June 16, 2016

Bureau of Ocean Energy Management

Subject: Comments on the 2017-2022 Outer Continental Shelf (OCS) Oil and Gas Leasing Proposed Program, BOEM–2016–0003

The Institute for Policy Integrity at New York University School of Law[1] respectfully submits these comments to the Bureau of Ocean Energy Management (BOEM) on its proposed five-year offshore leasing program for 2017-2022 ("Proposed Program"). Policy Integrity is a non-partisan think tank dedicated to improving the quality of government decisionmaking through advocacy and scholarship in the fields of administrative law, economics, and public policy.

The Outer Continental Shelf Lands Act (OCSLA) requires the Secretary of the Interior to develop five-year schedules that specify the timing for offshore leasing activity, after weighing the "economic, social, and environmental values of the renewable and nonrenewable resources."[2] When making these decisions, the agency should strive to consider all relevant factors, and to quantify all costs and benefits as fully and as accurately as possible—these norms are enshrined in legal precedents[3] and executive orders.[4]

Policy Integrity commends the agency's progress on addressing environmental, social, and economic uncertainty in its Proposed Program. Notably, BOEM qualitatively considers the option value, or informational value of delaying leasing until more information is available on relevant environmental, social, and technological uncertainties. In addition, BOEM will now consider environmental and social costs in its "hurdle price" analysis that helps determine whether and when to offer areas for lease.

Building on this progress, we recommend that BOEM take additional steps to strengthen its analysis in line with best practices and OCSLA's mandate to balance economic, social, and environmental values. Specifically, BOEM should:

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[1] No part of this document purports to present New York University School of Law's views, if any.
[2] 43 U.S.C. § 1344(a) (2010).
[3] *California v. Watt* ("*Watt I*"), 688 F.2d 1290, 1317 (D.C. Cir. 1981) (holding courts can review Interior's leasing discretion for arbitrariness and failure to consider relevant factors); *Motor Veh. Mfrs. Ass'n v. State Farm Ins.*, 463 U.S. 29, 43 (1983) (agency decisions are arbitrary if they entirely fail to consider an important aspect of the problem).
[4] Exec. Order No. 12,866 § 1(a), 58 Fed. Reg. 51,735, 51,735 (Oct. 4, 1993) (codified at 45 C.F.R. pt. 88); Exec. Order No. 13,563 § 1(a), 76 Fed. Reg. 3821, 3821 (Jan. 18, 2011) (affirming cost-benefit principles specified in Exec. Order 12,866).

- Reconsider its assumption that the greenhouse gas emissions generated in a "no sale" scenario would be essentially identical to the emissions in a lease sale scenario;
- Include the cost of downstream greenhouse gas emissions in its net benefits calculation;
- Continue to improve its option value analysis and application;
- Weigh option value when deciding where and when to issue leases at both the program and lease sale stages, and only issue leases if the economic, social, and environmental benefits outweigh the costs;
- Adjust minimum bids, rents and royalties to compensate the public for option value and the cost of environmental externalities associated with leasing; and
- Further improve its hurdle price analysis by accounting for economic, environmental and social uncertainty.

In addition to these general recommendations for the Proposed Program, we provide additional suggestions in the interest of improving BOEM's modeling. With respect to its MarketSim and Offshore Environmental Cost Model and resulting analyses, BOEM should:

- Conduct a thorough review of the literature and provide more detail about key parameter values including oil and natural gas elasticities;
- Conduct sensitivity analyses – including Monte Carlo simulations – to improve model transparency and accuracy;
- Adjust the models to accurately track upstream and downstream GHG emissions;
- Conduct model comparisons and backcasting to improve transparency and accuracy with respect to MarketSim and power sector models, in general; and
- Disclose the models' limitations when interpreting and discussing their results.

We look forward to working with BOEM on these issues to strengthen the Final Program.

I. Comments on BOEM's Proposed Five-Year Program

Section 18(a)(1) of OCSLA requires that BOEM conduct the Program "in a manner which considers economic, social, and environmental values of the renewable and nonrenewable resources contained in the OCS and the potential impact of oil and gas exploration on other resource values of the OCS and the marine, coastal, and human environments."[5] OCSLA Section 18(a)(3) requires "proper balance between the potential for environmental damage, the potential for discovery of oil and gas, and the potential for adverse impact on the coastal zone."[6]

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[5] 43 U.S.C. § 1344(a)(1).
[6] *Id.* § 1344(a)(3).

To effectuate this balance, BOEM conducts a cost-benefit analysis for offshore oil and natural gas production in the program areas under consideration in the Proposed Program, as well as a cost-benefit analysis of forgoing that production, or the "No Sale" option.[7] As described below, BOEM should improve its analysis for the 2017-2022 Proposed Program in order to strike an appropriate balance among economic, social, and environmental values.

A. BOEM's assumption that the greenhouse gas emissions generated in a "no sale" scenario would be essentially identical to the emissions in a leasing scenario is not based on any actual modeling of greenhouse gas emissions, and should not be treated as fact.

OCSLA requires BOEM to balance development benefits and risks and to receive fair market value when leasing offshore resources.[8] The climate change impact of BOEM's potential leasing ("Program") and "no action" ("No Sale") scenarios are highly relevant to its OCSLA Section 18 inquiry. However, BOEM fails to appropriately measure and weigh the downstream greenhouse gas emissions associated with its Program and No Sale alternatives.

BOEM states that in the No Sale option, the reduction in supply of offshore oil and natural gas "would cause only a small increase in hydrocarbon prices, so there would be very little decrease in the quantity of oil and natural gas demanded. Instead, increased imports and domestic onshore production as well as fuel switching would meet continued domestic demand for oil and natural gas products." [9] In addition, BOEM states, "[w]ith oil from the new Program not available, increased onshore production of oil, gas, and other energy sources such as coal would generate new air emissions. Also, replacement imports of oil cause corresponding increases in air emissions and oil spill risks from increased tanker operations along the U.S. coastal areas receiving the oil…"[10] However, there is little analytical support for these conclusions.

BOEM's Offshore Environmental Cost Model (OECM) calculates the level of emissions for carbon dioxide, methane, and nitrous oxide that would be emitted under the *production* and *transport* of both the Program and the No Sale Option. But importantly, it fails to model or calculate the resulting emissions from *downstream consumption* and end use. Instead, BOEM states that it, "does not consider the impact of the consumption of any

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[7] *See* U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF OCEAN ENERGY MANAGEMENT, 2017-2022 OUTER CONTINENTAL SHELF OIL AND GAS LEASING PROPOSED PROGRAM 5-10 to 5-20 (March 2016) (hereinafter "PROPOSED PROGRAM").
[8] 43 U.S.C. § 1344(a)(2).
[9] *See* PROPOSED PROGRAM at 5-16.
[10] *Id*.

of the fuel sources as they are *assumed to be roughly equivalent* under both the Program and No Sale Option."[11] Therefore, it does not calculate how a significant change in U.S. oil and natural gas supply will change price and demand and, therefore, total combustion and emissions.

Based only on the assumption that downstream emissions for the Program and No Sale options are "roughly equivalent," and its calculation of upstream emissions, BOEM concludes that "the emissions for carbon dioxide, methane and nitrous oxide are *greater* under selection of the No Sale Option than from the Program. Thus, there is a *reduction in GHGs from production on the OCS relative to selection of the No Sale Option*."[12] BOEM's assumption is unsupported by any modeling, and is called into question by several methodological inconsistencies.

First, basic economic principles of supply and demand provide that significant changes in oil and natural gas supply will affect oil and gas prices and, therefore, consumption levels and resulting greenhouse gas emissions. In the No Sale option, the cost of using oil and natural gas to generate electricity would be higher relative to the cost under the Program option. Demand would fall as consumers conserve energy, increase efficiency, or substitute other energy sources, including renewable sources. This, in turn, would reduce downstream greenhouse gas emissions, as compared to the Program option's climate impacts.[13] These are textbook economic principles.

While BOEM does acknowledge that *some* level of substitution would occur in the No Sale option, it understates this potential effect by saying merely that it "would cause only a small increase in hydrocarbon prices, so there would be very little decrease in the quantity of oil and natural gas demanded."[14] Based on our review of the models that BOEM used to prepare the analysis underpinning the Proposed Program—and as BOEM acknowledges—BOEM's MarketSim model and its 2015 revised Offshore Environmental Cost Model (OECM) do not adequately track downstream greenhouse gas emissions associated with offshore leasing. For example, the air quality module of OECM accounts for greenhouse gas and other air pollutant emissions from *upstream* activity in the natural gas and oil industries, alone. In short, BOEM does not know what the resulting greenhouse gas emissions are for each scenario.

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[11] BUREAU OF OCEAN ENERGY MANAGEMENT, DRAFT ECONOMIC ANALYSIS METHODOLOGY FOR THE 2017–2022 OCS OIL AND GAS LEASING PROGRAM 1-24 (2016), http://www.boem.gov/Economic-Analysis-Methodology/ (hereinafter "BOEM, 2017-2022 DRAFT ECONOMIC ANALYSIS") (emphasis added).
[12] PROPOSED PROGRAM at 3-1.
[13] For a more detailed analysis of these textbook principles *see* Brief of the Institute for Policy Integrity at New York University School of Law as Amicus Curiae in Support of Petitioners-Appellants, *WildEarth Guardians v. U.S. Bureau of Land Management*, Case No. 15-8109 (10th Cir. 2016), *available at* http://policyintegrity.org/documents/10th_Cir_BLM_Brief.pdf.
[14] PROPOSED PROGRAM at 5-16.

Furthermore, to the extent that BOEM relies upon elasticity of supply values that it uses in MarketSim to support its assumption that there would be equivalent greenhouse gas emissions in the No Sale and Program scenarios, BOEM uses an elasticity of supply of U.S. oil that is at least 25 years old. In addition, BOEM assumes identical elasticities of supply and adjustment parameters for onshore oil production in the lower 48 states, offshore oil production in the lower 48 states, Alaskan oil production, and all other domestic oil production in its MarketSim model. As discussed in more detail below in our comments on BOEM modeling, these identical elasticities of supply are unrealistic, given that the marginal cost curves of onshore, offshore, and Alaskan oil production are expected to be somewhat different, because of their unique production methods, transportation technologies, and other factors.

In short, BOEM's analytical modeling does not support its assumption that the greenhouse gas emissions in the No Sale and Program scenario would be identical or even "roughly equivalent."[15] BOEM should not rely on this assessment to carry out its OCSLA Section 18 mandate to balance development benefits and risks and receive fair market value when leasing offshore resources.[16]

Instead, in both its Programmatic Environmental Impact Statement and Proposed Five-Year Program analysis, BOEM should analyze the upstream and downstream climate and environmental impacts of its Proposed Program and the No Sale option. Complete and transparent disclosure of greenhouse gas emissions helps decision makers and the public make better decisions. BOEM should model each alternatives' energy market effects and resulting greenhouse gas emissions. This requires accounting for the substitution effects induced by each scenario—such as the substitution of additional onshore natural gas, oil, and renewable energy production and consumption (as well as increased energy conservation) in lieu of new offshore production and related consumption that would result from the "No Sale" option.

