7.3

ESTIMATING 70 YEARS OF LIFECYCLE GREENHOUSE GAS EMISSIONS FROM OIL AND GAS DRILLING IN FEDERAL WATERS

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1. INTRODUCTION

Anthropogenic emissions of greenhouse gases (GHGs) are the largest contributor to climate change (IPCC 2014). In its planning process, the Bureau of Ocean Energy Management (BOEM), the federal bureau responsible for oil and gas leasing in federal waters, analyzes potential GHG emissions when considering the potential environmental impacts of Outer Continental Shelf (OCS) oil and gas exploration, production and development. Pursuant to the Outer Continental Shelf Lands Act, BOEM is required to conduct a multi-year planning process to develop a schedule of lease sales for oil and natural gas offshore the U.S. This planning document, known generally as the Five-Year Program, covers offshore lease sales over a five-year time period, however, the impacts of oil and gas activity continue for decades due to the long time horizon of project development and production.

For its 2017-2022 OCS Oil and Gas Leasing Program ("2017-2022 Program"), BOEM has developed a new analytical approach to estimate the downstream GHG emissions for OCS oil and gas resources. This will allow BOEM to disclose the full lifecycle GHG emissions resulting from the exploration, development, production, processing, storage, transportation, and ultimate consumption of OCS oil and gas resources.

The analysis relies on historical oil and gas consumption patterns, emissions factors, and economic and production estimates. This approach has been used to examine emissions from oil and gas expected to be produced during the 2017-2022 Program, as well as emissions resulting from a no leasing scenario in which no new OCS leasing takes place and other domestic and international sources of energy are substituted. These emissions are estimated for different oil and gas price cases. The emissions estimates are subject to a number of assumptions as outlined in Section 4.0.

The social cost of carbon (SC-CO2), an estimate of the monetized damages associated with an incremental increase in carbon emissions, is applied to the estimated GHG emissions.

2.0 METHODOLOGY

The following analysis includes emissions from the three most common GHGs: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). GHGs with a high global warming potential, such as fluorocarbons, are used in very small quantities offshore, primarily in refrigeration and in circuit breakers, but are not deliberately released. This makes quantifying them very difficult, but their contribution relative to CO_2, CH_4, and N_2O emissions is very small; moreover, calculating these emissions would suggest the results have a greater degree of accuracy than is currently possible with available data.

While GHGs are global pollutants, their emissions are attributed to BOEM program areas in this analysis. Planning areas are the geographical unit of analysis in BOEM's Five-Year Program process. Program areas are the portions of the original OCS planning areas under consideration for leasing during the program development process.

The analysis has been spatially bounded to include emissions from U.S. consumption of

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OCS oil and gas, along with the substitution of sources for that energy under a no leasing scenario where there is no leasing from 2017 until 2022. The model covers all OCS operations, as well as onshore refining, processing, storage, distribution, and resource consumption. It excludes emissions from fluctuations regarding OCS operations, such as oil and gas companies' office space, changes in vehicle fuel efficiency in response to changing market conditions, and other secondary changes which may occur if BOEM does not make oil and gas leases available.

To support calculating the SC-CO_2, and to provide a direct comparison between the three different pollutants calculated, BOEM uses Global Warming Potential, also known as carbon dioxide equivalent (CO_2e). The purpose behind converting into CO_2e is to provide a direct comparison between emissions with different potential to trap heat and different atmospheric lifespans. For example, one metric ton of CH_4 has a similar impact as 25 metric tons of CO_2 (EPA 2016b). EPA's (2015) conversion factors are used (see Table 2-1).

Table 2-1. Global Warming Potential

Greenhouse Gas	Global Warming Potential (CO_2e)
CO_2	1
CH_4	25
N_2O	298
Source: EPA 2015	

2.1 EMISSIONS FROM EXPLORATION, DEVELOPMENT, PRODUCTION AND TRANSPORT

BOEM uses the Offshore Environmental Cost Model (OECM) to calculate the total GHG emissions associated with oil and gas activity occurring on the OCS (BOEM 2015a, 2015b). OECM provides estimates for the GHG emissions of typical activities associated with OCS production (e.g., platform construction, oil and gas well drilling), including potential oil spills occurring on the OCS. OECM uses economic inputs, resource estimates, and expected exploration and development scenarios with expected numbers of wells and associated production as the basis for its calculations.

2.2 EMISSIONS FROM ONSHORE PROCESSING, STORAGE AND DISTRIBUTION

Once onshore, oil is refined into petroleum products for specific uses, such as jet fuel, kerosene, and motor gasoline. A ratio of expected OCS production of crude inputs to refineries is used to scale refinery emissions. Crude oil input data from 2014 (EIA 2016c) are used together with 2014 GHG emissions from refineries (EPA 2016a). The same approach is used for natural gas storage and transmission; a ratio of OCS production and national gas consumption in 2014 (EIA 2016a) is used to scale the U.S. Environmental Protection Agency's (EPA) (2016a) inventory of natural gas systems emissions. These calculations are shown in Equation 1.

