse gas emissions, BOEM runs MarketSim for two different scenarios: the no-leasing scenario and the leasing scenario. To model the no-leasing scenario, BOEM calibrates resource quantities and prices to an adjusted version of EIA's reference case that assumes no future OCS leasing.

To model the leasing scenario, BOEM increases the supply of oil and gas in the relevant OCS regions over the relevant timeframes. MarketSim then solves for new equilibrium prices and resource and electricity quantities. This allows BOEM to assess how energy supplies and consumption change between the leasing and no-leasing scenario. Using that information, BOEM calculates the substitution effects and net greenhouse gas emissions from the proposed program.

[9] MarketSim also applies adjustment rates that capture the transition from short-run to long-run market effects by limiting the portion of supply or demand that is allowed to change annually.

A. BOEM's Existing Analysis Is Outdated, in Tension with the Published Literature, and as BOEM Recognizes, Suffers from Severe Data Limitations

Before delving into the more specific suggestions for improvement, three preliminary points about BOEM's substitution analysis merit a brief discussion. Specifically, BOEM's existing substitution analysis is outdated, in tension with the published literature, and suffers from severe data limitations. These factors suggest that BOEM should not place significant reliance on its substitution analysis without substantial revisions.

BOEM's Analysis Is Outdated

First, even on its own terms, BOEM's analysis is now outdated because it is based on laws and regulations on the books as of several years ago. In particular, BOEM ties its assessment of substitute energy sources to the 2020 version of the Annual Energy Outlook,[10] which was published in January 2020 and reflects the state of current policy at that time.[11] It is unclear why BOEM uses the 2020 version of the Annual Energy Outlook when that forecast is updated annually—meaning that the most recent version is from early 2022 and reflects current policies as of November 2021.[12] In fact, BOEM relies on the 2022 AEO forecast to assess energy consumption under baseline policies, making its decision to use an outdated forecast when assessing energy substitution especially odd.[13]

In light of recent developments such as the Inflation Reduction Act, however, even the 2022 version of the Annual Energy Outlook does not accurately reflect the long-term state of the energy sector, and BOEM should at minimum await for the 2023 version of the forecast. In particular, because the 2022 baseline is set to current policies as of November 2021, it does not include laws and regulations that have been passed since then. The Inflation Reduction Act is expected to substantially shift U.S. energy use away from fossil fuels and toward renewables, as concluded by three separate analyses—from Princeton University's Zero Lab,[14] the Rhodium Group[15] and Energy Innovation.[16] While the Inflation Reduction Act will clearly change the long-term national energy mix, these changes are reflected in neither BOEM's current analysis nor in the AEO 2022 forecast.

EIA expects to release an updated AEO forecast by March 2023, which will presumably include the Inflation Reduction Act and other policies enacted since November 2021.[17] At bare minimum, BOEM should await the updated AEO forecast to ensure that its analysis of substitute energy sources and greenhouse gas emissions accounts for the latest energy

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[10] Proposed Program, *supra* note 2, at 5-31 (describing "estimated energy market substitutes using baseline 2020 AEO data"); *accord id.* at 6-20.

[11] U.S. Energy Info. Admin., *Annual Energy Outlook 2020*, https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf.

[12] U.S. Energy Info. Admin., *Annual Energy Outlook 2022* at 2 (2022), https://www.eia.gov/outlooks/aeo/pdf/AEO2022_Narrative.pdf [hereinafter "AEO 2022"] (explaining that the reference case is "based on current laws and regulations as of November 2021").

[13] Proposed Program, *supra* note 2, at 1-4.

[14] Jesse D. Jenkins et al., *Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022* at 12 (Aug. 2022), https://repeatproject.org/docs/REPEAT_IRA_Prelminary_Report_2022-08-12.pdf (concluding that Inflation Reduction Act will reduce U.S. natural gas consumption by 9% and decrease domestic consumption of petroleum products by 13% by 2030); *id.* at 15 (finding that Inflation Reduction Act will substantially increase the development of solar and wind energy).

[15] Ben King et al., *A Congressional Climate Breakthrough* (July 2022), https://rhg.com/research/inflation-reduction-act/ (projecting substantial reductions in greenhouse gas emissions from Inflation Reduction Act).

[16] Megan Majajan et al., *Modeling the Inflation Reduction Act Using the Energy Policy Simulator* (Aug. 2022), https://energyinnovation.org/publication/modeling-the-inflation-reduction-act-using-the-energy-policy-simulator/ (similar).

[17] *See Annual Energy Outlook 2022*, U.S. Energy Info. Admin., https://www.eia.gov/outlooks/aeo/ (reporting "next release date").

policies. Furthermore, as discussed more below, other countries are likely to respond to U.S. action to address climate change by enacting their own emission-reduction policies.[18]

BOEM's Analysis Is in Tension with Published Literature

Second, BOEM's model finds less substitution to renewables and forgone consumption than published, peer-reviewed models. In particular, in a recent peer-reviewed article in the Journal of the Association of Environmental and Resource Economists, Ph.D. economist Brian C. Prest builds his own energy model and estimates how changes in federal resource management affect supply, demand, consumption, and emissions.[19] Prest finds a "leakage rate"—meaning the percentage of total emissions from OCS development that merely displace emissions from other sources and thus do not reflect gross emission reductions—of between 52% and 72%.[20] This is far lower than BOEM's leakage rate of approximately 77%.[21]

While Prest's model includes both onshore and offshore leasing and is therefore not directly comparable to BOEM's model, the substantial variation in leakage rates should urge further caution, particularly since Prest's model—unlike BOEM's—is dynamic, has been subject to peer-review, and is published in the economics literature. BOEM should compare elasticities between the two models and consider updating its reference case elasticities to more closely reflect the parameters in Prest's model. For example, as our original model runs below illustrate, reducing oil and gas supply elasticities and increasing renewable supply elasticities lowers the substitution rate and results in a higher estimate of net emissions from OCS leasing.[22]

In addition to Prest's work, BOEM's findings also stand in tension with a significant body of literature that has found much lower levels of international leakage. For instance, in a widely-cited paper, Burniaux and Martins (2012) use a simple general equilibrium model to find a central leakage estimate of approximately 10% for carbon policies in Annex I countries following the Kyoto Protocol.[23] This low leakage rate is largely consistent with more recent studies.[24] While the leakages assessed in these studies are not directly comparable to the specific issue of leakage from OCS leasing, the wide discrepancy between these published results and BOEM's high substitution rates calls for further caution.

Given these disparities, BOEM should consider conducting an extensive review of the leakage literature including sub-national, national, and multi-national leakage estimates for climate and energy policies. It should pay particularly close attention to leakage estimates that correspond most closely to a partial restriction of energy resources at the national level, such as sub-national carbon or energy policies.

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[18] *See infra* Part II.B.

[19] Brian C. Prest, *Supply-Side Reforms to Oil and Gas Production on Federal Lands: Modeling the Implications for CO2 Emissions, Federal Revenues, and Leakage*, 9 J. Assoc. Env't & Res. Economists 681 (2022).

[20] *Id.* at 688.

[21] *See infra* note 54 and accompanying text.

[22] *See infra* Part I.C.

[23] Jean-Marc Burniaux & Joaquim Oliveira Martins, *Carbon Leakages: A General Equilibrium View*, 49 Econ. Theory & the Global Env't 341 (2012).

[24] *See, e.g.*, Biying Yu et al., *Review of Carbon Leakage Under Regionally Differentiated Climate Policies*, Sci. Total Env't 782 (2021) (conducting a meta-regression with results that imply that if the United States reduced all its greenhouse gas emissions unilaterally by 50% with standard trade substitution assumptions and no border adjustments, that the leakage would be approximately 9%).

BOEM's Analysis Suffers from Severe Data Limitations Around Future Pathways

Third, as BOEM recognizes, the agency's substitution analysis suffers from severe limitations because it ignores the possibility of future U.S. or international action to limit climate change. Consider this: The AEO "reference case" on which MarketSim is predicated assumes current policies and thereby projects that oil and gas production and demand will continue to rise over the next several decades.[25] Yet that assumption is largely incompatible with international goals and commitments to mitigate global warming.[26] While BOEM's analysis treats the AEO reference case as the only possible baseline, the EIA has recognized that the reference case projections "are not predictions of what will happen, but rather, they are modeled projections of what may happen given certain assumptions and methodologies."[27] And that "assumption" is that the United States and foreign countries will not take additional action to mitigate climate change.[28]

There are in fact strong reasons to doubt that current policies will remain unchanged and the global energy system will remain so heavily reliant on fossil fuels. For one, there is a wide gap between existing policies and the international commitments that many countries (including the United States) have made to reduce their emissions.[29] For another, climate policies have tended to get stronger over time.[30] And for a third, current policies would spell devastating levels of global warming, enhancing the urgency of countries strengthening their policies to meet their international commitments.[31] Beyond that, regardless of policy, oil and gas could decline further than the AEO reference case projects due to market forces, such as the declining price of renewables.[32] So while the global community could remain heavily reliant on fossil fuels, there is also a strong chance that it could substantially reduce its long-term use of fossil fuels.[33] A recent elicitation by Resources for the Future found that the surveyed experts place just a 5% probability on global emissions rising consistent with AEO's current-policy projections.[34]

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[25] AEO 2022, *supra* note 10, at 3. *See also id.* at 6 fig.2 (showing growing energy consumption for natural gas and petroleum through 2050).

[26] *See infra* note 29.

[27] AEO 2022, *supra* note 10, at 2.

[28] *Id.* ("Our key assumptions in the Reference case provides a baseline for exploring long-term trends, based on current laws and regulations as of November 2021.").

[29] Intergovernmental Panel on Climate Change, Working Group III Contribution to the IPCC Sixth Assessment Report (A6R): Technical Summary TS-28 (2021), https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_TS.pdf [hereinafter "IPCC Working Group III Technical Summary"] (discussing "implementation gap . . . between [national] mitigation pledges[] and the expected outcome of existing policies"). According to analysis from Climate Action Tracker, nearly all countries are behind pace to meet their Paris Accord targets and pledges. Climate Action Tracker, *Climate Target Updates Slow as Science Ramps Up Need for Action* ii–iii (2021), https://climateactiontracker.org/documents/871/CAT_2021-09_Briefing_GlobalUpdate.pdf.

[30] *See* Nadja Popovich & Brad Plumer, *Yes, There Has Been Progress on Climate. No, It's Not Nearly Enough*, N.Y. Times (Oct. 25, 2021), https://www.nytimes.com/interactive/2021/10/25/climate/world-climate-pledges-cop26.html ("In 2014, Climate Action Tracker estimated that the world was on track for nearly 4 degrees Celsius of warming by 2100, compared with preindustrial levels. . . . This year, however, Climate Action Tracker painted a more optimistic picture, because countries have started doing more to restrain their emissions. Current policies put the world on pace for roughly 2.9 degrees Celsius of warming by 2100.").

[31] For instance, the Intergovernmental Panel on Climate Change projects that current policies as of 2021 would produce an average of 3.5 degrees Celsius of warming by 2100, with virtually no chance of remaining under 2 degrees of warming. IPCC Working Group III Technical Summary, *supra* note 29, at TS-42 tbl.TS.3 (presenting effects of current policies under pathway C7).

[32] *See* Alexander Q. Gilbert & Benjamin K. Sovacool, *Looking the Wrong Way: Bias, Renewable Electricity, and Energy in the United States*, 94 Energy 533 (2015) ("The [Annual Energy Outlook] consistently under projects most types of non-hydro renewables.").

[33] *See* IPCC Working Group III Technical Summary, *supra* note 29, at TS-31 tbl.TS2, TS-42 tbl.TS.3 (outlining wide range of emissions under different global mitigation pathways).

[34] Kevin Rennert et al., Resources for the Future, The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates 20–26 (2021), https://media.rff.org/documents/WP_21-28_V2.pdf. We are unaware of any studies on the topic concluding that future emissions consistent with AEO's policy-as-usual baseline are likely.

Yet BOEM's analysis is entirely predicated on this possibility, as its assumptions about resource quantities, prices, and elasticities all assume current policy. It relies entirely on the AEO "reference case," which has historically missed out on emerging energy trends by underestimating the pace of renewable-energy growth.[35] As detailed further below, BOEM's analysis should account for the range of future possibilities and not assume a worst-case outcome of limited climate mitigation as a single point estimate. The remainder of this Part offers BOEM suggestions for doing that.

B. BOEM Can Model Decarbonization Pathways in MarketSim by Adjusting Key Parameters and Conducting Sensitivity Analysis

As a first step toward improving its substitution analysis, BOEM should embrace sensitivity analysis around different parameters and assumptions.[36] Currently, BOEM calibrates MarketSim to both AEO's low and high oil price cases as its sole form of sensitivity analysis.[37] This is a significant underrepresentation of uncertainty. In reality, there are significant pathway, parametric, and structural uncertainties underlying MarketSim's 70-year projections. By exploring these uncertainties, BOEM can develop a better picture of the future possibilities and examine how potential decarbonization pathways may alter the climate impacts of OCS leasing.

The uncertainty in BOEM's substitution analysis extends to all key parameters: quantities, elasticities,[38] and prices. Uncertainty about the pace of global decarbonization most directly creates uncertainty about the quantities of different energy sources: namely, how much renewables will increase and different fossil fuels will decline.[39] Of course, the extent of these various developments is uncertain, emphasizing the importance of sensitivity analysis around different parameters. To conduct sensitivity analysis around quantity parameters, BOEM could look to trajectory estimates such as the Intergovernmental Panel on Climate Change's (IPCC) mitigation pathways that reflect different warming targets and project the quantity changes for different energy sources (oil, gas, coal, nuclear, and renewables) over time under each of those pathways.[40]

Elasticities could also drastically change under future pathways as the energy mix changes. For instance, the cross-price demand elasticity of renewables with respect to oil is likely to be much higher if and when electric-powered cars become more prevalent, as consumers would more easily be able to switch to electric vehicles in response to price changes in fossil fuels. Once again, however, BOEM's analysis relies on point estimates without any sensitivity analysis—and those

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[35] Gilbert & Sovacool, *supra* note 32.

[36] Longstanding guidance on cost-benefit analysis from the Office of Management and Budget embraces the use of sensitivity analysis around key parameters. Office of Mgmt. & Budget, Circular A-4 at 3 (2003) ("It is usually necessary to provide a sensitivity analysis to reveal whether, and to what extent, the results of the analysis are sensitive to plausible changes in the main assumptions and numeric inputs."); *id.* at 41 (advising agencies to "[u]se a numerical sensitivity analysis to examine how the results of your analysis vary with plausible changes in assumptions, choices of input data, and alternative analytical approaches" and to "[a]pply a formal probabilistic analysis of the relevant uncertainties").

[37] *See, e.g.*, Bureau of Ocean Energy Mgmt., Draft Economic Analysis Methodology for the 2023 – 2028 National Outer Continental Shelf Oil and Gas Leasing Program 5-24 (July 2022) [hereinafter "Economic Analysis Methodology"] (discussing "low [and] high price scenarios").

[38] For instance, one recent economics paper uses a wide range of elasticities for the price elasticity of demand for oil from -0.21 to -0.86 in recognition of the large uncertainty around this parameter. *See* Geoffrey Heal, *Economic Aspects of the Energy Transition*, Env't & Res. Econ. 1, 12 (2022).

[39] The IPCC's Sixth Assessment Report finds that, to reach emissions levels consistent with the Paris Agreement, fossil fuel use needs to be greatly reduced and coal use should be phased out by midcentury. *See* IPCC Working Group III Technical Summary, *supra* note 29, at TS-31 tbl.TS2.

[40] *Id.* (providing four different mitigation pathways reflecting different warming targets); *see also id.* at TS-42 tbl.TS.3.

point estimates are backward-looking and often rely on decades-old data.[41] Ideally, BOEM would conduct a Monte Carlo simulation over key parameter values followed by a decomposition analysis to examine the correlation between key outcomes of interest, like the substitution rate, and key parameters of interest, like demand and supply elasticities. Beyond understanding the range of potential outcomes, this analysis would enable BOEM to better understand the drivers of its substitution analysis and causes of potential disparities between its analysis and the academic literature.[42]

After using substitution analysis to identify key parameters, BOEM can then conduct additional analysis modifying those parameters to model decarbonization pathways. There are several ways to accomplish this task with respect to modeling and pathway choice. First, BOEM should select a range of decarbonization pathways from the published literature. In terms of modeling, BOEM can either recalibrate NEMS to these alternative mitigation pathways, which can then be used to specify a new baseline and elasticity values for NEMS. Alternatively, or in addition, BOEM can use expert elicitation to calibrate MarketSim's parameters conditional on the mitigation pathway. Both approaches are consistent with current approaches taken by BOEM in the calibration of NEMS.

In its latest AR6 report, the IPCC develops eight different mitigation pathways that span a very broad range of future trajectories. These eight pathways are assigned values starting with C1 and going up to C8[43]:

- C1: below 1.5°C with no or limited overshoot (SSP1-1.9);
- C2: below 1.5°C with overshoot
- C3: likely below 2°C with no or limited overshoot (SSP2-2.6)
- C4: below 2°C with overshoot
- C5: below 2.5°C (SSP4-3.7)
- C6: below 3°C (consistent with moderate action of climate pledges / SSP2-4.5)
- C7: below 4°C (consistent with current policy / SSP 3-7.0)
- C8: above 4°C (business-as-usual / SSP-8.5)

A recent expert elicitation from Resources for the Future found that a business-as-usual pathway[44] is very unlikely to occur (i.e., below a 5% statistical cutoff),[45] meaning that BOEM can likely disregard the C8 pathway. The same elicitation finds a 5th-to-95th probability range which is consistent with SSP1 and SSP3,46 making C1 and C7 good bounding pathways for BOEM's analysis. One option for BOEM is to run its analysis for each of the mitigation pathways between and inclusive of C1 and C7. Alternatively, to limit the number of sensitivity analyses, BOEM could run a subset of these seven pathways centered around the most likely pathway and spanning the corresponding temperature range. The current-policy pathway is already consistent with pathway C7, meaning that BOEM could run just a few additional pathways to get a wide representative range. However, if BOEM chooses to run only a single mitigation pathway, then it should probably select C6, which corresponds to the most likely outcome according to the recent Resources for the Future elicitation.[47]

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[41] *See* Bureau of Ocean Energy Mgmt., Consumer Surplus and Energy Substitutes for OCS Oil and Gas Production: The 2021 Revised Market Simulation Model (MarketSim) 17 (2021) [hereinafter "MarketSim 2021"], https://www.boem.gov/sites/default/files/documents//MarketSim%20Model%20Documentation.pdf (explaining that MarketSim's supply and demand elasticities are based on various studies dating back to 1998 and relying on historical data going as far back as 1960).

[42] *See supra* notes 19–24 and accompanying text.

[43] IPCC Working Group III Technical Summary, *supra* note 29, at TS-42 tbl.TS.3.

[44] Note that business-as-usual is different from a current-policy pathway. Business-as-usual ignores policy and assumes essentially that pre-regulatory trends continue. Current-policy assumes that trends will shift over time in line with current policies.

[45] Rennert et al., *supra* note 34, at 23–24.

[46] *Id.* at 26 fig.9.

[47] *Compare id.* at 26 (estimating between 2–3 degrees of warming by 2100 under most likely pathway) *with* IPCC Working Group III Technical Summary, *supra* note 29, at TS-42 tbl.TS.3 (showing median of 2.7 degrees of warming by 2100).

Selecting the mitigation pathways is just the first step, as BOEM will then have to adjust other modeling parameters, such as elasticities, that are also quite uncertain. These parameters will have to be adjusted under each mitigation pathway, as they could look very different under alternative pathways. One potential approach would be for BOEM to recalibrate its model to alternative NEMS cases and not rely exclusively on the reference case. In particular, the Low Oil and Gas Supply Case and the Low Renewables Cost cases reflect some of the changes to the energy market that will shift under decarbonization pathways.[48] However, these cases are limited in their variability, and if BOEM intends to model more ambitious decarbonization pathways, it must modify NEMS to achieve wider geographic and greenhouse gas coverage. Moreover, since NEMS is a domestically focused energy model, BOEM would also need to modify and adjust EIA's World Energy Projection System (WEPS) module—which is indirectly incorporated into MarketSim—to replicate potential global emission paths.

Links Between MarketSim, NEMS, and WEPS

Model	Geographical scale	Links between models	Output report
World Energy Projection System (WEPS)	World regions by country or country groups	Historical data and projections for the United States are based on AEO	EIA's International Energy Outlook (IEO)
National Energy Modeling System (NEMS)	Subnational regions and the rest of the world	Inputs to multiple modules are sourced from IEO (e.g., Canadian and Mexican natural gas demand projections, and the world liquid fuel demand and supply curves)	EIA' Annual Energy Outlook (AEO)
MarketSim	Lower 48 onshore and offshore, Alaska onshore and offshore, and the rest of the world	Resource prices and quantities are derived from AEO, as are most supply elasticities	BOEM's analysis for five-year program

After modifying NEMS and WEPS, BOEM can use these two models to recalibrate MarketSim. First, using the modified version of WEPS, BOEM can replicate a chosen greenhouse gas emissions pathway. Second, BOEM can then recalibrate the rest of the world in NEMS to these WEPS results, while similarly reducing domestic emissions in NEMS to match the chosen pathway. Results from this run can then be used to calibrate the new baseline quantities and prices in MarketSim to replicate the chosen pathway. Supply elasticities are also likely to change over time under decarbonization pathways, as stronger emission limitations will likely be present under more aggressive decarbonization pathways, thereby pushing some costs onto producers and shifting both demand and supply. Some elasticities such as electricity supply elasticities would need to be recalibrated to the model run using the approach laid out previously by BOEM.[49] Demand elasticities could be calculated through another methodology, most likely expert elicitation.