B. BOEM should include the cost of the downstream greenhouse gas emissions in its net benefits calculation.

OCSLA requires BOEM to balance development benefits and risks and to receive fair market value when leasing offshore resources. BOEM calculates the net benefits of the identified program areas by determining the net economic value of producing oil and gas from the area (the revenue generated from oil and gas minus the private expense of producing it), adding the domestic economic surplus (the benefits to consumers and producers from lower oil and gas prices), and subtracting the social and environmental

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[15] *See* BOEM, 2017-2022 DRAFT ECONOMIC ANALYSIS, *supra* note 11 at 1-24; PROPOSED PROGRAM at 3-1, 5-6.

[16] 43 U.S.C. § 1344(a)(2).

costs that BOEM quantifies using its Offshore Environmental Cost Model.[17] The net benefits of producing oil and gas from the program areas are compared to the net benefits of the no leasing alternative to calculate the incremental net benefits of including each area in the program.[18]

Courts have endorsed BOEM's use of cost-benefit analysis and quantification of environmental externalities to the fullest extent practicable in BOEM's net economic value analysis.[19] Executive Orders 12,866 and 13,563 direct agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits.[20] In making net benefits determinations, agencies are directed "to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible."[21]

However, in the Proposed Program, BOEM's net economic value analysis omits several conceivable effects, including, for both the Proposed Program and the No Sale options, greenhouse gas emissions associated with consumption.

In addition to the methodological shortcomings of BOEM's downstream greenhouse gas analysis highlighted above, which render its net benefits analysis incomplete, BOEM's Draft Economic Analysis Methodology for the 2017–2022 OCS Oil and Gas Leasing Program provides another questionable rationale for excluding downstream greenhouse gas emissions from its net benefits calculation: "[t]he net benefits analysis does not include the environmental and social costs of the downstream impacts of consuming oil and natural gas. This analysis considers only actions within the Secretary's authority."[22] This rationale is inconsistent with best practices for agency economic analysis.[23] Moreover, BOEM's explanation does not align with how it actually conducted its analysis; for example, BOEM does not have authority over greenhouse gas emissions from "the round-trip tanker voyages necessary to transport the oil to the U.S." that would arise in the No Sale option, yet it includes these costs in its net benefits analysis.[24]

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[17] PROPOSED PROGRAM at 5-10 to 5-20.
[18] *Id*. at 5-10 to 5-20.
[19] *California v. Watt*, 712 F.2d 584 (D.C. Cir. 1983) ("Watt II"); *Natural Resources Defense Council, et al. v. Hodel*, 865 F.2d 288 (D.C. Cir. 1988).
[20] Exec. Order 13,563, § 1(b)(3).
[21] *Id*. § 1(c).
[22] BOEM, 2017-2022 DRAFT ECONOMIC ANALYSIS, *supra* note 11 at n. 17.
[23] *See, e.g.*, NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS, OFFICE OF POLICY, U.S. ENVIRONMENTAL PROTECTION AGENCY, GUIDELINES FOR PREPARING ECONOMIC ANALYSES 8-1 to 8-6 (May 2014), https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.
[24] PROPOSED PROGRAM at 3-1.

After properly modeling the downstream greenhouse gas emissions for both the No Sale and Program scenarios (as discussed above), BOEM should use the Social Cost of Carbon and Social Cost of Methane to assign a cost value to the direct and indirect greenhouse gas emissions from the program, so that these costs can be included in its net benefit analysis and decision making process.[25] Even small relative increases or decreases in greenhouse gas emissions can be valued using the Social Cost of Carbon and Social Cost of Methane. A full analysis of these downstream greenhouse gas emission costs and benefits should be conducted for the Final Program.

C. BOEM should continue to analyze option value, and strengthen its option value techniques and application.

BOEM has taken an important step by using option value to inform its five-year program and help determine the optimal size, timing, and location of lease sales. In addition, BOEM should apply option value in a more transparent, quantitative manner.

Option value derives from the ability to delay decisions until later, when more information is available. The concept's most familiar application is in the financial markets, where investors calculate the value of options to wait for more information on stock prices before deciding whether to buy or sell shares. A conceptually identical and well-established methodology exists to quantify the value of waiting to gain greater information about environmental, social, and technological uncertainties.[26]

In this proposed program, BOEM includes a detailed discussion of option value and related resource valuation concepts.[27] Specifically, BOEM notes that:

- Environmental and social cost uncertainties can affect the size, timing, and location of offshore leasing;
- Environmental and cost uncertainties can affect the potential value and possible risks of Outer Continental Shelf (OCS) oil and gas leasing in each planning area;

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[25] *See* INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, UNITED STATES GOVERNMENT, TECHNICAL SUPPORT DOCUMENT: - TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS - UNDER EXECUTIVE ORDER 12866 (July 2015), https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.

[26] *See generally*, Avinash K. Dixit & Robert S. Pindyck, (1994); Michael A. Livermore, *Patience Is an Economic Virtue: Real Options, Natural Resources, and Offshore Oil*, 84 U. COLO. L. REV. 581, 591 (2013); *see also* Anthony C. Fisher, *Investment under Uncertainty and Option Value in Environmental Economics*, 22 RES. & ENERGY ECON. 197 (2000); W. Michael Hanemann, *Information and the Concept of Option Value*, 16 J. ENVTL. ECON. & MGMT. 23 (1989); Iulie Aslaksen & Terje Synnestvedt, *Are the Dixit-Pindyck and the ArrowFisher-Henry-Hanemann Option Values Equivalent?* (Statistics Norway, Discussion Paper No. 390, 2004).

[27] PROPOSED PROGRAM at 10-2 to 10-13.

- Option value can be a component of the fair market value of a lease; and
- The agency can raise minimum bids, rents, and royalties for leases to account for option value.[28]

This is a strong start. Now, BOEM should quantify the option value of delaying leasing until more information is available on relevant environmental, social, and technological uncertainties. Doing so would be consistent with federal Court of Appeals precedent, and BOEM can draw from established economic methods to conduct this analysis.

First, the decision of the U.S. Court of Appeals for the D.C. Circuit in *Center for Sustainable Economy v. Jewell* recognizes the relevance of option value to BOEM's offshore leasing program, as well as the value of quantification. The D.C. Circuit's decision acknowledged that there is "a 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."[29] Ultimately, the D.C. Circuit found that BOEM's failure to quantify option value was not arbitrary or irrational at this time because the methodology for quantifying option value is not "sufficiently well established."[30]

Importantly, the D.C. Circuit's indicated that quantitative methods might be developed in the future, and such methods would be preferable to a qualitative treatment of option value. The court stated: "Our holding is a narrow one . . . the agency is not permitted to substitute qualitative assessments for well-established quantitative methods whenever it deems such substitutions convenient."[31] The court further noted: "Had the path been well worn, it might have been irrational for Interior not to follow it."[32] This ruling strongly suggests that future advances in option value research could compel the agency to better quantify the risks and option value associated with its leasing practices, which could pay enormous dividends to the American public by prioritizing lower-risk leasing and securing more favorable fiscal terms. The D.C. Circuit's decision that option value is an important component of this analysis should lead BOEM to develop methodologies to quantify it.

Second, well-established methodologies exist to quantify option value in the natural resources context. The importance of option value to evaluate decisions under uncertainty

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[28] *Id*. at 10-2 to 10-6.
[29] *Center for Sustainable Economy v. Jewell,* 779 F.3d 588, 612 (D.C. Cir. 2015).
[30] *Id*. at 611.
[31] *Id*. at 612.
[32] *Id*.

has been widely recognized in the economics community for several decades.[33] The option value framework has long been applied to natural resource extraction decisions, including offshore oil drilling.[34] In fact, the petroleum industry routinely accounts for the value of waiting for more information on uncertain future oil prices and production costs, which explains the frequent practice of companies purchasing offshore leases but waiting long periods of time to begin drilling.[35] Any company that failed to account for option value would risk suboptimal returns on its leases compared to more sophisticated competitors, because failing to account for option value "is not just wrong; it is often very wrong."[36]

In this five-year program, BOEM considers the informational value of delay with respect to price uncertainty, as well as environmental and social uncertainty. However, the agency stated that "[i]t is not hard to envisage the broad outlines of a real options model of environmental impact; but it is surpassingly difficult to specify and estimate a useful, empirical model of that type."[37] However, by not using economic methodologies that would incorporate the option value of a resource, the proposed program overlooks an important factor in the decision, does not quantify all economic and environmental costs and benefits as accurately as possible, and ultimately may not make the optimal choices on the timing of leases.

For example, in determining the "Net Social Value" of leasing in each OCS region, BOEM uses three different oil price scenarios to help it calculate a range of Net Social Values for each OCS region. But, it fails to use quantitative analysis to help it weigh the environmental and social uncertainties associated with leasing and production in each region.[38] To assist BOEM, Policy Integrity attaches an exhibit to these comments with a

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[33] For practical guides to calculating options value, see, for example, Prasad Kodukula & Chandra Papudesu, PROJECT VALUATION USING REAL OPTIONS: A PRACTITIONER'S GUIDE (2006) and Johnathan Mun, REAL OPTIONS ANALYSIS: TOOLS AND TECHNIQUES FOR VALUING STRATEGIC INVESTMENT AND DECISIONS (2d Ed. 2005).
[34] James L. Paddock et al., O*ption Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases*, 103 Q. J. ECON. 479 (1988); Jon M. Conrad & Koji Kotani, *When to Drill? Trigger Prices for the Arctic National Wildlife Refuge*, 27 RES. & ENERGY ECON. 273 (2005).
[35] *See* Michael Rothkopf et al., *Optimal Management of Oil Lease Inventory: Option Value and New Information* (Rutgers Center for Operations Research, Research Report 22-2006, 2006); Ryan Kellog, *The Effect of Uncertainty on Investment: Evidence from Texas Oil Drilling* (Nat'l Bureau of Econ. Res., Working Paper No. 16,541, 2010); Timothy Dunne and Xiaoyi Mu, *Investment Spikes and Uncertainty in the Petroleum Refining Industry* (Fed. Reserve Bank of Cleveland, Working Paper No. 08-05, 2008); *see also* William Bailey et. al., *Unlocking the Value of Real Options*, OILFIELD REVIEW, Winter 2003, at 4 (describing how companies including ChevronTexaco, Anadarko, and El Paso Corporation incorporate real options into their decisionmaking processes).
[36] Avinash K. Dixit & Robert S. Pindyck, INVESTMENT UNDER UNCERTAINTY (1994).
[37] PROPOSED PROGRAM at 5-10 to 5-11.
[38] *Id*.

proposed framework for quantifying the option value associated with leasing in each OCS region.

