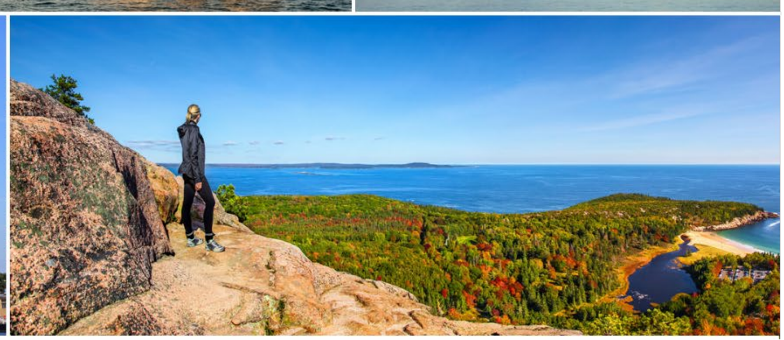
MAINE OFFSHORE WIND SOCIOECONOMIC ANALYSIS FINAL REPORT

Socioeconomic Analysis of Offshore Wind in the Gulf of Maine

Prepared for the Maine Governor’s Energy Office and Maine Offshore Wind Roadmap

December 2022

FINAL REPORT



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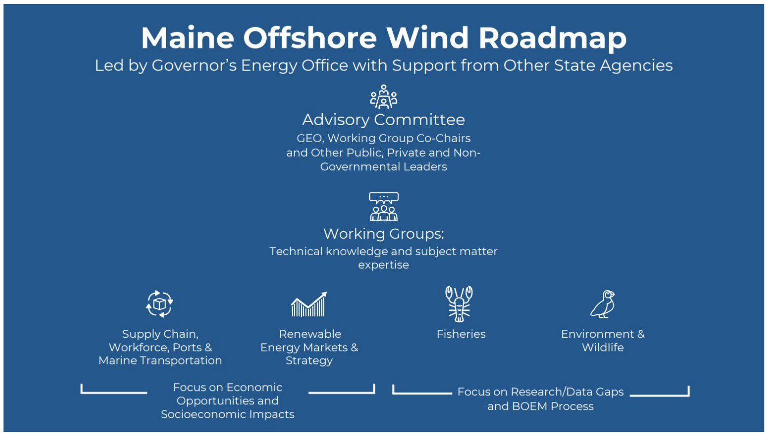
1 PROJECT OVERVIEW

1.1 Background

Through bipartisan legislation, the State of Maine enacted a renewable energy requirement of 80% of electricity coming from renewable sources by 2030 and set a goal of 100% by 2050.



The Governor's Energy Office (GEO) is developing an Offshore Wind Roadmap (the Roadmap) to explore how best to responsibly advance the offshore wind industry in the Gulf of Maine (GoM). Supported by a $2.166 million grant from the U.S. Economic Development Administration, the Roadmap is being developed by an advisory committee and four working groups with broad public input. It focuses on energy markets and strategies, fisheries, environment and wildlife, supply chain, workforce development, ports and infrastructure, and marine transportation. The Roadmap and Maine's participation in the OSW sector will also help achieve state goals outlined in Maine's 10-year Economic Development Strategy, to foster collaboration within the private and public sectors to create a more sustainable and diverse economy [150].

To inform the Roadmap, DNV completed a project with five interrelated tasks (Table 1-1). These tasks cover a variety of topics related to OSW development in the GoM, including the current state of the OSW industry and its trajectory over the next 30 years, a series of scenarios of various state and regional electricity needs and how OSW would fit into the electricity mix in each scenario, a socioeconomic analysis of the two most likely scenarios (this report), an assessment of potential deployment strategies for OSW in the GoM, and an overview of potential transmission strategies and technologies (also based on the scenarios in the Needs assessment). This report presents the results of Task 3, which will help GEO and the Roadmap working groups and advisory committee to identify the best outcomes for Maine's residents, economy, and heritage.

Table 1-1. Roadmap research completed by DNV

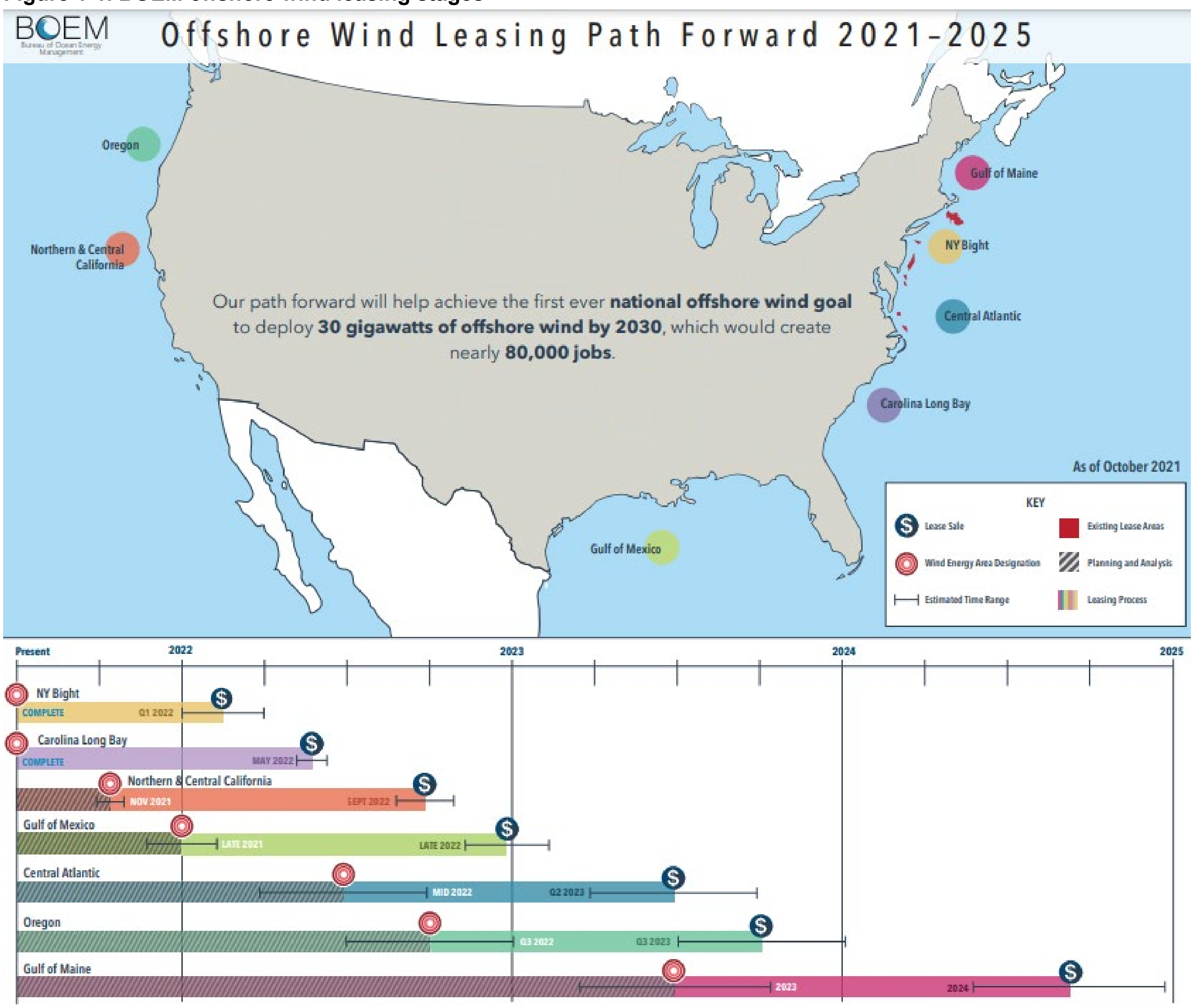
Task	Report title	Description
1	State of the Offshore Wind Industry	Assessment of global, U.S., and regional industry trends. Key takeaway is that bathymetry in GoM will require floating OSW development.
2	Offshore Wind Energy Needs Assessment	DNV modelled electricity demand for Maine and New England through 2050, developing scenarios that varied onshore development in Maine to assess the amount of OSW that could be developed in the GoM.
3	Socioeconomic Analysis of Offshore Wind Scenarios	This report. Assesses the potential socioeconomic impacts of the scenarios from the Needs Assessment (Task 2) that are most likely to occur.
4	Optimized Deployment Strategies to Maximize Maine Benefits	Identification and assessment of deployment strategies to develop the OSW industry in Maine, incorporating most likely scenarios from Needs Assessment.
5	Offshore Wind Transmission Strategy	Overview of floating OSW transmission strategies and technologies, incorporating Needs Assessment results.

1.2 OSW development process

In 2021, Governor Mills introduced legislation that was passed into law that established a prohibition on commercial wind projects in state waters, which are three miles from the coast [85]. This means that all OSW development in the GoM will take place in federal waters. The Bureau of Ocean Energy Management (BOEM) manages OSW development in federal waters.

