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OCS Oil and Natural Gas: Potential Lifecycle Greenhouse Gas Emissions and Social Cost of Carbon

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Foreword

This report evaluates greenhouse gas (GHG) emissions from oil and gas produced on the Outer Continental Shelf (OCS) of the United States. The Bureau of Ocean Energy Management (BOEM) believes this is the most comprehensive analysis conducted to date by a Federal resource management agency of the GHG emissions associated with the activities it authorizes. This report includes a methodology for analyzing the *full* lifecycle of activities resulting in the release of emissions, beginning with oil and gas exploration and production and ending with consumer use. BOEM intends to continue such public, full lifecycle reporting of GHG emissions in the future, with improvements garnered from feedback on this report and from other information.

The report concludes that America's GHG emissions will be little affected by leasing decisions under BOEM's 2017–2022 OCS Oil and Gas Leasing Program ("2017–2022 Program") and could, in fact, increase slightly in the absence of new OCS leasing. However, given analytical constraints, BOEM assumed that, for purposes of this analysis and the analysis that forms the basis of the 2017-2022 Program, foreign sources of oil will substitute for reduced OCS supply, and the production and transport of that foreign oil would emit more GHGs.

In addition to not fully capturing global market and GHG implications, BOEM recognizes that there is another, broader perspective than what is provided in this report. The Paris Agreement, to which the U.S. is a party, commits its parties to holding the increase in global average temperature to "well below 2° C above pre-industrial levels." The Intergovernmental Panel on Climate Change and other agencies and academics have evaluated what that commitment means for GHG emissions. In short, there is consensus that future global GHG emissions must be kept to about 1 trillion metric tons if global average temperature is to stay under the 2° C Paris Agreement commitment.

Each metric ton of GHG emissions associated with OCS oil and gas activities, or any other source, is a draw on Earth's 1 trillion metric ton emissions budget. Using externally developed estimates of global and U.S. carbon budgets, BOEM estimates that full lifecycle GHG emissions from past OCS oil and gas leasing and the 2017-2022 Program could represent as much as one-half percent of the remaining global carbon budget and potentially could represent up to 9 percent of the remaining carbon budget for the United States. While uncertainty obviously remains in estimating such numbers, it is helpful to provide a sense of scale with regard to the impact of OCS oil and gas development.

These two perspectives yield a wide range of potential GHG emissions that could result from oil and gas produced on the OCS. We welcome input on the approach used in this report in order to improve our analysis going forward.

BOEM is deeply invested in carrying out its statutory mission, balancing the development of domestic energy resources with the protection of our environment, informing decisions about America's energy future, and supporting deployment of alternatives to fossil fuels. In an effort to bring more transparency and awareness around the impacts of our decisions, BOEM offers this report for its methodology, information, and acknowledgement.

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Abstract

Anthropogenic emissions of greenhouse gases (GHGs) are the main contributor to climate change. Therefore, the Bureau of Ocean Energy Management (BOEM) analyzes potential GHG emissions when considering the potential environmental impacts of Outer Continental Shelf (OCS) oil and gas exploration and development. As a part of its environmental analyses, BOEM has historically estimated the direct GHG emissions resulting from oil and gas operations on the OCS. With this report, BOEM has developed a new analytical approach to estimate the combined upstream and downstream GHG emissions for OCS oil and gas resources, also known as lifecycle emissions. To better inform the public, this report discloses GHG emissions and the social cost of those emissions from the production, processing, storage, transportation, and ultimate consumption of OCS oil and gas resources that could be produced.

The analytical approach relies on historical consumption patterns, emissions factors, and economic and production estimates. The approach examines emissions from oil and gas produced on the OCS and eventually consumed under past, present, and future BOEM oil and gas leasing programs, as well as under No Action Alternative scenarios in which no new OCS leasing takes place and other domestic and international sources of energy are substituted. Three sets of GHG emissions estimates are considered: (1) emissions associated with the 2017–2022 OCS Oil and Gas Leasing Program ("2017-2022 Program"); (2) emissions from leasing under the 2012–2017 Program, to support the two remaining lease sales in the Program; and (3) emissions associated with development of oil and gas resources under leases prior to the start of the 2017–2022 Program. These three sets of emissions are estimated for different oil and gas price cases. The emissions estimates are subject to a number of assumptions as outlined in this report.

The social cost of carbon (SC-CO_2), an estimate of the monetized damages associated with an incremental increase in carbon emissions, is then applied to the estimated GHG emissions. The SC-CO_2 results are presented over a range of discount rates and displayed in 2017 dollars. A discussion of the uncertainty underlying these SC-CO_2 estimates is provided.

Key findings from this study include the following:

- Most lifecycle GHG emissions are the result of the consumption of oil and gas products.
- The price of oil and gas and volume of production has a large effect on the amount of oil and gas lifecycle GHG emissions.
- The magnitude of emissions and their related social costs are comparable for the 2017-2022 Program and the 2017–2022 Program's No Action Alternative.
- The production of oil and gas from other global sources can be more carbon-intense relative to oil and gas produced on the OCS.
- Absent policy changes or technological advancements, OCS emissions could consume a measurable increment of the remaining worldwide and domestic GHG emissions budget.

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Acronyms and Abbreviations

AEO	Annual Energy Outlook
bbl	barrels of oil
bcf	billions of standard cubic feet
BEA	Bureau of Economic Analysis
boe	barrel of oil equivalent
BOEM	Bureau of Ocean Energy Management
^{o}C	degrees Celsius
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DICE	Dynamic Integrated Climate Economy (model)
E&D	exploration and development
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
^{o}F	Fahrenheit
FUND	Climate Framework for Uncertainty, Negotiation and Distribution
GDP	gross domestic product
GHG	greenhouse gas
GOM	Gulf of Mexico
IAM	integrated assessment model
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IWG	Interagency Working Group on Social Cost of Greenhouse Gases
kg	kilograms
mcf	thousands of standard cubic feet
mmcf	millions of standard cubic feet
MMbbl	millions of barrels
N_2O	nitrous oxide
NEMS	National Energy Modeling System
NEPA	National Environmental Policy Act
OCS	Outer Continental Shelf
OECM	Offshore Environmental Cost Model
PAGE	Policy Analysis of the Greenhouse Effect
SC-CO_2	social cost of carbon
scf	standard cubic feet
U.S.	United States of America
UERR	undiscovered economically recoverable oil and gas resources
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	United States Global Change Research Program

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1. Introduction

The impact of greenhouse gas (GHG) emissions on the planet has been well documented (IPCC 2014, USGCRP 2014), and increasingly, governments at all levels are seeking to better understand how their decisions contribute to these emissions. The Bureau of Ocean Energy Management (BOEM) currently analyzes air pollutant emissions, including GHGs, every three years from the majority of oil and gas exploration, development, and production activities on the Outer Continental Shelf (OCS) through its Gulfwide Emissions Inventory (BOEM 2014). Future emissions from OCS oil and gas activities have also been estimated in the bureau's National Environmental Policy Act (NEPA) documents. However, the Gulfwide inventory and NEPA documents do not consider GHG emissions from the subsequent onshore processing, storage, distribution, and consumption of produced oil and gas resources.

The goal of this report is to examine the lifecycle GHG emissions associated with OCS oil and gas development activities both pre- and post-production, as well as the potential costs to society from these emissions. As part of this effort, BOEM will: (1) define a methodology for estimating the range of potential future emissions that could result from OCS oil and gas development; (2) estimate and disclose the contribution of future emissions from OCS lands already leased; (3) project a range of emissions that could ultimately result from development associated with both the current (2012–2017) and proposed (2017–2022) OCS Oil and Gas Leasing Programs; and (4) evaluate the social cost of carbon (SC-CO_2) of the 2017-2022 Program. The social cost of these emissions is an estimate of the monetized damages associated with the incremental increase in carbon emissions.

BOEM estimates the range of GHG emissions that are likely to be released during the lifecycle of oil and gas resources originating on the OCS. This includes all operations on the OCS associated with oil and gas leases (exploration, development, and production), onshore processing (refining and storage), delivery of these products to the final consumer, and the consumption of the oil and gas products. For context, BOEM compares these projected emissions to future annual emissions targets agreed to by the U.S. under the recent Paris Agreement, as well as a separately established U.S. emissions goal. Finally, BOEM calculates the anticipated social cost of these emissions by applying widely accepted criteria developed by the Federal government (IWG 2016).

With this report, BOEM is taking an important step toward a more complete disclosure to the public of the contribution of BOEM-permitted OCS oil and gas exploration, development, and production activities to national GHG emissions. This effort has been informed by the Council on Environmental Quality's recently issued *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* (Goldfuss 2016). The results of this report will allow BOEM to efficiently fulfill its responsibility to disclose the environmental implications of bureau actions in both planning efforts and NEPA documents.

BOEM estimates GHG emissions, expected to be released starting in 2017, with three different leasing activity subsets: leases to be issued under the 2017–2022 Program, leases that have or will be issued under the 2012–2017 Program, and OCS leases issued before the end of 2017 for all current and previous programs. This approach provides a context to consider the potential domestic and global contribution of OCS oil and gas program GHG emissions, with some insights as to how individual programs contribute to overall GHG emissions.

The results reflect a range of potential outcomes due to uncertainties inherent in energy markets. Among the more noteworthy factors are uncertainties regarding the amount of oil and gas resource potential offshore, uncertainty in future oil and gas price cases and anticipated production, and uncertainty about the future regulatory framework for GHGs that could reduce consumer demand for or supply of OCS oil and gas resources. Nonetheless, the report provides a broad picture of the consequences of OCS oil and gas exploration, development, and production activities.

This report will be revised as new information becomes available. At a minimum, BOEM expects to provide an update to this report within one year and for each subsequent Five-Year Program.

2. Overview of Climate Change

Climate change is broadly defined as the net global increase in temperature and related chemical and physical changes resulting from the release of certain pollutants associated with anthropogenic activities (IPCC 2014). Chief among the drivers of climate change are increasing atmospheric concentrations of carbon dioxide (CO_2) and other GHGs such as methane (CH_4, also known as natural gas), nitrous oxide (N_2O) and several fluorocarbons. Frequently, these emissions are converted into a single number, carbon dioxide equivalent (CO_2e), to reflect the different capacity of these gases to trap heat, as well as their differing atmospheric lifecycles (EPA 2016b). GHG molecules increase positive radiative forcing to alter temperature, humidity, wind, and precipitation patterns globally. The most recent U.S. National Climate Assessment highlights the history of that warming within the U.S., indicating that:

> U.S. average temperature has increased by 1.3°F to 1.9°F since 1895, and most of this increase has occurred since 1970. The most recent decade was the nation's and the world's hottest on record, and 2012 was the hottest year on record in the continental United States. All U.S. regions have experienced warming in recent decades, but the extent of warming has not been uniform. In general, temperatures are rising more quickly in the north. Alaskans have experienced some of the largest increases in temperature between 1970 and the present. People living in the Southeast have experienced some of the smallest temperature increases over this period (USGCRP 2014).