Third, BOEM should take a leadership role in analyzing and quantifying option value. Categories of quantified and unquantified costs and benefits are not immutable, and important categories of benefits that were once unquantified have subsequently become quantified.[39] Federal government agencies play an important role in moving categories of costs from the unquantified category to the quantified category, by undertaking quantification projects directly, as well as by funding research.[40] For example, the social cost of carbon (SCC) is a figure now widely used by government agencies to estimate the benefit from the reduction of one ton of carbon dioxide emissions.[41] Before 2008, agencies did not monetize this benefit, considering it too difficult given the uncertainty surrounding climate change effects and the complexity of translating climate damages into dollars.[42]

Similarly, BOEM or Interior should consider forming a working group to develop a methodology for calculating the option value associated with leasing in different areas. Indeed, such an approach would be consistent with both OCSLA's mandate to weigh the "economic, social, and environmental values of the renewable and nonrenewable resources" and consider all relevant factors,[43] as well as Circular A-4's instruction to quantify all costs and benefits as fully and as accurately as possible, including the option to delay.[44] Once created, this model could be used and refined in future government natural

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[39] Revesz, *Quantifying Regulatory Benefits*, 102 Cal. L. Rev. 1423, 1425, 1436 (2014).
[40] *Id.* at 1436, 1450-1456.
[41] *See* Michael Greenstone, Elizabeth Kopits & Ann Wolverton, *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 REV. ENVTL. ECON. & POL'Y, 23, 23 (2013) (defining the Social Cost of Carbon as a measure of "monetized damages associated with an incremental increase in carbon emissions").
[42] *See* Revesz, *supra* note 39 at 1434, 1439. In *Center for Biological Diversity v. National Highway Transportation Safety Administration*, the Ninth Circuit struck down the National Highway Transportation Safety Administration's corporate average fuel economy (CAFE) standards for light trucks covering model years 2008-2011 because the agency arbitrarily refused to quantify the benefits of reducing greenhouse gas emissions. 538 F.3d 1171, 1200 (9th Cir. 2008). The decision likely helped to set in motion the process of interagency collaboration to establish the Social Cost of Carbon. Revesz, *supra* note 39 at 1435.
[43] 43 U.S.C. § 1344(a) (2010).
[44] U.S. OFFICE OF MANAGEMENT &BUDGET, CIRCULAR A-4, at 39 (2003). The Circular contains a detailed section on the proper treatment of uncertainty, including uncertainty about environmental and social costs like loss of habitat, risks to endangered species, harms to human health and safety, and climate change. The section explains that: "Real options" methods have . . . formalized the valuation of the added flexibility inherent in delaying a decision. . . . [A] benefit can be assigned to the option to delay a decision. That benefit should be considered a cost of taking immediate action versus the alternative of delaying that action pending more information." The section further specifies that uncertainty should be quantified whenever possible, and that postponing a regulatory

resources leasing decisions by BOEM and other agencies, such as the Bureau of Land Management (BLM). Further, it could earn the American public billions of dollars net benefits from more optimal timing, location, and lease terms, as well as avoided catastrophic oil spills and other costs of high-risk drilling. In short, the up-front investment needed to quantify the option value associated with offshore leasing may be vastly outweighed by the long-term societal benefits.

D. BOEM should weigh option value when deciding where and when to issue leases at both the program and lease sale stages, and only issue leases if the economic, social, and environmental benefits outweigh the costs.

In the Arctic, Atlantic, and deepwater environments, there is heightened environmental uncertainty around the consequences of drilling, making an option value analysis useful at the program stage, as well as the lease sale stage.

There is significant uncertainty about the effects of oil spills, as well as offshore drilling's impact on wildlife, fisheries, and recreation. Certain regions, including the Arctic and Atlantic, pose relatively greater environmental and social uncertainty, given their limited track record of commercial drilling, restricted drilling infrastructure, and volatile weather. For example, the recent decision by the White House to protect 9.8 million offshore acres of the Chukchi and Beaufort Seas from oil and gas development, indefinitely, through a presidential memorandum reflects similar concerns and embraces a cautious approach consistent with option value. The Administration's recognition of the extreme risks and uncertainties inherent in Arctic OCS drilling reinforces the utility of an option value approach to BOEM'S five-year planning process.

Similarly, the Atlantic region is characterized by coastal population centers, sensitive habitat, and a lack of fixed infrastructure and existing drilling operations, all of which heighten the uncertainty associated with offshore leasing. In addition to large coastal populations that would be directly affected by oil spills, the Atlantic planning area ranks among the highest environmental sensitivity scores for all of the regions.[45] Moreover, ocean-dependent tourism, commercial and recreational fishing, and commercial shipping and transportation are established and important economic uses in and along the coast of the Mid- and South Atlantic Program Area that could be potentially impacted by oil and gas activity. Under current conditions, the economic value of commercial fishing along the

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decision is always an alternative, especially for irreversible decisions, since "the costs of being wrong may outweigh the benefits of a faster decision." Leasing and extracting natural resources are essentially irreversible decisions, and many of the potential environmental and social damages from drilling are irreversible as well. In contrast, the decision not to drill can be undone very easily.

[45] PROPOSED PROGRAM at 7-11 to 7-13.

coast of the MidAtlantic Planning Area could be more than $1.5 billion in total value added gross domestic product (GDP); ocean-dependent tourism in the Mid- and South Atlantic Planning Areas accounts for more than $6.5 billion and $4.4 billion in value added, respectively, to adjacent coastal areas.[46]

Consistent with an option value approach that weighs the risks of leasing against the utility of not leasing and waiting for more information about relative risks and benefits, BOEM does *not* include any proposed lease sales in the Atlantic region during the 2017-2022 Program.[47] BOEM states: "An important consideration in removing the Mid- and South Atlantic Program Area from the Proposed Program is concern regarding competing uses of the Program Area and the potential harm that oil and gas development could pose to those existing uses. The range, number and nature of conflicts in the Atlantic are unique to the region and require additional work to deconflict prior to including a lease sale in the Program."[48]

BOEM should continue to take these heightened uncertainties and sensitivities into account when finalizing its 2017-2022 Program, using option value analysis to aid in deciding when and where to issue leases. BOEM should issue leases during this five-year term only if the economic, social, and environmental benefits outweigh the costs, including the foregone value of delay. Because the federal government holds a perpetual option to develop OCS resources, it need not lease the rights to develop oil and gas resources to private companies during this five-year term in each region identified in this draft program. And, it must not do so if the societal benefits of leasing do not outweigh the costs. As such, BOEM should value the option to delay drilling beyond this five-year term; failing to do so risks leasing too many areas, too soon, and for too low a price. Even a qualitative analysis of option value may very well show that the government should not lease in certain areas in the near term. A quantitative option value analysis would more fully and transparently disclose the uncertainties associated with drilling in this region.

BOEM should also further assess option value at the lease sale stage, when more information on the risks of leasing, and the remaining uncertainties can be considered. Finally, as described below, the agency can and should adjust minimum bids, rents and royalties to compensate the public for remaining uncertain effects, as well as environmental externalities associated with drilling.

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[46] PROPOSED PROGRAM at S-9.
[47] *See* PROPOSED PROGRAM at S-3.
[48] *Id*. at S-9.

E. BOEM should adjust minimum bids, rents and royalties to reflect option value and the environmental and social externalities of resource development.

BOEM has discretion to adjust bids, rents and royalties to restore the proper balance between efficient levels of offshore development and safeguarding environmental and social values. The agency must collect a return of "fair market value for the lands leased and the rights conveyed."[49] The term "fair market value" is not defined in the statute, but the agency has interpreted the phrase to be based on the "value of the right to explore for and . . . develop" offshore resources, and not simply on the value of oil and gas actually produced.[50] More generally, the agency has discretion to prescribe "rental and other provisions" as conditions of leases.[51]

BOEM should interpret "fair market value" in light of OCSLA's overriding goal of balancing the nation's environmental and energy interests, as well as the agency's broad authority to prescribe lease provisions. A definition of "fair market value" that maximizes social welfare should account for the market price of the energy resource, the option value of leasing the resource, and the social and environmental cost of production and transportation—the cost to American taxpayers of production on public lands due to non-internalized externalities.[52]

BOEM should clarify how option value will be incorporated into later development stages. BOEM has acknowledged that the fiscal terms for leases can be tailored at the lease sale stage to improve the timing of activities where option value is found to be significant.[53] At the lease sale stage, BOEM should conduct an option value analysis to help it decide whether to lease all of the tracts initially identified for sale, and to set the specific minimum bids, rents, and royalties associated with leasing. For example, BOEM could use a quantitative model to assess environmental, social, and economic uncertainty, and use this model to adjust minimum bids. In the Proposed Program, BOEM acknowledges this possibility, stating: "Although difficult to do in practice, conceptually setting fiscal terms appropriately (e.g., appropriate levels of minimum bids or royalties) can provide another policy instrument for discouraging the premature acquisition, exploration, and development of marginally valued blocks as these terms increase the costs of blocks, thereby making them uneconomic to acquire at market prices below the hurdle prices."[54]

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49 43 U.S.C. § 1344(a)(4).
50 BOEM, PROPOSED OUTER CONTINENTAL SHELF OIL & GAS LEASING PROGRAM: 2012-2017 at 161 (2011).
51 43 U.S.C. § 1337(b)(6).
52 Externalities are costs borne by the public at large, not by the responsible party or polluter.
53 PROPOSED PROGRAM at 10-3.
54 *Id*. (citing Davis and Schantz 2000).

Current minimum bids, rents and royalties do not adequately incentivize companies to wait to drill until information on environmentally safer drilling techniques may emerge. Traditionally, areas with a history of development and greater proximity to available infrastructure have been offered with more taxing fiscal terms and shorter initial lease periods. For example, "frontier areas" have typically been offered with less taxing fiscal terms and longer initial periods. However, if the option value associated with developing frontier areas is fully accounted for in setting the lease terms, the minimum bid and rental rate should likely be raised in order to account for the informational value of delay.

Finally, BOEM should consider raising the rental royalty rates for leases that are expected to result in greater environmental externalities. In bidding on leases and developing those leases, private companies do not fully internalize the costs that offshore exploration and drilling impose on coastal and marine biota and habitats, air quality, property values, recreation, subsistence harvests, and commercial fishing.[55] Greenhouse gases are also emitted unchecked during the process of energy production and transportation from offshore regions.[56] Liability regimes may cover some costs from catastrophic spills, but the public is never compensated for many significant environmental, health, and economic damages caused by exploration and drilling operations. Because lessees have externalized many costs of energy development onto the public, offshore energy deposits are currently developed at an inefficiently high rate.