(1)

$$PE_{onshore} = R_{oil}\frac{Oil_{OCS}}{Oil_{Total}} + SD_{ng}\ \frac{NG_{OCS}}{NG_{Total}}$$

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

R_{oil} is total emissions from all oil refining onshore in metric tons (EPA 2016a)

SD_{ng} is total emissions from storage and distribution of natural gas in metric tons (EPA 2016a)

Oil_{OCS} and Oil_{Total} are oil expected to be produced on the OCS, and total U.S. oil refinery inputs in 2014 (EIA 2016c), respectively in barrels (bbl)

NG_{OCS} and NG_{Total} are natural gas expected to be produced on the OCS, and total U.S. natural gas consumption from 2014 (EIA 2016a), respectively in millions of standard cubic feet (mmcf)

Equation 1 is repeated for each of the GHGs being analyzed (CO_2, CH_4, and N_2O). R_{oil} and SD_{ng} are summed from EPA's most recent inventory (EPA, 2016a). R_{oil} includes emissions data from the following:

- Table 3-37 (Refining)
- Table 3-39 (Crude Refining)

SD_{ng} includes emissions data (EPA 2016a) from the following:

- Table 3-47 (Processing, Transmission and Storage, Distribution)
- Table 3-50 (Processing, Transmission and Storage, Distribution)

After refining, oil is primarily transported using oil products as an energy source (EPA 2008). To avoid double counting, motor gasoline and other oils discussed in Section 2.3, are assumed to be consumed in proportion to the transportation of OCS oil. For more information on this assumption, see Section 4.

2.3 EMISSIONS FROM CONSUMPTION

OCS oil and gas is assumed to be consumed in U.S. markets (for details on this assumption see Section 4). To estimate the types of petroleum products Americans consume and in what proportion, the Energy Information Agency's (EIA) (2016b) national 2015 consumption reports are used. A ratio is generated by dividing the national consumption of each petroleum product by overall oil consumption (see Equation 2). This calculation is repeated for each petroleum product quantified by EIA and is used to generate Table 2-2 below.

Table 2-2. U.S. 2015 Oil Consumption

Petroleum Product	2015 Consumption (1000s of Gallons)	2015 Consumption (% of Total)
Asphalt and Road Oil	5,258,190	1.77
Aviation Gasoline	175,018	0.06
Distillate Fuel Oil	60,999,348	20.52
Jet Fuel (Kerosene Type)	23,574,985	7.93
Kerosene	110,097	0.03
Propane	17,223,255	5.79
Other Liquid Petroleum Gases	19,205,935	6.46
Lubricants	2,069,550	0.70
Motor Gasoline	140,380,642	47.22
Petroleum Coke	5,368,055	1.81
Residual Fuel Oil #6	3,966,648	1.33
Other Oil	18,984,928	6.39

Source: EIA 2016b

(2)

$$C_i = \frac{Oil_i}{Oil_{Total}}$$

Where C_i is the consumption factor for end use of a petroleum product
Oil_i is the national consumption for a petroleum product in bbls (EIA 2016b)
Oil_{Total} is total oil products consumed nationally in bbls (EIA 2016b).

When oil is refined, the volume of product increases from the addition of other ingredients used to make each petroleum product. This volume increase is called processing gain. Currently, EIA estimates processing gain to be 6.7 percent across all petroleum products (EIA 2015).

By allocating expected OCS production proportionately, based on the petroleum products and incorporating oil processing gain, BOEM can apply EPA's emissions factors for GHG inventories (see Table 2-3). These categories of petroleum products do not match up perfectly between EIA and EPA. In two cases, distillate and residual fuel oils, there are multiple EPA emissions factors for a single EIA product category. In these instances, the amount of oil is evenly split among the possible emissions factors. This does not have a major effect on the overall analysis since the emissions factors for the different distillate and residual fuel oil categories are similar.

Table 2-3. Petroleum Emissions Factors for Greenhouse Gas Inventories in kg/gallons

Petroleum Product	CO_2	CH_4	N_2O
Asphalt and Road Oil	11.91	0.00047	0.00009
Aviation Gasoline	8.31	0.00036	0.00007
Distillate Fuel Oil #1	10.18	0.00042	0.00008
Distillate Fuel Oil #2	10.21	0.00041	0.00008
Distillate Fuel Oil #4	10.96	0.00044	0.00009
Jet Fuel (Kerosene)	9.75	0.00041	0.00008
Kerosene	10.15	0.00041	0.00008
Propane	5.72	0.00027	0.00005
Other Liquid Petroleum Gases	5.86	0.00028	0.00006
Lubricants	10.69	0.00043	0.00009
Motor Gasoline	8.78	0.00038	0.00008
Petroleum Coke	14.64	0.00043	0.00009
Residual Fuel Oil #5	10.21	0.00042	0.00008
Residual Fuel Oil #6	11.27	0.00045	0.00009
Other Oil (> 401^{o}F)	10.59	0.00042	0.00008

Source: EPA 2015

Some oil and natural gas are used as an ingredient for non-combustible products such as fertilizer and petrochemicals; this portion is removed from the consumption calculations since these products are not combusted and their normal use does not result in GHG emissions. EIA reports that 1.6 percent of all natural gas and 1.2 percent of all oil is never combusted (EIA 2012). Thus, the estimation for emissions from consumption of OCS oil is a summation of the emissions from each distinct petroleum product, as shown in Equation 3.

