

Economic Analysis Methodology for the 5-Year OCS Oil and Gas Leasing Program for 2012-2017

October 2011

Prepared by

Economics Division of the Bureau of Ocean Energy Management

October 2011



United States Department of the Interior
BUREAU OF OCEAN ENERGY MANAGEMENT
Washington, DC

REPORT AVAILABILITY

Extra copies of the report may be obtained from:

Environmental Sciences Division
U.S. Department of the Interior
Bureau of Ocean Energy Management
381 Elden Street (MS 4041)
Herndon, VA 20170-4817

Telephone: 703-787-1717

CITATION

Suggested citation:

U.S. Department of the Interior. Bureau of Ocean Energy Management. 2011. Economic Analysis Methodology for the 5-Year OCS Oil and Gas Leasing Program for 2012-2017. BOEM OCS Study 2011-050.

Table of Contents

Introduction.....	5
Overview	5
Methodology	6
Net Economic Value.....	7
Net Social Value	9
<i>Offshore Environmental Cost Model</i>	<i>9</i>
<i>OECM Oil Spill Modeling</i>	<i>12</i>
<i>OECM Air Emissions Modeling</i>	<i>13</i>
<i>Net Environmental and Social Costs</i>	<i>14</i>
<i>Market Simulation Model.....</i>	<i>14</i>
<i>Net Social Value Results from the OECM and MarketSim.....</i>	<i>16</i>
Net Benefits	17
<i>Estimation of Consumer Surplus in MarketSim.....</i>	<i>18</i>
<i>Primary versus Secondary Markets.....</i>	<i>18</i>
<i>Netting out Producer Surplus</i>	<i>21</i>
<i>Net Benefits Summary.....</i>	<i>22</i>
Assumptions and Input Data	23
Oil and Natural Gas Price-Level Assumptions	24
Cost Assumptions	24
Discount Rate	25
Anticipated Production	25
Production Profiles	26
Exploration and Development Scenarios.....	26
References and Selected Literature.....	28

Introduction

The purpose of this paper is to describe the methodology for the 2012-2017 proposed program Net Benefits analysis found in part IV.C of the proposed program decision document. The theoretical foundation and background for the Net Benefits analysis is covered extensively in prior programs (King 2007) and is not repeated in this paper. However, the Bureau of Ocean Energy Management (BOEM) has updated data sources and improved models used to estimate the program's Net Benefits.¹ The detailed documentation describing the factors used and model design of the Offshore Environmental Cost Model (OECM) will be published with or before the proposed final program document and is similar to documentation for recent programs (Plater 2001, Roach 2001). The draft documentation associated with model updates is adequate for BOEM to have confidence in the model design, technical integrity, and results. However, at the time of this report, the final documentation is not ready for external publication.

Overview

The Net Benefits analysis is a benefit-cost analysis by program area of the social gain from anticipated production of economically recoverable oil and natural gas resources expected to be leased and discovered as a result of the program. This analysis examines the benefits to the nation from the production of oil and natural gas as well as the environmental and social costs associated with the anticipated exploration, development, and production. The analysis also includes estimates of the environmental and social costs associated with obtaining energy from other sources that would be necessary should the No Sale option be selected for one or more program areas.

Selection of the No Sale option in any of the program areas means that no new leasing would take place in those areas for at least five years, and domestic oil and natural gas supply would be reduced by the amount of forgone production. Without the anticipated production from one or more of the program areas, there would be less domestic oil and gas supply but little change in domestic demand for energy. The increased gap between supply and demand would be met by additional imports (primarily of oil delivered by supertankers), more onshore oil and gas production, more biofuel and coal production, and other market substitutions. Energy usage would be expected to be slightly lower than it would be with a program due to increases in domestic prices (primarily for natural gas). Please see the section titled *Estimation of the Energy Market Substitutions* for a more in-

1 . The Offshore Environmental Cost Model (OECM), an internal BOEM model, is used to calculate the environmental and social costs of the recommended option and of the No Sale option for each program area. To calculate the change in consumer surplus anticipated from the proposed program, BOEM uses the Market Simulation Model (MarketSim) which estimates the energy market's response to the program's Exploration and Development (E&D) scenarios. The MarketSim model is also used to calculate conservation, energy types, and energy sources substituting for OCS oil and gas with the selection of No Sale. If the No Sale option is selected for each program area it is identical to the no action alternative (NAA) referred to in the EIS. The NAA is the market response and corresponding environmental and social costs absent of a 5-year Program.

depth discussion of the assumptions as to the energy sources that would replace outer continental shelf (OCS) production anticipated from the recommended program options.

The Net Benefits analysis provides the Secretary of the Interior with a logically consistent analytical basis for considering the values and alternative sale options for each program area. The results of the Net Benefits analysis are simply one criterion among many the Secretary considers in choosing among the OCS leasing alternatives. The rest of this paper provides the methodology for the Net Benefits and will walk the reader through the calculations.

Methodology

The methodology for estimating the potential value of OCS production from each recommended option in the program proposal is shown in Figure 1 through the different stages of the Net Benefits analysis composed primarily of *net economic value*, *net social value*, and *net benefits*. Figure 1 summarizes the calculations completed for each program area measuring the full social gain associated with adopting the proposed decision option for that area, as opposed to the results of the No Sale Option. As described below in the section on assumptions and input data, values calculated for the program are discounted at a social discount rate of 7 percent to the beginning year of the program (2012).

Figure 1 Components of Net Benefits Analysis

1	Anticipated Production of the Program Area	x	Assumed Oil and Gas Price Levels	=	Gross Revenue
2	Gross Revenue	-	Private Costs	=	Net Economic Value (NEV)
3	NEV	-	Environmental and Social Costs - Environmental and Social Costs of Energy Substitutes (Resulting from the No Sale Option)	=	Net Social Value (NSV) (Net Supply-Side Benefits)
4	NSV	+	Consumer Surplus Benefits - Lost Domestic Producer Surplus Benefits	=	Net Benefits

The different components of the Net Benefits analysis include impacts from economic activity as well as impacts associated with economic value. The first row of Figure 1 calculates the gross revenue of production which measures the direct contribution of anticipated production from the program area to the gross domestic product over the lifetime of the leases issued.

The second row measures what economists call the economic rent generated by the program and what is called net economic value (NEV) in the Net Benefits analysis.² The NEV can be viewed as the profit available to be shared by the oil industry and the government from producing the public resources made available by the program. Because this is a surplus, it can be shared without distorting the efficient allocation of productive resources. To the extent that factors of production employed as a result of sales in the program area have less lucrative opportunities elsewhere, the selection of the No Sale Option would impose additional private costs in the form of lost wages, etc. This analysis ignores these potential private losses because no reliable measures exist. However, it does include the parallel external costs that would result from holding no sales in the program area.

The third row measures the net social value (NSV) which is the NEV less the net external or environmental and social costs of the program relative to the No Sale Option. This calculation subtracts the external or non-market cost or benefits provided by the program to the program's NEV. External costs or benefits arise in this case because producers and consumers do not bear all the costs or receive all the benefits generated by the program. The measurable benefits of the proposed program consist of the NSV plus the net domestic consumer surplus.

The fourth row, adding the net consumer surplus benefits, includes the implicit pecuniary benefits afforded consumers in the form of reduced oil and gas prices generated by the incremental oil and gas supplied from the program, adjusted for losses of domestic producer surplus. The net consumer surplus benefits are added to the NSV to yield an estimate of the net benefits for each program area. The following sections provide greater detail about the components of the Net Benefits analysis.

Net Economic Value

The NEV approach is similar to customary cash flow modeling. The calculations involve aggregate measures of income and cost for the program areas but do not explicitly model individual firms or projects.

