Forecasting Environmental and Social Externalities Associated with Outer Continental Shelf (OCS) Oil and Gas Development – Volume 2:

Supplemental Information to the 2015 Revised Offshore Environmental Cost Model (OECM)





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DISCLAIMER

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Abbreviations and Acronyms

AEO2013 Annual Energy Outlook 2013 AEO2015 Annual Energy Outlook 2015

ARC Appalachian Regional Commission
BOEM Bureau of Ocean Energy Management

Btu British thermal unit (equal to about 1055 joules)

CAFE corporate average fuel economy CDEs catastrophic discharge events

CO carbon monoxide

CSR Concentrating Solar Resources
DOE U.S. Department of Energy
DOI U.S. Department of the Interior
DOL U.S. Department of Labor
DPP Draft Proposed Program
DWH Deepwater Horizon

E&D exploration and development

EDWPC East Delhi Waste Processing Company Pvt. Ltd.

EGS Enhanced Geothermal System

EIA U.S. Energy Information Administration EPA US Environmental Protection Agency

FAO Food and Agriculture Organization of the United Nations

FFV flexible-fuel vehicle

FWS U.S. Fish and Wildlife Service GAO Government Accountability Office

GLC Great Lakes Commission

gW gigawatt GWh gigawatt hour

IRENA International Renewable Energy Agency

kWh/m² kilowatt hour per square meter

LCF latent cancer fatality

LFG landfill gas

LMOP Landfill Methane Outreach Program

LPG liquefied petroleum gas

m meter(s)

MarketSim Market Simulation Model

mmscfd Million Standard Cubic Feet per Day (gas distribution)
MMTCO2e/yr million metric tons of carbon dioxide equivalent per year

MRIP Marine Recreational Information Program

MSW municipal solid waste

MW megawatt

NMFS National Marine Fisheries Service

NOAA National Oceanic and Atmospheric Administration

NOx nitrogen oxides

NRC U.S. Nuclear Regulatory Commission NRDA natural resource damage assessment NRDC Natural Resources Defense Council
NREL National Renewable Energy Laboratory

NSRE 2000 National Survey of Recreation in the Environment

NYT New York Times

OCS Outer Continental Shelf

OECM Offshore Environmental Cost Model
ORNL Oak Ridge National Laboratory
OSIR Oil Spill Intelligence Report
PBS Public Broadcasting System

PDARP Preliminary Damage Assessment and Restoration Plan

PJ petajoule

PM particulate matter
PV photovoltaic
PVC photovoltaic cell
RDF refuse-derived fuel

RUM Randomized Utility Maximization

SNG synthetic natural gas

SO₂ sulfur dioxide

TEEIC Tribal Energy and Environmental Information Clearinghouse

TNC The Nature Conservancy

Trustees Deepwater Horizon Oil Spill Natural Resource Trustees

TVA Tennessee Valley Authority

TWh terawatt hours

USDA U.S. Department of Agriculture USGS United States Geological Survey

UTTR undiscovered technically recoverable resources

VOC volatile organic compound
VSL value of a statistical life
WTG wind turbine generator
WTP willingness to pay

1. Introduction

The Bureau of Ocean Energy Management (BOEM) is charged with assisting the U.S. Secretary of the Interior in carrying out the mandates of the Outer Continental Shelf (OCS) Lands Act (Act), which calls for expedited exploration and development (E&D) of the OCS to, among other goals, "reduce dependence on foreign sources and maintain a favorable balance of payments in world trade." The Act also requires that BOEM prepare forward-looking five year schedules of proposed OCS lease sales that define as specifically as possible the size, timing, and location of the OCS territory(ies) to be offered for lease. As part of the development of these "Five Year Programs," BOEM completes an analysis of the environmental and social costs attributable to the exploration, development, production, and transport of oil and natural gas anticipated to result from the Program proposal, net of the environmental and social costs attributable to the No Action Alternative (NAA) (i.e., the costs associated with energy production from sources that would substitute for OCS production in the absence of the Program) and net of any benefits (measured as "negative costs") attributable to OCS oil- and natural gas-related activities.

To estimate the anticipated environmental and social costs attributable to oil and natural gas E&D activities on the OCS, as specified in an E&D scenario, BOEM utilizes the Offshore Environmental Cost Model (OECM), a revised Microsoft (MS) Access-based model, which has been updated in conjunction with development of the 2017-2022 Program. The OECM was designed to focus on capturing the most significant environmental and social costs from the proposed action and NAA. The report *Forecasting Environmental and Social Externalaties Associated with the Outer Continental Shelf (OCS) Oil and Gas Development – Volume 1: The 2015 Revised Offshore Environmental Cost Model (OECM)* (BOEM 2015-052) presents the model's cost calculation methodologies as well as descriptions of each calculation driver, including the sources of underlying data and any necessary assumptions. The purpose of this companion report (Volume 2) is to present supplemental information on environmeantal and social costs that BOEM considers in conjunction with the OECM results.

The OECM was designed to focus on the "main" energy market substitutions (i.e. increased imports and onshore production of oil and natural gas, fuel switching to coal, and reduced demand likely to occur as a direct result of programmatic decisions to make OCS oil and gas resources unavailable to the market) but multiple other "minor" energy substitutes (those that might occur in small quantities or without regard to programmatic decisions) exist. Chapter 2 of this report, *Energy Alternatives and the Environment*, gives consideration of the full range of possible energy sources sources that may potentially replace OCS production (including those not directly evaluated in the OECM) and provides a qualitative discussion of their environmental and social costs, recognizing that all energy sources have externalities. Specifically, the chapter presents oil and gas uses and alternatives by sector (e.g. residential, commercial, industrial, transportation, and electricity) and discusses current and future production trends and the environmental and social costs of the different energy sources.

¹ An E&D scenario defines the incremental level of OCS exploration, development, and production activity anticipated to occur within planning areas expected to be made available for leasing in the BOEM Five Year OCS Oil and Gas Leasing Program. 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, and the number of platforms removed.

While many of the impacts that the OECM estimates are associated with the possibility of oil spills from pipelines, tankers, and OCS platforms, it does not include impacts from catastrophic discharge events (CDEs) because these are extremely unlikely and their potential impacts difficult to estimate due to large variability in the factors that contribute to impacts. To supplement the costs considered in the OECM, Chapter 3 of this report, *Analysis of Impacts from a Catastrophic Spill* provides information on the potential environmental and social costs of a CDE. This chapter provides an overview of the available data and literature on potential CDE impacts, including response costs, ecological impacts, recreational impacts, commercial fishing impacts, fatal and nonfatal injuries, and value of oil spilled.

2. Energy Alternatives and the Environment

BOEM uses its internal Offshore Environmental Cost Model (OECM) to generate monetary estimates of the environmental and social costs attributable to oil and gas exploration and production activities anticipated to result from each Five Year decision option. The OECM produces a cost estimate not only for the environmental and social costs attributable to activities anticipated to result from the sale(s) in that option, but also for those attributable to the market substitutions anticipated to result from the No Action Alternative [i.e., the costs associated with energy production from sources that would substitute for OCS production in the absence of anticipated production from the sale(s)]. The costs associated with any No Action Alternative are a function of the type and scale of substitute resources predicted by a companion model, BOEM's Market Simulation Model (MarketSim) (Industrial Economics 2015).

One of the primary purposes of this chapter is to consider the full range of possible energy sources available, including those that are not directly affected by shorter-term levels of OCS oil and natural gas production and thus are not evaluated in the OECM. The OECM provides estimates for several energy sources that energy markets would likely substitute for forgone production of OCS oil and natural gas (i.e., increased imports and onshore production of oil and natural gas, fuel switching to coal, and reduced demand). These are referred to as "main" energy substitutes in the OECM. However, there are other "minor" energy substitutes, some of which could be directly affected by programmatic decisions (e.g., biofuels) and others (e.g., wind and solar energy) that may also be affected in a minor way but that serve more generally as substitutes for oil and gas in the long run. Government, corporate, and consumer decisions to increase or decrease generation capacity for the latter will affect demand for oil and gas overall and thus for OCS oil and gas as well over time. This chapter will discuss the full range of energy sources that may potentially replace OCS production in future decades and provide a qualitative discussion of their environmental and social costs, recognizing that all energy sources have externalities.

2.1 OVERVIEW OF ENERGY SERVICES

This section presents an overview of energy sources of interest to BOEM in analyzing the potential impacts associated with a non-OCS lease scenario (under the No Action Alternative). Energy source substitutes for OCS oil and gas production include (1) onshore oil and gas production, (2) imports of foreign-produced oil and gas, (3) coal production, (4) biofuels, (5) biomass, (6) geothermal, (7) hydroelectric, (8) municipal waste, (9) nuclear, (10) other natural gas (synthetic gas, coke oven gas, refinery gas, and biomass gas), (10) other oil (liquids from gas and coal), (11) solar (both concentrated resources and photovoltaic), and (12) wind (both onshore and offshore). As with OCS oil and gas production, each energy source yields environmental and social costs. A qualitative discussion of these costs is provided in Section 2.3 of this document.

The *Annual Energy Outlook 2015* (EIA 2015; referred to hereafter as AEO2015) serves as our primary reference for the energy sources that could serve as substitutes for new oil and gas production on the OCS through 2040. It should be noted that the AEO2015 projections are

based generally on federal, state, and local laws and regulations in effect as of the end of October 2014. The potential impacts of pending or proposed legislation, regulations, and standards are not reflected in the projections [for example, the U.S. Environmental Protection Agency's (EPA's) proposed Clean Power Plan]. In certain situations, however, where it is clear that a law or a regulation will take effect shortly after the publication of AEO2015, it may be considered in the projection.

U.S. energy consumption is expected to grow at a modest rate over the AEO2015 projection period, averaging 0.3% per year from 2013 through 2040 in the Reference case. A marginal decrease in energy consumption in the transportation sector contrasts with growth in most other sectors. Declines in energy consumption tend to result from the adoption of more energy-efficient technologies and existing policies that promote increased energy efficiency.

The following briefly defines each energy source.

Onshore Oil and Gas Production is crude oil and natural gas supplied from resources in the lower 48 states. Crude oil supply includes lease condensate, and natural gas is differentiated between non-associated gas and associated-dissolved gas. Non-associated natural gas is gas in a reservoir that is not in contact with significant quantities of crude oil. Associated-dissolved natural gas consists of the combined volume of natural gas that occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved).

Foreign Oil and Gas Imports represent crude oil and natural gas imported into the United States from foreign countries.

Fuel Switching to Coal reflects increases in coal production to replace OCS oil and gas production. It is important to note that coal is only a viable substitute for oil and gas for some end-use sectors (e.g., electricity generation).

Biofuels are liquid fuels and blending components produced from biomass (plant) feedstocks and are primarily used as energy for the transportation sector. Biodiesel, which is typically made from soybean, canola, or other vegetable oils; animal fats; or recycled grease, is a biofuel that can serve as a substitute for petroleum-derived diesel fuel or distillate fuel oil. Ethanol is a biofuel that is used principally for blending in low concentrations with motor gasoline as an oxygenate or octane enhancer. In high concentrations, ethanol is used to fuel alternative-fuel vehicles specially designed for its use.

Biomass is an organic non-fossil material of biological origin that constitutes a renewable energy source. Two major examples of biomass are wood/wood-derived fuels and biomass waste. Wood and products derived from wood that are used as fuel include round wood (cord wood), limb wood, wood chips, bark, sawdust, forest residues, charcoal, paper pellets, railroad ties, utility poles, black liquor, red liquor, sludge wood, spent sulfite liquor, and other wood-based solids and liquids. Biomass waste is organic non-fossil material of biological origin that is a byproduct or a discarded product (e.g., agricultural crop byproducts).

Geothermal represents energy obtained from hot water or steam extracted from geothermal reservoirs in the earth's crust that is used for geothermal heat pumps, water heating, or electricity generation.

Hydroelectric energy uses the kinetic energy of falling water to produce electricity. There are two categories of hydroelectric energy—*pumped storage* is hydroelectric power that is generated during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods, while *conventional* is hydroelectric power generated from flowing water that is not created by hydroelectric pumped storage.

Municipal Waste refers to energy produced from any organic matter, including sewage, sewage sludge, and industrial or commercial waste, and mixtures of such matter and inorganic refuse from any publicly or privately operated municipal waste collection or similar disposal system. Municipal waste can be further categorized as either biogenic waste (waste originating from the biological processes of living organisms) or non-biogenic waste (consisting of plastic, rubber, or other material of non-biological origin).

Nuclear energy consists of the thermal energy released from the fission of nuclear fuel in a reactor to generate electricity. A reactor includes fuel (fissile material), moderating material to control the rate of fission, a heavy-walled pressure vessel to house reactor components, shielding to protect personnel, a system to conduct heat away from the reactor, and instrumentation for monitoring and controlling the reactor's systems.

Other Natural Gas includes synthetic gas and supplemental gaseous fuels. Synthetic gas is a manufactured product, chemically similar to natural gas, resulting from the conversion or reforming of hydrocarbons. Synthetic gas can easily be substituted for or interchanged with pipeline-quality natural gas. Supplemental gaseous fuels are gaseous substances introduced into or commingled with natural gas that increase the volume of gas available for disposition, and include, but are not limited to, refinery gas, coke oven gas, manufactured gas, and biomass gas. Refinery gas, which is used as a refinery fuel and a petrochemical feedstock, is produced in refineries by distillation, cracking, reforming, and other processes. Coke oven gas is produced by the carbonization of coal in a coke oven at temperatures in excess of 1,000° C. Manufactured gas is obtained by destructive distillation of coal or by the thermal decomposition of oil, or by the reaction of steam passing through a bed of heated coal or coke. Biomass gas is a medium Btu gas containing methane and carbon dioxide that results from the action of microorganisms on organic materials such as those in a landfill.

Other Oil includes stock withdrawals (e.g., from the Strategic Petroleum Reserve) and liquids obtained from coal and gas. Coal liquefaction is a chemical process that converts coal into liquid hydrocarbons, including synthetic crude oil. Gas-to-liquids is a process that combines the carbon and hydrogen elements in natural gas molecules to make synthetic liquid petroleum products.

Solar converts the radiant energy of the sun into other forms of energy, such as heat or electricity. There are two categories of solar energy: thermal energy and PV. Solar thermal energy refers to the conversion of the sun's radiant energy into other forms of energy, such as heat. Solar thermal energy generally refers to the optical concentration of solar rays through an arrangement of mirrors to generate a high temperature working fluid (often piped to a central

engine). Photovoltaic (PV) solar energy uses a photovoltaic cell (PVC) to convert sunlight into electricity (direct current). A PVC is an electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts.

Wind energy is kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

The following sections are organized by sector (residential, commercial, industrial, and transportation) and include an evaluation of the data drawn from AEO2015 as they relate to energy use in each sector. The primary energy sources included in this discussion are coal, electricity, natural gas, petroleum, and renewables. The discussion by sector is followed by a section on the energy sources responsible for electricity generation, which include coal, natural gas, nuclear, renewables, and petroleum.

2.1.1 Oil and Gas Uses and Alternatives: Residential Sector

Table 1 presents data on the use of energy in the residential sector. Natural gas is predominantly used for space and water heating, cooking, and wet cleaning. Fuel oil, which is not used much in this sector, is primarily used for space and water heating.

Alternatives to these uses of natural gas and oil include liquefied petroleum gas (LPG), renewables (used directly), and electricity. Energy use in this sector is expected to decline in part because many homeowners are implementing efficiency upgrades to decrease the demand for space heating, which can be viewed as a substitute for the use of oil and gas. These efficiency upgrades refer to efficiency improvements in the construction of buildings to retain heat, rather than the efficiency of the heating equipment itself. Measures such as adding insulation, sealing leaks, and installing more efficient windows reduce the energy required to maintain a desired temperature. It is also expected that over the long term consumers will replace oil- and gas-fired equipment and appliances with electric-powered units, which are readily available, widely used, and have a lower capital cost.

Table 1. 2013 residential energy end-use splits, by fuel type (quadrillion Btu)

	Natural Gas	Fuel Oil	LPG	Other Fuel (1)	Renewable Energy (2)	Electric (3)
Space Heating (4)	3.32	0.44	0.30	0.01	0.58	1.63
Water Heating	1.20	0.05	0.06			1.35
Cooking	0.21		0.03			0.3
Wet Cleaning (7)	0.05					0.98
Space Cooling	0.02					2.03
Other (8)	0.25	0.01	0.04			3.66
Lighting						1.81
Refrigeration (5)						1.35
Electronics (6)						1.01
Computers						0.37
Total	5.05	0.50	0.43	0.01	0.58	14.54

Notes: (1) Kerosene assumed attributable to space heating. (2) Comprised of wood space heating. (3) Site-to-source electricity conversion (due to generation and transmission losses) = 3.075. (4) Includes furnace fans. (5) Includes refrigerators and freezers. (6) Includes television. (7) Includes clothes washers, dryers, and dishwashers. (8) Includes small electric devices, heating elements, motors, swimming pool heaters, hot tub heaters, outdoor grills, and natural gas outdoor lighting.

Source: EIA 2015

The most likely renewable energy source that will serve as a direct substitute for oil and gas (versus as a fuel for power plants) is a solar water heater. Solar water heaters usually have a gas or electric backup to provide supplemental heating on cloudy days, in cold seasons, or in high-demand hours. As a result, they do not eliminate the use of gas or electricity entirely. Another renewable energy source is a geothermal heat pump, which uses 25% to 50% less energy than conventional heating and cooling systems (DOE 2012b). However, high installation costs for underground or waterborne heat exchanger piping have limited the use of geothermal heat pumps. They are generally installed in new construction homes.

As shown in Table 2, electricity represents the largest energy source for the residential sectorfollowed by natural gas. Electricity is the only energy source expected to grow in this sector.

Table 2. AEO2015 residential energy source projections

Sector	Source	Energy (quadrillion Btu/year)		%Total 2013	%Total 2040	Annual Growth	
		2013	2040			Growth	
Residential	Electricity	14.54	15.75	68.9%	75.4%	0.5%	
Residential	Natural Gas	5.05	4.31	23.9%	20.6%	-0.6%	
Residential	Petroleum	0.94	0.49	4.4%	2.3%	-2.4%	
Residential	Renewables	0.58	0.35	2.7%	1.7%	-1.8%	
Residential-Total		21.11	20.90				

Source: EIA 2015, Table A2

2.1.2 Oil and Gas Uses and Alternatives: Commercial Sector

Table 3 presents how energy is used in the commercial sector. Natural gas is predominantly used for space and water heating, space cooling, and combined heat and power (shown in the other category). Fuel oil, which is not used much in this sector is primarily used for space and water heating. Alternatives to these uses of natural gas and oil include renewables (used directly) and electricity. The main renewable that can substitute for oil and gas in this sector is biomass with solar water heating, solar PV, and wind representing much smaller fractions of potential substitutes. With regard to potential energy substitutes, this sector is very similar to the residential sector. A more detailed discussion of the substitutes is presented in the residential sector.

Electricity and natural gas provide more than 95% of the energy used by the commercial sector. As shown in Table 4, both of these energy sources are expected to grow, with electricity growing more on both a percentage and absolute basis. As more efficiency standards are implemented, future energy use for heating and cooling will be reduced.

Table 3. 2013 commercial energy end-use splits, by fuel type (quadrillion Btu)

	Natural Gas	Fuel Oil (1)	Other Fuel (2)	Renewable Energy (3)	Electric (4)
Space Heating	1.86	0.15	0.26	0.12	0.49
Water Heating	0.54	0.02			0.28
Other (5)	0.74	0.20			5.14
Cooking	0.20				0.06
Space Cooling	0.04				1.50
Lighting					2.79
Ventilation					1.59
Refrigeration					1.13
Electronics					0.67
Computers					0.34
Total	3.37	0.37	0.26	0.12	13.99

Notes: (1) Includes distillate fuel oil. (2) Includes residual oil, propane, coal motor gasoline and kerosene. (3) Comprised of biomass. (4) Includes all site electricity and electricity loss due to generation and transmission losses. (5) Includes service station equipment, ATMs, telecommunications equipment, medical equipment, pumps, emergency electric generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings.

Source: EIA 2015

Table 4. AEO2015 commercial energy source projections

		Energy (quadrillion Btu/year)				_
Sector	Source	2013	2040	%Total 2013	%Total 2040	Annual Growth
Commercial	Electricity	13.99	16.46	77.3%	78.7%	0.8%
Commercial	Natural Gas	3.37	3.71	18.6%	17.7%	0.4%
Commercial	Petroleum/Other Fuel	0.63	0.58	3.5%	3.0%	-0.1%
Commercial	Renewables	0.12	0.12	0.7%	0.6%	0.0%
	Commercial-Total	18.10	20.92			

Source: EIA 2015, Table A2

2.1.3 Oil and Gas Uses and Alternatives: Industrial Sector

Energy consumption in the industrial sector is expected to grow faster than in all other sectors, according to AEO2015. As shown in Table 5, electricity, natural gas, and petroleum all contribute similar amounts of energy to this sector. A large portion of both consumption and anticipated growth is in the bulk chemicals industry, which is able to take advantage of increased domestic supply of natural gas, hydrocarbon gas liquids, and petrochemical feedstocks. The U.S. bulk chemical industry represents approximately 60% of the energy use (EIA 2015). While some energy is used in the bulk chemical manufacturing process for heat and power, most energy in that industry is used as feedstocks, or raw materials used in the manufacture of chemicals.

Table 5. AEO2015 industrial sector energy source projections

Sector	Source	Energy (quadı	%Total	%Total	Annual	
Sector	Source	2013	2040	2013	2040	Growth
Industrial	Electricity	9.98	11.97	32.0%	31.8%	0.9%
Industrial	Natural Gas	9.14	11.19	29.3%	29.7%	0.8%
Industrial	Petroleum	8.4	10.59	26.9%	28.1%	0.9%
Industrial	Coal	1.48	1.44	4.7%	3.8%	-0.1%
Industrial	Renewables	1.48	1.63	4.7%	4.3%	0.4%
Industrial	Biofuels	0.72	0.86	2.3%	2.3%	0.6%
Industrial-Total		31.20	37.68			

Source: EIA 2015, Table A2

The mix of industrial energy sources is expected to stay relatively constant from 2013 through 2040, reflecting the limited ability to switch from other fuels to natural gas in most industries. Consumption of renewable fuels increases from 2013 to 2040, although as a percentage of total energy consumption, renewable fuels remain a small fraction of total energy consumption in 2040. The paper industry remains the predominant user of renewable energy, accounting for roughly 66% of the energy consumed for heat and power in that industry (EIA 2015).

The main substitutes for oil and gas include biofuels, renewables, and electricity. Many facilities may switch from oil to gas, but we do not evaluate this possibility here since our focus is on

shifts from oil and gas to other fuel sources. There is also the possibility of recycled plastic and biobased chemicals being used as substitutes for plastic manufacturing.

2.1.4 Oil and Gas Uses and Alternatives: Transportation Sector

As shown in Table 6, petroleum products are predominantly used in the transportation sector and make up the majority of the energy used in this sector. The only significant substitutes for petroleum products in this sector are natural gas and more efficient vehicles. Greater fuel efficiency should be achieved in all of the transportation modes. In the near term, efficiency of the U.S. vehicle fleet is likely to be determined more by stricter regulatory requirements than by a demand from consumers for more efficient vehicles. The corporate average fuel economy (CAFE) standards will continue to require cars and trucks to be more fuel efficient over the next several decades. Gasoline-only vehicles, excluding hybridization or flex-fuel capabilities, represent about 46% of the total new sales in 2040. However, alternative fuel vehicles and vehicles with hybrid technologies show a significant growth in the market: gasoline vehicles with micro hybrid systems represent about 33%, E85 flexible-fuel vehicles (FFVs) 10%, full hybrid electric vehicles 5%, diesel vehicles 4%, and plug-in hybrid vehicles and electric vehicles 2% (EIA 2015).

The increased use of compressed natural gas and liquefied natural gas in vehicles represents close to 3% of the total energy use in the transportation sector.

Table 6. AEO2015 transportation sector energy source projections

Sector	Source	Energy (quadrillion Btu/year)		%Total 2013	%Total 2040	Annual Growth
		2013	2040			
Transportation	Petroleum	26	24.76	96.3%	93.0%	-0.2%
Transportation	Pipeline Fuel Natural Gas	0.88	0.96	3.3%	3.6%	0.3%
Transportation	Electricity	0.07	0.18	0.3%	0.7%	3.4%
Transportation	Compressed/Liquefied Natural Gas	0.05	0.71	0.2%	2.7%	10.3%
Transportation	Liquid Hydrogen	0	0	0.0%	0.0%	0.0%
Transportation-Total		27.00	26.61			

Source: EIA 2015, Table A2

2.1.5 Oil and Gas Uses and Alternatives: Electricity

Table 7 presents the fuels used to produce electricity and the amount of fuel used in 2013 and projected to be used in 2040. Petroleum, the only fuel projected to decrease in usage, is not used in a significant amount in fueling power plants. The absolute value of this decrease is insignificant compared to the use of petroleum in the transportation and industrial sectors. Generation from coal-fired plants and nuclear energy sources remains fairly flat into 2040. Renewables have the highest projected growth in terms of percentage and have a similar absolute growth as natural gas. Renewables will be an important substitute for natural gas, but both

renewables and natural gas will make up most of the capacity decrease resulting from the slower growth in the coal and nuclear industries. Climate change and energy policy could have a significant effect on shaping the electricity sector; Table 7 assumes that current laws and regulations affecting the energy sector remain unchanged through 2040.

Table 7. AEO2015 electricity fuel projections

Fuel	Energy-billion	n kilowatt-hours	% Total	% Total	Annual Growth	
ruei	2013	2040	2013	2040		
Coal	1586	1702	39.0%	33.7%	0.30%	
Natural Gas	1118	1569	27.5%	31.0%	1.30%	
Renewables	530	909	13.0%	18.0%	2.00%	
Nuclear	789	833	19.4%	16.5%	0.20%	
Other	20	25	0.5%	0.5%	0.80%	
Petroleum	27	18	0.7%	0.4%	-1.60%	
Total	4070	5056				

Source: EIA 2015, Table A2

Tables 1–5 do not identify the specific renewables that are expected to contribute to the increase in capacity. AEO2015 makes the following comment regarding renewable growth and provides additional details on renewables and their growth projections.