This warming is expected to result in rising sea levels, shrinking glacial coverage, loss of permafrost, and increasing extreme weather such as severe droughts, flooding, and stronger tropical cyclones (IPCC 2014). Other effects of GHGs include increasing oceanic concentrations of CO_2, leading to the acidification of the world's oceans and damage to environmental and cultural resources. Changes in climate regimes are also altering the range over which plants and animals live, by expanding some habitats while shrinking others, and possibly driving some species to extinction. In some regions, human beings are expected to also become displaced, retreating from the coastlines as seas inundate dry land,

and moving away from areas with increasingly hostile climate regimes. Some of these changes, such as the loss of permafrost, release additional GHGs, which accelerate or compound the harms associated with climate change. The U.S. National Climate Assessment describes this future warming as follows:

> The amount of warming projected beyond the next few decades is directly linked to the cumulative global emissions of heat-trapping gases and particles. By the end of this century, a roughly 3°F to 5°F rise is projected under a lower emissions scenario, which would require substantial reductions in emissions, and a 5°F to 10°F rise for a higher emissions scenario assuming continued increases in emissions, predominantly from fossil fuel combustion (USGCRP 2014).

The assessment goes on to describe the effects of this warming across the U.S. Increasing annual rainfall, particularly in the northeast, the Great Lakes, and the southeast, has the potential to cause more frequent flooding. This is in contrast to declining precipitation across Hawaii, which already has scarce freshwater resources. Droughts, oscillating with flooding events, are expected to become more common across the southwest. Melting permafrost in Alaska has the potential to damage or destroy parts of the state's infrastructure.

The world's oceans are also transforming (IPCC 2014, USGCRP 2014). Thus far the ocean has absorbed 90 percent of the heat associated with climate change. As the water absorbs heat, it expands and compounds sea level rise already occurring as a result of melting glaciers and ice caps. This threatens the nation's coasts, but also threatens low-lying areas farther inland, such as the lower Mississippi River basin. The impacts of shifting precipitation, temperatures, and coastlines will substantially impact the nation's agriculture, water resources, human health, energy, transportation, forests, ecosystems, and public and private infrastructure. All of these changes will have an impact on the American economy. Adaptation to these changes will be more difficult for those who have fewer resources, such as poor and minority communities.

3. United States' Greenhouse Gas Emissions

U.S. GHG emissions rose steadily from the industrial revolution through the end of the twentieth century. More recently, U.S. GHG emissions have leveled off, and compared to 2008, emissions have declined (see Figure 1). Substantial additional emissions reductions are needed around the world to avoid the worst impacts of climate change. This is reflected in recent U.S. commitments to reduce emissions under international agreements, as well as the longer-term U.S. goals articulated by the Obama Administration.

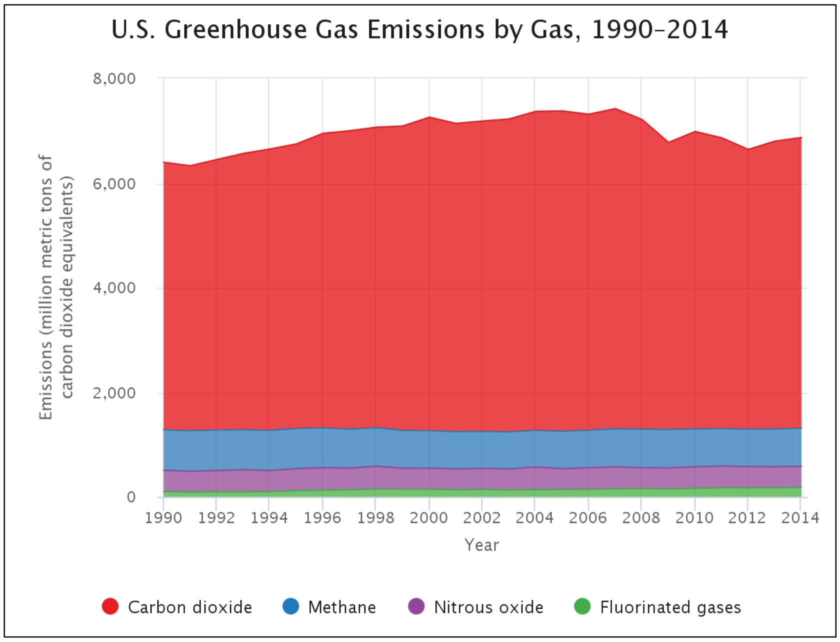

Figure 1. U.S. Total GHG Emissions from 1990 – 2014 (EPA 2016a)

U.S. emissions largely come from the consumption of fossil fuels including oil, natural gas, and coal. These fuels are consumed in different proportions across different economic sectors. The two largest generators of GHGs are electricity generation and transportation, both of which are needed to support the other sectors. GHG emissions from the transportation sector almost entirely originate from petroleum products, with coal and natural gas being the primary sources of GHGs in electricity generation. Oil and gas consumption are also the primary sources of GHGs from residential, commercial, and industrial sectors (see Figure 2).

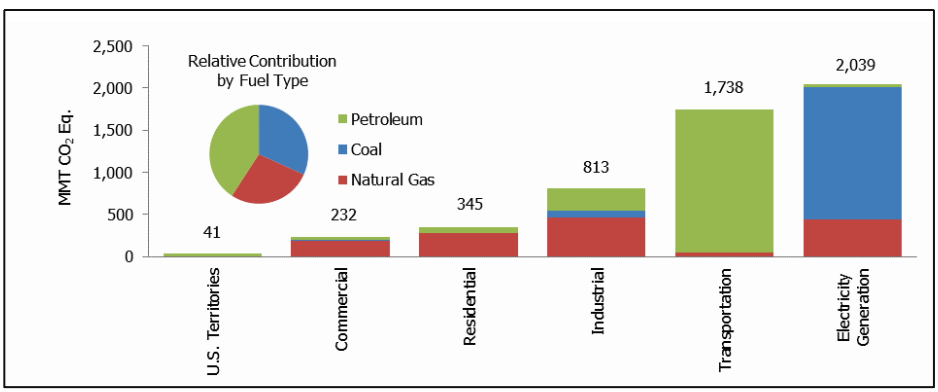

Figure 2. 2014 Greenhouse Gas Emissions by Fuel Type and Sector (EPA 2016a)

On April 22, 2016 (UNFCCC 2016), the United States joined the Paris Agreement, a United Nations' brokered agreement to keep the net global temperature increase to within 2°C (3.6°F) of the pre-industrial level, and preferably within 1.5°C (2.7°F). A recently published study asserts that to keep the planet from warming beyond 2°C (3.6°F), global emissions of GHGs between 2011 and 2050 must be kept below 1,100 million metric tons CO_2e (McGlade & Ekins 2015). It should be noted that the 2°C warming threshold would likely result in drastic changes to the world's climate system (Hansen 2016, IPCC 2014, USGCRP 2014).

The Paris Agreement requires countries to set goals to help stabilize GHG concentrations in the atmosphere at a level that would limit anthropogenic interference with the climate system. The goals are referred to as Intended Nationally Determined Contributions (INDC) (UNFCCC 2016). The United States has set its INDCs using a base year of 2005. In 2005, the United States emitted net emissions of 6,680,300,000 metric tons of CO_2e (EPA 2016a). By 2020, the U.S. intends to reduce its net GHG emissions to 17 percent below 2005 levels. By 2025, the U.S. proposes to have GHG emissions between 26 and 28 percent below 2005 levels. Independent of the Paris Agreement, the U.S. has set a goal to reduce net GHG emissions by 80 percent from 2005 levels by 2050 (White House 2015). As of 2014, U.S. net GHG emissions had declined 9 percent from 2005 levels (EPA 2015). See Table 3-1 for more information on emission reduction goals.

Table 3-1. Historical U.S. Emissions and Emissions Commitments

Year	Net CO_2e Emissions (metric tons)	Reduction from Base Year (%)
2005	6,680,300,000	–
2014	6,108,000,000	9
2020*	5,544,649,000	17
2025*	4,943,422,000 – 4,809,816,000	26 – 28
2050^	1,366,060,000	80

Notes:
* = U.S. emissions commitments under the Paris Agreement
^ = U.S. emissions commitment by the Obama Administration

To achieve these goals, the U.S. assumes a reduction in fossil fuel consumption, changes in agricultural practices and other activities that would mitigate the amount of GHG emissions released. The U.S. also assumes an increase in GHG sinks, which remove GHGs from the atmosphere, using practices like reforestation.

4. Greenhouse Gas Emissions Calculations Methodology

The following analysis includes emissions from the three largest GHGs: CO_2, CH_4, and N_2O. Fluorocarbons are used in very small quantities in refrigeration and in circuit breakers offshore, 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 fluorocarbon emissions would suggest the results have a greater degree of accuracy than is currently possible with available data. Additionally, the analysis has been spatially bounded to include emissions from U.S. consumption of OCS oil and gas, along with the substitution of sources for that energy under the No Action Alternative scenario where there is no 2017-2022 Program. The reasoning behind this is the insufficient data available for the kind and proportion of oil products used and a lack of information on overseas energy substitutions. The model estimates the emissions resulting from exploration, development, production, transportation to shore, onshore processing, delivery, and consumption of oil and gas products from the OCS, or their substitutes. This includes all OCS operations, as well as onshore refining, processing, storage, distribution, and consumption. It excludes emissions from secondary changes regarding OCS operations, such as BOEM's and oil and gas companies' office spaces, changes in vehicle fuel efficiency in response to changing market conditions, and others.

The following three subsections detail the approach for estimating GHG emissions. The first subsection addresses emissions released from offshore operations. The second subsection describes scaling emissions released as part of onshore processing and distribution, based on historic emission rates. Lastly, emissions resulting from consumption of petroleum and gas products are calculated using emissions factors and historic consumption patterns.