As the first step in the Net Benefits analysis, the NEV is calculated as the gross profit or economic rent for each program area. Table 1 summarizes the NEV estimates for each of the proposed program areas. Assumptions for the NEV calculations are covered in the section titled *Assumptions and Input Data*.

² Economic rent is typically defined as payment for goods and services beyond the amount needed to bring the required factors of production into a production process and sustain supply.

Table 1 Net Economic Value

	Net Economic Value		
	(\$ billions)*		
	Low	Mid	High
Central GOM	11.54	54.77	104.81
Western GOM	3.22	14.33	26.48
Eastern GOM	**	1.06	2.49
Chukchi Sea	5.19	19.60	58.96
Beaufort Sea	2.06	4.20	12.53
Cook Inlet	1.43	2.75	8.17
* Low-price case: \$60/bbl, \$4.27/Mcf; Mid-price case: \$110/bbl, \$7.83/Mcf; High-price case \$160/bbl \$11.39/Mcf. **No Eastern GOM production expected.			

The NEV is the discounted (7 percent) gross revenue from the produced oil and gas less the discounted costs of exploration, development, and production. These costs include payments to labor, money, capital goods, management expertise, and other factors of production. The resulting NEV includes both lease owner profits which are reinvested or distributed to investors and government tax and leasing revenues which accrue to the public. The NEV can also be equated to the sum of the present values of royalties, rents, bonuses, taxes, and after-tax profits. The NEV is calculated for each program area using the same schedules of exploration, development, and production activities that are modeled in the OECM to obtain the environmental and social costs for the proposed program and in the environmental impact statement (EIS) to evaluate the impact of the proposed program on the human environment.

The NEV equation format for a program area is:

$$NEV_i = \sum_{t=1}^n \left[\frac{(AG_{it} * PG_t) + (AO_{it} * PO_t) - C_{it}}{(1+r)^t} \right]$$

where:

NEV_i = the estimated net present value of gross economic rent in the i^{th} program area.

BOEM calls this "net economic value" or NEV.

AG_{it} = the anticipated production of natural gas from program area i in year t

PG_t = the natural gas price expected in year t

AO_{it} = the anticipated production of oil from program area i in year t

PO_t = the oil price expected in year t

C_{it} = a vector of exploration, development, and operating costs

r = a social discount rate

n = years of production associated with the leasing schedule

The BOEM calculates the NEV for three separate flat price cases consistent with the E&D scenario and corresponding production deemed likely by BOEM under the three

price scenarios. The BOEM believes that the net benefits approach as shown here provides decision makers the best information at the 5-year program stage to consider the relative value of planning and program areas for leasing.

The BOEM notes that the NEV value is different from the assessment of the regional economic impact of OCS activities measured elsewhere. (See the Equitable Sharing analysis for the economic impact of the program in part IV.C of the proposed program document.) A regional economic impact analysis measures the gross value produced by or relative importance of different industries or sectors, such as recreation, within a local or regional economy. But this approach does not reveal the contribution to social wellbeing from those activities because it does not consider the alternative activities forgone to provide these gross values. The NEV concept of value is recognized as an appropriate measure to compare the costs and benefits of policy alternatives.

Net Social Value

Whereas the NEV analysis considers the private costs incurred by the firms that explore for and develop OCS oil and gas resources, society also incurs external or environmental and social costs from OCS activities and facilities associated with offshore oil and gas production. The NSV is the NEV less the present value of the difference between the environmental and social costs anticipated from the recommended program area option and from sources that would replace OCS production if the No Sale Option were selected.

The environmental and social costs arise from uncompensated environmental and social damage during the exploration, development, production, and transportation of OCS oil and gas resources. The specific environmental and social costs modeled for the proposed program take a variety of forms including air pollution, risk of oil spills, pressure on local services during development, and a range of similar impacts. Regulations have internalized many of these costs onto production firms' balance sheets; however, some persist. The BOEM uses the OECM to calculate the external environmental and social costs from the recommended option in each of the program areas.

Offshore Environmental Cost Model

The OECM is used to estimate both the environmental and social costs that would result from OCS activities in each program area and the costs that would result without new leasing (i.e., the No Sale Option). The BOEM updated the OECM inputs and model structure for analyzing this 5-year program. The new OECM is an Access based model that uses the levels of OCS activity from the E&D scenarios employed in the NEV and the EIS along with the energy market substitutions from the Market Simulation Model (MarketSim) to calculate environmental and social costs. The OECM is not designed to represent impacts from global climate change, catastrophic events, or impacts to unique resources such as endangered species, because they cannot be quantified to a comparable degree with the other external costs included here. The reader is referred to the Draft 5-year EIS (BOEM 2011a) for a discussion of global climate change, catastrophic events, and impacts on unique resources. Information on resources at risk and potential impacts

from a catastrophic spill are discussed in Appendix B of the proposed program decision document.

The environmental and social costs from the No Sale Option are attributed to the program area which would have yielded the expected forgone production. This approach is used to achieve a consistent distribution of program benefits to the planning areas. More importantly, if benefits and costs are not allocated to the area of production, it would be nearly impossible to maintain the cause-and-effect link between a decision to lease in a specific program area and the full costs and benefits likely to result from that decision. The primary purpose of the Net Benefits analysis is to inform the Secretary about the value of the options for each of the program areas.

The following seven environmental and social cost categories along with the most recently available social and cost estimates are used in the OECM.

Recreation: The loss of consumer surplus that results when oil spills interfere with recreational offshore fishing and beach visitation.

- Estimates are limited to the use value of recreational fishing and beach visitation because they capture the primary recreational uses of coastal and marine resources that would be affected by OCS activity, and they are the uses for which relevant data are generally available on a consistent, national basis.

Air Quality: The monetary value of the human health and environmental damage caused by emissions generated by oil and gas activity.

- Emissions are calculated based on activity levels and the environmental and health effects are determined by the dispersion and monetization done by the Air Pollution Emission Experiments and Policy (APEEP) analysis model.
- A summary of the methodology is found in the section titled *OECM Air Emissions Modeling*.

Property Values: Impacts of the visual disturbances caused by offshore oil and gas platforms and losses in the market value of residential properties caused by oil spills.

- Impact is defined as the annual loss in potential rent from residential properties that result from visual disturbances from platforms as well as from damage from oil spill events.
- This is calculated as the product of the property value per linear meter of beach, the after tax discount rate, the fraction of year taken up by the event, and the length of oiled shore.

Subsistence Harvests: The replacement cost for marine subsistence species killed by oil spills in Alaska.

- The model assesses the impact of OCS oil and gas activities on Alaska subsistence harvests by estimating oil spill-related mortality effects among general subsistence species groups.

- The model assumes that all organisms killed by oil spills would have been harvested for commercial or subsistence purposes, determines the subsistence component of this lost harvest, and calculates a replacement cost.

Commercial Fisheries: The loss from fishing area pre-emption caused by the placement of oil and gas infrastructure (platforms and pipelines).

- The model assumes that there will be buffer zones around platforms. In most cases the buffer zones will be a circle with a radius of 805 meters (0.5 miles).
- The model also assumes that the total amount harvested is unaffected by oil and gas infrastructure. Nearly all fisheries in OCS waters are managed with annual catch limits set below the harvestable biomass.
- Non-catastrophic oil spill impacts are not expected to be long lasting. Commercial fishing is assumed to move areas and still meet catch limits.

Ecological: Restoration cost for habitats and biota injured by oil spills.

- The BOEM uses a habitat equivalency analysis (HEA)-based, restoration cost approach to estimate dollar damages in the model. Consistent with the standard economic view of natural resources as assets that provide flows of services, ecosystems are understood to provide a flow of ecosystem services. These services are valued by society, as demonstrated by our willingness to pay for their protection and/or enhancement.
- Changes in the quality or quantity of these services (e.g., due to ecosystem injuries caused by oil spills and/or development) have implications in terms of the value of the benefits they provide.