Solar photovoltaic (PV) technology is the fastest-growing energy source for renewable generation, at an annual average rate of 6.8%. Wind energy accounts for the largest absolute increase in renewable generation and for 40.0% of the growth in renewable generation from 2013 to 2038, displacing hydropower and becoming the largest source of renewable generation by 2040. Geothermal generation grows at an average annual rate of about 5.5% over the projection period, but because geothermal resources are concentrated geographically, the growth is limited to the western United States. Biomass generation increases by an average of 3.1%/year, led by cofiring at existing coal plants through about 2030. After 2030, new dedicated biomass plants account for most of the growth in generation from biomass energy sources.

It should be noted that onshore wind energy accounts for the largest share of the projected wind energy increase.

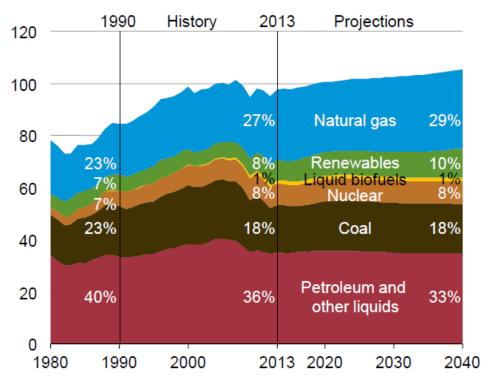
2.2 CURRENT AND FUTURE PRODUCTION OF ENERGY SOURCES

2.2.1 Current and Future Energy Use

Section 2 presents more detailed information on each of the potential energy substitutes, including generation amounts and U.S. locations where these energy sources are generated.

Figure 1 presents the percentage of 2013 energy consumption in the United States by energy source, as well as projections of energy consumption through 2040 (EIA 2015). This figure

indicates that there is little change in the percentage of total national energy production for liquid biofuels, nuclear, and coal from 2013 to 2040. Renewables increase from 8% to 10%, natural gas increases from 27% to 29%, and petroleum and other liquids decreases from 36% to 33%.

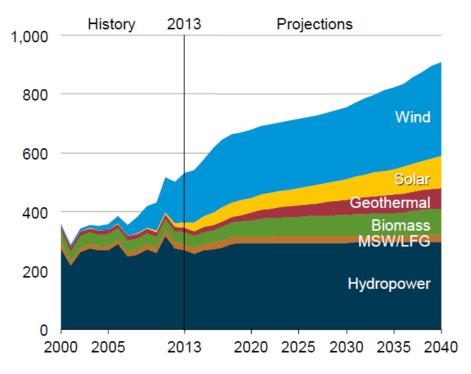


Source: EIA 2015, p. 24, Figure 31

Figure 1. Primary energy consumption by fuel in the reference case, 1980–2040 (quadrillion Btu)

2.2.2 Renewable Energy Current and Future Use

Electricity generation from both wind and solar energy has seen significant increases over the last several years, while production of other renewable energy sources has remained relatively stable. Figure 2 shows electricity generation by renewable fuel in the AEO2015 Reference case, 2000–2040, indicating that renewables increase to 18% of the total fuel source in 2040 and in fact surpass nuclear energy. Figure 2 shows the renewable electricity generation by fuel type per the AEO2015 Reference case. This figure shows the continued growth of wind and solar, along with an increase in geothermal as an energy source. Hydropower and biomass are projected to contribute similar amounts of energy in 2040 as in 2013.

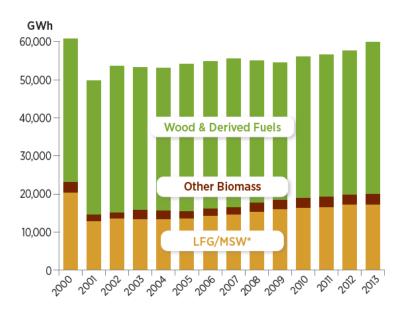


Source: EIA 2015, p. 25, Figure 34

Figure 2. Renewable electricity by fuel type in the Reference case, 2000–2040 (billion kilowatt hours)

Figure 3 displays the historical trend in energy generation from biomass sources, which shows relatively steady increases in electricity production from landfill gas/municipal solid waste and other biomass energy sources over the last decade, while production from wood and wood-derived fuels was fairly constant. (Note that the significant reduction in landfill gas and municipal solid waste between 2000 to 2001 is an artifact of a classification change—beginning in 2001, non-biogenic municipal solid waste and tire-derived fuels were reclassified from waste biopower to non-renewable energy sources.)

U.S. Biopower Electricity Generation Sources (GWh)



	LFG/ MSW*	Other Biomass	Wood and Derived Fuel	Total
2000	20,305	2,826	37,595	60,726
2001	12,714	1,834	35,200	49,748
2002	13,398	1,646	38,665	53,709
2003	13,383	2,428	37,529	53,340
2004	13,281	2,216	37,576	53,073
2005	13,470	2,009	38,681	54,160
2006	14,106	2,004	38,649	54,759
2007	14,462	2,063	39,014	55,539
2008	15,253	2,481	37,300	55,034
2009	15,982	2,461	36,050	54,493
2010	16,304	2,613	37,172	56,089
2011	16,398	2,824	37,449	56,671
2012	17,125	2,701	37,798	57,624
2013	17,142	2,816	39,936	59,894

Source: NREL 2014a, p. 78

Figure 3. Electricity generation by type of biomass energy source

Table 8 shows the generation amount of each of the renewables along with the percentage of total energy produced. By 2040, wind exceeds conventional hydroelectric power and solar and wood/other biomass both represent 1% of the total energy produced in the United States.

Table 8. Renewable generation amount and percentage of total energy produced

Energy Source	Reference Case 2013		Reference Case 2025		Reference Case 2040	
	Generation- gW	% of Energy Produced	Generation- gW	% of Energy Produced	Generation- gW	% of Energy Produced
Conventional hydroelectric power	275.2	4.4%	294.2	3.7%	297.0	3.3%
Geothermal	15.6	0.2%	38.5	0.5%	69.6	0.8%
Municipal waste	20.6	0.3%	23.9	0.3%	23.8	0.3%
Wood and other biomass	37.6	0.6%	65.5	0.8%	89.3	1.0%
Solar	11.2	0.2%	58.7	0.7%	110.1	1.2%
Wind	141.0	2.3%	234.9	3.0%	319.3	3.5%
Total	501.2		715.6		909.1	

Source: EIA 2015, Table A16

The International Renewable Energy Agency (IRENA) recently produced an alternative forecast for renewable energy in the United States (IRENA 2015). Unlike the AEO2015 business-asusual projections, IRENA forecasts the effects of potential future new investments and policies targeting support for renewable energy. According to IRENA's "REmap" analysis, the United States could reach a 27% renewable energy share by 2030 if the realizable potential of all the analyzed renewable energy technologies is implemented.

Table 9 presents a summary comparing the REmap analysis energy production projections with the *Annual Energy Outlook 2013* (current version at the time of the REmap work) (EIA 2003, or AEO2013) Reference case projections. Under REmap, wind and biomass accounts for nearly three-quarters of the total renewable energy use in 2030, and wind accounts for over two-thirds of total power sector energy. The remainder of REmap's 2030 energy production is equally divided between biomass, solar, and geothermal.

The REmap analysis also projects total biomass use to increase three-fold from 2010, with biomass accounting for more than half of total renewable energy use in 2030. The analysis concentrates additional biomass use in heating markets (buildings and industry). Although biomass may be the largest source of renewable energy in REmap 2030, wind, solar, and geothermal energy show the highest growth rates.

² IRENA is an intergovernmental organization that supports countries in their transition to a sustainable energy future. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar, and wind energy, in the pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity.

Table 9. Comparison of baseline, reference case, and REmap analysis energy supply and demand

Energy Source	2010	Reference 2030	REmap 2030
Total primary	energy supply (P.	J/year)	
Coal	21,045	20,401	8,469
Oil	31,365	29,360	26,618
Gas	22,862	25,575	20,384
Nuclear	8,905	10,090	7,828
Hydroelectric	936	1,059	1,550
Modern bioenergy (incl. biogas, biofuels)	4,183	6,609	12,651
Solar thermal	100	137	675
Solar PV	13	155	847
Wind	344	625	4,153
Geothermal	551	1,537	2,955
Total	90,303	95,547	86,124
Total final energy	gy consumption (I	PJ/year)	
Coal	1,468	1,458	1,458
Oil	30,956	29,040	26,297
Gas	14,700	16,301	11,219
Modern biomass (solid)	2,005	2,535	5,855
Modern biomass (liquid)	1,127	1,567	3,1 08
Solar thermal	96	126	996
Geothermal	11	25	25
Other renewables	0	0	261
Electricity	13,510	15,392	16,234
District Heat	278	234	234
Total	64,150	66,678	65,688
Gross electrici	ty generation (TW	/h/year)	
Coal	1,847	1,765	638
Natural gas	969	1,377	1,361
Oil	37	18	18
Nuclear	806	914	707
Hydroelectric	260	294	430
Biomass	95	238	490
Solar PV	4	43	235
Concentrated Solar Power	1	3	8
Wind onshore	96	164	994
Wind offshore	0	9	160
Geothermal	15	42	183
Total	4,130	4,868	5,224

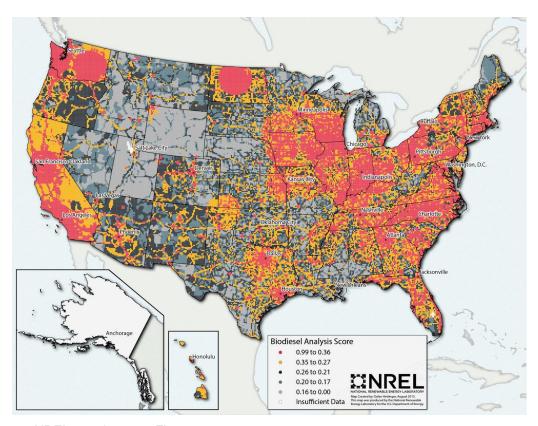
It is important to note that there are geographic challenges associated with connecting energy demand with renewable energy supplies. To demonstrate the potential challenge of meeting future energy demands with non-fossil fuels, the following summarizes information on the geographic distribution of minor energy source resources/markets. This information is largely a product of geographic energy analyses first performed in 2012 by the National Renewable Energy Laboratory (NREL) (NREL 2012a).

Biofuels

NREL used six market indicators to evaluate the existing and potential future regional market strength for biodiesel (blends of B20 and higher) and E85 ethanol (NREL 2014b). In the NREL analysis, each market indicator was mapped, combined with the others, and evaluated and adjusted by industry experts. The analysis suggested the weight the market indicators should be given, with the proximity of fueling stations being the most important indicator, followed by alternative fuel vehicle density, gasoline prices, state incentives, nearby resources, and, finally, environmental benefits.

Biodiesel

As indicated by Figure 4, markets for biodiesel appear throughout the Midwest, centered on the Chicago area. This is where the majority of biodiesel production occurs, providing both low shipping costs and a pro-biodiesel population. Urban areas and linking highways from Atlanta to Boston also show strong market potential because of high freight traffic and diesel registrations throughout the greater region. Memphis, Houston, Dallas, Denver, and Phoenix appear as additional areas of promising market potential due to high diesel prices and well-connected corridors of high freight tonnage. Wyoming, Utah, and Idaho have the weakest biodiesel markets despite the activity in Yellowstone National Park and Salt Lake City, and the existence of interstate highways connecting Idaho Falls to Boise.



Source: NREL 2014b, p. 12, Figure 4

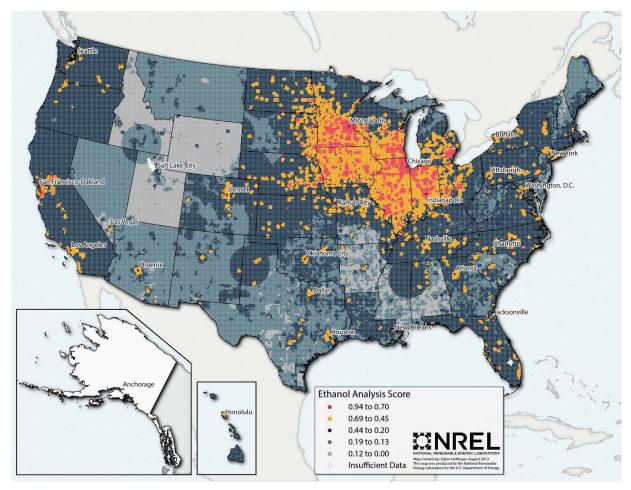
Figure 4. Geographic market potential for biodiesel

Geographic areas identified by NREL with unexpected biodiesel market strength include North Dakota and the Oklahoma panhandle, where biodiesel refineries and a high number of state incentives push market ratings into high categories.

North Carolina has many pro-biodiesel incentives and a disproportionate number of B20 refueling stations (18% of the nation's total, despite only having 3% of the total U.S. population). These refueling stations are well-dispersed throughout the state. Pennsylvania shows great promise due to high gasoline prices, freight tonnage, diesel vehicle registrations, and a number of biodiesel refineries. Hawaii is strong as well due to very high gasoline prices, many state incentives, a high density of diesel registrations, and seven B20 stations. However, the lack of biodiesel supply is currently overriding these indicators of high demand. The Appalachian region has poor biodiesel market potential even though it is surrounded by relatively strong biodiesel markets.

Ethanol

The NREL analysis found that ethanol markets are most robust in the Midwest (see Figure 5). Outside the Midwest, the urban areas surrounding the San Francisco Bay (including Sacramento), Los Angeles, Denver, New York City, Rochester-Buffalo, Houston, Miami, and Dallas have large markets (listed in order of the size of the geographic area that received scores in the highest quintile). The weakest ethanol markets are found in the region comprising Wyoming, Utah, Idaho, Nevada, and Montana. These states have very few pro-ethanol incentives, low FFV density, few fueling stations, and only one ethanol refinery.



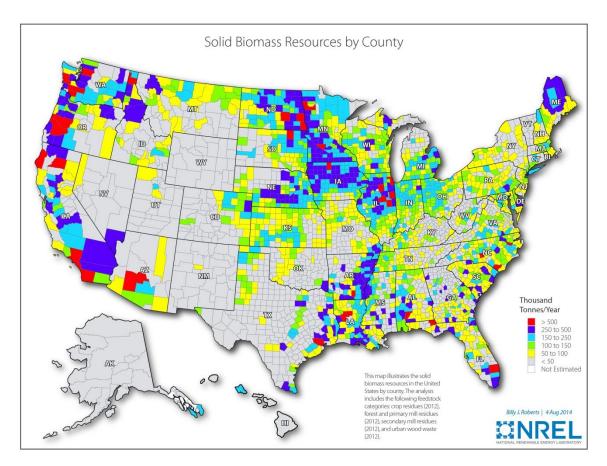
Source: NREL 2014b, p. 13, Figure 5

Figure 5. Geographic market potential for ethanol

Following its initial analysis, NREL made several changes to the prioritization of ethanol market indicators. Gasoline price was treated as less important for spurring adoption of FFVs than for other alternative fuel vehicles. The majority of FFVs on U.S. roads are owned by individual consumers, who tend to prioritize performance and design over life-cycle cost much more than fleet owners. Furthermore, ethanol retailers appear to peg the price of E85 to that of gasoline, which results in high gasoline costs not necessarily translating to substantial fuel savings when using E85. Therefore, the current pricing strategy of E85 is not providing as much incentive to use E85 as other fuels that have their price based on the feedstock and production cost of the fuel. For ethanol, nearby resources were weighted more heavily than all other factors, excepting existing E85 fueling infrastructure. More so for ethanol than for other fuels, NREL concluded that there are strong social, economic, and cultural ties to the feedstock and fuel production plants. Ethanol plants are located near corn-based economies, where farmers feel the positive effects that corn-based ethanol production has on corn prices, and where a great deal of farm work requires light-duty trucks, which are disproportionately FFVs.

Biomass

As indicated in Figure 6, the regions that show with the most biomass potential are in the Midwest for crops, and the West/South for forest residues.

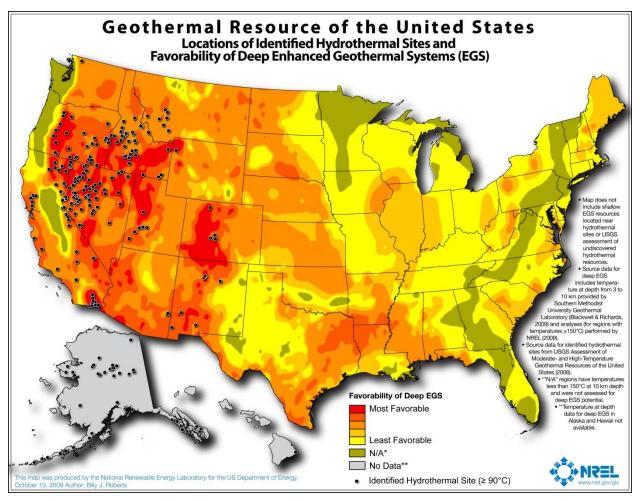


Source: NREL 2014c

Figure 6. Geographic market potential for biomass energy

Geothermal

Geothermal resources are primarily centered in the western United States. (see Figure 7). The Rocky Mountain States, and the Great Basin particularly, contain the most favorable resources. It should be noted that, especially in western states, a considerable portion of geothermal resources occur on protected land.



Source: NREL 2009

Figure 7. Geographic market potential for geothermal energy

Hydroelectric

Hydropower is currently the largest source of renewable power generation; however, it is expected to be overtaken by wind power due to the limited potential for new large-scale hydroelectric power plants. Figure 8 displays the estimated capacity for the top non-powered dams in the United States. Additional potential capacity can be assumed to be available from retrofitting and upgrading turbines at existing hydroelectric dams.

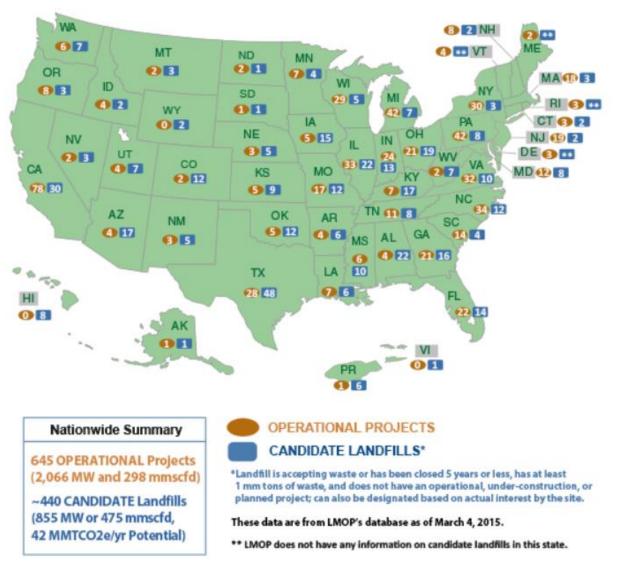


Source: NREL no date

Figure 8. Top non-powered dams with hydroelectric energy potential

Municipal Waste

Approximately one quarter of the currently operating landfill gas projects are using the energy produced to directly offset the use of other fuels such as natural gas, coal, or fuel oil (EPA 2015a). Energy production from landfill gas can be achieved through the use of various technologies, making it an option for large-scale as well as small-scale applications. Currently, the ability for landfill gas to be converted into other types of fuels (liquefied natural gas, high- or medium-Btu fuel, or methanol) is under investigation. Figure 9 gives the number of operational landfill gas projects as well as the number of identified candidate landfills for future projects in each state as of March 2015.



Source: EPA 2015b

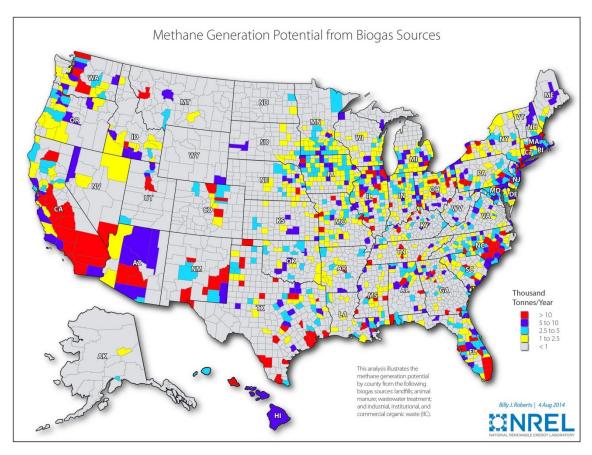
Figure 9. Operational landfill gas projects and candidate landfills for future landfill gas projects by state

2.2.3 Nuclear Energy Current and Future Use

The development of new nuclear power plants has been significantly impacted by "cheaper" natural gas a result of unconventional drilling as well as the nuclear incident in Fukushima, Japan. There have been 18 combined license applications for new nuclear plants in the United States, with seven of the applications having been suspended; six under review, two withdrawn, and three issued (NRC 2015). The facilities under review or that have been issued licenses are all located in the eastern United States.

2.2.4 Other Natural Gas Current and Future Use

NREL has developed a map of the potential county-level generation of methane from biomass gas resources. This map, which is presented as Figure 10, generally indicates the greatest resources in heavily populated metropolitan areas and areas with substantial livestock production.

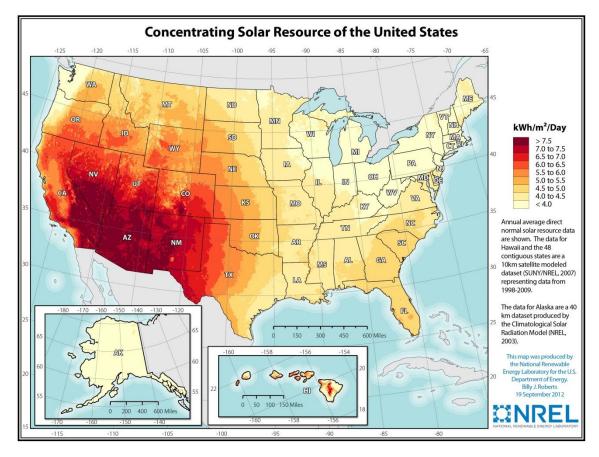


Source: NREL 2014d

Figure 10. Geographic market potential for biomass gas

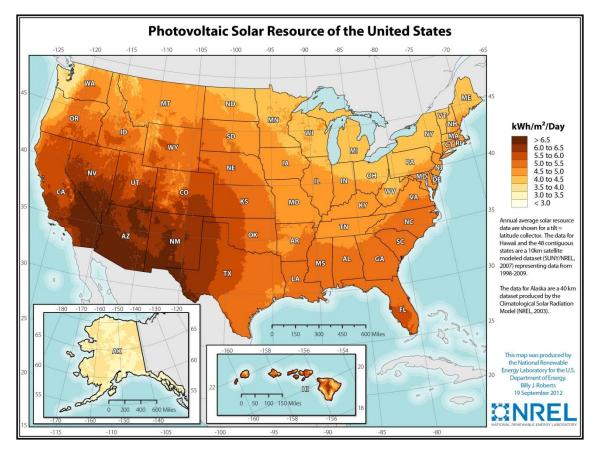
2.2.5 Location of Solar Energy Facilities/Opportunities in the United States

NREL has produced two maps characterizing the geographic distribution of solar resources. Figure 11 presents Concentrating Solar Resources (CSR), while Figure 12 displays PV resources. Technical potential for CSR exists predominately in the Southwest. This pattern holds for the potential for PV solar energy, although the NREL analysis indicates much less of a decline from the Southwest region's potential to the South Central and Southeast regions than indicted by the potential for CSR.



Source: NREL 2012b

Figure 11. Geographic market potential for concentrating solar resources

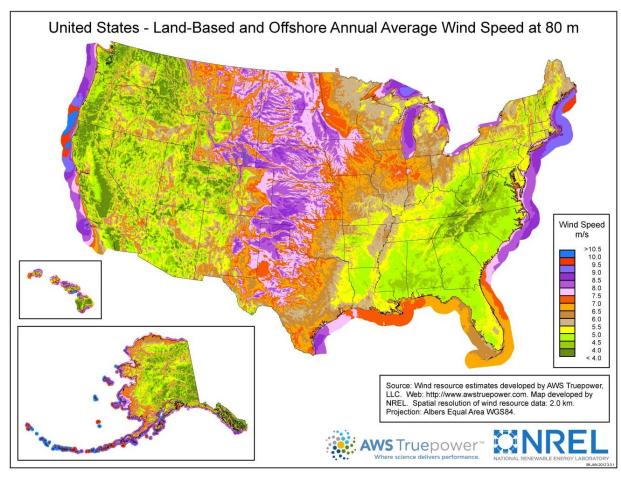


Source: NREL 2012c

Figure 12. Geographic market potential for PV solar resources

2.2.6 Location of wind Energy Facilities in the United States

The potential for onshore wind energy is greatest in the western and central Great Plains and lowest in the southeastern United States (see Figure 13). Areas in the Midwest routinely average wind speeds of 8.5 meters per second at a height of 80 meters. The ability to deliver electricity to consumers from these high resource areas, which are often far from consumption centers, can prove a challenge given the existing grid infrastructure. Technical potential for offshore wind power is present in significant quantities in all offshore regions of the United States. Wind speeds off the Atlantic Coast and in the Gulf of Mexico are lower than they are off the Pacific Coast, but the presence of shallower waters there makes these regions more attractive for development.