4.1 Emissions from OCS Exploration, Development, Production, and Transport

BOEM uses the Offshore Environmental Cost Model (OECM) to calculate the environmental and social costs and GHG emissions associated with oil and gas activity occurring on the OCS (BOEM 2015a, 2015b). OECM provides estimates for the monetized impact of typical activities associated with OCS production, including potential oil spills (other than catastrophic 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. GHG emissions from OCS operations are estimated as follows, and a single total emissions number is reported for each of the three major GHGs:

Equation 1:

$$PE_{offshore} = \sum PE_{equipment}$$

$PE_{offshore}$ is the total emissions from offshore production in metric tons
$PE_{equipment}$ are the incremental emissions from using each piece of equipment such as drilling wells, constructing platforms, delivering supplies, and transporting resources to shore.

4.2 Emissions from Onshore Processing, Storage, and Distribution

Once onshore, oil is generally 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 2016d) are used in coordination 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. It is assumed emissions from these activities are in proportion to the amount of oil and gas that make their way through these processes.

Equation 2.

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

$PE_{onshore}$ 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 2016d), 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)

This equation 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 (2016a) most recent inventory. 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 being refined, oil is primarily transported using oil products as an energy source (EPA 2008). To avoid double counting, motor and other oils estimated in Section 4.3, are assumed to be consumed in proportion to the transportation of OCS oil. For more information on this assumption, see Section 7.

4.3 EMISSIONS FROM CONSUMPTION

All oil and gas is assumed to be consumed in U.S. markets (for details on this assumption see Section 7). To determine the types of petroleum products Americans consume and in what proportion, EIA's (2016b) national 2015 consumption reports are used. A ratio is generated by dividing the national consumption of each petroleum product by overall oil consumption.

Equation 3.

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

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)

This calculation is repeated for each petroleum product quantified by EIA and is used to generate Table 4-1 below.

Table 4-1. U.S. 2015 Oil Consumption

Petroleum Product	2015 Consumption (1000s of Gallons)	2015 Consumption (% of Total)
Asphalt and Road Oil	5,258,180	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	3,342,396	47.22
Petroleum Coke	127,811	1.81
Residual Fuel Oil #6	94,444	1.33
Other Oil	452,022	6.39

Source: EIA 2016b
Note: Forty-two gallons is equal to 1 barrel of oil

When oil is refined, the volume of product increases as a result of the addition of other ingredients used to make each petroleum product. This volume increase is called the production gain. Currently, EIA estimates production 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 production gain, BOEM can apply EPA's recommended emissions factors for GHG inventories (see Table 4-2). 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 is a reasonable approximation since the fuel types are used enough in the U.S. for EPA to have researched and developed emissions factors for each. 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 very similar.

Table 4-2. 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 Type)	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 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 4 below:

Equation 4.

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

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 4-2.
1,000 converts kg to metric tons

Since natural gas is not refined into other combustible products, there is no processing gain; moreover, there is only a single product to assess even though natural gas is used in different markets. EPA (2015) provides a single set of emissions factors for natural gas (see Table 4-3), making the estimation straight forward, as follows:

Equation 5.

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

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 2-3. Natural Gas Emissions Factors for Greenhouse Gas Inventories in kg/scf

Petroleum Product	CO_2	CH_4	N_2O
Natural Gas	0.05444	0.00103	0.00010

Source: EPA 2015

Finally, total emissions, in metric tons, can be summed as E_{total}:

Equation 6.

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

4.4 Emissions from Energy Substitutes

To evaluate the difference between new OCS oil and gas leasing during the 2017–2022 Program and a No Action Alternative (i.e., no new leases in the 2017–2022 Program), 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 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, and nuclear and renewable energy sources are substituted for OCS oil and gas in lesser amounts. In addition, it is assumed that there would be some conservation measures, including reduced demand and consumption of all 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). MarketSim is the same model used to evaluate substitutions in the 2017–2022 Program economic analysis. This model simulates end-use domestic consumption of oil, natural gas, coal, and electricity in four sectors (residential, commercial, industrial, and transportation); primary energy production; and the transformation of primary energy into electricity. MarketSim mostly represents U.S. energy markets, but also captures interaction with world energy markets as appropriate. The model takes current measures of energy production, consumption, and prices assuming no new OCS leasing as a baseline to which a given scenario of OCS production is added. Accounting for substitution between different sources of energy, the model calculates equilibrating prices for oil, natural gas, coal, and electricity based upon the expected increase in OCS production of oil and gas.

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 (BOEM 2015a, 2015b, and 2016). These negligible emissions are not analyzed in this report with one exception. 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), its higher rate of GHG emissions per unit of energy makes it worth evaluating. Coal is expected to substitute for natural gas in electrical power generation. BOEM uses EPA's (2015) emissions factors (see Table 4-4) combined with the substitution rate estimated by MarketSim to calculate emissions from coal (see Equation 7).

Table 4-4. 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

Equation 7.

$$C_{cons} = O_{coal} * EF_{coal} * 1000$$

C_{cons} is the emissions from the consumption of substituted coal in metric tons
O_{coal} is the amount of coal replacing OCS products in British thermal units
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

The overall emissions as a result of substitution are totaled using emissions from exploration, development, production (including tankering), processing, storage and distribution, and consumption of the substituted resources. OECM, the model used to calculate offshore emissions (see Section 4.1), provides similar emissions values for non-OCS production. This includes emissions from oil, gas, coal, and other substituted sources of energy. If the energy, such as oil, is substituted by foreign sources, the GHG emissions released from bringing these products to the U.S. are included.

The summation of production and consumption of substituted sources is reflected in the following equation:

Equation 8.

$$E_{nd} = O_{prod} + CE_{oil} * S_{oil} + CE_{ng} * S_{ng} + C_{cons}$$

E_{nd} is the total emissions from oil and gas consumption when there is no new drilling on the OCS in metric tons
O_{prod} is the total emissions of all substituting sources in metric tons as estimated in OECM
CE_{oil} and CE_{ng} are total emissions from oil (see Equation 4) and natural gas (see Equation 5); consumption is 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 8 originates from OECM, which assumes oil production overseas is more GHG-intensive than production on the OCS. For example, CO_2 emissions occurring on the OCS are approximately 0.007759 metric tons per barrel of oil equivalent (boe) versus overseas production, which OECM estimates at 0.036522 metric tons per boe. This relationship between OCS and foreign oil production has been corroborated by other studies (Gordon 2015). To a lesser degree, these higher emissions can also be attributed to OECM assuming two-way trips of tankers bringing oil to the U.S.

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 CO_2e. The purpose behind converting into a 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_2e. EPA's (2015) conversion factors are used (see Table 4-5).

Table 4-5. Global Warming Potential in Metric Tons

Greenhouse Gas	Global Warming Potential (CO_2e)
CO_2	1
CH_4	25
N_2O	298

Source: EPA 2015

5. Social Cost of Carbon Calculations Methodology

GHG emissions have a cost to the environment and society. In 2010, the Interagency Working Group (IWG) on Social Cost of Carbon developed the original U.S. Government SC-CO_2 estimates. Through the interagency process, the IWG selected SC-CO_2 values for use in regulatory analyses and published their recommendations in February 2010. The SC-CO_2 values are the official Government estimates and represent the best available information for scientific and economic analyses. The IWG, currently called the Interagency Working Group on the Social Cost of Greenhouse Gases, subsequently revised the report in 2013, 2015, and most recently in August 2016 (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.

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)[1], 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 monetary value of future social costs.

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. Presenting this information is important because such outcomes, even if currently presumed to be unlikely, would be particularly harmful to society if realized. Therefore, a consideration of the potential impacts is relevant to the public and policymakers. Table 5-1 summarizes the SC-CO_2 estimates on a metric ton of CO_2e basis in five-year increments for the years 2010 through 2050.

Table 5-1. 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	High Impact (95th Pct 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

A number of key uncertainties with the SC-CO_2 estimates remain (IWG 2016). As a result, the current estimates should be treated as provisional because they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. A number of analytical challenges are being addressed by the research community, including research programs housed in many of the Federal agencies participating in the interagency

[1] SC-CO_2 estimates are averaged in the Technical Support Document based on the three IAMs: Dynamic Integrated Climate-Economy (DICE), Policy Analysis of the Greenhouse Effect (PAGE), and Climate Framework for Uncertainty, Negotiation and Distribution (FUND). For more information about these models and their underlying uncertainty, refer to the August 2016 Technical Support Document (IWG 2016).

process. The interagency group intends to periodically review and reconsider those estimates to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. The National Academies of Sciences, Engineering, and Medicine is expected to release a report in 2017 providing for longer-term recommendations for a more comprehensive update to the SC-CO_2.

The SC-CO_2 estimates in the August 2016 Technical Support Document (Table 5-1) are measured in 2007 dollars. BOEM adjusted these original values to 2015 dollars using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis (BEA 2016). For consistency with other recent BOEM economic analysis, including analysis in the 2017–2022 Program, BOEM further adjusted 2015 dollars to 2017 using the projected GDP chain-type price index from the EIA's 2016 *Annual Energy Outlook* (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. BOEM then applied the SC-CO_2 values (2017 dollars) to the total CO_2e emissions estimates described earlier in this report. 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.

6. OCS Oil and Gas Production Estimates

It is possible, but not particularly efficient, to estimate potential lifecycle GHG emissions at each stage of the OCS oil and gas program: five-year program (national), individual lease sale (region or sub-region), or every exploration and development plan (site-specific or project-scale). Consistent with CEQ's guidance, BOEM has adopted an approach based on the standard of proportionality.

BOEM estimates GHG emissions, expected to be released starting in 2017, associated with three different subsets of leasing activity: (1) leases potentially issued under the 2017–2022 Program including the Proposed Program and Proposed Final Program (also the Preferred Alternative identified in the Programmatic EIS); (2) leases that have been or may be issued under the 2012–2017 Program; and (3) OCS leases issued before the end of 2017 for all current and previous Programs (Table 6-1). This approach provides a broader context to consider the potential domestic and global contribution of OCS Program GHG emissions. The production estimates from the 2012–2017 Program case is entirely included in production expected from all leases issued before the end of 2017.

Table 6-1. Emissions Cases Analyzed

Scenario	OCS Planning Areas Considered				
	Gulf of Mexico	Southern California	Cook Inlet	Beaufort Sea	Chukchi Sea
2017–2022 Proposed Program (emissions after July 2017)	●	–	●	●	●
2017–2022 Proposed Final Program (Preferred Alternative in Final Programmatic EIS) (emissions after July 2017)	●	–	●	–	–
2012–2017 Program (emissions after Jan. 2017)	● (excluding Eastern Planning Area)	–	●	–	–
All Previous and Current Programs (only emissions after Jan. 2017)	●	●	●	●	–

Critical variables to estimate lifecycle GHG emissions include OCS activity levels as well as oil and natural gas produced from the OCS. It is important to note that the majority of GHG emissions will be from the combustion of OCS oil and natural gas produced, as compared to the activities required to explore, develop, produce, transport, process or refine, and distribute oil and natural gas.