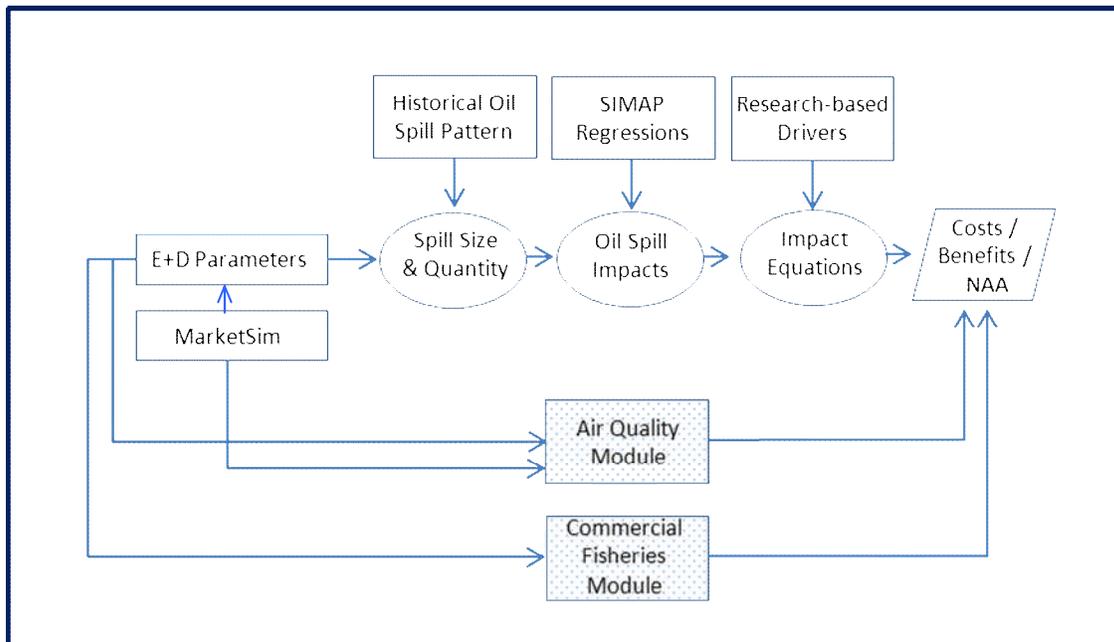
The category of *Fiscal Impacts* is in the OECM, but results are not reported here because discussion of fiscal results and impacts are covered in the Equitable Sharing analysis in part IV.C.3 of the proposed program.

Fiscal Impacts: The net cost of public infrastructure to coastal states and local governments given the revenues generated by OCS oil and gas exploration, development and production activities.

The OECM uses the parameters set forth in the E&D worksheet to estimate annual oil production and location of potential spills associated with each platform group. The OECM feeds this information into oil spill impact modeling system (SIMAP)-generated regressions to estimate the physical impacts of oiling.³ Then, using impact equations developed for each oil-spill driven cost category of recreation, property values, subsistence use, and ecological effects, the OECM employs the SIMAP regression outputs and impact-specific data elements to estimate costs and benefits. Due to the unique characteristics of the air quality and commercial fishing cost categories, the OECM employs the output from external modules to estimate impacts associated with OCS production in these sectors. Figure 2 depicts the OECM's general framework.

³ SIMAP is an oil spill impact modeling system providing detailed predictions of the three-dimensional trajectory, fate, impacts and biological effects of spilled oil.

Figure 2 OECM General Framework



OECM Oil Spill Modeling

The largest social and environmental costs modeled for the 2012-2017 proposed program decision document are OCS oil spills and air emissions. The general public views oil spills as the most serious risk posed by the OCS program. The environmental effects of oil spills and the costs associated with those effects vary widely depending on variables such as the amount and type of oil spilled, the location of the spill, whether the spill hits shore, the sensitivity of the ecosystem affected, weather, season, and so forth. Fortunately, the environmental and social costs associated with oil spills have been relatively well documented so there is a reasonable basis for oil-spill cost modeling in the literature.

The risk of an oil spill includes both the likelihood or probability of spill incidents of various types occurring and the consequences of those incidents.

$$\textit{Spill risk} = \textit{probability of spill} \times \textit{impacts of spill}$$

The probability of a spill is measured as the ratio of the amount spilled to the amount produced. The analysis performed for the proposed program uses aggregate estimates for all the spills that the model suggests are likely from the E&D scenario and anticipated production. The oil spill modeling approach cannot and does not try to measure the effects of any individual spill, nor does it take into account the unlikely event of a catastrophic spill of unprecedented proportions, which is addressed separately in the draft EIS and Appendix B of the proposed program decision document. The spill rates and size of spills are based upon all OCS spills from 1964-2010 excluding the catastrophic Deepwater Horizon (DWH) event. If a more recent period is chosen (1990-2009) to

reflect current technology and practice, the oil spill rate would be fraction of the 46 year rate used in the model and decrease the anticipated environmental costs of the proposed program. The BOEM is using the oil spill rate from the entire history of available program data, excluding DWH, as a rough balance between the remote chance of another DWH event and the otherwise much safer performance reflected in the more recent period.

Impacts of a spill depend on the spill size, oil type, environmental conditions, present and exposed resources, toxicity and other damage mechanisms, and population/ecosystem recovery following direct exposure. Inputs include habitat and depth mapping, winds, currents, other environmental conditions, chemical composition and properties of the oils likely to be spilled, specifications of the release (amount, location, etc.), toxicity parameters, and biological abundance.

The BOEM uses the existing and well-documented SIMAP (French-McCay 2004, French-McCay 2009), to project consequences associated with a matrix of potential conditions. Spills could occur in the context of OCS oil and gas exploration and development or in the context of imports that might serve as alternatives to OCS production. The SIMAP summarizes data that quantify areas, shore lengths, and volumes where impacts would occur with regression equations to simulate spills of varying oil types and sizes in each of the planning areas under a wide range of conditions. The results of these equations are then applied within the OECM (see Figure 2).

OECM Air Emissions Modeling

The OECM estimates the level of emissions for any given year based on the 2012-2017 proposed program E&D scenarios and schedule. Exploration and development of the OCS will lead to emissions of sulfur dioxide (SO₂), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), particulate matter (PM), and other air pollutants that may adversely affect human populations and the environment. To account for these effects, the OECM includes an air quality module that estimates (1) the emissions—by pollutant, year, and planning area—associated with a given E&D scenario and production rate and, (2) the monetary value of the environmental damage caused by these emissions, estimated on a dollar-per-ton basis. The model estimates emissions based on a series of emissions factors derived from BOEM data, and for planning areas along the coast of the contiguous United States, models the dispersion of these air emissions and converts the emissions to monetized damages using a modified version of the APEEP developed by Muller and Mendelsohn (2006).⁴

The specific air pollution impacts that the OECM examines include:

- Adverse human health effects associated with increases in ambient PM_{2.5} and ozone concentrations;

⁴ The model monetizes damages associated with emissions in Alaska planning areas using scaled estimates of the monetized damages by scaling the APEEP estimates of damages per ton of emissions for the Oregon-Washington planning area.

- Changes in agricultural productivity caused by changes in ambient ozone concentrations; and
- Damage to physical structures associated with increases in SO₂.

Because human health effects generally dominate the results of more detailed air pollution impact analyses (EPA 2010), excluding emissions-related changes in visibility, forest productivity, and recreational activity from the OECM is unlikely to have a significant impact on the model's results.