Source: NREL 2011

Figure 13. Geographic market potential for wind energy

2.3 ENVIRONMENTAL AND SOCIAL COSTS OF ENERGY SOURCES

2.3.1 Overview of Environmental and Social Costs of Energy Sources

This section focuses on the potential environmental costs associated with the primary alternatives to oil and gas. The OECM considers "main" energy market substitutions (i.e., increased imports and onshore production of oil and natural gas, fuel switching to coal, and reduced demand), but multiple other "minor" energy substitutes exist (e.g., nuclear, wind, and solar electricity; biofuels). This section provides a qualitative discussion of the environmental and social costs of both the main energy substitutes not already monetized in the OECM and minor energy substitutes. The OECM addresses the following environmental and social costs:

- Recreation
- Air quality
- Property values
- Subsistence use
- Commercial fishing

• Ecological effects

The purpose of this section is not to explore this subject in great detail. Rather, we make the point that negative as well as positive externalities (i.e., costs borne by society that are not reflected in a good's price) can be attributed to *all* forms of energy production, and any complete consideration of alternatives would seek to take these costs into account. An exception could be made when increased energy efficiency, or simple conservation, are the oil or gas substitutes, as those actions often will result in decreased use of the energy resources that give rise to environmental costs.

The primary alternatives to the direct use of oil and gas across all sectors are biofuels and electricity production for heat or for stationary or mobile power, using non-hydrocarbon fuel sources (i.e., coal, fissionable materials, or renewable resources). All energy sources have externalities.

The following activities are assumed to be the most significant in terms of potential environmental and social costs not addressed in the OECM or associated with the minor energy sources: (1) waste management issues, in particular with the nuclear and coal industry; (2) health and safety issues with the mining of coal and uranium; (3) groundwater impacts potentially associated with onshore oil and gas production; (4) surface water impacts from spills at onshore energy-producing facilities; (5) the air quality impacts of incremental emissions associated with biofuels (air quality impacts from traditional energy sources are covered in OECM); (6) socioeconomic issues associated with the loss of land from mining or processing activities, as well as the impacts to real estate values near energy production facilities; (7) ecological and wildlife impacts associated with all onshore energy production and offshore renewable energy production; and (8) the spill impacts from onshore energy production.

2.3.2 Waste Management

Waste management issues are also a concern, with the biggest concern being associated with nuclear power and coal-fired power plants. The country has been struggling for decades to determine how the spent fuel from the nuclear power plants will be managed on a long-term basis. The U.S. Department of Energy (DOE) has spent roughly \$12 billion on Yucca Mountain without a facility being constructed (NYT 2011). If a decision were made to proceed with construction of the facility, the total cost would be about \$100 billion.

On December 22, 2008, the walls of a dam holding 1.1 billion gallons of coal ash crumbled, spilling the material into the town of Kingston, Tennessee, and creating the largest industrial spill in U.S. history. The ash (waste residuals from burning coal mixed with water) wiped out roads, crumpled docks, and destroyed homes. In excess of \$1 billion has been spent to address this incident (USAToday 2013).

On February 2, 2014, a release of coal ash into the Dan River occurred at the Dan River Steam Station (Duke Energy) north of Eden, North Carolina. It is estimated that costs to remediate this spill will be roughly \$15 million (HP 2015).

2.3.3 Mining Health and Safety

Both the coal and nuclear industries rely on a fuel source that is mined. Health and safety issues associated with these mining activities are discussed below.

The U.S. Department of Labor (DOL) has tracked fatalities associated with coal mining since 1900 (DOL 2015). From 1900 through 1930, there were typically about 2,000 deaths per year associated with mining. From 1931 through 1948, the typical number of deaths had decreased to about 1,000 per year. From 1949 through 1984, the number had been reduced to the approximate range of 100 to 500 deaths per year. The annual fatalities have continued to decrease and have recently been in the range of 20 per year.

Research accumulated against coal has shown that human health impacts from coal emissions on miners, workers, and local communities are severe. The release of heavy metal and organic compounds pose major health risks. Among health risks are lung cancer, bronchitis, heart disease, and other health conditions.

The fuel for nuclear power plants, uranium, is also mined. Uranium mining is believed to be the cause of a statistically significant amount of lung cancers as a result of exposure of the miners to radon based on some epidemiological studies. While these studies are not conclusive, the industry has taken steps to improve ventilation and reduce the radon content in the mines.

2.3.4 Groundwater Impacts

Many onshore energy-producing activities have the potential to contaminate groundwater. Unconventional drilling for oil and gas, if not performed properly, has the potential to contaminate groundwater. Groundwater contamination can prevent the local community from using the groundwater for drinking and can cause other threats to human health and the environment if the groundwater is withdrawn and used or upon its discharge to a surface water. Groundwater contamination is one of the key items that will cause sites to become Superfund sites and require millions of dollars to remediate.

2.3.5 Surface Water Impacts

Surface water impacts are a specific concern for on-shore energy production. According to an EPA report released June 4, 2015 (EPA 2015c), groundwater withdrawals used for hydraulic fracturing that exceed the land's natural recharge rates decrease water storage in aquifers and can potentially mobilize contaminants or allow the infiltration of lower quality water from the land surface. Additionally, a general decrease in groundwater being discharged to streams can also affect surface water quality.

EPA (2015c) also characterized 151 spills due to hydraulic fracturing (fracking). In about 9%, or 13, of those spills, fluids reached surface water. These spills have the potential to contaminate drinking water resources, possibly affecting human health.

On November 2010, an estimated 6,300 to 57,000 gallons of Marcellus Shale produced water was illegally discharged at XTO Energy Inc.'s Marquardt pad and flowed into the Susquehanna River watershed. Although no impacts to water wells and springs were observed within one mile at the last sampling, produced water constituents could eventually reach drinking water sources through surface runoff or infiltration to the ground (EPA 2015c).

Hydroelectric facilities can have major impacts on aquatic ecosystems if proper actions are not taken (e.g., fish ladders and intake screens). If these actions are not taken, fish and other organisms can be injured and killed by turbine blades. In addition to direct contact with the turbine blades, there can also be wildlife impacts both from the damned reservoirs and downstream from the facility. Reservoir water is usually more stagnant than normal river water and will therefore have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds can crowd out other river animal and plant life.

2.3.6 Air Quality Impacts

Air emissions can jeopardize a region's ability to maintain or achieve attainment status, be harmful to the health of the local population, increase greenhouse gas emissions, and also present a safety hazard (e.g., release of methane into confined spaces). From a life-cycle perspective, all of the energy sources will contribute air emissions, with most of the renewables having negligible to no air emissions during operations and coal having the greatest amount of air emissions during its life-cycle. In just one year, 50,000 U.S. deaths can be attributed to air pollution from coal-fired power generation, while death counts reach over 200,000 per year globally (Flannery and Stanley 2014).

With nuclear power, small amounts of radioactivity are released, including small quantities of radioactive gases (krypton-85, xenon-13, and iodine-131). These gases may be detectible but are never at harmful levels (WNA 2013).

Contributing significantly more to pollution, fracking emits unhealthy levels of smog and toxic air contaminants. Exposure to such pollutants can cause eye, nose, and throat irritation, respiratory illnesses, central nervous system damage, birth defects, cancer, or premature death. Preliminary results from a study in Pennsylvania, for example, show impacts among newborns that could be linked to air pollution such as increases in low birth weight. Additionally, researchers who looked at air pollution levels near fracking sites in Colorado found an increase in chronic and sub-chronic effects stemming mainly from oil and gas pollutants which have the capability to harm the respiratory and neurological system, leading to symptoms like shortness of breath, nosebleeds, headaches, dizziness, and chest tightness (NRDC 2014).

One of the renewables that has the potential to impact air quality is biofuels. Most studies have found that producing first-generation biofuels from current feedstocks results in emission reductions in the range of 20%–60% relative to fossil fuels, provided the most efficient systems are used and carbon releases deriving from land-use change are excluded (GF 2015). Brazil, which has extensive experience of producing ethanol from sugar cane, shows even greater reductions. Second-generation biofuels, although still insignificant at the commercial level,

typically offer emission reductions between 70%–90%, compared with fossil diesel and petrol (excluding carbon releases related to land-use change).

2.3.7 Socioeconomic Impacts

A study performed in 2010 indicated that there can be a 3%–7% decrease in housing values for neighborhoods located within 2 miles of a power plant compared to neighborhoods with similar housing and demographic characteristics (Davis 2010). The report mentions some evidence that there are larger decreases from homes located within a mile of a plant.

Eastern Kentucky and its coal industry seem to pose a similar issue. According to the Appalachian Regional Commission, there is a relationship between coal-dependent economies and undiversified economies, fewer professional service employment position, and lower educational attainment. The disadvantages the Appalachian region of the United States have long been associated with poor public health outcomes within the surrounding population, making the costs outweigh the benefits in the region (ARC/USDA 2010).

2.3.8 Ecological and Wildlife Impacts

One of the most mentioned wildlife impacts of power plants is associated with onshore wind turbines. A recent study in which researchers used 58 mortality estimates that met their criteria estimates that between 140,000 and 328,000 birds die each year from collisions with monopole turbines, which now comprise the vast majority of U.S. wind turbines (Loss et al. 2013). Another study concludes that about 368,000 fatalities for all bird species are caused annually by collisions with wind turbines (Erikson et al. 2014).

Wildlife impacts associated with onshore oil (pipelines) include fragmentation of land. Depending on scale, these constructions and installations may cause displacement of wildlife, along with deforestation and general distortion of the terrestrial landscape. Additionally, the discharge and disposal of wastes from onshore operation installations may harm the surrounding land and its habitats, resulting in death of fauna and flora. Spills associated with pipelines and onshore oil have the potential to destroy acres of land along with its inhabitants (Ramirez and Mosley 2015).

2.3.9 Onshore Spills

The largest onshore oil spill in U.S. history occurred on July 26, 2010. Enbridge's pipeline ruptured and released nearly 3 million liters of tar sands diluted bitumen into a tributary of the Kalamazoo River in Michigan. Final costs of \$1.04 billion include cleanup and remediation, along with a fine levied by the Pipeline and Hazardous Materials Safety Administration. Communities along the creek inlet and the river experienced sickness from the fumes that blanketed miles of intersecting wetlands and waterways. The spill contaminated 20 miles of the river and local drinking water supply, and more than 50 homes near the site were evacuated (NWF 2010).

Earlier, on June 12, 2010, 33,600 gallons of oil leaked from the Chevron Oil Co. pipeline on its way to the nearby refinery. Although the oil was stopped before it ran into the Great Salt Lake, approximately 200 birds were coated with oil (NWF 2010).

Pipeline spills have also been known to cause casualties. In November of 2007, two people were killed, seven injured, and four homes were destroyed after 430,000 gallons of liquid propane were released in Carmichael, Mississippi from a ruptured pipeline. Additionally, 70 acres of woodland were devastated in the process (NWF 2010).

One of the energy sources that has been associated with spills is the unconventional drilling (fracking) of oil and gas. Roughly 865,000 gallons of oil spilled from a Tesoro Logistics pipeline in Tioga, North Dakota, in September 2013 (DESMOG 2013). The pipeline was carrying oil from a fracking operation to a rail facility. The estimate to clean up this spill was \$4 million.

More recently, in January 2015, 3 million gallons of a brine from a fracking operation spilled in western North Dakota (PBS 2015). The leak reached the Missouri River and contaminated two creeks near Williston—Blacktail Creek and the Little Muddy River. The Little Muddy River empties into the Missouri River, one of the town's sources of drinking water. There have been conflicting reports on the presence of any threats to human health and the environment from the spill, although it was the largest saltwater spill in North Dakota history.

2.3.10 Environmental and Social Impacts by Energy Source

The tables that follow summarize environmental and social costs into the following categories:

- Air impacts
- Geologic impacts
- Health and human safety impacts
- Land use impacts
- Noise impacts
- Socioeconomic impacts
- Transportation impacts
- Vegetation impacts
- Visual resource Impacts
- Waste management impacts
- Water resources impacts
- Wildlife impacts

Table 10. Onshore oil and gas production

Impact Type	Impact(s)
Air Impacts	Construction would cause a temporary increase in emissions of carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds
	(VOCs) from construction equipment exhaust.
	Construction would generate airborne particulates during clearing and
	road construction.
	Operation would generate formaldehyde, a hazardous air pollutant.
	Carbon dioxide is released from oil and natural gas combustion, and
	could contribute to local, regional, or global climate change.
Geologic Impacts	 Impacts to soil as a result of construction activities, including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure.
	Disturbance of the soil could increase the potential for erosion due to loss
	of ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include: the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities.
	Hazards associated with possibility of fires, spills/releases of hazardous
	chemicals during operations.
	Exposure to gaseous and particulate emissions.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.
	 Nearby residents may be subject to additional noise during plant operation.
Socioeconomic Impacts	Potential adverse impacts to desirability of real estate and decreased
	property values in the surrounding area.
	Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure.
	 Increased employment opportunities to support construction and operations.
Transportation Impacts	Traffic flow on local roads will increase during construction and operation.
Vegetation Impacts	Removal of vegetation during initial land-clearing and construction activities.
	Compacted soils from construction can inhibit germination and root
	growth for native plant species, and new alien species can establish.
	Noxious weeds can be spread from unwashed construction equipment,
	vehicles transporting noxious weed-inoculated soil or plant materials into un-infested areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource Impacts	Visual intrusion that would be visible for miles.
	Nighttime lighting may be noticeable to nearby residential neighborhoods.
	Construction would contribute to visual impacts with its associated dust, large cranes, pit excavations, and well drilling.
	Cooling tower could produce a vapor plume that could be visible against a
	dark nighttime sky from all viewpoints.

Table 10. Onshore oil and gas production

Impact Type	Impact(s)
Waste Management Impacts	 Wastewater from oil and gas production activities (e.g., produced water/fracking fluids) may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Petroleum coke, sludges, hazardous and nonhazardous solid waste may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management.
Water Resources Impacts	 Construction activities would have the potential to release liquids (oils and fuel) to surface and groundwater. Construction and operation of the facilities would increase the potential for contaminated stormwater runoff to be discharged into surface waters, reduce groundwater recharge and increase risk of contamination in surface waters. Construction activities could cause erosion of sediments into adjacent floodplains or bodies of water located offsite and degradation of water quality from stormwater runoff. Releases of hazardous chemicals and oil used on-site could affect surface water and groundwater quality. Groundwater may be required to provide water for operation of the facility and deplinish supply of groundwater.
Wildlife Impacts	 Wildlife displacement/avoidance during initial land-clearing and construction activities. Transmission lines pose some collision risk to avian species. Potential habitat contamination from hazardous materials for land and aquatic species.

Sources: DOI 1978; TNC 2011.

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Table 11. Oil and gas imports

Impact Type	Impact(s)
Air Impacts	 Air emissions from compressor stations may include methane, ethane, benzene, toluene, xylene, CO, ozone and other pollutants. (Pipeline) Air emissions from engines during transport. (Tanker)
Geologic Impacts	 Large amount of soil disturbance involved in laying pipeline poses erosion and sedimentation risks, particularly in steeper areas, near water bodies, and during heavy rain events. (Pipeline) Disturbance of the soil could increase the potential for erosion due to loss of ground cover and exposure of soils to precipitation and runoff. (Pipeline)
Health and Human Safety Impacts	 Potential casualties during transport. (Tanker) Possibility of a fire or explosion during transport, transfer or storage. Ruptures emitting toxic chemicals such as benzene, hydrogen sulfide, toluene and xylene. (Pipeline)
Land Use Impacts	 Use of land for right-of-way and land for ancillary facilities (e.g., access roads, pump stations, and construction camps) that will not be available for other uses. (Pipeline)
Noise Impacts	 Construction noise impacts. (Pipeline) Noise pollution at compressor stations. (Pipeline)
Socioeconomic Impacts	The potential for a future embargo under the import option is such that American productivity and policy could become subservient to foreign influence. (Tanker)
Transportation Impacts	Increased vessel traffic. (Tanker)
Vegetation Impacts	 Fragmentation of large patches of forest into smaller ones. (Pipeline) Vegetation can be affected by surface disturbance, changes in water flows, the arrival of alien species and air contamination. (Pipeline)
Visual Resource Impacts	 Temporary effect on quality of scenic resources during construction. (Pipeline) Above ground facilities' effects on quality of scenic resources via views from travel routes and residential and recreational areas. (Pipeline)
Waste Management Impacts	Oily waste from pigging operations and maintenance on valves may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. (Pipeline)
Water Resources Impacts	 Oil spills affecting surface water and groundwater. An incident involving release of a container vessel's bunker fuel could cause a significant environmental impact. (Tanker) Risk of stream bed collapse with "bore crossing" techniques if poorly designed or executed. (Pipeline)
Wildlife Impacts	 Anchor damage in biologically sensitive areas. (Tanker) Natural habitat loss and fragmentation, changes in species movement. (Pipeline) Oil spills caused by groundings and collisions tend to occur in shallow waters around headlands and straits, which are waters that also tend to be favorable for fisheries and mariculture. (Tanker)

Sources: GLC 2014; DOI 1978; Woolgar 2008; TNC 2011.

Table 12. Coal production

Impact Type	Impact(s)
Impact Type Air Impacts	 Construction would cause a temporary increase in emissions of CO, NOx, VOCs, and fugitive dust from construction equipment operation. (Fischer-Tropsch Process) The processing of coal into liquid fuel would result in a minor impact to air quality due to emissions, primarily nitrogen and carbon dioxide. The gasification process would result in an increase in annual air emissions of NOx, CO, sulfur oxides, particulate matter (PM), VOCs (a precursor of ozone), and reactive organic gases. (Shell Gasification) Some odors would be emitted during operation of the facilities. Sources for these odors would include diesel engine exhaust from locomotives, trucks, maintenance equipment, and coal yard loaders; the coal pile and coal handling; sulfur storage and handling; and ammonia
	 storage and handling. (Shell Gasification) Heat Recovery Steam Generator stack emissions include mercury and beryllium. Carbon dioxide emissions could contribute to local, regional, or global climate change.
Geologic Impacts	 Impacts to soils as a result of construction activities including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Disturbance of the soil could increase the potential for erosion due to loss of
	ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Potential for injuries and fatalities associated with mining coal. Typical work hazards associated with heavy industrial activities. Hazards associated with possibility of fires, spills/releases of hazardous chemicals. (Shell Gasification) Short- and long-term inhalation exposure can lead to non-cancerous health impacts, including exposure from manganese, hydrogen chloride, hydrogen fluoride, and acrolein. Potential impact on quality-of-life issues affecting daily life for asthmatics, such as restricted activity days and days with symptoms.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.Vehicle and rail traffic would create noise during facility operations.
Socioeconomic Impacts	 Potential adverse impacts to desirability of real estate and decreased property values in the surrounding area. Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure. Increased employment opportunities to support operations.
Transportation Impacts	 Construction-related truck traffic. Increased traffic on roads and highways. Increased rail traffic.

Table 12. Coal production

Impact Type	Impact(s)
Vegetation Impacts	 Removal of vegetation during initial land-clearing and construction activities. Compacted soils from construction can inhibit germination and root growth for native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles transporting noxious weed-inoculated soil or plant materials into uninfested areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource Impacts	 Flare stack would be noticeably visible and probably look different from other developments in the area. Water Vapor Plume emission may be visible from surrounding area under certain weather conditions. Nighttime lighting may be noticeable to nearby residential neighborhoods. Transmission lines would contribute to visual impacts.
Waste Management Impacts	 Gasification byproducts generated by operation would include gasifier slag, fine solids, elemental sulfur, and sludges from water and wastewater treatment which may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Gasification ash may be released during on-site transfer or management and require some form of on-site or off-site management. During construction, typical construction refuse and debris would be generated and would need to be disposed of properly. During construction, potentially hazardous waste materials (waste oils, solvents, and paints) would be generated and may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Wastewater generated on site may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management.
Water Resources Impacts	 Construction activities would have the potential to release liquids (oils and fuel) due to increased presence and use of construction-related hazardous substances and waste. Construction and operation of the facilities would increase the area of impervious surfaces. Water that previously would infiltrate the soil to enter the groundwater would instead become stormwater runoff and be discharged into streams, thus reducing groundwater recharge. Water use increases during facility operations. Waste generated during facility operations includes diesel and process water containing hydrocarbons which may spill during onsite transfer or management and require some form of onsite or offsite management. Construction activities could cause erosion of sediments nto adjacent surface water features located offsite and degradation of water quality from stormwater runoff. Gasification, turbine condensers, and fuel gas saturation process would require a water source (surface water or groundwater) for facility operations and would generate wastewater that could spill during onsite transfer or management and also require onsite or offsite management.

Table 12. Coal production

Impact Type	Impact(s)
Wildlife Impacts	 Wildlife displacement/avoidance during initial land-clearing and construction. Potential habitat contamination from hazardous materials for land and aquatic species. Operation of the flare would create an altered visual environment at night when the flame would be visible to active wildlife, specifically birds, which could be attracted to the flame. Transmission lines pose some collision risk to avian species.

Source: DOE 2007a.

Table 13. Biofuels

Impact Type	Impact(s)
Air Impacts	 The processing of biofuel feedstocks can affect local air quality with CO, particulates, NOx, sulphates, and VOCs released by industrial processes. Carbon dioxide emissions could contribute to local, regional, or global climate change.
Geologic Impacts	 Impacts to soils as a result of construction activities including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Disturbance of the soil could increase the potential for erosion due to loss of ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include: the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities. Operations involving high temperatures and pressures, as well as flammable/toxic liquids, and the potential for exposure to PM. Risk of potential spills and exposures to released vapors. Potential fire hazard due to the storage of large quantities of flammable liquids.
Land Use Impacts	 Loss of land for industrial use. Diversion of farmland use from food supply to biofuel feedstock supply.
Noise Impacts	 Construction noise impacts. During operation, some equipment (such as chippers) may contribute to some additional noise.
Socioeconomic Impacts	 Potential for land rights disputes as industrial-scale crops are planted to produce biofuel feedstock. Diversion of farmland use from food supply to biofuel feedstock supply can jeopardize food security and could raise food prices. Could impact local industry that supports other land uses such as recreation and hunting. Can impact the nonmarket values of open space.
Transportation Impacts	 Increase in traffic during construction, as well as increased traffic for facility employees during operation.
Vegetation Impacts	 Loss of agrobiodiversity induced by intensification on croplands, in the form of crop genetic uniformity. Low levels of genetic diversity increases the susceptibility of these crops to new pests and diseases.
Visual Resource Impacts	 Nighttime lighting may be noticeable to nearby residential neighborhoods. Clearing of land for construction and/or land use changes may lead to temporary aesthetic impacts.
Waste Management Impacts	Potential for the production of small quantities of hazardous materials (waste oils, lubricants, solvents, cleaners, paints) during construction which may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management.
	 Char and ash produced during operations may be released during on-site transfer or management and require some form of on-site or off-site management.

Table 13. Biofuels

Impact Type	Impact(s)
Water Resources Impacts	 Many of the crops currently used for biofuel production – such as sugar cane, oil palm and maize – have relatively high water requirements at commercial yield levelsthe processing of feedstocks into biofuels can use large quantities of water, mainly for washing plants and seeds and for evaporative cooling. Irrigated production of the key biofuel feedstocks have the greatest impact on local water resource balances.
	 Converting pastures or woodlands into maize fields (example) may exacerbate problems such as soil erosion, sedimentation and excess nutrient (nitrogen and phosphorus) runoff into surface waters and infiltration into groundwater.
	 Excess nitrogen into water pathways causing "dead zones." Pesticides and other chemicals can wash into waterbodies, negatively affecting water quality.
Wildlife Impacts	 Biodiversity loss following land conversion and habitat loss. Agricultural expansion driven by higher prices could endanger areas rich in bird species diversity.

Sources: DOE 2007b; FAO 2008; German et al. 2011.

Table 14. Biomass

Impact Type	Impact(s)
Air Impacts	Construction, harvesting and transportation would generate emissions and dust
F	from operation of equipment.
	Biomass project's power plant/wood boiler/biorefinery uses fuel and generates
	greenhouse gases, primarily carbon dioxide, methane, nitrous oxide and a small
	amount of sulfur dioxide (SO ₂).
	Carbon dioxide emissions could contribute to local, regional, or global climate
	change.
Geologic Impacts	Impacts to soils as a result of construction activities including grading, paving,
	and establishing impervious surfaces to support the plant and associated
	infrastructure.
	Disturbance of the soil could increase the potential for erosion due to loss of
	ground cover and exposure of soils to precipitation and runoff.
	The harvesting of biomass can result in short-term disturbances to and
	modifications of soil structure.
Health and Human	Potential occupational risks during construction include the movement of heavy
Safety Impacts	objects; slips, trips and falls; the risk of fire or explosion from general
	construction activities; and spills and exposures related to the storage and
	handling of chemicals and disposal of hazardous waste.
1 111 1 (-	Typical work hazards associated with heavy industrial activities.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.
Socioeconomic	Increased employment opportunities to support operations.
Impacts	Could impact local industry that supports other land uses such as recreation
	and hunting.
Tananantatian	Can impact the nonmarket values of open space.
Transportation	Increase in traffic during construction, as well as increased traffic for facility and the second during an area to the second during the second durin
Impacts	employees during operation.
Vegetation Impacts	Removal of vegetation during initial land-clearing and construction activities.
	Compacted soils from construction can inhibit germination and root growth for notice plant appairs, and now align appairs, and notice plant appairs.
	 native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles
	transporting noxious weed-inoculated soil or plant materials into un-infested
	areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource	Transmission lines would contribute to visual impacts.
Impacts	 Nighttime lighting may be noticeable to nearby residential neighborhoods.
Waste Management	Potential for the production of small quantities of hazardous materials (waste)
Impacts	oils, lubricants, solvents, cleaners, paints) during construction that may produce
	hazardous air pollutants, be released during on-site transfer or management,
	and require some form of on-site or off-site management.
	Ash produced during operations may be released during on-site transfer or
	management and require some form of on-site or off-site management.
Water Resources	General construction impacts could affect water resources by increased
Impacts	stormwater runoff being generated from the construction locations which could
	carry sediment and contamination loads into vicinity surface waters during times
	of heavy rain, and contamination from construction activities infiltrating area
	soils and percolating down into the groundwater.
	 Increased stormwater runoff occurs from developed sites as vegetation is
	removed and as the amount of impervious surface area increases, posing a risk
	of contaminating water and harming aquatic life.
	Reduction of groundwater levels due to the irrigation demand of biomass crops
	prior to harvesting.