BOEM should adjust rents and royalties to ensure that the government collects a fair return for these valuable rights, and to restore the proper balance between efficient levels of offshore development and safeguarding environmental and social values. Increases could be based on average external costs generated by operations in each offshore planning region. For greenhouse gases emitted during production, the agency can use the Social Cost of Carbon and Social Cost of Methane to price the externality.[57] Policy Integrity has analyzed how such royalty rate increases can be measured and implemented in the case of federal coal production.[58] This analysis may be relevant to future work on tailoring offshore royalty rates to recoup the social and environmental costs of production.

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[55] *See* BOEM, FORECASTING ENVIRONMENTAL AND SOCIAL EXTERNALITIES ASSOCIATED WITH OCS OIL AND GAS DEVELOPMENT: THE REVISED OFFSHORE ENVIRONMENTAL COST MODEL (2012).
[56] *See* U.S. EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2012, at 3-54 (2014).
[57] *See* INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2010).
[58] *See* Jayni Foley Hein and Peter Howard, *Illuminating the Hidden Costs of Coal*, Institute for Policy Integrity, New York University School of Law (Dec. 2015), *available at* http://policyintegrity.org/files/publications/Hidden_Costs_of_Coal.pdf.

F. BOEM should further improve its hurdle price analysis by accounting for economic, environmental and social uncertainty.

BOEM's Proposed Program, for the first time, considers environmental and social costs in its hurdle price analysis, which it uses to determine whether offering an area for lease in the present Program would provide greater economic value compared to delaying and offering the area in a future Program.[59] This revision provides the agency with more information on how timing and location considerations can maximize social value.

The hurdle price for each program area is compared to actual prices prior to each lease sale held under the Program. In this way, hurdle prices inform decision-making at both the Program stage and lease-sale stage. Though hurdle price analysis is only one component of the detailed analysis Interior undertakes in its five-year plan, incorporating environmental and social costs in its hurdle price analysis is an important step forward.

While BOEM's hurdle price analysis accounts for price uncertainty, it fails to account for environmental and social uncertainty.[60] Accordingly, in the Program stage, the hurdle price findings should be taken as a guide only for price-based option value. And to capture the option value of new information becoming available that could make an area more or less profitable to lease, the Secretary may choose to include or exclude areas regardless of the relationship between the hurdle prices and current prices. In the attached economic appendix, we describe how BOEM can calculate a "social hurdle price" by modifying the agency's existing dynamic programming model to include externalities associated with drilling (as BOEM now does in the Proposed Program) and the corresponding uncertainty underlying them (which BOEM should do for the Final Program). A social hurdle price could then be calculated for each lease sale, or subsection of tracts in a lease sale, in order to account for externalities and environmental, social, and economic uncertainty.

II. Comments on BOEM's MarketSim and Offshore Environmental Cost Model (OECM)

As compared to capacity expansion models— such as U.S. Energy Information Administration (EIA)'s National Energy Modeling System (NEMS) model and ICF International's Integrated Planning Model (IPM)—BOEM's MarketSim is a relatively simple partial-equilibrium model of U.S. energy markets. Specifically, it models the supply and demand of multiple energy resources (coal, natural gas, oil)[61] and energy by four domestic

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[59] PROPOSED PROGRAM at 10-3, 10-13.

[60] *Id*. at 10-16.

[61] Renewables (nuclear, hydro, wind, solar, other electric, net imports) are captured in the energy supply function, although in less detail.

sectors (residential, commercial, industrial, and transportation) at the national scale.[62] MarketSim's key demand and supply parameters are elasticities and adjustment parameters. Own-price and cross-price demand and supply elasticities – which capture the percentage change in quantity demanded or supplied for a percentage change in price – are drawn from the literature, though some parameters were derived from NEMS or from the expert input of Dr. Stephen Brown[63] when peer-reviewed estimates were unavailable in the literature.

BOEM calculates adjustment rates – which limit the portion of demand and supply that can change annually – using estimates of the lifespan of "energy producing and consuming capital" drawn from the literature; parameters reflect modeler assumptions or are based on the opinion of Dr. Brown when peer-reviewed estimates were unavailable in the literature. Given that BOEM runs MarketSim from 2010 to 2084, adjustment parameters are necessary to capture the movement from short-run to long run equilibrium; otherwise, the model would move between long-run equilibria instantaneously. The remaining parameters are calibrated against baseline data from NEMS – a customized run of NEMS that runs to 2084 instead of 2040, and excludes "new offshore leasing on the OCS off the lower 48 states from the model's calculation" – given the estimated elasticities and adjustment rates. To simulate new leases, the quantity of oil and gas supplies are increased from their baseline values over the relative time period and new equilibria prices are solved (BOEM, 2015).

A. Model Transparency

BOEM has developed a highly transparent model. BOEM's MarketSim is publicly available, there is clear documentation of inputs and assumptions, and it is relatively simple such that it is easy to understand which assumptions drive the results.[64] In

[62] Demand, coal production, and electricity production is modeled at the national scale (with some consideration of imports and exports), while oil and natural gas supply is modeled at fairly aggregate spatial scales (e.g., Alaska, Lower 48, and other). The model captures the rest of the world through the modeling of imports and exports for oil, natural gas, and coal.

[63] Dr. Brown is a professor of energy economics at UNLV who is also a visiting fellow at Resources for the Future (where he previously served as founding co-director of the Center for Energy Economics and Policy) and is an Associate Editor for *Energy Policy*. For more information, see https://www.unlv.edu/people/stephen-brown.

[64] NEMS and IPM lack this transparency. While NEMS is publicly available and has extensive documentation, its level of modeling detail makes it difficult to disentangle what is driving the results; this latter problem is highlighted by its module and sub-module structure that allows for a highly complex modeling environment in which the impact of a single module assumption is difficult to tease out. IPM is the least transparent of the three models. The model is not publicly available. While there is some documentation on the model—as provided by EPA (2013; 2015)—the model is a black box given its proprietary nature (IPW, 2016). Consultants worked on the coal

particular, the cross-price elasticity assumptions between oil, gas, and coal are clear. Additionally, the relatively simple structure of MarketSim allows for sensitivity analysis, particularly Monte Carlo simulation – although BOEM has not conducted any such analyses (BOEM, 2015; BOEM, 2016).

However, in the classic tension between transparency and realism, the model may be overly simple such that it may not capture important nuances of the energy resource market. The model also does not explicitly model generation, transmission, transportation, regulations, or leasing policies (royalty rates, minimum bids, or rental rates). Instead, these components are implicitly captured by the underlying parameters of the model. Thus, the model is only as accurate as its elasticity and adjustment parameters and NEMS' baseline scenario, which drive the model's results.

B. Elasticities and Other Parameter Values

The accuracy of MarketSim is debatable, as some key parameters are out-of-date and all parameters are based on one publication only, or the opinion of one expert. While most elasticity and adjustment parameters are based on estimates no more than a decade old, the elasticity of supply of U.S. oil (0.51) is at least 25 years old. The supply estimates are drawn from Brown (1998), which in turn takes its estimates from EMF (1991); this latter study reports the average long-run price elasticity of supply for U.S. crude oil inferred from eleven world oil market models using six scenarios (GDP growth and oil price paths).[65] Given that BOEM uses MarketSim to analyze the impacts of new oil and gas leases in the Outer Continental Shelf, the application of such a dated elasticity for the U.S. oil

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supply curves (i.e., Wood Mackenzie) and coal transportation networks (specifically Hellerworx and Tetratech) further making reproducibility difficult. Furthermore, given the realism of the model—i.e., it includes regional, sector, regulatory and system constraint detail—IPM is a complex model that requires significant processing power to solve. Thus, like NEMS, it is difficult to disentangle which assumptions are driving the model or to conduct a sensitivity analysis (including a Monte Carlo simulation). Thus, IPM is on the opposite side of the transparency-realism continuum as compared to MarketSim.

[65] It appears that the estimates are drawn from Chapter 5 of EMF (1991), which is an earlier version of Huntington (1992) also cited by Brown (1998) in a corresponding footnote. Huntington infers short-run (one-year), medium-run (ten-year), and long-run (twenty-year) supply elasticities from eleven world oil market models using six scenarios of GDP growth (low, medium, and high) and oil price-path (flat and rising price-paths). Of the eleven models, five used supply parameters determining by author judgement and the remaining six used econometric-based estimates – which likely pre-date the 1989 start of the EMF-11 study of which Huntington (1992) is a part. Interestingly, the mean estimate of 0.51 cited by Brown (1998) does not match 0.394 found in Huntington (1992), and is instead closer to the median estimate of 0.475; however, the Brown (1998) estimate is within the range of estimates – 0.162 and 0.662 – found by Huntington, which characterized by a variance of 0.033. Potentially, there may have been a citation mistake because the short-run elasticity is 0.052.

market is problematic. BOEM should conduct a more extensive search of elasticities to find up-to-date estimates that meet its requirements. If a more up-to-date estimate cannot be found, sensitivity analysis over this parameter assumption is critical. BOEM has not conducted such sensitivity analysis.

Each of MarketSim parameters are based on only one source: drawn from a peer reviewed publication, derived from NEMS, or based on the expert opinion of Dr. Brown. For many of these parameters, alternate estimates are available in the literature. For example, MarketSim assumes an elasticity of supply of U.S. oil of 0.51 based Brown (1998), though alternative estimates are available from Huntington (1992), Gately (2004), and Greene and Ahmad (2005). Furthermore, MarketSim assumes that demand for coal increases with the price of natural gas using an estimate of the cross-price elasticity of coal with respect to natural gas prices drawn from Jones (2014), though alternative estimates are available from Ko and Dahl (2001), EIA (2012) and Gao et al. (2013).

To reflect the fundamental uncertainty underlying their parameter values, BOEM should use the range of estimates in the literature to inform its parameter choice, instead of a sole estimate. Even when alternative estimates are unavailable, the variance of the underlying estimate is often available (indicating further uncertainty over the parameter estimate) to infer a range. If expert elicitation is used, multiple experts should be surveyed instead of just one to provide a range. Again, a sensitivity analysis informed by the range of estimates in the literature, expert responses, and the variance of these estimates should be conducted to reflect the true parameter uncertainty (Roman et al., 2008).

Furthermore, given that strong assumptions are required to calibrate the current version of MarketSim, it is unclear if the data is available to accurately calibrate the model at its current level of fuel source disaggregation (i.e., fuel, region, and mine/well type). Few studies estimate regional (e.g., lower 48, Alaska, etc.) and mine/well-type specific (e.g., onshore, offshore, etc.) supply elasticities. Thus, due to a lack of data, BOEM was forced to extrapolate nation-wide supply elasticities to fuel source specific values.

