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Bureau of Ocean Energy Management

Subject: Comments on the Draft Proposed 2017-2022 Outer Continental Shelf (OCS) Oil and Gas Leasing Program, BOEM-2014-0059

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 draft proposed five-year offshore leasing program for 2017-2022. 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]

In its draft proposed leasing program for 2017-2022, the Interior Department qualitatively considers the option value, or informational value of delaying leasing until more information is available on relevant environmental, social, and technological uncertainties. Policy Integrity commends the agency's progress on addressing environmental, social, and economic uncertainty in its latest draft proposed program. We also urge BOEM to 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:

- Use option value, or the informational value of delay, to better inform its five-year offshore leasing program and to help determine the optimal size, timing, and location of lease sales;

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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 that courts can review Interior's leasing decisions 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).

- Take meaningful steps to quantify the option value associated with leasing in each Outer Continental Shelf (OCS) region;
- Transparently weigh option value when deciding where and when to issue leases, and only issue leases if the economic, social, and environmental benefits outweigh the costs; and
- Clarify in the program how option value will be incorporated into later development stages, for example, by adjusting minimum bids, rents and royalties to compensate the public for the full value of the rights conveyed.

Policy Integrity looks forward to working with BOEM on these important issues.

(1) Both BOEM and the United States Court of Appeals recognize the relevance of option value to the offshore leasing program.

In this draft proposed program, BOEM takes an important step toward addressing option value for environmental and social cost uncertainty. 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.[5]

In this draft proposed program, BOEM includes a detailed discussion of option value and related resource valuation concepts.[6] This is a positive development that Policy Integrity has long advocated for through prior comments and correspondence with the agency.[7] Specifically, BOEM notes that:

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[5] *See generally*, Avinash K. Dixit & Robert S. Pindyck, INVESTMENT UNDER UNCERTAINTY (1994); James L. Paddock et al., *Option 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); 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).
[6] U.S. Department of the Interior, Bureau of Ocean Energy Management, 2017–2022 OUTER CONTINENTAL SHELF OIL AND GAS LEASING DRAFT PROPOSED PROGRAM 8-2 to 8-13 (Jan. 2015) [hereinafter "Draft Proposed Program"].
[7] *See, e.g.*, Letter from Michael A. Livermore, Executive Director of Institute for Policy Integrity to Steven Textoris, Five-Year Program Manager, Bureau of Ocean Energy Management (Feb. 7, 2011), available at http://policyintegrity.org/documents/BOEM_Comments_2-7.pdf; Michael A. Livermore, *Patience Is an Economic Virtue*, *supra* note 5; Institute for Policy Integrity, *The BP Gulf Coast Oil Spill, Option Value, and the Offshore Drilling Debate* (April 20, 2011), available at http://policyintegrity.org/publications/detail/the-bp-gulf-coast-oil-spill-option-value-and-the-

- Environmental and social cost uncertainties can affect the size, timing, and location of offshore leasing;
- Environmental and cost uncertainty can "greatly affect the Net Social Value" of offshore leasing in each Outer Continental Shelf (OCS) planning area;
- 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.[8]

Policy Integrity strongly supports BOEM's use of option value to better inform its five-year program and help determine the optimal size, timing, and location of lease sales. However, Policy Integrity encourages BOEM to apply option value in a more transparent, quantitative manner. Our comments and corresponding economic analysis highlight how BOEM can strengthen its option value analysis and application, consistent with best practices.