Alternatively, BOEM could conduct expert elicitation for each chosen climate pathway and then recalibrate MarketSim to this expert elicitation.[50] Elicitation can be a particularly valuable tool for forecasting future elasticities because the academic literature in this area is limited. To develop elasticities using elicitation, BOEM could provide qualified experts

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[48] A description of the NEMS cases is available at U.S. Energy Info. Admin., Annual Energy Outlook 2022: Case Descriptions (Mar. 2022), https://www.eia.gov/outlooks/aeo/assumptions/pdf/case_descriptions_2022.pdf.

[49] *See* MarketSim 2021, *supra* note 41, at 22 ("Where appropriate economic research does not exist or could not be obtained for a specific supply elasticity value, projections from the AEO 2020 low-world price, high-world price, and reference cases were used to infer these values. Elasticity estimates may be inferred from the AEO projection for a given year by comparing the differences in energy prices between two scenarios with the differences in energy quantities.").

[50] "Expert elicitation is a formal, highly-structured and well-documented process for obtaining the judgments of multiple experts. Typically, an elicitation is conducted to evaluate uncertainty. This uncertainty could be associated with: the value of a parameter to be used in a model; the likelihood and frequency of various future events; or the relative merits of alternative models." Env't Prot. Agency, *Guidelines for Preparing Economic Analyses* xiii (2016).

with the chosen IPCC mitigation pathway and the relevant information from the corresponding WEPS and NEMS runs, and then ask the experts to forecast supply and/or demand elasticities. This approach is largely consistent with BOEM's current approach, which derives some elasticities using NEMS while taking others from expert forecasts.[51] Potentially, BOEM could combine a broader expert elicitation with IPCC pathways to recalibrate MarketSim in a way to bypass WEPS, though BOEM would have to develop the methodology.

C. Illustrative Modeling Demonstrates that Under Decarbonization Pathways, the Climate Effects of OCS Leasing Are Far Greater Than BOEM Currently Projects

We modeled some of the recommendations outlined in the subsection above. First, we conducted sensitivity analysis adjusting individual elasticities, quantities, and prices.[52] We then ran more comprehensive model runs in which we concurrently adjusted numerous quantity and elasticity parameters, in an attempt to simulate the type of changes that would be expected under a range of decarbonization pathways. Results are presented in turn below.

As detailed further below, our results evince two key takeaways. First, under decarbonization pathways, the proposed program likely displaces other fossil-fuel sources much less—and renewable sources much more—than BOEM currently projects under the current-policy reference case. This means that greenhouse gas emissions of the no-leasing option could be much lower than BOEM currently projects, and thus net greenhouse gas emissions from the proposed program much higher than BOEM projects. In fact, under our illustrative model runs presented below, the proposed program results in three to four times the total greenhouse gas emissions that BOEM currently projects. While these runs are meant as illustrations rather than definitive projections, they strongly support the theory that the climate impacts of OCS leasing could be substantially higher than BOEM projects under the current-policy baseline.

Second, there is a large amount of uncertainty about the substitution effects of OCS leasing, and assumptions about quantity and elasticity parameters can have large effects on the ultimate results. This result underscores the importance of considering a range of pathways and parameter estimates. While the analyses below explore a range of different sensitivities and mitigation pathways, they are meant only as illustrative examples rather than the full range of potential outcomes.

Sensitivity Analysis of Supply and Demand Elasticities

We began by conducting sensitivity analyses around various key MarketSim parameters to identify the parameters that are driving BOEM's analysis and how changing those parameters alters the results. For each set of supply and demand elasticities in the model, we conducted two separate sensitivity analyses—one under which those elasticities are halved, the other in which those elasticities are doubled. Using these new sensitivity estimates, we then re-ran the model to determine how the particular change would affect BOEM's calculation of substitution impacts and net emissions. In each run, only a single set of elasticity parameters was changed while other elasticities, quantities, and prices were kept constant from BOEM's own model runs.

Results in the tables below represent the ratio of net greenhouse gas emissions to gross greenhouse gas emissions. By "gross greenhouse gas emissions," we mean the total lifecycle emissions attributable to production from OCS leasing, on a gross basis (i.e. without considering substitution impacts). By "net greenhouse gas emissions," we mean the gross

[51] *See* MarketSim 2021, *supra* note 41, at 17, 19 (explaining sourcing of demand and supply elasticities).

[52] Prior to conducting sensitivity analysis, it was necessary to make some modeling adjustments. Details are provided in Appendix A.

greenhouse gas emissions minus the total lifecycle emissions attributable to production from energy substitutes under the no-leasing scenario, thereby capturing the net change in emissions from the leasing program.[53] Accordingly, the higher the ratio of net emissions to gross emissions, the greater the net emissions from the proposed program under the specified assumption.

We calculate greenhouse gas emissions from new leasing and substitute sources respectively focusing on the mid-level leasing scenario for the Gulf of Mexico region (including both Gulf of Mexico program areas), since this region stands to receive all but one of the proposed lease sales. Under BOEM's modeling assumptions, without any of our adjustments, net emissions from this region comprise approximately 22.9% of gross emissions, implying a leakage rate of 77.1%.[54] Thus, estimates from our sensitivity runs above approximately 22.9% mean that net emissions resulting from OCS leasing are higher under the specified assumption. Results below approximately 22.9% mean that net emissions from OCS leasing are lower under the specified assumption. Results close to 22.9% mean that altering this parameter made little change.

Under our sensitivity analyses, the results are as follows:

Table 1: Sensitivity Analysis of Supply Elasticities
(ratio of net-to-gross GHG emissions of OCS leasing under specified assumption)

	Oil		Natural Gas	Coal	Electricity		All
	U.S.	Rest of World	U.S.	U.S.	Fossil Fuels	Renewables	Imports
1/2*Supply elasticities	25.76%	31.37%	26.99%	22.94%	22.56%	21.63%	22.96%
2*Supply elasticities	18.75%	13.66%	19.24%	22.84%	22.98%	24.19%	22.71%

Note: MarketSim does not model the supply elasticities for natural gas, coal, or electricity from the rest of the world. Imports include the following energy sources: Canadian pipeline oil imports, gas imports (pipeline), gas imports (LNG), electricity imports, and coal imports.

As Table 1 shows, oil and natural gas supply elasticities are largely driving BOEM's results. This is consistent with the expectation that lower price responses of producers would lead to less fossil-fuel energy produced under the no-leasing scenario and thus higher net emissions from OCS production (i.e. lower leakage rate). In particular, lower supply elasticities equate to higher estimates of net greenhouse gas emissions from the proposed program, whereas higher supply elasticities equate to lower estimates of net emissions from the proposed program.

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[53] In other words, gross emissions would equal net emissions if all energy were perfectly elastic (i.e., negative infinity demand elasticities). Both net and gross emissions capture full lifecycle emissions. As detailed below, BOEM should include all emissions in its net benefits analysis rather than restrict that analysis to upstream emissions. *See infra* Part II.A.

[54] According to the estimates that BOEM presents in its draft environmental impact statement, net emissions from the Gulf of Mexico region under mid-leasing activity total approximately 24.3% of gross emissions—a slight discrepancy from our finding of 22.9% when we run MarketSim. *See* Draft EIS, *supra* note 82, at C-9 to -13 tbls.C-6 to -10 (reporting 1430 million metric tons of CO2e in gross emissions from Gulf of Mexico region under mid-leasing activity, tbl.C-8, and 347 million metric tons in net emissions: 12 from domestic production and consumption, tbl.C-8, plus 335 from increased foreign consumption, tbl.C-10. 347/1430 = 24.3%). We reviewed our analysis numerous times and were unable to identify the source of this discrepancy. However, the discrepancy is small enough that we consider our model runs to be reliable.

This phenomenon is particularly pronounced for oil supply elasticity from the rest of the world: Halving the supply elasticity increases net emissions to approximately 31.4% of gross emissions—compared to approximately 22.9% under BOEM's analysis with all parameters set at their default levels. Doubling the supply elasticity, on the other hand, decreases net emissions to just 13.7% of gross emissions.

In contrast to oil and natural gas elasticities, supply elasticity for renewable electricity has a more modest effect, with higher elasticities producing a greater estimate of net emissions. Supply elasticities for coal, imports, and fossil fuel electricity have a minimal effect.[55]

We next present results from our sensitivity analysis of demand elasticities. Results are presented below in Table 2.

Table 2: Sensitivity Analysis of Demand Elasticities
(ratio of net-to-gross GHG emissions of OCS leasing under specified assumption)

	Oil	Natural Gas	Coal	Electricity				Fossil Fuel		
	U.S.	U.S.	U.S.	Fossil Fuels	Residential, commercial, industrial	Transport	Other	Rest of World	Imports and Exports	Transport
1/2*Own Price elasticities	20.03%	21.18%	22.86%		22.42%	22.82%	22.84%	13.96%	21.41%	20.95%
2*Own Price elasticities	27.88%	25.57%	22.90%		23.56%	22.98%	22.94%	35.49%	25.30%	26.45%
1/2*Cross Price elasticities	23.47%	23.98%	23.21%	23.73%						
2*Cross Price elasticities	21.67%	20.53%	22.21%	21.08%						

Note: Black cells represent elasticities not modeled explicitly in MarketSim.

On the demand side, as Table 2 shows, lower own-price elasticities for fossil fuels produce lower estimates of net emissions whereas higher own-price fossil fuel elasticities produce higher estimates of net emissions. This result varies by source, with the rest of world fossil-fuel-demand elasticity having the largest effect (35.5% net emissions with doubling the elasticity; 14% with halving the elasticity). Cross-price elasticities for fossil fuels have a more modest impact, with lower cross-price elasticities for domestic oil, natural gas, and coal producing higher estimates of net emissions. Electricity own-price demand elasticities have a very small impact.

Sensitivity Analysis of Resource Quantities and Prices

In addition to conducting sensitivity analysis around elasticities, we also conducted sensitivity analysis around resources quantities and prices (prior to the lease sales from the proposed program). In particular, for each quantity and price in the model, we conducted two separate sensitivity analyses—one in which the quantity or price increased by 10%, the other in which it decreased by 10%. We once again re-ran the model to assess the impact of each particular change, again

[55] This could potentially point to a problem with MarketSim, as the supply elasticity of coal is typically thought to be an important parameter. *See* Burniaux & Martins, *supra* note 23. However, there may be plausible explanations for this finding—such as the different context of these studies (like, Annex 1) or the rapidly declining demand for U.S. coal—and we are uncertain if it indicates an issue with MarketSim.

leaving all other inputs and parameters constant aside from the single set of changes. We again calculated greenhouse gas emissions focusing on the mid-level leasing scenario for the Gulf of Mexico region.

Once again, results in the table below represent the fraction of net greenhouse gas emissions to gross greenhouse gas emissions, considering all lifecycle emissions and foreign downstream emissions. Estimates above approximately 22.9% mean that net emissions from OCS leasing increase under that sensitivity analysis. Results below approximately 22.9% mean that net emissions from OCS leasing decrease under that sensitivity analysis. Results close to 22.9% mean that this sensitivity analysis made little change. Resources and quantities were increased and decreased by only 10% under this sensitivity analysis. Our results are thus not directly comparable to the results for elasticity sensitivity—where parameters were doubled and halved—as smaller changes from the baseline run are expected.

Table 3: Sensitivity Analysis of Resource Quantities and Prices (ratio of net-to-gross GHG emissions of OCS leasing under specified assumption)

	Oil		Natural Gas	Coal	Electricity		All
	U.S.	Rest of World	U.S.	U.S.	Fossil Fuels	Renewables	Imports
0.9*Quantity	23.05%	22.54%	22.90%	22.99%	23.04%	22.71%	22.87%
1.1*Quantity	22.71%	23.16%	22.82%	22.75%	22.72%	23.02%	22.88%
0.9*Price	22.87%		22.87%	22.87%	22.87%		
1.1*Price	22.87%		22.87%	22.87%	22.87%		

Notes: Outside of imports and exports, MarketSim does not represent the markets for natural gas, coal, or electricity in the rest of the world. Imports include the following energy sources: Canadian pipeline oil imports, gas imports (pipeline), gas imports (LNG), electricity imports, and coal imports.

As Table 3 reflects, decreasing the quantity of fossil fuels relative to the EIA reference case generally causes an increase in net emissions from OCS leasing, whereas increasing the quantity of fossil fuels generally causes a decrease in net emissions (although the magnitude of this effect is often small). The key exception is Rest of World oil, which goes the opposite direction.[56] Additionally, increasing the quantity of renewables relative to the EIA reference case has the effect of increasing net emissions from OCS leasing, whereas decreasing the quantity of renewables relative to the EIA reference case has the effect of decreasing net emissions from OCS leasing. However, at the 10% scale shown here, all of these effects are fairly modest.[57] Changes to resource prices have a very small effect on net emissions (not even discernible when looking at two decimal places).

[56] A potential explanation is that rest-of-world weighted oil supply elasticities are smaller than domestic weighted oil supply elasticities in MarketSim. Decreasing world oil supply results in more oil being produced domestically and less being produced from the rest of the world, meaning that more oil would be produced under the no-leasing scenario because of higher domestic oil supply elasticities. This results in higher emissions under the no-leasing scenario and thus lower net emissions from OCS leasing. A similar explanation applies to the finding that imports shift in the same direction as rest of world oil in Table 3, though that impact is minimal.

[57] As an illustrative exercise to compare the significance of quantity parameters versus elasticity parameters, we conducted two additional sensitivity analyses: 1) halving the quantity of domestic oil, and 2) doubling the quantity of renewables. Halving the quantity of domestic oil produced a result of 23.83%. Doubling the quantity of renewables produced a result of 23.87%. These relatively modest findings, which are directly comparable to the elasticity sensitivity estimates, indicate that certain elasticities drive the MarketSim results more than quantities.

Because the EIA reference case understates the quantity of renewables and overstates the quantity of fossil fuels under decarbonization pathways, these results suggest that if the model is adjusted to account for the potential for decarbonization, then it would likely find higher net greenhouse gas emissions resulting from OCS leasing. Illustrative runs to this effect are presented next.

Illustrative Model Runs

As an illustrative example, the authors of this report built out three illustrative runs in MarketSim intended to show how decarbonization considerations may affect BOEM's results of the proposed program's climate impacts.

Our three analyses all share several common features. For each analysis, we substantially decreased the quantities of oil, gas, and coal, while simultaneously increasing the quantity of renewables to make up for the shortfall. This adjustment is obviously consistent with what would occur under decarbonization pathways, although the precise extent of these various changes is of course uncertain.

Our analyses focused on two sets of quantity changes, which we deem the "less aggressive quantity outlook" and the "more aggressive quantity outlook." Though as discussed above, we suggest that BOEM evaluate a wider range of quantity changes to simulate different global decarbonization pathways.[58]

- Less aggressive quantity outlook: Oil and gas quantities decrease both domestically and globally by 25%, coal decreases by 80%, and renewables increase by approximately 3.3 times, which is equivalent to reduced energy supply from other sources in terms of barrel of oil equivalent.[59] This outlook is loosely equivalent to the IPCC pathways for meeting 2° C.[60]
- More aggressive quantity outlook: Oil and gas quantities decrease both domestically and globally by 50%, coal decreases by 90%, and renewables increase by approximately 5.1 times, which again makes up for the reduced energy supply from other sources. This outlook is loosely equivalent to the IPCC pathways for meeting 1.5° C.[61]

Predicting the direction of elasticity changes under decarbonization pathways is less obvious than predicting quantity changes (and far less literature on the topic exists), but several directional changes seem likely. On the supply side, we decreased supply elasticities of fossil fuels, given that producers will be less responsive to energy price changes due to increasingly higher costs to expand as future decarbonization pathways may call for producers to internalize environmental costs. Meanwhile, we increased supply elasticities of electricity, as technological improvements and policies promoting renewable development will continue to lower production costs in the electricity sector.

On the demand side, we increased own-price demand elasticities for both fossil fuels and electricity, as improved technological progress can greatly expand consumer choice and lead to increased sensitivity to prices changes for any single

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[58] *See supra* notes 43–47 and accompanying text.

[59] Under decarbonization pathways, resource quantities would change gradually over time. However, effecting such a change in MarketSim is very time-intensive given the model's current structure. Accordingly, in each illustrative model run, quantity changes were applied uniformly across all 70 years modeled in MarketSim. We selected quantity estimates that are roughly equivalent to the IPCC forecasts to reach 1.5° C and 2° C for 2050, which is near the midpoint of MarketSim's 70-year analysis. This means that quantity changes are overestimated in the earlier years of the analysis and underestimated in the later years. Because we find that the substitution rate is relatively insensitive to resource quantity changes, this simplifying assumption likely had a fairly modest effect on our results.

[60] *See* IPCC Working Group III Technical Summary, *supra* note 29, at TS-31 tbl.TS2.

[61] *See id.*

energy source.[62] Moreover, as electric cars gradually replace internal-combustion-engine vehicles,[63] consumers are expected to be more sensitive to changes in fossil fuel prices due to the ease of switching from fossil fuels to electricity; we thus also increased the cross-price elasticities of electricity with respect to fossil fuels. It is not clear to us which direction other elasticities and energy prices will move under decarbonization pathways, so we left these other parameters at their default levels.

Our illustrative analyses focus on two relatively crude sets of elasticity changes, which we deem the "less aggressive elasticity outlook" and the "more aggressive elasticity outlook."

- Less aggressive elasticity outlook: Double the elasticities that we expect to increase, halve the elasticities we expect to decrease, and leave constant those for which we are uncertain or do not expect to substantially move.[64] (See discussion above of which elasticities we expect to move in which direction).
- More aggressive elasticity outlook: Quadruple the elasticities that that we expect to increase, quarter those we expect to decrease, and leave constant those for which we are uncertain or do not expect to substantially move. (See discussion above of which elasticities we expect to move in which direction).

Admittedly, both the more and less aggressive elasticity outlooks reflect crude assumptions that were necessary given the timing constraints of this exercise. As detailed above, we encourage BOEM to generate elasticities for decarbonization pathways through a more rigorous mechanism such as NEMS and/or expert elicitation.[65]

We ran three illustrative modeling runs.

- Illustrative Run 1: more aggressive quantity outlook and less aggressive elasticity outlook (see Table 5 for results)
- Illustrative Run 2: less aggressive quantity outlook and less aggressive elasticity outlook (see Table 6 for results)
- Illustrative Run 3: more aggressive quantity outlook and more aggressive elasticity outlook (see Table 7 for results)[66]

We again focused our analysis on the mid-level leasing scenario for the Gulf of Mexico program region. Substitution and net emission results for each illustrative model run are presented below. We also present the climate-damage valuation under each model run using a range of social cost of greenhouse gases estimates. Part II.C offers further discussion of the social cost of greenhouse gases, explains why the single climate-damage estimate applied by BOEM is likely an undervaluation, and recommends that the agency apply a broader range of climate-damage valuations consistent with our analysis here.

First, however, for sake of comparison, we present the results from BOEM's baseline runs—that is, with elasticities and quantities left unchanged from BOEM's analysis.[67] Results from this "reference case" are presented in Table 4.

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[62] *See supra* note 38.

[63] *See, e.g.*, Reda Cherif et al., *Riding the Energy Transition: Oil Beyond 2040*, Int'l Monetary Fund 4 (2017).

[64] MarketSim is not a dynamic model and its elasticities are fixed over time. This is a modeling limitation, as elasticities should adjust over time as the energy sector evolves. *See infra* Part I.D for further discussion.

[65] *See supra* notes 49–51 and accompanying text.

[66] We deemed the fourth permutation—the less aggressive quantity outlook with the more aggressive elasticity outlook—the least plausible, and did not run it.

[67] Our results under the baseline model run are very similar to the results that BOEM reports in its proposed program. Once again, there are small discrepancies that should not affect the reliability of our model runs. *See supra* note 54.

Table 4: Substitution and Net Emissions Under Reference Case (i.e. BOEM's Assumptions)

Source	Change as % of Forgone Consumption
ONSHORE PRODUCTION	28.6%
Oil	10.6%
Natural Gas	18.0%
EXISTING OFFSHORE PRODUCTION	0.4%
Oil	0.3%
Natural Gas	0.1%
IMPORTS	51.2%
Oil	50.5%
Natural Gas	0.7%
OTHER	6.2%
Biofuels	0.4%
Other Oil	5.8%
Other Natural Gas	0.0%
COAL	0.8%
Domestic	0.8%
Imported	0.0%
ELECTRICITY	2.3%
Nuclear	0.1%
Hydro	0.0%
Solar	1.7%
Wind Onshore	0.4%
Wind Offshore	0.0%
Other Electric	0.1%
Imports	0.0%
REDUCED DEMAND	10.5%
Oil	4.3%
Natural Gas	7.1%
Coal	-0.4%
Electricity	-0.5%

Total Net Greenhouse Gas Emissions (Mmt CO2e)[68]	**329**
Net Emissions as a Percentage of Total Gross Emissions	**22.9%**
Social Cost of Greenhouse Gases (3% discount rate)[69]	**$12 billion**
Social Cost of Greenhouse Gases (2.5% discount rate)	**$17 billion**
Social Cost of Greenhouse Gases (2% discount rate)	**$28 billion**
Social Cost of Greenhouse Gases (1% discount rate)	**$86 billion**
Social Cost of Greenhouse Gases (3% discount rate, 95th percentile damages)[70]	**$38 billion**

As Table 4 shows, under BOEM's baseline runs, about 80% of the forgone production under the no-leasing scenario is replaced by other forms of oil and gas production. Reduced demand comprises about 10.5% of forgone production, while coal and renewables comprise small percentages of substitution. As noted above, total net emissions under BOEM's baseline runs total about 22.9% of total gross emissions, implying approximately 77.1% of greenhouse gas emissions leakage from OCS leasing.