Table 14. Biomass

Impact Type	Impact(s)
Wildlife Impacts	 During (woody) biomass harvest, change in successional stage and forest structure impact wildlife species differently. Late successional stage species such as birds that nest in mature forests would be negatively impacted following the first harvest, and early successional stage species such as mammals that live and feed on young forest stages would be positively impacted. New transmission lines could increase potential hazards to birds such as collision or electrocution. Noise from biomass harvesting activities could temporarily affect wildlife.

Source: DOE 2011a.

Table 15. Geothermal

Impact Type	Impact(s)
Air Impacts	Construction would cause a temporary increase in emissions of CO, NOx,
	VOCs, and fugitive dust from construction equipment operation.
	Emissions associated with generating electricity from geothermal
	technologies are negligible because no fuels are combusted.
Geologic Impacts	Impacts to soil as a result of construction activities, including grading,
	paving, and establishing impervious surfaces to support the plant and
	associated infrastructure.
	Disturbance of the soil could increase the potential for erosion due to loss
	of ground cover and exposure of soils to precipitation and runoff.
Health and Human	Potential occupational risks during construction include the movement of
Safety Impacts	heavy objects; slips, trips and falls; the risk of fire or explosion from
	general construction activities; and spills and exposures related to the
	storage and handling of chemicals and disposal of hazardous waste.
	Typical work hazards associated with heavy industrial activities. Typical work hazards associated with heavy industrial activities.
	Exposure of individuals to drilling mud and geothermal fluid or steam diving a valential and development (F&D) drilling activities.
	during exploration and development (E&D) drilling activities.
	Exposure of individuals to hydrogen sulfide contained in geothermal fluid or steam during exploration, development, and operation phases.
	 Exposure of individuals to hazardous materials used and stored at
	facilities, such as petroleum oil, lubricants, paints, solvents and herbicides.
Land Use Impacts	 Could remove farmland or forestland from production.
Land Ose impacts	If water is not re-injected into the ground after use to maintain pressure
	underground, it may cause sinking of land at the surface.
Noise Impacts	Construction noise impacts.
Noise impacts	 Areas with minimal noise sources (remote areas) would experience a
	greater change in the noise characteristics.
Socioeconomic Impacts	Potential adverse impacts to desirability of real estate and decreased
Cociococi cimio impacto	property values in the surrounding area.
	Population growth associated with facility construction and operation may
	lead to increased demand on the local public infrastructure.
	 Increased employment opportunities to support operations.
	Could impact local industry that supports other land uses such as
	recreation and hunting.
	Can impact the nonmarket values of open space.
Transportation Impacts	Increased traffic on nearby roads during construction.
·	Increased traffic for facility employees during operation.
Vegetation Impacts	Removal of vegetation during initial land-clearing and construction
130000	activities.
	Compacted soils from construction can inhibit germination and root growth
	for native plant species, and new alien species can establish.
	Noxious weeds can be spread from unwashed construction equipment,
	vehicles transporting noxious weed-inoculated soil or plant materials into
	un-infested areas, or from transfer of topsoil inoculated with noxious
	weeds.
Visual Resource	Transmission lines would contribute to visual impacts.
Impacts	Nighttime lighting may be noticeable to nearby residential neighborhoods.
Waste Management	Solid waste and hazardous waste (paints, coatings, solvents) generated
Impacts	during construction may produce hazardous air pollutants, be released
	during on-site transfer or management, and require some form of on-site
	or off-site management.

Table 15. Geothermal

Impact Type	Impact(s)
Water Resources Impacts	 Potential for groundwater contamination when drilling wells and extracting hot water or steam (can be prevented with proper management techniques).
Wildlife Impacts	 Loss of wildlife habitat from the surface disturbance required for construction of drilling pads and access roads. Project generated noise could keep some animals away from areas directly affected by surface disturbance during the on-site project construction and drilling activities.

Source: TEEIC 2015.

Table 16. Hydroelectric

Impact Type	Impact(s)
Air Impacts	Construction would cause a temporary increase in emissions of CO, NOx, VOCs, and fugitive dust from construction equipment operation. If a large amount of vegetation is growing along the riverbed when a dam is built, it can decay in the lake that is created, causing the buildup and release of methane, a greenhouse gas.
Geologic Impacts	 Impacts to soil as a result of construction activities, including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Potential for slope failures, landslides, and rock falls during construction where construction involves earth moving. Erosion of shoreline and sediment transport. Reservoir-triggered seismicity (where the chance exists). Changes in channel morphology and bed surface texture in the bypassed and peaking reaches from changes in project operations affecting supply and transport of sediment.
Health and Human Safety Impacts	 Potential occupational risks during construction include: the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities.
Land Use Impacts	The construction of hydropower plants can alter sizable portions of land when dams are constructed and lakes are created, flooding land that may have once served as wildlife habitat, farmland, and scenic retreat.
Noise Impacts	Construction noise impacts.
Socioeconomic Impacts	 Potential for gain or loss of water-based recreation and fisheries. Displacement of residents for construction of the dam and creation of water body.
Transportation Impacts	Increase in traffic during construction, as well as increased traffic for facility employees during operation.
Vegetation Impacts	 Removal of vegetation during initial land-clearing and construction activities. Compacted soils from construction can inhibit germination and root growth for native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles transporting noxious weed-inoculated soil or plant materials into un-infested areas, or from transfer of topsoil inoculated with noxious weeds. Colonization of invasive plant species due to the fluctuating water levels in the reservoirs.
Visual Resource Impacts	 Transmission lines would contribute to visual impacts. Nighttime lighting may be noticeable to nearby residential neighborhoods. Possible positive or negative visual effects due to lake creation, depending on setting.
Waste Management Impacts	 Some material may need to be dredged from reservoirs and disposed of properly. Hazardous and nonhazardous wastes related to maintenance activities may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management.

Table 16. Hydroelectric

Impact Type	Impact(s)
Water Resources Impacts	Construction may cause the change of surface water flow patterns and increase erosion and sedimentation.
	 In cases where cofferdams are being used during construction, future erosion may result in the release of lower oxygenated water downstream. If wells are emptied in order to fill reservoirs, groundwater levels would be affected by construction of reservoir. After the reservoirs are filled, high evaporation rates could degrade the water quality in the reservoirs and seepage from the reservoirs could affect nearby groundwater quality. Fluctuation of water levels in the reservoirs could have an impact on acid production from water interaction with the rocks surrounding the reservoirs.
	 Discharge of pollutants (e.g., fuels, lubricants, and other hazardous materials) and other contaminants (e.g., human waste and petroleum products) into adjacent rivers, streams, and reservoirs and groundwater; and contamination of water supply systems.
Wildlife Impacts	Filling the reservoirs and creating a new source of drinking water for wildlife has the potential to alter migration movement for some species and disturb wildlife habitat.
	Hydroelectric power plants affect various fish populations in different ways.
	 Construction activities will create adverse impacts for wildlife, and will create hazardous areas for local wildlife, including open pits, material stockpiles, shade created by equipment, and clearing of vegetation.
	Birds are likely to view the ponds as a safe source of drinking water or resting area. However, high total dissolved solids concentrations in these proposed ponds could be harmful or fatal to birds and other wildlife.
	 New transmission lines could increase potential hazards to birds such as collision or electrocution.

Source: ORNL et al. 2010.

Table 17. Municipal waste

Impact Type	Impact(s)
Air Impacts	 Emissions of fugitive dust and exhaust from vehicles and equipment during construction and increased emissions of criteria pollutants, formaldehyde, and acetaldehyde during operations. During the operation phase the main sources of pollution should be the boiler stack emissions, emissions from refuse-derived fuel (RDF) plant, and fugitive dust and odor emissions from waste handling and processing emissions due to vehicular movement. Possible air pollutants released during operations include PM, VOCs, CO, SO₂, NOx, formaldehyde and acetaldehyde. Carbon dioxide emissions could contribute to local, regional, or global climate change.
Geologic Impacts	 Impacts to soil as a result of construction activities, including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Disturbance of the soil could increase the potential for erosion due to loss of ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include: the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	 Construction noise impacts. Increased truck traffic may cause higher noise levels. Noise emissions from equipment such as shredders, boilers, generators, etc.
Socioeconomic Impacts	 Potential adverse impacts to desirability of real estate and decreased property values in the surrounding area. Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure. Increased employment opportunities to support operations.
Transportation Impacts	 Increase in traffic during construction, as well as increased traffic for facility employees during operation.
Vegetation Impacts	 Removal of vegetation during initial land-clearing and construction activities. Compacted soils from construction can inhibit germination and root growth for native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles transporting noxious weed-inoculated soil or plant materials into uninfested areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource	Transmission lines would contribute to visual impacts.
Impacts	Nighttime lighting may be noticeable to nearby residential neighborhoods.

Table 17. Municipal waste

Impact Type	Impact(s)
Waste Management Impacts	 Generation of solid waste from materials used during construction may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Solid and hazardous waste may be generated (explosives, lead acid batteries, etc.) which may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Solid waste byproduct produced after pyrolysis (ash, slag, char) may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Generation of leachate is possible if some of the waste noted above is stored on site.
Water Resources Impacts	 Increased water demand, sewage production, and natural gas usage during operations. Increased storm water run-off during construction and operations at facility location. Potential for contaminants (fuels and lubricants) to enter water sources during construction if not properly contained.
Wildlife Impacts	 Wildlife displacement/avoidance during initial land-clearing and construction activities. Transmission lines pose some collision risk to avian species. Potential habitat contamination from hazardous materials for land and aquatic species.

Sources: DOE 2011b; EDWPC 2008; DOE 2011c.

Table 18. Nuclear

Impact Type	Impact(s)
Air Impacts	 Construction would cause a temporary increase in emissions of CO, NOx, VOCs, and fugitive dust from construction equipment operation. During operation, releases to the environment of heat and moisture from the primary cooling system, operation of auxiliary equipment (generators and boilers), and emissions from workers' vehicles would be the primary impacts to air quality. No greenhouse gases emitted related to the direct generation of electricity.
Geologic Impacts	 Impacts to soils as a result of construction activities including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Disturbance of the soil could increase the potential for erosion due to loss of ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities. Public and workers would be exposed to increased ambient background radiation.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.
	Some impact to ambient background noise.
Socioeconomic Impacts	 Potential adverse impacts to desirability of real estate and decreased property values in the surrounding area. Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure. Increased employment opportunities to support operations.
Transportation	Increase in traffic during construction, as well as increased traffic for facility
Impacts Vegetation Impacts	 employees during operation. Removal of vegetation during initial land-clearing and construction activities. Compacted soils from construction can inhibit germination and root growth for native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles transporting noxious weed-inoculated soil or plant materials into uninfested areas, or from transfer of topsoil inoculated with noxious weeds. The thermal plume discharged into the water source, along with chemical and physical impacts, may have a negative impact on the aquatic ecosystem for nuclear plants that use water bodies as a heat sink. Biota would be exposed to increased ambient background radiation.
Visual Resource	Transmission lines would contribute to visual impacts.
Impacts	 Nighttime lighting may be noticeable to nearby residential neighborhoods. Cooling towers and their associated vapor plumes would be clearly visible to nearby residents.

Table 18. Nuclear

Impact Type Waste Management Impacts	 Impact(s) During construction, typical construction refuse and debris, hazardous and nonhazardous wastes, are generated that may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. During operation, waste management would involve the following, which will require on-site and off-site management: Transuranic waste
	 Low-level radioactive waste Mixed low-level radioactive waste Chemical waste Solid waste Sanitary wastewater Liquid low-level radioactive waste
Water Resources Impacts	 Construction activities would have the potential to release liquids (oils and fuel) due to increased presence and use of construction-related hazardous substances and waste. Construction and operation of the facilities would increase the area of impervious surfaces. Water that previously would infiltrate the soil to enter the groundwater would instead become stormwater runoff and be discharged into streams, thus reducing groundwater recharge. Construction activities could cause erosion of sediments into adjacent surface water features located offsite and degradation of water quality from stormwater runoff. Groundwater and/or surface water would be withdrawn to provided water needed for operation of the facility (if withdrawing from surface water, impact would fluctuate with water levels) The groundwater withdrawal can have a potential offsite impact of that water not being available to other users Also, neighboring groundwater users may experience higher pumping costs due to the physical drawdown of the hydraulic head of the confined aquifer
Wildlife Impacts	 Wildlife displacement/avoidance during initial land-clearing and construction activities. Noise impacts during operation may lead to habitat loss through avoidance, reduced reproductive success, and mortality. The thermal plume discharged into the water source may have a negative impact on the aquatic ecosystem. The chemical and physical impacts from the water discharge into the water source may have a negative impact on the aquatic ecosystem. Biota would be exposed to increased ambient background radiation from a nuclear unit. Transmission lines pose some collision risk to avian species.

Source: WNA 2013.

Table 19. Other natural gas

Impact Type	Impact(s)
Air Impacts	Synthetic natural gas (SNG) plants can be major point sources of emissions
·	of sulfur compounds (primarily SO ₂) and hydrocarbons, and to a lesser
	extent, of CO, NO _x and particulates.
	Carbon dioxide emissions could contribute to local, regional, or global
	climate change.
Geologic Impacts	Impacts to soil as a result of construction activities including grading,
	paving, and establishing impervious surfaces to support the plant and
	associated infrastructure.
	Disturbance of the soil could increase the potential for erosion due to loss of
	ground cover and exposure of soils to precipitation and runoff.
Health and Human	Potential occupational risks during construction include: the movement of
Safety Impacts	heavy objects; slips, trips and falls; the risk of fire or explosion from general
	construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste.
	 Typical work hazards associated with heavy industrial activities.
	Exposure to gaseous and particulate emissions.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.
,	Some impact to ambient background noise.
Socioeconomic Impacts	Potential adverse impacts to desirability of real estate and decreased
·	property values in the surrounding area.
	Population growth associated with facility construction and operation may
	lead to increased demand on the local public infrastructure.
	Increased employment opportunities to support operations.
Transportation Impacts	Increase in traffic during construction, as well as increased traffic for facility
	employees during operation.
Vegetation Impacts	Removal of vegetation during initial land-clearing and construction activities.
	Compacted soils from construction can inhibit germination and root growth
	for native plant species, and new alien species can establish.
	Noxious weeds can be spread from unwashed construction equipment, washing a strange of the province washing and the strange of the
	vehicles transporting noxious weed-inoculated soil or plant materials into un-infested areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource Impacts	Transmission lines would contribute to visual impacts.
Visual Nesource impacts	Nighttime lighting may be noticeable to nearby residential neighborhoods.
Waste Management	Hazardous and nonhazardous wastes from construction and operations
Impacts	may produce hazardous air pollutants, be released during on-site transfer or
pasto	management, and require some form of on-site or off-site management.
Water Resources	May have indirect impacts on the quality of the surface waters and ground
Impacts	waters due to extensive water withdrawals, possible intermedia transfer of
-	pollutants or accidents and system failures.
	The intermedia pollution transfer routes may include percolation of
	wastewaters from impoundments and leachates from landfill/mines,
	uncontrolled runoff from plant sites and precipitation of air pollutants from
\\/:\d\\\formale	the facility.
Wildlife Impacts	Wildlife displacement/avoidance during initial land-clearing and construction activities.
	activities.
	 Natural habitat loss and fragmentation, changes in species movement. Potential habitat contamination from hazardous materials for land and
	Potential nabitat contamination from nazardous materials for land and aquatic species.
Source: EDA 1070	αγιατίο ορεοίεο.

Source: EPA 1979.

Table 20. Other oil

Impact Type	Impact(s)
Air Impacts	 Atmospheric emissions of NO_x, CO, SO₂, VOCs, and PM from emissions of vehicles, heavy equipment, machinery and tools during construction, and during routine operations. Airborne dust arising from soil moving operations during construction. Synthesis gas contains certain hazardous air pollutants (mercury, beryllium, benzene, hydrogen chloride, hydrogen fluoride, etc.) to be removed from emissions by scrubbers. Smoke and odors due to burning of vegetation for land clearing. Carbon dioxide emissions could contribute to local, regional, or global climate change.
Geologic Impacts	Grading of soils for construction of facility and feedstock banks could lead to increased erosion.
Health and Human Safety Impacts	 Potential occupational risks during construction include: the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Typical work hazards associated with heavy industrial activities. Exposure to SO₂, NOx, PM 10 microns in diameter or smaller, CO in plant emissions.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	 Construction noise impacts. Sources of noise during routine operations include turbine/generators, air inlets, exhaust systems, cooling towers, pumps, and compressors.
Socioeconomic Impacts	 Potential adverse impacts to desirability of real estate and decreased property values in the surrounding area. Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure. Increased employment opportunities to support operations.
Transportation Impacts	 Increase in traffic during construction, as well as increased traffic for facility employees during operation. Possible increased railway traffic if fuel materials shipped via railcar.
Vegetation Impacts	 Removal of vegetation during initial land-clearing and construction activities. Compacted soils from construction can inhibit germination and root growth for native plant species, and new alien species can establish. Noxious weeds can be spread from unwashed construction equipment, vehicles transporting noxious weed-inoculated soil or plant materials into un-infested areas, or from transfer of topsoil inoculated with noxious weeds.
Visual Resource Impacts	 Transmission lines would contribute to visual impacts. Nighttime lighting may be noticeable to nearby residential neighborhoods. Vapor plume from cooling towers may be visible during some conditions.

Table 20. Other oil

Impact Type	Impact(s)
Waste Management Impacts	 Hazardous and nonhazardous wastes from construction and operations may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Byproducts generated during operation, including slag, ash, sludges, and elemental sulfur, may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management. Wastewater may produce hazardous air pollutants, be released during on-site transfer or management, and require some form of on-site or off-site management.
Water Resources Impacts	 Stormwater runoff during construction could decrease surface water quality. Chemicals present in facility effluents could negatively impact water quality.
Wildlife Impacts	 Wildlife displacement/avoidance during initial land-clearing and construction activities. Transmission lines pose some collision risk to avian species. Potential habitat contamination from hazardous materials for land and aquatic species.

Source: DOE 2007a.

Table 21. Solar

Impact Type	Impact(s)
Air Impacts	 Construction would cause a temporary increase in emissions of CO, NOx, VOCs, and fugitive dust from construction equipment operation. No greenhouse gases emitted related to the direct generation of electricity.
Geologic Impacts	 Impacts to soil as a result of construction activities, including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Disturbance of the soil could increase the potential for erosion due to loss of ground cover and exposure of soils to precipitation and runoff.
Health and Human Safety Impacts	 Potential occupational risks during construction include the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities; and spills and exposures related to the storage and handling of chemicals and disposal of hazardous waste. Increased number of traffic accidents or retinal damage due to glare from equipment associated with solar developments.
Land Use Impacts	Loss of land for industrial use.
Noise Impacts	Construction noise impacts.Equipment, motor vehicles, high pressure steam blow.
Socioeconomic Impacts	 Potential adverse impacts to desirability of real estate and decreased property values in the surrounding area. Population growth associated with facility construction and operation may lead to increased demand on the local public infrastructure. Increased employment opportunities to support operations. Visibility of solar developments from recreational areas could reduce visitation and tourism in the area.
Transportation Impacts	 Increase in traffic during construction. Glare from the solar receivers can impact nearby roadways.
Vegetation Impacts	 Solar development will typically require the total removal of vegetation at most facilities, increasing the risk of invasive species introduction, changes in species composition and distribution, habitat loss (e.g., dune or riparian areas), and damage to biological soil crusts. Indirect impacts also likely in terms of dust deposition, altered drainage patterns, runoff, and sedimentation.
Visual Resource Impacts	 Solar development would alter the character of largely rural areas along with development of supporting infrastructure. Transmission lines would contribute to visual impacts.
Waste Management Impacts	 Hazardous wastes similar to those generated during construction of other industrial facilities (cleaners, paints, fuels, etc.) and nonhazardous wastes during construction of solar energy facility that could be released during on-site management and will also require on-site and off-site management. Hazardous materials required for routine maintenance of solar components and equipment: May include water treatment needs for washing fluids May include dielectric fluids
Water Resources Impacts	 Solar thermal projects with wet-cooling systems require large volumes of water. Solar thermal projects with dry-cooling systems need less than one-tenth of the amount of water required for wet-cooling systems. Modification of surface and groundwater flow systems. Water contamination resulting from chemical leaks or spills. Water quality degradation by runoff or excessive withdrawals.

Table 21. Solar

Impact Type	Impact(s)
Wildlife Impacts	 Loss of habitat, disturbance, loss of food and prey species, loss of breeding areas, effects on movement and migration, introduction of new species, habitat fragmentation, and changes in water availability. Operation of the project may result in bird collisions with the heliostat mirrors and incineration at or near focused solar heat at the central tower. Construction would have the potential to interrupt wildlife movement through the area.

Sources: DOE 2010a; DOE 2012a.

Table 22. Wind (onshore and offshore)

Impact Type	Impact(s)
Air Impacts	 Construction would cause a temporary increase in emissions of CO, NOx, VOCs, and fugitive dust from construction equipment operation. Offshore air emissions sources include vessel traffic, installation of anchoring devices, energy conversion devices, transformer/service platforms, and
	underwater cables.
Coologio Imposto	No greenhouse gases emitted related to the direct generation of electricity. One have imposted to sell on a result of construction activities in cluding greening.
Geologic Impacts	 Onshore, impacts to soil as a result of construction activities, including grading, paving, and establishing impervious surfaces to support the plant and associated infrastructure. Seabed scarring/scouring/drilling and sedimentation during construction. Alteration of seafloor topography, such as through erosion, and changes in sediment transport along the coast.
Health and Human Safety Impacts	Potential occupational risks during construction include the movement of heavy objects; slips, trips and falls; the risk of fire or explosion from general construction activities.
	 Hazards include working at heights, working on and/or over water, working in confined spaces, working with machinery, and the danger of being hit by falling objects.
	Hazards associated with ocean vessel operation (e.g., collisions, rough seas, underwater hazards).
	Potential for accidental impacts between small aircraft and wind turbines.
	Possible risk of a rotor blade breaking and parts being thrown off the turbine.
	Potential for fires due to electrical shorts, insufficient equipment maintenance, or contact with power lines.
Land Use Impacts	Port facilities may need modifications to support the heavier components of offshore wind energy construction.
	Long-term, permanent loss of land possible depending on size and location of project.
	Existing waterway uses could potentially be affected by offshore wind facility development (e.g., transit lanes, recreational boating, undersea cable installations, shellfish beds or fishery areas).
Noise Impacts	Onshore, increase in noise due to use of heavy equipment during construction.
	Offshore construction noise can propagate underwater beyond immediate project area.
	 Vehicle (onshore) and vessel (offshore) traffic would create periodic noise during facility operations.
Socioeconomic Impacts	 Impacts on property values, tourism, and recreation would be location-specific, and could be positive or negative.
Transportation	Short-term increase in onshore and offshore traffic during construction.
Impacts	Periodic onshore (vehicular) and offshore (vessel) trips during operation for maintenance activities.
	For offshore wind farms, navigational safety of ocean-going vessels and aircraft can be impacted.
Vegetation Impacts	 Removal of vegetation during initial land-clearing and construction activities. Construction promotes conditions such that new alien species can establish. Seafloor vegetation can be disturbed during construction.
Visual Resource Impacts	 Changes to scenic quality (e.g., nighttime lighting) depending on location. Vessels on par with visible traffic associated with transport of workers and equipment for construction, maintenance, and facility decommissioning.

Table 22. Wind (onshore and offshore)

Impact Type	Impact(s)
Waste Management	Hazardous and nonhazardous wastes produced during construction could be released during an airc and afficient and airc and afficient and afficient and airc and afficient and afficient and airc and afficient and airc and afficient and afficient and airc and
Impacts	released during on-site management and will require on-site and off-site management.
Water Resources Impacts	 Onshore, stormwater runoff from construction could carry sediment and contamination loads into vicinity surface waters. Dredging and other offshore construction activities can lead to sedimentation.
	Wind turbines in areas with little rainfall may require the use of a small amount of water.
Wildlife Impacts	Avifauna Impacts Wildlife displacement/avoidance during initial land-clearing and construction activities.
	Risk of birds colliding with equipment during construction and operation of wind turbine generators or migratory raptors using them as perches. Fish/Essential Fish Habitat/Marine Mammal Impacts
	 Potential impacts of waste discharge, and/or oil and fuel spills during construction and operation.
	Disturbance of the seafloor could result in impacts on seafloor habitat under and adjacent to the foundation and cables.
	 Increases in water turbidity can displace prey fish. During operation, foundations may provide artificial reef habitat. Sea Turtle Impacts
	Sea turtle impacts Sea turtle nests or aggregates of hatchlings could be destroyed.
	 Disorientation by nearby lights could lead hatchlings away from the surf; onshore lighting may also draw hatchlings back out of the surf.
	Bat Impacts
	Bats could develop barotrauma (condition in which the lungs of bats are fatally damaged from the negative pressure created around operating turbines). Turbing point applied but applied to the least in the property of
	 Turbine noise could impede bat echolocation, resulting in decreased foraging efficiency.

Sources: DOE 2010b; MMS 2007; MMS 2009.