BOEM's management process has three main phases: planning and analysis; wind energy area designation; and the leasing process. It is managing seven regions around the east, west, and Gulf (of Mexico) coasts, each of which is at a different point in the process (Figure 1-1) [152].

Figure 1-1. BOEM offshore wind leasing stages



As of the writing of this report, the GoM is in the first of the three phases. BOEM is not expected to announce the locations of the lease areas until mid-2023. Thus, researchers do not currently know where OSW arrays will be deployed in the GoM. This limits the extent and precision of any socioeconomic analyses conducted at this time. While it is possible to characterize potential effects based only on the overall generation capacity predicted, it not possible to quantify meaningful location-dependent effects at this time and at least until the lease areas are known. This means that meaningful analyses related to interactions with other ocean users such as fisheries, effects on specific ports, specific transmission corridors and landings, and some ecological analyses are not feasible until additional information is available such as the location, size, and number of leases. After the leases are known, preliminary impacts can be assessed. Once the layout, configuration, fishing activity, and other project details are known, additional impacts can be better understood. Details of the theoretical maximum wind energy capacity, the ocean surfaces affected, transmission landings, and the overlap with other known ocean activities in the Gulf (e.g., commercial fishing) evolve and become increasingly more detailed as the lease and development processes unfold. Developers often conduct more detailed environmental assessments and estimates of commercial fishing impacts as part of the permitting process after specific areas of the ocean, total generation capacity, turbine design, and turbine layout have been determined.

Furthermore, OSW, particularly floating OSW,[1] is a relatively new technology that is expected to experience rapid technological evolution in the coming decades. There are only a few, small-scale installations of floating OSW currently operational, and most of the worldwide growth is expected to occur after 2030 [153]. Details of the theoretical maximum wind energy capacity, the ocean surfaces affected, transmission landings, and the overlap with other known ocean activities in the Gulf (e.g., commercial fishing) evolve and become increasingly more detailed as the lease and development processes unfold. Developers often conduct more detailed environmental assessments and estimates of commercial fishing impacts are conducted as specific areas of the ocean, total generation capacity, turbine design, and turbine layout have been determined.

1.3 Other research

This study takes place in a sea of related studies that are completed, ongoing, or planned. To date, BOEM has held two GoM task force meetings, is processing the Research Array lease request, and completed a request for information in 2022 on a broad range of topics. It has completed or is currently conducting over 55 studies related to the GoM [155]. BOEM conducted a one-time analysis of the potential commercial fishery impacts of OSW development on lease areas that had been sold and were in the early stages of development in 2013 [161].

BOEM will complete a National Environmental Policy Act (NEPA) analysis prior to announcing lease areas in the Gulf of Maine. NEPA studies usually explore potential effects on air quality, ecology, commercial and recreational fishing, recreation and tourism, and ocean navigation and military exercises. The National Oceanic and Atmospheric Association (NOAA), U.S. Department of Energy (DOE), and Maine Sea Grant have also funded several socioeconomic studies for the GoM which will cover topics such as public engagement, lobstering data, community resilience, and procedural and distributive justice in the OSW development and deployment process. DOE and BOEM have both identified the social science aspects of offshore wind development as priorities and have plans to include it in future activities and research.

1.4 Study objectives

The objectives of this study were to identify potential benefits and costs of OSW development in the GoM for the two most probable scenarios described in the Needs Assessment [157]. The analyses were constrained to these two scenarios and to the information available at the time the research was conducted. The specific topics covered in this report were identified through a process with multiple stakeholders, including GEO, each of the four Roadmap working groups, DNV, and two Maine university professors who have studied the economic impacts of sustainability and renewable energy in Maine.

This report estimates dollar values of quantifiable outcomes from economic development, avoided carbon emissions, and health outcomes from cleaner air. It discusses benefits and risks that are more difficult to monetize at this time, including

[1] DNV anticipates that the depth of the waters of the GoM will require floating turbines rather than the more mature and widely-deployed fixed-bottom turbines.

effects on the commercial fishing industry, port development, leadership in research and development, effects on tourism and recreation, other effects on coastal communities, and ecological effects.

1.5 Research approach

To conduct this study, DNV followed the principles established in the National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources [163], adjusting for the amount of specific information that is currently available about future OSW development in the GoM.[2] We also followed the guidelines for assessing the socioeconomic effects of OSW farms published by Oxford Brookes University [42] to the extent possible at the early stage of the OSW development process when the research took place.

The research employed three techniques: a review of existing research on the effects of OSW, in-depth interviews with people in Maine, and quantitative estimation. In addition to helping determine the research topics, the stakeholders identified above also reviewed interim deliverables and provided input on sources for secondary research, interview samples, interview questions, and reporting.

1.5.1 Literature review

DNV read, reviewed, analyzed, and summarized 176 articles, reports, and presentations to research and better understand the socioeconomic effects of OSW development in 5 key areas: fisheries and other ocean users, ecology, tourism and recreation, communities, and equity. Sources included numerous BOEM studies, published research, state and federal reports, and international evaluation studies. DNV received these sources directly from the stakeholders we worked with as well as government websites, research databases, and Google Scholar. The research team completed the bulk of the literature review in November 2021. Since then, additional sources have been added only to address specific questions from reviewers.

1.5.2 In-depth interviews

To supplement this existing research, DNV conducted 64 in-depth interviews. We completed interviews with 16 coastal and non-coastal communities, 17 tourism and recreational industry trade groups/representatives, and 31 individuals and organizations in the commercial fishing industry. DNV developed separate interview guides for each target group, focusing on issues that we anticipated or were advised would be important to each group. Major interview topics included the current status of respondents' organization/community, any challenges they are experiencing as an organization/community (not just related to OSW), and their perspectives, thoughts, and possible benefits and challenges of the potential development of OSW in Maine. DNV worked closely with GEO and the Roadmap working groups to develop the content of the interviews. We consulted with two university professors, the Department of Marine Resources, and two major commercial fishing organizations in the State to help refine the interview questions.

The interviews were completed between January 2022 and April 2022 and included a variety of perspectives from individuals spread out around the state. Two different reviewers identified common themes expressed in the interview responses. In cases where their reviews did not initially agree with one another, they reconsidered the responses together to reach a consensus. A third, more senior analyst went over this work a third time, vetted the identified themes against the interview responses, and tabulated how many respondents expressed each theme.

In addition to the interviews conducted, it is important to note that there are four working groups meeting on a recurring basis and have received feedback and make recommendations for market strategies relating to identify optimal pathways for

[2] The National Standard Practice Manual is a well-established set of research standards within the energy evaluation industry. While it does not address OSW specifically, its principles are applicable in a general sense, and provided a theoretical foundation for how to conduct this study.

various OSW scenarios. There are also others living in Maine that may not have been interviewed during this study but are engaged in the Roadmap creation.

1.5.3 Quantified impacts

DNV described the state of the OSW industry and the most likely implications for Maine and identified several potential wind development scenarios in previous reports [153] [157]. DNV used these scenarios to estimate the impact of OSW development on jobs, carbon dioxide, and health impacts of non-carbon air pollutants. This report focused on the two decarbonization scenarios developed in the other DNV analyses. These scenarios both assume substantial decarbonization efforts in the region and provide a base and high estimate of OSW deployment in 2030, 2040, and 2050. Anchoring the socioeconomic analyses on these two scenarios gives readers a sense of the range of outcomes that are likely to occur over the next several decades.

In the base case demand, diverse portfolio scenario, Maine's OSW capacity needs are projected to grow from 155 MW in 2030 to 2,086 MW in 2050. Regional needs will grow from 155 MW in 2030 to 3,312 MW in 2050. The high-decarbonization, high-demand scenario differs from the base case scenario at the regional level. In the high-decarbonization scenario, regional OSW needs ramp up more quickly (1,619 MW by 2040) and are ultimately higher (11,216 MW in 2050). The needs for Maine specifically are the same in both scenarios.

DNV used established, industry-standard, federal government resources and techniques to calculate the quantified impacts.

- For the economic impact analysis, we used the National Renewable Energy Lab's (NREL) Jobs & Economic Development Impact (JEDI) models [95]. These are industry-standard models used to estimate the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels. DNV repeated the analyses under a set of assumptions for low proportions of local materials and labor, and again for high proportions of local materials and labor.
- DNV used data from the Energy Information Administration (EIA) [29] to estimate how much carbon dioxide emissions would be avoided in each of the two scenarios. The social cost of carbon was based on the most recent federal calculation [32].
- DNV used the Environmental Protection Agency's (EPA) Avoided Emission and Generation Tool (AVERT) [31] to determine amounts of pollutants avoided by using OSW generation rather than fossil fuels,[3] and the EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping tool (COBRA) [154] to monetize the public health effects of that pollution. The COBRA model considers the costs of a wide variety of respiratory medical events including death, cardio-vascular-related hospital admissions, asthma-related complications, and missed workdays.

Appendix A describes the methods in detail.

[3] As described in more detail in the appendix on air quality, this analysis assumed that all other renewable sources would be maximized and the residual displaced fossil fuel generation would be from natural gas turbines. As of the writing of this report, almost all of Maine's (96%) and the region's (98%) fossil fuel generation is from natural gas, and there are no fossil fuel projects in the ISO New England interconnection queue.