We next present results under our first illustrative model run. In that model run, we combine the more aggressive quantities (oil and gas reduced by 50%, coal by 90%) with the less aggressive elasticities (elasticities doubled and halved). Results are presented in Table 5.

[68] Total net greenhouse gas emissions include emissions from all sources—domestic lifecycle emissions and increased foreign consumption.

[69] BOEM calculates the social cost of greenhouse gases using the Interagency Working Group's climate-damage estimate at a 3% discount rate. As discussed in *infra* Part II.C, this valuation very likely underestimates climate damages. Consistent with the recommendations in that section, we here apply climate-damage valuations using lower discount rates. *See infra* Part II.C for further discussion.

[70] The Working Group also developed climate-damage valuations using a 5% discount rate. Under this run, that valuation produces a climate-damage estimate of $4 billion. Due to the lack of support for a 5% discount rate in the economics literature, we do not include that rate in this table.

Table 5: Substitution and Net Emissions Under Illustrative Run 1: More Aggressive Quantity Outlook and Less Aggressive Elasticity Outlook

Source	Change as % of Forgone Consumption
ONSHORE PRODUCTION	**11.5%**
Oil	5.4%
Natural Gas	6.1%
EXISTING OFFSHORE PRODUCTION	**0.2%**
Oil	0.2%
Natural Gas	0.0%
IMPORTS	**53.4%**
Oil	53.2%
Natural Gas	0.2%
OTHER	**3.2%**
Biofuels	0.2%
Other Oil	3.0%
Other Natural Gas	0.0%
COAL	**0.1%**
Domestic	0.1%
Imported	0.0%
ELECTRICITY	**16.7%**
Nuclear	1.0%
Hydro	0.0%
Solar	12.2%
Wind Onshore	2.6%
Wind Offshore	0.0%
Other Electric	0.8%
Imports	0.0%
REDUCED DEMAND	**15.0%**
Oil	12.6%
Natural Gas	14.3%
Coal	0.0%
Electricity	-11.9%

Total Net Greenhouse Gas Emissions (Mmt CO2e)	**936**
Net Emissions as a Percentage of Total Gross Emissions	**65.0%**
Social Cost of Greenhouse Gases (3% discount rate)	**$38 billion**
Social Cost of Greenhouse Gases (2.5% discount rate)	**$53 billion**
Social Cost of Greenhouse Gases (2% discount rate)	**$85 billion**
Social Cost of Greenhouse Gases (1% discount rate)	**$247 billion**
Social Cost of Greenhouse Gases (3% discount rate, 95th percentile damages)[71]	**$116 billion**

As Table 5 shows, substitution to onshore sources of oil and gas declines substantially (from 28.6% to 11.5%) under this illustrative model run compared to the reference case. Reduced demand also increases overall, driven by higher reduced demand for oil and gas. Substitution to solar and wind increases substantially, from 2.1% under the reference case to 14.8% in this model run. Imports are largely static and actually increase slightly. Driven by these changes, total emissions under the no-leasing scenario decline substantially and so net emissions from OCS leasing greatly increase—from 329 to 936 Mmt, an increase of about 2.84 times.

We next present results under the less aggressive quantity outlook (oil and gas reduced by 25%, coal by 80%) with the less aggressive elasticity outlook (elasticities doubled and halved).

[71] The Interagency Working Group on the Social Cost of Greenhouse Gases also developed climate-damage valuations using a 5% discount rate. Under this run, that valuation produces a climate-damage estimate of $13 billion. Due to the lack of support for a 5% discount rate in the economics literature, we do not include that rate.

Table 6: Substitution and Net Emissions Under Illustrative Run 2: Less Aggressive Quantity Outlook and Less Aggressive Elasticity Outlook

Source	Change as % of Forgone Consumption
ONSHORE PRODUCTION	11.8%
Oil	5.5%
Natural Gas	6.4%
EXISTING OFFSHORE PRODUCTION	0.2%
Oil	0.2%
Natural Gas	0.0%
IMPORTS	53.3%
Oil	53.1%
Natural Gas	0.2%
OTHER	3.2%
Biofuels	0.2%
Other Oil	3.0%
Other Natural Gas	0.0%
COAL	0.1%
Domestic	0.1%
Imported	0.0%
ELECTRICITY	9.6%
Nuclear	0.6%
Hydro	0.0%
Solar	7.1%
Wind Onshore	1.5%
Wind Offshore	0.0%
Other Electric	0.4%
Imports	0.0%
REDUCED DEMAND	21.7%
Oil	12.3%
Natural Gas	14.6%
Coal	-0.1%
Electricity	-5.2%

Total Net Greenhouse Gas Emissions (Mmt CO2e)	**928**
Net Emissions as a Percentage of Total Gross Emissions	**63.4%**
Social Cost of Greenhouse Gases (3% discount rate)	**$37 billion**
Social Cost of Greenhouse Gases (2.5% discount rate)	**$52 billion**
Social Cost of Greenhouse Gases (2% discount rate)	**$84 billion**
Social Cost of Greenhouse Gases (1% discount rate)	**$245 billion**
Social Cost of Greenhouse Gases (3% discount rate, 95th percentile damages)[72]	**$115 billion**

As Table 6 shows, overall emissions from this illustrative model run are very similar to the prior one: 928 vs. 936 Mmt (both of which are nearly triple total emissions from the reference case). The substitution tables reveal additional differences between the two model runs, but all outputs change in the same direction from the reference case. This further suggests, as indicated by the substitution analyses presented in Tables 1–3, that elasticities are driving the results more than quantities.

Last, we present results under the more aggressive quantity outlook (oil and gas reduced 50%, coal 90%) with the more aggressive elasticity outlook (elasticities quadrupled and quartered).

[72] The Interagency Working Group on the Social Cost of Greenhouse Gases also developed climate-damage valuations using a 5% discount rate. Under this run, that valuation produces a climate-damage estimate of $13 billion. Due to the lack of support for a 5% discount rate in the economics literature, we do not include that rate.

Table 7: Substitution and Net Emissions Under Illustrative Run 3: More Aggressive Quantity Outlook and More Aggressive Elasticity Outlook

Source	Change as % of Forgone Consumption
ONSHORE PRODUCTION	3.5%
Oil	1.8%
Natural Gas	1.6%
EXISTING OFFSHORE PRODUCTION	0.1%
Oil	0.1%
Natural Gas	0.0%
IMPORTS	54.0%
Oil	53.9%
Natural Gas	0.1%
OTHER	1.0%
Biofuels	0.1%
Other Oil	1.0%
Other Natural Gas	0.0%
COAL	0.0%
Domestic	0.0%
Imported	0.0%
ELECTRICITY	20.0%
Nuclear	1.1%
Hydro	0.1%
Solar	14.6%
Wind Onshore	3.2%
Wind Offshore	0.0%
Other Electric	1.0%
Imports	0.0%
REDUCED DEMAND	21.4%
Oil	18.1%
Natural Gas	18.0%
Coal	0.0%
Electricity	-14.7%

Total Net Greenhouse Gas Emissions (Mmt CO2e)	**1,227**
Net Emissions as a Percentage of Total Gross Emissions	**88.6%**
Social Cost of Greenhouse Gases (3% discount rate)	**$52 billion**
Social Cost of Greenhouse Gases (2.5% discount rate)	**$73 billion**
Social Cost of Greenhouse Gases (2% discount rate)	**$118 billion**
Social Cost of Greenhouse Gases (1% discount rate)	**$342 billion**
Social Cost of Greenhouse Gases (3% discount rate, 95th percentile damages)[73]	**$160 billion**

Table 7 presents our most aggressive decarbonization assumptions, and produces the starkest results. Under this illustrative model run, substitution to onshore oil and gas decreases even further from the baseline run (to 3.5%) while substitution to solar and wind increases even further (to 17.8% total). Meanwhile, oil and gas demand decrease even further as a result of OCS leasing, whereas demand for electricity increases further. Total net emissions increase to 1,227 Mmt, or 88.6% as a percentage of gross emissions, indicating an even lower leakage rate of 11.4% after accounting for more aggressive climate actions. This is about 3.73 times the total net emissions under the reference case presented in Table 4.

[73] The Interagency Working Group on the Social Cost of Greenhouse Gases also developed climate-damage valuations using a 5% discount rate. Under this run, that valuation produces a climate-damage estimate of $13 billion. Due to the lack of support for a 5% discount rate in the economics literature, we do not include that rate.

While the results presented in our three illustrative model runs (Tables 5–7) are provided as illustrations reflecting some crude assumptions, they strongly support the assertion that under decarbonization pathways, OCS leasing will substitute more for renewables and less for other fossil-fuel sources, and so the net climate impacts of leasing will be far more severe than BOEM currently projects. This further evinces the need for BOEM to model a range of decarbonization pathways and not to rely on a single pathway that assumes a worst-case outlook in which current policies[74] remain forever static. BOEM should model these possible pathways more rigorously consistent with our recommendations above.

D. BOEM Should Consider Replacing MarketSim with the National Energy Modeling System or Another Dynamic Model, Particularly over the Longer Term

As detailed throughout this Part, there are numerous ways that BOEM can update MarketSim to better capture decarbonization pathways and model a range of potential futures. If BOEM continues to use MarketSim—as it now has for multiple OCS leasing programs—then we strongly urge it to make those types of updates. However, there are limits to what can be done in MarketSim due to constraints in the model.

For instance, MarketSim is a partial-equilibrium, Excel-based model that has not been peer-reviewed. Problematically, its parameters are exogenous and its elasticity parameters are static over time even though, in reality, those elasticities are likely to change substantially over the coming decades.[75] And MarketSim's modeling of both renewables and international energy markets is very limited.[76] For these reasons, it is unlikely that MarketSim can model the energy sector with the robustness that the problem demands. BOEM should consider transitioning to a different energy model.

If BOEM chooses to explore other options, NEMS would make a natural choice. In fact, MarketSim already draws heavily from NEMS, as 17 of its 29 supply elasticities are derived using a version of NEMS.[77] NEMS is also a more sophisticated, realistic, and rigorous model than MarketSim, as well as more accepted within the academic community.[78] Unlike MarketSim, the NEMS model is dynamic, meaning that endogenous parameters change over time and in response to one another. NEMS also models other regions of the world in more detail. And it is more consistent with the standard computable general equilibrium (CGE) models used for the ex-ante analysis of leakage in the economic literature.[79]

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[74] Or, in BOEM's case, policies as of late 2019 or early 2020. *See supra* notes 10–13 and accompanying text.

[75] *See, e.g.*, Matthias Kalkuhl & Robert J. Brecha, *The Carbon Rent Economics of Climate Policy*, 39 Energy Econ. 89 (2013) (projecting that technological progress and the possibility of fuel switching between oil, gas, and coal could lead to a higher elasticity than reported by empirical studies, at least over the long-term); Elizabeth A. Stanton & Frank Ackerman, *Emission Reduction, Interstate Equity, and the Price of Carbon*, Econ. for Equity & Env't (2010) (finding demand for fossil fuels may be more elastic in the future as state and federal policy expand consumer choice).

[76] Redesigning MarketSim to represent global energy markets beyond oil, including international markets for gas, coal, and electricity (including from renewables)—without any other changes—would likely decrease its projection of net greenhouse gas emissions from OCS leasing as international producers decrease their natural gas and other fuel production in response to increased U.S. production and export of natural gas. This is beyond the scope of this report. Even so, Prest (2022) still finds a lower substitution rate of greenhouse gases than BOEM despite modeling global markets of both oil and gas, suggesting that more holistic modeling updates (not even including updating the baseline for decarbonization scenarios, as detailed in Parts I.A–C) would likely decrease leakage. *See supra* notes 19–22 and accompanying text.

[77] MarketSim 2021, *supra* note 41, at 20 tbl.5 (2021) (reporting 17 different elasticities derived either "from AEO 2020," "from specialized NEMS runs of the AEO 2015 provided to DOI by EIA," "from specialized NEMS runs of the AEO 2018 provided to DOI by EIA," or "from the AEO 2020").

[78] Using Google Scholar searches of "National Energy Modeling System" versus "MarketSim" AND "leases," we find multiple pages of publications using or discussing NEMS versus just 13 citations of MarketSim.

[79] *See, e.g.*, Yu et al., *supra* note 24.

Another option for BOEM would be to adapt another peer-reviewed model. As discussed above, Brian Prest developed a peer-reviewed model of federal resources that captures many of the same dynamics as MarketSim, but more dynamically.[80] BOEM could similarly update Dr. Prest's model to capture a range of future decarbonization pathways. In the literature more broadly, economists have extensively used CGE models of the global economy to estimate the leakage of unilateral climate action at subnational, national, and multi-national levels. Though many CGE models are used in the literature, the most common one is GTAP (standing for Global Trade Analysis Project), which models the economy in far more detail than MarketSim.[81] Given the common use of CGE models like GTAP in the leakage literature, these models would form a reliable basis to model BOEM's leakage problem than MarketSim if BOEM chooses to go a different route than NEMS.

[80] *See supra* notes 19–22 and accompanying text.

[81] *See, e.g.*, Burniaux & Martins, *supra* note 23; Yu et al., *supra* note 24.

II. For Numerous Additional Reasons, BOEM's Analysis Drastically Understates the Climate Costs of OCS Leasing

As detailed in the prior Part, BOEM's analysis likely underestimates the greenhouse gas emission increases that will result from OCS leasing by assuming long-term global reliance on oil and gas consistent with current policy case as modeled under the EIA reference case. As discussed in this Part, BOEM's analysis understates the climate costs of OCS leasing for at least three additional reasons.

Most significantly, as detailed first, while BOEM's environmental impact statement acknowledges that the proposed program would result in billions of dollars in climate damages,[82] its net benefits analysis actually find climate change to be a *benefit* of OCS leasing. This apparent contradiction is because BOEM omits downstream emissions from its net benefits analysis based on an incorrect legal interpretation of its authority to consider downstream effects, and instead focuses its analysis on just upstream emissions, which are a small subset of total emissions. But BOEM is not restricted from considering downstream emissions—a conclusion summarized below and detailed further in the Policy Integrity report titled *Interior's Authority to Consider Downstream Emissions from Offshore Leasing*. Therefore, it should incorporate those emissions into its net benefits analysis instead of incorrectly concluding that OCS leasing presents a climate benefit based on an incomplete analysis.

This Part also explains that BOEM disregards the potential for foreign reciprocity and applies social cost of greenhouse gases valuations that are widely considered to be underestimates. This Part concludes in its final section by providing our original modeling showing that if downstream emissions are considered using more appropriate climate-damage valuations, then climate damages alone from OCS leasing approach or potentially exceed the total benefits estimated by BOEM.

A. BOEM Should Incorporate Downstream and Midstream Emissions, Which OCSLA Does Not Prevent the Agency from Considering, Into Its Net Benefits Analysis

Despite projecting that OCS leasing will result in substantial downstream and midstream greenhouse gas emissions,[83] BOEM does not include the resulting climate costs in its net benefits analysis.[84] Instead, BOEM focuses the assessment of climate impacts in its net benefits analysis only on upstream emissions.[85] And because BOEM concludes that substitute energy sources will generally have greater upstream emissions than those from OCS development—a conclusion that could look much different under more reasonable long-term baselines, as discussed in Part I—its net benefits analy-

[82] Bureau of Ocean Energy Mgmt., 2023–2028 National Outer Continental Shelf Oil and Gas Leasing program Draft Programmatic Environmental Impact Statement C-20 tbl.C-14 (2022) (hereinafter "Draft EIS") (estimating climate cost of emissions from increased oil consumption due to OCS leasing).

[83] *Id.* at C-10 tbl.C-7 (2022) (projecting a net of 160 million metric tons of midstream and downstream emissions in Gulf of Mexico Program Area 1 and Cook Inlet under mid-activity level).

[84] Proposed Program, *supra* note 2, at 5-35.

[85] *See id.* at 5-36.

sis ultimately treats climate change as a benefit of the proposed program.[86] Although climate change is a substantial cost of the proposed program, the net benefits analysis treats it as a benefit.

According to BOEM, the omission of downstream emissions from its net benefits analysis is required because, according to the agency, the U.S. Court of Appeals for the D.C. Circuit ruled in *Center for Biological Diversity v. Department of the Interior* (*CBD*) that BOEM "lacks the discretion to analyze the effects of consumption of OCS oil and gas" at the program stage.[87] But BOEM misreads *CBD*, which held simply that the Outer Continental Shelf Lands Act (OCSLA) does not *require* BOEM to consider downstream effects.[88] And a fuller analysis reveals that BOEM is permitted to consider downstream greenhouse gas emissions in administering the leasing program. Accordingly, BOEM should include all emissions in its net benefits analysis and not restrict its analysis to upstream emissions only.

The attached Institute for Policy Integrity brief, titled *Interior's Authority to Consider Downstream Emissions from Offshore Leasing*, details Interior's authority to consider downstream emissions in administering the leasing program.[89] That policy brief highlights key OCSLA text, legislative and regulatory history, and case law to show that the statute permits BOEM to consider downstream emissions, and that BOEM's contention that the agency may not assess those effects is wrong for several reasons. This section provides a brief summary of that report's main points.

To begin, no judicial decision bars Interior from considering downstream environmental effects—and some key caselaw in fact supports BOEM's authority to consider downstream emissions.[90] As noted above, *CBD* holds only that OCSLA does not require BOEM to consider such effects. The case's dicta admittedly goes further, but the dicta is based on a flawed analysis that disregards key OCSLA text and history. Consistent with that text and history, the D.C. Circuit later held that OCSLA does not bar BOEM from looking beyond local environmental effects.[91] And the U.S. Court of Appeals for the Ninth Circuit held in 2020 that BOEM may consider downstream environmental impacts in administering the leasing program.[92]

These more recent judicial decisions are consistent with OCSLA's text. In fact, OCSLA gives Interior broad discretion to craft an offshore-leasing program that it determines best meets "national energy needs" and that is also "consistent with" several "principles" requiring consideration of local environmental effects, among other factors.[93] Contrary to BOEM's suggestion, however, those principles do not define the universe of factors that Interior may consider. And nothing else in OCSLA prevents Interior from taking into account a broad range of other considerations—including non-local, downstream, and midstream environmental effects—when determining how best to meet "national energy needs."[94]

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[86] *Compare* Proposed Program, *supra* note 2, at 5-36 tbl.5-8 *with id.* at 5-43 tbl.5-12 (showing higher social cost of greenhouse gases from upstream emissions under no-leasing option versus leasing option). *See also id.* at 5-51 tbl.5-16 (showing incremental negative social cost of upstream greenhouse gas emissions—in other words, social benefit of upstream greenhouse gas emissions—under most scenarios for Gulf of Mexico Program Area 1 and Cook Inlet).

[87] *Id.* at 5-35 (citing Center for Biological Diversity v. U.S. Dep't of Interior ("*CBD*"), 563 F.3d 466 (D.C. Cir. 2015)). BOEM does not provide a specific reason for omitting midstream emissions.

[88] *CBD*, 563 F.3d at 484 ("[W]e *hold* that OCSLA does not *require* Interior to consider the global environmental impact of oil and gas consumption before approving a Leasing Program.") (emphasis added).

[89] Laura Figueroa, Donald Goodson & Max Sarinsky, Inst. for Pol'y Integrity, *Interior's Authority to Consider Downstream Emissions from Offshore Leasing* (2022).

[90] *Id.* at pt. I.

[91] Ctr. for Sustainable Econ. v. Jewell, 779 F.3d 588, 606 (D.C. Cir. 2015).

[92] Ctr. for Biological Diversity v. Bernhardt, 982 F.3d 723, 740 (9th Cir. 2020) (explaining that Interior "has the statutory authority to act on the emissions resulting from [downstream] oil consumption" and that, "[i]f it later concludes that such emissions will be significant, it may well approve another alternative . . . or deny the lease altogether."); *see also* Native Vill. of Point Hope v. Jewell, 740 F.3d 489, 504 (9th Cir. 2014) (recognizing significance of "adequately consider[ing] cumulative effects of [an OCS] lease sale on the environment, including . . . the effects of the sale on climate change").

[93] 43 U.S.C. § 1344(a).