The U.S. Court of Appeals' decision 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. On March 6, 2015, the U.S. Court of Appeals for the District of Columbia Circuit issued its ruling in *Center for Sustainable Economy v. Jewell*.[9] Petitioner Center for Sustainable Economy challenged the Department of the Interior's 2012-2017 offshore leasing program for failure to comply with the provisions of OCSLA Section 18(a), which govern how the Department is to balance competing economic, social, and environmental values.[10] Among other claims, Petitioner argued that OCLSA Section 18 required BOEM to explicitly consider and quantify the information value, or option value, of delaying leasing in specific regions of the Outer Continental Shelf.[11]

The Court's decision recognizes the utility of option value to BOEM's offshore leasing program, acknowledging 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

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offshore-drilling-debate/; Institute for Policy Integrity, Petition to the U.S. Department of the Interior pursuant to the Outer Continental Shelf Lands Act and the Administrative Procedure Act (April 25, 2011), available at http://policyintegrity.org/documents/Petition_to_BOEMRE_on_Option_Value.pdf; Institute for Policy Integrity, Comments on the Preparation of the 2017-2022 Outer Continental Shelf Oil and Gas Leasing Program, BOEM-2014-0059 (July 31, 2014), available at http://policyintegrity.org/documents/Comments_to_BOEM_on_2017-22_Program.pdf.

[8] Draft Proposed Program at 5-20, 8-3 to 8-19.

[9] *Center for Sustainable Economy v. Jewell,* D.C. Circuit Case No. 12-1431 (March 6, 2015). Policy Integrity served as counsel to Petitioner, Center for Sustainable Economy.

[10] *See id*; *see also* Opening and Reply Briefs for Petitioner in *Center for Sustainable Economy v. Jewell*, D.C. Circuit Case No. 12-1431. Petitioner also raised claims under the National Environmental Policy Act, which were held to be unripe, and additional OCSLA claims, two of which the Court found to be forfeited due to failure to adequately raise these issues through the administrative process. Nothing in these comments should be construed to waive these or any other future claims.

[11] *Id*.

develop and what new information comes to light."[12] Ultimately, the Court 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 yet "sufficiently established."[13] Importantly, the Court's holding indicates that quantitative methods might be developed in the future, and such methods would be preferable to 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."[14] The court further noted: "Had the path been well worn, it might have been irrational for Interior not to follow it."[15]

This ruling strongly suggests that future advancements in option value research could compel the agency to better quantify the 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 financial terms.

> **(2) BOEM should quantify the option value of delaying leasing until more information is available on relevant environmental, social, and technological uncertainties.**

Well-established methodologies exist to quantify option value in the natural resources context. The importance of option value to evaluating decisions under uncertainty has been widely recognized in the economics community for several decades.[16] The option value framework has long been applied to natural resource extraction decisions, including offshore oil drilling.[17] 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.[18] Any company that failed to account for option value would risk suboptimal returns on its leases compared to more

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[12] D.C. Cir. Case No. 12-1431 at 38-39.
[13] *Id*. at 41.
[14] *Id*. at 42.
[15] *Id*. at 42.
[16] *See supra* note 5. 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).
[17] Paddock et al., *supra* note 5; Fisher, *supra* note 5; Conrad & Kotani, *supra,* note 5.
[18] *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).

sophisticated competitors, because failing to account for option value "is not just wrong; it is often very wrong."[19]

In this draft five-year program, BOEM considered the informational value of delay with respect to price uncertainty, and qualitatively discussed environmental and social uncertainty. However, the agency stated that "it is surpassingly difficult to specify and estimate a useful, empirical model" for quantifying the option value associated with OCS leasing.[20] By not using economic methodologies that would incorporate the option value of a resource, the draft 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 optimal choices on the timing of leases.

For example, in determining the "Net Social Value" of leasing in each OCS region, BOEM notes that its estimates "are rooted in uncertainty at many levels beyond just price," including extraction cost, as well as environmental and social cost uncertainty.[21] However, while BOEM uses three different oil price scenarios to help it calculate a range of Net Social Values for each OCS region, it fails to use quantitative analysis to help it weigh the environmental and social uncertainties associated with leasing and production in each region.[22]

To assist BOEM, Policy Integrity attaches an exhibit to these comments with a proposed framework for quantifying the option value associated with leasing in each OCS region. We would welcome the opportunity to work with BOEM to refine the methodology to quantify option value for environmental and social cost uncertainty associated with OCS leasing.