For example, BOEM currently assumes identical elasticities of supply and adjustment parameters for onshore oil production in the lower 48 states, offshore oil production in the lower 48 states, Alaskan oil production, and all other domestic oil production in its MarketSim model using values provided in Brown (1998) and by Dr. Brown (BOEM, 2015); this is an unrealistic assumption given that it is unlikely that the marginal cost curves of onshore, offshore, and Alaskan oil production are so similar given their different production and transportation technologies. Similarly, BOEM assumes identical elasticities of supply and adjustment parameters for conventional natural gas production in the lower 48 states, Alaskan natural gas production, and offshore natural gas production. Given that one of the primary purposes of this model is to analyze the impact of oil and natural gas regulations, this strong assumption of parameter equality across production regions and mine/well types in the oil and gas sectors implies that the model predictions are less reliable than MarketSim's current level of disaggregation implies.[66] As a consequence, BOEM should conduct sensitivity analysis over parameter values and should limit its reliance on MarketSim to conduct substitution analysis.

Even if BOEM could successfully calibrate each of these regional parameters using estimates from the literature, it is nearly impossible to keep elasticities and adjustment parameters up-to-date. This is because analyses of proposed leases from 2017 to 2022 will need to account for proposed or recently enacted regulations for which data is unavailable. Specifically, many of these parameter estimates are based on historical data that do not reflect the impacts of recently enacted or proposed regulations. And given the simple model structure of MarketSim that does not explicitly model regulations or leasing policies, the model omits the impacts of these regulations and policies.[67] Given this model shortcoming, BOEM must frequently update its parameter values (in order to capture these policies to the best of its ability) and conduct a sensitivity analysis over key parameters. Additionally, BOEM should update the structure of MarketSim to reflect current regulations and leasing policies. Doing so would allow for the explicit modeling of regulation and policy changes. This latter improvement to MarketSim would also improve the calibration of the supply and demand functions underlying the model.[68]

C. Modeling Greenhouse Gas Emissions

MarketSim does not track upstream or downstream externalities – including greenhouse gases – across temporal or spatial dimensions. Instead, BOEM uses another model – the 2015 revised Offshore Environmental Cost Model (OECM) – to estimate the value of externalities from exploration and development of oil and nature gas sites in the Outer Continental Shelf. This model accounts for impacts to recreation, air quality, property values, subsidence harvests, commercial fishing, and ecology from oil spills, emissions, and platforms and other infrastructure placement (BOEM, 2012). The air quality module of OECM accounts for greenhouse gas and other air pollutant emissions from upstream

[66] For example, the elasticity of supply for onshore U.S. oil production could be more inelastic or more elastic than the value provided by Jones (2014) – i.e., 0.51 – for U.S. oil production. This difference may have significant implications for the overall impact of a decline or increase in offshore oil production.

[67] To the extent that these policies are captured in NEMS' baseline scenario (i.e., are predicted by EIA), they may be partially captured in the calibrated supply and demand constants.

[68] For example, current elasticity of supply estimates for oil, natural gas, and coal internalize leasing policies – including the royalty rate – into their values. By explicitly modeling these policies in the specification of the supply curve, BOEM would more accurately capture the shape of the supply functions during calibration as implied by the elasticity estimate. Also, this would allow for BOEM to explicitly account for proposed or recently enacted changes in policies, like an increase in the coal, natural gas, or oil royalty rates.

activity in the natural gas and oil industries – i.e., platforms (installation, operation, and removal), well activity (exploration, delineation, development, and production), transportation (helicopter trips and support vessels), and distribution (pipe laying and tankers) – using emission factors, and does not account for downstream emissions. It also accounts for upstream emissions from substitute activities: onshore oil and natural gas production, coal production, and importation of oil and liquefied natural gas. In calculating the cost of these upstream emissions, OECM accounts for only the health impacts associated with $PM_{2.5}$ and ozone, agricultural impacts from ozone, and damages to structures from SO_2, and does not account for the cost of climate change despite the availability of the Social Cost of Carbon (SCC) (BOEM, 2012; BOEM, 2016, IWG, 2013). For the final economic analysis of the 2017-2022 leasing program, BOEM should update OECM to value greenhouse gas (GHG) emissions using the official U.S. SCC estimates.

Despite tracking upstream GHG emissions, BOEM does not account for downstream GHG emissions. Instead, it makes the assumption that downstream emissions are unaffected by new leases. BOEM provides little evidence for this proposition, except to argue that: there are potentially counter-veiling effects from rejecting the lease plan (a decrease in GHG emissions from a decrease in oil and gas consumption and an increase in GHG emissions from a substitution of coal for gas); GHG emission estimates are highly uncertain (given that emissions differ by fuel type and use which OECM and MarketSim cannot track); and the overall impact on emissions are small. With respect to the first two arguments, OECM and MarketSim should be adjusted to account for both upstream and downstream GHG emissions, and if the model is unable to track emissions accurately, BOEM should not rely on the model to estimate GHG emissions. Furthermore, it may not be true that there are no impacts on GHG emissions from offshore leasing. Even small relative increases in GHG emissions can be valued using the SCC (IWG, 2010).

Given that BOEM does not track emissions using MarketSim, it is unsurprising that MarketSim's current structure also does not address U.S. climate pledges and future greenhouse gas policies that will impact future U.S. and global demand for fossil fuels (Stockman, 2016). Given that long-run demand and supply elasticities and adjustment parameters are estimated using historical data, climate polices and new technologies are captured to the extent that they are integrated into the remaining supply and demand parameters, i.e., the calibrated demand and supply constants. Since these parameters are calibrated against NEMS' baseline scenario, MarketSim essentially captures climate mitigation to the extent that NEMS's captures it. However, NEMS – and therefore MarketSim – fails to account for future policies aimed at reducing U.S. and global greenhouse gas emissions, and therefore, is not consistent with the United States' stated climate goals (Stockman, 2016). To address this model shortcoming, BOEM should develop several future economic-climate scenarios that provide alternative calibration baselines over which to conduct sensitivity analysis.

D. Recommendations to Improve BOEM's Modeling

In this section, we make five sets of recommendations to improve BOEM's modeling. These include: developing a range of parameter values, conducting sensitivity analysis (including Monte Carlo simulation), modifying MarketSim, running model tests, and limiting the interpretation of results.

Develop a Range of Parameter Values

BOEM should conduct a thorough review of the literature and provide more detail about parameters. Specifically, BOEM should provide a central (mean or median) and a range of estimates drawn from the literature. Ideally, BOEM would specify a triangular or normal distribution for parameters using these values, and the variances of the underlying estimates. At a minimum, BOEM should conduct such an analysis over key parameter values such as the oil and natural gas elasticities for each fuel source.

For parameters where estimates are unavailable in the literature, the use of expert elicitation is an acceptable alternative. However, this elicitation should not rely on just one author. Instead, BOEM should identify multiple experts to survey in order to develop a range of possible estimates, which can be further characterized by its central value and variance.[69] This would allow BOEM to conduct an informed sensitivity analysis over these parameter values.

Sensitivity Analysis

As discussed above, it is critical that BOEM adopt sensitivity analysis in its assessment of the 2017-2022 Outer Continental Shelf Oil and Gas Leasing Program. There are three types of sensitivity analysis that it should adopt. First, BOEM should explore the impact of key parameters on model results. For example, the elasticities of supply and demand of natural gas are potentially key drivers of model results, and the impact of various values drawn from the literature should be explored. Second, BOEM should run a Monte Carlo simulation. In its simplest version, BOEM should calibrate triangular or normal distributions for each key parameter based on the range of estimates in the literature and the central value and variance of these estimates, and then randomly draw from these distributions to run the model. Conducting these analyses would allow BOEM to determine the robustness of its current results.

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[69] For example, EPA surveyed twelve experts in an expert elicitation on the mortality impacts of a decrease in $PM_{2.5}$ in the United States. It utilized its responses to specify a concentration-response function, and explore uncertainty (Roman et al., 2008).

BOEM should also conduct a sensitivity analysis over the future economic-climate scenario. The current baseline to which the MarketSim's constant parameters are calibrated essentially assumes that the United States remains on the business as usual emissions pathway (Stockman, 2016). Instead, BOEM should consider multiple scenarios including (1) Paris Agreement, (2) a more ambitious climate policy, and (3) a lower cost renewable energy scenario. A potential source of alternative scenarios is the IPCC (2000; 2014). Given that the U.S. is party to the Paris Agreement, BOEM's baseline should at minimum be consistent with U.S. greenhouse gas pledges in the Paris Accord. Making these changes would help to make BOEM'S Five-Year Program more consistent with U.S. climate goals.

Modifications

We recommend several modifications to the MarketSim model – some of which will increase its complexity and others that will simplify it.

First, BOEM should include leasing policies (royalty rates, minimum bids, and rental rates) into the model structure. Of the various policies, royalty rates are the simplest to add through a simple adjustment to the current supply curve:

$$Q_S = a + b * P$$

where Q_S is the quantity of fuel supplied from the fuel source, P is the price of the fuel, and a and b are parameters to:

$$Q_S = a + b * (1 - \theta)P$$

where θ is the royalty rate. To the extent possible, explicitly modeling leasing policies and other regulations (including greenhouse gas regulations) would allow for a more accurate calibration of supply and demand curve shape. Additionally it would allow BOEM to simulate the impact of future leases by accounting for recently enacted and proposed policy changes.

Second, BOEM should adjust MarketSim and OECM to track upstream and downstream GHG emissions. In the case of MarketSim, BOEM should develop fuel source specific (fuel, region, and mine/well type) emission factors. To accurately measure GHG emissions from coal, a further disaggregation of fuel sources for coal (beyond Domestic and Imports) is necessary to account for differing methane emission rates between underground and surface mines and differing emission levels based on transportation distances between mines and power plants by regions (e.g., coal mined in the Powder River Basin must travel long distances). For both MarketSim and OECM, the Social Cost of Carbon and the Social Cost of Methane should be applied to these emissions to estimate their external cost to society (Hein and Howard, 2015).

Last, BOEM should consider updating its current fuel source (fuel, region, and mine/well type) breakdowns for oil and natural gas if the data is not available to accurately calibrate supply curves. For example, BOEM should consider replacing the supply curves for the "Lower 48 Onshore", "Lower 48 Offshore", "Alaska", and "Other" with a "United States" supply curve due to a lack of empirical evidence for the correct elasticities and adjustment parameters. A similar critique applies to natural gas and electricity supply curves. If BOEM cannot find the appropriate elasticities and chooses not to re-aggregate its supply curves, BOEM should limit its reliance on MarketSim to conduct substitution analysis and to calculate the corresponding impact on net GHG emissions.

Model Testing

Ideally, more work can and should be done to test the accuracy of MarketSim relative to other power sector models. Relative to more complex models like NEMS and IPM, one could argue that MarketSim is too simple and would require significant modification to make equally accurate predictions as more sophisticated models. However, a simpler, more transparent power sector model may be preferable to more complex models if it makes accurate predictions. With a simpler model like MarketSim, we are aware of its shortcomings, which cannot be said of the more complex models. Additionally, a simpler model structure like MarketSim allows for more explicit modeling of uncertainty by enabling sensitivity analysis and Monte Carlo simulations. However, this tradeoff of complexity for transparency is only worthwhile if the simple model makes relatively accurate predictions.