Activity levels and production levels for the 2017–2022 Program and 2012–2017 Program cases are derived from exploration and development (E&D) scenarios prepared by BOEM and presented in detail in supporting Programmatic EIS documents (BOEM 2012, 2016a). E&D scenarios describe the potential resources available for leasing and how those potential resources, if found, might be explored and discovered, developed, and produced. The E&D scenarios provide estimates of the types, location, and timing of oil- and gas-related activities and production that could result from a Five-Year Program following lease sales. E&D scenarios are characterized by substantial uncertainty, but are useful to understand the potential GHG emissions that could occur under a given range of possible Program outcomes. Anticipated production estimates reflected in the E&D scenarios represent the portion of undiscovered economically recoverable oil and gas resources (UERR) available on unleased blocks in each of the program areas. UERR refers to that portion of the undiscovered technically recoverable oil and gas resources that could be explored, developed, and commercially produced at given cost and price considerations using present or reasonably foreseeable technology. Activity elements of an E&D scenario include the number of exploration wells drilled, the number of platforms installed, the number of development wells drilled, miles of new pipeline constructed, anticipated aggregate oil and gas production, the number of platforms removed, etc.

It is imperative to realize that E&D scenarios, as well as underlying price assumptions, do not constitute predictions or forecasts. BOEM does not necessarily expect a particular E&D scenario to be realized. Considerable uncertainty surrounds future activity levels and production given geologic risk and economic risk, especially in frontier areas like the Alaska OCS where there is currently no or very limited OCS activity. In some cases, BOEM's E&D scenarios could overestimate activity levels and production. In particular, the E&D scenarios for the Alaska OCS represent a wide range of possible outcomes, from a more probable exploration-only scenario in the Arctic OCS to a more aggressive, but less probable scenario envisioning a substantial build-out of Arctic OCS production operations. However, in these cases the hypothetical E&D scenario is considered so as to understand the potential environmental implications should BOEM leasing activity ultimately lead to such an outcome.

OCS production for the third subset of leasing activity (i.e., future emissions from OCS leases issued prior to and through the 2012–2017 Program) is derived using methods similar to those used by the Energy Information Agency (EIA) in its 2016 AEO (EIA 2016c) and relies in part on EIA data. Special National Energy Modeling System (NEMS) runs provided by the EIA are used to estimate OCS oil and gas production assuming no new leasing after the last sale in the 2012–2017 Program (EIA 2014). Production estimates are provided for the Gulf of Mexico (GOM), Pacific, and Alaska OCS Regions through 2040. EIA's (2014) documentation for NEMS describes the uncertainty inherent in the estimates. The difference between the special NEMS run and EIA's Reference Case in the 2016 AEO is the removal of any assumed OCS production associated with leases issued after the 2012-2017 Program. These special NEMS runs are used as part of the scenario discussed in Section 6.3, which considers all leases issued before the end of 2017. Low- and high- oil price cases (variable price) are also considered where the removal of OCS production beyond the 2012–2017 Program is also considered. In order to provide a complete lifecycle analysis, BOEM extrapolates the potential future OCS production under the special NEMS runs from 2040 through approximately 2075 assuming an aggregated, non-linear OCS production decline curve.

For OCS emissions, corresponding activity levels are not directly estimated because OECM cannot process production estimates without a corresponding E&D scenario. BOEM approximates OCS emissions by assuming a proportional ratio of activity to production (i.e., emissions per production unit). Separate emissions factors are calculated for GHGs across the entire OCS. The emissions factors are calculated as averages across program areas from the OECM results for the 2012–2017 and 2017-2022 Programs. These emissions factors are calculated on a per-barrel of oil basis, and in the case of gas, a barrel of oil equivalent basis.

6.1 2017–2022 OCS Oil and Gas Leasing Program

The 2017–2022 Proposed Program case considers the activities and production from ten lease sales in the GOM and one sale in each of Alaska's program areas: Beaufort Sea, Chukchi Sea, and Cook Inlet. The Proposed Final Program, also the Programmatic EIS's Preferred Alternative, includes the sales in the Cook Inlet and GOM, while excluding the two Arctic lease sales in the Beaufort and Chukchi Seas. The Programmatic EIS describes the potential 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 6-2). Chapter 3 of the Final Programmatic EIS describes the magnitude and timing of OCS activities and production in detail. The E&D scenarios for the 2017-2022 Program are 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 6-2. Oil and Natural Gas Production Estimates for 2017–2022 Program

Price Scenario	Price		Program Area				Total Production Comparison	
			GOM (10 sales)	Chukchi Sea (1 sale)	Beaufort Sea (1 sale)	Cook Inlet (1 sale)	Proposed Program	Proposed Final Program
Low	Oil ($/bbl)	$40	2,106	–	–	84	2,189 MMbbl	2,189 MMbbl
	Natural Gas ($/mcf)	$2.14	5,470	–	–	37	5,507 bcf	5,507 bcf
Mid	Oil ($/bbl)	$100	3,531	2,644	2,295	209	8,680 MMbbl	3,740 MMbbl
	Natural Gas ($/mcf)	$5.34	12,011	1,116	4,029	93	17,250 bcf	12,104 bcf
High	Oil ($/bbl)	$160	5,593	4,231	3,673	335	13,831 MMbbl	5,928 MMbbl
	Natural Gas ($/mcf)	$8.54	22,122	1,785	6,447	149	30,503 bcf	22,271 bcf

Note: Production estimates are based on the 2016 National Assessment of OCS UERR

BOEM also estimates energy substitutes using MarketSim that could occur in the absence of a new Five-Year Program, assuming there are no major changes in energy supply or demand (BOEM 2016c). Major energy substitutes include onshore oil and natural gas, imported oil, and other energy sources (e.g., hydropower, renewable energy). BOEM assumes demand is reduced slightly through reduced energy consumption (Table 6-3). These substitution rates are used in the comparative No Action Alternative analysis for the 2017–2022 Program.

Table 6-3. Energy Substitutes assuming no 2017–2022 Program

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

6.2 2012–2017 OCS Oil and Gas Leasing Program

The 2012–2017 Program case considers the activities and production from ten lease sales in the GOM (five Western Planning Area sales and five Central Planning Area sales) and a single sale in the Cook Inlet. The two lease sales held in the GOM Eastern Planning Area are not considered because no bids were received on the lease sales. The 2012–2017 Final Programmatic EIS describes the potential range of OCS activities and production that could be possible over the 50-year life assumed for the 2012-2017 Program (BOEM 2012). BOEM considers oil and natural gas production corresponding to the same low-, mid-, and high-price scenarios considered in the 2012–2017 Final Programmatic EIS (see Tables 6-4 and 6-5 for production estimates). Chapter 4 of the Final Programmatic EIS describes the magnitude and timing of OCS activities and production volume in detail. The E&D scenarios for the 2012-2017 Program is based on the 2011 National Assessment (BOEM 2011). Two other activity and production cases in the GOM are also evaluated, given that the 2012 E&D scenarios for the Program are likely overly optimistic when considering the lower levels of current Program leasing activity witnessed through actual lease sale results and in light of recent market conditions.

Table 6-4. Production Estimates for the 2012–2017 Program

Price Scenario	Price		Area		2012–2017 Program Total
			GOM Western Planning Area / Central Planning Area Only (10 sales total)	Cook Inlet (1 sale)	
2012–2017 Low	Oil ($/bbl)	$60	2,796 MMbbl	100 MMbbl	2,896 MMbbl
	Natural Gas ($/mcf)	$4.27	12,105 bcf	0 bcf	12,105 bcf
2012–2017 Low Adjusted	Activity levels and OCS production reduced by 50% in the GOM to account for lower oil and gas prices and commensurately reduced leasing levels.				
2012–2017 High	Oil ($/bbl)	$160	5,310 MMbbl	200 MMbbl	5,510 MMbbl
	Natural Gas ($/mcf)	$11.39	23,659 bcf	680 bcf	24,339 bcf
2012–2017 High Adjusted	Activity levels and OCS production reduced by 50% in the GOM to account for lower oil and gas prices and commensurately reduced leasing levels.				

Note: Production estimates are based on the 2011 National Assessment of OCS UERR

Table 6-5. Production Estimates for OCS Leases Issued through the 2012–2017 Program

Scenario		Gulf of Mexico, Pacific, and Alaska OCS Production
AEO 2016 ***Low Oil Price Case*** **(extrapolated to 2075)**	Oil	17,381 MMbbl
	Natural Gas	29,493 mcf
AEO 2016 ***Reference Case*** **(extrapolated to 2075)**	Oil	18,536 MMbbl
	Natural Gas	35,330 mcf
AEO 2016 ***High Oil Price Case*** **(extrapolated to 2075)**	Oil	19,223 MMbbl
	Natural Gas	38,350 mcf

Note: Production estimates are based on Special NEMS runs considering OCS UERR from the 2011 National Assessment.

6.3 OCS OIL AND GAS ACTIVITIES AND PRODUCTION ON LEASES ISSUED BEFORE THE END OF 2017

This case considers future production after January 2017 in the GOM OCS, Southern California Planning Area, Beaufort Sea Planning Area, and Cook Inlet Planning Area (potential Lease Sale 244) on leases issued up through the 2012-2017 Program lease sales. OCS production under existing leases at the end of the 2012–2017 Program is keyed to the 2011 National Assessment (BOEM 2011). The production estimate in this dataset also includes the 2012-2017 Program described in Section 6.2. This estimate is based on different economic inputs and should not be directly or explicitly compared to the other two production scenarios.

7. Key Assumptions

This analytical model makes a number of assumptions, which could reduce its accuracy; the assumptions are characterized here. The principal variable in this estimation is the production estimates of OCS oil and gas; the underlying uncertainty in the estimates of the amount of oil and gas to be produced has a profound impact on overall accuracy. These production estimates are 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 is assumed over the next 40–70 years for oil and gas.

This analysis uses a projection of near constant 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. The Reference Case is the best baseline currently available. This analysis could be adapted in the future to incorporate policy shifts that affect demand for oil and gas.

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.

Historically, engines have become increasingly efficient both in the offshore and onshore environments, but those engines by and large have remained dependent on fossil fuels. Moreover, the *President's Climate Action Plan* (White House 2013) calls for energy and transport efficiency improvements, including transitioning from more intense GHG 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, and also through Government 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 oil products by volume. As battery technologies continue to improve, plug-in electric vehicle prices could continue to drop (Nyvist and Nilsson 2015), and the 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 those resources.