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3. Analysis of Impacts from Catastrophic Oil Spills

In the aftermath of the Deepwater Horizon (DWH) oil spill in April 2010, BOEM is making consideration of the potential impacts of low-probability/high-consequence events more explicit in its assessments of future exploration, development, and production activities on the OCS.³ A decision as to whether or not to proceed with proposed lease sales (auctions) necessarily carries with it the risk, however slight, of catastrophic discharge events (CDEs). Because these events are extremely infrequent and only limited data are available on their impacts, the OECM--the model that BOEM uses to assess the net environmental costs associated with its Five Year Leasing Programs—was not designed to estimate the costs of a CDE. To supplement results generated by the OECM for BOEM's 2012-2017 Proposed Final Program, the Bureau performed an analysis of the potential environmental and social costs of a catastrophic spill in any of the BOEM planning areas.⁴ The purpose of this chapter is to re-visit the data and literature on these impacts and, where possible, present updated estimates of the per-barrel impacts associated with a catastrophic spill. In reviewing this information, we consider potential impacts associated with a well blowout as well as impacts related to a catstrophic tanker spill. The former is likely to occur several miles from shore, while the latter is more likely to occur in the nearshore environnment.

As a preemptive caveat to the data and methods presented in this chapter, we emphasize that the environmental impacts of a CDE are highly uncertain. The magnitude of these impacts depends on multiple factors, including the volume of oil spilled, the duration of the spill, the proximity of the spill location to sensitive resources, meteorological conditions at the time of the spill (e.g., whether the wind is blowing toward shore), the type of oil spilled, and response and containment capabilities. Compounding these uncertainties is the limited data available on CDE impacts. Only two catastrophic spills have occurred in U.S. waters: the *Exxon Valdez* spill in 1989 and the *Deepwater Horizon* blowout and spill in 2010. While a wealth of data are available on both spills, it is uncertain whether these spills are representative of future catastrophic spills. The remainder of this chapter presents a review of the available data and literature on potential CDE impacts and, where possible, our estimates of these impacts on a regional basis for the following categories of impacts:

- Response costs;
- Ecological impacts;
- Recreation, inclusive of beach recreation, recreational fishing, boating, and wildlife viewing;
- Commercial fishing impacts;
- Fatal and nonfatal injuries; and
- Value of spilled oil.

³ BOEM historically considered the impacts of catastrophic oil spills in developing the Five Year Program, but discontinuted the practice in response to declining frequency and severity of oil spills. This practice was resumed following the Deepwater Horizon oil spill.

⁴ See BOEM (2012).

After presenting the available information on the impacts above, we discuss the impacts associated with response actions such as the use of dispersants and *in situ* burns. We conclude by identifying the most significant uncertainties in our analysis and their implications for our estimates of catastrophic impacts.

3.1 RESPONSE COSTS

Spill containment and cleanup refers to all costs related to emergency response following an oil spill, and the physical cleanup of any spilled oil. This includes a number of fixed costs such as setting up a response center and mobilizing labor and equipment, in addition to a variety of costs tied to the length and intensity of the cleanup effort, such as equipment rental costs, and wages for cleanup and monitoring crews.

3.1.1 Variability and Uncertainty of Response Costs

Several factors may affect the spill containment and cleanup costs associated with a given CDE. Most of these factors are related to the specific circumstances of the spill, creating significant uncertainty in efforts to generalize the average cost of oil spill response. Some of the key uncertainties include the following:

- Proximity of the spill to infrastructure critical for response, such as ports, airports, and population centers;
- Proximity of the spill to response/clean-up equipment resources;
- Proximity to potentially affected resources, particularly shoreline (i.e., distance from shore that spill occurs);
- Oil type (different types volatize at different rates);
- Wind, weather, and prevailing currents;
- Season, which is a determinant of temperature and ice cover;
- Differences in technical feasibility of cleanup, as affected by shoreline habitat type; and
- Cleanup strategy (mechanical, dispersants, in-situ burn, etc.).

Despite the uncertainty surrounding the circumstances of any given spill, a body of research exists related to response costs based on historical spill data. In particular, this research indicates response costs per barrel are significantly correlated with the length of shoreline oiled, the type of oil spilled, and the volume of oil spilled.⁵

The correlation between response costs and the length of shoreline oiled is particularly strong because shoreline cleanup requires much more complex, time consuming, and expensive techniques than cleanup of oil in open water. Etkin (2000) notes that in almost any spill, shoreline cleanup is the most expensive and time-intensive phase of the cleanup. Additionally, the type of shoreline oiled can have a considerable impact on the cleanup cost. For instance, a rocky shore is much easier to access and clean than a coastal marsh. Etkin (2004) estimates that on average, oiled wetland is more than three times as expensive to clean up as oiled rocky shore.

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⁵ See Etkin (1999), Etkin (2000).

Additionally, Etkin (2004) estimates that oiled sandy shore is 20 percent more expensive to clean up than oiled rocky shore.

The historical spill record also shows a clear relationship between the barrels of oil spilled and the response cost per barrel. In general, as the size of an oil spill increases, the response cost per barrel decreases. This is a result of the considerable fixed costs associated with an oil spill cleanup operation, such as the need to set up a response center and mobilize equipment and labor. However, response costs associated with the two historical catastrophic spills in U.S. waters, Exxon Valdez and Deepwater Horizon, do not follow this trend.

The Exxon Valdez incident resulted in the spillage of 257,000 barrels of oil into Prince William Sound. Exxon spent approximately \$4.2 billion dollars to contain and clean up the spill, or roughly \$16,000 per barrel of oil spilled. The Deepwater Horizon incident resulted in the leakage of 3.19 million barrels of oil into the Gulf of Mexico. BP spent approximately \$16.3 billion on cleanup and containment, or roughly \$5,100 per barrel of oil spilled. In contrast, historical data on non-catastrophic spills from the OSIR International Oil Spill Database indicates that in the U.S., the average response cost for a spill greater than 32,000 barrels is only \$122 per barrel (Etkin, 2000).¹⁰

3.1.2 Estimation of Response Costs by Region

Since the response costs associated with non-catastrophic oil spills do not appear to be reliable indicators of the response costs associated with catastrophic spills, our estimates of the per-barrel response costs associated with a catastrophic spill are based on the response costs for the Deepwater Horizon and Exxon Valdez spills. The per barrel response costs observed for the Exxon Valdez serve as our point estimate of response costs in Cook Inlet, and the response costs observed for the *Deepwater Horizon* spill serve as our estimate for response costs in the Gulf of Mexico.

We also use response costs observed for the *Deepwater Horizon* spill as the basis for our response cost estimate for the Atlantic. We would expect response costs in the Atlantic to be similar to response costs in the Gulf of Mexico for two reasons. First, both regions have heavily populated coastal areas, with ready access to ports, airports, equipment, and labor. Additionally, the shoreline habitat types observed in the Central Gulf and Mid-Atlantic regions are generally similar. 11 Since shoreline cleanup commands such a large portion of response resources, the

⁷ See ADFG, Exxon Valdez Oil Spill Trustee Council.

⁶ See Etkin (1999), Etkin (2000).

⁸ See U.S. District Court (2015). Though 4 million barrels of oil were released from the well, roughly 800,000 were contained, leaving only 3.19 million barrels that were discharged into the Gulf of Mexico. Though recovery of the 800,000 barrels was part of the response, we calculate per barrel costs using the 3.19 million barrels to provide a conservative estimate of response costs per barrel spilled.

⁹ See BP (2015).

¹⁰ This estimate does not take into account oil spills that occurred within the last 15 years. While it is possible that average response costs have changed in the last 15 years, this source remains the most comprehensive analysis of oil spill response costs available.

¹¹ We use the Mid-Atlantic for this comparison based on information in the DPP indicating that the Mid-Atlantic accounts for more than 80 percent of the undiscovered technically recoverable resources in the Atlantic Program Area. The Central Gulf Planning Area was chosen for purposes of comparison because historically the Central Gulf has seen greater levels of oil and gas activity than the other two Gulf planning areas.

similarities in shoreline habitat type indicate that cleanup costs in both locations are likely to be similar, assuming similar levels of shoreline oiling. If anything, shoreline cleanup is likely to be less expensive in the Mid-Atlantic than in the Central Gulf, because the Mid-Atlantic has a higher proportion of beaches and a lower proportion of wetlands than the Central Gulf. As a result, using the response costs observed for the *Deepwater Horizon* spill as the basis for the response cost estimate in the Atlantic is likely to provide a conservative estimate. Table 23 presents the distribution of shoreline types in the Central Gulf and Mid-Atlantic, as calculated from the National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index data. For additional perspective, Table 23 also shows the distribution of shoreline types for the Mid-Atlantic, South Carolina, and Georgia combined (i.e., the states near the Program Area) and for the Mid-Atlantic and New Jersey combined.

Table 23. Distribution of shoreline habitat

Shoreline Classification	Percent of Shoreline in Central Gulf	Percent of Shoreline In Mid-Atlantic	Percent of Shoreline in Mid-Atlantic, South Carolina, and Georgia	Percent of Shoreline in Mid-Atlantic and New Jersey
Marshes and Swamps	67%	50%	45%	44%
Beaches	17%	33%	39%	38%
Tidal flats	6%	2%	2%	1%
Man-made structures	5%	3%	2%	3%
Riprap	3%	10%	10%	11%
Rocky and steep shorelines	1%	0%	1%	1%
Vegetated banks	1%	1%	1%	2%

Source: NOAA Office of Response and Restoration. Environmental Sensitivity Index Maps. Accessed 7/20/15 at: http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html

Notes

- (1) The NOAA Environmental Sensitivity Index data include shoreline information for coastal rivers and other inland waterways that are unlikely to be impacted by CDEs. As a result, we exclude information on these inland waterways when calculating regional proportions of shoreline habitat types. For instance, the Environmental Sensitivity Index data include information on shoreline habitat along the Potomac River, but we do not include this information in our calculation of shoreline types in the Mid-Atlantic.
- (2) Additionally, we exclude coastal areas landward of the Outer Banks in North Carolina from our calculation of shoreline habitat types in the Mid-Atlantic. We assume that the Outer Banks would prevent oil from reaching this area.
- (2) Shoreline types which account for less than one percent of total shoreline are not included in this table.

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¹² See NOAA Office of Response and Restoration.

The Arctic region presents the greatest difficulty in estimating cleanup and containment costs. This is a result of both the unique geography of the Arctic region and the lack of historical spill response operations to examine. While the Exxon Valdez spill provides the best comparison available, there are several reasons why a spill in the Arctic may result in considerably different response costs than a spill in southern Alaska. One major difference is that the Arctic is hundreds of miles away from major ports, airports, and population centers. In the event of a spill, it would likely take longer to move equipment and labor to the spill site than in any other region. A delayed initial response to a spill has the potential to result in a greater volume of oil spilled, or a greater amount of shoreline oiling. Additionally, the Chukchi and Beaufort Seas are relatively open as compared to the relatively enclosed Cook Inlet (and Prince William Sound). As a result, a catastrophic oil spill may disperse into open water to a greater extent in the Artic, resulting in comparatively less shoreline oiling. The greater preponderance of ice cover along the Arctic shoreline as compared to Cook Inlet also has the potential impact spill response costs. Often times, ice can act as a natural barrier, containing oil out at sea where it is easiest to clean up. 13 However, if sea ice is spread too thin to contain the oil, it may just hinder response activities. Additionally, under certain conditions spilled oil may become encapsulated by ice, potentially adding to the length of the response effort when the ice melts and releases the trapped oil.

As a result of the particularly significant uncertainty associated with responding to a spill in the Arctic, we present the cleanup and containment costs for this region as a range. At the low end of the range, we assume a per barrel response cost equal to that associated with *Deepwater Horizon*. For the high end of the range, we apply the per-barrel response cost associated with *Exxon Valdez*. Table 24 presents cleanup and containment cost estimates for catastrophic spills in the Gulf of Mexico, Atlantic, Cook Inlet, and the Arctic.

Table 24. Estimated response costs per barrel by geographic region

Cost Category	Gulf Of Mexico	Atlantic	Cook Inlet	Arctic
Response Cost	\$5,100/barrel	\$5,100/barrel	\$16,000/barrel	\$5,100/barrel - \$16,000 /barrel

Note: All values presented in 2017 dollars.

3.2 ECOLOGICAL DAMAGES

Similar to response costs, the ecological damages associated with a CDE are variable and dependent upon a number of uncertain factors. Many of these factors are the same as those that contribute to uncertainty in response costs, such as oil type, weather, proximity to shoreline, and habitat type. Among these, oil type and weather conditions affect the dispersion, evaporation and volatilization rate of oil, which influences the quantity of ecological resources oiled. Oil type, proximity to shoreline, and habitat type all influence the magnitude of damages associated with oiled ecological resources. For instance, a mile of oiled wetland typically causes greater ecological damage than a mile of oiled beach. Similarly, a mile of shoreline oiled with crude typically causes greater ecological damage than a shoreline oiled with a lighter petroleum product such as gasoline. Ecological damages are also dependent on the season, which affects the

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¹³ See Transportation Research Board and National Research Council (2014).

presence or absence of migrating species, and the vulnerability of species to oiling. For instance, shoreline oiling may be considerably more damaging during the growing season, when the oil could impact plant reproduction and seed development.

Given these significant uncertainties and the lack of historic data on catastrophic spills, we estimate a range of ecological cost estimates for each region. The high-end ecological cost estimates are derived from settlement data for the two catastrophic oil spills that have occurred in the U.S., the *Deepwater Horizon* and *Exxon Valdez* spills. Since historic examples of catastrophic spills in the Atlantic and Arctic do not exist, we developed the high-end estimates for these regions by applying scaling factors to the *Deepwater Horizon* and *Exxon Valdez* damage estimates.

The low-end estimates of ecological costs are based on the per barrel damages for other (non-catastrophic) spills, using settlement and assessment data published by NOAA and the U.S. Fish and Wildlife Service (FWS). While these spills are smaller in size relative to the *Deepwater Horizon* and *Valdez* spills and may have occurred in circumstances different than what might be expected from offshore oil and gas development, they still provide insight into geographic differences in ecological costs and the potential per barrel magnitude of these costs.

3.2.1 Gulf of Mexico

The low-end estimate of the per-barrel ecological damages resulting from a catastrophic spill in the Gulf of Mexico is based on the damages for eight previous spills in the region. Table 25 presents the number of barrels spilled and estimated ecological costs associated with each spill, as obtained from the associated natural resource damage assessment (NRDA) documents. Across these eight spills, the per barrel ecological damage ranges from \$8 to \$1,400, with an average value of \$580 per barrel. This value serves as our low end per-barrel value for the Gulf of Mexico.

The recently announced settlement for the *Deepwater Horizon* spill serves as the basis for the high-end ecological costs per barrel spilled in the Gulf of Mexico. While the settlement has not yet been finalized through a consent decree, BP has reached an agreement in principle with the United States and five Gulf states. ¹⁴ The terms of the agreement include approximately \$8 billion ¹⁵ to compensate for damages to natural resources. ¹⁶ This value represents total natural resource damages, including any damages to recreational resources. To isolate the ecological portion of these damages, we subtract approximately \$720 million (adjusted from 2015\$ to 2017\$) in recreational use damages, as estimated in the Preliminary Damage Assessment and Restoration Plan (PDARP) for the *Deepwater Horizon* spill. Total ecological damages are thus estimated to be approximately \$7.2 billion, or \$2,200 per barrel of oil spilled (in 2017 dollars). ¹⁷

¹⁴ See DOJ (2015)

¹⁵ \$8 billion reflects \$1 billion in early restoration costs, a \$7.1 billion settlement paid out over 15 years, and an additional \$700 million to cover any presently unknown future natural resource damages. All of these costs were adjusted to 2017 dollars. In addition, the 15-year stream of payments for \$7.1 billion was adjusted for inflation to convert from nominal dollars to real year 2017 dollars.

¹⁶ See NOAA (2015).

¹⁷ Note that the estimate of \$720 million in recreational damages from the Deepwater Horizon spill differs from the \$600 million estimate presented later in this document. This is due to the fact that the \$720 million figure reflects compounding between the time of the spill and the publication of the PDARP. Because the time between a

Table 25. NRDA estimates of ecological damages from past spills on the Gulf Coast (2017\$)

Spill Name	Spill Year	Barrels Spilled	NRDA Settlement	NRDA Cost Per Barrel
Mosquito Bay ¹	2001	3,000	\$1,800,000	\$610
Westchester ²	2000	12,000	\$99,000	\$8
Devon LA Corp ³	2002	300	\$65,000	\$220
Equinox Oil, Alma Energy4	1998	1,500	\$1,200,000	\$770
OCEAN 255/B-155/BALSA 37 Spill ⁵	1993	8,600	\$9,600,000	\$1,100
Blake IV and Greenhill Petroleum Corp. Well 25 ⁶	1992	2,900	\$4,000,000	\$1,400
Chevron BLDSU #5, West Bay Field ⁶	1995	260	\$110,000	\$430
Texaco Pipeline Company Lake Barrel oil spill ⁶	1997	6,500	\$880,000	\$130
Average		4,400	\$2,200,000	\$580

Notes:

All values rounded to two significant digits. When it was possible to make a distinction, NRDA settlement values represent only the ecological portion of natural resource damages.

Sources:

See Settlement Agreement, Mosquito Bay (2001)

3.2.2 Atlantic

We estimate low-end ecological cost values for CDEs occurring in the Atlantic based on the estimated damages or settlement values for 18 previous spills in the region. Table 26 lists these 18 spills, and the associated settlement values for ecological damages. As indicated in the table, the ecological damages or settlement values for these spills average approximately \$790 per barrel.

CDE's occurrence and the publication of a PDARP depends on factors unrelated to damages (e.g., the negotiating strategies of the responsible parties and the Trustees, the number of Trusteess involved), we excluded compounded interest from our estimates of damages where possible. For impacts other than recreation, we made no adjustments for compounding, however, since the Deepwater Horizon PDARP does not describe the monetization of ecological damages.

² See United States of America, the State of Louisiana v. Marine Oil Trader 3, Ltd. and Ermis Maritime Corp (2003)

³ See North Pass Settlement Agreement (2006)

⁴ See In re: Equinox Oil Company, Inc. / Alma Energy Corporation, Debtors. Settlement Agreement (2006).

See FLDEP, NOAA, and U.S. DOI (1997)

⁶ See BOEMRE (2010)

Table 26. NRDA estimates of ecological damages from past spills on the Atlantic Coast (2017\$)

Spill Name	Spill Year	Barrels Spilled	NRDA Settlement	NRDA Cost Per Barrel
Anitra ¹	1996	1,000	\$1,300,000	\$1,300
North Cape ²	1996	20,000	\$10,000,000	\$520
T/V Bow Mariner ³	2004	82,000	\$640,000	\$8
Kinder Morgan Sodium Hydroxide ⁴	2004	11,000	\$110,000	\$10
Cibro Savannah⁵	1990	17,000	\$470,000	\$28
Exxon Bayway ⁶	1990	14,000	\$15,000,000	\$1,100
B.T. Nautilus ⁷	1990	6,200	\$4,300,000	\$690
Bouchard Barge ⁸	2003	2,300	\$1,500,000	\$650
Julie N ⁹	1996	4,300	\$1,200,000	\$290
M/S Star Evviva ¹⁰	1999	570	\$2,500,000	\$4,300
T/V Posavina ¹¹	2000	1,400	\$140,000	\$100
Barge RTC 380 ¹²	1992	640	\$330,000	\$520
Evergreen International M/V Ever	2002			
Reach Vessel ¹³		300	\$1,000,000	\$3,500
Chelsea Creek (Global Oil/Irving Oil	2006			
Pipeline) ¹³		520	\$12,000	\$23
Jahre Spray ¹³	1995	1,400	\$200,000	\$140
M/T Kentucky ¹⁴	1994	310	\$34,000	\$110
M/V Presidente Rivera ¹⁵	1989	6,000	\$4,100,000	\$680
M/V World Prodigy ¹⁶	1989	7,000	\$1,000,000	\$150
Average		9,700	\$2,500,000	\$790

Notes:

All values rounded to two significant digits. When there was enough information available, NRDA settlement values represent only the ecological portion of natural resource damages. Sources:

¹See NJDEP (2004)

² See NOAA, U.S. DOI, State of Rhode Island (1999)

³ See U.S. FWS (2010)

⁴ See NOAA Damage Assessment, Remediation, and Restoration Program.

⁵ See Montauk Oil Transportation Corp. v. Steamship Mutual Underwriting Association (Bermuda)

⁶ See United States of America, the State of New York, the State of New Jersey, and the city of New York v. Exxon Corporation.

See United States of America, the State of New York, the State of New Jersey, and the city of New York v. Nautilus Motor Tanker Co., Ltd.

⁸ See United States of America, Commonwealth of Massachusetts, and the State of Rhode Island v. Bouchard Transportation Company, Inc., Tug Evening Tide Corporation, and B. No 120 Corporation.

⁹ See United States of America and the State of Maine v. Amity Products Carriers, Inc.

¹⁰ See U.S. FWS, S.C. DNR, Office of the Governor (2004)

¹¹ See NOAA, U.S. DOI, MA EEA (2004)

¹² See Settlement Agreement, in the matter of Barge RTC 380 (1994)

¹³ See BOEMRE (2010)

¹⁴ See Pennsylvania DEP (1995)

¹⁵ See NJDEP (1996) ¹⁶ See NOAA (1996)

Ideally, the high-end estimate of ecological damages for a catastrophic spill in the Atlantic would be estimated based on one or more historic examples of such a spill in the region. Since a catastrophic oil spill has never occurred off the Atlantic coast of the United States, we estimate the high-end costs of a catastrophic spill in the region by scaling the per barrel damages associated with the *Deepwater Horizon* oil spill in the Gulf of Mexico. The sample of non-catastrophic oil spills used to estimate low-end costs (presented in Tables 25 and 26) indicated that the average oil spill in the Atlantic resulted in ecological damages per barrel 35 percent higher than the average ecological damages in the Gulf of Mexico (\$790 per barrel versus \$580 per barrel). As a result, this analysis assumes that a catastrophic spill in the Atlantic would result in ecological damages per barrel that are 35 percent greater than the damages from the *Deepwater Horizon* spill. Scaling the *Deepwater Horizon* settlement value in this way suggests that a catastrophic spill in the Atlantic would result in ecological damages of approximately \$3,000 per barrel

3.2.3 Cook Inlet

While no catastrophic oil spills have occurred in Cook Inlet, the *Exxon Valdez* spill occurred in the neighboring Prince William Sound. Because of the similarities between the two locations, ¹⁸ we use the per barrel ecological damages associated with the *Exxon Valdez* spill as the high-end estimate for the ecological damages expected to result from a catastrophic oil spill in Cook Inlet. The *Exxon Valdez* settlement included approximately \$1.1 billion to compensate for damages to ecological resources, or approximately \$4,200 per barrel of oil spilled (in year 2017 dollars).

A review of NRDAs led by NOAA and FWS did not identify any non-catastrophic spills in Cook Inlet that might inform the estimation of a low-end ecological damages value for the area. In the absence of such data, we develop a low-end estimate by scaling the low-end value for the Gulf of Mexico by the ratio of ecological damages from *Exxon Valdez* compared to *Deepwater Horizon*. Specifically, as noted above, the eight historic NRDAs in the Gulf of Mexico indicated average ecological damages of \$580 per barrel. Additionally, the *Deepwater Horizon* agreement indicates ecological damages of \$2,200 per barrel, while the *Exxon Valdez* settlement resulted in ecological damages that were 86 percent higher, at \$4,200 per barrel. As a result, we assume that the low-end ecological damages for Cook Inlet are 86 percent greater than the average settlement of \$580 per barrel seen in the Gulf of Mexico, or \$1,080 per barrel.

3.2.4 Arctic

The uncertainty surrounding ecological damages is particularly high in the Arctic, given that there is no historic record of NRDAs associated with oils spills of any size in the region. Since the Arctic environment is most similar to that of Cook Inlet, the ecological damage estimates produced for Cook Inlet serve as the starting point for the estimation of Arctic-specific values. Lacking any historic spills to compare between the two regions, the OECM was used to develop scaling factors to apply to the low-end and high-end values for Cook Inlet.

¹⁸ The similarities between the two locations were confirmed by outputs from the OECM. The BOEM 2017-2022 DPP scenario for Cook Inlet was run for both Cook Inlet and the Gulf of Alaska planning area, where Prince William Sound is located. The OECM produced very similar estimates of ecological damages in both planning areas (differing by only 2 percent), suggesting that oil spills tend to have similar impacts on the ecological resources in each planning area.

Though the OECM was not designed to model the impacts of a catastrophic spill, the impacts of a series of smaller spills can be analyzed to identify the relative difference in ecological impacts between Cook Inlet and the Arctic. Specifically, this was achieved by modeling identical E&D scenarios in both Cook Inlet and the Arctic. The identical E&D scenarios are associated with identical spill sizes and frequencies. As a result, any difference in ecological damages produced by modeling the same E&D scenario in both Cook Inlet and the Arctic will reflect the influence of environmental factors specific to each region. For this analysis, we used the E&D scenario associated with the 2017-2022 Draft Proposed Program (DPP) for Cook Inlet to model ecological impacts in both Cook Inlet and the two Arctic planning areas (Chukchi Sea and Beaufort Sea).

The OECM results suggest that ecological impacts in the Beaufort Sea are 35 percent greater than in Cook Inlet, while ecological impacts in the Chukchi Sea are 130 percent greater than in Cook Inlet. The difference in results between the two Arctic planning areas may be driven by a number of factors, including sensitivity of shoreline habitat, presence of biota populations, and the impact of ocean currents on shoreline oiling. To be conservative, we use the 130 percent factor estimated for the Chukchi Sea to scale the per-barrel damage values for Cook Inlet. Applying this factor to the low-end estimate for ecological damages in Cook Inlet (\$1,080 per barrel) yields a low-end value for the Arctic of \$2,500 per barrel. Using this same approach, we estimate a high-end cost value for the Arctic of \$9,700 per barrel.

3.2.5 Summary

Table 27 presents the range of ecological costs estimated to result from a catastrophic oil spill in the Gulf of Mexico, Atlantic, Cook Inlet, and the Arctic. The lowest ecological impacts associated with a catastrophic oil spill are expected in the Gulf of Mexico, while the highest impacts are expected in the Arctic.