Net Environmental and Social Costs

In order to get a better picture of the net environmental and social costs of the 5-year program, the environmental and social costs likely from the selection of a No Sale Option must also be estimated and subtracted from each program area's environmental and social costs. The BOEM uses its MarketSim to estimate the substitutions for offshore oil and gas production in the absence of sales in each of the areas. The MarketSim calculates the energy market substitutions of additional imports, onshore production, and fuel switching as well as reduced consumption of oil and gas that would replace the production in each program area, then the OECM calculates the environmental and social costs from those substitutions.

Market Simulation Model

The MarketSim is an Excel-based model that calculates the consumer surplus and energy market substitutions associated with changes in the energy markets. The MarketSim models oil, gas, coal, and electricity markets under a special energy projection baseline, which excludes new OCS production; i.e., selecting the No Sale Option for every program area, taken from special runs by the U.S. Energy Information Administration's (EIA) National Energy Modeling System (NEMS).⁵ The E&D scenarios from each program area are then introduced into the model as a shock to this special baseline, triggering a series of simulated price changes until each fuel market reaches equilibrium or supply equals demand. The MarketSim uses elasticities derived from the special EIA NEMS runs and elasticities from other credible elasticity studies (examples: Dahl 2010, Serletis 2010) to estimate the changes that would occur to prices and energy production and consumption through 2064.

There are important enhancements to the MarketSim modeling approach in this analysis than used in past 5-year programs. The current version of the model increases both the scope and detail of modeled fuel markets by adding coal and electricity markets to account for substitution between alternate fuel sources according to the cross-price elasticities between any given pair of fuels. In order to more correctly depict this substitution, the current model also increases the granularity with which it models production and consumption. Each fuel is modeled separately for residential, commercial, industrial, and transportation demand with the own-price and cross-price

⁵ NEMS projections including production from new OCS leasing is typically reported in EIA's Annual Energy Outlook.

elasticity specific to each submarket and fuel. Additionally, each fuel’s production is modeled at a more detailed level than solely based on domestic onshore, domestic offshore, and import sources. This complexity allows MarketSim to simulate changes in prices and the resulting substitution effects between fuels as OCS oil and gas production increases. Additional detail about how MarketSim models fuel substitutions across energy markets and sources is described in the section titled *Primary versus Secondary Markets*.

For the NSV calculation, MarketSim uses price elasticities between each of the different energy markets in each of the separate end-use markets to calculate the quantity and type of fuel use if no new leasing occurred in OCS program areas during the period of the proposed program. The energy market substitutions must be factored in to the Net Benefits analysis because the decision not to include a program area will lead to less energy production, meaning that additional sources of energy would need to be made available to continue to meet domestic demand. The production reduction without new leasing would lead to slightly higher prices which would lead to only a small change in the quantity of oil and gas demanded. As a result, additional domestic production, increased imports, or fuel switching would be necessary to meet the continuing demand for oil and gas resources. Based on the anticipated production at the mid-price scenario, MarketSim estimates the proportion of energy market substitutions that would occur from excluding planning areas as shown in Table 2. Excluding one or more program areas would result in the corresponding decline in domestic offshore production and that production would be replaced with the percentages of the given substitutes.⁶

Table 2 Substitute Energy Results of the No New Program

Energy Sector	Percent of OCS Production Replaced
Onshore Production	17%
Onshore Oil	2%
Onshore Gas	15%
Imports	67%
Oil Imports	58%
Gas Imports	9%
Coal	6%
Electricity from sources other than Coal, Oil, and Natural Gas	3%
Other Energy Sources	2%
Reduced Demand	6%

If OCS oil and, to a lesser extent, natural gas are not produced, imports of foreign oil will increase substantially. Most of this oil would be imported by tanker, entailing risks of oil spills and attendant environmental and social costs. Subtracting the environmental and social costs associated with these increased imports from the environmental and social

⁶ The exact percentages will vary between program areas depending if the area is gas or oil prone.

costs associated with OCS production yields the net environmental and social costs associated with OCS activities.

Onshore oil and gas production. Emission factors for onshore oil and gas production for the contiguous United States are based on the Western Regional Air Partnership's (WRAP) 2002 emissions inventory for oil and gas activities in ten western states. These states include Alaska, Arizona, California, Colorado, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Wyoming (WRAP 2009). Excluding oil and gas operations in the coastal states of Alaska and California which are included in the WRAP inventory, emission factors were developed for onshore oil and gas production by dividing the emissions estimates from the WRAP inventory (with some adjustments) by Department of Energy estimates of onshore oil and gas production in the eight states analyzed.

Imports of oil by tanker. For tankers carrying oil imported into the U.S, the analysis applies the same emission factors used for tankers transporting crude oil from Alaska to the West coast of the contiguous 48 states.

Net Social Value Results from the OECM and MarketSim

The net environmental and social costs in program area i , NE_i , equal

$$NE_i = \sum_{k=1}^s \sum_{t=1}^n \left[\frac{E_{ikt}}{(1+r)^t} \right] - \sum_{k=1}^s \sum_{t=1}^n \frac{A_{ikt}}{(1+r)^t}$$

where:

NE_i = the net environmental and social costs in program area i .

E_{ikt} = the cost to society of the k^{th} environmental externality occurring in program area i in year t .

A_{ikt} = the cost to society of the k^{th} environmental externality occurring in program area i in year t from substitute production and delivery with the No Sale Option.

r = social discount rate

The net environmental and social costs are subtracted from NEV to obtain the NSV associated with OCS production. The NSV is a bit of a misnomer because it does not include consumer surplus benefits resulting from changes in the market price of oil and gas due to the program, which are added in the next stage of the Net Benefits analysis. The NSV from a program area i (NSV_i) is $NSV_i = NEV_i - NE_i$

Table 3 shows the external costs BOEM estimates for each program area and its most likely substitute. Costs without holding sales in each area mostly come from the risk of oil spills and air emissions from additional tanker imports and greater air emissions resulting from increased onshore production of oil, gas, and other energy sources such as coal. As shown in Table 3 for all program areas, the costs of relying on the substitute sources of energy are greater than the environmental and social costs from producing

program area resources under the proposal.⁷ The difference between the costs of the energy market substitutes without a program area and the costs of each program area proposal is almost entirely due to the air emissions impacts. When OCS oil is not available, it is mostly replaced with increased imports, causing the corresponding air emissions and oil spill risk of tankers along the U.S. coastal areas receiving the imported oil. Onshore gas production and oil imports produce emissions closer to population centers. These discharges create a greater exposure influence on health than do air emissions miles offshore. Environmental and social costs resulting from foreign oil and gas production for export to the United States and from transportation of oil and gas to U.S. waters or borders are excluded from the model because this Net Benefits analysis is confined to a national, U.S. perspective.

Table 3 Environmental and Social Costs

	Program			No Sale Option			Net		
	(\$ billions)								
	Low	Mid	High	Low	Mid	High	Low	Mid	High
Central GOM	2.52	4.25	4.96	5.48	9.43	10.94	-2.97	-5.18	-5.98
Western GOM	1.44	2.14	2.42	1.44	2.23	2.53	0.00	-0.09	-0.11
Eastern GOM (2 Sale)	*	0.05	0.07	*	0.10	0.14	*	-0.05	-0.08
Chukchi Sea	0.01	0.02	0.04	0.10	1.26	3.76	-0.09	-1.23	-3.72
Beaufort Sea	0.01	0.01	0.01	0.04	0.25	0.83	-0.03	-0.25	-0.82
Cook Inlet	0.00	0.00	0.01	0.01	0.04	0.01	-0.01	-0.03	-0.01

*No production is expected in the Low-price case for the Eastern GOM. However, if a few environmental wells are drilled there will be a small environmental cost.