BOEM should take a leadership role in analyzing and quantifying option value. Federal government agencies often serve as a catalyst for quantifying important categories of costs and benefits, and can also play a significant role in providing resources for quantification. Policy Integrity encourages BOEM to take a leadership role in quantifying option value, working with other economic and scientific experts. Such efforts would be consistent with best analytical practices, as well as the Court of Appeals' decision in *Center for Sustainable Economy v. Jewell.*[23]

Categories of quantified and unquantified costs and benefits are not immutable, and important categories of benefits that were once unquantified have subsequently become quantified.[24] 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.[25]

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[19] Avinash K. Dixit & Robert S. Pindyck, *supra* note 5.
[20] Draft Proposed Program at 8-9.
[21] Draft Proposed Program at 5-20.
[22] *Id*.
[23] D.C. Cir. Case No. 12-1431 at 42.
[24] Richard L. Revesz, *Quantifying Regulatory Benefits*, 102 CAL. L. REV. 1423, 1425, 1436 (2014).
[25] *Id*. at 1436, 1450-1456.

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.[26] 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.[27] Following a successful legal challenge to a federal agency that had failed to quantify the benefits of reducing greenhouse gas emissions, an interagency working group was formed to develop a methodology to quantify the social cost of carbon.[28] The social cost of carbon is now regularly used by federal agencies in drafting regulations, as well as by state policymakers.[29] The value of a statistical life ("VSL") is another example where federal agencies served as the catalyst for the quantification of an important measure of regulatory costs and benefits.[30] The value of a statistical life, calculated by willingness-to-pay methods, is now part of standard federal agency practice.

Similarly, BOEM should consider forming a working group to develop a methodology for calculating the option value associated with offshore 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,[31] 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.[32] Further, the

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[26] *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").

[27] *See* Revesz, *supra* note 24 at 1434, 1439.

[28] In *Center for Biological Diversity v. National Highway Transportation Safety Administration*, the Ninth Circuit invalidated 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 24 at 1435; *see also* Interagency Working Group on the Social Cost of Carbon, UNITED STATES GOVERNMENT, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT UNDER EXECUTIVE ORDER 12866 (May 2013, Revised November 2013).

[29] *See, e.g.*, U.S. Department of Energy, Energy Conservation Program: Energy Conservation Standards for Residential Dishwashers; Proposed Rule, RIN 1904–AD24, 79 Fed. Reg. 76142, 76144-76184 (Dec. 19, 2014); State of Minnesota Public Utilities Commission, *Notice of Updated Environmental Externality Values*, PUC docket numbers E-999/CI-93-583 and E-999/CI-00-1636 (June 5, 2013).

[30] Revesz, *supra* note 24 at 1438-1440. The value of a statistical life developed, in part, from an effort by President Ford's Council on Wage and Price Stability to resolve a methodological conflict between the Occupational Safety and Health Administration (OSHA) and the Office of Information and Regulatory Affairs (OIRA). *Id*.

[31] 43 U.S.C. § 1344(a) (2010).

[32] 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

U.S. Court of Appeals' holding in *Center for Sustainable Economy v. Jewell* suggests that advancements in option value research could improve the agency's leasing practices, to better fulfill the mandate of OCSLA Section 18.[33]

While developing such a methodology will have a discrete upfront cost, once created, this model could be used and refined in future government natural resources leasing decisions by BOEM and other agencies, such as the Bureau of Land Management. Further, it could earn the American public billions of dollars in 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 initial investment required to quantify the option value associated with offshore leasing may be vastly outweighed by the long-term societal benefits.