[94] *See id.*

OCSLA's legislative history further confirms that Interior may consider downstream environmental effects.[95] Congress enacted OCSLA in 1953 and overhauled it in 1978 in response to the energy crisis caused by the 1973–74 oil embargo. The House and Senate Reports for the 1978 amendments demonstrate that, while Congress wanted to ensure Interior still had broad authority when making offshore-leasing decisions, it was also concerned about environmental harm from OCS energy production and consumption. In fact, Congress believed increased OCS development would alleviate a near-term energy crisis while supplying energy "with substantially less harm to the environment," including through downstream effects, "than almost any other source" then available.[96] Over time, however, Congress expected that new and potentially cleaner energy sources would emerge. Lacking a crystal ball, Congress left it to Interior to determine how best to meet national energy needs through offshore leasing while also "considering all the economic, social, and environmental impacts of oil and gas activities."[97]

Interior has done exactly that over the past four decades. In particular, Interior has considered downstream environmental effects, including greenhouse gas emissions, at both the planning and leasing stages since the 1980s.[98] In doing so, Interior has often highlighted downstream environmental advantages of OCS natural gas relative to dirtier onshore sources such as coal, noting, for example, that natural gas is an "environmentally preferred source of energy for electricity generation."[99] BOEM's claim in the proposed program that such effects are beyond the scope of the agency's consideration is at odds with this longstanding history.[100]

For all these reasons, BOEM is incorrect that it cannot consider downstream and midstream greenhouse gas emissions at the programmatic stage, and should incorporate those emissions into its net benefits analysis. Doing so is critical because downstream and midstream emission are far greater than the direct emissions that BOEM incorporates into its net benefits analysis.[101] In fact, as noted above, considering downstream and midstream emissions in this analysis would reveal that BOEM's current finding of a climate benefit is incorrect, and that in fact the proposed program comes at a large climate cost.[102]

B. BOEM Should Consider the Potential for Reciprocal Foreign Emission Reductions

BOEM's substitution analysis proceeds on the assumption that if the OCS is not leased for oil and gas development, then market forces will drive other U.S. and foreign fossil-fuel sources to fill the void. Though this is likely true to some extent,[103] it also not the full picture, since the global oil supply is determined not only by market forces but also by government policies and international negotiations. And literature suggests that as the U.S. takes strong action to mitigate climate change, other nations become more likely to follow suit through reciprocal actions. BOEM overlooks the possibility that forgoing OCS leasing will incentivize other nations to take similar actions that reduce their own emissions.

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[95] Figueroa et al., *supra* note 89, at pt. III.
[96] S. Rep. No. 95-284, at 42 (1977).
[97] H. Rep. No. 95-590, at 149 (1977).
[98] Figueroa et al., *supra* note 89, at pt. IV.
[99] Minerals Mgmt. Serv., *Proposed Final Outer Continental Shelf Oil & Gas Leasing Program 2002–2007* at 71 (2002).
[100] *See* Smiley v. Citibank, 517 U.S. 735, 740 (1996) ("[A]gency interpretations that are . . . long standing come . . . with a certain credential of reasonableness, since it is rare that error would long persist.").
[101] *Compare* Draft EIS, *supra* note 82, at C-9 tbl.C-6 (upstream emissions) *with id.* at C-10 tbl.C-7 (midstream and downstream emissions).
[102] *See supra* notes 83–86 and accompanying text.
[103] Though this extent is largely predicated on future climate mitigation. *See* Part I.

Because the world's climate is a single interconnected system, all nations stand to benefit greatly when foreign countries reduce their greenhouse gas emissions. Reducing emissions therefore promotes U.S. strategic interests, as it encourages and incentivizes other nations to reduce their emissions in a reciprocal fashion.[104] Evidence indicates that the U.S. strategy of combining its domestic efforts with its diplomatic engagement is indeed spurring foreign reciprocity. For instance, following the announcement in April 2021 of a new U.S. commitment to reduce greenhouse gas emissions to 50–52% below 2005 levels by 2030, numerous other countries reciprocally increased the ambition of their own climate targets.[105] And this activity is just the latest evidence of reciprocity in international climate actions.[106] By reducing the extent of oil and gas leasing, in other words, BOEM may incentivize other countries to do the same, which in turn would reduce climate pollution originating in other countries.

In January 2021, Trevor Houser and Kate Larsen published a conservative estimate of the number of tons of greenhouse gases that the rest of the world had committed to reduce for each ton that the United States has pledged to reduce: a figure they call the "Climate Reciprocity Ratio."[107] Using only the quantifiable, unconditional pledges that 51 countries had made since 2014 to cut emissions through 2030, Houser and Larsen conservatively estimate that for every ton the United States pledged to reduce, these other countries had collectively pledged to reduce 6.1–6.8 tons in return.[108] Their paper builds off of the work of Yale University economics professor Matthew J. Kotchen, whose research finds that countries should lower their own emissions well beyond what would be optimal from a narrow domestic perspective, since emission reductions in one country provides a strategic benefit that leads to reciprocal emission reductions from other countries.[109]

In short, both economic theory and historical data suggest that U.S. emission reductions spur other countries to take reciprocal action. Yet this reciprocity effect is absent in BOEM's modeling and analysis, which concludes that in the absence of OCS leasing, market forces will supply most of the fossil-fuel energy that the OCS would have provided. BOEM should perform sensitivity analysis that assesses how OCS leasing would affect global greenhouse gas emissions under reasonable assumptions about global reciprocity, potentially starting with empirical estimates in the literature such as those discussed above. Even if BOEM does not model this effect quantitatively, it should recognize that reciprocity offers another explanation that its net emission figures are likely underestimates.

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[104] *See* Peter Howard & Jason A. Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Colum. J. Env't L. 203, 221–22 (2017) (discussing "tragedy of the global climate commons" that encourages nations to work together to reduce their greenhouse gas emissions).

[105] Japan accelerated its reduction goal from 26% to 46–50%; Canada strengthened its target from 30% to 40–45%; South Korea strengthened its target to achieve net zero emissions by 2050; China promised to peak coal use by 2025 and phase down coal consumption after that, and to join the Kigali Amendment to reduce hydrofluorocarbon emissions; Argentina pledged to strengthen its goal by 2.7% and make previously "conditional" targets "unconditional" instead; Brazil committed to a net zero target by 2050 (ten years earlier than its previous 2060 goal); South Africa shifted its emission peak ten years earlier; and New Zealand, Bhutan, and Bangladesh all committed to submit more ambitious plans in the near future. U.S. Dept. of State, Leaders' Summit on Climate: Day 1, Apr. 22, 2021, https://perma.cc/3X8A-KF4G; Climate Action Tracker, *Warming Projections Global Update: May 2021* at 3 (2021), https://perma.cc/7JYN-N2DU.

[106] Some past reciprocity has been explicit. The Kigali Amendment, for example, is the latest internationally negotiated climate treaty, with more than 120 parties so far committing to common but differentiated responsibilities to phase down hydrofluorocarbons. *See* U.N., Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer (2016), https://perma.cc/SEX3-HAQA.

[107] Trevor Houser & Kate Larsen, Rhodium Grp., *Calculating the Climate Reciprocity Ratio for the U.S.* (2021), https://perma.cc/7MJ8-DN23 (calling their estimate "deliberately conservative").

[108] The estimate is conservative because it omits any conditional pledges, any pledges that are not readily quantified into specific reductions, any actions from countries that have not formally submitted Nationally Determined Contributions to the United Nations, any reductions occurring after 2030, and any foreign actions already achieved before 2014 that may have motivated U.S. pledges in the first place. *Id.*

[109] Matthew J. Kotchen, *Which Social Cost of Carbon? A Theoretical Perspective*, 5 J. Assoc. Env't & Res. Econ. 673, 678 (2017)

C. The Incremental Climate-Damage Valuations Applied Here Are Conservative, and BOEM Should Conduct Further Analysis Around Higher Values

Assessing the climate effects of OCS leasing entails not just quantifying emissions, but also assessing the incremental climate-change damages that those emissions will cause. On this second step, BOEM appropriately estimates incremental climate damages using valuations developed by the Interagency Working Group on the Social Cost of Greenhouse Gases (Working Group).[110] But the Working Group provided a range of climate-damage estimates that it characterized as conservative underestimates, and BOEM uses a single point estimate toward the low end of the Working Group's range. While it is appropriate for BOEM to rely on the Working Group's methodology, it should conduct additional analysis using higher valuations endorsed by the Working Group rather than relying on a single, conservative valuation.

The Working Group developed its climate-damage estimates through a rigorous and transparent process incorporating the best available science. Those values have been applied in dozens of previous agency actions[111] and upheld in federal court.[112] The Working Group provided a range of four different valuations for the social cost of greenhouse gases, which vary based on the discount rate (for three of the four valuations) and the damages estimate (for the other).[113] Those values are provided below in Table 8.

Table 8: Interagency Working Group's Social Cost of Carbon Valuations (in 2020$ per metric ton of carbon dioxide)[114]

Year of Emissions	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	95th Percentile Damages (3% Discount Rate)
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

As this table illustrates, the Working Group's valuations provide a wide range of climate-damage valuations. For emissions in the year 2030, for instance, the Working Group forecasts a damage range of $19–$187 per ton of carbon dioxide (the Working Group has provided a similar range of estimates for emissions of methane[115] and nitrous oxide[116]). But in this analysis, BOEM selects a single climate-damage valuation: the Working Group's 3% discount rate valuation.[117] The damage estimate is toward the low end of the Working Group's range. Returning to year 2030 emissions, the climate-

[110] Economic Analysis Methodology, *supra* note 37, at 1-20.
[111] Howard & Schwartz, *supra* note 104, at 270–84 (listing all uses through mid-2016).
[112] Zero Zone v. Dept. of Energy, 832 F.3d 654, 679 (7th Cir. 2016).
[113] Interagency Working Grp. on the Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide – Interim Estimates Under Executive Order 13,990 at 5–6 (2021) [hereinafter "IWG, 2021 TSD"].
[114] *Id.* at 5 tbl.ES-1.
[115] *Id.* at 5 tbl.ES-2 (showing range of climate-damage valuations for methane).
[116] *Id.* at 6 tbl.ES-3 (showing range of climate-damage valuations for nitrous oxide).
[117] *See* Draft EIS, *supra* note 82, at C-18 ("The results shown here use the 3% discount rate[.]").

damage valuation that BOEM uses is $62. This is far closer to the low end of the range ($19, or $43 less than $62) than the high end of the range ($187, or $125 greater than $62). BOEM's usage of a single climate-damage valuation not only disregards uncertainty, but also likely undervalues climate damages.

This undervaluation is especially pronounced because the Working Group has recognized that its full range of estimates, taken as a whole, "likely underestimate societal damages from [greenhouse gas] emissions."[118] There are two main reasons for this underestimation. First, "the latest scientific and economic understanding of discount rates" strongly indicates that the Working Group's social cost of greenhouse gases estimates undervalue the climate damages that will be borne by future generations.[119] The Working Group explained that discount rates of "2 percent and lower" are likely appropriate for valuing climate damages.[120] Second, the integrated assessment models that are used to produce the Working Group's estimates "do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature."[121] The Working Group is currently in the process of updating its climate-damage valuations to reflect the latest and best available science.[122] Recent research points strongly to higher climate-damage valuations, and as it completes its update,[123] the Working Group has suggested that agencies also apply higher climate-damage valuations that use lower discount rates.[124] In fact, a recent analysis from Resources for the Future found that the proper present-day social cost of greenhouse gases is $185[125]—more than three times higher than the figure BOEM uses in this analysis and even greater than the Working Group's highest climate-damage valuation (at a 3% discount rate with 95th percentile damages).

BOEM should conduct additional analysis to better ensure that it does not undervalue the true climate costs of OCS leasing. If the Working Group (or any other U.S. agency) releases its updated values before BOEM finalizes this program, then BOEM should use those updated values. If BOEM finalizes this analysis before the Working Group updates its climate-damage valuations, it should conduct additional sensitivity analysis using alternative values. In particular, BOEM should apply the full range of valuations provided by the Working Group, which is consistent with the Working Group's recommendation.[126] BOEM should prioritize the Working Group's higher valuations at lower discount rates, like the Office of Management did in a recent analysis.[127]

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[118] IWG, 2021 TSD, *supra* note 113, at 4.

[119] *Id.*; *accord id.* at 16–22 (reviewing literature on intergenerational discounting and finding substantial support for discount rates of 2 percent or lower). *See also* Jason Schwartz & Peter Howard, *Valuing the Future: Legal and Economic Considerations for Updating Discount Rates*, 39 Yale. J. Reg. 595, 616–34 (2022) (surveying literature supporting use of lower discount rates, particularly over long time horizons).

[120] IWG, 2021 TSD, *supra* note 113, at 21; *see also id.* at 4 (explaining that "new data and evidence strongly suggests that the discount rate regarded as appropriate for intergenerational analysis is lower" than the 2.5–5% range that the Working Group applies).

[121] *Id.* at 4; *accord id.* at 30–32 (discussing omitted impacts in further detail, including "the incomplete treatment of catastrophic and non-catastrophic impacts in the [models], their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons"); Economic Analysis Methodology, *supra* note 37, at 1-20; *id.* at 2-1 ("Although the IWG estimates of SC-GHG encompass many potential damages associated with GHG emissions, there may be categories of impacts that are not included in the monetization.");

[122] IWG, 2021 TSD, *supra* note 113, at 36.

[123] *E.g.* Kevin Rennert et al., *Comprehensive Evidence Implies a Higher Social Cost of CO2,* Nature (forthcoming 2022) (finding central social cost of carbon value of $185 using discount rate of 2%).

[124] IWG, 2021 TSD, *supra* note 113, at 4 ("Consistent with the guidance in E.O. 13990 for the IWG to ensure that the SC-GHG reflect the interests of future generations, the latest scientific and economic understanding of discount rates discussed in this TSD, and the recommendation from OMB's Circular A-4 to include sensitivity analysis with lower discount rates when a rule has important intergenerational benefits or costs, agencies may consider conducting additional sensitivity analysis using discount rates below 2.5 percent.").

[125] Rennert et al., *supra* note 123.

[126] IWG, 2021 TSD, *supra* note 113, at 4 (advising agencies to use the "set of four values" without marking any single value as the central or preferred estimate).

[127] Office of Mgmt. & Budget, *OMB Analysis: The Social Benefits of the Inflation Reduction Act's Greenhouse Gas Emission Reductions* (2022), https://www.whitehouse.gov/wp-content/uploads/2022/08/OMB-Analysis-Inflation-Reduction-Act.pdf (monetizing emissions using Working Group's valuation at 2.5% discount rate).

To be further consistent with the Working Group's recommendation, BOEM should also conduct further analysis around even lower discount rates—perhaps 2% and 1%[128]—to reflect state-of-the-art literature on the topic and to anticipate likely updates by the Working Group. To do so, it could look to the "value of carbon" estimates from the New York State Department of Environmental Conservation, which applied a 2% discount rate as its central value (and a 1% discount rate as an alternative value) but otherwise used the Working Group's modeling inputs.[129] As noted above, the Working Group itself has suggested that agencies conduct additional analysis using lower discount rates and explained that such analysis is consistent with longstanding White House guidance on intergenerational discounting.[130]

Table 9 below presents a broad range of social cost of greenhouse gases estimates for both BOEM's own runs (the reference case presented above in Table 4) and for our Illustrative Run 1 analysis under a decarbonization pathway (results presented above in Table 5). Once again, results are presented under mid-level activity for the Gulf of Mexico region. For each model run, we monetize climate damages (from all sources—domestic lifecycle and foreign combustion) using the social cost of greenhouse gases at three of the four Working Group valuations plus valuations at 2% and 1% discount rates. [131] Results from this table are identical to outputs shown in Tables 4 and 5, but are pulled out here for contextualization.

Table 9: Climate-Damage Valuations Under Reference Case and Illustrative Run 1

	Reference Case (BOEM's policy-as-usual run)	Illustrative Run 1 (Decarbonization)
3% discount rate (Working Group)	$12 billion	$38 billion
2.5% discount rate (Working Group)	$17 billion	$53 billion
2% discount rate (N.Y. DEC)	$28 billion	$85 billion
1% discount rate (N.Y. DEC)	$86 billion	$247 billion
3% discount rate, 95th percentile damages (Working Group)	$38 billion	$116 billion

[128] IWG, 2021 TSD, *supra* note 113, at 16–21 (surveying literature offering support for discount rates in this range).

[129] N.Y. Dep't of Env't Conservation, *Establishing a Value of Carbon: Guidelines for Use by State Agencies* 16–18 (2020), https://www.dec.ny.gov/docs/administration_pdf/vocfguid.pdf. Pursuant to DEC's estimates, at a discount rate of 2%, social cost valuations for year 2020 emissions equal $125 per ton of carbon dioxide, $2,782 per ton of methane, and $44,727 per ton of nitrous oxide. *Id.* at 3. *See also* N.Y. Dep't of Env't Conservation & Res. for the Future, *Estimating the Value of Carbon: Two Approaches* (2020) (explaining considerations and methodology).

[130] IWG, 2021 TSD, *supra* note 113, at 4 ("Consistent with the guidance in E.O. 13990 for the IWG to ensure that the SC-GHG reflect the interests of future generations, the latest scientific and economic understanding of discount rates discussed in this TSD, and the recommendation from OMB's Circular A-4 to include sensitivity analysis with lower discount rates when a rule has important intergenerational benefits or costs, agencies may consider conducting additional sensitivity analysis using discount rates below 2.5 percent."); *see also* Circular A-4, *supra* note 36, at 35–36 (recommending lower discount rates, potentially "rang[ing] from 1 to 3 percent per annum" to evaluate policies with "important intergenerational benefits or costs"). Because climate impacts occur over a far longer time horizon than the other effects of the proposed program, there is no conflict between discounting climate damages below 3% while discounting other program impacts at a 3% rate. *See* Nat'l Acads. Scis., Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 182 (2017) [hereinafter "NAS 2017"] (recognizing that some differences in the application of discount rates may be warranted "when only some categories [of costs and benefits] have an intergenerational component").

[131] Due to the lack of support for a 5% discount rate in the economics literature, we do not include that rate in this table. Climate-damage valuations using this estimate total $4 billion for the Reference Case and $13 billion for Illustrative Run 1.

As Table 9 demonstrates, climate-damage valuations can increase substantially when we use alternative valuations beyond the 3% valuation that BOEM applies. Under the reference case, the $12 billion damage valuation that BOEM applies increases to $17–86 billion when considering additional damage valuations using lower discount rates. Under Illustrative Run 1, the $38 billion damage valuation identified using the climate-damage valuation that BOEM applies increases to $53–247 billion when considering additional damage valuations using lower discount rates.

For the sake of comparison, BOEM finds that incremental net economic value under mid-level activity from the Gulf of Mexico program region totals $46.95 billion.[132] Accordingly, as Table 9 illustrates, total climate damages alone could approach or even exceed net economic value if BOEM accounts for all emissions and applies a wider range of climate-damage estimates. This effect would be even more pronounced if BOEM were to analyze decarbonization pathways and not rely exclusively on the current-policy baseline.

In a recent paper in Nature, a team of experts concluded that the 2% discount rate was the most suitable rate for the social cost of greenhouse gases.[133] Using that discount rate here under the two model runs highlighted above finds that the proposed program would produce climate damages of $28–85 billion from the Gulf of Mexico program region under mid-level activity. This result alone provides strong evidence that the costs of OCS leasing may exceed the benefits, as the $46.95 billion in net economic value that BOEM finds for that region[134] falls within the middle of the range. And of course, climate damages are just one cost from OCS leasing, and do not include costs resulting from oil spills, harms to biodiversity and wildlife, and other environmental and social harms from OCS leasing. Some of those other, non-climate harms are discussed in the following Parts of this report.

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[132] This figure is derived by adding the net economic value in both Gulf of Mexico program areas under the leasing scenario, as reported in Proposed Program, *supra* note 2, at 5-33 tbl.5-6 and then subtracting the net economic value from substitute sources in both Gulf of Mexico program areas under the no-leasing scenario, as reported in *id.* at 5-42 tbl.5-11. Under a decarbonization pathway, BOEM's calculations of net economic value from OCS leasing would also change, meaning that this $46.95 value is not directly comparable to the climate-damage valuations under Illustrative Run 1. However, it is not entirely clear whether the cost of oil would increase or decrease under a future decarbonization pathway, as both supply and demand would shift in. Therefore, it is unlikely that net economic value would change by nearly the same degree as climate cost under a decarbonization pathway.

Furthermore, if BOEM applies lower discount rates to estimate climate damages, it may also wish to consider applying lower discount rates to assess economic value, which would increase the agency's assessment of net economic value. However, because climate damages occur over longer time horizons than the economic benefits of OCS leasing, lower discount rates are more warranted for climate damages relative to economic benefits. *See supra* note 130.

[133] Rennert et al., *supra* note 123. Note that these authors also updated the damage functions, resulting in an even higher social cost of carbon valuation of $185 per metric ton.

[134] *See supra* note 132 for a description of this calculation.

III. BOEM's Economic Analysis Improperly Disregards the Costs of Catastrophic Oil Spills, and Its Analysis of Those Oil Spills Understates Their Risk

Although some of BOEM's supporting documentation considers oil spill risk,[135] BOEM entirely omits the risk of catastrophic oil spills resulting from OCS leasing from its net benefits analysis.[136] This omission is not consistent with best practices for cost-benefit analysis, and the agency's rationales for disregarding catastrophic oil spills are inconsistent and disregard countervailing evidence. At the same time, as detailed further below, BOEM's calculations of catastrophic oil spill risk in its supporting documentation likely understate these risks, perhaps substantially so.

A. BOEM Should Incorporate Catastrophic Oil Spills into Its Net Benefits Analysis

BOEM's draft economic analysis methodology includes a section where it estimates the risk and severity of catastrophic oil spills.[137] Those estimates are considerable, yet BOEM omits them from its net benefits analysis.

BOEM's Oil-Spill Probability Estimates Are Substantial

BOEM's oil-spill probability estimates are substantial. For instance, BOEM estimates a 5.7% chance of an oil spill of magnitude above 150,000 barrels in the Gulf of Mexico program area 1 from leasing under the proposed program at mid-level activity.[138] It projects an approximately 2% chance of an oil spill above 10 million barrels from the same region under mid-level activity[139]—an oil spill that would be approximately 2.5 times larger than the Deepwater Horizon disaster.[140] BOEM projects that such an oil spill in the Gulf of Mexico would likely cost between $69.8–85.4 billion in market costs alone—not accounting for the risk to wildlife and biodiversity.[141] Just looking at the figures that BOEM provides, it is clear that potential oil-spill costs can be substantial.