Region	Low-End Ecological Cost	High-End Ecological Cost
Gulf of Mexico	\$580/barrel	\$2,200/barrel
Atlantic	\$790/barrel	\$3,000/barrel
Cook Inlet	\$1,080/barrel	\$4,200/barrel
Arctic	\$2 500/barrel	\$9.700/barrel

Table 27. Range of NRDA costs by geographic region (2017\$)

3.3 RECREATIONAL USE

Coastal and marine resources provide recreational services such as beach use, boating, fishing, and wildlife viewing that are valuable to the public and that enhance the welfare of those who consume these services. If these resources are oiled as a result of a CDE (or expected to be oiled), the recreational value that they provide may be diminished, as oiling may impair the use of these resources. The diminished recreational value provided by affected resources may be reflected in reduced use of these resources (e.g., reduction in the number of beach trips) or reductions in individuals' willingness to pay (WTP) to use the affected resource. In the case of a CDE affecting large portions of the coast, these impacts are likely to be particularly substantial because widespread oiling would limit the ability of individuals to engage in coastal recreation at other sites located near their preferred site. For a smaller spill affecting a single beach, the

availability of substitutes in the same area may partially mitigate the recreational impact of the spill. Given the potential scale and duration, a CDE could limit these substitution options.

Estimating the recreational value lost as a result of CDE requires information on (1) the baseline level of activity for the full suite of recreational activities affected, (2) the change in the level of recreational activity, and (3) the per unit (e.g., per user day or per beach trip) value that individuals place on these activities in the baseline and during the impact period. This information would allow one to estimate recreational value in the absence of the CDE and with the CDE. Obtaining this information, however, presents a number of challenges, as described below for each of the items outlined above.

• Specification of baseline recreational resource use: The specification of the baseline would ideally reflect use in the impacted area in the absence of a CDE. However, the timing and location of a CDE, both of which are substantial determinants of a CDE's impact, are highly uncertain. With offshore oil production occurring year-round, a CDE could occur during periods of high use or during periods when use is relatively low. Similarly, a CDE could affect coastal and marine areas frequented by recreators or areas where recreation is more limited.

Aside from uncertainties related to CDE location and timing, gauging baseline use is also complicated by the fact that variables besides the occurrence of a CDE affect the use of recreational resources. In particular, changes in weather affect the use of coastal recreation sites, with higher temperatures and a lack of precipitation typically leading to higher use than cooler temperatures and/or rain. Thus, even if use data are available for an impacted area in the aftermath of a CDE, the prior year's data may not be representative of the actual baseline for that CDE. For example, if a hurricane had struck during the prior year but not during the spill year, use during the prior year would likely be an under-representation of baseline use.

- Estimating the change in coastal recreation activity: Estimating changes in the use of coastal resources attributable to a CDE is complicated by the non-spill factors described in the baseline discussion above. Changes in the use of coastal recreation sites could reflect the impact of a CDE as well as the weather, macroeconomic conditions, gas prices, and other variables. Distinguishing between the influence of a CDE and these other variables may not be possible in all cases. In addition, the spatial resolution of the available use data may not allow one to focus exclusively on use in areas affected by a CDE. For example, some data sources report use by state rather than for individual sites.
- Valuation: The value of the recreational uses of coastal and marine resources is highly variable depending on the attributes of the sites potentially affected by a CDE. Key attributes that affect value include the amenities available at the site (e.g., fish pier), how crowded a site is, the cleanliness of the site, or the prevalence of fish at the site (for recreational fishing sites). Furthermore, because a CDE may affect the attributes of a site, the value that individuals place on the site may change as a result of a CDE. Thus, even if existing literature provides estimates of recreational value under non-CDE conditions, the occurrence of a CDE could affect the value of recreational activity that still takes place after the CDE occurs.

In addition to the challenges outlined above related to the measurement of baseline use, changes in use associated with a CDE, and recreation value, the available data on each of these variables is also fairly limited for most coastal areas. While use data are available from a few sources, many of these sources are either outdated or limited in the scope of activities or geographic areas that they cover. For example, the National Survey on Recreation and the Environment (Leeworthy and Wiley, 2001), includes estimates of the number of user days for beach use, but these data are for the year 2000 and are not disaggregated beyond the state level. Data on the changes in use associated with a CDE are even more limited, as only two catastrophic spills have ever occurred in the U.S. (e.g., the Exxon Valdez spill in 1989 and the Deepwater Horizon spill in 2010). While data associated with these spills may inform the assessment of the recreational impacts associated with a CDE, these events represent just two data points in a wide distribution of recreational impacts that may occur as a result of a CDE. Finally, while the environmental economics literature includes several studies related to the value of different coastal recreational activities, many of these studies are fairly dated or focus on marginal changes on the value of recreation that are not transferrable to assessment of the impacts of a CDE. For example, some studies estimate changes in the value of a recreational fishing day per acre of coastal marsh developed or preserved.

Despite these and other limitations, the available data nevertheless can be used to approximate the potential recreational costs of a CDE for four recreational activities: beach use, recreational fishing, boating (Gulf of Mexico only), and wildlife viewing (Cook Inlet only). We present our estimates of these damages, on a per barrel basis, and our approach for developing these estimates in the sections that follow. While a CDE would likely affect activities other than those examined here, such as scuba diving, the available data for these other activities were insufficient to support development of impact estimates.

3.3.1 Shoreline Recreation and Boating

Our assessment of the potential per-barrel damages related to shoreline recreation (beach use and inland fishing) and boating focuses on impacts in the Gulf of Mexico, the Atlantic, and Cook Inlet. For the Gulf of Mexico region, we present the estimated damages associated with the *Deepwater Horizon* spill as an indicator of potential impacts. We obtained this information from the PDARP and the associated administrative record issued by the *Deepwater Horizon* Oil Spill Natural Resource Trustees (the Trustees). The PDARP provides aggregate results from the Trustees' comprehensive study of the spill's impacts on recreational activites, including swimming, sunbathing, shoreline fishing, inland fishing, and boating. The Trustees' assessment of lost recreational use associated with the *Deepwater Horizon* spill represents one of the most comprehensive and robust economic studies of coastal recreation ever conducted.

Due to the more limited data available for the Atlantic and Cook Inlet, we apply a different approach for these regions. For both regions, we assume that a CDE would occur near the beginning of the peak season for coastal recreation and would affect recreational activity for several months. Based on this information, we develop estimates of baseline use in both areas for an extended period of several months. We then estimate the percent reduction in use based

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¹⁹ Aside from subsistence fishing, which we examine below, we are not aware of any recreational fishing that takes place in the Arctic.

²⁰ See NOAA (2015)

on the observed changes in use for the *Deepwater Horizon* and *Exxon Valdez* spills. Applying these percentage reductions to the estimates of baseline use yields estimates of the lost user days associated with a CDE. We value the reduction in recreational use based on estimates presented in the economic literature. We present the details of this approach below by region.

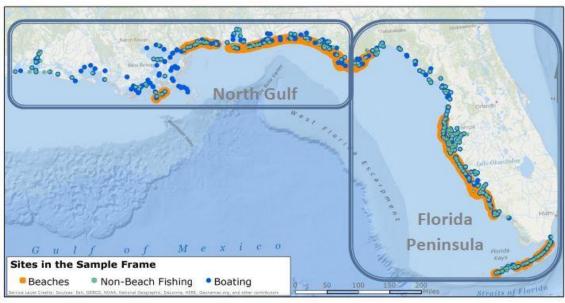
Note that the recreational activity examined in this section includes beach use (inclusive of fishing on sandy beaches), inland fishing, and boating. While much of the environmental economics literature examines beach use and fishing separately, we examine them together here because the most robust and detailed data that we identified combine the two.

Gulf of Mexico (GOM)

As noted above, we rely on the results of the lost recreational use assessment included in the *Deepwater Horizon* (DWH) PDARP and the associated administrative record to approximate the impacts of a CDE on coastal recreation in the Gulf of Mexio region. The DWH assessment examines three categories of recreation: shoreline use, inland fishing, and boating. Shoreline use includes any and all saltwater recreation occurring on sandy beaches, including swimming, sunbathing, and fishing. Inland fishing, as distinct from shoreline fishing, represents fishing at salwater locations not located on sandy beaches. Boating refers to pleasure boating and fishing on motorboats or sailboats.

To estimate changes in recreational use associated with the spill, the Trustees mounted a significant data collection effort that involved a series of onsite recreator surveys and aerial counts of recreators partaking in recreationl activities at coastal sites. The Trustees measured the number of recreators at 743 beach segments throughout the Gulf through overflights (conducted by low-flying airplanes), and onsite interviews and counts (conducted by survey teams on foot). To capture the impacts to recreational anglers at non-beach saltwater access points, the Trustees sampled 323 sites from a list of non-beach saltwater sites provided by NOAA's Marine Recreational Information Program (MRIP). For the boating study, the Trustees conducted counts and interviews to measure the number of recreational boaters entering the Gulf at 103 sites in the North Gulf and 90 sites in the Florida Peninsula. Sites were selected from MRIP's list of 534 saltwater boating access points open to the public. Using these various data, the study team estimated the level of recreational activity during the impact period and after recreational use returned to baseline levels. The difference between the two represents the change in use associated with the spill.

The Trustees estimated the changes in shoreline recreation associated with the *Deepwater Horizon* spill over a large area spanning the North Gulf and the Florida Pensinsula over a period of 19 months. Figure 14 below shows a map of the sites sampled throughout the impact area (including non-beach fishing and boating sites). The duration of spill impacts to recreation varied within the area shown in Figure 14 and by activity. For example, the impact period for shoreline use in the Florida Peninsula was June 2010 through January 2011, while the impact period for shoreline use in the North Gulf (i.e., closer to the blowout site) was May 2010 through November 2011. In addition, within the North Gulf, impacts for shoreline use were longer in duration than impacts for inland fishing. Table 28 outlines the different impact periods by activity and region.



Source: NOAA (2015)

Figure 14. Map of recreation sites sampled in the Deepwater Horizon lost recreational use assessment²¹

Table 28. Duration of losses to shoreline recreation, by region and activity, for the Deepwater Horizon lost recreational use assessment

			2010			2011														
Activity	Region	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Shoreline	North Gulf																			
Use	Peninsula																			
Inland Fishing	North Gulf																			
Boating	North Gulf																			

Source: Adapted from NOAA (2015)

Tables 29 and 30 below, taken from the PDARP, present the recreational use estimates from what the Trustees refer to as Tier 1 of the damage assessment.²² These Tier 1 damages are based on the Trustee's detailed infield data collection effort and cover the period June 2010 through

 $^{^{21}}$ See NOAA (2015). 22 The Trustees' Tier 2 estimates of damages, which rely on less detailed information than the Tier 1 estimates, as summarized below.

November 2011. Consistent with the PDARP's presentation of results, Table 29 presents use estimates for shoreline use and inland fishing combined. As shown in the table, the Trustees' Tier 1 assessment estimated that the *Deepwater Horizon* spill resulted in 12.47 million lost user days for shoreline use and inland fishing. This value represents a 23.3 percent reduction relative to the baseline of 53.4 million user days over the entire 18-month impact period for Tier 1. Note that Table 29 splits the impact period for shoreline use and inland fishing into two separate subperiods. For the first period—June 2010 through January 2011—the estimated reduction in use is 32.5 percent, whereas the estimate for the second period—February 2011 through November 2011—is lower at 10.0 percent.

Table 29. Deepwater Horizon shoreline and inland fishing study lost use estimates – tier 1

Region	Baseline Estimate	Spill Estimate (User Days During Spill)	Loss Estimate (Lost User Days)	Percent Decline				
June 2010 through J	June 2010 through January 2011							
North Gulf	14,207,507	7,782,270	6,425,237	45.2%				
Peninsula	17,471,871	13,601,695	3,870,176	22.2%				
Overall	31,679,378	21,383,965	10,295,413	32.5%				
February 2011 throu	gh November 20	11						
North Gulf	21,754,732	19,580,582	2,174,149	10.0%				
Total (Months 1-18)	53,434,109	40,964,547	12,469,562	23.3%				

Source: NOAA (2015)

Table 30. Deepwater Horizon boating study lost use estimates - tier 1

	Baseline	Boating Days During Spil	Lost Boating	Percent
Region	Boating Days	Impactperiod	Days	Decline
North Gulf	759,605	544,231	215,374	28.4%

Source: NOAA (2015)

To estimate the economic value of recreational losses associated with the *Deepwater Horizon* spill, the Trustees developed two Randomized Utility Maximization (RUM) models for saltwater recreation in the Gulf of Mexico region. One model covers both shoreline use and inland fishing, while the other is specific to boating. These models capture the value of lost trips, as well as the value of substitute trips and diminished-value trips (i.e., trips that still occurred with the spill but were of lesser value because of the spill). The Trustees collected the data necessary to estimate these models from a local survey targeting adults who live in Louisiaina, Mississippi, Alabama, Florida, and selected counteies in Texas and Georgia, and a national survey that targeted adults living in the contiguous U.S., excluding the areas targeted in the local survey.

Using the survey data, the valuation models provide a quantitative description of people's recreation behavior. For example, the shoreline valuation model estimates the number of recreation trips from throughout the contiguous U.S. to different shoreline areas in the Gulf of Mexico region. This behavior, combined with the costs associated with different site choice options, form the basis of the models' valuation of recreation. Calibrating the models to the reduction in use measured through the overflights and infield surveys (see Tables 29 and 30), the Trustees estimated a value per lost user day of \$36.25 for shoreline use and inland fishing and \$16.20 per day for boating, both in year 2015 dollars. In year 2017 dollars, these values are \$37.87 and \$16.93, respectively. When applied to the lost user day estimates presented above in Tables 29 and 30, this translates to losses of more than \$475 million in total, as summarized in Table 31.

Table 31. Summary of Tier 1 recreation impacts associated with the Deepwater Horizon spill

	Lost User Days	Value Of Recreation Impacts (2017\$)
Shoreline	12,325,512	\$466,800,000
North Gulf	8,455,336	\$320,200,000
Peninsula	3,870,176	\$146,600,000
Inland Fishing	144,050	\$5,500,000
Boating	215,374	\$3,600,000
_	Total	\$475,900,000

Note: The value of recreation impacts presented in this table is lower than the estimate of approximately \$523 million in the PDARP for the Deepwater Horizon spill. The difference reflects the compounding of damages from 2010 to 2015 in the PDARP. For the purposes of the present analysis, we do not compound impacts.

Source: Values derived from English and McConnell (2015). Values from this memorandum were converted to year 2017 dollars.

The Tier 1 losses shown in Table 31 reflect the extensive infield data collection undertaken by the Trustees. The coverage of the infield studies, however, does not include all locations, times of day, or months impacted by the spill. For example, the study team's primary infield data collection did not capture use of the beach at night. To address these gaps in coverage, the Trustees performed a series of supplemental analyses using various other data sources. These Tier 2 analyses and the losses estimated by each analysis are summarized in Table 32.

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²³ Please see Appendix B for a summary of additional GOM beach use and fishing valuation estimates.

Table 32. Tier 2 secondary shoreline study damages

	Coverage Gap			Damages		
	Filled	Lost User Days		(\$2017)		
	Lost user days in	Shoreline use:	1,550,137			
	May 2010 not	Inland fishing:	22,708	\$60,100,000		
Early Data	included in Tier 1.	Boating:	72,871	φου, 100,000		
Collection		Total:	1,645,716			
	Shoreline activity					
Supplemental	before regular	1,234	821	\$46,800,000		
Shoreline	sampling hours for	1,254	,021	Ψ40,000,000		
Study	the Tier 1 sutdy.					
	Boating activity for					
	boats launched	22,8	\$400,000			
Backyard	from private	,	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	ψ.00,000		
boating	residences.					
	Fishing occurring					
	outside the daily	152,	517	\$5,800,000		
Night fishing	sampling hours					
For-hire	Fishing from for-	216,	089	\$8,200,000		
fishing	hire fishing boats.	,		4 0,000		
	Underestimate of	N. .	P 11	# 0 000 000		
Fixed costs	value due to fixed	Not app	\$2,600,000			
of boating	costs incurred					
National	Federal lands					
parks and	outside Tier 1	23,2	\$900,000			
other Federal	sample area	,				
lands	\$124,600,000					
	TOTAL					

Source: Adapted from NOAA (2015). Monetized values converted to year 2017 dollars without compounded interest.

Combining the Tier 1 and Tier 2 damages yields 15,669,110 lost user days for shoreline use and inland fishing and 311,140 lost user days for boating. Together, these correspond to damages of approximately \$600 million, as shown below in Table 33. Dividing this estimate by the *Deepwater Horizon* spill size (3.19 million barrels, net of oil recovered by BP), the estimated impacts to GOM beach recreation on a per-barrel basis are approximately \$188.²⁴

Table 33. Summary of recreational impacts associated with the Deepwater Horizon oil spill

	Value Of Recreational Impacts
Tier	(2017\$)
Tier 1 (Primary Analysis)	\$475,900,000
Tier 2 (Supplemental	\$124,600,000
Analyses)	
Total	\$600,500,000

²⁴ See U.S. District Court (2015) for the estimate of the spill volume.

Atlantic

As noted above, the impacts of a CDE on coastal recreation will depend on when and where a CDE occurs. For the purposes of estimating the recreational impacts of a CDE in the Atlantic OCS Region, we assume that a CDE would affect recreation in the states along the Mid-Atlantic OCS Planning Area. Based on BOEM's 2017 – 2022 Draft Program Proposal, more than 80 percent of the undiscovered technically recoverable resources (UTTR) of the Program Area are in the Mid-Atlantic. Thus, the Mid-Atlantic represents the portion of the Atlantic region most at risk to a CDE. As a sensitivity analysis, however, Appendix A examines the recreational impacts of a scenario in which a CDE in the Atlantic affects coastal recreation in the Mid-Atlantic and as far north as New Jersey. The sensitivity analysis also considers another scenario in which a CDE in the Atlantic affects recreation in Georgia and South Carolina, as well as the Mid-Atlantic.

In addition to a CDE's location, its timing and the duration of its impact are also highly uncertain. As a simplifying assumption, this analysis examines the impacts of a hypothetical CDE in the Atlantic with timing and duration of impacts consistent with the *Deepwater Horizon* spill in the Gulf of Mexico. Specifically, we assume that the CDE would occur in the spring and would affect shoreline recreation (beach use and fishing on sandy beaches) and inland fishing as follows:

• Shoreline recreation: We assume that the CDE would affect shoreline recreation from May of the year that the spill occurs through November of the following year. This time horizon is consistent with the duration of shoreline impacts in the North Gulf following the *Deepwater Horizon* spill (see Table 28 above). While it is possible that the duration of impacts may be shorter for areas relatively far from the CDE site (i.e., similar to the Florida peninsula for the *Deepwater Horizon* spill), we assume a 19-month impact period consistent with that for the North Gulf to avoid potential underestimation of impacts.

In specifying shoreline recreation in the baseline, we split the 19-month period into two sub-periods: May to January and February to November. As described in greater detail below, we assume different percent changes in use for these two periods, based on the changes observed following the *Deepwater Horizon* spill.

• *Inland fishing:* We assume that a CDE in the Mid-Atlantic and would affect inland fishing from May of the spill year through March of the following year across the entire area. This time horizon is consistent with the assessment of inland fishing impacts for the *Deepwater Horizon* spill.

Note that our quantitative assessment of potential recreational impacts in the Atlantic does not include boating impacts. While a CDE is likely to affect boating in the Atlantic, the available data on boating in this region are limited. In addition, the results of the *Deepwater Horizon* lost recreational use assessment suggest that boating impacts are small relative to impacts related to beach use and fishing.

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²⁵ See BOEM (2015).

To develop an estimate of baseline beach use for the Mid-Atlantic region, we rely on beach recreation data from the 2000 National Survey of Recreation in the Environment (NSRE). ²⁶ The NSRE is a comprehensive survey of outdoor recreation participation in the United States and was conducted by the U.S. Forest Service and NOAA. The results of the survey include estimates of beach visitor days by state for the year 2000. To estimate the percentage of annual beach visits occurring during the May – January period, we examined the National Park Service's monthly visitation data for 2009–2014 for Assateague Island National Seashore (Maryland), Cape Hatteras National Seashore (North Carolina), and Cape Lookout National Seashore (North Carolina).²⁷ Based on these monthly data, we estimate that 88 percent of annual visitation at National Seashores in the Mid-Atlantic occurs between May and January. Under the assumption that this value applies to all beaches in Delaware, Maryland, North Carolina, and Virginia, we estimate baseline beach visitation during the May through January period of 68.6 million beach days. Using visitation data for the same National Seashores, we estimate that 96 percent of annual visitation on the Atlantic occurs between February and November. Applying this value to the NSRE data, we estimate 74.9 million beach trips to the states included in our study for the February-November period. Taken together, we estimate a total baseline beach visitation of 143.5 million beach days across the two sub-periods. (i.e., May to January and February to November). Table 34 presents our baseline estimates for the Mid-Atlantic. To provide additional perspective on use in the Mid-Atlantic, the table also includes baseline estiamtes for New Jersey, South Carolina, and Georgia.²⁸ The latter two are near the Program Area, but the waters offshore from these states contain less than 20 percent of the UTTR in the Program Area, as noted above.

Table 34. Beach use baseline for the Atlantic

State	Estimated Number of Beach Visits May – January	Estimated Number of Beach Visits February – November	Total Beach Visits May of Spill Year – November of The Following Year
Delaware	11,290,000	12,320,000	23,620,000
Maryland	16,400,000	17,890,000	34,290,000
Virginia	16,440,000	17,940,000	34,380,000
North Carolina	24,500,000	26,730,000	51,230,000
Mid Atlantic Total		74,880,000	143,520,000
BEACH USE IN OTH	HER STATES IN THE AT	TLANTIC	
New Jersey (North Atlantic)	35,850,000	39,120,000	74,970,000
South Carolina (South Atlantic)	29,210,000	31,870,000	61,070,000
Georgia (South Atlantic)	7,440,000	8,120,000	15,560,000

We estimate baseline use for inland fishing for the Atlantic Program Area based on inland angler trip data from NOAA's MRIP. ²⁹ NOAA's MRIP was initiated in 2007 and generates estimates of

²⁸ Baseline data are only presented for periods in which impacts are expected.

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²⁶ See Leeworthy and Wiley (2001).

²⁷ See NPS (2014).

²⁹ See NOAA (2014). Note that we use only the inland angler data from MRIP rather than total angling. We do not use the data for all angling to avoid potential double counting of anglers that are likely to be reflected in

angler's catch and effort; the data are collected in six two-month periods (i.e. waves). Angler trip data for Wave 1 (January and February), Wave 2 (March and April), Wave 3 (May and June), Wave 4 (July and August), Wave 5 (September and October), and Wave 6 (November and December) were downloaded for the Mid – Atlantic states, as well as for New Jersey, South Carolina, and Georgia for the years 2009 - 2014. To limit the angler trip data to the assumed impact period of a CDE (May – March), we divide Wave 2 data data for each year and state by two, assuming that fishing activity is evenly split between the two months in each wave. For every state and wave, we then calculate the average number of angler trips across the six years for which we compiled data. For example, we average the number of angler trips taken during Wave 3 (May and June) in Delaware across the years 2009, 2010, 2011, 2012, 2013, and 2014. We then sum the wave-level averages for each state to determine the average number of trips during the assumed impact period (May – March). Summing across states, we estimate slightly less than 7.13 million baseline angler trips for the Mid-Atlantic region, as shown in Table 35 below.

Table 35. Recreational inland angler trips baseline for the Atlantic: May – March impact period³⁰

04-4-	Estimated Number of Angler Trips
State	May – March
Delaware	650,000
Maryland	2,410,000
Virginia	2,230,000
North Carolina	1,830,000
Mid Atlantic Total	7,130,000
INLAND FISHING IN OTHER	STATES IN THE ATLANTIC
New Jersey (North Atlantic)	2,570,000
South Carolina (South	
Atlantic)	980,000
Georgia (South Atlantic)	620,000

To estimate the change in recreation associated with a CDE in the Atlantic Program Area, we assume that proportional changes in recreational activity estimated in the Gulf of Mexico due to the *Deepwater Horizon* spill would also apply to the Atlantic. Thus, consistent with the data presented above in Table 29 for shoreline use and inland fishing, we assume that a CDE occurring in the spring would lead to a 32.5 percent reduction in shoreline use and inland fishing combined from May through January across the entire mid-Atlantic. For February through November during the year following the CDE, we assume a 10 percent reduction in use. Based on these assumptions and the baseline data presented above in Tables 34 and 35, we estimate that

the NSRE data that we use to estimate beach visitation. Because the beach visitation data in the NSRE includes any activities on the beach, the NSRE documentation (Leeworty and Wiley 2001) cautions against adding beach visitation data to other activities. Because inland fishing by definition does not occur on sandy beaches, anglers involved in inland fishing are unlikely to be reflected in the NSRE data for beach recreation.

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³⁰ Please see Appendix A for additional damage estimates associated with a spill that affects NJ, SC, and GA.

³¹ Ideally, we would derive separate estimates of the percent reduction in use for shoreline use and inland fishing. The PDARP and associated administrative record for the Deepwater Horizon spill, however, do not include baseline estimates for inland fishing alone. Instead, the baseline data include shoreline use and inland fishing together.

a CDE in the Atlantic would result in a total of 29.8 million lost beach days and 2.2 million lost inland fishing trips, as summarized in Table 36.