Net Benefits

The last stage in the Net Benefits analysis is to add the net domestic demand side benefits or consumer surplus less lost domestic producer surplus to the NSV. In addition to the NSV from the proposed program, OCS oil and gas contributes to society through lowering the price of oil and gas compared to what individuals would be willing to spend. This concept of value is recognized as an appropriate measure to compare the costs and benefits of policy alternatives. The consumer surplus is calculated using BOEM's MarketSim. In addition to calculating consumer surplus, the MarketSim model also calculates the energy market substitutions in the absence of leasing in any of the program

⁷ The BOEM notes the effects estimated by the OECM may be construed as substantial in absolute terms but fairly small in relative terms. For example, the OECM estimates environmental costs for the air emissions associated with a given E&D scenario. Although this is a large figure in monetary terms, these costs are small relative to the environmental costs associated with air pollutant emissions for the entire United States.

areas. In order to maintain consistency, this model uses the same assumptions and scenarios as all other portions of the 5-year program analysis.

Estimation of Consumer Surplus in MarketSim

To assess changes in the welfare of U.S. consumers under a given E&D scenario, MarketSim estimates the change in consumer surplus for each of the end-use energy markets included in the model. For a given energy source, changes in consumer surplus occur as a result of changes in both price and quantity relative to baseline conditions. Given the interrelatedness of the different energy markets, price and quantity may change not only due to shifts in supply functions driven by the E&D scenario itself, but also from shifts in demand functions associated with cross-price effects that result from shifts in the supply functions of other energy sources. In addition, changes in quantity and price for a given year relative to the baseline reflect the assumption in the MarketSim that the amount of energy consumed and produced in a given year depends partially on the quantity consumed and produced in the prior year.

Primary versus Secondary Markets

The proposed 5-year program would increase the amount of offshore oil and gas production marketed to the economy. The impact of this new energy production will cause spillover effects to other segments of the U.S. energy markets. For example, increased offshore oil production would likely reduce oil prices and lead to a reduction in coal demand as coal would be relatively more expensive due to cross-price effects. Changes in this and other indirectly affected markets may also have feedback effects on oil and gas markets. Estimating changes in consumer surplus associated with the new 5-year program therefore requires careful consideration of surplus changes across multiple markets. The rest of this section covers some of the more technical aspects of the MarketSim modeling.

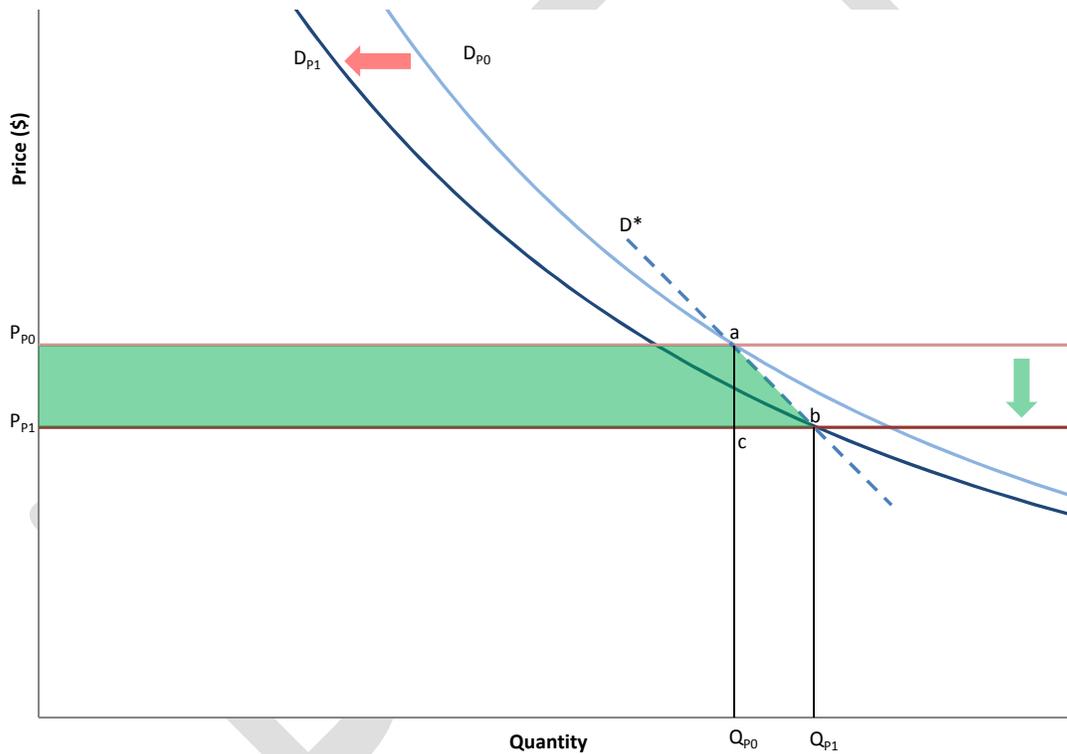
To estimate changes in consumer surplus within the model's multi-market structure, MarketSim draws on the approach outlined in Boardman *et al.* (1996).⁸ Recognizing that government interventions in the primary market may have spillover effects on other secondary markets, Boardman *et al.* (1996) present a systematic approach for appropriately estimating welfare changes in general equilibrium. Putting the Boardman *et al.* approach in the context of offshore oil and gas production, BOEM's 5-year program leads to an outward shift in the supply function within one or more primary markets, oil and/or gas. This shift leads to a price reduction in the primary market, as shown by the change from P_{P0} to P_{P1} in Figure 3. Due to cross-price effects, this reduction in price in the primary market causes the demand function for substitutes to shift inward, as shown in Figure 4, reducing the quantity of substitutes demanded from Q_{S0} to Q_{S1} . As explained in Boardman *et al.* (1996), this reduction in quantity for substitutes does not lead to a change in consumer surplus that is not already reflected in the primary market surplus

⁸ This approach is also highlighted in Mohring (1993), Thurman (1991), Thurman and Wohlgenant (1989), and Gramlich (1998).

change described below, because the location of the demand curve within the primary market reflects the existence of substitutes. More specifically, the demand function in the primary market is located further to the left than it would be in the absence of substitutes.

The shift in demand in the secondary market also leads to a reduction in price within that market, from P_{S0} to P_{S1} in Figure 4. As described in Boardman et al. (1996), this reduction in price leads to an increase in consumer surplus represented by area $P_{S0}deP_{S1}$ in Figure 4. This surplus change is not reflected in the primary market. Within MarketSim, this area is estimated as two components. For the rectangle $P_{S0}dfP_{S1}$, this portion of consumer surplus is simply $\Delta P \times Q^*$. To calculate the area of def , MarketSim calculates the definite integral of D_{S1} over the range $[Q^*, Q_{S1}]$ and subtracts the area of the rectangle Q^*feQ_{S1} .