(3)

$$CE_{oil} = PG * CP_{oil}(1 - NC_{oil}) * \sum_{i=1}^{i=n}[C_i * EF_i] * 1{,}000$$

CE_{oil} is total emissions from oil consumption in metric tons
PG is the percent processing gain
CP_{oil} is OCS oil produced in gallons
NC_{oil} is the proportion of oil which is not combusted
C_i is the consumption factor for end use of a petroleum product (ratio, see Equation 3)
EF_i is the emission factor for each petroleum product in kilograms (kg) per gallon.
$_i$ refers to each of the petroleum products listed in Table 2-3.
1,000 converts kg to metric tons

Since natural gas is not refined into multiple combustible products, there is no processing gain; moreover, there is only a single product to assess even though natural gas is used for distinct purposes. EPA (2015) provides a single set of emissions factors for natural gas (see Table 2-4), as shown in Equation 4. Finally, total emissions, in metric tons, can be summed as shown in Equation 5.

(4)

$$CE_{ng} = CP_{ng}(1 - NC_{ng}) * EF_i * 1{,}000$$

CE_{ng} is total emissions from natural gas consumption in metric tons,
CP_{ng} is natural gas produced and consumed in mmcf,
NC_{ng} is the proportion of natural gas that is not combusted in mmcf, and
EF_i is the emission factor for natural gas in kg per mmcf
1,000 converts kg to metric tons

Table 2-4. Natural Gas Emissions Factors for Greenhouse Gas Inventories in kilograms/standard cubic feet

Petroleum Product	CO_2	CH_4	N_2O
Natural Gas	0.05444	0.00103	0.00010

Source: EPA 2015

$$E_{total} = PE_{offshore} + PE_{onshore} + CE_{oil} + CE_{ng} \tag{5}$$

2.4 EMISSIONS FROM ENERGY SUBSTITUTES

To evaluate the difference between new OCS oil and gas leasing during the 2017-2022 Program and a no leasing scenario, BOEM uses information from EIA to estimate energy sources that would be used in absence of the 2017-2022 Program to meet energy demand. The determination of energy substitutes adopts EIA's Annual Energy Outlook (AEO) assumptions that account for current laws, not potential future policies that could reduce emissions. BOEM estimates the GHG emissions that would otherwise be emitted from the other sources of energy Americans could use in place of OCS oil and gas from new leasing. Energy substitution includes meeting energy needs from other sources of oil and natural gas such as production from state submerged lands, onshore domestic production, and international imports. Coal, biofuels, nuclear, and renewable energy sources are substituted for OCS oil and gas in lesser amounts. In addition, BOEM's modeling indicates that there would be some conservation, reducing demand of energy sources due to higher oil and gas prices in the absence of new OCS resource availability. To determine the amount of GHG emissions for substituted energy sources, BOEM estimates the lifecycle emissions of the oil, gas, and other sources of energy used to replace OCS oil and gas.

Changes in energy consumption patterns are estimated using BOEM's energy market simulation model, MarketSim (Industrial Economics, Inc. 2015). This model simulates end-use domestic consumption of energy. MarketSim mostly represents U.S. energy markets, but also captures interaction with world energy markets as appropriate.

For purposes of these GHG calculations, BOEM assumes nuclear, biofuels, solar, and wind sources have negligible GHG emissions at final consumption either because the emissions are small by unit, or because the amount of substituted emissions are less than one percent of the total 2017-2022 Program emissions (BOEM 2015a, 2015b, and 2016). Although coal is expected to substitute for a very small portion of OCS oil and gas (less than one percent in the 2017-2022 Program), because of its higher rate of GHG emissions per unit of energy it is evaluated. Coal is expected to substitute for natural gas in electrical power generation, so BOEM uses EPA's (2015) emissions factors (see Table 2-5) combined with the substitution rate estimated by MarketSim to calculate emissions from coal (see Equation 6).

$$C_{cons} = O_{coal} * EF_{coal} * 1000 \tag{6}$$

C_{cons} is the emissions from the consumption of substituted coal in metric tons
O_{coal} is the amount of coal that substitutes for OCS products in British thermal units, estimated by MarketSim
EF_{coal} is the emissions factor for Mixed Coal (Electric Power Sector) in metric tons per British thermal unit (EPA 2015)
1000 converts kg to metric tons

Table 2-5. Coal Emissions Factors for Greenhouse Gas Inventories in kilograms/million British Thermal Units

Emissions Source	CO_2	CH_4	N_2O
Mixed (Electric Power Sector)	95.52	11	1.6

Source: EPA 2015

The emissions resulting from substitution are totaled using emissions from exploration, development, production, processing, storage and distribution, and consumption of substituted resources. OECM, the model used to calculate offshore emissions (see Section 2.2), provides emissions values for substituted production. This includes emissions from the production of oil, gas, coal, and other substituted sources of energy. If the energy, such as oil, is substituted by foreign sources, OECM also includes the GHG emissions released from bringing these products to the U.S. market. The summation of substituted sources is reflected in Equation 7.