To test the accuracy of MarketSim relative to other power sector models, BOEM should run several scenarios to determine the difference in model predictions. These scenarios should potentially include: (1) an increase in offshore oil and natural gas leasing, (2) a decrease in onshore oil and/or coal leases, (3) an increase in royalty rates, (4) an increase in freight rail costs, (5) an increase in tanker costs, and (6) the imposition of a regulation that imposes restrictions on the electricity mix. To the extent possible, BOEM should also backcast MarketSim and other power sector models – like NEMS and IPM – to compare how accurately these models replicate past scenarios. Without such model comparisons, BOEM should assume that its relatively simple model is limited in its ability to make accurate predictions – particularly at a disaggregate scale – relative to more sophisticated, though more opaque, power sector models.

Limitations

BOEM should discuss its analysis of the Proposed Program within the context of its chosen model. Specifically, BOEM should interpret model results with its model's strengths and weaknesses in mind. Part of this discussion should include the model's individual limitations, the model's limitations relative to other power sector models (like NEMS and IPM), and the limitations of power sector models in general (Boyd, 2016).

BOEM should be wary of answering questions which its model is not designed to answer (Boyd, 2016). For example, BOEM should not make definitive statements about net greenhouse gas emissions given MarketSim's lack of fuel-source (fuel, region, and mine/well type) specific supply parameters for oil and natural gas; MarketSim's and OECM's inability to track greenhouse gas emissions fully (upstream and downstream); and its current lack of sensitivity (uncertainty) analysis in MarketSim and OECM (such as a Monte Carlo simulation). Even if BOEM makes the modifications suggested here, BOEM should be careful making definitive statements about GHG emissions given the relative simplicity of OECM and MarketSim compared to other power sector models (like NEMS and IPM), without conducting inter-model comparisons and backcasting.

Respectfully submitted,

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References for Modeling Comments

[BOEM, 2015] Industrial Economics, Inc. (2015). Consumer Surplus and Energy Substitutes for OCS Oil and Gas production: The 2015 Revised Market Simulation Model (MarketSim). *U.S. Department of the Interior, Bureau of Ocean Energy Management.* OCS Study BOEM 2015-054.

[BOEM, 2015b] Industrial Economics, Inc. (2015). Forecasting Environmental and Social Externalities Associated with OCS Oil and Gas Development: The Revised Offshore Environmental Cost Model. *U.S. Department of the Interior, Bureau of Ocean Energy Management.* OCS Study BOEM 2012-025

Boyd, E. (2016). Power Sector Modeling 101. United States Department of Energy's Office of Energy Policy and System Analysis. *Energy Policy and Systems Analysis Presentation: Energy Modeling 101.* Available at http://energy.gov/sites/prod/files/2016/02/f29/EPSA_Power_Sector_Modeling_020416.pdf.

Brown, S. P. (1998). Global warming policy: some economic implications. *Economic Review-Federal Reserve Bank of Dallas*, 26.

[EIA, 2012] U.S. Energy Information Administration. (2012, June). "Fuel Competition in Power Generation and Elasticities of Substitution." Available at https://www.eia.gov/analysis/studies/fuelelasticities/pdf/eia-fuelelasticities.pdf.

[EMF, 2001] Energy Modeling Forum. (1991). *International Oil Supplies and Demands,* EMF Report 11 (Stanford, Ca.: Stanford University).

[EPA, 2013] ICF International. (2013) Documentation for EPA Base Case v.5.13 using the Integrated Planning Model. United States Environmental Protection Agency # 450R13002.

[EPA, 2015] ICF International. (2015) EPA Base Case v.5.15 using IPM: Incremental Documentation. United States Environmental Protection Agency.

Gao, J., Nelson, R., & Zhang, L. (2013). Substitution in the electric power industry: An interregional comparison in the eastern US. *Energy Economics*, *40*, 316-325.

Gately, D. (2004). OPEC's incentives for faster output growth. *The Energy Journal*, 75-96.

Greene, D. L., & Ahmad, S. (2005). *Costs of US oil dependence: 2005 update*. United States. Department of Energy.

Hein, J. F., & Howard, P. (2015). Illuminating the Hidden Costs of Coal. *The Institute for Policy Integrity Report*.

Huntington, H. G. (1992). *Inferred demand and supply elasticities from a comparison of world oil models* (pp. 239-261). In *International Energy* Economics, ed. Thomas Sterner (London: Chapman and Hall), 239-61.

[IPCC, 2000] Nakicenovic, N., & Swart, S. (2000). IPCC Emissions Scenarios. *Retrieved Apr*, *1*, 2015.

[IPCC, 2014] Stocker, T. F. (Ed.). (2014). *Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

[IPW, 2016] Inside Washington Publishers. (2016, May 20). EPA Appears Open to States' Push for More Accurate Emissions Model. Available at http://iwpnews.com/EPA-Daily-News/Daily-News/feed/rss/menu-id-1046/Page-493.html.

[IWG, 2010] Interagency Working Group on Social Cost of Carbon (2010). Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. *United States Government.* Available at https://www3.epa.gov/otaq/climate/regulations/scc-tsd.pdf.

[IWG, 2013] Interagency Working Group on Social Cost of Carbon (2013). Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. *United States Government.* Available at https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf.

Jones, C. T. (2014). The role of biomass in US industrial interfuel substitution. *Energy Policy*, *69*, 122-126.

Ko, J., & Dahl, C. (2001). Interfuel substitution in US electricity generation. *Applied Economics*, *33*(14), 1833-1843.

Roman, H. A., Walker, K. D., Walsh, T. L., Conner, L., Richmond, H. M., Hubbell, B. J., & Kinney, P. L. (2008). Expert judgment assessment of the mortality impact of changes in ambient fine particulate matter in the US. *Environmental science & technology*, *42*(7), 2268-2274.

Stockman, L. (2016). Government Assumes U.S. Will Fail Climate Goals in its 5-year Offshore Drilling Proposal. *Oil Change International*. Available at http://priceofoil.org/content/uploads/2016/04/5YearPlan-ClimateTest.pdf.

Appendix A: Theoretical Conditions for Preservation

There are two types of option value: real option value – also known as, Dixit-Pindyck option value - and quasi-option value – also known as, Arrow-Fisher-Hanemann-Henry option value. The former option value is the full value of future flexibility – the complete value of maintaining the option to invest - while the latter is the value of future learning conditional on delaying the leasing decision. Mathematically, in a discrete investment problem, real option value is "the maximal value that can be derived from the option to invest now or later (incorporating learning) less the maximal value that can be derived from the possibility to invest now or never (Traeger, 2014)."[1] Alternatively, quasi option value is mathematically equal to the value of preservation to the decision maker who anticipates learning less the value of preservation to the decision maker who anticipates only the ability to delay his/her decision, and not learning (Traeger, 2014). The two values are related, but not identical.

In discrete investment or development problems, the real option value and quasi-option value concepts are related. Real option value can be decomposed into the following expression:

$$\mathrm{DPOV} = \mathbf{Max}\{QOV + SOV - \mathbf{Max}\{NPV, 0\}, 0\}$$

where DPOV is the real option value of an investment, *QOV* is quasi-option value of an investment, *SOV* is simple option value of an investment, and *NPV* is the expected net present value of an investment.[2] While quasi-option value is the "the value of learning under postponement" defined above, simple option value is "the value of the option to carry out the project in the second period, conditional on not carrying out the project in the first period, in the absence of information flow (Traeger, 2014)." Alternatively, the expected net present value of a project is the expected additional value from developing now instead of later when the development project is perceived in now or never terms.[3] Traeger (2014) defines the sum of quasi and simple option values – i.e., QOV + SOV – as the "full value of sophistication."

In the special case of a non-trivial option value – the expected net present value rule is positive (i.e., the naïve planner who fails to recognize the future availability of information and the ability to delay supports development) and the optimal decision (when recognizing the future availability of new information and the ability to delay) is to preserve - the real option value (ROV) expression above simplifies to:

$$\mathrm{DPOV} = QOV + SOV - NPV.$$

[1] See equation (5) in Traeger (2014).

[2] See equation (9) in Traeger (2014).

[3] The expected net present value of a project is "the different between the expected aggregate costs and benefits of carrying out a project in net present value terms (Traeger, 2014)." Under certainty or reversibility, the traditional net present value rule is that an investor (developer) should invest (develop) if the net present value of the project is non-negative.

This expression further simplifies to

$$\text{DPOV} = QOV + PPV$$

where PPV is the pure postponement value of the investment – the expected additional value from waiting to develop instead of developing now in the absence of learning (Mensink and Requate, 2005). [4,5]

Using the above definitions (for the general case) and the conditions defined for optimal preservation defined by Traeger (2014), we can define when the Department of the Interior (DOI) should delay leasing of an Outer Continental Shelf (OCS) region. A necessary and sufficient condition for preservation, which we will define as society being strictly better off by postponing the project, is

$$NPV < QOV + SOV.$$

In other words, if the expected net present value from drilling is strictly less than the "full value of sophistication," society is strictly better off when DOI preserves the corresponding OCS region. Alternatively, a sufficient condition for society being strictly better from preservation is that the real option value is positive: i.e.,

$$DPOV > 0.$$

Under the special condition of a non-trivial solution where $\text{DPOV} = QOV + SOV - NPV$, it is easy to see that the former condition implies the latter condition (and vice versa).

Traeger (2014) also demonstrates that a necessary and sufficient condition for leasing is:

$$NPV > QOV + SOV.$$

Additionally, society is indifferent from a social welfare perspective between leasing and preservation if and only if:

$$NPV = QOV + SOV.$$

Alternatively, a sufficient condition for society being weakly better off from leasing is:

$$NPV > 0 \text{ and } DPOV = 0.$$

When this latter sufficient condition holds, such that

$$\text{DPOV} = \mathbf{Max}\{QOV + SOV - NPV, 0\},$$

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[4] See equation (10) in Traeger (2014).

[5] Mensink and Requate (2005) examine the relationship between real option value and quasi-option value (when "there will be a non-trivial option value of postponing the investment decision." Traeger (2014) proves that the Mensink and Requate (2005) results are a special case of his results.

it is possible that society is indifferent between preservation or leasing ($NPV = QOV + SOV$) or prefers leasing ($NPV > QOV + SOV$). The special case of a non-trivial option value does not apply when the sufficient condition for development holds.