2 FINDINGS

DNV split its findings across 10 topical areas. These topics represent a broad spectrum of largely independent socioeconomic concerns. Because of the current uncertainties around the lease and development process, the report provides a range of potential socioeconomic outcomes based on plausible scenarios. We provide monetized estimates where it is practical and a more qualitative discussion of potential outcomes where monetization is not possible. The report also concludes with recommendations for ongoing research as uncertainties decrease.

2.1 Economic impacts

Economic impact findings are based solely on the quantification of impacts; no findings are derived from interviews. DNV used the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) OSW tool to estimate the job creation and economic benefits based on the two selected OSW scenarios. Within each scenario, DNV modeled the economic impacts that will occur if there is a low amount[4] of Maine-sourced materials and labor (local content) in the supply chain, and again if there is a high amount[5] of local content in the supply chain. Altogether, there are four scenarios, as shown to the right.

Demand for renewables	Amount of local content (Maine-sourced materials and labor)
Base	Low[4]
Base	High[5]
High	Low
High	Low

The JEDI models estimate economic impacts through earnings from jobs created during the construction and operations phases of OSW development, split into the following categories:

- **Installation, manufacturing, and supply chain jobs** are those needed to directly construct or operate the wind turbines, such as on-site construction crews, equipment manufacturers, consultative services and design firms, security crews, and maintenance personnel. This category also includes indirect jobs such as legal services, natural resource suppliers, construction equipment suppliers, accounting services, and wholesalers.
- **Induced jobs** are the additional jobs created in the economy by the spending of the people with manufacturing and supply chain jobs. These include jobs from retailers, restaurants, health care providers, food providers, and housing markets.[6]

Table 2-1 through Table 2-3 show the annual economic impacts in 2021 USD (rounded to the nearest million) over the 20-year lifetime of the arrays. These totals include wages earned for short-term jobs created during construction and long-term jobs that span the entire 20-year operations phases for the OSW installations. Capacities listed in each row are what the scenarios predict will be installed by that year. Economic impacts in each row are calculated assuming that 100% of the listed capacity was installed in the listed year. Based on these calculations, Maine could experience up to 33,000 short-term and 13,000 long-term jobs. Workforce development programs that provide training to people living in disadvantaged communities will be important to ensuring equitable access to these economic impacts.

[4] (10% turbines, balance of system, electric infrastructure; 30% ports, staging, vessels, labor)
[5] (50% turbines, balance of system, electric infrastructure; 80% ports, staging, vessels, labor)
[6] Indirect and induced jobs do not include any jobs created in research and development, such as those described in section 2.1.

Table 2-1. 2030 scenarios – economic impacts by local content

Demand scenario	MW	Construction (one-time)		Operations (Annual for 20 years)	
		Low local content	High local content	Low local content	High local content
Base case	155	$24M	$55M	$5M	$12M
Decarbonization	155	$24M	$55M	$5M	$12M

Table 2-2. 2040 scenarios – economic impacts by local content

Demand scenario	MW	Construction (one-time)		Operations (Annual for 20 years)	
		Low local content	High local content	Low local content	High local content
Base case	305	$25M	$73M	$7M	$21M
Decarbonization	1,619	$114M	$362M	$36M	$113M

Table 2-3. 2050 scenarios – economic impacts by local content

Demand scenario	MW	Construction (one-time)		Operations (Annual for 20 years)	
		Low local content	High local content	Low local content	High local content
Base case	3,312	$209M	$678M	$74M	$231M
Decarbonization	11,216	$704M	$2,265M	$248M	$778M

The calculation of local job impacts, including the geospatial distribution of those impacts, is not possible at this time. The JEDI models used to estimate economic impacts do not take into account, nor provide output on, specific geospatial locations where those economic impacts would occur. While it might be reasonably assumed that much of the local impact would cluster around ports used as staging areas for construction and maintenance activities, it is currently unknown which ports would be selected. The State of Maine has commissioned another effort to study the effects on ports in more depth (https://www.maine.gov/energy/offshorewind/projects/searsportstudy).

The accurate calculation of meaningful, potential negative impacts on other ocean-using industries such as commercial fishing is not currently feasible given the lack of information around scale and location of future federal offshore wind lease areas designated by the BOEM. Over the course of the coming year and beyond, additional information will become available that would aid in more accurate understanding potential impacts; however, the full impacts will not be known until there is additional information available about the offshore wind projects and policies and ability for fishing to occur within the leased area. The following information is needed to calculate meaningful predictions for these impacts:

- The specific areas of federal leasing
- The specific turbine locations, configurations, distance between turbines and leases, mooring technology, and inter-array cabling
- Corridors, technology, and depth of ocean-to-shore transmission cabling
- Ability and willingness to navigate and fish in and around projects
- Levels and specific types of harvesting currently happening in areas where arrays and transmission are proposed. Sources such as the Northeast Ocean Data portal (https://www.northeastoceandata.org) and the Department of Marine Resources have data of this nature.
- The proximity of realistic alternative areas to harvest

- Identify ports used by effected fishermen

After direct impacts to commercial fishing are quantified, economic multipliers such as those reported by the Economic Policy Institute [174] can be applied to calculate indirect (supply-chain) and induced jobs that would also be affected.

Once lease areas are announced, preliminary estimates of potential effects on other ocean users can be developed. BOEM will complete a National Environmental Policy Act (NEPA) analysis prior to announcing lease areas in the Gulf of Maine. NEPA studies usually explore potential effects on air quality, ecology, commercial and recreational fishing, recreation and tourism, and ocean navigation and military exercises.

Permitting studies often include more precise commercial fishing impact estimates. Arrays typically occupy only small portions of lease areas, so more precise estimates are possible as developers formulate specific locations, plans, and layouts for arrays. Permitting studies typically occur after this information is available and thus can provide the most precise predictions of economic impacts on fisheries and other ocean users.

2.2 Avoided emissions

Avoided emissions findings are based on the quantification of impacts; no results are derived from interviews. To estimate socioeconomic benefits from avoided air pollution, DNV focused on changes to the regional generation mix. As noted earlier, DNV's scenarios predict that the regional electricity needs in 2040 and 2050 cannot be met with only onshore renewable sources. In this case, OSW will offset what would otherwise be fossil fuel generation. Thus, OSW will have carbon and other air pollution benefits.

The climate-changing effects of carbon dioxide emissions are felt everywhere, and the effects of other air pollutants can be wide-ranging. For example, emissions in Vermont and New Hampshire can drift into Maine and affect Maine residents. Thus, reducing emissions anywhere in the region can be expected to create benefits for Maine residents. Table 2-4 shows the regional OSW generation from each of the two scenarios, the additional onshore renewables available in each scenario, and the resulting difference that represents the displaced fossil fuel generation that would occur in each scenario if OSW generation were unavailable.

Table 2-4. Regional displaced fossil fuel generation by scenario

Demand scenario	Projected OSW (GWh)			Displaced Fossil-Fuel (GWh)		
	2030	2040	2050	2030	2040	2050
Base	695	1,365	14,843	0	1,365	14,843
High	695	7,257	50,262	0	7,257	50,262

Note: Emissions depend on actual generation (GWh) and when it occurs, rather than capacity (GW).

Assuming displaced fossil fuel generation will come 100% from natural gas, generates conservative estimates of pollutants because some small amount of peaking capacity could be filled by Maine's existing oil-fired and coal-fired plants, which will produce more carbon and criterion pollutants than natural gas turbines. The generally accepted emissions factors for natural gas are:

- 53.06 kg CO2 / MMBtu, or 0.053 MTCO2 / MMBTU.[7] This also aligns with the universal emissions factor provided by the Climate Registry [19].

[7] Methane (CH4) and Nitrous oxide (N2O) are not included here because these emissions are considered to be de minimis.

- According to the EIA [29], combined-cycle natural gas plants built after 2010 have heat rates between 6,700 and 7,000 Btu/kWh. Subsequent calculations will use the midpoint (6,850 Btu/kWh) for purposes of estimation. This corresponds to 6,850,000 Btu/MWh or 6.85 MMBtu/MWh.

Multiplying these conversion factors together results in an estimate of 363 kg CO_2/MWh of gas-fired electricity, or 0.363 $MTCO_2$/MWh. Note, this estimate only considers emissions from combustion for electricity generation. These estimates consider only Scope 1 emissions. Full lifecycle emissions that include losses during extraction, processing, and transmission to power plants could increase these emissions by 25% [175]. Furthermore, reduction of the use of natural gas for onsite combustion for heating and cooking that would result from the electrification assumed in the scenarios is also excluded from this analysis.

OSW and other renewable energy sources are not 100% free of greenhouse gas (GHG) effects. However, their GHG footprints are a tiny fraction of those of fossil-fuel sources. The median lifecycle GHG emissions for wind-generated electricity is less than 3% that of natural gas-generated electricity, and a system that combines wind-generated electricity and battery storage has approximately 10% the GHG emissions of natural gas-generated electricity [175].