$$E_{nd} = O_{prod} + CE_{oil} * S_{oil} + CE_{ng} * S_{ng} + C_{cons} \quad \textbf{(7)}$$

E_{nd} is the total emissions from the consumption of substitute energy sources when there is no new drilling on the OCS in metric tons
O_{prod} is the total emissions of the production of coal, oil, and natural gas from substituting sources in metric tons as estimated
CE_{oil} and CE_{ng} are total emissions from oil (see Equation 4) and natural gas (see Equation 5) consumption (measured in metric tons)
S_{oil} and S_{ng} are the oil and gas substitution rates, estimated by MarketSim
C_{cons} is the emissions from the consumption of substituted coal in metric tons (see Equation 8)

O_{prod} in Equation 7 originates from OECM. Emissions from these substituting sources, which use data from the National Energy Technology Laboratory (NETL 2009), show that oil production overseas is more GHG-intensive than production on the OCS. For example, CO_2 emissions occurring on the OCS are approximately 0.008 metric tons per barrel of oil equivalent (boe) versus overseas production, which OECM estimates at 0.037 metric tons per boe. This relationship between OCS and foreign oil production has been corroborated by other studies (Gordon 2015). OECM also includes the assumption of round trip (versus one-way) tanker trips. To a lesser and uncertain degree, these higher emissions can also be attributed to this simplifying assumption.

2.5 SOCIAL COST OF CARBON

GHG emissions have a cost to the environment and society. In 2010, the Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases developed the original U.S. Government SC-CO_2 estimates (IWG 2016). The SC-CO_2 estimates allow agencies to incorporate the social benefits of reducing CO_2 emissions into its decision-making. The IWG defines the SC-CO_2 as the "the monetized damages associated with an incremental increase in carbon emissions in a given year." Monetized impacts include, but are not limited to, changes in net agricultural productivity and human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

Table 2-6. Social Cost of CO_2, 2010 – 2050 in 2007 Dollars per Metric Ton of CO_2

Discount Rate Year	5% Average	3% Average	2.5% Average	95th Percentile at 3%
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

Source: Interagency Working Group Technical Support Document (IWC 2016)

For each emissions year, the IWG recommends four sets of SC-CO_2 values: three values based on the average SC-CO_2 from three integrated assessment models (IAMs), discounted at 2.5, 3, and 5 percent, as well as a fourth value corresponding to the 95th percentile of the frequency distribution of SC-CO_2 estimates at the 3 percent discount rate. Discounting is the process used for determining the present value of future costs and benefits.

As a result of the extensive scientific and economic literature on the potential for lower-probability, higher-impact outcomes from climate change, this fourth value is included to represent results should actual climate change outcomes align with this lower-probability scenario. Table 2-6 summarizes the SC-CO_2 estimates on a metric ton of CO_2e basis in five-year increments for the years 2010 through 2050.

The SC-CO_2 estimates in Table 2-6 are from the IWG's August 2016 Technical Support Document. BOEM adjusted the values in the report, represented in 2007 dollars, into 2015 dollars using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis (BEA 2016). 2015 dollars were then further adjusted to 2017 using the projected GDP chain-type price index from the EIA's 2016 AEO. For years beyond 2050, which are outside the scope of the interagency report (IWG 2016), BOEM derived SC-CO_2 values using the average growth rates for the 2040–2050 period. The SC-CO_2 values (2017 dollars) were then applied to the total CO_2e emissions estimates. To calculate a present value of the stream of monetary values, BOEM discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SC-CO_2 in each case.

3.0 OIL AND GAS PRODUCTION ESTIMATES

The 2017-2022 Program considers the activities and production from ten lease sales in the Gulf of Mexico (GOM) and one sale in the Cook Inlet. The 2017-2022 Proposed Program included sales in the Arctic Ocean (one in the Beaufort Sea and another in the Chukchi Sea), but these two lease sales were removed from the 2017-2022 Proposed Final Program. BOEM's Environmental Impact Statement describing the potential impacts of the Program also describes the range of OCS activities and production that could be possible over the 40 to 70 year life of the 2017-2022 Program (BOEM 2016a). BOEM considers production levels at low-, mid-, and high-price scenarios (Table 3-1). Oil and gas production for the 2017-2022 Program is based on the *Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, 2016* ("National Assessment") (BOEM 2016b).

Table 3-1. Oil and Natural Gas Production Estimates for 2017–2022 Program

	Low ($40/bbl; $2.14/mcf)		**Mid ($100/bbl; $5.34/mcf)**		**High ($160/bbl; $8.54/mcf)**	
	Oil (MMbbl)	**Natural Gas (bcf)**	**Oil (MMbbl)**	**Natural Gas (bcf)**	**Oil (MMbbl)**	**Natural Gas (bcf)**
Gulf of Mexico	2,106	5,470	3,531	12,011	5,593	22,122
Cook Inlet	84	37	209	93	335	149
Chukchi Sea*	–	–	2,644	1,116	4,231	1,785
Beaufort Sea*	–	–	2,295	4,029	3,673	6,447
2017-2022 Program*	2,189	5,507	3,740	12,104	5,928	22,271

* The 2017-2022 Program does not include the Beaufort and Chukchi Seas leases.