Appendix B: Requirements for Option Values

The conditions for each option value to arise are irreversibility (e.g., the leasing decision and drilling cannot be undone), uncertainty (e.g., uncertainty in market, environmental, and social prices and costs), and the ability to delay (e.g., the Department of the Interior (DOI) can postpone leasing until a future five year plan). Additionally, quasi-option value requires the decision variable to be discrete (e.g., the DOI decides whether to allow or delay drilling in an OCS region). Neither option value requires risk aversion – they exist under the assumption of a risk neutral society.

There are multiple types of uncertainty that the DOI faces when making a leasing decision for an OCS region. In terms of market uncertainty, the DOI faces an uncertain price of oil, fixed cost of drilling (i.e., exploration and development costs), marginal cost of drilling (i.e., extraction costs), and quantity of oil. In so far as the government is unlikely to learn new information about the quantity of oil without exploration – which is directly associated with allowing leasing in that particular OCS region - the latter type of uncertainty does not apply to the government leasing decision; an expected quantity of oil should be utilized instead. With respect to externalities, the DOI faces uncertainty with respect to the risk of oil spills (i.e., the probability of spills and the magnitude of costs when an event occurs), the marginal social cost of oil extraction (e.g., pollution, congestion, etc.), and the fixed social cost of oil extraction (e.g., additional infrastructure costs). With respect to environmental externalities associated with drilling, there are uncertainties with respect the effect of drilling on the environment[6] and the price of environmental services.[7] Finally, the DOI also faces uncertainty with respect to the level and value of amenities from the OCS region. To the extent that this type of uncertainty can be folded into the marginal and fixed social costs of extraction, this latter type of uncertainty, like the quantity of oil, does not need to be explicitly modeled.

[6] The effects of drilling could be via two of the parts of the model: (1) spill size and quantity, and (2) oil spill impacts. See figure on page 3 of BOEM (2012).

[7] The price of the effect is captured through the impact equations. Like the physical effects of drilling, prices are uncertain. While we may learn the effects of drilling (i.e. learn what state of the world we are in), we are unlikely to learn the price of the environmental services. Instead, as more estimates become available, the distribution of estimates will potentially center on a particular value; this should be thought of the variance of a meta-analysis declining over time as more points become available, and should not be thought of as uncertainty surrounding a point estimate which will always be there.

Appendix C: Methodologies for Integrating Option Value into Department of the Interior's Decision Making

The Department of the Interior (DOI)'s currently proposed methodology of calculating net social value does not quantitatively include the real option value associated with drilling (BOEM, 2015). Instead, Bureau of Ocean Energy Management (BOEM) conducts a hurdle price analysis to ensure that leases are sold for a fair market price. To the extent that this methodology limits early leasing within the OCS region, real option value is partially integrated into the DOI's leasing decision.

Using a hurdle price analysis, the agency only accounts for the real option value as it relates to market price uncertainty. Thus, they exclude market uncertainty as it relates to the market costs of drilling (e.g., exploration, development, and extraction)[8] and the social costs of drilling (e.g., environmental, infrastructure, and catastrophic oil spills). As a consequence, the DOI potentially initiates leasing within OCS regions too early. For example, as more data on the environmental effects of drilling become available (i.e. as we learn more about the state of the world we live in), the uncertainty surrounding the net social benefits of drilling would be less, leading to more precise environmental damage estimates. The additional value of this information – also known as quasi-option value - is always nonnegative (Fisher and Hanemann, 1990). By ignoring the possibility of acquiring further information about the consequences of a development action on the environment, the DOI inevitably underestimates the net benefits of preservation over development. To the extent that the uncertainty surrounding current market and social cost estimates is significant, the DOI is initiating leasing in the the Artic and Atlantic regions prematurely.

While calculating the full option value corresponding to the preservation of an OCS region is not as simple as the net social value calculations and hurdle price analysis that the agency is currently using, there are several well established methodologies that the agency can use to capture the full option value: contingent valuation, engineering-economic approach, or programming model. The following sections discuss each of the available methods for integrating the real option value associated with the preservation of an OCS region in a DOI's leasing decision.

Contingent Valuation

To estimate real option value or quasi-option value, the DOI could use contingent valuation techniques. In particular, they could survey various regulators involved in the relevant oil-

[8] "Once the largest field size is set, the WEB2 model requires estimates of costs associated with that field. Cost inputs for the WEB2 model came from the commercial Que$tor cost modeling system and from data collected by BOEM for the socioeconomic analysis of the Five-Year Program (i.e., the economic impact model MAG-PLAN). The Que$tor software allows BOEM to calculate the expected costs of developments, specifically for the size of the largest geologic field in the planning area (BOEM, 2015)."

environmental planning decisions to determine the value that they place on waiting (Fisher and Hanemann, 1990; Jakobsson and Dragun, 1996).[9] Specifically, to elicit a willingness to pay estimate corresponding to quasi-option value, Fisher and Hanemann (1990) suggest asking the relevant regulator:

> "What would you (as a decision maker concerned to use the resources of a site efficiently) be willing to pay for information about future benefits of preservation and development, information that would be available before you had to decide whether to preserve or develop in the future, assuming you do not foreclose the option to preserve in the future by choosing to develop now?"[10]

While this question may appear difficult at first sight, the regulators responsible for natural resources leasing decisions are highly sophisticated. Given their ability to understand the question's nuances, they will likely be able to provide a comprehensive answer (Fisher and Hanemann, 1990).

Although straightforward to implement, this methodology is not ideal for use in this instance. While the DOI clearly has the welfare of U.S. citizens in mind when making its leasing decision, this methodology requires that the relevant planner optimize net social welfare in its decision making process. However, given that it is nearly impossible to prove that any agency does so, it is difficult to know if such a methodology accurately captures option value without comparing estimates from the second and third methodologies outlined below. More importantly, contingent valuation is a stated preference technique, and only provides a subjective estimate of option value. Given that the relevant planning agency (i.e., the DOI) is also the agency that would be conducting the estimate, the subjectivity of the resulting estimates would be even more problematic.

Engineering Economic Approach

To estimate quasi-option value and simple option value, an "engineering-economic approach" could be applied whereby the theoretical model developed by Arrow and Fisher is parameterized using studies from the literature, additional analysis (using the available data), and surveys of experts (Fisher and Hanemann, 1990).[11]

In the simplest case, the DOI could develop a model with two periods and two future states. In this problem, the first period represents the current five year plan (e.g., 2017 to 2022) while the second period can be interpreted as all future periods covered by a sequence of five year plans

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[9] According to Jakobsson and Dragun (1996), "Option price [real option value plus consumer surplus] can be determined using surveys."

[10] Similarly, decision makers could be elicited for willingness to accept estimates.

[11] Examples include Fisher and Hanemann (1990), Albers and Robinson (2007), Adger et al. (1994), and Tegene et al. (1999).

(Mensink and Requate, 2005).[12] The two future states represent the most likely scenarios where preservation is and is not optimal; the corresponding probabilities of each state would require specification.

Using this model, we can calculate "the full value of sophistication" – the combined sum of quasi and simple option values. Following Traeger (2014), we can specify this value as

$$QOV + SOV = \mathbf{E} \max_{d_{2\in\{0,1\}}} u_2(d_2|\bar{\theta}) - \mathbf{E}u_2(0|\bar{\theta})$$

where u_2 is the second period social welfare function, d_2 is an indicator variable equal to one if the DOI chooses to lease in the OCS region during the second period and 0 otherwise, and $\bar{\theta}$ is a random variable representing "the uncertain component of the problem (Traeger, 2014)." If we incorporate uncertainty around the amenity into fixed and marginal social costs of drilling, the second period welfare function is

$$u_2(d_2|\theta) = (1 - d_2)A + d_2[A + \pi_2(\bar{\theta})] = A + d_2\pi_2(\bar{\theta})$$

where *A* is the level of amenities from the OCS region and π_2 is the net social return on leasing the OCS region in period 2. Plugging this into the previous expression, we can rewrite the "full value of sophistication" as

$$QOV + SOV = \mathbf{E} \max_{d_{2\in\{0,1\}}} [A + d_2\pi_2(\bar{\theta})] - A = \mathbf{E} \max_{d_{2\in\{0,1\}}} d_2\pi_2(\bar{\theta})$$

From this expression, we know that the "value of sophistication" is dependent on: (1) the form of the second period social welfare function, and (2) how the random parameter enters that welfare function.

Adapting Conrad and Kotani (2005) model[13] – an academic paper that analyzes the leasing decision from the social planner's perspective – we can specify a second period social welfare function

$$\pi_2(\bar{\theta}) = -K(\bar{\theta}) + Q[P(\bar{\theta}) - C(\bar{\theta})]$$

where *K* is the fixed social cost of leasing (i.e., exploration and development, oil spill, and infrastructure) the OCS region in the second period, *Q* is the expected amount of oil in the OCS region, *P* is the price of oil in the second period, and *C* is the marginal social cost of leasing (i.e., extraction, pollution, and disruptions) in the second period. Assuming that there are *j* future states, we can simplify the expression for the "full value of sophistication" to

[12] Under this interpretation, the second period value function represents the expected present value of all future net benefits from the optimal leasing decision.

[13] Conrad and Kotani (2005) develop an optimal stopping problem for Alaska's Arctic National Wildlife Refuge (ANWR). Unlike the Arrow-Fisher model, this is a continuous time model. While the authors model an externality from drilling, they make the unrealistic assumption that drilling causes the complete loss of amenities from the ANWR region. Furthermore, while the authors assume an uncertain oil price, they make the simplifying assumption that market and social costs of drilling are certain.

$$QOV + SOV = \sum_{j=1}^{2} \rho_j * \mathbf{max}\{-K_j + Q[P_j - C_j], 0\}$$

where ρ_j is the probability of state *j* occurring. From this specification for a two-period and two future state model, it is clear that the DOI can calculate the "full value of the sophistication" – the value necessary to adjust its current net social value calculation – by specifying ρ_j, K_j, P_j, and C_j.

Given that the simple assumptions made in our two-period, two future state model may be overly simplistic, analysts can extend the model to consider additional future states and time periods. As the dimensions of the problem increase, the use of a programming model to find a solution will become necessary. In particular, the DOI could develop and parameterize a numerical (i.e., simulation) model, instead of a simple theoretical model (Mahul and Gohin, 1999, and Ha-Duong, 1998), such as they have done for the optimal stopping problem with WEB2 (discussed more below). Using this new model, simulations could be run under different future scenarios (e.g. low drilling cost, high drilling cost, etc.). The agency, and the U.S. government more generally, are familiar with such scenario-based simulations.[14] Calculating quasi-option value would require only one more step in which the value of the additional information can be calculated by comparing the results of these simulations that are run under certainty to those that are run under uncertainty using the formulas established in the literature.