2.2.1 Social cost of carbon

As highlighted by the most recent International Panel on Climate Change (IPCC) report [62], the Earth is likely to experience significant, additional climate change by the end of the century. Current estimates place the likely change between 1.5 and 4 degrees Celsius, depending on how aggressively and effectively humans can curb greenhouse gas emissions. The IPCC report cautions that climate change will increase the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, agricultural and ecological drought, and the proportion of intense tropical cyclones, and will raise sea levels. Furthermore, abrupt ocean circulation changes are also possible and more likely as climate change accelerates, which could destroy ocean biomes. All of these extreme climate events are likely to cause expensive harm to the citizens of Maine.

Estimates of the social cost of carbon attempt to monetize the negative impacts of climate change, per ton of carbon emissions, primarily due to extreme weather events and sea-level rise. President Biden’s 2021 executive order puts the social cost of carbon at $51 per metric ton, in 2020 USD, using a 3% discount rate[8] [32]. The U.S. Federal estimate was recently found to be influential on the estimates of carbon pricing experts worldwide, who most often cited a value of approximately $50/metric ton [158].

It should be noted that these estimates do not include adverse effects on ecology, such as wildfire risks and fishery habitats that are likely to result from climate change. Thus, these estimates are conservative when considering the avoided costs from harm to fisheries or coastal communities due to OSW development in relation to the likely conditions if no action is taken to curb climate change.

Using DNV’s calculations for metric tons of carbon emissions created by gas-fired electricity (see Section 2.2 above), multiplied by the social cost of carbon of $51 per metric ton of CO_2, the avoided carbon cost of OSW generation is $18.51 per MWh. Table 2-5 combines estimates of displaced fossil fuel generation multiplied by $18.51 per MWh to arrive at the total avoided carbon cost in 2030, 2040, and 2050 for each of the two scenarios. These estimates are in 2021 USD with a 3% discount rate.

[8] Economic analyses apply a discount rate to control for the effects of inflation on long-term analyses. Because of inflation, current dollars are worth (able to purchase more) than future dollars. Thus, long-term impacts must be discounted for an assumed inflation rate to put them on equal terms with present impacts. The social cost of carbon in the cited executive order ranges from $14/metric ton at a 5% discount rate to $76/metric ton at a 2.5% discount rate.

Table 2-5. Estimated avoided carbon costs by scenario

Demand	Displaced fossil fuel (GWh)			Annual carbon cost of displaced fossil fuel (2021 USD)		
	2030	2040	2050	2030	2040	2050
Base	0	1,365	14,843	$0	$25,270,245	$274,788,459
High	0	7,257	50,262	$0	$134,348,841	$930,500,406

Displaced fuel was rounded to nearest GWh for this table while carbon cost was based on exact MWh.

2.2.2 Air quality and health effects

Our estimates of air quality and health effects are based on the same assumptions that OSW will displace fossil fuel generation in 2040 and 2050 because onshore renewables will not be able to meet regional demand. Nitrous Oxide (NOx) is the primary non-carbon air pollutant produced by natural gas-fired electricity generation [97]. NOx and its conversion to fine particulate matter (PM2.5) after release into the atmosphere is the primary contributor to air quality and health effects due to natural gas-fired electricity generation that would be displaced by OSW. According to the latest AVERT estimates [31], the avoided NOx rate per MWh of OSW in New England is 0.16 pounds. This is based on the current mix of electricity generation in New England, where natural gas accounts for 98% of the fossil fuel mix. Thus, it represents a good approximation of the avoided emissions from natural gas-fired electricity generation. This is equivalent to 0.073 metric tons of NOX (MTNOx) per GWh.

Using the GWh estimates for each year in each scenario and the 0.073 MTNOx/GWh conversion factor results in the avoided NOx estimates shown in Table 2-6. DNV then used the EPA COBRA model [154] to estimate the health cost effects of that amount of NOx emission reductions, using electric utility combustion and a 3% discount rate.

Table 2-6. Avoided NOx emissions and avoided healthcare costs

Demand	Avoided NOx (MT)			Benefits low (2021 USD)			Benefits high (2021 USD)		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Base	0	100	1,084	0	54,152	588,847	0	122,651	1,333,701
High	0	530	3,669	0	287,897	1,993,966	0	652,070	4,516,165

2.3 Public perception and community involvement

Results on public perception and community involvement integrate information obtained from in-depth interviews and secondary research. Lessons in best practices for community involvement can be learned from onshore wind and other OSW developments. Key findings for this section and the sources that informed them are shown in Table 2-7.

Table 2-7. Public perception and community involvement key findings

Key finding	Derived from	
	Interviews	Secondary research
Meaningful community engagement that includes deliberative multidirectional communication, that seeks to reconcile technical needs and community values, and that gives communities the power to collaboratively negotiate for community benefits has been a successful model for onshore and OSW developers in the past.	✓	✓
Messages must come from trusted sources.	✓	✓

Key finding	Derived from	
	Interviews	Secondary research
Without proactive communication, misinformation can spread.	✓	
Proactive, multidirectional public engagement is a necessary – but not sufficient – component of procedural equity.		✓
Mindful policy is required to address historic inequities suffered by Indigenous tribes and avoid additional harm.		✓

Meaningful community engagement that includes deliberative, multidirectional communication that seeks to reconcile technical needs and community values, and that gives communities the power to collaboratively negotiate for community benefits, has been a successful model for onshore and OSW developers in the past [4], [47], [60], [65], [72]. Proactive communication can mitigate local concern and uncertainty. Tourists and local communities want to know how wind energy projects can affect them and want to know about a project early in the process, rather than be presented with what has already been designed and developed. Our interviews with different communities and ocean users found that education, direct communication, and local community engagement with developers and other community groups are essential to informing the community and bridging the education gap about OSW development. The literature review of best practices in the U.K. found that developers often assign a community liaison to ensure the earliest possible involvement and engagement of local communities [42].

Messages must come from trusted sources. Our interviews indicated that some sources of information were more likely to be trusted than others. The community interviews underscored the importance of engaging local information sources to educate the public such as libraries, churches, and town managers. Interviews with fishermen mentioned the Department of Marine Resources as a trusted information source. Interviews with tourism representatives reiterated the importance of engaging with "trusted flagbearers." As mentioned above, a developer's community liaison can help facilitate this process as well [42].

Without proactive communication, misinformation can spread. State agencies are key sources of accurate information on OSW. In our interviews, many stakeholders shared that they receive information about OSW from other sources such as social media platforms, suggesting a possibility for misinformation. Interestingly, numerous stakeholders expressed certainty that any proposed OSW projects would send all of their power only to Massachusetts and not to Maine, although this is not necessarily the case.

Proactive, multidirectional public engagement is a necessary—but not sufficient—component of procedural equity. Procedural equity also requires additional attention to ensure that historically marginalized groups have decision-making power and a seat the table [164], [165], [166].

Mindful policy is required to address historic inequities suffered by Indigenous tribes and avoid additional harm [84] [124] [144] [148]. People living on Indigenous tribal lands can realize ecological, economic, and health benefits from decarbonization of the energy system. However, without policy approaches that deliberately recognize and seek to increase tribal sovereignty, there is a risk of continuing a history of exploitative resource development and energy inequities on tribal lands.

2.4 Fisheries

The commercial fishing industry is very important to Maine's economy and heritage, and it is one of the largest active users of the GoM. It has an estimated total economic impact of $3 billion annually and employs over 16,000 licensed fishermen. Lobster is also a particularly important part of this industry, representing about 80% of both the total Maine harvest and the national lobster catch. Commercial fishing forms the economic and cultural bedrock for many of the Gulf's coastal communities, and it is one of the largest industries in the entire state. This section explores the major concerns raised during the in-depth interviews and those identified in secondary research (Table 2-8). These findings cover the key issues that arose during these interviews and in the existing research – there may be other issues that could not be covered in the allotted interview time or than have since become more prominent.

Table 2-8. Fisheries key findings

Key finding	Derived from	
	Interviews	Secondary research
Members of the fishing industry are worried about losing harvesting areas.	✓	✓
Multidirectional communication that occurs as early in the planning process as possible is a best practice to avoid conflict and minimize negative impacts to commercial fisheries.	✓	✓
Navigation routes might increase in length.	✓	✓
There will be multiplier effects for any lost maritime jobs.	✓	✓
Co-location might be feasible if safety concerns are addressed.	✓	✓
Previous experiences with regulations around the protection of right whales are affecting fishery response to OSW.	✓	
Fishermen found it difficult to provide ideas for mitigation measures that adequately addressed their concerns.	✓	

Members of the fishing industry are worried about losing harvesting areas. No observational study on the actual effects of floating offshore wind installations on commercial fisheries could be located for this report. Such research is a priority for BOEM and groups representing the commercial fishing industry. Domestic and European fisheries have identified the possible loss of fishing access as one of the most detrimental impacts potentially resulting from OSW projects [47]. A majority of the interviewed Maine fishermen expressed concern about the possible loss of harvesting areas due to OSW and submarine transmission corridors. Many studies on the economic risks to fishermen from specific arrays in specific areas of the ocean assume that fishermen can easily shift to harvesting a different part of the ocean. The interview results suggest this assumption may be overly optimistic. The interviewed fishermen stressed that there is a strong social convention among Maine fishermen and lobstermen to harvest only within specific areas that have often been negotiated over generations. Maine state lobster licenses also restrict fishing to within one of seven zones, the boundaries of which extend into federal waters of their permitted zones. Displacement could create further conflict, accelerate arguments over space, and necessitate moving to less productive locations. Additionally, even if fishermen could shift their harvesting areas, interviewees shared that their work is highly dependent on a detailed knowledge of fish behavior built up over years or decades that might not apply in unfamiliar waters.