Table 3-2. Energy Substitutes Assuming No 2017–2022 Program

Energy Sector	Percent of OCS Production Replaced		
	Low	Mid	High
Total Onshore Oil and Natural Gas Production	28%	24%	26%
Oil	3%	4%	3%
Natural Gas	25%	20%	22%
Production from Existing State/Federal Offshore Leases	1%	1%	1%
Total Imports	61%	65%	63%
Oil Imports	60%	65%	63%
Gas Imports	0 %	0%	0%
Coal	< 1%	<1%	< 1%
Electricity from Sources other than Coal, Oil, and Natural Gas	1%	1%	1%
Other Energy Sources	3%	3%	3%
Reduced Demand/Consumption	7%	7%	7%

In the absence of the 2017-2022 Program, BOEM estimates energy substitutes using MarketSim (BOEM 2016c). BOEM's modeling shows that demand is reduced due to higher oil and gas prices likely to occur under this scenario, but that the vast majority of demand remains and must be fulfilled using other energy sources (Table 3-2).

4.0 KEY ASSUMPTIONS

This analytical model makes a number of assumptions, which could reduce its accuracy. The principal variable in this estimation is the OCS oil and gas production estimates, meaning any underlying uncertainty in the oil and gas production estimates has a profound impact on overall accuracy of the greenhouse gas emissions from the 2017-2022 Program. These production estimates are also a critical input into MarketSim and OECM, models which in turn necessarily rely on a series of assumptions. Other critical assumptions that affect the GHG emissions estimates are as follows:

1. Near constant demand for oil and gas is assumed over the next 40–70 years.

This analysis uses a projection of near constant oil and gas demand over the next 40–70 years using the 2016 AEO Reference Case, for which EIA does not assume any future changes in laws or policies other than what is incorporated in existing laws and policies. As countries, including the U.S., address climate change with individual policy targets, this assumption could no longer hold. Additionally, as new energy sources become more economically feasible, they could displace existing sources and/or alter the composition of energy supply. This analysis could be adapted in the future to incorporate policy shifts that affect demand for oil and gas.

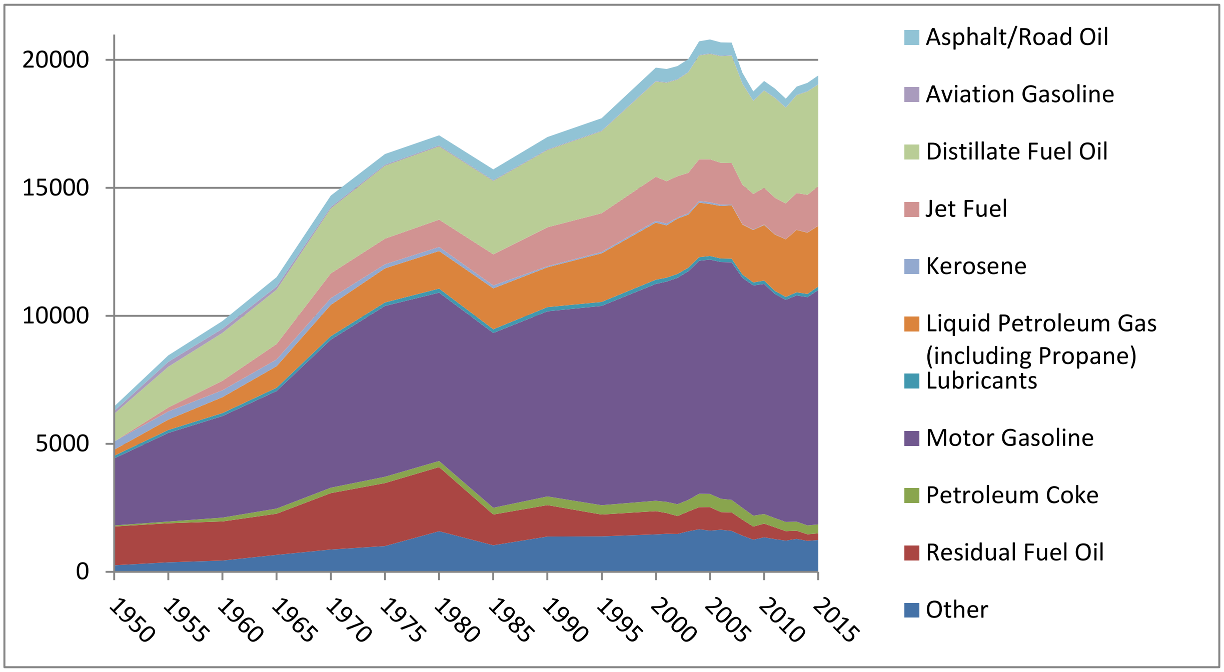

Figure 1. Historical U.S. Average Consumption per day of Petroleum Products by Year (1950 – 2015) in Thousands of Barrels (EIA 2016b)

2. Engines used for production, processing, and consumption of oil and gas will not become more efficient, and oil and gas will remain a primary energy source.