Figure 3 shows how consumption patterns of oil have changed in the past, including the rise of jet fuel and motor gasoline use, and the contraction of residual fuel oil use. Despite these longer-term shifts, petroleum products maintain a reasonable level of continuity 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.

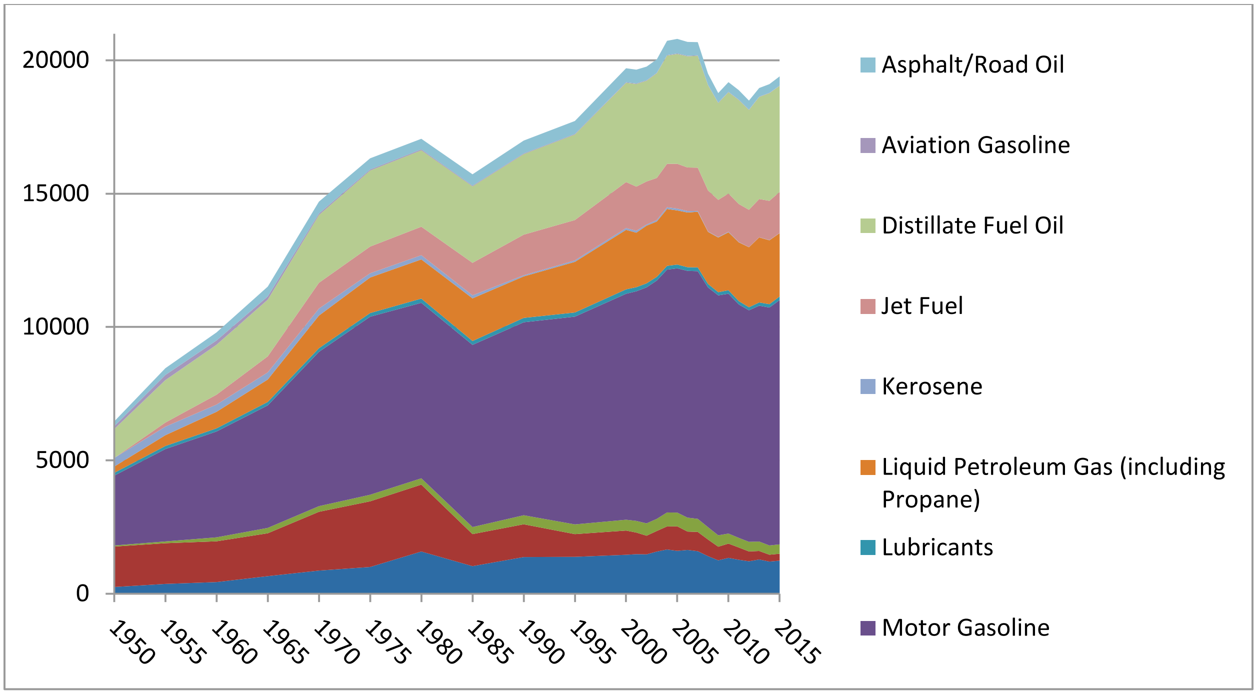

Figure 3. Historical U.S. Average Consumption per day of Petroleum Products by Year (1950 – 2015) in Thousands of Barrels (EIA 2016b)

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. 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 with consumption patterns. 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. This impacts both the evaluation of OCS activities, as well as energy substitutions, thereby still allowing a user to directly compare emissions.

These assumptions are necessary because it is uncertain how oil consumption will change in the future. However, this assumption is reasonable because of the historical stability in proportionality of petroleum product consumption.

3. All oil and gas on 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. This assumption is currently the only way to conduct this analysis currently; however, it ensures emissions will not be underestimated. Petroleum products that are not combusted are accounted for in this analysis.

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 4-2 for both residual and distillate fuel oil emissions factors. This assumption is necessary given the uncertainty of how these fuels are consumed, but it is reasonable given how similar EPA's emissions factors are for each petroleum product with multiple emissions factors.

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

Production gain is the increase in volume as oil is refined into petroleum products. Although all petroleum products have a production gain, it is not the same for each product. Currently, EIA (2015) estimates production gain as 6.7 percent, but that will likely change in the future. This assumption is necessary given the lack of available information regarding the production gain of individual fuels.

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 wide range of emissions factors, there is some loss in accuracy for petroleum products consumed overseas, since other counties 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. These assumptions are reasonable given the small amount of oil and gas products exported (EIA 2016e).

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 about the type of products OCS oil is refined into become available; the analytical model would be adjusted to accommodate such information. This assumption is necessary given the current lack of information.

8. Oil transportation is powered with oil in proportion to the overall production.

According to the EPA (2008), the vast majority of transporting oil to market 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 a no action analysis is not taken into account.

Although MarketSim estimates a foreign reduction in consumption, MarketSim provides the reduction for oil only. MarketSim does not model natural gas fluctuations in the global market. However, for the global oil market, MarketSim substitutions under the No Action Alternative 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. GHG impacts for this reduction in oil consumption, as well as possible changes for natural gas, are not captured in this analysis.

The implications for oil and gas production in other countries relating to U.S. decisions about issuing leases are highly uncertain. In the substitution analysis based on MarketSim, the assumption is made that other oil producing countries will supply oil for U.S. import without additional restraints due to GHG-related policies in those countries. This might change in the future if other countries establish policies to achieve their GHG-related targets.

Excluding the foreign oil and gas markets is reasonable. 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. For gas consumption, BOEM does not have information related to how changes in the U.S. market would affect other countries.

8. Results

The approach described in Sections 4.1 – 4.3 is applied to the three different OCS program scenarios discussed in Section 6. The approach described in Section 4.4 is applied to the No Action Alternative, meaning not issuing new leases, to the 2017–2022 Program. The SC-CO_2 is calculated using the method described in Section 5. All GHG emissions estimates for each price case in all three scenarios are provided in Appendix A.

8.1 EMISSIONS AND SOCIAL COST OF CARBON FROM THE 2017–2022 PROGRAM

This scenario evaluates the oil and gas emissions and SC-CO_2 on leases that could be awarded during the 2017–2022 Program (see Section 6.1).

8.1.1 Emissions from the 2017–2022 Program

The emissions resulting from the proposed leases and the alternative sources of energy consumed are provided in the three different price scenarios in Table 8-1. Results are presented for the OCS Program Areas considered in the Proposed Program and Proposed Final Program. The Proposed Final Program, also the Preferred Alternative in the 2017–2022 Final Programmatic EIS, excludes leasing in the Arctic OCS. Both are considered to support the NEPA analysis for the 2017–2022 Program.

Table 8-1. Estimated Emissions from the 2017–2022 Program and the No Action Alternative in Thousands of Metric Tons of CO_2e

Area	Low-Price Scenario		Mid-Price Scenario		High-Price Scenario	
	Program	No Action	Program	No Action	Program	No Action
Beaufort Sea	120	0	1,073,570	1,122,120	1,985,070	2,019,670
Chukchi Sea	20	0	1,380,500	1,405,400	1,943,310	2,043,210
Cook Inlet	39,480	40,620	97,620	150,570	156,820	240,930
Gulf of Mexico	1,245,920	1,258,110	2,282,770	2,243,740	3,801,480	3,719,880
Total Proposed Program	***1,285,540***	***1,298,730***	***4,834,450***	***4,957,430***	***7,886,680***	***8,020,550***
Total Proposed Final Program / Preferred Alternative	***1,285,400***	*	***2,380,390***	*	***3,958,300***	*

Notes: Emissions estimates have been rounded to the nearest 10,000 metric tons. Numbers may not add up due to rounding.
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.

In the 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, it is possible to distribute the GHG emissions for each price scenario. A graph for each price scenario for the Proposed Program and the No Action Alternative scenarios is provided in Figure 4.

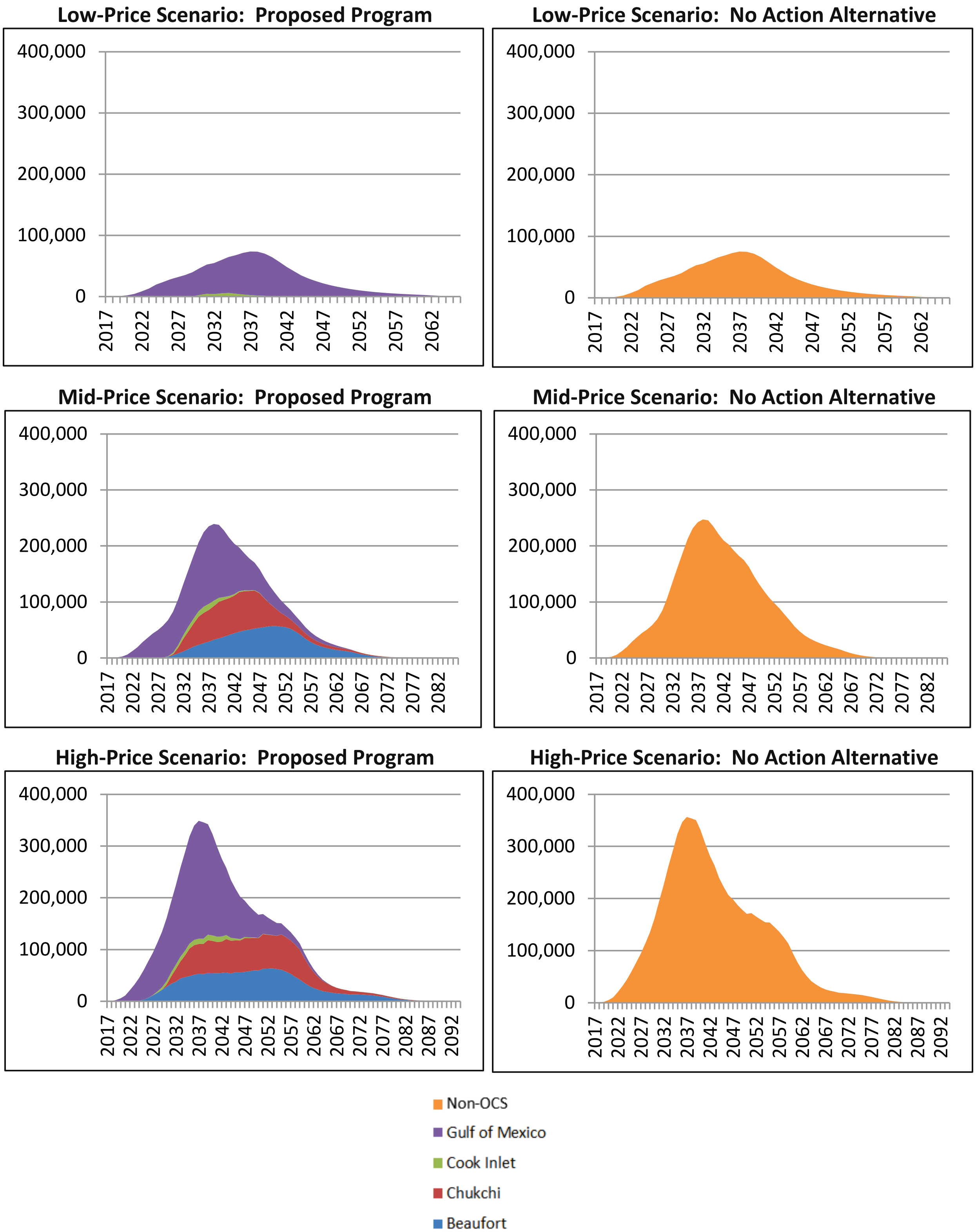

Figure 4. Estimated GHG emissions for the 2017–2022 Proposed Program (*left*) and No Action Alternative (*right*) where oil and gas is recovered from other sources, including substitution of other sources of energy such as coal. Emissions are distributed over time in thousands of metric tons of CO_2e.