BOEM presents the risk of an oil spill region-by-region, under mid-level activity, and only for this single proposed program. The risk of a catastrophic oil spills appears even higher when analyzing joint and cumulative probabilities. Specifi-

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[135] Economic Analysis Methodology, *supra* note 37, at 3-1 to -16; Draft EIS, *supra* note 82, at 267–73, G-1 to -3.

[136] Proposed Program, *supra* note 2, at 5-26 ("The [Offshore Environmental Cost Model] is also not designed to represent impacts from catastrophic oil spill events. The OECM only considers a range of oil spills up to 100,000 barrels.").

[137] Economic Analysis Methodology, *supra* note 37, at 3-1 to -16.

[138] *Id.* at 3-8 tbl.3.

[139] *Id.*

[140] *See* Env't Prot. Agency, Deepwater Horizon – BP Gulf of Mexico Oil Spill, https://www.epa.gov/enforcement/deepwater-horizon-bp-gulf-mexico-oil-spill#:~:text=4%20million%20barrels%20of%20oil,be%20responsible%20for%20the%20spill (reporting spill size of approximately 4 million barrels).

[141] Economic Analysis Methodology, *supra* note 37, at 3-11 tbl.6. BOEM calculates oil-spill costs through "the value of the resources used or destroyed as a result of the spill, as well as the response (e.g. cleanup) expenses." *Id.* at 3-8. As discussed further below, this does not include non-market costs such as harms to biodiversity and wildlife.

cally, the report authors derived several additional sets of probability estimates using the numbers that BOEM provides. While BOEM presents its estimates region-by-region, we calculated the joint probability of having a catastrophic oil spill in any OCS region from the proposed leasing plan by multiplying the regional probabilities of not having an oil spill over five years across all the regions.[142]

Using this spill-risk data, we then calculated two additional probabilities of interest. First, we calculated the joint probability of having an oil spill over multiple five-year leasing plans (i.e., the cumulative probability).[143] Second, while BOEM presents catastrophic spill-risk figures only under mid-level activity, we approximated the probability of a catastrophic spill under high activity.[144] Results are presented in the two tables below. While these calculations are derived using BOEM's own risk estimates, as discussed below, there are reasons to believe that BOEM underestimates the risk of oil spills, and so these figures should be regarded as low-end estimates.[145]

Table 10: Risk of Catastrophic Oil Spills from All Program Areas Under Mid Activity

Spill Size Volume (Barrels)	150,000	500,000	1,000,000	2,000,000	5,000,000	10,000,000
Probability of spill from this leasing plan	15%	12%	10%	8%	7%	6%
Probability over two plans	28%	22%	19%	16%	13%	11%
Probability over three plans	39%	31%	27%	23%	19%	16%
Probability over four plans	48%	39%	34%	30%	25%	21%
Probability over five plans	56%	46%	41%	36%	30%	26%
Probability over six plans	63%	52%a	46%	41%	35%	30%

[142] This analysis involves three steps: 1) calculate the probability of not having a spill of a given size in each region by subtracting the corresponding probability of having a spill from one; 2) multiply the regional probabilities of not having an oil spill over five years across all the regions open for leasing in the next five-year plan; 3) subtracting the product from the prior step from one.

[143] For this calculation, we used the same methodology as described in the prior footnote, with a slight modification. This time, in the second step, we took the joint probability of not having an oil spill over the current five-year plan to the power of X, with X representing the number of total leasing plans considered.

[144] To calculate the probability of a spill under high activity, we take the ratio of barrels of oil equivalents produced in each OCS region under high activity relative to mid-level activity. Then, before step one in the methodology described in *supra* note 142, we multiply the regional probability of a particular spill size for the five-year plan under mid-level activity by this ratio assuming that the probability of an oil spill increases within a region linearly with the amount of production.

[145] *See infra* notes 194–196 and accompanying text.

Table 11: Risk of Catastrophic Oil Spills from All Program Areas Under High Activity

Spill Size Volume (Barrels)	150,000	500,000	1,000,000	2,000,000	5,000,000	10,000,000
Probability of spill from this leasing plan	27%	21%	18%	15%	12%	11%
Probability over two plans	47%	37%	33%	28%	23%	20%
Probability over three plans	61%	50%	45%	39%	33%	28%
Probability over four plans	72%	61%	55%	49%	41%	36%
Probability over five plans	79%	69%	63%	56%	48%	43%
Probability over six plans	85%	75%	69%	63%	55%	49%

As these tables illustrate, the risk of an oil spill is even higher than BOEM presents if high-level activity is considered, or if BOEM considers the risk over multiple leasing plans. For instance, the risk of an oil spill above 150,000 barrels from all program areas under high-level activity stands at 27%, and there is an 11% chance of an oil spill above 10-million barrels from all program areas under high-level activity. Because a 10 million-barrel spill would carry a cost of between $69–$356 billion, according to BOEM,[146] this suggests an average cost between roughly $7–$39 billion from such an oil spill over all program areas from this single plan. When multiple leasing plans are considered, those probability estimates, and hence the potential costs, jump considerably.

Omitting Catastrophic Spills from the Net Benefits Analysis Is Inconsistent with Best Practices

Despite these substantial cost estimates, BOEM omits catastrophic oil spills from its net benefits analysis, claiming that oil-spill costs are "far less certain than other components of the net benefits analysis."[147] But omitting catastrophic oil spills from the net benefits analysis is inconsistent with economic best practices and biases the analysis.

Circular A-4, the Office of Management and Budget's longstanding guidance document on conducting cost-benefit analysis, provides well-accepted practices for "good regulatory analysis" that are used throughout the executive branch.[148] That document does not instruct regulators to disregard uncertain impacts. On the contrary, it offers detailed guidance on how regulators can incorporate uncertain impacts into a monetized cost-benefit analysis, explaining that "important uncertainties connected with your regulatory decisions need to be analyzed and presented as part of the overall regulatory analysis."[149] In particular, it explains that regulators should "combine [estimated] probability distributions to provide estimated benefits and costs" of uncertain impacts and should generally use "the average or the expected value of [those] benefits and costs" in their central analysis, with sensitivity analysis around other possibilities.[150]

In light of this guidance, BOEM's claim that catastrophic oil spills are too uncertain to incorporate is highly questionable, particularly since, as discussed above, the risks of such a spill are hardly negligible. Moreover, when it comes to the

[146] Economic Analysis Methodology, *supra* note 37, at 3-11 tbl.6. As explained in this report, these figures are likely underestimates. *See infra* notes 177–193 and accompanying text.

[147] *Id.* at 3-1; *accord* Proposed Program, *supra* note 2, at 5-26 ("The lack of robust data and the unpredictable nature of catastrophic oil spills, including the many factors that determine their severity, make efforts to quantify their costs much more uncertain than those to quantify other measures considered in the net benefits analysis.").

[148] Circular A-4, *supra* note 36, at 1.

[149] *Id.* at 38; *see also id.* at 38–42 (discussing the treatment of uncertainty in regulatory impact analysis).

[150] *Id.* at 42.

economic benefits of OCS leasing, BOEM does not take the same approach to uncertainty as it does with catastrophic oil spills. Much like those oil spills, "[e]nergy market projections are uncertain because we cannot foresee with certainty many of the events that shape energy markets—as well as future developments in technologies, demographics, and resources."[151] For instance, in the proposed program, BOEM uses multiple resource price estimates[152] and incorporates a wide range of resulting economic-benefit projections into its net benefits analysis.[153] In fact, BOEM's economic-benefit estimates under the high-price scenario are roughly 500 times higher than its economic-benefit estimates under the low-price scenario.[154] As BOEM's economic value analysis demonstrates, it is possible to incorporate highly uncertain estimates into a cost-benefit analysis. The wide uncertainty in these estimates also casts doubt on the agency's claim that catastrophic oil spills are "far less certain than other components of the net benefits analysis."[155]

BOEM should therefore incorporate catastrophic oil spills into its net economic benefits analysis. While there is a range of plausible estimates of the damage from catastrophic oil spills, the proper estimate is "certainly not zero."[156]

B. BOEM's Omission of Catastrophic Oil Spills from Its Net Benefits Analysis Is Inconsistent and Its Rationales Ignore Countervailing Considerations

As explained in the prior subsection, BOEM should include catastrophic oil spills in its net benefits analysis just like it includes other uncertain impacts such as the economic benefits of OCS leasing. BOEM considering certain major oil spills when assessing the potential costs of substitutes to OCS leasing (which are in essence benefits of OCS leasing) makes its failure to include similar oil spills when assessing the costs of OCS leasing even more problematic. Moreover, as detailed below, BOEM's justification that oil spills are becoming less frequent over time ignores evidence that oil spills are also becoming larger over time and that attempts at improving well safety have been largely ineffective.[157]

BOEM Considers Catastrophic Spill Risk from the No-Leasing Option, but Not OCS Leasing

First, while BOEM disregards the risk of oil spills over 100,000 barrels from wells when calculating the costs of OCS leasing,[158] its net benefits analysis includes catastrophic spill risk from tankers for calculating the costs of substitutes for OCS leasing. In particular, BOEM explains that the environmental and social costs of the No Sale option "include impacts from increased tankering"[159] and provides a methodology for calculating the "cost estimates for a catastrophic tanker oil spill."[160] Accordingly, BOEM models the risk of oil spill differently by source, as it assigns no value to well spills

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[151] AEO 2022, *supra* note 10, at 2.

[152] Proposed Program, *supra* note 2, at 5-30 tbl.5-5 (using price range of $40–$160 per barrel of oil).

[153] *Id.* at 5-33 tbl.5-6 (showing a range of $730 million to $359 billion in net economic value for Gulf of Mexico program area 1, with similarly disparate ranges for other program areas).

[154] *Id.* (359.86 divided by 0.73 equals approximately 493).

[155] Economic Analysis Methodology, *supra* note 37, at 3-1.

[156] Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1200 (9th Cir. 2008) (rejecting an agency vehicle fuel-efficiency rule as arbitrary and capricious when the agency relied on an otherwise quantified cost-benefit analysis but claimed that the rule's significant climate impacts were too uncertain to quantify in that analysis).

[157] *See infra* notes 167–176 and accompanying text.

[158] Proposed Program, *supra* note 2, at 5-26.

[159] *Id.* at 5-43.

[160] Economic Analysis Methodology, *supra* note 37, at 3-16. BOEM does not state that catastrophic oil spills are omitted from the net benefits analysis of the no-leasing scenario, in contrast to its treatment of catastrophic oil spills from the leasing scenario.

above 100,000 barrels[161] while modeling tanker spill risk at a mean and median spill size of 250,000 barrels.[162] BOEM does not provide an explanation for modeling larger tanker spills than well spills in its net benefits analysis, which is particularly problematic given that its own analysis in the Draft Economic Analysis Methodology finds that there is a sizeable risk of catastrophic well oil spills.[163]

BOEM's inconsistent treatment of catastrophic spill risk for different sources is not only unexplained, but it also tilts the analysis in favor of the no-leasing option because catastrophic spill risk from wells (which are not modeled) results from OCS leasing whereas catastrophic spill risk from tankers (which are) comes from substitutes to OCS leasing and thus are effectively a benefit of OCS leasing.[164] Accordingly, this produces the counter-intuitive conclusion that catastrophic oil spill risk—which is actually a substantial cost of OCS leasing—is counted as a benefit of the proposed program. Moreover, the fact that BOEM models catastrophic tanker oil spill risk—which presumably features many of the same uncertainties as catastrophic well oil spill risk—casts further doubt on BOEM's omission of catastrophic well spills from its net benefits analysis.[165]

Furthermore, BOEM does not model the variation of oil spill risk from tankers by geographic variation or time. This is despite noting that "tankers tend to have more accidents close to shore, where the impacts are generally more severe."[166] This is critical, as domestic shipping of oil by tanker is to likely create more risk of oil spills, particularly to the United States, than international ships as domestic tankers must navigate significantly more coastline relative to international trips into U.S. waters. At a minimum, BOEM should model the differing risk between domestic and international oil tankers, particularly given that the largest U.S. oil spill was a domestic tanker (Exxon Valdez).

BOEM's Overlooks Evidence of Increasing Spill Costs

Second, while BOEM continually touts efforts "to both reduce the likelihood of such an event and mitigate the prospect of a well control event developing into a catastrophic spill[167]"—which it offers as evidence that its spill-damage costs represent an upper bound— it does not recognize other evidence indicating that the costs of a potential oil spill could be growing.

In particular, a recent economic paper concludes that the cost of oil spills has been increasing over time.[168] As the authors of that peer-reviewed study explain, oil spills have become progressively more costly in real terms with each passing decade: oil spills in the 1980s were $191 million higher than those in the 1960s–70s, spills in the 1990s were $255 million higher than those in the 1980s, and oil spills in the 2000s were even more costly (all values were adjusted for inflation to 2010$).[169] The authors conclude that that "[t]his increasing time trend highlights the fact that although the number of

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[161] Proposed Program, *supra* note 2, at 5-26; *see also* Bureau of Ocean Energy Mgmt., Forecasting Environmental and Social Externalities Associated with Outer Continental Shelf (OCS) Oil and Gas Development, Volume 1: 2018 Revised Offshore Environmental Cost Model (OECM) D-4 tbl.D-1 (2018), https://espis.boem.gov/final%20reports/BOEM_2018-066.pdf [hereinafter "OECM 2018"] (specifying 100,000 barrels as largest spill size for OCS platforms and wells).

[162] OECM 2018, *supra* note 161, at D-7 tbl.D-4.

[163] *See supra* notes 138–145 and accompanying text.

[164] *See* Proposed Program, *supra* note 2, at 5-43; Economic Analysis Methodology, *supra* note 37, at 3-15 to -16.

[165] *See supra* Part III.A; *see also* Proposed Program, *supra* note 2, at 5-26 ("The lack of robust data and the unpredictable nature of catastrophic oil spills, including the many factors that determine their severity, make efforts to quantify their costs much more uncertain than those to quantify other measures considered in the net benefits analysis.").

[166] Economic Analysis Methodology, *supra* note 37, at 3-15.

[167] *Id.* at 3-2; *accord id.* at 3-1 ("Robust regulatory programs at BSEE and BOEM, along with improved industry practices since *Deepwater Horizon,* have reduced the likelihood of the occurrence of an event of similar magnitude."); *id.* at 3-5 ("Significant Federal Government and industry efforts continue to reduce the likelihood of an OCS catastrophic oil spill and reduce the duration of a spill should one occur.").

[168] Maria Allo & Maria L. Loureiro, *Estimating a Meta-Damage Regression Model for Large Accidental Oil Spills*, 86 Ecol. Econ. 167 (2013).

[169] *Id.* at 171.

incidents is decreasing, those that do occur are much larger and important in terms of size and corresponding damage."[170] While the study authors do not theorize as to the reason for this increase, numerous factors may be responsible including recent increases in oil tanker size, drilling depth,[171] and the scarcity of environmental services.[172]

Additionally, while BOEM highlights various efforts by Interior's Bureau of Safety and Environmental Enforcement (BSEE) "to reduce potential risk in offshore energy exploration and development,"[173] it overlooks several Government Accountability Office (GAO) reports finding that those efforts have been insufficient and often ineffective.[174] For instance, one of those reports highlighted BSEE's "outdated policies and procedures" for maintaining safety standards that may "undermin[e] the effectiveness of investigations."[175] In a recent decision, the D.C. Circuit faulted BOEM for disregarding these GAO reports when similarly touting BSEE's efforts to reduce oil-spill risk.[176]

While BOEM highlights efforts that may reduce the risk and severity of a catastrophic oil spill, it should also recognize evidence that the cost of oil spills is increasing, and that certain efforts to decrease oil-spill risk have been ineffective. Such evidence also provides a further basis for BOEM to incorporate catastrophic oil spills into its net benefits analysis, as it suggests that the costs of those spills can be severe.

C. BOEM Should Reconsider Its Methodologies for Calculating Oil-Spill Cost and Risk, Which Likely Produce Underestimates

BOEM's estimates of catastrophic oil-spill costs in its draft economic analysis methodology (which it omits from its net benefits analysis) also overlook several key considerations. For instance, BOEM's replacement-cost methodology severely undervalues the costs of oil spills that do occur by omitting non-market harms such as impacts to wildlife and human health. Additionally, for several reasons discussed below, BOEM's methodology also likely underrepresents the likelihood of a catastrophic oil spill occurring in the first place. For these reasons, BOEM's analysis very likely underestimates the environmental and social costs of oil spills, and the agency should reconsider it.

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[170] *Id.*

[171] *See* Lucija Muehlenbachs et al., *The Impact of Water Depth on Safety and Environmental Performance in Offshore Oil and Gas Production*, 55 Energy Pol'y 699 (2013) ("[F]or an average platform, each 100 feet of added depth increases the probability of a company-reported incident by 8.5%.").

[172] *See* Thomas Sterner & U. Martin Persson, *An Even Sterner Review: Introducing Relative Prices into the Discounting Debate*, 2 Rev. Env't Econ. & Pol'y 61 (2008) (explaining "that future scarcities caused by the changing composition of the economy and climate change should lead to rising relative prices for certain goods and services").

[173] Economic Analysis Methodology, *supra* note 37, at 3-3; *see also id.* at 3-3 to -6 (describing various programs).

[174] U.S. Gov't Accountability Off., *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others* (GAO-17-317) (2017) [hereinafter "GAO, Substantial Efforts Needed"], https://www.gao.gov/assets/gao-17-317.pdf; U.S. Gov't Accountability Off., *Oil and Gas Management: Stronger Leadership Commitment Needed at Interior to Improve Offshore Oversight and Internal Management* (GAO-17-293) (2017), https://www.gao.gov/assets/gao-17-293.pdf; U.S. Gov't Accountability Off., *Oil and Gas Management: Interior's Bureau of Safety and Environmental Enforcement Restructuring Has Not Addressed Long-Standing Oversight Deficiencies* (GAO-16-245) (2016), https://www.gao.gov/assets/gao-16-245.pdf.

[175] GAO, Substantial Efforts Needed, *supra* note 174, at 137.

[176] Gulf Restoration Network v. Haaland, No. 20-5179, 2022 WL 3722429, at *5–6 (D.C. Cir. Aug. 30, 2022) ("BOEM sidestepped the GAO report and offered only unelaborated statements that BSEE's enforcement was 'rigorous.' In the circumstances here, that was not good enough.").

BOEM's Replacement-Cost Methodology Does Not Account for Other Monetizable Costs

Perhaps most notably, BOEM undervalues the harm from oil spills by accounting only for "the value of the resources used or destroyed as a result of the spill, as well as the response (e.g., cleanup) expenses."[177] By measuring only resource loss and cleanup costs, BOEM ignores "the values above the restoration cost at which society could value the damaged resource,"[178] including non-market harms such as irreversible damages to the marine ecosystem, biodiversity, and endangered species. Additionally, BOEM's methodology disregards harms to human life[179] and health[180] resulting from well-control events and resulting oil spills, along with the temporary suffering and opportunity cost that results from the time it takes to replace damaged resources.

While BOEM briefly recognizes that its analysis omits some of these impacts,[181] it fails to recognize the body of research on society's willingness to pay to avoid such harms. In particular, well-established economic techniques are available that capture value both "from the use of an environmental resource (use values), including both commercial and noncommercial uses, or from its existence even in the absence of use (nonuse value)."[182] As the National Research Council has explained, "if policymakers consider trade-offs and benefits and costs when making policy decisions, then quantification of the value of ecosystem services is essential. Failure to include some measure of the value of ecosystem services in benefit-cost calculations will implicitly assign them a value of zero."[183]

To incorporate non-market values into its economic analysis of oil spills, BOEM can look to existing research on the topic. For example, a 1992 study on the Exxon Valdez oil spill "revealed that many Americans who have not visited Alaska and never intend to do so nevertheless place high values on maintaining the [state's] pristine and unique but fragile coastal and aquatic ecosystems."[184] This study found that the total value to the U.S. population to prevent a spill like Exxon Valdez was around $5.38 billion[185] (roughly $10.5 billion in present value). Likewise, a more recent study found that the total value to the U.S. population to prevent a spill like Exxon Valdez was around $10.87 billion.[186] Additionally, a wide range of studies have evaluated the costs of the Deepwater Horizon oil spill, focusing on economic harms overall[187]

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[177] Economic Analysis Methodology, *supra* note 37, at 3-8.

[178] *Id.* at 2-5.

[179] For instance, 11 workers died from the Deepwater Horizon explosion.

[180] *See, e.g.*, Louis-Philippe Beland & Sara Oloomi, *Environmental Disaster, Pollution and Infant Health: Evidence from the Deepwater Horizon Oil Spill*, 98 J. Env't Econ. & Mgmt. 1 (2019) ("[T]he oil spill of 2010 increased concentrations of PM2.5, NO2, SO2, and CO in affected coastal counties, increased incidence of low birth weight (<2500 g) and premature born infants (<37 weeks of gestation). Heterogeneity effects reveal more pronounced adverse infant health outcomes for black, Hispanic, less educated, unmarried, and younger mothers."); Tim Slack et al., *Deepwater Horizon Oil Spill Exposure and Child Health: A Longitudinal Analysis*, 42 Population & Env't 477 (2021) (detailing negative impacts of Deepwater Horizon oil spill on children's health).

[181] *Id.*

[182] National Research Council, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* (2005), https://nap.nationalacademies.org/download/11139#.

[183] *Id.*

[184] *Id.* at 47.