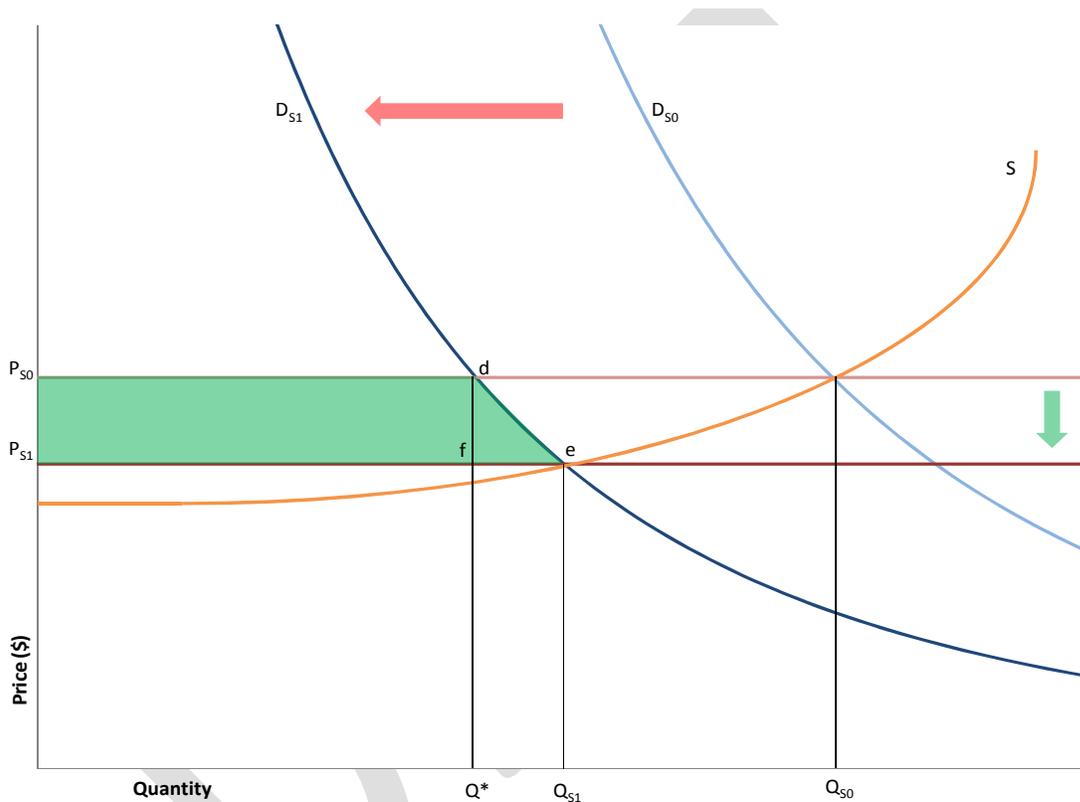
Figure 3 Primary Market Consumer Surplus Change



Boardman *et al.* (1996) suggest a different approach for estimating consumer surplus changes within the primary market. Returning to the context of BOEM’s 5-year program, the program itself causes a shift in supply, which, as described above, causes a reduction in price for substitutes. (See Figure 3.) As the price of substitutes decreases, demand switches from the primary market to the substitutes causing demand within the primary market to decline, as represented by the inward shift in demand in Figure 3. Equilibrium in the primary market therefore changes from point *a* in the baseline to point *b* following implementation of the 5-year program and full adjustment of all the energy markets. Boardman *et al.* (1996) suggest that the associated change in consumer surplus should be estimated along the equilibrium demand curve represented by the line D^*

connecting points *a* and *b* in Figure 3. Unlike D_{P0} and D_{P1} , which hold the prices of all other goods constant, the equilibrium demand curve shows demand once prices in other markets have fully adjusted to the change in the primary market. Using the equilibrium demand curve, the change in the primary market's consumer surplus includes two components. First, the price effect on the baseline quantity is represented by rectangle $P_{P0}acP_{P1}$, calculated as $\Delta P \times Q_{P0}$. Second, the additional consumer surplus associated with the increase in quantity is calculated as triangle abc , calculated as $0.5(\Delta Q \times \Delta P)$. In total, the change in consumer surplus for this primary market is the trapezoid $P_{P0}abP_{P1}$.

Figure 4 Market Consumer Surplus Change (reduced quantity and price)



To estimate the changes in consumer surplus associated with BOEM's 5-year program, MarketSim applies the approach from Boardman et al. (1996) outlined in Figure 3 and Figure 4. One complicating factor in the application of this approach is that oil and gas may be both primary and secondary markets. That is, OCS production of oil may affect gas markets and OCS gas production may affect oil markets. Similarly, because electricity may be produced with OCS gas, and to a much lesser extent OCS oil, the electricity market may be both a primary and secondary market.⁹ A key distinction between primary and secondary markets in Boardman, however, is that primary markets

⁹ To avoid double counting consumer surplus changes associated with oil and gas used for electricity production, MarketSim's estimation of the consumer surplus changes for oil and gas does not include oil and gas used for electricity generation. Changes in consumer surplus associated with oil and gas used for this purpose are reflected in the model's consumer surplus calculations for electricity consumers.

see an increase in the equilibrium quantity demanded while secondary markets experience a reduction in quantity.¹⁰ For the purposes of estimating the change in consumer surplus, MarketSim therefore treats oil, natural gas, or electricity as primary markets if the quantity demanded with the new 5-year program increases relative to the baseline. For example, if the equilibrium quantity of oil in the 2020 transportation market is higher in the 5-year program scenario than the No Sale Option in each program area (in this case, the special baseline EIA NEMS projection quantity), the 2020 oil transportation market will be treated as a primary market and its change in consumer surplus will be calculated based on the approach shown in Figure 3. Conversely, if the quantity of oil, gas, or electricity demanded decreases from the baseline to the E&D scenario, MarketSim calculates the consumer surplus change based on the secondary market approach (Figure 4).¹¹

This rule does not apply to coal which is always treated as a secondary market in MarketSim. Because E&D oil and gas production effects on coal markets are only indirect, coal is never considered a primary market for the purposes of MarketSim's consumer surplus change calculations.

Netting out Producer Surplus

The MarketSim calculates the consumer surplus of the oil, gas, coal, and electricity markets. However, most of this surplus is not a net gain to society because it is actually transferred producer surplus. Producer surplus, the difference between the actual price that producers receive and the minimum price they would be willing to accept, diminishes as consumer surplus increases. In the case of OCS oil and gas production, additional OCS production lowers the price consumers pay for oil and gas, thus increasing consumer surplus. However, as prices fall, producers receive a smaller price for every unit of production, thus lowering their producer surplus. In both the primary and secondary markets the rectangle portion of consumer surplus is the transferred producer surplus. The rectangle is simply the difference in price as a result of the 5-year program on each unit of consumption (or production in the case of producer surplus) that would have been purchased at the higher price. The net gain in consumer surplus is the triangular portion of the consumer surplus as it is the additional consumption as a result of the lower price. For primary markets, the net gain in consumer surplus is triangle *abc* (Figure 3) while the net consumer surplus in the secondary market is the triangle *dfe* (Figure 4). These small triangles are the net surplus gain. However, since most OCS oil would be replaced by increased imports the lower oil price that results from the new 5-year program would mostly affect foreign producers. The lower oil price lowers foreign producer surplus, but looking at purely domestic surplus gains, both the triangle and rectangle portions of consumer surplus are the domestic net benefit. The consumer surplus reported in the Net Benefits analysis is the net domestic consumer surplus, meaning losses of domestic producer surplus are netted out of consumer surplus. The net

¹⁰ The opposite would be true for policies that reduce supply.

¹¹ The BOEM notes that MarketSim may treat a given market as a primary market one year and a secondary market in other years. For any given year, MarketSim determines primary/secondary market status based on the change in quantity demanded relative to the baseline.

domestic consumer surplus, the demand side benefits that result from a new 5-year program, are shown in Table 4 for each of the program areas.

Table 4 Net Domestic Consumer Surplus

	Net Domestic Consumer Surplus		
	\$ Billions		
	Low	Mid	High
Central GOM*	15.47	25.79	30.55
Western GOM	4.06	6.11	7.05
Eastern GOM	0.00	0.27	0.40
Chukchi Sea	2.12	3.06	6.60
Beaufort Sea	0.82	0.61	1.46
Cook Inlet	0.64	0.57	1.23

*Gulf of Mexico

Net Benefits Summary

The sum of the NSV and the net domestic consumer surplus benefits constitutes the total net benefits associated with the program area resources. The estimated total net benefits of resources in the currently available program areas form one of the bases for developing program options. Table 5 shows the estimates of the components of the Net Benefit analysis for the available program areas in the proposed program and the EIS alternatives for each of the three price cases.