Multidirectional communication that occurs early in the planning process is a best practice to avoid conflict and minimize negative impacts to commercial fisheries [21] [47] [113]. The Roadmap process includes a working group dedicated to fisheries. However, close to half (42%) of the fisheries and one-fourth of the community interviews (24%) suggested that more could be done to fully engage the fishing community in the dialog.

Navigation routes might increase in length. Several interviewees expressed concern that the location of arrays might require changes to the routes they take to get to harvesting areas. This could increase steaming times[9] and fuel costs, which would be harder on smaller fisheries. In at least one case in Europe, a wind farm was sited in a way that restricted a transit area that was previously freely accessible [159]. There are ongoing conversations on the East Coast related to this risk [171] [172].

There will be multiplier effects for any lost maritime jobs. Reduced harvesting areas and increased transit costs could harm profits and possibly lead to a loss of maritime jobs. Economic multiplier effects due to indirect (supply-chain) and induced effects would operate in a negative feedback loop. The loss of one fishing vessel creates economic ripples in ancillary industries including reduced demand for fuel, bait, ice, dockage, and maintenance, and reduced supply for downstream industries such as seafood dealers. Lost fishing and supply chain jobs would have negative induced effects on overall economic activity in the community as families have reduced disposable income. According to the Economic Policy Institute, each fishing job supports approximately 2.3 indirect and induced jobs [174]. SEAMaine also recently completed a fishery workforce inventory specific to Maine [176] that indicates a greater number of supply chain (indirect) jobs per fishing job (1.2 indirect jobs) than the more general Economic Policy Institute report (0.94 indirect jobs). Many fishing communities exist in rural areas where alternative employment is not readily available. These losses would affect crews, their families, and parts of the unique rural Maine coastal economy that are heavily dependent on commercial fisheries. Fishermen expressed concern about the potential loss of their heritage and a lack of alternative employment options.

Co-location might be feasible if safety concerns are addressed. Maine fishermen are concerned about the safety of operating near OSW turbines. There remain substantial unknowns around the implications of inter-array cabling, mooring, and ocean-to-shore transmission corridor that will become clearer as the development process matures. Co-location or multi-use areas have been considered in some areas of Europe [47] [67].

Previous experiences with regulations around the protection of right whales are affecting fishery response to OSW. As of May 1, 2022, new federal regulations require lobstermen to alter their gear to prevent whales from becoming entangled. These regulations are contentious and commercial fisheries have taken legal action to attempt to change them [160]. The State of Maine has been attempting to engage the fishing industry about OSW at the same time. During interviews, 61% of the fishermen voiced frustration about the timing of OSW development. They expressed concerns over cumulative effects, and that OSW development would impose additional restrictions on their industry which is already affected by climate change, the development of other industries, and regulatory oversight and enforcement. Some of this concern may be based on an incomplete understanding of the OSW development process, how long it will be before the GoM sees substantial construction, and where the turbines will eventually reside.

Fishermen found it difficult to provide ideas for mitigation measures that adequately addressed their concerns. For many fishermen, fishing isn't just a job, it is a way of life, part of their heritage, and a source of cultural identity. Within such a context, simple economic compensation would be an insufficient way to mitigate lost jobs. The current context of uncertainties about the overlaps of lease areas with harvesting areas, technical details of floating arrays and co-location

[9] Steaming times are calculated as the ship's total traveled distance multiplied by its speed.

possibilities, and the lack of research on ecological effects made it difficult for interviewees to suggest mitigation strategies or understand how they would adapt. DNV also observed a higher level of refusal to answer the question about what OSW developers could do to compensate fishermen for negative impacts to their fishing business than other questions. Continuing to engage in a supportive dialogue with the fishing community around these issues will be essential to mutually optimal outcomes.

A secondary goal of the interviews was to gain a better understanding of where fishermen are currently harvesting. A limited number of interviewees that were willing to disclose their finishing locations stated that the average distance from shore is between 3 and 30 miles from the coast. This is not necessarily representative of the lobster industry as a whole. They reported that harvesting in federal waters (past 3 miles) has increased in recent years, and few boats are large enough to safely operate past 30 miles. They named five harvesting “hot spots”:

- Platts Bank is considered prime groundfish habitat.
- Jeffreys Ledge about 30 miles offshore is considered a “hot spot” for cod and pollock.
- Tibbet’s Ledge near Boothbay is a favorite for ground fishing.
- Any “ledge” in the Gulf that contains rocky shoals and muddy, gravelly bottoms along the coast is a hot spot.
- The area where the Research Array is being proposed is a winter habitat for lobster.

It should be noted that these are only the areas that were mentioned by interviewees. It is not meant to be an exhaustive list, and these reports have not been verified against objective data sources.

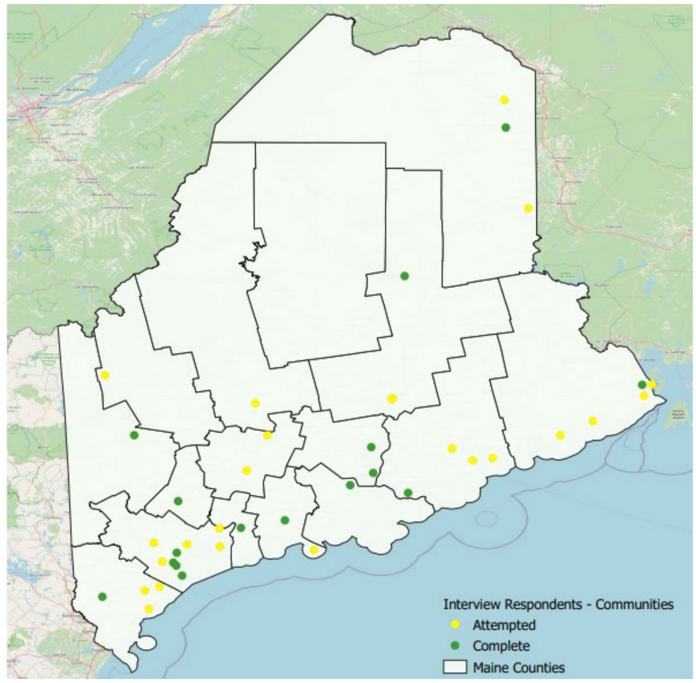
Sources such as the Northeast Ocean Data portal (https://www.northeastoceandata.org/) and the Department of Marine Resources have more complete data on harvesting locations.

2.5 Coastal & non-coastal communities

This section explores the major concerns raised during the in-depth interviews with respondents in coastal and non-coastal communities. All the findings in this section were based on interview responses.

The research team attempted to speak to communities across much of Maine and completed interviews with 17 of them (Figure 2-1). The communities that completed interviews represented both coastal and inland communities. Most (14 out of 17) of the respondents were representatives in city government positions such as town managers or directors of economic development. A few (3 out of 17) of the respondents represented trade organizations such as chambers of commerce. Seven of the 17 interviews were in areas with high socioeconomic vulnerability, 3 were in areas with moderate socioeconomic vulnerability, and 7 were in areas with low socioeconomic vulnerability [170].

Figure 2-1. Attempted and completed community interviews



The primary issue facing most towns is the availability of affordable housing. Most (71%) of the community interview respondents cited housing availability as a primary concern. Increased population via migration from other states with higher costs of living is driving up housing prices, putting strain on local infrastructure, and creating skilled labor (plumbers, electricians, etc.) shortages. Town managers are concerned that this problem will worsen if OSW development brings more people to Maine.

Community officials are concerned about their communities' resiliency to the impacts of climate change. 41% of the respondents cited concerns about climate change impacts. Drought, rising sea levels, coastal erosion, and a higher volume of runoff are straining existing infrastructure. Town managers reported regularly encountering resistance from community members when changes are proposed. In one anecdote, a town manager stated that even though a primary section of downtown now experiences regular flooding due to higher tides and storm surges, she has been unable to make the necessary improvements because residents do not want to change the visual aesthetic of that area. While OSW seeks to alleviate the larger issue of climate change, there is an immediate need for investment in existing infrastructure, and town managers suggested that a portion of the revenue from OSW be allocated for these improvements. This would allow local leaders to deliver the message that OSW is creating additional benefits in the community and improving everyday life for the residents.

The third-most commonly mentioned issue from interviewees (35%) is concerns regarding social and financial equity. Issues in this category include homelessness, income disparities, and tribal diversity/equity/inclusion.