[185] Robert T. Carson et al., *A Contingent Valuation Study of Lost Passive Use Values Resulting From the Exxon Valdez Oil Spill. Report to the Attorney General of the State of Alaska*, A Report to the Attorney General of the State of Alaska (1992), https://mpra.ub.uni-muenchen.de/6984/1/MPRA_paper_6984.pdf.

[186] Robert T. Carson et al., *Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spills*, 25 Env't & Res. Econs. 257 (2003).

[187] *E.g.* Yong Gyo Lee et al., *Ultimate Costs of the Disaster: Seven Years After the Deepwater Horizon Oil Spill*, 29 J. Corp. Accounting & Fin. 69 (2018) ("This study documents an ultimate cost to BP of $144.89 billion in the United States."); Yong Gyo Lee & Xavier Garza-Gomez, *Total Cost of the 2010 Deepwater Horizon Oil Spill Reflected in US Stock Market*, 12 J. Accounting & Fin. 73 (reporting at least $251.9 billion in total cost from the Deepwater Horizon oil spill).

as well as specific costs to local fisheries,[188] human health[189] and mental health,[190] local housing values,[191] recreation,[192] and travel.[193] These studies could assist BOEM in estimating the non-use value of avoiding a catastrophic oil spill, which the agency's analysis currently omits.

BOEM's Analysis Likely Underestimates Catastrophic Oil Spill Risk

BOEM's analysis likely undervalues catastrophic oil-spill damage for several additional reasons. For one, while BOEM uses wells drilled from 1964–2017 to estimate the probability of an oil spill,[194] this approach underestimates the probability of an oil spill because it does not account for the full lifespan of more recently drilled wells that remain active. As BOEM explains in this proposed program, once "production begins" on a well, "it can continue for several decades"[195]—meaning that it also remains vulnerable to an oil spill for several decades. Accordingly, wells produced in the last several decades that are part of BOEM's dataset remain susceptible to oil spills, and so counting those wells for the purposes of probability calculations as non-spilled wells skews the analysis. Accordingly, the analysis could suffer from a significant underrepresentation of the probability of an oil spill, and BOEM should reevaluate its methodology to account for the possibility that existing wells could be subject to an oil spill in the future.

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[188] Christa Court et al., *Effects of the Deepwater Horizon Oil Spill on Human Communities: Catch and Economic Impacts*, in Deep Oil Spills (Steven A. Murawski et al., eds., 2020) ("[T]he economic impacts for the period 2010–2020 of foregone commercial fishing revenues and recreational fishing expenditures as a result of the *Deepwater Horizon* oil spill are a loss of over 25,000 jobs, $2.3 billion in industry output, $1.2 billion in total value added or gross regional product, $700 million in labor income, $160 million in state and local tax revenues, and $160 million in federal tax revenues."); U. Rashid Sumalia et al., *Impact of the Deepwater Horizon Well Blowout on the Economics of US Gulf Fisheries*, 69 Can. J. of Fisheries & Aquatic Scis. 499 (2012) (finding that the Deepwater Horizon spill could result in total economic losses of $8.7 billion); Ashley McCrea-Strub et al., *Potential Impact of the Deepwater Horizon Oil Spill on Commercial Fisheries in the Gulf of Mexico*, 36 Fisheries 332 (2011).

[189] *See supra* note 129.

[190] Stacy Buckingham-Howes et al., *Prolonged Financial Distress After the Deepwater Horizon Oil Spill Predicts Behavioral Health*, 46 J. Behavioral Health Servs. & Rsch. 294 (2019) (finding elevated levels of drug use, alcohol use, mood problems, and depressive symptoms among those financially affected by the Deepwater Horizon oil spill); Rajeev Ramchand et al., *Exposure to the Deepwater Horizon Oil Spill, Associated Resource Loss, and Long-Term Mental and Behavioral Outcomes*, 13 Disaster Med. & Pub. Health Preparedness 889 (2019) (finding higher rates of depression and anxiety among those affected by oil spill).

[191] Javier Cano-Urbina et al., *The Effects of the BP Deepwater Horizon Oil Spill on Housing Markets*, 43 J. Housing Econ. 131 (2019) ("[T]he BP oil spill caused a significant decline in home prices of between 4% and 8% that persisted until at least 2015. This implies housing markets capitalized $3.8 billion to $5.0 billion in spill damage inclusive of clean-up and restitution effects.").

[192] Sergio Alvarez et al., *A Revealed Preference Approach to Valuing Non-Market Recreational Fishing Losses from the Deepwater Horizon Oil Spill*, 145 J. Env't Mgmt. 199 (2014) (estimating $585 million in losses to anglers from Deepwater Horizon); Eric English et al., *Estimating the Value of Lost Recreation Days from the Deepwater Horizon Oil Spill*, 91 J. Env't Econ. & Mgmt. 26 (2018) (estimating $520 million in lost recreation).

[193] John C. Whitehead et al., *Estimating Lost Recreational Use Values of Visitors to Northwest Florida Due to the Deepwater Horizon Oil Spill Using Cancelled Trip Data*, 33 Marine Res. Econ. 119 (2018) (finding $207 million in such damages); Eric English et al., *Lost Use-Value from Environmental Injury When Visitation Drops at Undamaged Sites*, 95 Land Econ. 152 (2019).

[194] Economic Analysis Methodology, *supra* note 37, at 3-7.

[195] Proposed Program, *supra* note 2, at 5-5.

Additionally, while BOEM uses regression analysis to calculate the probability of different sizes of oil spills,[196] it uses a mean regression analysis that is suboptimal for a distribution, like this one, with a long tail on one side.[197] Mean regression analysis in this case is suboptimal because, in such circumstances, the median regression produces unbiased estimates of the standard errors and is asymptotically efficient. Accordingly, BOEM should use a median regression rather than a mean regression. The report authors have conducted a median regression using BOEM's data, and find that doing so increases the probability of a catastrophic oil spill—thus supplying one additional reason that BOEM understates catastrophic oil spill risk. Further details are provided in the technical appendix.[198]

[196] Economic Analysis Methodology, *supra* note 37, at 3-14.

[197] *See* Carolina Bancayrin-Baguio, *Performance of Median and Least Squares Regression for Slightly Skewed Data*, World Acad. Sci., Eng't & Tech. 226 (2009) (because the probability of an oil spill conditional on the size of the spill is skewed, OLS produces biased standard errors and is less efficient).

[198] *See* App'x B.

IV. BOEM Neglects Key Environmental and Social Cost Uncertainties While Biasing Its Analysis of Price Uncertainty in a Manner to Support OCS Leasing

In Chapter 9 of its proposed program, BOEM assesses whether leasing each OCS region would assure fair market value. As part of this analysis, BOEM assesses "the value of waiting to lease" each OCS region, which is known in economics as "option value," to assess "whether each program area would provide greater value if leasing it is included in the 2023–2028 Program or delayed."[199] BOEM assesses the option value of most uncertainties purely qualitatively, including uncertainties around key environmental and social costs.[200] However, BOEM considers price uncertainty qualitatively through its analysis of hurdle prices.[201]

Option value is the informational value of delaying irreversible decisions, such as when and on what terms to sell nonrenewable resources to private companies.[202] BOEM holds, on behalf of the American public, a perpetual option to develop or lease its fossil-fuel resources. When the government sells the right to develop a tract to a private lessee, it extinguishes the perpetual option that it holds on behalf of the American people, and sells a time-limited option to a private actor, valid for the duration of the lease. Consideration of option value requires that BOEM determine when and where exercising its perpetual options would be most socially opportune, including by accounting for environmental, social, and economic impacts.[203] The value associated with the option to delay can be large, especially when there is a high degree of uncertainty about price, extraction costs, and the social and environmental costs imposed by drilling. Indeed, the D.C. Circuit has recognized the "tangible present economic benefit to delaying the decision to drill for fossil fuels to preserve the opportunity to see what new technologies develop and what new information comes to light."[204]

Yet BOEM's analysis largely sidesteps major environmental and social uncertainties, and BOEM should improve its analyses of environmental and social cost uncertainty and hurdle prices. For environmental and social cost uncertainty, BOEM should more carefully consider established methodologies to assess these uncertainties quantitatively and incorporate those costs directly into its net benefits analysis. With respect to its hurdle price analysis, BOEM should correct fundamental errors in its analysis that misconstrue the purpose of hurdle price analysis and, as a result, bias the analysis in favor of OCS leasing. Furthermore, as explained at the top of this section, BOEM should carefully analyze relevant uncertainties at the programmatic stage and, in doing so, should account for the large quantity of currently nonproducing OCS leases that makes delay more attractive.

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[199] Proposed Program, *supra* note 2, at 9-1.
[200] *Id.* at 9-5 to -13.
[201] *Id.* at 9-14 to -17.
[202] Michael A. Livermore, *Patience Is an Economic Virtue: Real Options, Natural Resources, and Offshore Oil*, 84 U. Colo. L. Rev. 581, 585, 589 (2013).
[203] *Id.*
[204] *Ctr. for Sustainable Econ.*, 779 F.3d at 610.

A. BOEM Should Carefully Analyze Relevant Uncertainties at the Programmatic Stage

At the start of its option value analysis, BOEM suggests that there may be limited value to considering uncertainties at the programmatic stage due to the "pyramidal structure of the National OCS Program development and lease sale processes," through which Interior has broad "flexibility to cancel a lease sale" that is included in the five-year program.[205] While this observation has some merit, there are several key caveats that underscore the need for BOEM to carefully consider option value at the programmatic stage.

First, as a practical matter, BOEM's analyses of individual lease sales are typically less comprehensive than its analysis at the programmatic stage, as they lack a dedicated discussion of option value or any quantitative cost-benefit weighting. In the most recent lease sale for which BOEM published an environmental review—Lease Sale 258—the agency's draft environmental impact statement is about half the length of its draft environmental impact statement for the proposed program[206] and, unlike the proposed program here, does not contain any discussion of option value or provide a monetized cost-benefit analysis. Instead, individual lease sales often incorporate BOEM's analysis at the five-year planning stage without additional analysis of key programmatic concerns.[207] Because the programmatic stage has served as BOEM's venue for assessing option value, as a practical matter is important for BOEM to conduct this analysis robustly and to assess the potential for analytical improvements at the programmatic stage.

There may also be legal reasons for BOEM to consider option value robustly at the programmatic stage. For one, while BOEM is correct that it enjoys broad discretion to reconsider individual lease sales that are proposed in the five-year program,[208] a recent federal district court decision suggests that this discretion is not unlimited[209]—a legal conclusion that, if followed in future cases, would reinforce the need for BOEM to carefully weigh all relevant factors before including a lease sale in the proposed program. Moreover, the U.S. Court of Appeals for the D.C. Circuit has recognized the "tangible present economic benefit to delaying the decision to drill for fossil fuels to preserve the opportunity to see what new technologies develop and what new information comes to light," and explained that BOEM could act arbitrarily and capriciously if it fails to sufficiently assess option value at the programmatic stage.[210] The fact that this case was decided at the programmatic stage—and not in the context of a particular lease sale—further underscores the importance of robustly assessing option value for the proposed program rather than delaying the analysis to the leasing stage.

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[205] Proposed Program, *supra* note 2, at 9-5.

[206] *Compare* Draft Environmental Impact Statement, Cook Inlet Planning Area, Oil and Gas Lease Sale 258 (Oct. 2021) (265 pages including appendix) *with* Draft EIS, *supra* note 82 (503 pages between two volumes).

[207] *See, e.g.*, Gulf Restoration Network v. Haaland, No. 20-5179 (D.C. Cir. Aug. 30, 2022), slip op. at 7 (explaining that BOEM "considered the effect of allowing no new leasing in the Gulf and even in the entire Shelf" at the five-year planning stage and then "incorporated that analysis by reference" when assessing the environmental impacts of individual lease sales under that five-year plan).

[208] *See supra* note 205 and accompanying text; *see also CBD*, 563 F.3d at 483 (recognizing that Interior "may list areas [in its five-year plan] that [it] does not intend to lease"). Historically, Interior has frequently declined to hold lease sales that it previously included in its five-year plan. Congressional Research Service, Five Year Program for Offshore Oil and Gas Leasing: History and Program for 2017–2022, at 10 tbl.1 (Aug. 23, 2019), https://fas.org/sgp/crs/misc/R44504.pdf.

[209] Louisiana v. Biden, No. 2:21-cv-00778-TAD-KK, 2022 WL 3570933 (W.D. La. Aug. 18, 2022) (finding Biden administration's "pause" on federal oil and gas leasing unlawful in part because Interior "ha[s] no authority to make significant revisions in the OCSLA Five-Year Plan without going through the procedure mandated by Congress").

[210] *Ctr. for Sustainable Econ.*, 779 F.3d at 610.

B. BOEM Should Factor the Large Quantity of Undeveloped Leases into Its Option Value Analysis

In Part I of its proposed program, BOEM recognizes that most active OCS leases are nonproducing and explains that "the number of active, non-producing leases" is crucial to the agency's assessment of OCS resources needed "to meet national energy needs."[211] While the fact that only "[s]lightly more than one quarter of the 1,963 active leases in the [Gulf of Mexico] are currently in production[212] is certainly relevant to assessing "the size . . . of leasing activity . . . [that] will best meet national energy needs" over the next five years,[213] this fact also has implications for BOEM's option value analysis and suggests that the costs of delay are likely low and could very well be outweighed by the benefits of delay.

Fossil-fuel developers already have vast stocks of existing leases. In the OCS, producers currently hold more than 7.7 million acres of nonproducing leases—almost three times more than the 2.75 million acres of currently producing leases.[214] And according to the most recent statistics, developers are currently holding more than 12 million acres of nonproducing onshore leases.[215] Importantly, these huge numbers of nonproducing leases are largely not borne out of economic necessity, but rather a deliberate strategy on the part of fossil-fuel developers to increase private value at the potential expense of the public interest. In particular, companies often have a "perverse incentive … to sit on undeveloped federal land," because by having subsurface reserves as assets on a balance sheet, a company can "immediately improve its overall financial health, boost its attractiveness to shareholders and investors, and even increase its ability to borrow on favorable terms."[216] By stockpiling federal lands and waters, moreover, companies can wait until conditions are optimal from their own perspective (rather than society's).[217] In other words, these developers are considering option value by stockpiling leases.

Due in part to the large reserve of nonproducing leases, any new OCS leasing is not likely to result in additional development for many years.[218] If there remains a need for additional energy after fossil-fuel developers have gotten closer to exhausting their reserves, then Interior could engage in additional leasing at that time. But if other energy sources, including renewable sources, step in to meet national demand and limit the need for additional OCS leasing, then leasing

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[211] Proposed Program, *supra* note 2, at 7. BOEM also considers the number of non-producing leases in forecasting future OCS production. *Id.* at 1-15.

[212] *Id.* at 7.

[213] 43 U.S.C. § 1344(a).

[214] Combined Leasing Report as of Aug. 1, 2022 Bureau of Ocean Energy Mgmt., https://www.boem.gov/sites/default/files/documents/regions/pacific-ocs-region/oil-gas/Lease%20stats%208-1-22.pdf.

[215] These statistics are from the end of the fiscal year 2021. *Compare* Oil and Gas Statistics, Bureau of Land Mgmt. tbl. 2, https://www.blm.gov/programs-energy-andminerals-oil-and-gas-oil-and-gas-statistics, *with id*. tbl. 6.

[216] Ctr. for Am. Progress, *Oil and Gas Companies Gain by Stockpiling America's Federal Land* 3 (2018), https://www.americanprogress.org/issues/green/ reports/2018/08/29/455226/oil-gas-companies-gainstockpiling-americas-federal-land/; *see also* Taxpayers for Common Sense, *Gaming the System: How Federal Land Management in Nevada Fails Taxpayers* 4 (2019), https://www.taxpayer.net/wp-content/uploads/2019/07/TCS-Nevada-Federal-Oil-Gas-Report_-July-2019.pdf ("Certain companies and interests take advantage of the low acquisition and ownership costs for federal leases to amass sizeable lease holdings . . . . Their aim is to profit by re-selling some fraction of the leases to major producers who might want to take a gamble and actually explore for oil and gas reserves on the federal land.").

[217] Livermore, *supra* note 202, at 585 (explaining that "[m]odels for taking account of option value have been used extensively in the private sector").

[218] Proposed Program, *supra* note 2, at 1-16 ("[O]il and gas production from new leases will likely not commence until approximately 5 (shallow water) to 10 years (deep water) after lease award."); *id.* at 5-5 (recognizing that "first production is often not achieved until at least 10 years after lease award"); *see also* Congressional Budget Office, Options for Increasing Federal Income From Crude Oil and Natural Gas on Federal Lands 3 (2016) (noting "long lag time between leasing a parcel and beginning production from that parcel").

that occurs now would have unnecessarily exacerbated the climate crisis for limited benefit.[219] Thus, the high number of non-producing leases (coupled with uncertainty around long-term oil and gas demand) suggests that the costs of delay are relatively low.

Thus, while BOEM does elsewhere recognize the significance of the large number of currently nonproducing leases, it should also consider this important fact in its assessment of option value. Ideally, BOEM would explicitly model the time until oil development. But even if this is not feasible, BOEM's option value analysis should recognize that the high number of nonproducing leases suggests that the costs of delay are relatively low and makes delay more attractive.

C. BOEM Should Quantify Environmental and Social Cost Uncertainty Using Established Economic Techniques

While BOEM provides a fairly brief qualitative discussion of environmental and social cost uncertainty,[220] it does not consider these uncertainties quantitatively and thus does not include them in its net benefits analysis. But existing methodologies have been used in the natural resources context to quantify relevant uncertainties, and BOEM should incorporate these established techniques into its analysis.

Although BOEM states that "relatively few studies . . . apply real options concepts to possibly irreversible environmental impacts from oil and gas activities,"[221] the option value literature in the natural resources context is in fact increasingly well developed.[222] Numerous papers address option value in the context of oil and natural gas extraction,[223] catastrophic oil spills,[224] and greenhouse gas emissions.[225] Thus, BOEM is now capable to estimating the portions of option value corresponding to both market and environmental cost, and BOEM should apply these methodologies to supplement its option value analysis to include quantitative considerations of environmental and social cost uncertainty.[226]

In particular, the "optimal stopping model" approach, through which the analyst specifies a stochastic or random process to model the value of learning and delay—estimated using available data—provides a particularly compelling avenue for BOEM to model social and environmental cost uncertainty. Notably, this is the same essential approach that BOEM

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[219] BOEM recognizes that falling demand for oil and gas as a result of decarbonization efforts could reduce the need for OCS leasing and increase its net climate impacts. *See* Proposed Program, *supra* note 2, at 3 ("According to the International Energy Agency, a roadmap to net-zero emissions by 2050 for the global energy sector would require no new investment in fossil fuel supply projects[.]"); *id.* at 5-50 to -56 (conducting a hypothetical net-zero analysis and recognizing that the net climate costs of OCS leasing would likely increase under a decarbonization pathway).

[220] *Id.* at 9-9 to -12.

[221] *Id.* at 9-10.

[222] *See* Esther W. Mezey & Jon M. Conrad, *Real Options in Resource Economics*, 2 Ann. Rev. Res. Econ. 33 (2010); Courtney M. Regan, et al., *Real Options Analysis for Land Use Management: Methods, Application, and Implications for Policy*, 161 J. Env't Mgmt. 144 (2015); Jon Anda, Alexander Golub & Elena Strukova, *Economics of Climate Change Under Uncertainty: Benefits Of Flexibility*, 37 Energy Pol'y 1345 (2009).

[223] *See generally* Mezey & Conrad, supra note 222, at 44–47; Jon M. Conrad & Koji Kotani, *When to Drill? Trigger Prices For The Arctic National Wildlife Refuge*, 27 Res. & Energy Econ. 273, 276 (2005); Jon M. Conrad, *Wilderness: Options to Preserve, Extract, or Develop*, 22 Res. & Energy Econ. 205 (2000).

[224] *See generally*, George Dikos & Sgouris P. Sgouridis, *On the Optimal Timing of the Oil Pollution Act: Is There More Value in Waiting than Acting*, 1 Int'l J. Ocean Sys. Mgmt. 100 (2008).

[225] *See generally* Anda et al, supra note 222; Alexander Golub & Michael Brody, *Uncertainty, Climate Change, And Irreversible Environmental Effects: Application Of Real Options To Environmental Benefit-Cost Analysis*, 7 J. Env't Stud. & Scis. 519 (2017); Peter Howard, Alexander Golub & Oleg Lugovoy, *Option Value and the Social Cost of Carbon: What Are We Waiting For* (Inst. for Pol'y Integrity Working Paper No. 2020/1) (2020).

[226] The D.C. Circuit has explained that failing to quantify option value could present a legal challenge if BOEM disregards "well established" quantitative methods. *Ctr. for Sustainable Econ.*, 779 F.3d at 612.

uses to quantify price uncertainty.[227] Using the same approach, BOEM could extend its existing methodology to model uncertainty in externality costs. And insofar as BOEM lacks sufficient data to fully assess these uncertainties using an optimal stopping model, it could augment its data using expert evaluation—much like BOEM has already done to supply MarketSim parameter values that were not available in the literature.[228]

Moreover, as discussed above in Part II.C, a relatively straightforward way for BOEM to recognize and account for environmental cost uncertainty would be to assess the climate costs of OCS leasing using a range of alternative damage valuations.[229] As that section details, it is widely recognized that the climate-damage valuations that BOEM applies are very likely underestimates, and both the Working Group and other expert authorities have developed other valuations supplying a range of higher incremental damage estimates.[230] BOEM should begin to account for environmental cost uncertainty by applying those higher estimates. But as discussed in this section, it should also quantify other sources of environmental and social cost uncertainty.