The United States has pledged to reduce emissions by filing an INDC with the United Nations as part of the Paris Agreement (See Section 3 and Table 3-1). Tables 8-2 and 8-3 provide a comparison of the U.S. GHG reduction commitments to the estimated OCS oil and gas lifecycle emissions for the high- and low-price scenarios in those specific years. Since the 2017-2022 Program did not exist in 2005 and 2014, these lines are blank, but are included to show both the base year (2005) for measuring U.S. GHG emission commitments and the most recent U.S. GHG inventory available (2014), respectively. The percentages illustrate the proportion of the total U.S. GHG commitments that would be represented by OCS-related emissions if the BOEM production scenarios are ultimately realized.

Table 8-2. Estimated Emissions from the 2017–2022 Proposed Program and the No Action Alternative in Thousands of Metric Tons of CO_2e

Year	U.S. GHG Commitment[a]	Low-Price Scenario				High-Price Scenario			
		Proposed Program[d]		No Action Alternative		Proposed Program[d]		No Action Alternative	
		CO_2e	%	CO_2e	%	CO_2e	%	CO_2e	%
2005[b]	6,680,300	–	–	–	–	–	–	–	–
2014[b]	6,108,000	–	–	–	–	–	–	–	–
2020	5,544,649	2,030	0.05	1,660	0.03	5,880	0.11	5,040	0.09
2025	4,943,422	23,930	0.48	24,180	0.49	60,240	1.22	59,890	1.21
	4,809,816		0.50		0.50		1.25		1.25
2050[c]	1,336,060	13,820	1.03	13,808	1.03	167,210	12.52	170,700	12.78

Notes: Estimates are rounded to the nearest 10,000 metric tons. Percentage refers to the percent of U.S. Commitment.
[a] U.S. commitments in later years assume many changes in policy, many of which have not yet fully formulated; in contrast, the 2017-2022 Program does not take into account any future policy, or other changes that could assist the U.S. achieve those commitments that has not yet been implemented.
[b] The U.S. commitments column shows historical data for 2005, which shows the base year for U.S. GHG reduction commitments, and 2014, which shows the most recent U.S. GHG emissions inventory.
[c] Meeting these commitments is expected to require substantial changes in the U.S. energy market. These changes could reduce the amount of oil and gas being produced or GHG emissions from OCS production, and consequently reduce the amount of CO_2e emissions released from the consumption of OCS resources. This table does not account for such changes, as BOEM lacks the necessary information about specific policies not yet fully formulated.
[d] This includes all program areas, including the Arctic leases. Under the low-price scenario, there is no Artic production, but under the high-price scenario, Arctic emissions represent approximately 50 percent of the Program's emissions.

However, it is critical to acknowledge that meeting the U.S. commitment for 2050 is expected to require substantial future changes in Government policies to reduce domestic oil and gas demand, most of which have yet to be fully formulated. In contrast, the emissions estimates for the 2017–2022 Program do not take into account such future policies or other changes[2] that could assist the U.S. in meeting its commitments. Since new Government policies could take a variety of forms, it is difficult to assess how they would affect OCS production. As specific policies are adopted, it would become possible to adapt the model to account for these changes. See Section 7 for information on assumptions made about future demand.

[2] Transformative technological changes (e.g., rapid U.S. consumer adoption of electric vehicles) also have the potential to contribute to meeting U.S. emissions targets. Such changes, if realized, are likely to be driven by some combination of market forces and Government actions.

Table 8-3. Estimated Emissions from the 2017–2022 Proposed Final Program in Thousands of Metric Tons of CO_2e

Year	U.S. GHG Commitment[a]	Low-Price Scenario: Proposed Final Program[d]		High-Price Scenario: Proposed Final Program[d]	
		CO_2e	%	CO_2e	%
2005[b]	6,680,300	–	–	–	–
2014[b]	6,108,000	–	–	–	–
2020	5,544,649	2,030	0.05	5,880	0.11
2025	4,943,422	23,910	0.48	56,870	1.15
	4,809,816		0.50		1.18
2050[c]	1,336,060	13,820	1.03	45,160	3.38

Notes: Estimates are rounded to the nearest 10,000 metric tons. Percentage refers to the percent of U.S. Commitment.
[a] U.S. commitments in later years assume many changes in policy, many of which have not yet fully formulated; in contrast, the 2017-2022 Program does not take into account any future policy, or other changes that could assist the U.S. achieve those commitments that has not yet been implemented.
[b] The U.S. commitments column shows historical data for 2005, which shows the base year for U.S. GHG reduction commitments, and 2014, which shows the most recent U.S. GHG emissions inventory.
[c] Meeting these commitments are expected to require substantial changes in the U.S. energy market. These changes could reduce the amount of oil and gas being produced or GHG emissions from OCS production, and consequently reduce the amount of CO_2e emissions released from the consumption of OCS resources. This table does not account for such changes, as BOEM lacks the necessary information about specific policies not yet fully formulated.
[d] The Proposed Final Program only includes lease sales in the Gulf of Mexico and Cook Inlet Program Areas, excluding lease sales in the Artic Program Areas.

The proportion of emissions from oil and gas is also not constant across the different price cases (see Figure 5). Under the high-price scenario, the GHGs emitted from onshore processing and consumption of oil is proportionately higher relative to gas compared to the low-price scenario.

8.1.2 Social Cost of Carbon from the 2017–2022 Program

To calculate a present value of the stream of monetary values, BOEM discounted the values for the 2017–2022 Program in each of the four cases using the specific discount rate that had been used to obtain the SC-CO_2 in each case. Tables 8-4, 8-5, and 8-6 provide these net present value results for the Program and No Action Alternative cases for each of the three price scenarios[3].

[3] In the Proposed Program and Proposed Final Program, BOEM analyzes three different price scenarios: low-, mid-, and high-prices. The low-price scenario is $40/barrel of oil and $2.13/thousand scf of natural gas. The mid-price scenario is $100/barrel of oil and $5.35/thousand scf of natural gas. The high-price scenario is $160/barrel of oil and $8.54/thousand scf of natural gas. All price scenarios represent a constant, inflation-adjusted price throughout the life of the 2017-2022 Program.

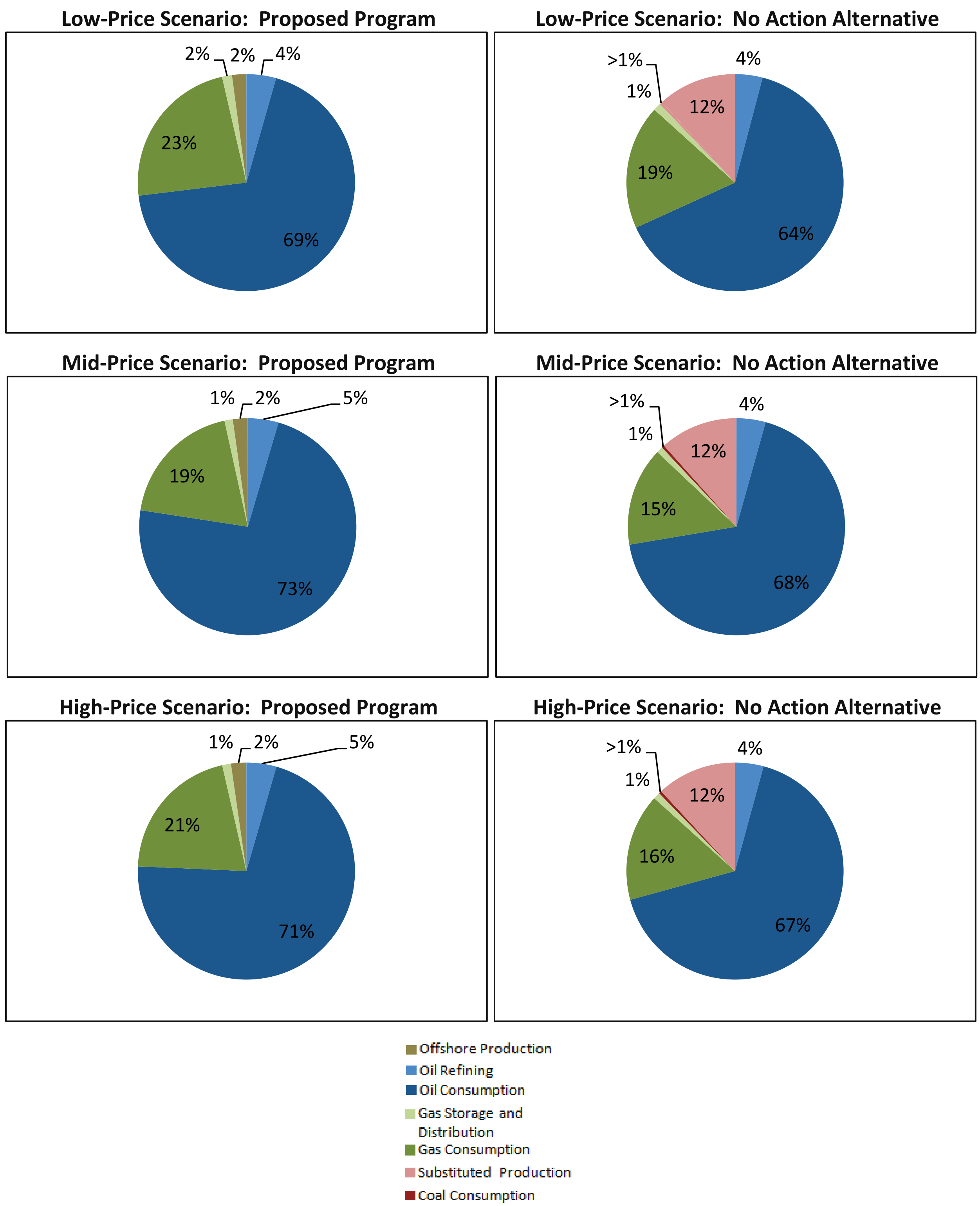

Figure 5. Estimated CO_2e Emissions by Source for the 2017–2022 Proposed Program (*left*) and the No Action Alternative (*right*), as a Percent of Total. The Offshore Production category includes operations occuring on the OCS, which produce oil and gas. The Oil, Gas, and Coal Consumption categories 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.