Table 36. Estimated reduction in recreational activitity in the Atlantic following a CDE

State	Estimated Reduction in Shoreline Visits	Estimated Reduction in Inland Fishing Trips
Delaware	4,900,000	210,000
Maryland	7,120,000	750,000
Virginia	7,140,000	700,000
North Carolina	10,640,000	570,000
TOTAL	29,790,000	2,230,000

We estimate the value of lost recreational use in the Atlantic based on the results of studies from the empirical environmental economics literature. For beach use, we rely on three specific studies from this literature. Parsons (2003) estimates \$25 per lost trip (in 2003 dollars) associated with closing all Delaware beaches to Delaware residents. Based on the results of another study by Parsons (2000), the damage assessment of lost human use for the Buzzards Bay oil spill applies a per beach trip value of \$28.02 in 1997 dollars. Focusing on the value of seven different beaches in North Carolina, Bin (2004) estimates user day values ranging from \$21 to \$72 for these beaches. Averaging across these studies and converting to year 2017 dollars, we estimate a value of \$47.21 per activity day. Applying this value to the estimated reduction in beach visitor days associated with a CDE, we estimate a loss in the value of beach recreation of \$1.4 billion for the Mid-Atlantic region, as shown in Table 37.

To estimate the value of the reduction in inland fishing in the Atlantic, we apply value-per-trip estimates obtained from two valuation studies that focus specifically on this region. McConnell and Strand (1994) estimate a mean WTP for one day fishing trips by wave (e.g., March/April, May/June, etc.) for nine east coast states, with an average of \$81.82 across all states and waves (in 1988 dollars). Whitehead and Haab (2000) estimate a median compensating variation per trip for site access in North Carolina of \$1.08 in 2000 dollars.³⁴ Averaging across studies and converting to year 2017 dollars yields an estimated value of \$78.00 per fishing trip.³⁵ Based on this value and the 2.2 million lost fishing trips estimated above, we estimate approximately \$174 million in inland fishing losses for the Mid-Atlantic region.

Table 37. Summary of recreational damages associated with a CDE in the Atlantic

	Estimated Damages	
Damage Category	(2017\$)	
Shoreline Use	\$1,407,000,000	
Inland Fishing	\$174,000,000	
TOTAL	\$1,580,000,000	

³² This value was derived using a model that was originally developed by Parsons (2000), The model was adapted for use in the Buzzards Bay assessment.

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³³ See Parsons (2003), Bin (2004) and Bouchard B-120 Oil Spill Lost Use Technical Working Group (2009)

³⁴ See McConnell and Strand (1994) and Whitehead and Haab (2000).

³⁵ Note, we keep the separate WTP values in McConnell and Strand separate when calculating the average.

To estimate recreational damages on a per-barrel basis, we divide the estimated shoreline and inland fishing damages by by the spill volume associated with the *Deepwater Horizon* spill (3.19 million barrels) ³⁶, which results in an estimate of \$441 per barrel for shoreline use and \$54 per barrel for inland fishing, both in year 2017 dollars. While the spill volume associated with a CDE in the Atlantic may differ from the volume associated with the *Deepwater Horizon* blowout, we determined that this would be the most appropriate spill volume to use given that our analysis for the Atlantic uses the percentage reduction in shoreline use for the Gulf of Mexico.

Cook Inlet

For Cook Inlet, our assessment of the shoreline recreational impacts of a CDE is limited to recreational fishing, as beach use is likely to be minimal in the area's relatively cool climate. Similar to our approach for assessing recreational fishing impacts in the Gulf of Mexico and the Atlantic, we estimate baseline use, approximate the proportional change in use, and apply estimates from the empirical economics literature to value these changes. The data sources that we apply for Cook Inlet, however, differ significantly from those applied in the Gulf of Mexico and the Atlantic, as detailed below.

To estimate the baseline number of recreational fishing trips in Cook Inlet, we use data on the annual number of saltwater angler days in Cook Inlet from the Alaska Department of Fish and Game's Sport Fishing Survey. ³⁷ The Department's Sport Fish Division has conducted the survey annually by mail since 1977 and uses the data collected to estimate the state's sport fishing harvest by species and the total level of sport fishing activity. Using annual Cook Inlet data from the Survey for 2009-2013, we arrive at an average baseline of 172,600 angler trips.

As an indicator of the potential reduction in recreational fishing in Cook Inlet in response to a CDE, we assume that the reduction observed in southcentral Alaska following the *Exxon Valdez* spill would also apply to recreational fishing in Cook Inlet. Based on the Alaska Department of Fish and Game's annual survey of Alaska anglers, Mills (1992) estimates that the *Exxon Valdez* spill led to a 14.9 percent reduction in fishing trips between 1988 and 1989 in the area affected by the spill. Applying this percent reduction to the Cook Inlet baseline of 172,600 angler trips results in a total of 25,800 angler trips lost due to a CDE.

To place a value on angler days in Cook Inlet, we draw from the values estimated in two studies: Hamel (2000) and Hausman (1995). Hamel (2000) estimates the mean compensating variation per fishing day for Central and Lower Cook Inlet for both Alaskans (\$81.47 in year 1997 dollars) and nonresidents (\$119.79 in year 1997 dollars). Together, the average compensating variation in year 2017 dollars is \$155. In the context of the *Exxon Valdez* spill, Hausman (1995) estimates a 1989 consumer surplus per sport fishing trip of \$148. Inflated to 2017 dollars, this estimate is \$296. Averaging across studies, we arrive at \$226 per fishing trip in year 2017 dollars. Applying this value to the estimated loss of 25,800 angler trips lost from a CDE results in total damages of \$5.8 million. On a per-barrel basis (using the spill size from *Exxon Valdez* of 257,000 barrels), estimated loses are \$22.62 in 2017 dollars. We use the spill volume from the *Exxon Valdez* spill

³⁶ See U.S. District Court (2015).

³⁷ See ADFG (2013).

to calculate damages on a per barrel basis because the percentage reduction in recreational fishing reflected in our damages estimate is based on the impact of the *Valdez* spill.

3.3.2 Wildlife Viewing

In addition to impacting beach use and recreational fishing, a CDE may also affect recreational wildlife viewing in coastal areas. Our assessment of the impacts of a CDE on wildlife viewing focuses on Cook Inlet, as wildlife viewing represents an appreciable portion of coastal recreation in the area. We were unable to identify wildlife viewing data specific to Cook Inlet, but such data are available in aggregate for southcentral Alaska. Because Cook Inlet makes up a substanstial portion of southcentral Alaska and offers an abundance of wildlife viewing opportunities, we apply the data for southcentral Alaska as an indicator of wildlife viewing in Cook Inlet.

To develop an estimate of baseline wildlife viewing, we integrate data from several sources, based on the following three-step approach.

- 1. *Estimate visitation to southcentral Alaska:* As an initial step in estimating the baseline level of wildlife viewing on an annual basis, we estimate the total visitation to southcentral Alaska in the typical year. Based on visitation data for the years 2009 through 2014 from the McDowell Group (2014), we estimate that there are approximately 1,605,000 non-resident trips to Alaska each year on average. An earlier report published by the McDowell Group (2011) also states that 56 percent of visitors to Alaska visit southcentral Alaska. Applying this value to the total number of visitors to the state, we estimate that approximately 899,000 individuals visit southcentral Alaska each year. While much of the wildlife viewing in southcentral Alaska may be in areas other than Cook Inlet, we use these data to develop a conservative (i.e., potentially high end) estimate of the potential impacts of a CDE in Cook Inlet.
- 2. Estimate number of visitors to southcentral Alaska engaged in wildlife viewing: The McDowell Group (2011) also indicates that 52 percent of visitors to Alaska engage in wildlife viewing. Based on this value and the estimated 899,000 visitors to southcentral Alaska on an annual basis, we estimate that approximately 467,400 visitors to southcentral Alaska engage in wildlife viewing on an annual basis.
- 3. Estimate wildlife viewing days: To translate the number of wildlife viewing visitors to the number of wildlife viewing days in southcentral Alaska, we derive a multiplier using valuation data from the U.S. Fish and Wildlife Service (2009). While the FWS study focuses on valuation rather than visitation, the values estimated by FWS for nonresident wildlife viewing in Alaska include the mean economic value per year per visitor and the value per day per visitor. Assuming that each visitor takes one trip to Alaska per year, dividing the former by the latter yields an estimate of the average number of wildlife viewing days per trip. Following this approach, we estimate six days per wildlife viewing trip. Applying this value to the number of visitors presented above (467,400), we estimate an average of 2,764,000 wildlife viewing days in southcentral Alaska. We note

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³⁸ See McDowell Group (2011).

the possibility that the estimate of six days per trip could be an overestimate if the economic value per year from FWS reflects activities other than wildlife viewing. Nevertheless, in the interest of developing a conservative (i.e., potentially high end) estimate, we applied the FWS data assuming that the data reflect wildlife viewing only.

Consistent with BOEM's 2012 analysis of catastrophic spill impacts, we assume a high-impact spill scenario in which a CDE occurs in the summer and last for 80 days, which represents 53 percent of the summer season. Based on this value and assuming that wildlife viewing is uniformly distributed over the summer season, we estimate that 1.5 million wildlife viewing days will be affected by a CDE in the Cook Inlet Area. To estimate the economic value of these losses, we assume that half of the value of a wildlife viewing day will be lost for affected trips. Applying this assumption to the FWS (2009) estimate of the mean per-day value of wildlife viewing in Alaska for non-residents (\$129 adjusted to year 2017 dollars), we estimate a loss of approximately \$65 per affected viewing day. Thus, we estimate wildlife viewing losses in Cook Inlet of approximately \$94.6 million. Because the assumptions specified in this section may apply to CDEs of varying sizes, we do not express these damages on a per barrel basis.

3.4 COMMERCIAL FISHING

The occurrence of a CDE could have wide-ranging impacts on commercial fisheries in the affected region. Most directly related to the supply of commercially harvested species, exposure to discharged oil may result in several adverse effects to these species, such as premature hatching, reduced growth rates, genetic abnormalities, and mortality, each of which would contribute to reduced landings (Sumaila et al., 2012). In addition to these direct effects, indirect exposure to discharged oil through the food web may adversely affect the condition and/or abundance of harvested species. Even if vessel operators are able to maintain landings at historical levels in the face of these direct and indirect effects, the cost of achieving these landings may increase, putting upward pressure on seafood prices. With respect to demand, consumers may reduce their consumption of seafood in response to a spill to avoid real or perceived risks associated with consuming contaminated seafood. In effect, consumers' WTP for seafood (i.e., the value that they derive from seafood) may fall, at least temporarily, as a result of a spill.

Accurately estimating the welfare losses associated with the commercial fishery impacts of a CDE would require detailed information on affected fisheries, both before the spill and in its aftermath. In particular, such an analysis would require information on changes in landings, production costs, consumption, and pricing. Gauging the changes in these variables, however, is fraught with uncertainty. Depending on the timing and location of a CDE, changes in landings could vary. For example, a spill that occurs in close proximity to a fishery immediately before the start of the fishing season would likely lead to higher impacts to landings than spills farther away from fisheries at the end of the season. The extent to which vessel operators are able to make operational changes to minimize the impact of a spill is also likely to vary. Fishermen harvesting mobile species that limit their exposure to discharged oil might be able to fish in areas not impacted by the spill and achieve the same or similar landings as they would absent the spill, whereas such a change may not be possible in fisheries for oysters and other less mobile species.

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³⁹ See BOEM (2012).

⁴⁰ See BOEM (2012).

Other examples of potential mitigating behaviors, the success of which would vary depending on the circumstances, include switching to other species or fishing earlier or later in the season.

The reaction of seafood consumers to a CDE is also highly uncertain. While the literature includes demand functions for several harvested species⁴¹, the occurrence of a CDE could fundamentally change these functions in uncertain ways for an unspecified period of time. Factors affecting these changes may include the size of the area oiled, the species potentially affected by oiling, and consumer attitudes regarding the potential risks of consuming contaminated seafood. Because of the limited number of CDEs to have occurred historically, the nature of the changes in demand due to these and other factors is unknown.

3.4.1 Commercial Fishing Approach

Due to the uncertain magnitude of the changes in seafood prices, production costs, and demand functions that would result from a CDE, we present estimated changes in revenues—rather than changes in producer and consumer surplus—as the metric of impacts for the commercial fishing sector. For each region—the Gulf of Mexico, the Atlantic, and Cook Inlet—we compiled recent landings data to serve as the baseline.⁴² We then estimated the reduction in landings for each region based on a series of region-specific assumptions, as described in greater detail below.

Gulf of Mexico

To estimate the reduction in commercial fishery revenues associated with a CDE in the Gulf of Mexico, we draw from the observed changes in commercial fisheries in response to the *Deepwater Horizon* spill. Based on historical landings data published by NOAA's National Marine Fisheries Service (NMFS)⁴³, we estimate that the total volume of landings in 2010 in the Gulf was approximately 22 percent lower than the average of the three previous years (2007 through 2009). Using a slightly different baseline of 2008-2009 and 2011-2013, the estimated reduction in the volume of landings increases to 25 percent, as summarized in Table 38. When measured in terms of revenues rather than volume, the landings impacts of the *Deepwater Horizon* spill are lower than the estimated changes in volume. As shown in Table 39, we estimate that landings revenues declined by 8 to 16 percent as a result of the spill, depending on the years used as the baseline. This lower impact may reflect an increase in prices associated with the spill-related reduction in harvests.

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⁴¹ For example, see Blomo et al., 1982 and Houston et al., 1989 for demand of Gulf of Mexico shrimp and Park et al., 2004 for demand of snapper/grouper.

⁴²Commercial fishing is currently banned in the Arctic.

⁴³ See NOAA/NMFS (undated).

Table 38. Estimated change in Gulf of Mexico landings volume following the Deepwater Horizon oil spill

Species	Change in Volume of Landings in 2010 Relative to 2007- 2009	Change in Volume of Landings in 2010 Relative to 2008-2009 And 2011-2013
	102,100 metric tons	135,900 metric tons
Mehhaden	(-23%)	(-28%)
	19,300 metric tons	17,200 metric tons
Shrimp	(-19%)	(-17%)
	2,800 metric tons	2,100 metric tons
Eastern Oysters	(-28%)	(-23%)
	6,800 metric tons	5,100 metric tons
Blue Crab	(-27%)	(-22%)
	5,500 metric tons	6,000 metric tons
Other	(-13%)	(-14%)
TOTAL	136,500 metric tons (-22%)	166,200 metric tons (-25%)

Note: Values in first line of each cell represent the change in landings measured in metric tons. The value in parentheses represents the percent change in landings.

Source: Data based on landings data reported by NOAA/NMFS.

Table 39. Estimated change in Gulf of Mexico landings revenue following the Deepwater Horizon oil spill

	Change in Landings Revenue in 2010 Relative to 2007-	Change in Landings Revenue in 2010 Relative to
Species	2009	2008-2009 and 2011-2013
	\$14,000,000	\$25,300,000
Mehhaden	(-19%)	(-30%)
	\$27,600,000	\$68,000,000
Shrimp	(-7%)	(-15%)
	\$16,600,000	\$14,900,000
Eastern Oysters	(-21%)	(-19%)
	\$4,200,000	\$7,100,000
Blue Crab	(-8%)	(-13%)
	\$2,500,000	\$16,200,000
Other	(-2%)	(-9%)
	\$64,900,000	\$131,600,000
TOTAL	(-8%)	(-16%)

Note: Values in first line of each cell represent the change in landings revenue measured in year 2017 dollars. The value in parentheses represents the percent change in landings revenue.

For the purposes of estimating the impacts associated with a future CDE, we assume a 16 percent reduction in landings revenue, consistent with the higher of the two values shown in Table 39. We use the estimated percentage change in landings *revenue* rather than the percent change in landings volume because the change in landings revenue is our metric of impacts in the absence of information that would allow us to estimate changes in producer and consumer surplus. Applying the 16 percent value to the average of landings revenues for 2011 through 2013, the

thee most recent years for which data are available, we estimate commercial fishery damages of \$131 million (year 2017\$). Based on the estimated 3.19 million barrels of oil spilled and not recovered as a result of the *Deepwater Horizon* blowout, this value translates to \$40.92 in commercial fishing damages per barrel spilled.

Atlantic

To estimate the commercial fishing impacts of a CDE in the Atlantic, we rely on the impacts estimated for the Gulf of Mexico following the *Deepwater Horizon* blowout and spill. More specifically, we assume that the proportional change in landings revenues estimated for the Gulf of Mexico in the aftermath of the *Deepwater Horizon* spill (16 percent) also applies to the commercial fishing impacts of a CDE occurring in the Atlantic. We apply this proportional change in landings revenues to fisheries in the states neighboring the Mid-Atlantic OCS planning area, consistent with our approach for recreational impacts. If a CDE were to occur in the Atlantic, it is unlikely that it would affect all fisheries in the Atlantic. As noted above, BOEM's 2017 – 2022 Draft Program Proposal indicates that approximately 80 percent of the UTTR of the Atlantic Program Area are in the Mid-Atlantic. ⁴⁴ Based on this information, we focused on fisheries in the Mid-Atlantic.

Table 40 presents the landings revenues reported by NMFS for the four states that neighbor the Mid-Atlantic Planning Area (North Carolina, Virginia, Maryland, and Delaware) and our estimates of the change in landings associated with a CDE. As indicated in the table, baseline landings are approximately \$368.4 million per year. Note that many of the species shown in the table are typically caught in embayments or other areas close to shore, far removed from potential well sites on the OCS. However, because a catastrophic spill could occur from a tanker transporting oil to shore, including these nearshore fisheries in the assessment is appropriate. As indicated in the table, based on the available data, we estimate that a CDE would lead to a \$57.6 million reduction in landings. Based on this value and the 3.19 million barrels of unrecovered oil discharged during the *Deepwater Horizon* spill, we estimate that a CDE in the Atlantic would lead to commercial fisheries damages of \$18.06 per barrel.

As additional perspective on the baseline landings data shown in Table 40 for the Mid-Atlantic, we note that NMFS estimates annual landings of approximately \$237 million for New Jersey, South Carolina, and Georgia combined—three states that could potentially be affected by a CDE in the Atlatnic Program Area. Approximately 83 percent of these landings represent commercial fishing activity in New Jersey.

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⁴⁴ See BOEM (2015).

Table 40. Commercial fishery landings revenue in the mid-Atlantic (2017\$)

Species	Average Annual Landings Revenue: 2011-2013 ¹	Estimated Change in Landings Revenue Due to a Catastrophic Spill
Blue Crab	\$121,100,000	\$18,900,000
Scallops	\$61,200,000	\$9,600,000
Menhaden	\$33,700,000	\$5,300,000
Eastern Oyster	\$26,000,000	\$4,100,000
Striped Bass	\$15,000,000	\$2,300,000
Flounder	\$17,000,000	\$2,700,000
Other	\$94,500,000	\$14,800,000
TOTAL	\$368,400,000	\$57,600,000

Notes:

1. 2011-2013 landings revenue from the NMFS.

Cook Inlet

Our approach for estimating the commercial fishing impacts of a CDE in Cook Inlet reflects the unique geographic features of Cook Inlet relative to the Gulf of Mexico and the Atlantic. More specifically, because Cook Inlet is small relative to the Gulf of Mexico and Atlantic and has limited access to open water, we assume that a catastrophic spill in Cook Inlet would affect all fisheries in the area and that a full year's landings would be lost. Table 41 presents the average annual ex-vessel revenues over the 2012-2014 period (the three most recent years for which data are available). Based on the data in the table, we estimate that a catastrophic spill in Cook Inlet would result in \$43.5 million in commercial fisheries damage. Because these impacts could be realized across a wide range of spill volumes, we do not generate a per barrel estimate of damages.

Table 41. Average annual Cook Inlet commercial fishery landings (2017\$)

Species	Average Annual Ex Vessel Value: 2012-2014 ¹
Chinook	\$338,000
Sockeye	\$40,271,000
Coho	\$752,000
Pink	\$1,264,000
Chum	\$904,000
TOTAL	\$43,528,000

Source: ADFG (2014).

3.5 SUBSISTENCE

Many coastal communities throughout the United States rely on coastal and marine natural resources for subsistence. In particular, Native Alaskan communities in Cook Inlet and the Arctic depend on resources such as Bowhead whales and other marine species to meet their basic needs. Oil released during a CDE may contaminate large portions of the Alaskan coastal and marine environment, making it impossible for communities to subsist on the resources that are normally available. These communities would be particularly impacted if a CDE were to occur during the peak season for subsistence harvest.

To estimate the impacts of a CDE on subsistence, we would ideally use data on baseline subsistence harvests, estimates of the change in subsistence associated with a CDE, and the economic value of lost subsistence. Information on all three of these variables, however, is quite limited. With respect to baseline subsistence activity, the Alaska Department of Fish and Game's Division of Subsistence maintains subsistence data in *The Community Subsistence* Harvest Information System (CSIS). 45 However, these data vary considerably between communities in terms of the years and species covered. Information on the change in subsistence associated with a CDE is even more limited, with a sample of only two catastrophic spills to draw from. Even if better data on changes in subsistence were available, estimating the value of these changes is complicated by the cultural value of subsistence harvests to many communities.

Based on the limited data available, we estimate the potential subsistence impacts of a CDE for Cook Inlet and the Arctic, as presented below. While a CDE in the Gulf of Mexico or the Atlantic may affect subsistence in these areas as well, insufficient data are readily available to support analysis of these impacts.

3.5.1 Cook Inlet

A CDE in the Cook Inlet area, like the Exxon Valdez spill, could have major impacts on local residents who engage in subsistence fishing and hunting. According to a 2012 report on subsistence in Alaska, the annual wild food harvest for rural areas in Alaska is 295 pounds per capita. 46 We use this as our baseline for the annual subsistence harvest for communities along Cook Inlet that would be affected by a CDE in the area.

To estimate the reduction in subsistence associated with a CDE in Cook Inlet, we draw from the estimated subsistence impacts of the Exxon Valdez spill on communities in Southcentral Alaska. A study published by the Minerals Management Service and the Alaska Department of Fish and Game on the long-term consequences of the *Valdez* spill estimates that the spill led to approximately a 50 percent reduction in per capita subsistence in the year of the spill and a 25 percent reduction the following year. ⁴⁷ Applying these values to our baseline estimate of 295 pounds per capita yields a loss of 148 pounds per capita in the year of a spill and a loss of 74 pounds per capita the following year.

To determine the total Native Alaskan population potentially affected by a CDE in Cook Inlet, we use 2010 Census Demographic Profiles of Alaskan communities and calculate that 4,100 Native Alaskans live in the communities that were affected by Exxon Valdez as of 2010. 48,49 Based on this value and the estimated subsistence losses per capita outlined above, we estimate a 907,000-pound reduction in subsistence as a result of a CDE in Cook Inlet.

As described above, placing a value on subsistence harvests is made difficult by the important cultural value of subsistence among many Native Alaskan communities. As an indicator of value, we rely on the value applied in the OECM, which represents a per kilogram replacement

⁴⁵ See ADFG, Division of Subsistence (2015).

⁴⁶ See ADFG, Division of Subsistence (2014).

⁴⁷ See Tables VII-1 and VII-2 in MMS (2001).
⁴⁸ See Tables V-5 in MMS (2001) for a list of the affected communities.

⁴⁹ See ADLWD (2010),

cost of subsistence harvest.⁵⁰ Originally developed by Sharpe (2001), this value was developed in the context of valuing the total replacement costs of subsistence harvests, including the cultural dimension of subsistence, to local communities if a spill were to occur. Adjusted for inflation, this value is \$120 per kilogram (or approximately \$55 per pound) in year 2017 dollars. Applying this value to the 907,000-pound reduction in subsistence, we estimate that a CDE in Cook Inlet would result in subsistence losses of approximately \$49.5 million. Table 42 presents the derivation of this estimate based on the steps outlined above.

To estimate subsistence damages per barrel of oil spilled, we divide total damages by the spill volume associated with the *Exxon Valdez* spill (257,000 barrels). This yields an estimate of approximately \$192.53 per barrel. Because the change in subsistence per capita applied in this analysis is based on the impacts of *Valdez*, the *Valdez* spill volume is the most appropriate for deriving a per barrel estimate.

Table 42. Estimated Cook Inlet subsistence losses

	Year of Spill	Year After Spill	Total
Baseline Subsistence Harvest Per Capita (lbs)	295	295	n/a
Subsistence Loss (%)	-50%	-25%	n/a
Per capita subsistence loss (lbs)	-148	-74	221
Estimated Pounds lost, (Based on 4,100 Native Alaskans in Southeast Alaska)	-604,750	-302,375	-907,125
Value at \$120/kg or \$55/lb (\$2017)	\$49,479,545		
Per-Barrel Losses, based on (\$2	\$192.53		

3.5.2 Arctic

Given their remote location, communities near the Chukchi Sea and Beaufort Sea in the Arctic rely greatly on subsistence use to meet their basic needs. To calculate the baseline subsistence harvests in the Arctic, we use data found in the *Final Environmental Impact Statement for Issuing Annual Quotas to the Alaska Eskimo Whaling Commission for a Subsistence Hunt on Bowhead Whales for the Years 2013 through 2018* from NOAA's NMFS. To determine the reduced subsistence harvest, we assume that the fall bowhead whale hunt and marine mammal harvest are lost in the year of a catastrophic spill and that both the spring and fall harvests are lost the following year. These assumptions are consistent with those in BOEM (2012).

Table 43 summarizes our calculations for the estimated value of Native Alaskan lost subsistence harvests for a CDE in the Arctic. At \$120/kg, the total value of Arctic lost subsistence harvest due to a CDE is estimated at approximately \$209 million (year 2017\$). Because these damages may occur for a range of potential catastrophic spill sizes, we do not present these damages on a per barrel basis.

⁵⁰ See Industrial Economics (2012).

⁵¹ See NOAA NMFS (2013). Beaufort communities are Kaktoviki and Nuiqsut; Chukchi communities are Barrow, Kivalina, Point Hope, and Wainwright.