Engines have become increasingly efficient, but have largely remained dependent on fossil fuels. Moreover, the *President's Climate Action Plan* (White House 2013) calls for energy and transport efficiency improvements, including transitioning away from GHG-intense energy sources. One of the key tenets of the *President's Climate Action Plan* is the reduction of methane from oil and gas production facilities. Efficiency improves through the need for greater economy, as well as through regulation. These changes could alter the fuel type or quantity of oil and gas used to generate power. Similar changes will impact other types of oil and gas products, such as lubricants and plastics. These changes will alter more than just the amount of oil, but the portion of each barrel being consumed by any sector. For instance, in 2015, motor gasoline represented 47 percent of all petroleum products by volume. As battery technologies continue to improve, plug-in electric vehicle prices could continue to drop (Nyvist and Nilsson 2015), and percent of oil used for motor gasoline could drop as the share of electric vehicles increases. However, as the American electrical grid is increasingly dependent on natural gas, such shifts could increase demand for gas resources.

Figure 1 shows how consumption patterns of oil have changed in the past, including the rise of jet fuel and motor gasoline use, and the reduced use of residual fuel oil. Despite these longer-term shifts, demand for petroleum products has been fairly consistent from year to year. For example, motor gasoline, the largest consumed petroleum product, has never exceeded 47 percent (2015) of total consumption, nor has it dropped below 39 percent (1980) since 1950. During that entire time, it remained the largest petroleum product consumed by Americans.

Without a definitive method of estimating oil consumption and petroleum markets for the coming 70 years, it is impossible to predict how oil and gas consumption will change. However, using 2015 data still provides a useful approximation of consumption because the consumption patterns have not radically changed over the short-term. Longer-term trends could be incorporated by keeping the model up-to-date as consumption patterns shift. It is likely that efficiency will continue to improve, meaning less oil and gas will be required to generate the same amount of energy. This also affects upstream calculations, including the offshore exploration, development, and production, and onshore processing, storage, and distribution. Since this assumption equally affects OCS leasing, and its substitution, the user can still directly compare emissions.

3. All estimated oil and gas on proposed OCS leases is produced, processed, and consumed.

This analysis assumes all the oil and gas expected to be discovered on the OCS is produced, processed, and consumed. In reality, some oil and gas is lost, either by not being brought to production, or through inefficiencies at various stages of processing and distribution or other incidents, such as spills. These results assume that all oil removed from the OCS makes its way through to a customer and is consumed with perfect efficiency.

4. 'Other' oils, distillate fuel oil, and residual fuel oil are approximated.

There are several places where EIA's consumption categories do not match with EPA's emissions factors. Since EIA groups pentanes, petrochemical feedstocks, naptha-type jet fuel, still gas, waxes, and crude oil into a single 'Other' category, EPA's 'Other Oil (> 401^{o}F)' emissions factors are used. Similarly, EPA has two emissions factors for 'Residual Fuel Oil' and three for 'Distillate Fuel Oil,' but EIA reports distillate and residual fuel oils broadly. As a result, it is assumed there is equal consumption for each emissions factor, with half of residual fuel oil using each EPA emissions factor, and a third of oil for each distillate fuel oil emission factor. These assumptions reduce the model's accuracy. See Table 2-3 for both residual and distillate fuel oil emissions factors.

5. Processing gain is equal across all petroleum products and steady over time.

Processing gain is the increase in volume as oil is refined into petroleum products. Although all petroleum products have a processing gain, it is not the same for each product. Currently, EIA (2015) estimates processing gain as 6.7 percent overall, but that will likely change in the future.

6. All oil and gas is consumed domestically.

Emissions from the export of U.S.-produced oil and gas are relatively minor compared to the amount produced, processed, and consumed domestically. This assumption slightly underestimates the emissions from transportation of these products to other countries. Since emissions factors for natural gas do not vary, if they are consumed overseas, their emissions factors remain the same. However, since oil is consumed in a variety of products, which have a range of emissions factors, there is some loss in accuracy for petroleum products consumed overseas, since other countries do not consume these products in identical proportions to the U.S. Even with the loss of accuracy, approximating global emissions from oil using the United States as the example provides a reasonable example of oil consumption.

7. OCS oil is refined into the same petroleum products and consumed in the same proportions as oil and gas nationally.

It is likely OCS oil is refined into specific petroleum products, and those products are not in the same proportions as oil from all sources. However, neither BOEM nor EIA have information specifically identifying what petroleum products OCS oil is refined into, and in what proportions. Should more specific information become available; the model would be adjusted to accommodate such information.

8. Petroleum product distribution is powered with petroleum products in proportion to the overall production.

According to the EPA (2008), the vast majority of petroleum products distribution is powered with petroleum products. It is therefore assumed this oil is consumed in proportion to the oil produced from the OCS. Since this oil is already accounted for as part of the consumption calculations, there is no additional attempt to incorporate these emissions separately, which would result in double counting these emissions.