Most (59%) respondents are generally supportive the State's plan to move forward with OSW development in the GoM. The most enthusiastic supporters articulated a sense of urgency to mitigate climate change and reduce the dependence on fossil fuels. Three (18%) of the respondents expressed mixed opinions about OSW. One (6%) respondent strongly opposed OSW. They stated that the process has been exclusive of lobstermen, and that profits from OSW should benefit the health of Maine by paying lobstermen rather than non-profit organizations. Two-thirds (65%) of interviewees are aware of the state's clean energy goals, but not the details. Another 18% are familiar with the goals as well as the details.

Community respondents were concerned about some potential tradeoffs from offshore wind. The greatest concern was negative impacts to the commercial fishing industry. Overall, the 17 respondents indicated they are highly reliant on the commercial fishing industry with an average score of 4.3 on a 5-point scale. Respondents whose communities were more dependent on commercial fishing expressed stronger concerns about avoiding negative impacts to that industry. A natural aesthetic is important to many of the communities - approximately half (47%) of the respondents indicated that nature and natural beauty attracts tourism.

Local content and self-sufficiency are part of the Maine "brand." One-third (30%) of respondents noted the importance that Maine is viewed as self-sufficient and suggested that there is an opportunity for OSW to expand on this concept by promoting "carbon-neutral" or "carbon-offset" experiences that are powered by wind from the GoM.

2.6 Tourism and recreation

Tourism in another important Maine industry. In 2021, Maine had over 15 million tourists, who spent $7.9 billion. The industry supports over 143,000 jobs. This section explores the major concerns raised during the in-depth interviews and those identified in secondary research (Table 2-9).

Table 2-9. Tourism and recreation key findings

Key finding	Derived from	
	Interviews	Secondary research
Interviewees are concerned about climate change and recognize that OSW is one way to help mitigate it.	✓	
The tourism and recreation industry is unfamiliar with Maine's Renewable Energy Goals and the GEO's conversations surrounding OSW.	✓	
Interviews and existing research indicate there are mixed reactions to the sight of OSW turbines	✓	✓
If placed far enough from shore, the turbines will be minimally visible, if at all.		✓
Recreational organizations and tourism businesses that rely on wildlife to attract customers expressed concern about the potential impact of OSW on wildlife such as whales and seabirds.	✓	
Offshore wind development could increase recreational fishing.		✓

Interviewees are concerned about climate change and recognize that OSW is one way to help mitigate it. The majority (80%) of respondents noted climate change as a tourism and recreational industry concern. Some interviewees even noted the current impacts of climate change on their businesses, including the loss of seabird populations and the migration of whales further from whale boat tours' traditional routes.

The tourism and recreation industry is unfamiliar with Maine's Renewable Energy Goals and the GEO's conversations surrounding OSW. Very few respondents (13%) were aware of the GEO OSW working groups. Only 20% were familiar with Maine's renewable energy goals. Several interviewees expressed gratitude for being included in this effort and to be allowed to speak on behalf of the tourism and recreational industry. These interviewees also suggested opportunities to include them more in the OSW process moving forward, specifically through direct communication and education, and sources such as town managers that can share this information, which is discussed further in Section 2.1.

Interviews and existing research indicate there are mixed reactions to the sight of OSW turbines. All (100%) respondents stated that Maine's scenery, natural beauty, and "untouched" feel are the main draw for tourists and recreators. Half (53%) said visible wind turbines would harm their business by obstructing Maine's scenery and natural beauty. One interviewee suggested that OSW could spur innovation in the tourism industry through the development of boating trips to view turbines and educating visitors about OSW.

> *"Certainly the viewshed and aesthetics would be impacted. People don't come to Maine from industrialized cities to see industrialized activities in the water. We are very concerned where the windmills will be placed. We want to see them go somewhere where [they] can't be seen."*
>
> – Tourism and Recreation Industry Interviewee

Existing research on the Block Island wind farm off the coast of Rhode Island found that the reactions of tourist and recreational groups were mixed and trended toward positive [117]. Other research suggested that wind turbines could increase tourism through "curiosity trips" to see the turbines [17]. People who would not otherwise visit a beach might go there specifically to view them if they are visible from shore.

If placed far enough from shore, the turbines will be minimally visible, if at all. As of the writing of this report, Governor Mills introduced legislation to establish a 10-year moratorium on new OSW projects located in State waters [85], limiting the proximity to shore. DNV conducted an analysis to demonstrate the daytime visibility of OSW turbines. Figure 2-2 shows the visibility of a 495-foot turbine with an 820-foot rotor diameter at 2 through 8 miles from shore. This size is approximately what the Department of Energy predicts offshore turbine sizes will be in 2035 [100]. As demonstrated by the figure, there will be little to no visibility (from the shore at sea level) of an OSW turbine installed at least 10 miles offshore. The current preferred site for the Research array is no closer than 23 miles to shore, and likely will utilize shorter turbines, so they will have little to no visibility from shore.

Figure 2-2. DNV Offshore wind turbine visibility analysis results

Recreational organizations and tourism businesses that rely on wildlife to attract customers expressed concern about the potential impact of OSW on wildlife such as whales and seabirds. These parties referenced the noise (under and above water), light, and turbine speed as having potentially negative and sometimes detrimental impacts on seabird populations by disorienting and ultimately displacing them. Interviewees cite experiencing the negative impacts of climate change on seabird and whale populations in the GoM and hope that OSW is developed to avoid more harm to these populations that their businesses rely on. As described in section 2.8, additional research on the ecological effects of OSW turbines is needed.

Offshore wind development could increase recreational fishing. Though our interviews did not address the impacts of OSW on recreational fishing, our literature did suggest that underwater fixed-bottom structures, such as those used for OSW development, can act as fish aggregators for things like mussel growth, fish attraction, and artificial reefs [59]. This could create new recreational fishing opportunities. Increased recreational fishing opportunities could be beneficial to some, though it might also contribute to over-crowding in certain areas of the ocean [117].

2.7 Port development

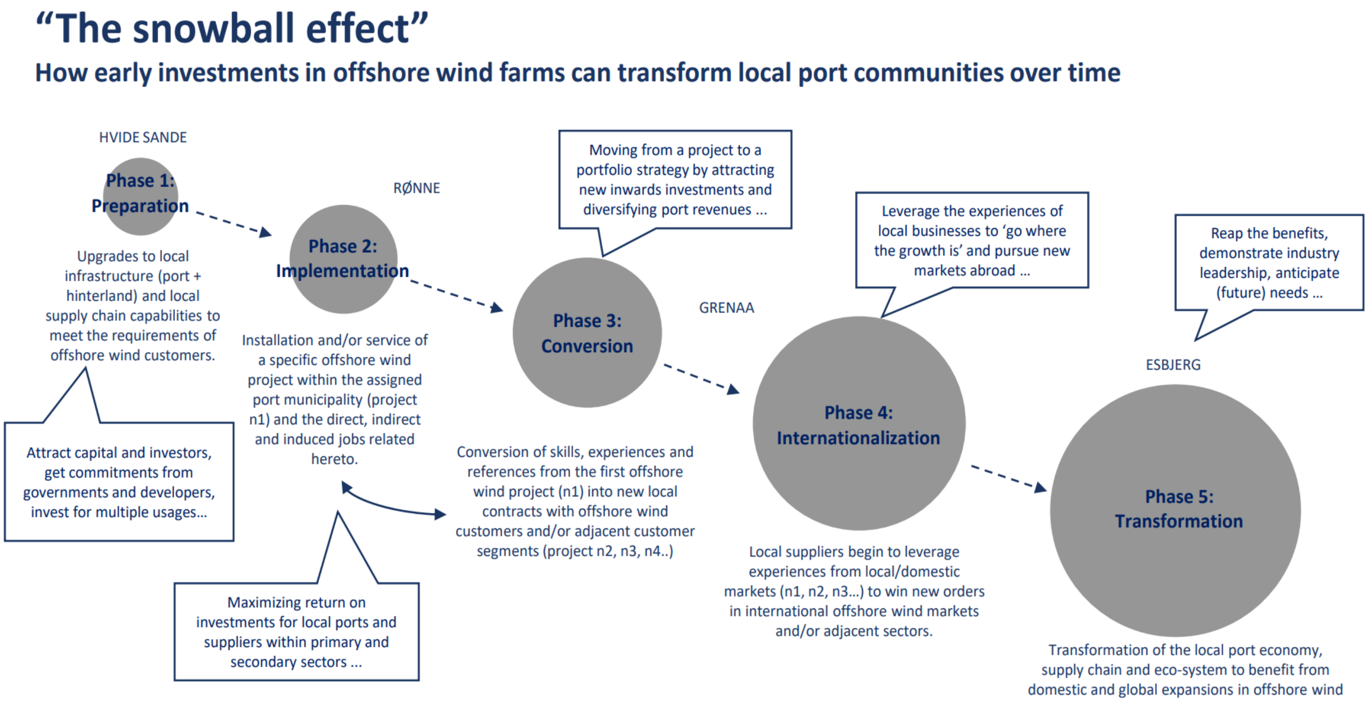
Findings in this section are based exclusively on the literature review. DNV anticipates a high probability of moderate positive economic impact for at least one port on the GoM due to an increased need for specialized and improved port facilities. This probability and the level of impact scale with the degree of OSW development that will be installed in the GoM. Less OSW development decreases the probability and magnitude of positive economic impacts from port development; more OSW development increases the probability and magnitude of positive economic impacts from port development.