Table 8-4. SC-CO_2 Results for the Low-Price Scenario in Dollars

Social Cost of Carbon for Program and No Action Alternative (Low-Price Case)				
Discount Rate	**$ billions**			
	Program Area	**Program**	**NAA**	**Net Difference**
5.0%	Beaufort Sea	0.00	0.00	0.00
	Chukchi Sea	0.00	0.00	0.00
	Cook Inlet	0.34	0.34	-0.01
	Gulf of Mexico	10.10	10.20	-0.10
	Total Proposed Program	***10.44***	***10.55***	***-0.11***
	Total Proposed Final Program	***10.44***	***	***
3.0%	Beaufort Sea	0.00	0.00	0.00
	Chukchi Sea	0.00	0.00	0.00
	Cook Inlet	1.46	1.49	-0.02
	Gulf of Mexico	44.54	45.00	-0.46
	Total Proposed Program	***46.01***	***46.49***	***-0.48***
	Total Proposed Final Program	***46.01***	***	***
2.5%	Beaufort Sea	0.01	0.00	0.01
	Chukchi Sea	0.00	0.00	0.00
	Cook Inlet	2.29	2.32	-0.04
	Gulf of Mexico	70.00	70.73	-0.72
	Total Proposed Program	***72.30***	***73.05***	***-0.75***
	Total Proposed Final Program	***72.29***	***	***
3.0% 95th Percentile	Beaufort Sea	0.01	0.00	0.01
	Chukchi Sea	0.00	0.00	0.00
	Cook Inlet	4.45	4.53	-0.07
	Gulf of Mexico	135.69	137.10	-1.41
	Total Proposed Program	***140.16***	***141.63***	***-1.47***
	Total Proposed Final Program	***140.15***	***	***

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.

Table 8-5. 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.

Table 8-6. SC-CO_2 Results for the High-Price Scenario in Dollars

Social Cost of Carbon for Program and No Action Alternative (High-Price Case)				
Discount Rate	$ billions			
	Program Area	Program	NAA	Net Difference
5.0%	Beaufort Sea	12.49	12.80	-0.31
	Chukchi Sea	12.04	12.49	-0.45
	Cook Inlet	1.26	1.29	-0.03
	Gulf of Mexico	30.49	30.53	-0.05
	Total Proposed Program	***56.27***	***57.11***	***-0.84***
	Total Proposed Final Program	***31.75***	*	*
3.0%	Beaufort Sea	60.78	62.17	-1.39
	Chukchi Sea	59.18	61.36	-2.18
	Cook Inlet	5.58	5.72	-0.14
	Gulf of Mexico	135.08	135.32	-0.24
	Total Proposed Program	***260.63***	***264.57***	***-3.94***
	Total Proposed Final Program	***140.66***	*	*
2.5%	Beaufort Sea	98.07	100.25	-2.18
	Chukchi Sea	95.59	99.09	-3.49
	Cook Inlet	8.78	8.99	-0.22
	Gulf of Mexico	212.48	212.86	-0.37
	Total Proposed Program	***414.93***	***421.19***	***-6.26***
	Total Proposed Final Program	***221.36***	*	*
3.0% 95th Percentile	Beaufort Sea	186.58	190.81	-4.23
	Chukchi Sea	181.86	188.55	-6.69
	Cook Inlet	17.05	17.47	-0.42
	Gulf of Mexico	411.75	412.50	-0.75
	Total Proposed Program	***797.25***	***809.33***	***-12.09***
	Total Proposed Final Program	***428.80***	*	*

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.

8.2 EMISSIONS FROM THE 2012–2017 PROGRAM

This case evaluates the oil and gas emissions of leases awarded, or to be awarded, during the current (2012–2017) program. Additionally, the original projections for the current program have been adjusted based on the lower levels of leasing activity witnessed through actual lease sale results and in light of recent market conditions (see Section 6.2). The original projections and the adjusted projections were both analyzed and are provided in Table 8-7. Note that this analysis is a subset of the oil and gas leases discussed in Sections 6.3 and data output provided in Section 8.3.

Table 8-7. Estimated Emissions from the Current 2012–2017 Program in Thousands of Metric Tons of CO_2e

Area	Low-Price Scenario		High-Price Scenario	
	Original Current Program	Adjusted Current Program	Original Current Program	Adjusted Current Program
Cook Inlet	43,960	43,960	127,370	127,370
Gulf of Mexico	1,969,160	984,580	3,777,740	1,888,870
Total	***2,013, 120***	***1,028,540***	***3,905,110***	***2,016,240***

Notes: Estimates are rounded to the nearest 10,000 metric tons. Numbers may not add up due to rounding.

8.3 EMISSIONS FROM LEASES ISSUED BEFORE THE END OF 2017

This case includes emissions from the beginning of 2017, considering the oil and gas emissions of all leases awarded before the end of 2017 (see Section 6.3), but only the oil and gas not yet produced as of the start of 2017. Although OCS leases are already issued, or will be by the end of 2017, the emissions analyzed here have yet to occur. This analysis includes existing leases from all OCS planning areas with active leases, including the GOM, Alaska, and Southern California (see Table 8-8).

Table 8-8. Estimated Emissions from OCS Leases Potentially Issued before December 2017 for the Oil and Gas Not Yet Produced in Thousands of Metric Tons of CO_2e

	EIA's Low Oil Price Case	EIA's Reference Case	EIA's High Oil Price Case
Total	9,387,360	10,238,460	10,718,460

Note: Estimates are rounded to the nearest 10,000 metric tons.

Figure 6 shows how the proportion of emissions from oil and gas activities fluctuates for each different EIA oil price case. The proportion of GHG emissions for this scenario is relatively consistent even as prices change. Table 8-9 provides a comparison of the U.S. GHG reduction commitments to the estimated OCS oil and gas lifecycle emissions for EIA's Low and High Oil Price cases in the years identified for U.S. GHG emissions goals.

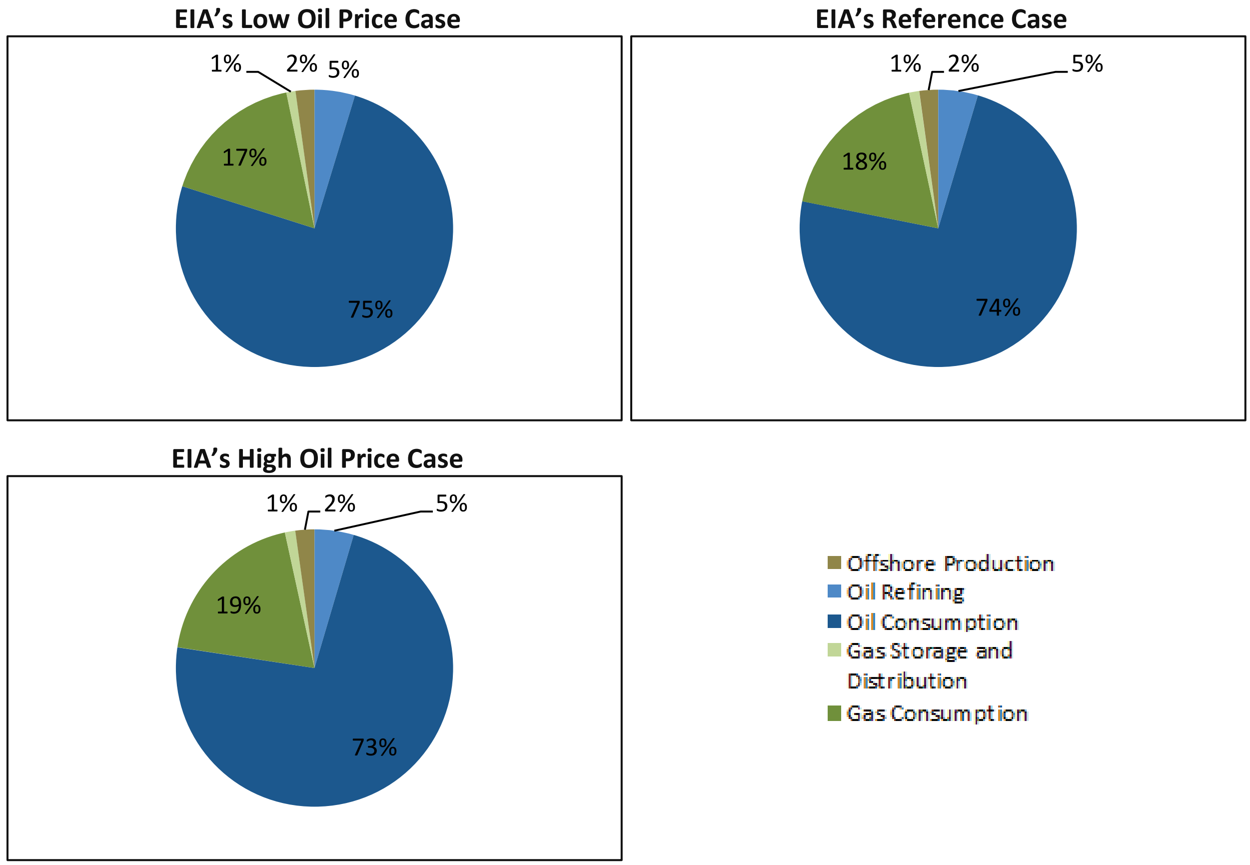

Figure 6. Estimated CO_2e Emissions by Source for Leases Issued Before the End of 2017 as a Percent of the Total. The Offshore Production category includes operations occuring on the OCS, which produce oil and gas. The Oil and Gas Consumption categories only include emissions from the final consumption of the resource.