9. The percent of oil and gas that remains un-combusted is the same as 2011.

Since EIA (2012) has not updated their non-combusted use of fossil fuels since 2011, this is the most up-to-date information available. Similar to other assumptions, this no-change assumption reduces the overall accuracy of the analysis.

10. The reduction in foreign consumption of oil and gas in the no leasing scenario is not taken into account.

Just as there is a small amount of reduced domestic consumption without an OCS leasing program, there is also reduced demand for oil in foreign markets. MarketSim estimates this reduction in foreign oil consumption. For the global oil market, MarketSim substitutions under the no leasing scenario show a reduction in foreign oil consumption of approximately 1, 4, and 6 billion barrels of oil for the low-, mid-, and high-price scenarios, respectively, over the duration of the 2017-2022 Program. However, this analysis does not consider the reduced GHG emissions from the reduced foreign consumption.

Oil consumption in each country is different, and BOEM does not have information related to which countries would consume less oil. This is important information since consumption patterns vary by country. Thus, GHG impacts for this reduction in oil consumption are not captured in this analysis.

MarketSim represents the U.S. natural gas market with exports and imports, but does not directly model changes in foreign natural gas consumption without an OCS program. BOEM does not have information related to how changes in the U.S. market would affect other countries' consumption of natural gas.

5.0 RESULTS

These results estimate the oil and gas emissions and SC-CO_2 on leases that could be awarded during the 2017-2022 Program (see Section 3.0).

5.1 EMISSIONS RESULTS

The emissions resulting from the proposed leases and the substitute sources of energy consumed in the absence of new OCS leasing are provided for the three different price scenarios in Table 5-1.In the low-price case of the Proposed Program, the emissions in the Beaufort and Chukchi Seas are only from exploration activities since no production is expected under a low-price scenario. With no actual production expected under this scenario, there would be no production to substitute, resulting in zero emissions. Using estimated timing of production and offshore activities, GHG emissions are distributed over time for each price scenario. A graph for the mid-price scenario for the Proposed Program and the no leasing scenario is provided in Figure 2. Figure 3 shows the proportion of emissions from stages of the oil and gas lifecycle from both having the OCS program and from the substitute energy sources without the program. Note that these percentages, are similar across price case scenarios.

Table 5-1. Estimated Lifecycle Emissions from the Leases Sold in the 2017–2022 Program and the Substitute Energy Sources Under the No Action Alternative in Thousands of Metric Tons of CO_2e

Area	Low-Price Scenario		Mid-Price Scenario		High-Price Scenario	
	Program	No Leases	Program	No Leases	Program	No Leases
Gulf of Mexico	1,245,920	1,258,110	2,282,770	2,243,740	3,801,480	3,719,880
Cook Inlet	39,480	40,620	97,620	150,570	156,820	240,930
Chukchi Sea*	20	0	1,380,500	1,405,400	1,943,310	2,043,210
Beaufort Sea*	120	0	1,073,570	1,122,120	1,985,070	2,019,670
2017-2022 Program*	1,285,540	1,298,730	4,834,450	4,957,430	7,886,680	8,020,550

Notes: Emissions estimates have been rounded to the nearest 10,000 metric tons. Numbers may not sum due to rounding.
*The 2017-2022 Program does not include the Beaufort and Chukchi Seas leases.

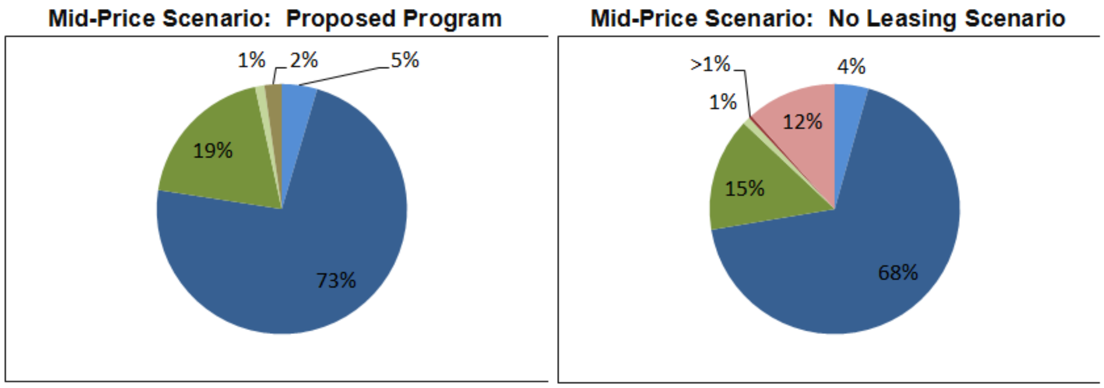

Figure 3. Estimated CO_2e Emissions by Source for the 2017–2022 Proposed Program (*left*) and the No Action Alternative (*right*), as a Percent of Total. The Offshore Production category includes operations occuring on the OCS, which produce oil and gas. The Oil, Gas, and Coal Consumption categories only include emissions from the final consumption of the resource. These ratios represent the Proposed Program, which includes the Arctic lease sales. The Proposed Final Program does not include Arctic lease sales.