Table 5 Net Benefits

	Net Social Value			Net Domestic Consumer Surplus			Net Benefits		
	(\$ billions)								
	Low	Mid	High	Low	Mid	High	Low	Mid	High
Central GOM	14.50	59.95	110.79	15.47	25.79	30.55	29.97	85.73	141.34
Western GOM	3.22	14.41	26.59	4.06	6.11	7.05	7.28	20.52	33.65
Eastern GOM	-0.16	1.11	2.56	0.00	0.27	0.40	-0.16	1.38	2.96
Chukchi Sea	5.27	20.83	62.67	2.12	3.06	6.60	7.39	23.90	69.27
Beaufort Sea	2.09	4.45	13.36	0.82	0.61	1.46	2.90	5.06	14.82
Cook Inlet	1.44	2.79	8.18	0.64	0.57	1.23	2.08	3.35	9.41

Figure 5 provides the Mid-price case calculations for Central GOM program area. This example provides values and displays the net benefits calculations in the same format as Figure 1 in the *Methodology* introduction.

Figure 5 Net Benefits Analysis Result for Central GOM Mid-price Case (\$billions)*

Anticipated Production 3.77 BBO 16.41 tcf (Table 7)	x	Assumed Oil and Gas Price Levels \$110/bbl and \$7.38/gas (Table 6)**	=	Gross Revenue 118.91***
Gross Revenue 118.91***	-	Private Costs of Program 64.14***	=	Net Economic Value (NEV) 54.77 (Table 1)
NEV 54.77 (Table 1)	-	Environmental and Social Costs of Program Proposal 4.25 (Table 3) - Environmental and Social Costs of Energy Substitutes (Selection of the No Sale option) 9.43 (Table 3) = Net Environmental and Social Costs -5.18 (Table 3)	=	Net Social Value (NSV) 59.95 (Table 5)
NSV 59.95 (Table 5)	+	Consumer Surplus Benefits - Lost Domestic Producer Surplus Benefits = 25.79 (Table 4)	=	Net Benefits 85.73 (Table 5)
<p>*All figures are discounted at 7 percent. **For NEV analysis prices and costs are inflated at 3% each year ***From internal model calculations</p>				

In this case the external costs from the No Sale Option exceed those under the recommended option, so the net environmental and social effects add benefits equal to about 10 percent to the NEV of the proposed program. The estimated net domestic consumer surplus from the pecuniary effects of the program on mostly gas prices adds benefits equal to about 56 percent of that NEV.

Assumptions and Input Data

Considerable uncertainty surrounds future production from the OCS and resulting impacts on the economy. A broad range of future conditions can result from a lease sale schedule. To be useful an analysis must be both specific and realistic, which is difficult in the face of uncertainty. Price expectations play an especially important role in estimating the value of the proposed program. For instance, industry will be much more likely to develop hydrocarbon resources in frontier areas if industry expects future oil and natural gas prices to rise. Despite a broad range of future conditions that can result from activities associated with the program, BOEM strives for consistency by using standard input assumptions in calculating each component of the economic analysis. The analysis in the draft EIS that accompanies the program decision document also uses the same set

of assumptions as the Net Benefits analysis. Six subsets make up the full assumption set for the economic analysis.

For the proposed program analysis, the assumption set is:

- oil and natural gas prices
- cost assumptions
- the discount rate
- anticipated production
- production profiles
- exploration and development scenarios

Oil and Natural Gas Price-Level Assumptions

Leasing from the 2012-2017 program is expected to stimulate exploration, development, and production activity for a period of 40 to 50 years. Although oil prices can experience a high degree of volatility during this period, BOEM uses three level-price scenarios in which the inflation-adjusted, or “real,” prices for oil and gas are assumed to remain constant to allow decision makers to more easily envision the range of possible production, benefits, and costs if prices rise or fall. Use of forecast or variable prices in the analysis would make it difficult for the decision makers to separate out the impacts of price changes from the differences in program areas. For this reason, the proposed program analysis includes resource and net benefit estimates for each of the three level price scenarios. The three price scenarios for the 2012-2017 proposed program shown in Table 6.

Table 6 Proposed Program Price Scenarios

	Oil (per bbl)	Gas (per mcf)
Low	\$60	\$4.27
Mid	\$110	\$7.83
High	\$160	\$11.39

Cost Assumptions

If prices increase significantly, their impact on oil and gas activities are not immediately felt due to long lead times needed to explore for resources and new infrastructure required to support higher activity levels. In addition, large increases in resource prices create additional competition for existing drilling rigs and investment dollars from other parts of the world which raises the cost of exploration, development, and production which in turn dampens the production boost from increased resource prices. Based on a historical analysis, BOEM uses a cost-price elasticity factor to calculate the NEV for each planning area price scenario. Using the base case of \$110/bbl, the assumed costs increase at one-half the rate of price in a rising price environment above base and costs drop at one-fourth the rate of price in a declining price environment below base.

Discount Rate

Based on a review of the literature, familiarity with returns to the industry, guidance from OMB Circular A-94 and the rate used in other BOEM economic analyses, a real social discount rate of 7 percent is used for all calculations. All values are discounted back to 2012 dollars.

Anticipated Production

Anticipated production is the estimated quantity of oil and natural gas expected to be produced as a result of the lease sales included in the proposed program. The Net Benefit analysis as summarized in the proposed program document at part IV.C, *Comparative Analysis of OCS Planning Areas*, uses anticipated production as a key empirical input to calculate the NEV of future production streams.

Total volume of anticipated production as a result of the proposed program in mature areas like much of the GOM is based on sale specific production trends but is also heavily influenced by recent leasing and drilling activity. Also considered is BOEM's internal 10-year production forecast which includes reserves, announced finds and expected production from undiscovered resources. The GOM has experienced a downturn in leasing and drilling activity over the past 5-plus years, especially in the Western GOM. The decline in activity has influenced BOEM to adjust downward the anticipated GOM production from this proposed program compared to the 2007-2012 program.

The anticipated production from frontier areas like the Alaska Arctic is based on judgments regarding the level of industry leasing and exploration activities that could lead to the discovery and development of new commercial fields consistent with the corresponding price assumptions. The estimates shown in Table 7 for Alaska Arctic areas are conditional on the assumption that initial development occurs on current leases and future OCS projects are produced through this infrastructure.

Economically recoverable resource estimates from the 2011 National Assessment form the basis for anticipated proposed program OCS production. The program's incomplete exploration activity over entire planning areas is insufficient to discover the entire resource endowment. The National Assessment models the undiscovered, technically and economically recoverable oil and natural gas resources located outside of known OCS oil and gas fields. The assessment considers recent geophysical, geological, technological, and economic information and uses a play analysis approach to resource appraisal. A complete description of the national resource assessment methodology may be accessed at: <http://www.boem.gov/revaldiv/Methodology.htm>.

Table 7 shows anticipated production estimates for program areas included in the proposed program.