Benefits from port development are partially accounted for in the previous economic development estimates (Section 2.1) via the local content assumptions used in the JEDI models. Additionally, DNV has identified a “first mover” effect from European examples that suggest that port(s) that develop OSW construction support early on are more likely to be used as staging ports for later OSW development later. This creates the potential for cascading benefits from early port development.

DNV’s literature review suggests there are strong socioeconomic benefits to positioning Maine’s ports as centers of OSW development and operation. The State of the Offshore Wind Industry: Today through 2050 report [153] mentions Eastport, Searsport, and Portland as 3 locations with the potential to serve the OSW industry, with benefits affecting both infrastructure spending and employment at and around the ports. Maine Port Authority's final report on the Searsport Intermodal Commodity Study [83] describes an already thriving trade of onshore wind components cycling through the port. The terminal provides ample space for turbine storage, and the proposed development of a nearby industrial park could bring OSW component manufacturing to the area.

As an example of what might happen to Maine's ports when OSW is installed, researchers from a Danish study of four port communities and over 20 stakeholders involved in the installation and operations of some of Denmark's largest OSW farms describe how OSW can lead to a snowball effect for local ports and the surrounding communities (Figure 2-3). The study finds that early investment in port infrastructure enables these communities to specialize in OSW development and begin to export skills and services to other jurisdictions, which for Maine could easily mean other states and Canada.

Figure 2-3. Cascading benefits from early port development [107]



2.8 Offshore wind industry advancement

Findings in this section are based exclusively on the literature review. Significant OSW development in the GoM is likely to advance local expertise and research related to OSW engineering, construction, and components and will help achieve state goals listed in Maine's 10-year Economic Development Strategy to foster collaboration within the private and public sectors to create more sustainable and diverse economy [150]. This expertise is likely to include all components except the manufacture of turbines. This development will scale with the extent of OSW deployment in the Gulf. Lesser deployment will reduce the probability of substantial industry advancement and greater deployment will increase the probability of industry advancement.

Alongside the potential for a specialized Maine labor force operating from robust Maine port infrastructure is the opportunity for Maine businesses and institutions to capitalize on intellectual ownership of OSW components and technology. A report on UK OSW supply chain stresses the importance of building up UK intellectual ownership in the face of heavy pressure from mainland European incumbents [143]. This report segments the OSW supply chain into 3 tiers:

- **Tier 1 (Prime Contractors)** – This level is dominated by large incumbents tied to and including the turbine OEMs and companies specializing in the foundations and substations for OSW.
- **Tier 2 (Principal Suppliers)** – This level consists of companies specialized in the fabrication and installation of turbine foundations. The UK has difficulty breaking into this market because mainland European incumbents often have better state funding and access to large quaysides with significant water depths.
- **Tier 3 (Specialist Suppliers)** – This level is the most competitive, and consists of companies delivering sensors, software, mooring technologies, or other components supporting the operations and maintenance of turbines after they are produced.

While the UK has limitations for breaking into tiers 1 and 2, Maine as a forerunner of US OSW can foster successful tier 2 companies. This is already being demonstrated with the platform technology being developed by the University of Maine and could lead to a host of other tier 2 and tier 3 businesses headquartered in Maine. There are no foreign competitors who could fabricate turbines at home and then drag them to Maine, but Maine could serve this purpose for both Maine and other states of the US. With Maine ports able to provide the large quaysides necessary to assemble and transport turbines to their destination, the local port economies could see the buildup of successful Maine-owned businesses situated near the ports.

The University of Maine is a leading contributor to OSW research and development [138]. Other Maine institutions, such as Colby, Bates, Maine Maritime Academy, University of Maine School of Law, and various community colleges are poised to play a prominent role in OSW development as well. Offshore wind development in the GoM is likely to increase the extent and value of the scholarship coming out of Maine's colleges and universities. These effects are not included in the economic impact estimates in section 2.1. One area of specific note is the research and development (R&D) of platform materials used for floating OSW. The current state of the art uses steel components. However, the University of Maine is researching the use of concrete foundations. If concrete foundations can be perfected, it would likely bring patent revenue to the university. The exact monetary value of these patents is currently impossible to estimate. It would also increase the likelihood of utilizing local Maine supply chains for GoM OSW developments because Maine has local concrete production, but no local steel production.

Another way that concrete foundations could create a benefit is through a reduction in the carbon footprint of OSW construction itself. DNV performed a comparative study of concrete and steel substructures for floating ocean wind turbines (FOWT), both spar and semi-submersible, and determined that concrete floaters have a lower carbon footprint and cost less than their steel counterparts [149]. Compared to steel, concrete has a much lower carbon footprint. According to the Portland Cement Association, each metric ton of concrete can be expected to produce 100kg of carbon dioxide. (Each ton of cement produces 900kg of CO_2, but concrete is a mixture of aggregate material and cement, with only a small faction composed of cement [106]). In contrast, one ton of steel produces approximately 1.85 tons of carbon dioxide. DNV estimates current construction methods require approximately 2,000 tons of steel per MW of floating OSW. Depending on how much concrete is needed to achieve the same floating performance, and how much of the fleet utilizes it instead of steel, the carbon savings could be substantial.

2.9 Potential ecological impacts

Findings in this section are based exclusively on the literature review. There are potentially positive and negative ecological impacts from OSW development. With the currently available information, DNV cannot predict specific ecological impacts from OSW development. At a minimum, estimating specific impacts depends on knowing the size and location of lease areas. Specifics about arrays that are not known until much further along in the development process also inform potential ecological effects. Details such as specific foundation technology, nacelle height, blade length, layout, inter-array cabling, and mooring all matter. Studies of observed effects of floating arrays in other parts of the world will provide some information about ecological effects. And more local studies will be necessary to understand interactions with the unique characteristics of the GoM. What can be said with confidence at this point is that the magnitude and probability of ecological impacts will increase with additional OSW deployment.

Climate change effects must be assessed to determine impacts on ecologically and economically significant fish and invertebrate species in the GoM. Extensive research has shown that climate change is already affecting several fisheries in the GoM [99]. While climate change has positively impacted some fisheries (e.g., American lobster [*Homarus americanus*] and summer flounder [*Paralichthys dentatus*]) due to northward shifts of fish and invertebrates to the warming GoM waters, other Maine fisheries may be negatively impacted due to decreased fish recruitment from increased ocean acidification and other factors making the waters unsuitable for early fish life stages. For example, Atlantic herring (*Clupea harengus*) spawn may be negatively affected by climate change effects because they are more sensitive to ocean acidification and warming ocean temperatures [77]. Elevated ocean temperatures have shown decreased survival rates in Atlantic herring larvae, which was determined to be caused by a decrease in food availability [120]. While research has not yet directly linked its stock decline to climate change [104], the Atlantic cod (*Gadus morhua*) population has already seen significant declines and it may be exacerbated by climate change due to increased embryonic sensitivity caused by ocean acidification [22]. Further research is required to determine the potential climate change impacts on Maine's fisheries and how OSW development's reduction in greenhouse gas production may positively affect these fisheries in the long term.

Artificial reef effects could improve fish habitats. Research has shown that OSW structures can attract some fish species and promote benthic habitat creation, which could provide beneficial protection for some species of depleted fish and invertebrate populations [59]. Research from the incoming GoM research array will likely provide further insight into specific artificial reef effects of OSW structures in the GoM.

Further investigation is needed into novel mitigation measures for entanglement and vessel strike risk. There should be further investigation into ways to reduce vessel strike risk to marine mammals and sea turtles. While there have not been any documented incidences of entanglement or vessel strike injuries or death of marine mammals at OSW facilities, the level of risk needs to be fully understood to adequately assess potential cumulative impacts on marine mammals. For example, the GoM is an important foraging area for NARW due to the high concentrations of key copepod prey species (particularly, *Calanus finmarchicus*) [53] [99]. Climate change impacts are impacting copepod concentrations which may indirectly affect NARW foraging success [91]. More research is needed to investigate the cumulative impacts of OSW development that accounts for all potential impacts on marine mammal populations, particularly for NARW.

Impacts to birds and bats on Maine coastal islands from OSW development require further research. There is an extensive complex of Maine coastal islands that supply essential foraging, nesting, and migratory staging areas to vulnerable seabird species, such as the federally-listed roseate tern. While the Atlantic puffin breeding colonies have recovered in recent years, there are still environmental concerns due to their vulnerability to potential reproductive impacts. There is research showing that many marine birds can effectively avoid OSW turbines [167], [168], [169], but further assessment of the impacts of this avoidance behavior on the fitness and reproductive success of marine birds in the GoM is needed. The full extent of unique circumstances that species in the GoM encounter is currently unknown. BOEM and other agencies are planning studies to improve this knowledge. Studies on the Research Array will likely elucidate how these behavioral shifts could have long-term impacts on marine bird populations in the GoM specifically and how they could be avoided, minimized, or mitigated. Studies conducted just before permitting will have access to details about proposed arrays that will also help formulate specific estimates of ecological effects.