Choosing the engineering-economic approach has some clear advantages. The main advantage of this method is that it allows for a simple adjustment to the net social value currently calculated by the DOI. As demonstrated earlier, subtracting the sum of quasi and simple option values from the net social value currently estimated by the DOI makes for a new decision rule without further adjustments. Furthermore, this method is objective to the extent that a reliable method can be developed to specify the values of the random parameters (the price of oil and the social costs of leasing) and the corresponding probabilities using studies from the literature, available data, and surveys of experts. If some of the parameters for such a model (e.g. probabilities of various scenarios) cannot be determined, Monte Carlo simulations, which are frequently used in physicals sciences and finance when there is significant uncertainty, can be used.

Optimal Stopping Model

The final approach to incorporating the real option value, as it relates to the social value of information, is to utilize an optimal stopping model. This is the approach taken by the DOI in their hurdle price analysis, which solely considers the option value corresponding to the

[14] See BOEM (2012) and the recently released White House (2014).

uncertainty of oil price. The main advantage of using an optimal stopping model is that it allows the analyst to specify a stochastic process that can be estimated using available data.

The DOI uses an in-house dynamic programming model – When Exploration Begins, version 2 (WEB2) – to conduct their hurdle price analysis. In their analysis, the hurdle price is the lowest price at which delaying development is greater than the value of exploration for the largest potential undiscovered field – the field with the highest net value per equivalent barrel. The inputs into WEB2 are the expected quantity of oil and natural gas,[15] costs, and prices. The cost inputs are from the commercial FieldPlan and MAG-Plan, and may not include externality cost estimates. By using the price model specified in WEB2,[16] the DOI assumes the oil price follows a mean reversion process.[17] Other fiscal terms are assumed to remain constant (BOEM, 2012).

The main shortcoming of the DOI's analysis is that it assumes that the market and externality costs of leasing are certain. In addition to failing to consider external costs of drilling in their hurdle price analysis, the DOI fails to model uncertainty over the market and environment impacts from drilling. While Policy Integrity in no way advocates that the hurdle price is the best methodology, if the DOI chooses to utilize an optimal stopping model, a social hurdle price should be calculated by modifying the agency's dynamic programming model to include externalities of drilling and the corresponding uncertainty underlying them and market costs. In other words, the agency should construct a social hurdle price by including additional uncertainties in WEB2. This analysis should also allow for regional differences between the OCS regions with respect to costs and their corresponding uncertainties.

We propose a possible extension of the Conrad and Kotani (2005) model[18] to utilize in place of the DOI's current hurdle price analysis.[19] If the DOI chooses to preserve the OCS region in period t, society receives a net return equivalent to the magnitude of amenities from the OCS region (A). Alternatively, if the DOI leases within the OCS region in period t, society receives net social welfare equal to

$$V_F(P,K,C) = A - K + Q\int_{\lambda}^{\lambda+\tau} (\mathbf{E}[P] - \mathbf{E}[C])e^{-\delta t}dt$$

where A is the social value of amenities from the OCS region, K is the fixed social cost of drilling, C is the marginal social cost of drilling, P is the price of oil, Q is the annual amount of oil

[15] To estimate the quantity of oil, the DOI uses "field counts at various levels of uncertainty (BOEM, 2012)." Based on this analysis, the DOI's hurdle price analysis uses supply estimates for "the mean probability, an accepted and unbiased statistical approach in the presence of uncertainty (BOEM, 2012)."

[16] Given that WEB2 is an internal model, presumably the DOI estimated the mean-reversion parameters using oil price data.

[17] This assumption is supported by several studies: Pindyck and Rubinfeld (1991), Schwartz (1997), and Andersson (2007).

[18] See footnote 13.

[19] An extension of the DOI's hurdle price analysis would require similar adjustments to their WEB2 model.

extracted from the OCS region, δ is the discount rate, λ is the time it takes to start extraction relative to when the leasing decision is made, and τ is the time it takes to extract the oil in the OCS region relative to when the extraction begins.[20] We assume that P, K, and *C* are random variables. Following the DOI, we assume that the price of oil follows a mean-reversion process.[21] Given the likelihood that the marginal social cost of development declines over time with improved technologies, we assume that *C* follow a geometric Brownian motion with downward drift. Finally, following Dikos and Sgouridis (2008), we assume that *K* follows either a geometric Brownian motion or mean reversion processes with Poisson jumps where the Poisson jumps are necessary to account for the cost of oil spills included in the fixed cost component.[22] Instead of solving for a trigger price, we solve the model for a trigger-plane in the P-K-C space.[23]

As mentioned previously, the main advantage of this estimation strategy is it provides a clear method to estimate the stochastic processes underlying uncertain price and cost variables. In actual application, long time series data exists for only some random variables, such as oil prices, to estimate the parameters of the stochastic processes and to test between the alternative processes proposed in the literature.[24] In the case of market cost and externality cost data, there may be only short time-series data or no data available; this is particularly true for regional data pertaining to OCS regions that have not undergone leasing. In some cases, data for related process made be available to estimate the stochastic process.[25] If data are unavailable, experts can be surveyed to parameterize the model. When short-time series data or expert opinions are utilized, the use of sensitivity analysis over the assumed stochastic processes and Monte Carlos simulations over the parameters is suggested.

[20] The current specification assumes that a constant amount of *Q* units of oil are extracted from OCS region annually. Alternative assumptions about the path of extraction are possible. Furthermore, if the extraction path is uncertain, the DOI can specify the annual amount of extracted oil as a random variable.

[21] Some authors suggest the inclusion of Poisson jumps to the mean reversion process to to account for the arrival of important information that can cause oil price spikes. Another alternative is to allow the equilibrium price of oil (i.e., the mean) to vary stochastically (Dias and Rocha, 1999).

[22] Poisson processes have also been utilized in the forestry literature to model wildfires and other low probability, catastrophic events in forest management (Reed, 1984; Insley and. Lei, 2007)

[23] Under certain parameter values, no solution may exist implying permanent preservation is optimal from a societal point of view.

[24] As demonstrated in Conrad and Kotani (2005).and Fackler (2007), the resulting option value estimate depends on the assumed stochastic process(es).

[25] For example, in the forestry literature, the value of forest amenities is unobservable. By assuming that visitation rates to the forests are proportional to the level of amenities, Conrad (1997) demonstrates that visitation rates and amenities are governed by identical stochastic processes. This allows Conrad (1997) and Forsyth (2000) to estimate parameters in the stochastic process governing forest amenities using availability visitation data.

REFERENCES

Adger, N., Brown, K., Cervigni, R., & Moran, D. (1994). *Towards estimating total economic value of forests in Mexico*. Centre for Social and Economic Research on the Global Environment.

Albers, H. J., & Robinson, E. J. (2007). Spatial-temporal aspects of cost-benefit analysis for park management: An example from Khao Yai National Park, Thailand. *Journal of Forest Economics*, *13*(2), 129-150.

Andersson, H. (2007). Are commodity prices mean reverting?. *Applied Financial Economics*, *17*(10), 769-783.

Arrow, K. J., & Fisher, A. C. (1974). Environmental preservation, uncertainty, and irreversibility. *The Quarterly Journal of Economics*, 312-319.

[BOEM, 2015] Bureau of Ocean Energy Management, Department of the Interior. (2015). 2017—2022 Outer Continental Shelf Oil and Gas Leasing - Draft Proposed Program. Revised January, 2015.

[BOEM, 2012] Bureau of Ocean Energy Mgmt., Department of the Interior. (2012). Forecasting Environmental and Social Externalities Associated with OCS Oil and Gas Development: The Revised Offshore. Revised June, 2012. Department of the Interior JA4517.

Conrad, J. M. (1997). On the option value of old-growth forest. *Ecological Economics*, *22*(2), 97-102.

Conrad, J. M., & Kotani, K. (2005). When to drill? trigger prices for the arctic national wildlife refuge. *Resource and Energy Economics*, *27*(4), 273-286.

Dias, M. A. G., & Rocha, K. M. C. (1999, June). Petroleum concessions with extendible options using mean reversion with jumps to model oil prices. In *3rd Real Options Conference* (pp. 1-27).

Dikos, G. and S.P. Sgouridis. (2008). On the optimal timing of the oil pollution act: Is there more value in waiting than acting?, *International Journal of Ocean Systems Management* 1(3):100-117.

Dixit, A.K., Pindyck, R.S., 1994. *Investment Under Uncertainty*. Princeton University Press, Princeton, NJ.

Fackler, P. L. (2007). Comment on Conrad and Kotani. *Resource and Energy Economics*, *29*(2), 159-164.

Fischer, C., Withagen, C., & Toman, M. (2004). Optimal investment in clean production capacity. *Environmental and Resource Economics*, *28*(3), 325-345.

Fisher, A. C., & Hanemann, W. M. (1990). Option value: theory and measurement. *European Review of Agricultural Economics*, *17*(2), 167-180.

Forsyth, M. (2000). On estimating the option value of preserving a wilderness area. *Canadian Journal of Economics/Revue canadienne d'économique*, *33*(2), 413-434.

Ha-Duong, M. (1998). Quasi-option value and climate policy choices. *Energy Economics*, *20*(5), 599-620.

Industrial Economics, Inc. (2012). Energy alternatives and the environment. U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2012-021. JA 4807-48774

Insley, M., & Lei, M. (2007). Hedges and trees: incorporating fire risk into optimal decisions in forestry using a no-arbitrage approach. *Journal of Agricultural and Resource Economics*, 492-514.

Jakobsson, K. M., & Dragun, A. K. (1996). *Contingent valuation and endangered species: methodological issues and applications*. Edward Elgar Publishing.

King. (2007). *Economic Analysis for the OCS 5-Year Program 2007-2012: Theory and Methodology*, JA 5304.

Mahul, O., & Gohin, A. (1999). Irreversible decision making in contagious animal disease control under uncertainty: an illustration using FMD in Brittany. *European review of agricultural economics*, *26*(1), 39-58.

Mensink and Requate. (2005). *The Dixit-Pindyck and the Arrow-Fisher-Hanemann-Henry Option Values are not Equivalent,* Resource and Energy Economics, 27, 83-88.

Pindyck, R. S., & Rubinfeld, D. L. (1991). *Econometric models and economic forecasts* (Vol. 3). New York: McGraw-Hill.

Reed, W. J. (1984). The effects of the risk of fire on the optimal rotation of a forest. *Journal of environmental economics and management*, *11*(2), 180-190.

Schwartz, E. S. (1997). The stochastic behavior of commodity prices: Implications for valuation and hedging. *The Journal of Finance*, *52*(3), 923-973.

Tegene, A., Wiebe, K., & Kuhn, B. (1999). Irreversible investment under uncertainty: Conservation easements and the option to develop agricultural land. *Journal of Agricultural Economics*, *50*(2), 203-219.

Traeger, C. P. (2014). On option values in environmental and resource economics. *Resource and Energy Economics*, *37*, 242-252.

The White House. (2014). *The Cost of Delaying Action to Stem Climate Change.* http://www.whitehouse.gov/sites/default/files/docs/the_cost_of_delaying_action_to_stem_climate_change.pdf