Table 7 Proposed Program Production Estimates*

	Oil (billion barrels)			Gas (trillion cubic feet)			BBOE		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
Central GOM	2.24	3.77	4.34	9.47	16.41	19.07	3.92	6.69	7.73
Western GOM	0.56	0.86	0.97	2.63	4.07	4.59	1.03	1.58	1.79
Eastern GOM**	0.00	0.05	0.07	0.00	0.11	0.16	0.00	0.07	0.10
Chukchi Sea	0.50	1.00	2.15	0.00	2.50	8.00	0.50	1.44	3.57
Beaufort Sea	0.20	0.20	0.40	0.00	0.50	2.20	0.20	0.29	0.79
Cook Inlet	0.10	0.10	0.20	0.00	0.04	0.68	0.10	0.11	0.32

* After publication of the January 2009 DPP decision document, BOEM completed a subsequent resource assessment (2011 assessment) resulting in revised estimates of unleased, undiscovered economically recoverable resources. The new estimates are reflected in the anticipated production numbers in this table. The low-price case represents a scenario under which inflation-adjusted prices are \$60 per barrel for oil and \$4.27 per mcf for natural gas throughout the life of the program. Prices for the mid-price case are \$110 per barrel and \$7.38 per mcf. Prices for the high-price case are \$160 per barrel and \$11.39 per mcf.

** Current information does not indicate that the number of sales would affect anticipated production for the Eastern GOM. The two-sale option allows the Secretary to consider any new information that might arise from exploration on existing leases subsequent to his decision on the program, when deciding whether to hold a second sale.

Production Profiles

Production profiles or schedules show the distribution of anticipated production by year over the life of program related activity in each program area. Generally, production begins earlier in established shallower near shore areas in the GOM. Deepwater and frontier areas production schedules begin later and the activity tends to stretch over longer periods. The BOEM uses a 40 to 50 year time period from each lease sale to model the E&D activity. While production related to leasing in the 2012-2017 program may extend beyond the activity period with secondary recovery techniques, new technology, or growth in reserve/resource estimates, the models estimate results for 40 years in the GOM and 50 years in Alaska following a lease sale in this proposed program.

Exploration and Development Scenarios

Associated with various production levels in each program area are the activities required for exploration and development of OCS oil and gas resources. The list of these activities and facilities is called an E&D scenario. It is these factors of production and activities that yield the hydrocarbon resources and cause environmental and social impacts. The timing of production and revenue streams as well as production and social and environmental cost factors depend on the specified schedule of the various E&D activities. Table 8 shows the summary level E&D scenario for the Mid-price case attributable to each program area included in the proposed program. The E&D scenario for the Low- and High-price cases include corresponding though not linear well, facility and pipeline activity levels.

Table 8 Proposed Program E&D Scenario for the Mid Price (\$110/bbl, \$7.38/Mcf) Case

	Gulf of Mexico			Alaska		
	Central	Western	Eastern	Cook Inlet	Beaufort Sea	Chukchi Sea
No. of sales	5	5	2	1	1	1
Anticipated Production (BBOE)	6.69	1.58	0.07	0.11	0.29	1.44
Years of activity	40	40	40	40	50	50
Exploration & Delineation Wells	1,388	380	12	4	6	12
Development & Production Wells	1,725	476	10	42	40	100
Subsea	9	1	1	0	10	36
Platforms	274	86	0	1	1	2
Pipeline miles	3,979	1,149	37	50	60	100

DRAFT

References and Select Literature

- Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David Weimer. 1996. *Cost-Benefit Analysis Concepts and Practice*. Upper Saddle River, New Jersey: Prentice Hall.
- Boskin, Michael J., and Marc S. Robinson. 1987. "The Value of Mineral Rights, Correction and Update." *American Economic Review* 77(5): 1073-4.
- Boskin, Michael J., Marc S. Robinson, Terrance O'Reilly, and Praveen Kumar. 1985. "New Estimates of the Value of Federal Mineral Rights and Land." *American Economic Review* 75(5): 923-36.
- Dahl, Carol. 2010. "Review and Critique of Elasticities Used in the World Energy Projections Plus Model." U.S Energy Information Administration, Department of Energy, Office of Integrated Forecasting and Analysis. Washington D.C. February 1, 2010.
- Foster, William G. 2000. *Petroleum Supply and Demand Elasticity Estimates*. Presented to the U.S. Department of the Interior, Minerals Management Service in partial fulfillment of Contract No. 1435-01-99-CT-30996.
- French McCay, D.P. 2004. Oil spill impact modeling: development and validation. *Environmental Toxicology and Chemistry* 23(10): 2441-2456.
- French-McCay, D.P. 2009. "State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling." Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response. Emergencies Science Division. Environment Canada, Ottawa, ON, Canada: 601-653.
- Gramlich, Edward M. 1998. *A Guide to Benefit-Cost Analysis, Second Edition*, Prospect Heights, Illinois: Waveland Press, Inc.
- King, William E. 2007. "Economic Analysis for the OCS 5-Year Program 2007-2012: Theory and Methodology." OCS Report MMS 2007-017. Available at: <http://www.gomr.boemre.gov/PI/PDFImages/ESPIS/4/4329.pdf>.
- Mohring, Herbert. 1993. "Maximizing, Measuring, and Not Double Counting Transportation-Improvement Benefits: A Primer on Closed- and Open-Economy Cost-Benefit Analysis." *Transportation Research Part B* 27B(6): 413-424.
- Muller, Nicholas Z. and Robert Mendelsohn. 2006. *The Air Pollution Emission Experiments and Policy Analysis Model (APEEP): Technical Appendix*. Available at <https://seguecommunity.middlebury.edu/view/html/site/nmuller/node/2367900>.
- Plater, J. R. and William W. Wade. 2001. *Forecasting Environmental and Social Externalities Associated with OCS Oil and Gas Development: The Offshore Environmental Cost Model, Volume 1: Model Methodology, Documentation, and Sample Output*. U.S. Department of the Interior. Minerals Management Service. MMS OCS Study 2001-017.
- Roach, Brian, William W. Wade, and J. R. Plater. 2001. *Forecasting Environmental and Social Externalities Associated with OCS Oil and Gas Development: The Offshore Environmental Cost Model, Volume 2: Determinants of Environmental and Social Costs*. U.S. Department of the Interior. Minerals Management Service. MMS OCS Study 2001-018.

- Rosenthal, Donald H., Marshall B. Rose, and Lawrence J. Slaski. 1988. "Economic Value of the Oil and Gas Resources on the Outer Continental Shelf." *Marine Resource Economics* 5(2): 171-89.
- Serletis, Apostolos; Govinda. R. Timilsina, and Olexandr Vasetsky. 2010. "Interfuel Substitution in the United States." *Energy Economics* 32: 737-745.
- Thurman, Walter N. 1991. "Applied General Equilibrium Welfare Analysis." *American Journal of Agricultural Economics* 73(5).
- Thurman, Walter N. and Michael K. Wohlgenant. 1989. "Consistent Estimation of General Equilibrium Welfare Effects." *American Journal of Agricultural Economics* 71(4).
- U.S. Department of the Interior. Minerals Management Service. 2007. Proposed Outer Continental Shelf Oil & Gas Leasing Program 2007-2012, Decision Document.
- U.S. Department of the Interior. Bureau of Ocean Energy Management. 2011a. Outer Continental Shelf Oil and Gas Leasing Program: 2012-2017 Draft Programmatic Environmental Impact Statement. OCS report BOEM 2011-001.
- U.S. Department of the Interior. Bureau of Ocean Energy Management. 2011b. Proposed Outer Continental Shelf Oil & Gas Leasing Program 2012-2017, Decision Document.
- U.S. Department of the Interior. Bureau of Ocean Energy Management. 2011c. Outer Continental Shelf Petroleum Assessment 2011.
- U.S. Environmental Protection Agency (EPA). 2010. *The Benefits and Costs of the Clean Air Act: 1990 to 2020 – Summary Report*. 16 August 2010. Available at <http://www.epa.gov/oar/sect812/prospective2.html>.
- Western Regional Air Partnership Stationary Sources Joint Forum. 2009. Point and Area Source Pivot Tables for Regional Haze Planning Emissions Scenarios, Plan 02d. Accessed at <http://www.wrapair.org/forums/ssjf/pivot.html> on May 15, 2010.