(3) 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 and offshore drilling's impact on wildlife, fisheries, and recreation in the Arctic and Atlantic regions, as well as in deepwater areas. Certain Arctic and Atlantic OCS regions pose relatively greater environmental and social uncertainty, given their limited track record of commercial drilling, restricted drilling infrastructure, and volatile weather. The Arctic and Atlantic planning areas also rank among the highest for relative environmental sensitivity of all the planning areas.[34]

BOEM should take these heightened uncertainties and sensitivities into account when developing its 2017-2022 program, using an option value analysis to aid in deciding when and where to issue leases, including whether to defer leasing beyond this five-year term in certain areas. BOEM should also analyze option value when deciding whether to hold specific lease sales, as well as in setting the financial terms for leases.

The Arctic region is characterized by diverse ecosystems, extreme environmental conditions, geographic remoteness, and a relative lack of fixed infrastructure to

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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 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.

[33] D.C. Cir. Case No. 12-1431 at 42.

[34] Draft Proposed Program at 6-29, 7-10.

support drilling. The environmental sensitivity of the Alaskan OCS is well known: the Beaufort and Chukchi Sea Planning Areas have the highest sensitivity scores for birds and invertebrates.[35] These scores are also driven by the region's high susceptibility to climate change, which is an additional stressor on Arctic ecosystems.[36] The Arctic region is also home to Alaska Native communities, which rely on the Arctic's resources for subsistence and cultural traditions. Each of these are important factors in considering the costs and benefits of conducting offshore oil and gas activities on the Arctic Outer Continental Shelf, including the option value of leasing in this region.

In addition, the Bureau of Safety and Environmental Enforcement (BSEE) and BOEM's proposed new requirements for exploratory drilling on the Arctic Outer Continental Shelf highlight many of the particular environmental sensitivities and uncertainties associated with drilling in this region.[37] For example, as the proposed rule notes: "The challenges to conducting operations and responding to emergencies in the extreme and variable environmental and weather conditions in the Arctic are severe."[38] Further, 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.[39]

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, as well as to the lease sale stage. Such uncertainties can and should be accounted for in the balance that BOEM undertakes between development and preservation.

BOEM states that it tentatively scheduled the Alaskan leases sales in the Beaufort and Chukchi Seas later in the five-year OCS period due, in part, to an option value analysis.[40] But, because BOEM does not use a quantitative method to measure option value for each

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[35] Draft Proposed Program at 6-29, 7-10.

[36] BOEM's approach to relative environmental sensitivity accounts for the vulnerability and resilience of an OCS region's ecological components to the potential impacts of oil and gas development, within the context of existing conditions, including climate change. Draft Proposed Program at 6-16. The Chukchi and Beaufort Sea planning areas were found to have the greatest susceptibility to climate change of all the OCS regions. Anticipated effects of climate change include changes in temperature, sea ice melt and freshwater influx, permafrost thaw, ocean acidification and upwelling effects, sea level rise and saltwater intrusion, coastal erosion and land loss, and changes in species composition. *Id*. at 6-26 to 6-27.

[37] Department of the Interior, Oil and Gas and Sulphur Operations on the Outer Continental Shelf—Requirements for Exploratory Drilling on the Arctic Outer Continental Shelf, 80 Fed. Reg. 9916, 9920 (Feb. 24, 2015).

[38] *Id*.

[39] Presidential Memorandum, Withdrawal of Certain Areas of the United States Outer Continental Shelf Offshore Alaska from Leasing Disposition (Jan. 27, 2015), available at https://www.whitehouse.gov/the-press-office/2015/01/27/presidential-memorandum-withdrawal-certain-areas-united-states-outer-con.

[40] Draft Proposed Program at 8-10.

proposed OCS region, it is difficult for the public to understand how, if at all, option value influenced the agency's analysis. Moreover, consistent with an option value approach, BOEM should consider delaying lease sales in such areas altogether, or at least beyond the five-year program at issue. And, BOEM should further assess option value at the lease sale stage, when it can consider additional information on the risks of leasing and remaining uncertainties.

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. BOEM's draft program identifies a portion of the mid- and south-Atlantic for possible offshore leasing in 2021.[41] BOEM would open an area to offshore drilling that has never before been commercially developed and for which no safe record of development exists.