Table 43. Estimated Arctic subsistence losses

	Average Whales ⁵² [A]	Estimated KG Harvested ⁵³ [B=A × 11,472]	Value of Annual Bowhead Harvest [C=B × \$120]	Ratio Marine Mammals Harvest (kilos) ⁵⁴	Estimated Marine Mammals Harvest (kilos) [E=B×D]	Estimated Value of Other Marine Mammals [F=E × \$120]	Estimated Value of Fall BW & Annual Marine Mammal Harvest for Year of Spill [G]	Estimated Value of All Bowhead Whale & Marine Mammal Harvest for Year Following Spill (\$120/KG) [H]
Fall Beaufort		-						
Harvest	4.1	47,399	\$5,687,912				\$5,687,912	\$5,687,912
Spring Beaufort Harvest	0	0	\$0					\$0
Beaufort Marine								
Mammals				0.080	3,788	\$454,533	\$454,533	\$454,533
Total Beaufort	4.1	47,399	\$5,687,912		3,788	\$454,533	\$6,142,445	\$6,142,445
					Total Es	stimated Beaut	ort Subsistence Losses	\$12,284,890
Fall Chukchi Harvest	7.5	85,741	\$10,288,962				\$10,288,962	\$10,288,962
Spring Chukchi Harvest	14.2	162,727	\$19,527,290					\$19,527,290
Chukchi Marine Mammals				2.63	652,975	\$78,357,022	\$78,357,022	\$78,357,022
Total Chukchi	21.7	248,469	\$29,816,252		652,975	\$78,357,022	\$108,173,274	\$108,173,274
Total Estimated Chukchi Subsistence Losses					\$196,819,258			

⁵² Calculated based on 38 years of historical harvest data in Figure 3.5.2-3 in NOAA/NMFS (2013). We sum the cumulative totals by spring and fall for Chukchi communities and Beaufort communities and divide the sums by 38 to obtain the seasonal average number of bowhead whales harvested.

53 The average whale weighs 25,339 pounds, or 11,472 kilograms. See Table 3.5-2 in NOAA/NMFS (2013).

54 Calculated from comparing whale and marine mammal harvests in the Beaufort and Chukchi communities, see Table 3.5-3 in NOAA/NMFS (2013).

3.6 **FATAL AND NONFATAL INJURIES**

CDEs may unfortunately cause serious injuries or fatalities to individuals located near the well. To estimate the costs associated with the loss of life and nonfatal injuries associated with a CDE, we draw upon the historical experience of the two well blowout events in the U.S. that led to fatalities. The first, which occurred in 1984, caused four fatalities and three non-fatal injuries. The second, the *Deepwater Horizon* blowout in 2010, resulted in 11 fatalities and 17 non-fatal injuries.⁵⁵ For the purposes of estimating the impacts of a potential CDE in the future, we average the fatalities and non-fatal injuries across these two events. This results in an average of eight fatalities and ten non-fatal injuries per incident.

We estimate the economic value of fatalities based on the value of a statistical life (VSL). Drawing from the U.S. EPA's meta-analysis of the VSL literature, we estimate that the VSL in year 2017 dollars and at year 2017 income levels is approximately \$9.5 million. 56 The adjustment for income reflects a VSL elasticity with respect to income (i.e., the percent change in VSL due to one percent change in income) of 0.4, consistent with the value from Kleckner and Neumann (1999) used in EPA regulatory impact analyses. Based on the estimated value of eight deaths per incident and the VSL of \$9.5 million, the total cost of fatalities due to a CDE is estimated to be \$75.8 million (in year 2017\$).

Viscusi (2005) estimates that workers place a value on non-fatal injuries that ranges from \$20,000 to \$70,000 per expected job injury.⁵⁷ Using the midpoint of this range (\$45,000), and inflating it to year 2017 dollars, we estimate a value of \$57,100 per injury. Applying this value to the assumed ten injuries per incident, we estimate costs of approximately \$571,000 associated with non-fatal injuries resulting from a CDE. Summing this with the \$75.8 million associated with CDE-related fatalities, we estimate \$76.4 million in damages associated with fatalities and non-fatal injuries. Because a blowout resulting in these impacts would result in spills ranging substantially with respect to the volume of oil spilled, we do not estimate the value of fatal and non-fatal injuries on a per-barrel basis.

3.7 **VALUE OF SPILLED OIL NOT RECOVERED**

Another cost associated with a CDE is the value of spilled oil not recovered. Recognizing that the dollar per barrel value of oil is highly unpredictable and will vary over time and that the timing of a CDE is highly uncertain, we estimate the value of spilled oil using the oil prices associated with BOEM's Low, Mid-, and High Oil Price E&D scenarios. These values are \$40, \$100, and \$160 per barrel, respectively.

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 ⁵⁵ See BOEMRE (2010).
 ⁵⁶ See U.S. EPA (2014).

⁵⁷ See Viscusi (2005).

3.8 IMPACTS OF DISPERSANTS AND IN-SITU BURNS

While dispersants and in-situ burns can be effective oil spill response strategies, they also have potential environmental costs. In-situ burns produce large amounts of smoke, which contains particulate matter and air pollutants such as sulfur dioxide, nitrogen dioxide, and carbon monoxide. These pollutants have the potential to negatively impact the health of response workers and residents of nearby coastal areas. PM—from direct PM emissions or from precursor emissions that transform into PM—presents the greatest concern, as studies have demonstrated that concentrations of particulate matter within the smoke plume can remain above background levels several miles downwind of the burn site. In-situ burns also have the potential to damage vegetation in coastal areas, and leave behind an oil residue that can sink and smother benthic resources under certain conditions (Barnea, 1995).

Dispersants can reduce oil exposure for surface dwelling organisms, and prevent oil from reaching the shoreline habitat. However, these benefits come with the tradeoff of distributing oil throughout the water column and into the benthic environment. Even in a diluted form, exposure to dispersed oil can cause injury to fish, oysters, coral reefs, and other subsurface ecological resources. As a result, the net ecological impact of dispersant usage is necessarily dependent on the relative vulnerability of surface and subsurface habitats in a given location (NRC, 2005). The ecological impacts of the chemical dispersants themselves are not as large of a concern, as the dispersants in use today are generally less toxic than the dispersed oil. Research on dispersant use during the *Deepwater Horizon* spill confirmed this lower toxicity, finding that dispersant-oil mixtures were generally no more harmful to aquatic species than oil alone (EPA, 2010).

3.9 UNCERTAINTIES

Due to the various assumptions and limitations of the available data described in the previous sections, the CDE damage estimates presented throughout this chapter exhibit substantial uncertainty. Table 44 documents the most significant of these uncertainties and describes their potential impact on our estimates of CDE-related damages.

Table 44. Uncertainties, limitations, and assumptions of analysis

Impact Category	Uncertainties, Limitations, and Assumptions	Implications for Impact Estimates
	We assume that the response costs for the Deepwater Horizon spill are representative of response costs for CDEs occurring in the Gulf of Mexico.	Assumption could lead to overestimation or underestimation of impacts, depending on the timing and location of a CDE and conditions when the CDE occurs (e.g., currents and wind direction).
	We assume that response costs in the Atlantic are the same as those in the Gulf of Mexico.	Because wetlands are less prevalent on the Atlantic shoreline, we may overestimate response costs for the Atlantic.
Response Costs	We assume that the response costs for the Exxon Valdez spill are representative of response costs for CDEs occurring in Cook Inlet.	 Assumption could lead to overestimation or underestimation of impacts, depending on how the timing, size, and duration of a CDE in Cook Inlet differ from the experience of the Exxon Valdez spill in Prince William Sound.
	We assume that a CDE in the Atlantic Program Area would affect shoreline in the states whose waters are adjacent to the Mid-Atlantic OCS Planning Area.	Assumption could lead to overestimation of impacts, depending on the location of a CDE and conditions when the CDE occurs. If oil from a CDE flows to the North Atlantic or South Atlantic, response costs may be lower due to the higher proportion of beaches and lower proportion of wetlands in these regions.
	We assume that response costs for a CDE in the Arctic will be greater than or equal to the response costs for the <i>Deepwater Horizon</i> spill (\$5,100/barrel) and less than or equal to the response costs for the <i>Exxon Valdez</i> spill (\$16,000/barrel).	Assumption could lead to overestimation or underestimation of impacts, depending on the location of a CDE and conditions when the CDE occurs
Ecological Damages	We assume that the ecological damages for the Deepwater Horizon spill are representative of ecological damages for CDEs occurring in the Gulf of Mexico.	Assumption could lead to overestimation or underestimation of impacts, depending on the timing and location of a CDE and conditions when the CDE occurs (e.g., currents and wind direction).

Impact Category	Uncertainties, Limitations, and Assumptions	Implications for Impact Estimates
	We assume that average NRDA values for non-catastrophic oil spills will be representative of low-end ecological damages for a CDE.	 Assumption could lead to overestimation of impacts if a CDE matches the trend seen in the historical spill record suggesting that ecological damages per barrel generally decrease as spill size increases. Assumption could lead to underestimation of impacts if a CDE results in ecological damages similar in magnitude to the two previous catastrophic spills in U.S. waters (Exxon Valdez and Deepwater Horizon), which produced significantly higher ecological damages per barrel than historical non-catastrophic spills.
	We assume that high-end ecological damages from a CDE in the Mid-Atlantic will be 35 percent higher than the ecological damages for the <i>Deepwater Horizon</i> oil spill, based on higher average NRDA values for non-catastrophic oil spills in the Atlantic versus the Gulf.	Assumption could lead to overestimation or underestimation of impacts, depending on whether the factors determining ecological damages from non- catastrophic spills are the same factors that would determine ecological damages from a CDE.
	We assume that the ecological damages for the Exxon Valdez spill are representative of ecological damages for a CDE occurring in Cook Inlet.	Assumption could lead to overestimation or underestimation of impacts, depending on how the timing, size, and duration of impacts for a CDE in Cook Inlet differ from the experience of the Exxon Valdez spill in Prince William Sound.
	We assume that ecological damages resulting from a CDE in the Arctic will be 130 percent higher than the ecological damages resulting from the Exxon Valdez oil spill, based on results generated by the OECM for Cook Inlet and the Chukchi Sea planning area.	Assumption could lead to overestimation or underestimation of impacts, depending on how the timing, size, and duration of impacts for a CDE in the Arctic differ from the experience of the Exxon Valdez spill in Prince William Sound.
	We assume the Deepwater Horizon spill is representative of a CDE in the Gulf of Mexico region.	 Assumption could lead to overestimation or underestimation of impacts, depending on the timing and location of a CDE.
Recreation	We assume that the timing, size, and duration of impacts for a CDE in the Atlantic is consistent with the observed experience for the Gulf of Mexico following the <i>Deepwater Horizon</i> spill.	Assumption could lead to overestimation or underestimation of impacts, depending on how the timing, size, and duration of impacts for a CDE in the Atlantic differ from the experience of the <i>Deepwater Horizon</i> spill.

Impact Category	Uncertainties, Limitations, and Assumptions	Implications for Impact Estimates
	We assume that a CDE in the Atlantic would affect recreation in the states near the Mid-Atlantic OCS Planning Area.	Assumption could lead to overestimation or underestimation of impacts, depending on the location of a CDE and conditions when the CDE occurs. For example, oil from a CDE could spread up the coast to the North Atlantic, impacting New Jersey. Alternatively, the oil from a CDE on the Atlantic could drift into the open ocean away from the coast.
	Our quantitative assessment of potential recreational impacts in the Atlantic does not include boating impacts.	Likely leads to slight underestimation of impacts. Based on the experience of the <i>Deepwater Horizon</i> spill, however, boating impacts are small relative to beach use and coastal fishing.
	The 2000 NSRE data used to derive baseline beach use in the Atlantic are fairly outdated.	Use of these data could lead to overestimation or underestimation of use, depending on the trajectory of use since 2000.
	We assume that the reduction in recreational fishing observed in south-central Alaska following the Exxon Valdez spill would also apply to recreational fishing in Cook Inlet.	Assumption could lead to overestimation or underestimation of impacts, depending on amount of oiling relative to the <i>Valdez</i> spill and the timing of a CDE relative to the timing of <i>Valdez</i> .
	 For recreational fishing in Cook Inlet, we assume a CDE volume equal to that of the Exxon Valdez spill to calculate damages on a per barrel basis. 	Assumption could lead to overestimation or underestimation of impacts depending on damages per barrel for future CDEs relative to damages per barrel for the <i>Valdez</i> spill.
	In the absence of wildlife viewing data specific to Cook Inlet, we used data for southcentral Alaska as a whole.	Likely leads to overestimation of wildlife viewing impacts since not all wildlife viewing in southcentral Alaska is in Cook Inlet.
	 Consistent with BOEM's 2012 analysis of catastrophic spill impacts, we assume a high-impact spill scenario for wildlife viewing in Cook Inlet in which a CDE occurs in the summer and last for 80 days, which represents 53 percent of the summer season. 	Assumption could lead to overestimation of impacts if a CDE occurs during another time of the year.
	To estimate the economic value of Cook Inlet wildlife viewing losses, we assume that half of the value of a wildlife viewing day will be lost for affected trips.	Assumption could lead to overestimation or underestimation of impacts, depending on the extent to which recreators change their wildlife viewing behavior in response to a CDE.

Impact Category	Uncertainties, Limitations, and Assumptions	Implications for Impact Estimates
Subsistence	 Information on baseline subsistence harvests, estimates of the change in subsistence associated with a CDE, and an economic value of lost subsistence is limited. 	Because these data are so limited, our estimates of subsistence impacts are highly uncertain and may be overestimates or underestimates.
	Economic valuation methods are ill-suited to quantifying the cultural value of subsistence for Native Alaskan communities.	Value of subsistence to Native Alaska communities may be underestimated.
	We assume that the reduction in subsistence observed in south-central Alaska following the Exxon <i>Valdez</i> spill would also apply to subsistence in the Artic.	Assumption could lead to overestimation or underestimation of subsistence impacts depending on the extent to which future CDEs affect the level of subsistence relative to the impacts of the Valdez spill.
	For subsistence in Cook Inlet, we use the spill volume from the Exxon Valdez spill to calculate damages on a per barrel basis.	Assumption could lead to overestimation or underestimation of impacts depending on damages per barrel for future CDE relative to damages per barrel for the <i>Valdez</i> spill.
	 In the Artic, consistent with BOEM (2012), we assume that the fall bowhead whale hunt and marine mammal harvest are lost in the year of a catastrophic spill and that both the spring and fall harvests are lost the following year. 	Assumption could lead to overestimation or underestimation of subsistence impacts depending on the extent to which future CDEs affect subsistence harvests.
Fatal and Nonfatal Injuries	Our estimate of the number of fatalities associated with a CDE is based only on two data points: a blowout in 1984 spill and the <i>Deepwater Horizon</i> blowout in 2010.	Assumption could lead to overestimation or underestimation of the number of fatalities associated with a CDE. The actual number is likely to vary depending on the cause of the spill and the number of people aboard a platform during a CDE.
Value of Oil Spilled	We assume a range of oil price values based on the low and high price assumptions that inform BOEM's low and high E&D scenarios.	Given the wide range of oil prices used, impacts are most likely within the range estimated.

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Appendix A: Damage Estimates For Additional CDE Scenarios In The Atlantic Region

As described in Chapter 3 of this document, our analyses of the recreational and commercial fishing impacts associated with a catastrophic spill in the Atlantic focus on the Mid-Atlantic due to the fact that approximately 80 percent of the undiscovered technically recoverable resources of the Program Area are in the Mid-Atlantic. To assess the possibility that a CDE in the Atlantic Program Area may affect a larger geographic area than the Mid-Atlantic, this appendix presents estimates of recreational and commercial fishing impacts for two alternative CDE scenarios in the Atlantic region. Alternative Scenario 1 represents a CDE that affects shoreline use and commercial fishing from New Jersey through the Mid-Atlantic. Alternative Scenario 2 is a CDE that affects the Mid-Atlantic through South Carolina and Georgia. The overall methods for estimating the recreational and commercial fishing impacts associated with these alternative scenarios are similar to those used in the main body of this document for the assessment of impacts in the Atlantic. Due to the more expansive geographic scope of the alternative scenarios, however, the data inputs that we use for these scenarios differ slightly from the data applied in our primary analysis for the Atlantic.

Specific to recreation, our assumptions regarding the timing of potential recreational impacts in New Jersey, South Carolina, and Georgia are also similar to what we assume for the Mid-Atlantic. More specifically, we assume that impacts to shoreline use would be realized from May of the spill year through November of the following year and that infland fishing impacts would last from May through March. Below we present our analyses for Alternative Scenarios 1 and 2 for shoreline recreation, inland fishing, and commercial fishing, respectively.

SHORELINE RECREATION

Drawing from the same data sources described in Chapter 3 of this document, Table A-1 presents baseline shoreline use for the areas represented under Alternative Scenario 1 and Alternative Scenario 2. As indicated in the table, baseline use between the two scenarios is quite similar but slightly higher under Alternative Scenario 2. To estimate the reduction in shoreline use associated with a CDE under these alternative scenarios, we apply the same proportional reductions in use as assumed in Chapter 3: a 32.5 percent reduction for May of the spill year through January the following year and a 10 precent reduction for February through November of the following year. Based on these assumptions, we estimate a reduction in use of 45.4 million user days under Alternative Scenario 1 and a 45.7 million user day reduction under Alternative Scenario 2.

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Table A-1. Baseline shoreline use for alternative scenarios: may of spill year through November of the following year

State	Alternative Scenario 1	Alternative Scenario 2
New Jersey	74,970,000	-
Delaware	23,620,000	23,620,000
Maryland	34,290,000	34,290,000
Virginia	34,380,000	34,380,000
North Carolina	51,230,000	51,230,000
South Carolina	-	61,070,000
Georgia	-	15,560,000
TOTAL	218,500,000	220,100,000

As described above, we estimate the value of lost beach days in the Mid-Atlantic based on the results of three studies from the empirical environmental economics literature. Parsons (2003) estimates \$25 per lost trip (in 2003 dollars) associated with closing all Delaware beaches to Delaware residents; Parsons (2000) applies a per beach trip value of \$28.02 in 1997 dollars based on the Buzzards Bay spill assessment; and Bin (2004) estimates user day values ranging from \$21 to \$72 for seven North Carolina beaches. In addition, specific to the addition of New Jersey for Alternative Scenario 1, Leeworthy and Wiley (1991) estimate \$31.45 in consumer surplus per activity day at beaches in New Jersey. Combining this with the three other studies used for the Mid-Atlantic, we estimate a value of \$49.72 per user day for Alternative Scenario 1. For Alternative Scenario 2, we apply the same user day value as presented in the main body of this document for the Mid-Atlantic (\$47.21 per user day).

Applying the user day valuation estimates for the two Alternative Scenario areas to the reductions in use described above, we estimate recreational damges of \$2.3 billion for Alternative Scenario 1 and \$2.2 billion for Alternative Scenario 2. Table A-2 summarizes these damages and also presents the associated estimates of damages per barrel spilled. The latter are based upon the spill volume associated with the *Deepwater Horizon* spill.

⁵⁹ See Parsons (2003), Bin (2004) and Bouchard B-120 Oil Spill Lost Use Technical Working Group (2009)

⁶⁰ The Parsons (200) value was derived using a model that was originally developed by Parsons (2000), The model was adapted for use in the Buzzards Bay assessment.

Table A-2. Shoreline use damages summary for alternative scenarios

Scenario	Number of Lost Visits	Value Per Trip (\$2017)	Total Damages	Per-Barrel Impact (\$2017)
Alternative Scenario 1: Mid- Atlantic and New Jersey	45,360,000	\$49.72	\$2.3 billion	\$707
Alternative Scenario 2: Mid- Atlantic, South Carolina, and Georgia	45,700,000	\$47.21	\$2.2 billion	\$676

INLAND FISHING

To determine the baseline number of recreational inland fishing trips in New Jersey, South Carolina, and Georgia, we rely on inland angler trip data from NOAA's MRIP.⁶¹ Using the same procedures as outlined in Chapter 3 of this document for the Mid-Atlantic states, we estimate the baseline values shown in Table A-3. To estimate the reduction in inland fishing activity for each of the Alternative Scenarios, we assume a 32.5 percent reduction in use for May of the spill year through January of the following year and a 10 percent reduction in February and March of the following year, consistent with reductions applied in the main body of this document for the Mid-Atlantic. Applying these values to the baseline angler trips for each Alternative Scenario, we estimate approximately 3.0 million lost angler trips under Alternative Scenario 1 and 2.7 million lost angler trips under Alternative Scenario 2.

Table A-3. inland fishing baseline for alternative scenarios: May of spill year through March the following year

State		Alternative Scenario 1	Alternative Scenario 2
New Jersey		2,570,000	-
Delaware		650,000	650,000
Maryland		2,410,000	2,410,000
Virginia		2,230,000	2,230,000
North Carolina		1,830,000	1,830,000
South Carolina		-	980,000
Georgia		-	620,000
	TOTAL	9,690,000	8,730,000

To estimate the value of lost fishing trips, we rely upon per-trip estimates from the empirical literature summarized in Chapter 3 plus additional estimates from McConnell and Strand (1994) for New Jersey, South Carolina, and Georgia. Combining the New Jersey value (\$74.78) with the other estimates we identified for the Mid-Atlantic, we estimate a value of \$77.38 per fishing trip for Alternative Scenario 1. Similarly, integrating the South Carolina and Georgia values (\$144.25 and \$87.60, respectively) with the estimates for the Mid-Atlantic yields an estimate of \$90.23 per fishing trip for Alternative Scenario 2.

Based on the per trip fishing values for Alternative Scenarios 1 and 2 and the estimated reductions in inland fishing for each scenario, we estimate inland fishing losses of \$234.7 million

⁶¹ See NOAA (2014)

for Alternative Scenario 1 and \$245.4 million for Alternative Scenario 2. Table A-4 summarizes these damages and also presents damages on a per barrel basis.

Table A-4. Inland fishing damages for alternative scenarios

	Number of	Value Per Trip	Total	Per-Barrel Impact
Scenario	Lost Trips	(\$2017)	Damages	(\$2017)
Alternative Scenario 1:				
Inland fishing impacted				
in the Mid-Atlantic and				
New Jersey	3,000,000	\$77.38	\$234,700,000	\$74
Alternative Scenario 2:				
Inland fishing impacted				
in the Mid-Atlantic,				
South Carolina, and				
Georgia	2,700,000	\$90.23	\$245,400,000	\$77

COMMERCIAL FISHING

The assessment of commercial fishing impacts for Alternative Scenarios 1 and 2 follows the same apppoach as described in the main body of this document for the Mid-Atlantic. We rely on landings revenue from the NMFS for the years 2011 through 2013 to define the baseline. To estimate the change in landings associated with a CDE, we assume that such an event would reduce landings by the same percentage as observed in the Gulf of Mexico following the *Deepwater Horizon* blowout and spill in 2010 (16 percent). Based on this approach, Table A-5 presents our estimates of baseline landings and commercial fishing damages for Alternative Scenarios 1 and 2. As indicated in the table, both landings and damages are highest under Alternative Scenario 1 than Alternative Scenario 2, due in large part to the relatively high landings and impacts in New Jersey. Relative to the estimate presented in Chapter 3 of this document for the mid-Atlantic, Alternative Scenario 1 represents a 53 percent increase in estimated damages and Alternative Scenario 2 represents an 11 percent increase.

Table A-5. Commercial fishing baseline and damages for alternative scenarios (2017\$)

	Alternative	Alternative Scenario 1		Scenario 2
State	Baseline Landings	Estimated Change in Landings	Baseline Landings	Estimated Change in Landings
New Jersey	\$195,700,000	\$30,600,000	-	-
Delaware	\$8,300,000	\$1,300,000	\$8,300,000	\$1,300,000
Maryland	\$87,800,000	\$13,700,000	\$87,800,000	\$13,700,000
Virginia	\$192,000,000	\$30,000,000	\$192,000,000	\$30,000,000
North Carolina	\$80,300,000	\$12,600,000	\$80,300,000	\$12,600,000
South Carolina	-	-	\$24,900,000	\$3,900,000
Georgia	-	-	\$16,100,000	\$2,500,000
Total	\$564,100,000	\$88,200,000	\$409,400,000	\$64,000,000

Note: Baseline landings estimates reflect average landings from 2011 through 2013 from the NMFS.

UNCERTAINTY

An important uncertainty of this assessment of the Alternative Scenarios is that the same reductions in use and landings, in proportional terms, are assumed for New Jersey, South Carolina, and Georgia as off the coast of the Mid-Atlantic states. Thus, Alternative Scenario 1 assumes that the percentage reductions in use and landings are the same along the stretch of coast extending from North Carolina through New Jersey, and Alternative Scenario 2 assumes the same proportionate reduction from South Carolina to Delaware. To the extent that oiling or the threat of oiling declines with distance from the site of a CDE, however, the change in recreational activity and commercial fishing may not be as great for areas far from the CDE site.

APPENDIX B. SUPPLEMENTAL RECREATIONAL USE VALUES FOR THE GULF OF MEXICO

Tables B-1 and B-2 below provide additional beach use and recreational fishing use valuation estimates for the GOM region.

Table B-1. Gulf of Mexico valuation studies for beach recreation

		Estimated		Estimated
Study	Location	Value	Dollar Year	Value (2017\$)
Bell and Leeworthy				
(1986)	Florida	\$13.19	1986	\$29.83
Bell and Leeworthy				
(1990)	Florida	\$34.00	1990	\$64.48
Leeworthy and	Florida Keys/Key			
Bowker (1997)	West	\$97.00	1997	\$149.80
	Clearwater Beach,			
	FL	\$55.96	1990	\$106.13
Leeworthy and	Honeymoon Island			
Wiley (2004)	State Park, FL	\$14.91	1990	\$28.28
Parsons et al.	Padre Island National			
(2009)	Seashore, Texas	\$20.00	2008	\$23.02

Table B-2. GOM recreational fisher per trip valuation estimates

Study	Location	Estimated Value	Dollar Year	Estimated Value (2017\$)
Downing and Ozuna (1996)	Texas (multiple locations)	\$108.30	1989	\$216.48
Leeworthy and Bowker (1997)	Florida Keys/Key West	\$97.00	1997	\$149.80
Whitehead and Haab (2000)	West coast of Florida	\$7.72	2000	\$11.11
Bergstrom et al (2004)	Lower Atchafalaya River Basin estuary, Louisiana	\$30.73	2004	\$40.32