Table 8-9. Estimated Emissions from all Leases Issued before the End of 2017 in Thousands of Metric Tons of CO_2e

Year	U.S. GHG Commitment[a]	EIA's Low Oil Price Case		EIA's Reference Case		EIA's High Oil Price Case	
		CO_2e	%	CO_2e	%	CO_2e	%
2005[b]	6,680,300	–	–	–	–	–	–
2014[b]	6,108,000	–	–	–	–	–	–
2020	5,544,649	382,320	6.90	387,960	7.00	397,540	7.17
2025	4,943,422	305,900	6.19	328,090	6.64	353,020	7.14
	4,809,816		6.36		6.82		7.34
2050[c]	1,336,060	106,850	8.00	129,100	9.66	133,220	9.97

Notes: Estimates are rounded to the nearest 10,000 metric tons. Percent refers to the percent of U.S. commitment.

[a] U.S. commitments in later years assume many changes in policy, many of which have not yet fully formulated; in contrast, the 2017-2022 program does not take into account any future policy, or other changes that could assist the U.S. achieve those commitments which has not yet been implemented.

[b] U.S. commitments column shows historical data for 2005, which shows the base year for U.S. GHG reduction commitments, and 2014 which shows the most recent U.S. GHG inventory.

[c] Meeting these commitments are expected to require substantial changes in the U.S. energy market. These changes may reduce the amount of oil and gas being produced or GHG emissions from OCS production, and consequently reduce the amount of CO_2e emissions released from the consumption of OCS resources. This table does not account for such changes, as BOEM lacks the necessary information about specific policies not yet fully formulated.

8.4 OCS Emissions Compared to the Global and Domestic Carbon Budgets

By combining expected GHG emissions from past OCS program leasing and those being considered under the 2017–2022 Proposed Final Program, it is possible to describe the potential, incremental use of the remaining global and domestic CO_2e emissions budget. It is important to note that the 2017-2022 Proposed Final Program excludes Arctic OCS leasing.

Table 8-10 uses estimates in McGlade and Ekins (2015), Peters et al. (2015), Gignac and Mathews (2015), IPCC's (2014) Climate Change Synthesis Report, and the International Energy Agency (2015) to estimate the contribution of OCS leasing to the remaining GHG emissions that could be released without exceeding 2°C increase in global temperatures. Since the Program and its substitution emissions are comparable at the scale of consideration, a single table is presented representing both cases. The results show the potential for a meaningful incremental contribution of OCS oil and gas to the remaining global and domestic GHG emissions possible without exceeding 2°C of worldwide warming. The GHG emissions expected to be released after that date are shown in a separate column.

The estimates for global CO_2e emissions not leading to an exceedance of 2°C global temperature increase are in the neighborhood of 1 trillion metric tons, ranging from 768 to 1,180 billion metric tons. BOEM expects emissions from OCS leases already issued, combined with 2017–2022 Proposed Final Program to consume between 0.5 and 1 percent of the remaining global emissions budget. If all Arctic program areas were considered, between 0.5–2 percent of the budget would be consumed. Two analyses allocate a U.S. share of future global CO_2e emissions not leading to an exceedance of 2^oC, placing the budgeted U.S. amount between 34 and 123 billion metric tons. BOEM estimates that OCS leases already issued, combined with emissions from 2017–2022 program leases, would consume between 1 and 9 percent of the total U.S. budget. However, there is a considerable amount of uncertainty in estimating these kinds of national emissions budgets given the wide range presented in McGlade and Ekins (2015) and Peters et al. (2015) studies. The estimates from the two studies have an end date of 2050, beyond which only a small amount of additional emissions could be emitted. BOEM's contribution to these additional emissions is listed separately in Table 8-10.

Table 8-10. Emissions from the 2017–2022 Proposed Final Program and Active Leases Issued Before the End of 2017 Compared to Various Carbon Budget Analyses

Carbon Budget Analysis	Timescale	Global Emissions Budget		U.S. Emissions Budget		Post-2050 Emissions
	Years	Billion Metric Tons	Percent Consumed[c]	Billion Metric Tons	Percent Consumed[c]	Billion Metric Tons
Using CO_2e						
McGlade and Ekins (2015)[a]	2011-2050	1,100	0.1 - 0.3%	–	–	0.072– 1
Gignac and Mathews (2015)[a]	2014-onward	1,000	0.1 - 0.4%	78 – 97	1- 5%	–
IPCC (2014)[a,b]	2011-onward	1,000	0.1 - 0.4%	–	–	–
IEA (2015)[a]	2014-onward	880 – 1180	0.1 - 0.5%	–	–	–
Using CO_2 only						
Peters et al. (2015)[a]	2015 – 2050	765	0.2 – 0.4%	34 – 123	1 – 9%	0.071 – 1

Notes: The carbon budget analyses reflect the amount of carbon that can be released without causing warming of more than 2^oC. The percent range covers EIA's Low and High Oil Price cases.

[a] Meeting these commitments is expected to require substantial changes in the U.S. energy market. These changes could reduce the amount of oil and gas being produced or GHG emissions from OCS production, and consequently reduce the amount of CO_2e emissions released from the consumption of OCS resources. This table does not account for such changes, as BOEM lacks the necessary information about specific policies not yet fully formulated.

[b] Uses the Complex Model with 66 percent certainty.

[c] To provide the full range of possible outcomes, when a range is provided in the Global and U.S. Emissions Budget columns, the Low Case Budget is compared to the High Case OCS lifecycle emissions, and the High Case Budget is compared to the Low Case OCS lifecycle emissions scenario.

[d] The Peters et al. (2015) paper only evaluated the CO_2 emissions, and so it is compared to only OCS CO_2 emissions.

9. Conclusion

In each price case, and in each scenario for the 2017–2022 Program, U.S. GHG emissions would be slightly higher if BOEM were to have no lease sales, assuming 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 Proposed Program and the No Action Alternative were the same. Emissions from substitutions are higher due to the exploration, development, production, and transportation of oil from international sources being more carbon-intensive. 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 Proposed Program and the No Action Alternative are relatively similar, in large part due to the assumed substitution of more GHG-intensive oil and gas sources in the absence of a new OCS leasing program.

In addition, the estimates for the 2017–2022 Program do not take into account any future policy or technological adaptations; therefore, the U.S. GHG emissions originating from OCS production become proportionately larger if U.S. commitments to reduce GHG emissions are achieved. Similarly, the cumulative effect of OCS emissions consumes a meaningful increment of the remaining worldwide and domestic GHG emissions budget. Assuming policies, regulations, and other factors to reduce GHG emissions continue to be implemented, these changes would affect the production and consumption of oil and gas, produced on the OCS in similar ways to energy produced elsewhere.

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. Such changes could affect the GHG emissions from each scenario, price case, and the No Action Alternative for the 2017–2022 Program.

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Appendix A – Additional Greenhouse Gas Emissions Tables

Table A-1. Estimated Emissions from Leases Issued before December 2017 for the Oil and Gas Not Yet Produced, in Thousands of Metric Tons Rounded to the Nearest 10,000

	Low-Price Scenario			Mid-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total	**9,183,490**	**7,350**	**70**	**10,010,160**	**8,270**	**70**	**10,476,900**	**8,760**	**80**

Note: Numbers may not add up due to rounding.

Table A-2. Estimated Emissions from the Current 2012–2017 Program in Thousands of Metric Tons Based on the Original Projections Rounded to the Nearest 10,000

Area	Low-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Cook Inlet	43,260	20	0.4	124,070	120	0.8
Gulf of Mexico	1,905,540	2,400	10	3,656,330	4,570	20
Total	**1,948,800**	**2,420**	**10**	**3,780,400**	**4,680**	**20**

Note: Numbers may not add up due to rounding.

Table A-3. Estimated Emissions from the Current 2012–2017 Program in Thousands of Metric Tons based on Revised Projections Rounded to the Nearest 10,000

Area	Low-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Cook Inlet	43,260	20	0.4	124,070	120	0.8
Gulf of Mexico	996,030	1,200	6	1,828,170	2,290	10
Total	**974,400**	**1,220**	**6**	**1,952,240**	**2,410**	**10**

Note: Numbers may not add up due to rounding.

Table A-4. Estimated Emissions from the 2017–2022 Proposed Program in Thousands of Metric Tons Rounded to the Nearest 10,000

Area	Low-Price Scenario			Mid-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Beaufort Sea	120	0	0	1,055,980	600	10	1,944,570	1,450	10
Chukchi Sea	20	0	0	1,354,290	930	10	1,913,350	1,020	20
Cook Inlet	38,800	20	0.3	96,010	55	0.8	156,200	90	1
Gulf of Mexico	1,218,630	990	10	2,228,140	2,000	20	3,708,070	3,450	24
Total	**1,257,570**	**1,010**	**10**	**4,734,420**	**3,600**	**30**	**7,720,190**	**6,010**	**54**

Note: Numbers may not add up due to rounding.

Table A-5. Estimated Emissions from the 2017–2022 Proposed Final Program, or Preferred Alternative in the Final Programmatic EIS, in Thousands of Metric Tons Rounded to the Nearest 10,000

Area	Low-Price Scenario			Mid-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Cook Inlet	38,800	20	0.3	96,010	55	0.8	156,200	90	1
Gulf of Mexico	1,218,630	990	10	2,228,140	2,000	20	3,708,070	3,450	24
Total	**1,257,430**	**1,010**	**10**	**2,324,150**	**2,055**	**21**	**3,864,270**	**3,540**	**25**

Note: Numbers may not add up due to rounding.

Table A-6. Estimated Emissions from the 2017–2022 No Action Alternative in Thousands of Metric Tons Rounded to the Nearest 10,000

Area	Low-Price Scenario			Mid-Price Scenario			High-Price Scenario		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Beaufort Sea	0	0	0	1,073,360	1,840	10	1,913,510	3,380	10
Chukchi Sea	0	0	0	1,356,220	1,840	10	1,969,070	2,770	20
Cook Inlet	38,830	70	0.3	146,590	150	0.9	234,250	250	1
Gulf of Mexico	1,195,640	2,390	10	2,131,810	4,290	15	3,523,170	7,570	30
Total	**1,234,480**	**2,460**	**10**	**4,751,510**	**8,130**	**40**	**7,636,860**	**13,980**	**60**

Note: Numbers may not add up due to rounding.

Appendix B – Unit Conversions

Unit Conversions	
1 kilogram (kg)	1,000 metric tons
1 metric ton	0.907185 short tons
1 barrel (bbl)	42 gallons
1 million barrels (MMbbl)	1,000,000 barrels (bbl)
1 thousand cubic feet (mcf)	1,000 standard cubic feet (scf)
1 million cubic feet (mmcf)	1,000,000 standard cubic feet (scf)
1 billion cubic feet (bcf)	1,000,000,000 standard cubic feet (scf)
1 barrel of oil equivalent (boe)	5,620 standard cubic feet (scf) gas

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