The environmental, social, and economic uncertainties associated with drilling in this region are high: an oil spill in the Atlantic could have grave consequences for recreational, commercial, and ecological values in major economic centers such as Virginia Beach or Charleston, South Carolina. Although the probability of a catastrophic oil spill may be low, the 2010 Deepwater Horizon oil spill demonstrated that even such low probability events can have devastating economic and environmental results when they occur. In addition to large coastal populations that would be directly affected by oil spills, the mid- and south-Atlantic planning areas have among the highest environmental sensitivity scores of all of the regions.[42] They also have the highest environmental sensitivity scores for mammals and turtles, and above average scores for fish.[43]

Further, many of the Atlantic and remote Arctic planning areas lack near-shore and onshore infrastructure to support drilling, heightening the uncertainty. In areas with new oil and gas development, a network of onshore support facilities is needed to support offshore production.[44] Potential onshore and near-shore effects include transportation, processing facilities, construction facilities, terminals, disposal facilities, and oil spill response staging areas.[45] Onshore and near-shore infrastructure may result in a variety of adverse impacts including the destruction or alteration of existing habitats, permanent or temporary displacement of species, and behavioral disruption that may have acute or long-term impacts on individuals and populations.[46] While some Atlantic and Alaskan areas have significant infrastructure in place (for example, in areas that support state oil and gas production), others have very little and would require significant development of onshore facilities.

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[41] *Id*. at 9-8, 9-10.
[42] Draft Proposed Program at 7-10.
[43] *Id*.
[44] Draft Proposed Program at 7-6, 7-10.
[45] Draft Proposed Program at 7-10 to 7-11.
[46] Draft Proposed Program at 7-11.

When BOEM develops its Offshore Environmental Cost Model for the 2017-2022 program, it should include these anticipated coastal and onshore infrastructure costs.[47] While BOEM cannot necessarily mitigate uncertain infrastructure effects during its programmatic planning process, it can and should account for the social and environmental uncertainty inherent in regions that lack existing infrastructure through an option value analysis at the program stage.[48] Later, it should also consider uncertain impacts at the lease sale stage, using an option value analysis. Finally, as described below, it 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.

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. The government must take all of these heightened uncertainties into account in its 2017-2022 program. Even a qualitative analysis of option value may very well show that the government should not lease in certain areas—such as the Arctic and Atlantic—in the near term. A quantitative option value analysis would more fully and transparently disclose the uncertainties associated with drilling in this region.

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 should not do so if the societal benefits of leasing do not outweigh the costs, including the foregone informational value of delay. 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. Further, BOEM should explicitly consider the option value associated with each lease sale. At the lease sale stage, BOEM will have more information about the specific risks and uncertainties relevant to the leases at issue; it should fine-tune its option value analysis at the same time that it conducts its environmental impact analysis.

In short, BOEM must not undersell the American public's non-renewable natural resources and unnecessarily expose the public to high-risk drilling. An option value approach would ensure that the government only leases when and where the present societal benefits outweigh the costs, including the value of delay.

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[47] Assigning zero costs to coastal and onshore infrastructure impacts would be irrational and break with legal precedent interpreting the requirements of OCSLA Section 18(a). *See Natural Res. Def. Council, Inc. v. Hodel*, 865 F.2d 288, 311 (D.C. Cir. 1988) (valuing wetlands lost to OCS-related infrastructure); *Watt I*, 668 F.2d at 1317 (explaining that consideration of environmental damage may not be "postponed or foregone" to a later program stage.) Petitioners in *Center for Sustainable Economy v. Jewell* raised this claim with respect to BOEM's 2012-2017 program. The D.C. Circuit in did not reach the merits of this claim, finding it forfeited due to failure to adequately put Interior on notice through the commenting process. D.C. Cir. Case No. 12-1431 at 21.
[48] Draft Proposed Program at 7-11, n. 41.