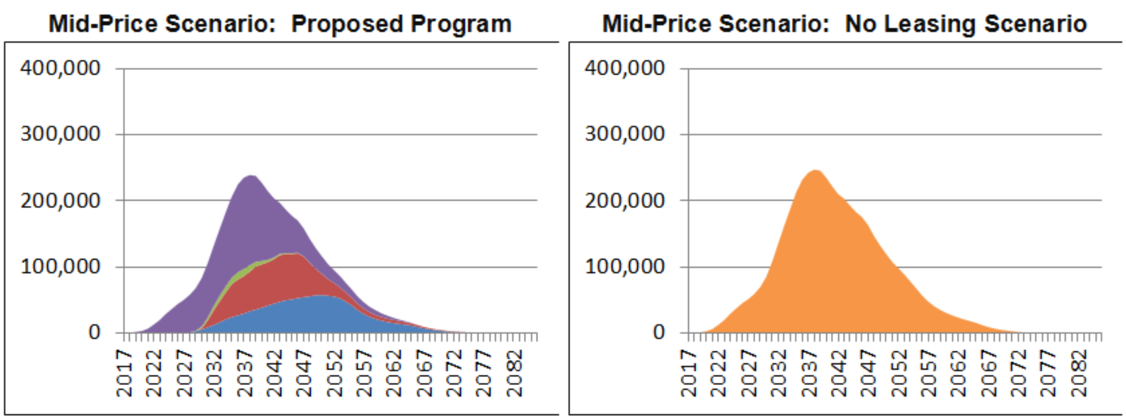

Figure 2. Estimated Lifecycle GHG emissions from the Leases Sold in the 2017-2022 Proposed Program (*left*) and the Substitute Energy Sources under the No Action Alternative (*right*). Emissions are distributed over time in thousands of metric tons of CO_2e.

5.2 SOCIAL COST OF CARBON RESULTS

To calculate a present value of the stream of monetary values, BOEM discounted the values for the 2017-2022 Program using the four discount rates from the Interagency Working Group: 2.5, 3, and 5 percent, as well as a 3 percent discount rate corresponding to the 95th percentile of the frequency distribution of SC-CO_2 estimates. Table 5-2 provides the net present value results for the 2017-2022 Program and no leasing scenario for the mid-price scenario.

Table 5-2. SC-CO_2 Results for the Mid-Price Scenario in Dollars

Social Cost of Carbon for Program and No Action Alternative (Mid-Price Case)				
Discount Rate	**$ billions**			
	Program Area	**Program**	**NAA**	**Net Difference**
5.0%	Beaufort Sea	7.76	7.99	-0.23
	Chukchi Sea	8.52	8.86	-0.34
	Cook Inlet	0.80	0.83	-0.02
	Gulf of Mexico	18.32	18.65	-0.33
	Total Proposed Program	*35.76*	*36.33*	*-0.93*
	Total Proposed Final Program	*19.12*	*	*
3.0%	Beaufort Sea	38.08	39.20	-1.13
	Chukchi Sea	39.97	41.51	-1.55
	Cook Inlet	3.54	3.64	-0.10
	Gulf of Mexico	81.15	82.61	-1.46
	Total Proposed Program	*162.73*	*166.97*	*-4.24*
	Total Proposed Final Program	*84.69*	*	*
2.5%	Beaufort Sea	61.44	63.25	-1.81
	Chukchi Sea	63.68	66.13	-2.45
	Cook Inlet	5.54	5.70	-0.16
	Gulf of Mexico	127.64	129.93	-2.29
	Total Proposed Program	*258.30*	*265.01*	*-6.70*
	Total Proposed Final Program	*133.18*	*	*
3.0% 95th Percentile	Beaufort Sea	117.01	120.47	-3.46
	Chukchi Sea	122.56	127.30	-4.74
	Cook Inlet	10.79	11.10	-0.31
	Gulf of Mexico	247.35	251.81	-4.46
	Total Proposed Program	*497.70*	*510.67*	*-12.97*
	Total Proposed Final Program	*258.14*	*	*

Key: * = The estimated distribution (%) of substitutions for the Proposed Final Program would be slightly different than those under the Proposed Program. The gross emissions estimates should be similar to the No Action Alternative under the Proposed Program.

6.0 CONCLUSION

In each price case of the 2017-2022 Program analysis, U.S. GHG emissions would be slightly higher if BOEM were to have no lease sales. These results assume no major market or policy changes. However, the margin is small, and uncertainties in the assumptions could account for the difference, even though assumptions used in analyzing the 2017-2022 Program and the no leasing scenario were the same. Emissions from substitutions are higher due to the exploration, development, production, and transportation of oil from more carbon-intensive sources. Even so, the majority of GHG emissions are a result of oil and gas product consumption. As reflected in the analysis, the emissions and associated social costs from the 2017-2022 Program and the no leasing scenario are relatively similar, in large part due to the estimated substitution of more GHG-intensive oil and gas sources in the absence of a new OCS leasing program.

Future changes in climate or other policies, supply and demand, shifting economic circumstances, or technological advances could substantially affect the assumptions and results of this analysis.

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