D. BOEM Should Reevaluate Its Hurdle Price Analysis to Ensure Consistency with Best Practices and Not Bias the Analysis to Favor Leasing

To assess option value with respect to resource price uncertainty, BOEM conducts a hurdle price analysis.[231] The aim of BOEM's analysis is to maximize the present value of social net benefits of OCS leasing over time, by representing the barrel of oil equivalent price at which BOEM should open at least one field of the OCS region to exploration.

BOEM's Hurdle Price Analysis Does Not Follow Standard Economic Practices

In reality, however, BOEM incorrectly performs its hurdle price analysis and, as a result, its analysis is likely biased toward development. BOEM should redesign its hurdle price analysis to correctly model the structure of the leasing program and eliminate the current bias toward OCS leasing.

On this point, some background on hurdle price analysis is useful. In a hurdle price analysis, an investor or trader seeks to identify what is referred to as a "strike price" of a call option—that is, the observed price at which the option is "in the money" and presents a profit opportunity.[232] The key feature here is that this analysis is based on observed (i.e. actual) prices—not forecasted future prices.[233] In contrast to this standard practice, however, BOEM bases its analysis on

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[227] Economic Analysis Methodology, *supra* note 37, at 4-4 ("The price model in WEB3 represents the range of possible future prices generated by a specific algorithm that models a mean-reverting stochastic process.").

[228] *See* MarketSim 2021, *supra* note 41, at 12 ("No data on the adjustment rates for specific energy sources were readily available. In the absence of such data, MarketSim uses expert input from Dr. Stephen Brown of the University of Las Vegas (UNLV) for several adjustment rates.").

[229] *See supra* Part II.C.

[230] *Id. See also* Rennert et al., *supra* note 123.

[231] Proposed Program, *supra* note 2, at 9-14 to -17. BOEM uses WEB3 to calculate a hurdle price due to oil price uncertainty in its Fair Market Value analysis. *Id.* at 9-15.

[232] Avinash K. Dixit & Robert S. Pindyck, Investment Under Uncertainty 6–7 (Princeton Univ. Press, 1994) ("Firms invest in projects that are expected to yield a return in excess of a required or 'hurdle' rate. Observers of business practice find that such hurdle rates are typically three or four times the cost of capital. In other words, firms do not invest until price rises substantially above long-run average cost.").

[233] *See id.*; *see also* Proposed Program, *supra* note 2, at 9-14 ("The hurdle price is defined as the market price below which the social value of delaying to a future program the exploration of a large field in the sale area would exceed the value of immediate exploration of those fields within this program."); Economic Analysis Methodology, *supra* note 37, at 4-4 ("If the market price *at the time of leasing* happens to be lower than the calculated hurdle price, then a delay of leasing is indicated") (emphasis added).

forecasted prices rather than observed prices.[234] BOEM explains that its unorthodox approach to hurdle price analysis is compelled by the tiered structure of leasing program[235]—at which lands are designated for leasing at the planning stage but are not leased until the subsequent leasing stage. However, BOEM does not properly adjust its analysis under the circumstances, but instead applies an overly simplified methodology that biases the analysis in favor of leasing.

In particular, BOEM's reliance on forecasted resource prices is problematic because the price forecasts that it relies on are extremely simplistic and basically assume that oil prices will rise continuously upwards in the future.[236] Because the price forecast that BOEM applies predicts future prices to rise in an essentially continuously upwards fashion,[237] the agency's analysis is biased in favor of development. Indeed, the AEO forecast that BOEM applies clearly does not correspond to a mean-reversion process, as identified by BOEM,[238] but instead follows a model with upward drift.[239] This is fundamentally inconsistent with the BOEM's Web3 model, and effectively guarantees that production regions will pass the hurdle price analysis in most circumstances.

Rather than assume that prices will simply rise over time, BOEM should conduct a more complicated hurdle price calculation based on the actual structure of the leasing program. In other words, the potential for an information update at the lease sale stage should inform the calculation of option value at this first stage. In fact, BOEM should not only model the time it takes to start extraction relative to when the leasing decision is made in this first stage of the leasing decision, but also model it in the second stage mentioned by BOEM. Currently, however, BOEM does not model option value in its lease sale analyses.

BOEM Should Revisit Its Calculations of Expected Field Size

In addition to revising its approach to forecasted prices, BOEM should also revisit its consideration of potential field size in its hurdle price analysis. According to BOEM, the potential field size corresponds to the "expected field size" in the event that "resources are found" during exploration.[240] BOEM further specifies that this "expected field size" is "the largest field size in each program area."[241] But this assumption is improper because traditionally the expected value of a random variable equals the mean of its underlying distribution.[242] And while there may be some basis not to use the mean

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[234] *See* Proposed Program, *supra* note 2, at 9-15 ("Price forecasts from EIA are used to create a per-BOE price appropriate for each program area based on their natural gas-oil ratios . . .; if these prices are below the hurdle price, from the monetized option value perspective calculated here, delaying the exploration of an undiscovered field of the size shown in Column B is more valuable than immediate exploration.").

[235] Economic Analysis Methodology, *supra* note 37, at 4-7.

[236] EIA's Annual Energy Outlook, which BOEM incorporates into the MarketSim model, assumes that oil and natural gas prices increase with drift. *See* Table 12: Petroleum and Other Liquids Prices, U.S. Energy Info. Admin, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2022&cases=ref2022&sourcekey=0 (projecting petroleum prices through 2050); Table 13: Natural Gas Supply, Disposition, Prices, U.S. Energy Info. Admin, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=13-AEO2022&region=0-0&cases=ref2022&start=2020&end=2050&f=A&linechart=ref2022-d011222a.3-13-AEO2022&chartindexed=0&sourcekey=0 (projecting natural gas prices through 2050). EIA's NEMS model does not specify a stochastic model for prices. However, it implicitly models prices increasing with drift.

[237] In the 2022 AEO forecast, the oil and natural gas prices initially decline and then increase. *See id.* Therefore, even when resources prices are high as in the current moment, projected resource prices exceed current prices in the long run (i.e., in around 8 to 12 years in the 2022 forecast). In regions where the oil price is more heavily weighted, this occurs even sooner, which should make this bias worse.

[238] Proposed Program, *supra* note 2, at 9-13 ("The hurdle prices are calculated assuming a mean-reverting price model.").

[239] *See supra* notes 236–237 and accompanying text. AEO's upward-drifting price forecasts also raise serious questions of whether BOEM should be using MarketSim, as it is calibrated to NEMS, as this model directly contradicts the evidence of mean-reversion without drift found by BOEM using WEB3.

[240] Proposed Program, *supra* note 2, at 4-2.

[241] *Id.*

[242] Circular A-4, *supra* note 36, at 42 (stating that the "best estimates are usually the *average* or expected value of benefits and costs) (emphasis added).

here because the developer presumably has some information with respect to the geographic dispersion of oil reserves,[243] it is also improper to assume the maximum field size because that assumes that developers have perfect information—an assumption that is clearly untrue given that developers have just a "20% success rate for exploratory drilling."[244] A field size between the mean and the maximum is therefore appropriate. By using the maximum instead, BOEM once again biases its analysis in favor of development, since, as the agency acknowledges, larger field sizes produce lower hurdle prices and thereby favor development.[245]

BOEM Should Consider Alternatives Beyond a 10-Year Delay

BOEM also inappropriately truncates its hurdle price analysis by only "calculat[ing] the social value of offering leases now versus waiting" with "delays of 1 through 10 years."[246] In reality, BOEM not only has the option of OCS leasing now versus in the next ten years, but also has the option to delay beyond ten years, or not to lease a region at all. Thus, BOEM should explicitly model concurrent option values.[247] If this is difficult using its current model structure, BOEM should consider a simplified lattice model to improve the ease of the calculation.[248] Alternatively, BOEM could explore running the model over a longer time range of 1 to 50 years.

As this section explains, BOEM's hurdle price analysis is improperly biased toward development and fails to follow economic best practices. BOEM should revisit its analysis to address these flaws.

E. BOEM Should Conduct Sensitivity Analysis Around Key Environmental Cost Parameters And Other Modeling Inputs

While OCS leasing is characterized by many environmental and social cost uncertainties, BOEM's analysis largely disregards these uncertainties by using point estimates or forgoing quantification altogether. But economic tools allow for the study of uncertainty, and BOEM should embrace those tools to model uncertainty rather than dismiss it.

As explained throughout this report, there are numerous examples of uncertainties that BOEM disregards in its net benefits analysis. BOEM's substitution analysis is characterized by uncertainties around long-term parameters, yet the agency relies on point estimates that tend to minimize environmental cost.[249] The social cost of greenhouse gases allows for a range of climate-damage estimates, yet BOEM applies point valuations near the bottom end of the range.[250] Catastrophic oil spills are uncertain, yet BOEM ignores them completely from its net benefits analysis.[251] And other critical environmental and social costs are also uncertain, yet BOEM's option value analysis models only price uncertainty and does not model any environmental uncertainties.[252] The continual result of these modeling choices is that large environ-

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[243] Economic Analysis Methodology, *supra* note 37, at 4-2 ("BOEM still maintains that the proxy for the largest field size is appropriate because with the largest field size, developers have more information with which to make their drilling and development decisions rather than a random draw. Thus, the larger fields are more likely to be developed first.").

[244] *Id.*

[245] *Id.* ("The largest field size, all else being equal, tends to have the highest net value per equivalent barrel of resources and thus would be the most profitable in a sale and provide the lowest hurdle price."); *accord* Proposed Program, *supra* note 2, at 9-14 n.75.

[246] Economic Analysis Methodology, *supra* note 37, at 4-1.

[247] Warren J. Hahn & James S. Dyer, *Discrete Time Modeling of Mean-Reverting Stochastic Processes for Real Option Valuation*, 184 Eur. J. Operational Rsch. 534, 546 (2008).

[248] *Id.*

[249] *See supra* Part I.

[250] *See supra* Part II.C.

[251] *See supra* Part III.A.

[252] *See supra* Part IV.C.

mental costs are disregarded or undervalued. Yet BOEM does not treat uncertainty with economic benefits the same way,[253] as it mathematically forecasts price uncertainty in a way that tends to improperly favor development.[254]

In addition to the suggestions for each of these issues above, BOEM should model uncertainty by running sensitivity analyses around key parameters in its OECM, WEB3, and MarketSim models. Specifically, for each key parameter, BOEM should provide a central (mean or median) estimate and a range of estimates drawn from the literature. For parameters where estimates are unavailable in the literature, the use of expert elicitation is an acceptable alternative. This is consistent with BOEM's use of expert opinion in the calibration of MarketSim. However, this elicitation should not rely on one author only, as BOEM does for MarketSim.[255] Instead, BOEM should identify multiple experts to survey to develop a range of possible estimates, which can be further characterized by its central value and variance. BOEM should then re-run its analysis with this range of parameters, providing a range of plausible results reflecting uncertainty. Part I offers more detailed suggestions for conducting such analysis in MarketSim.

[253] *See supra* note 154 and accompanying text (noting that BOEM's economic-benefit estimates under the high-price scenario are roughly 500 times higher than its economic-benefit estimates under the low-price scenario).

[254] *See supra* Part IV.D.

[255] *See* MarketSim 2021, *supra* note 41, at 12 ("No data on the adjustment rates for specific energy sources were readily available. In the absence of such data, MarketSim uses expert input from Dr. Stephen Brown of the University of Las Vegas (UNLV) for several adjustment rates.").

V. BOEM Should Reconsider Its Treatment of Energy Security, as the Research It Cites Suggests that Continued Fossil-Fuel Reliance Increases National Vulnerability to Supply Shocks

BOEM counts national energy security as an unquantified benefit of OCS leasing, reasoning that "domestic oil production can boost the share of stable supplies in the world market while increased oil imports, often from unstable regions, can have the opposite effect."[256] But OCS leasing can also harm domestic energy security by making the United States more reliant on oil and gas and thus more susceptible to future price volatility in that sector.[257] BOEM should review the available evidence more closely and recognize the potential that OCS leasing comes at a cost to energy security.

BOEM's discussion of energy security relies on research from Brown and Huntington,[258] who defined an "oil security premium" as "the externality portions of the economic losses associated with the potential disruptions in world oil supply that result from the increased consumption of either domestic or imported oil."[259] The authors explain that this premium can be broken into multiple parts: (1) the change in expected transfers for inframarginal oil imports (i.e., the expected transfer of U.S. revenue out of the country due to the continued purchase of oil at higher energy import prices); and (2) the change in expected GDP losses.[260] While the authors find that "the substitution of domestic oil for imported oil only slightly improves U.S. oil security," they ultimately conclude that "[o]il conservation is more effective than increased domestic oil production at improving U.S. oil security."[261]

This finding raises doubts about BOEM's conclusion that OCS leasing improves domestic oil security, and merits close attention. On the one hand, as BOEM recognizes, substituting imports for domestic production nominally decreases the risk of oil shocks and, when considered in a vacuum, increases energy security. But on the other hand, because OCS leasing also increases domestic energy consumption and makes the nation more reliant on fossil-fuel energy that trades in global markets, this has the countervailing effect of making the United States economy more vulnerable to price shocks and thereby decreases energy security. And as Brown and Huntington concluded, decreased oil consumption improves

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[256] Economic Analysis Methodology, *supra* note 37, at 2-6; *see also* Proposed Program, *supra* note 2, at 1-11 ("Domestic production can contribute to both U.S. and world energy security by providing additional supply that can help limit the impact of supply shocks and reduce future price volatility.").

[257] *See* Proposed Program, *supra* note 2, at 1-11 (recognizing generally that "[a]s the U.S. transitions to a new energy economy on the pathway to meeting climate goals, it will rely less on oil and gas and be less susceptible to global oil and gas supply shocks," but failing to connect this to the effects of OCS leasing).

[258] Economic Analysis Methodology, *supra* note 37, at 2-6.

[259] Stephen P.A. Brown & Hillard G. Huntington, *Assessing the U.S. Oil Security Premium*, 38 Energy Econ. 118, 119 (2013). Given BOEM's citation to Brown & Huntington's work and its reference to "externalities associated with oil supply disruptions," it appears that this is the concept that BOEM has in mind. Economic Analysis Methodology, *supra* note 37, at 2-6.

[260] *See* Brown & Huntington (2013), *supra* note 259; *see also* Stephen P.A. Brown, *New Estimates of the Security Costs of US Oil Consumption*, 113 Energy Policy 171, 171 (2018) ("[O]nly the changes in the expected macroeconomic losses and the changes in the expected transfers on the inframarginal barrels of imported oil should be included in oil security premiums."). In turn, this latter component can be broken down into: a) the probability of a global supply shock event occurring, and b) the damages to U.S. economy if such an event occurs.

[261] Brown (2018), *supra* note 260, at 182 (describing results of previous work with Dr. Huntington).

energy security far more than substituting domestic oil for foreign oil.[262] BOEM recognizes only the security benefits of domestic production and disregards the costs of domestic consumption, providing a lopsided and incomplete analysis that biases the agency's result in favor of OCS leasing.

While BOEM assesses energy security qualitatively, Brown and Huntington's research provides a model to quantify the energy security premium, and other economists have subsequently built on their model.[263] Relying on that research, the Environmental Protection Agency has monetized energy security benefits in recent rulemakings.[264] BOEM could apply a similar methodology here, and if it did so, it would likely conclude that the energy benefits of OCS leasing are close to zero or potentially negative. Details are provided in the technical appendix.[265]

In short, the very research that BOEM cites to claim that OCS leasing will boost energy security actually offers considerable grounds for skepticism. BOEM should therefore reconsider its claims about energy security and recognize that there may be a security cost to OCS leasing by making the country more reliant on fossil fuels and thereby more vulnerable to price shocks.

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[262] *Id.*

[263] *See* Brown & Huntington (2013) *supra* note 136; Brown (2018), *supra* note 260; Alan Krupnick et al., *Oil Supply Shocks, US Gross Domestic Product, and the Oil Security Premium*, Res. for the Future 6–7 (2017) (describing computational model).

[264] *See* Env't Prot. Agency, Revised 2023 and Later Model Year LightDuty Vehicle GHG Emissions Standards: Regulatory Impact Analysis 3-19 to -29 (2022).

[265] *See* App'x C.

Conclusion

BOEM's net benefits analysis of the proposed OCS leasing program omits the vast majority of environmental costs—including climate costs from downstream emissions, catastrophic oil spills, and other critical environmental and social cost uncertainties. As detailed in this report, extensive evidence clearly demonstrates that the costs of OCS leasing are far greater than BOEM acknowledges, and suggests that those costs may exceed the benefits of OCS leasing. This analysis thus calls into question BOEM's conclusion that OCS leasing is cost-justified, and highlights numerous areas where BOEM should improve its analysis consistent with economic best practices. BOEM should reexamine its analysis and follow the recommendations in this report to ensure that it considers the costs and benefits of OCS leasing robustly and even-handedly.

Appendix A: Substitution Modeling

As detailed above in Part I, we conducted original substitution modeling by adjusting BOEM's own models. Sensitivity analyses and scenario runs are discussed in Part I. This Appendix section offers some additional technical detail on how we adjusted the models in order to set up our sensitivity and scenario runs.

As discussed in Part I, we calculated greenhouse gas emissions from new leasing and substitute sources respectively focusing on the mid-level leasing scenario for the Gulf of Mexico Region. We calculate net emissions as the difference in total emissions between the new leasing scenario and the no lease scenario, including both domestic lifecycle emissions and foreign downstream emissions.

Specifically, we calculated upstream greenhouse gas emissions using the BOEM's Offshore Environmental Cost Model (OECM). We calculated midstream and downstream greenhouse gas emissions following the technical report of the 2022 version of the Greenhouse Gas Lifecycle Energy Emissions Model (GLEEM)[266] with the following corrections to the methodology presented in that technical report:

1. In the following equation (a1), which appears as Equation 2 on page 3 of the GLEEM report, the unit of $Coal_{Production}$ is corrected to be short tons instead of the reported unit of millions of short tons.[267] The purpose is to correct the unit of emissions associated with coal, i.e., $PM_{coal}\frac{Coal_{Production}}{Coal_{Total}}$, to be metric tons; otherwise the unit would be millions of metric tons, which is inconsistent with the units of emissions from oil and gas.

$$PE_{offsite} = R_{oil}\frac{Oil_{Production}}{Oil_{Total}} + SD_{ng}\frac{NC_{Production}}{NG_{Total}} + PM_{coal}\frac{Coal_{Production}}{Coal_{Total}} \qquad \text{(a1)}$$

where

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

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

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

Oil_{Total} is total U.S. oil refinery inputs in bbl

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

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

NG_{Total} is total U.S. natural gas consumption from 2021 in mmcf

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

$Coal_{Production}$ is coal expected to be produced in short tons

$Coal_{Total}$ is total U.S. coal consumption from 2021 in short tons

[266] Bureau of Ocean Energy Mgmt., The Greenhouse Gas Life Cycle Energy Emissions Model (GLEEM) 2022 Version, https://www.boem.gov/sites/default/files/documents/environment/GLEEM_2022_Technical_Paper.pdf.

[267] It is not clear whether BOEM used the wrong unit in its actual model runs, although this seems unlikely given the reported results. However, the methodology reported in BOEM's technical document is erroneous.

2. The following emission factors are corrected following the Environmental Protection Agency (EPA) data. The reason is that their original values documented in the report are inconsistent with the EPA data from which these emission factors are sourced:[268]
   - The propylene emission factor for CO2 is corrected to be 6.17 kg/gal instead of the original value of 6.00 kg/gal.
   - The natural gas emission factor for CH4 is corrected to be 1.039 kg per million cubic feet (mmcf) instead of the original value of 1,039 kg/mmcf.
   - The natural gas emission factor for N2O is corrected to be 0.1 kg/mmcf instead of the original value of 100 kg/mmcf.

3. The following equation (a2), which appears as Equation 6 on page 7 of the GLEEM report, is corrected as equation (a3). The purpose is to convert the units of emission factors for coal, i.e., kg/short ton, to metric tons/short ton; otherwise, the unit of total emissions from coal consumption would be inconsistent with the description in the original report:

$$CE_{coal} = CP_{coal}(1 - NC_{coal}) * \sum_{i=1}^{n}[C_i * EF_i] * 0.907185 \qquad \text{(a2)}$$

where

CE_{coal} is total emissions from coal consumption in metric tons

CP_{coal} is coal produced and consumed in short ton

NC_{coal} is the proportion of coal that is not combusted

C_i is the consumption factor for end use of a petroleum product

EF_i is emission factor for coal in kg/short ton

$$CE_{coal} = CP_{coal}(1 - NC_{coal}) * \sum_{i=1}^{n}[C_i * EF_i] * 1/1000 \qquad \text{(a3)}$$

To calculate midstream and downstream emissions for substitute sources under the no-leasing scenario, we calculate substitutions for oil and gas separately using the oil-only or gas-only new leasing scenario. Table A-1 reports their respective substitution rates in the reference case where all parameters are at the default levels. For example, 0.905 represents the ratio of oil from onshore production, existing offshore production, imports and other sources, which would have been produced in the absence of oil production associated with the new leasing, relative to the forgone oil production of the new leasing. In addition to oil, gas, and coal, which are the main sources of greenhouse gas emissions, forgone oil and gas production can also be substituted by electricity and reduced demand.