(4) BOEM should adjust minimum bids, rents and royalties to reflect option value and the environmental and social externalities of resource development, and clarify in the Program how option value will be incorporated into later development stages.

BOEM has discretion to adjust bids, rents and royalties to restore the proper balance between allowing 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," and does so through minimum bids, rents, and royalties.[49] "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] The agency 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.

BOEM should clarify how option value will be incorporated into later development stages. In this draft program, BOEM notes that 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. BOEM notes that raising the minimum bid may increase buyer selectivity, and thus "the efficiency of the lease sale process," and that "the minimum bid can be adjusted to improve timing of activities where option value is found to be significant."[52] Policy Integrity agrees with this assessment.

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. 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 and the corresponding uncertainty underlying them and market costs. While BOEM currently uses a hurdle price analysis at the program stage that accounts for price uncertainty, it can and should use a similar analysis at the lease sale stage, as well, and include environmental and social uncertainties in this model. A social hurdle price could 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.

After a lease sale is scheduled, BOEM determines its financial terms, which must provide the public with fair market value for the rights conveyed.[53] BOEM should adjust the minimum bids, rents, and royalties for offshore leases to account for environmental and

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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] Draft Proposed Program at 8-19.
[53] Draft Proposed Program at 8-19.

social uncertainty, as well as environmental externalities. 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 financial terms and shorter initial lease periods. By contrast, "frontier areas" have typically been offered with less taxing financial terms and longer initial periods.[54] However, if the option value associated with developing frontier areas is fully accounted for in setting the lease terms, the minimum bid, rent, and royalties should likely be raised in order to account for the informational value of delay.

The government's perpetual option to develop resources is worth more in areas with greater uncertainty. When it sells a lease, BOEM extinguishes its perpetual option and gives a time-limited option to private developers. Raising the minimum bids and rents to compensate for the American public's loss of this perpetual option would help to secure fair market value for the rights conveyed. This may have the effect of decreasing the number of blocks leased in the immediate term, therefore increasing competition and bids in other areas.[55] Further, unlike the agency's current escalating rent schedule, BOEM should use non-escalating rents in areas where the option value is greater, in order to avoid improperly incentivizing risky drilling. Finally, BOEM should consider raising the royalty rate for leases found to have higher option value, as well as leases that are expected to result in greater environmental externalities, as described in the next section.

When recovering the fair market value for the right to explore and develop offshore resources, BOEM should not give away for free the options value or the right to inflict environmental and social 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.[56] Greenhouse gases are also emitted unchecked during the process of energy production and transportation from offshore regions.[57] 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 actually collects a fair return for these valuable rights, and to restore the proper balance between allowing efficient levels of offshore development and safeguarding environmental and social values. Increases could be based on average external costs generated by operations in each

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[54] *Id*. at 8-20.
[55] *See id*. at 8-19.
[56] *See* BOEM, FORECASTING ENVIRONMENTAL AND SOCIAL EXTERNALITIES ASSOCIATED WITH OCS OIL AND GAS DEVELOPMENT: THE REVISED OFFSHORE ENVIRONMENTAL COST MODEL (2012).
[57] *See* EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2012, at 3-54 (2014).

offshore planning region and the options value for each region, taking into account the specific environmental and social sensitivities of the region. For greenhouse gases emitted during production, the agency can use the social cost of carbon to price the externality.[58]

Finally, because OCSLA emphasizes regional differences and balances, BOEM should transparently disclose this regional distribution of costs and benefits and should not just report nationally averaged effects of drilling versus postponement. BOEM should give careful consideration to the uncertain environmental sensitivities and uncertain drilling and remediation technologies facing Arctic regions.

Respectfully submitted,

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[58] *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). BOEM should further coordinate with other agencies on an administration-wide climate policy to address the greenhouse gases from the inevitable combustion of the oil and gas produced. Adjusting royalties to reflect the social cost of combustion could be one option.

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:

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

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[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

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

[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

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[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

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[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.

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[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.

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