[268] Env't Prot. Agency, Emission Factors for Greenhouse Gas Inventories (last modified Apr. 1, 2021), https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf. Once again, it is not clear whether this is a modeling error or simply a reporting error.

Table A-1 Substitute Energy Results

Substituting energy	Forgone oil production	Forgone gas production
Oil	0.905	0.072
Gas	0.021	0.574
Coal	0.004	0.016

In the sensitivity analysis, we re-run the model to examine the impact of one particular set of adjustments in the baseline quantities, supply elasticities, or demand elasticities. We compare the net emissions under each case of interest with gross emissions. By "gross emissions," we mean the total lifecycle emissions attributable to production from OCS leasing, on a gross basis (i.e. without considering substitution impacts). By "net emissions," we mean the gross greenhouse gas emissions minus the total lifecycle emissions attributable to production from energy substitutes under the no-leasing scenario, thereby capturing the net change in emissions from the leasing program. In the gross emissions case, we set all own-price demand elasticities as -100 while keeping other elasticities as the default levels. In the reference case, net emissions account for 22.87% of gross emissions.

Following these adjustments, we then ran the sensitivity analyses and scenario runs described in Part I. Methodologies and results are presented in that Part.

Appendix B: Oil Spills

Inconsistencies Between Risk Assessments in OECM and Economic Analysis Methodology

The relative probability of oil spill size (conditional on a spill occurring) for crude oil wells between the Offshore Economic Cost Model (which BOEM integrates into its net benefits analysis) and BOEM's separate catastrophic spill analysis in the Draft Economic Analysis Methodology are not consistent. Using data of oil spills from wells of all sizes (0.5 barrels to 4,900,000 barrels) from 1964 to 2017, BOEM estimates the probability of an oil spill at the well level conditional on spill size. Relative to OECM, BOEM's analysis of catastrophic oil spills implies much lower relative probabilities for small oil spills and much higher probabilities for catastrophic oil spills. These high conditional probabilities for catastrophic oil spills, particularly compared to oil spills from tankers (discussed below), raises questions about why BOEM is omitting the cost of oil spills above 100,000 barrels from wells from its net benefits analysis.

Table B-1:
Relative Frequency of Oil Spill Sizes in OECM vs.
BOEM's Catastrophic Spill Analysis Conditional on a Spill Occurring

Spill Size (Barrels of Oil)	OECM	BOEM's Catastrophic Analysis	Our Median Regression
1 to 10	63.13%	41.66%	42.58%
10 to 100	26.84%	24.31%	24.45%
100 to 1,000	9.73%	14.18%	14.04%
1,000 to 10,000	0.29%	8.27%	8.06%
10,000 to 100,000	0.00%	4.83%	4.63%
100,000 to 1,000,000	-	2.82%	2.66%
1,000,000 to 10,000,000	-	1.64%	1.53%
Over 10,000,000	-	2.28%	2.04%

This table shows, for various models, the relative probabilities of oil spills of various size conditional on an oil spill occurring. The rows of the table are the sizes of oil spills. The columns represent alternative models: the OECM model used by BOEM to assess the costs of non-catastrophic oil spills (which it incorporates into its net benefits analysis); BOEM's catastrophic analysis that it uses to assess the costs of catastrophic oil spills (which it does not incorporate into its net benefits analysis); and our re-estimation of BOEM's catastrophic model using a median regression instead of OLS to address the non-normality of the underlying data conditional on oil spill size.

BOEM also assumes that there is an equal risk of spills over time and per region. The only source of variation in spills under BOEM's analysis is the number of wells per region. As multiple factors may influence risk of spill rate beyond number of wells, BOEM ideally would account for factors that may lead to regional variation. If this is impossible due to lack of data, BOEM should be careful in over-interpreting how spill risk is changing over time.

Underestimate of Catastrophic Risk in BOEM's Regression Analysis

We can replicate the regression that BOEM estimates for catastrophic oil spills. Testing for normality using the Cameron & Trivedi's decomposition of IM-test, we reject the null of normality at the 5% statistical level based on the strong evidence of skewness.[269] If we use a quantile regression (specifically, a median regression) to address potential outliers, we find lower values for both distribution parameters in the power complementary cumulative distribution function $F\ (X > x\ ) = \alpha X^{\beta}$: the relative frequency of spill occurrence (α), and the power relation between spill size and frequency (β). If skewness is truly a problem, then OLS overestimates complementary cumulative probabilities for oil spills under 2,584 barrels and underestimates complementary cumulative probabilities for spills over 2,584 barrels. As a catastrophic spill for oil wells is far larger than 2,584 barrels, the agency's current regression underestimates that probability of catastrophic risks, assuming that using the power function is appropriate. If BOEM believes that the power function is the appropriate power-law probability distribution, then it should review the literature, as it is clear that BOEM's strategy of estimating this distribution using least-squares is methodologically flawed.[270]

Inappropriate Probability Distribution Function:

The probability distribution function selected by BOEM to model catastrophic oil spills is inappropriate.

First, the complementary cumulative density function is not appropriately defined for small oil spills. The complementary cumulative density function equals

$$P\ (X > x) = 1 - F_X(X)$$

where $P\ (X \leq x) = F_X(X)$ is the cumulative probability distribution function, such that $0 \leq F_X(X) \leq 1$. Since oil spills cannot be negative, we know that

$$\lim_{x \to \infty} 1 - F_X(X) = 0$$

This appears to be true. We also know that

$$\lim_{x \to 0} 1 - F_X(X) = 1,$$

though this appears not to be true. Specifically,

$$\lim_{x \to 0} 0.00096 \times x^{-0.24092} = \lim_{x \to 0} 0.00096 \times \left(\frac{1}{x}\right)^{0.24092} \to \infty.$$

From this proof, we can tell that the power function as currently estimated is not a complementary cumulative density function. This is potentially problematic as most of the data comes from non-catastrophic oil spills, though spill sizes never decline below 0.5 barrels in the BOEM dataset and BOEM never uses the distribution to estimate the probability of oil spills below 1 barrel. Even so, a simple solution would be to focus on estimating the probability of an oil spill conditional on the spill occurring, as BOEM determines the probability of a spill occurring at a well exogenously at 0.149% over the lifetime of each well based on historical data.

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[269] A. Colin Cameron & P.K. Trivedi, Microeconometrics: Methods and Applications 97–98 (Cambridge University Press, 2005).

[270] Rudolf Hanel, *Fitting Power-Laws in Empirical Data with Estimators that Work for All Exponents*, 12 PLOS One (2017) ("Statistically sound ways to fit power-laws were advocated and discussed in [the article] . . . overcome intrinsic limitations of the *least square* (LS) fits to logarithmically scaled data, which were and are widely (and often naively) used for estimating exponents.").

Second, BOEM's power complementary cumulative distribution function does not have a defined mean or variance. Based on BOEM's complementary probability distribution function, the cumulative and probability distribution functions are $F\ (X) = 1 - \alpha X^{\beta}$ and $f(X_{jjk}) = -\beta\alpha X^{\beta-1}$. However, this distribution's mean is infinite if $\beta > -1$ and the variance is infinite if $\beta > -2$.[271] According to BOEM's own calculations, the expected cost of drilling in the outer-continental shelf is infinite and the variance is infinite as the 95th confidence interval of β is between -0.24092 and -0.22844. These results imply that BOEM should never allow drilling in the outer-continental shelf as the expected damages and the option value corresponding to the risk of oil spills from drilling, which can be approximated by 0.4 times the standard deviation of the distribution according to the Bachelier model (Haug, 2007; Anda et al., 2009), are infinite.

Proposed Solution

To address this issue, BOEM should take several steps to improve its estimation. First, as mentioned earlier, BOEM should focus on estimating the probability of an oil spill of a particular size conditional on a spill occurring. Second, BOEM should consider limiting the maximum size of the oil spill from a well, as spills sizes are limited. For example, in the case of tanker spills, the maximum spill size is the physical capacity of the largest oil tanker. For wells, given that the largest oil spill observed in the dataset is approximately 5 million barrels, BOEM could set the maximum oil spill at 10 million barrels. Third, BOEM should consider using an alternative probability distribution function with fat tails, given BOEM's indication of high levels of unknowability about large oil spills, and defined mean and variance expressions. Finally, BOEM should include catastrophic impacts in OECM addressing issues of unknowability using methodologically sound principles: using a fat-tailed distribution consistent with the discussion of unknown unknowns in the literature on the economics of climate change and conducting an uncertainty analysis; and calculating the option value associated with irreversible leasing and extraction decisions.

[271] The mean of the distribution equals: $\mu = \int_L^U xf(X)dx = \frac{\alpha\beta}{\beta+1}\left[L^{\beta+1} - U^{\beta+1}\right]$ where L and U are the upper and lower limits of the distribution. As the domain of the distribution is between 0 to ∞, we know that

$$\lim_{U\to\infty} \frac{\alpha\beta}{\beta+1}\left[L^{\beta+1} - U^{\beta+1}\right] \to \infty$$

when $\beta > -1$. A similar proof is possible for the variance.

Appendix C: Energy Security

As detailed in Part V of the report, BOEM's claim that energy security is a benefit of OCS leasing disregards a key consideration: that the published literature finds that as the United States becomes more dependent on fossil fuels, it becomes less energy secure because it is more susceptible to oil price shocks. That Part summarizes that literature and explains that empirical estimates of the energy security premium suggest that OCS leasing could come at a cost to energy security. This section details that latter finding.

Quantitative Estimates of Energy Security Premium

BOEM chooses to treat energy security qualitatively despite citing a working paper version of Brown and Huntington (2013), which quantitatively estimates the energy security premium corresponding to U.S. consumption of imported oil, U.S. consumption of domestic oil, and the perfect substitution of U.S. consumption of domestically produced oil for oil imports.[272] In fact, since its publications, these numerical estimates have been updated by the authors multiple times: Brown and Huntington (2015), Krupnick et al. (2017), and Brown (2018).[273] Using the Brown and Huntington (2013) methodology, EPA (2021) also estimates the energy security premium corresponding to the U.S. consumption of imported oil for use in regulatory analysis.[274]

These calculations are based the parametric expressions for energy security premiums derived in Brown and Huntington (2013), which require four sets of parameters: (1) probabilities of oil supply disruptions of various sizes, (2) estimated short-run supply and demand elasticities; (3) the elasticity of U.S. GDP to oil price increases that result from supply disruptions, and (4) a projection of world oil market conditions. The security premiums differ based on the selected value of these parameters, as well as the current forecasts of world oil market conditions specified in the latest Annual Energy Outlook forecasts (i.e., the predominant source of projected market conditions in these studies).

In recent years, the estimates of the energy security premium have declined relative to earlier publications. Specifically, the short-run price elasticities of demand and supply increase in magnitude (i.e., become more elastic) and the elasticity of U.S. GDP to oil price shocks has become more inelastic leading to lower premiums.[275] These estimate changes reflect improved macroeconomic modeling combined with a shift towards a more resilient U.S. economy to oil price shocks, as reflected by more flexibility shown by U.S. consumers and producers, lower oil imports, a lower oil-to-GDP ratio, and less oil price shocks.[276] To reflect greater resilience of the U.S. economy, Krupnick et al. (2017) and Brown (2018) estimate risk premiums using newly estimated elasticities; however, they also estimate risk premiums combining the old and new elasticities to address concerns that some of these improved numbers also reflect an under-representation of large oil price shocks on the U.S. economy in recent data.[277] In contrast, the EPA uses meta-analyses of the underlying elasticities finding security premiums between the new and combined estimates of Krupnick et al. (2017) and Brown

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[272] Stephen P.A. Brown & Hillard G. Huntington, *Assessing the U.S. Oil Security Premium*, 38 Energy Econ. 118, 119 (2013).

[273] Stephen P.A. Brown & Hillard G. Huntington, Evaluatin/g US Oil security and Import Reliance, 79 Energy Policy 9 (2015); Alan Krupnick et al., *Oil Supply Shocks, US Gross Domestic Product, and the Oil Security Premium*, Res. for the Future 6–7 (2017).

[274] Env't Prot. Agency, Revised 2023 and Later Model Year LightDuty Vehicle GHG Emissions Standards: Regulatory Impact Analysis 3-19 to -29 (2022).

[275] *See, e.g.*, Krupnick et al., *supra* note 273; EPA (2021), *supra* note 274.

[276] Stephen P.A. Brown, *New Estimates of the Security Costs of US Oil Consumption*, 113 Energy Pol'y 171, 171 (2018). Specifically, more recent AEO forecasts also project lower US imports of oil and lower import prices. *See* EPA (2021), *supra* note 274, at 3-26.

[277] Krupnick et al., *supra* note 273; Huntington, *supra* note 273.

(2018).[278] Under the assumption of perfect substitution, these papers' best estimates imply an energy security externality of between $0.45/barrel to $1.29/barrel (in 2021$).[279] These small estimates led Brown (2018) to conclude that "the substitution of domestic oil for imported oil only slightly improves U.S. oil security. Oil conservation is more effective than increased domestic oil production at improving U.S. oil security."[280] Even then, these estimates, which focus exclusively on perfect substitution of domestic oil for foreign oil substitution and ignore dynamics, are too high and are likely even the wrong sign.

For the purposes of BOEM, these estimates fail to model the impact of increased domestic production of oil on U.S. consumption of oil imports. Specifically, the above estimates of the energy security premium for imported versus domestic oil assume perfect substitution (see Table 1), which does not hold according to MarketSim. Estimates of the energy-security premium can be derived for different levels of domestic-to-foreign substitution within the United States using the data in the papers discussed herein. That premium declines as substitution declines, and ultimately becomes negative. The premium turns from positive to negative at a substitution level of between 76% to 77%, meaning that if a one-barrel increase in U.S. production pushes out 0.76 to 0.77 barrels of foreign oil, there is an externality of $0.

As MarketSim implies a substitution rate of 92% over its model run (i.e., one barrel increase in U.S. consumption of U.S. produced oil decreases U.S. consumption of imported oil by 0.92 barrels),[281] which is calibrated to the base reference case of AEO consistent with a policy-as-usual scenario, this energy security premium is $0.30/barrel to $0.85/barrel. Given the value of internal consistency, it is important to note that NEMS, which is the model to which MarketSim is calibrated, produces an even lower net externality of $0.17 under 92% substitution. However, as discussed in Part I of this report, BOEM's substitution rates are too high compared to the literature and fail to account for the likelihood of future climate policy.[282] If the actual relevant substitution rate is at or below about 77%, this would suggest that there is actually a cost to energy security. In any event, even assuming BOEM's substitution rate, the energy security premium is very low.

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[278] EPA (2021), *supra* note 274, at 3-26 to -28.

[279] Krupnick et al., *supra* note 273; Brown (2018), *supra* note 276.

[280] Brown (2018), *supra* note 276, at 182.

[281] This figure was derived from BOEM's detailed results tab of MarketSim, which the authors of this report obtained through a Freedom of Information Act request. The calculation is change in U.S. consumption of oil imports divided by change in U.S. consumption of U.S.-produced oil (i.e., it is the change in U.S. consumption of foreign oil for a one-barrel increase in U.S.-produced oil). This figure differs from other substitution figures discussed in this report because it is focused only on domestic oil.

[282] *See supra* Part I.

Table C-1. Aggregate and net oil security premiums, 2015–2040 average (2021$ per barrel)

Model	Gross energy security premium: Consumption of imported oil	Gross energy security premium: Consumption of domestic oil	Net energy security premium with 100% Substitution: Imported versus domestic oil	Net Energy Security Premium with 92% Substitution	Net Energy Security Premium with 84% Substitution	Breakeven substitution rate
Benchmark-O	$7.91	$6.13	$1.78	$1.15	$0.52	77%
Benchmark-N	$1.87	$1.43	$0.45	$0.30	$0.15	76%
Benchmark-E	$5.52	$4.23	$1.29	$0.85	$0.41	77%
SVAR-BH	$1.28	$0.98	$0.30	$0.19	$0.09	77%
DSGE-S	$0.45	$0.32	$0.13	$0.09	$0.05	72%
NEMS	$1.07	$0.82	$0.25	$0.17	$0.08	77%
EPA	$3.60	$2.75	$0.85	$0.56	$0.27	76%

Reference: Gross and net energy security externality estimates are from Krupnick et al. (2017), Brown (2018), and EPA (2021) where rows represent the model used and columns represent the type of energy security.

The first three rows correspond to the old, new, and combined estimates from Brown (2018) discussed above using the Brown and Huntington (2013, 2015) approach cited by BOEM, while the fourth through sixth rows represent estimates from the SVAR, DSGE, and NEMS model. The last row refers to EPA (2021)'s estimates using elasticities derived using meta-analysis.

The first two columns of data equal the external costs of increased energy security risks from consuming imported oil and domestically produced oil, respectively, while the third column equals the difference between them. This latter value is equal to the net external energy security benefit of producing one barrel of U.S. oil assuming a 100% substitution rate of domestically produced oil for imported oil. The fourth and fifth columns equal the net external cost if the substitution rate is 92% and 84%, respectively. The sixth column equal the substitution rate necessary to ensure a $0 external energy security benefit/cost of producing one barrel of U.S. oil.

Short-Run vs. Long-Run Energy Security

There are also broader concerns beyond short-run security, namely long-run energy security and larger dynamics at play in longer time-horizons. As noted by Tietenberg and Lewis in their textbook *Environmental and Natural Resources Economics*, "We must consider vulnerability in a dynamic, rather than static, framework…The domestic supply expansion would…also tend to drain domestic reserves faster, which could make the nation more vulnerable in the long-run."[283] In fact, the drawing down of reserves of non-renewable resources to address potential energy insecurity in the near-term makes this resource unavailable for use in the future to address long-term energy insecurity. Thus, by expanding domestic production, the United States is really substituting short-run security for long-run security. The value of any such sub-

[283] Thomas H. Tietenberg & Lynne Lewis, Environmental and Natural Resources Economics 155, 157 (11th ed., 2018). Tietenberg and Lewis also state: "Because oil is a depletable resource, a user cost is associated with its efficient use. To reorient the extraction of that resource toward the present, as a self-sufficiency strategy would do, reduces future net benefits. Thus, the self-sufficiency strategy tends to be myopic in that it solves the short-term vulnerability problem by creating a more serious one in the future."

stitution must be governed by the social discount rate, which does not appear in any of the calculations in the literature. Beyond reduced oil supply in the long-run, to the extent that current resource extraction undermines domestically-produced renewables, there are long-run costs. Even if the impact of increased domestic oil production on domestic production of renewables is relatively small in the short-run, it may still have a large impact on medium-run and long-run energy security as even small amounts of renewables and carbon capture and storage projects can lead to substantial future price declines from learning-by-doing. In fact, lower oil prices may also disincentives infrastructure investment by energy companies, just as it disincentives conservation of oil resources by consumers.[284] Thus, increased current production could slow down the United States's transition to electrification by incentivizing further oil use and disincentivizing the necessary infrastructure investment leading to less diversification of the U.S. energy mix in the future and, thus, more future domestic energy security risks.

In contrast to these theoretical results, the Brown and Huntington (2013, 2015), Krupnick et al. (2017), Huntington (2018), and EPA (2021) estimates of energy security premiums over time point in the opposite direction: their energy security premiums increase over time rather than decrease. As the underlying elasticities and probabilities of supply disruptions remain constant, these increases are driven by projections of world oil market conditions over time, which are almost universally taken from EIA's AEO forecasts. These forecasts often predict increasing world and United States oil consumption, as well as increased U.S. domestic production, oil prices, and GDP.[285] This expansion of oil consumption by the United States increases domestic vulnerability, while increasing GDP leads to larger losses, putting upward pressure on the domestic security premiums. As the oil security premium associated with substituting domestic production for foreign production remains constant,[286] it is the rise in oil consumption over time that drives increasing premiums over time.

However, as noted by BOEM, AEO's reference scenario represents policy-as-usual. If nations move to address climate change, oil and gas consumption and imports will likely decline and domestic renewable energy will likely increase leading to a decline in the energy security premiums.[287] Similarly, substitution between oil and electricity will likely increase in the transportation sector resulting in a greater impact of increased domestic production on domestically produced renewables. The combination of limited availability of oil imports and high levels of substitution between domestic oil and domestic electricity (presumably generated from domestic renewable sources) point towards extremely limited security benefit of increased domestic oil production in the future. This should imply a decline in energy security premiums over time as oil consumption potentially plummets.

In our report, we conduct an experiment to estimate the global substitution rate of emissions from increased production in the OCS as proposed in the five-year plan. Using this model run, we can also estimate the domestic substitution rate relevant for calculating the net energy security externality from producing additional oil in the OCS. In our central climate action run, we find that the relevant substitution rate declines from 92% to 84% implying security benefits between $0.15/barrel to $0.41/barrel according to the Brown (2018) updated estimates. The NEMS model implies a value of $0.08 using an 84% domestic substitution rate, though this may still overstate the energy security benefits as the NEMS model used to estimate the energy-security premiums is calibrated on a current policy scenario instead of the mostly likely (climate action) scenario. Even still, these estimates may overstate the risk premium as these risk premium estimates do not factor in other energy sources (e.g., natural gas or renewables), which are domestically produced or long-run energy security concerns.

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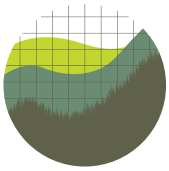
[284] Peter M. Schwarz, *Energy Security*, in Energy Economics (Routledge, 2017).
[285] *See, e.g.*, Brown and Huntington (2013), *supra* note 273; Brown (2018), *supra* note 276
[286] Krupnick et al., *supra* note 273, at 18.
[287] Proposed Program, *supra* note 2, at 5-52 to -56.



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