In the U.S., BOEM has completed and is conducting much of the research to assess the potential impacts of OSW development in the GoM. Completed research includes assessments for federally protected species for 2010 through 2019, frameworks for studying the potential impact on marine mammals and sea turtles, a risk assessment model for encounter rates between large whales and vessel traffic from OSW installations, best management practices for Atlantic

OSW facilities, a vulnerability index for migratory bird species, and a study on potential bat interactions. Ongoing research includes estimating effects on North Atlantic right whales (NARW), zooplankton, and other protected species; exploring the effects of sound on several fish species and invertebrates; anticipating shifts in migratory bird distributions; and modeling collision risk for three protected bird species. BOEM is currently planning aerial surveys of several areas of the Gulf [155].

2.10 Energy equity

This section considers energy equity and environmental justice perspectives related to OSW development in the GoM. Most of the equity-related impacts extend beyond concerns specific to the two scenarios this study focused on. Also, as stated elsewhere in the report, the stage of OSW development in the GoM at the time of this report limits the quantifiability of the equity-related impacts. To cover the topic of energy equity more broadly, the research team utilized the Initiative for Energy Justice's (IEJ) "Justice in 100 Metrics" [165] energy equity framework.

The IEJ framework is similar to other frameworks such as those developed by the American Council for an Energy-Efficient Economy (ACEEE) [164] and the University of Michigan's Energy Equity Project's framework [166], as well as scholarship published in academic journals [16] [66] [86] [121].

The IEJ framework enumerates four dimensions of energy equity:

1. Access and affordability
2. Procedural equity
3. Economic participation
4. Health and environmental impacts.

Elements of this report and the Offshore Wind Roadmap process fit into the above dimensions as follows.

2.10.1 Access and affordability

An equitable renewable energy policy is one that ensures and expands energy access to all people, particularly those historically harmed by the energy system. In order to be accessible, energy must be affordable.

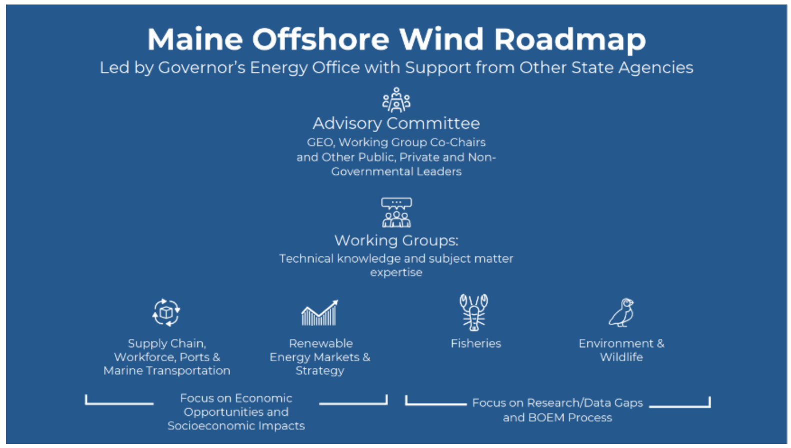
Increased electricity rates are a risk, especially for low- and moderate-income households. The cost to generate each unit of electricity with a floating wind turbine is currently higher than with other generation methods, including most of those currently supplying electricity to Maine. However, the State of the Offshore Wind Industry report [153] prepared by DNV alongside this report predicts that generation costs for floating OSW will decrease substantially over time. Furthermore, generation costs are not the only factor that determines consumers' electricity rates. Other cost-of-service factors such as transmission and distribution also make a difference. Finally, the scenarios upon which this study was based assume aggressive energy efficiency program implementation and electrification of home heating and transportation fuels. Even if electricity costs more than it does today, electrified heating and vehicles are significantly more efficient than most current fossil-fueled technologies. These efficiency gains could partially or fully offset any increases in electricity rates on energy burdens and affordability. Mindful implementation of electricity rate-setting, deployment of energy efficiency programs, and electrification programs will be necessary to ensure that the energy burdens of low- and moderate-income households do not increase.

Ensuring equitable access to electricity requires mindful policy. In many parts of the country, Tribal lands have substantially less access to electricity than other areas. Non-tribal rural areas may also have historically less access than urban areas. As generation capacity increases, new policies could help increase access to electricity in areas with historically less access.

2.10.2 Procedural equity

Just decision-making processes are those that give those most impacted by the energy system proportional access to decision-making power and agency in their energy future. As marginalized communities have historically been excluded from these decision-making processes, extra care is required to ensure they receive a seat at the table. Proactive, multidirectional public engagement as described in more detail in section 2.5, is a necessary—but not sufficient—component of procedural equity as well.

Figure 2-4. Maine OSW roadmap organization



The Roadmap process attempts to gather input and provide decision-making power to a wide range of stakeholder groups. There are topically-focused working groups who each represent various stakeholder groups. The working groups hold regular, publicly accessible meetings. There have also been several different socioeconomic and social impacts studies of OSW in the GoM.

As the Roadmap process unfolds, there is an opportunity for greater engagement of frontline communities, and black, Indigenous, and people of color (BIPOC). Responsible engagement of historically marginalized groups is an ongoing process. About one-third of the community interviews were with communities with high socioeconomic vulnerability scores, and continued interaction with those communities will keep them in the conversation and yield additional insights as the OSW development process evolves. Because the research pursued for this study was unable to contact Indigenous representatives, it cannot report on their concerns.

Multidirectional communication that seeks to minimize negative impacts to commercial fisheries also falls under procedural equity.

2.10.3 Economic participation

Just economic policies are those that ensure that economically vulnerable populations share in the economic benefits generated by OSW projects, and that any potential negative economic impacts do not disproportionately affect certain populations.

Workforce development programs will be necessary to ensure equitable participation in new jobs. Section 2.1 describes substantial new jobs and economic impacts for the state of Maine arising from anticipated OSW development in the GoM. Maine does not currently have a sufficient workforce to fill all those jobs, so training will be necessary to maximize the local share of labor. Equity requires ensuring that those workforce development opportunities and new jobs are accessible to people in economically vulnerable areas.

Commercial fisheries and the communities that depend on them are the population at greatest risk of disproportionate negative impact from OSW arrays situated in the GoM. Although a meaningful quantitative estimate of the economic risk to fisheries is not feasible at the time of this study, there are credible concerns about negative impacts from OSW development in the GoM. There are numerous small ports along the Maine coast whose economies depend on commercial fishing. Furthermore, fishing has cultural and heritage importance for many of these communities, making it more than simply a commercial activity, and complicating potential mitigation strategies.

2.10.4 Health and environmental impacts

The equitable distribution of health and environmental benefits means that areas that have suffered more harm from the existing energy system receive a greater share of the benefits of the clean energy transition. Moreover, it is crucial that no further harm is done to these communities and populations.

The health and environmental benefits described in this study are considered at the regional level. Locational health and environmental impacts were not feasible for this study. However, the estimated benefits are calculated by considering avoided costs. Thus, to the extent that specific areas suffer greater harm from pollution emitted by fossil-fuel infrastructure, those areas would also experience proportionately more of the benefits accounted for in this study.

3 CONCLUSIONS

This study combined extensive secondary research with in-depth interviews to provide a basis for considering the wide-ranging potential socioeconomic effects of OSW development in the GoM. Few specifics have been determined at the current stage of development, and it will be important to refine these types of analyses as those details emerge. Key findings at this stage include:

- The State of Maine has created a process intended to include broad stakeholders in the dialog. Proactive communication from the State is an important means of developing transparency, reducing misinformation, and opening a reciprocal dialogue between the State, community leaders and members, and other stakeholders. The State should be responsive to the feedback it receives through this dialogue, making it clear that diverse voices are being heard and considered in both directions. Fuller, more multidirectional engagement with commercial fisheries, Indigenous people, and communities that could be affected by OSW development will be important to maintaining and improving procedural equity.
- In the various scenarios analyzed, some amount of OSW will be necessary to meet state and regional decarbonization goals. The avoided carbon dioxide emissions will have a value of almost $1 billion by 2050.
- Offshore wind development in the GoM could bring as much as $3 billion in wages for Maine citizens by 2050.
- Commercial fisheries are very concerned about whether and how much OSW development in the GoM will negatively impact their ability to access the best harvesting areas in the Gulf and increase transit times. At the current stage of development, it is not feasible to provide meaningful estimates of the potential economic impacts on commercial fisheries, however, this is a critically important area for future focus.
- The tourism and recreation industry is concerned about the effects of climate change generally, and how OSW will help achieve decarbonization goals. Its greatest specific concern about OSW is whether the turbines will affect viewsheds. Existing research on the positive and negative impacts of turbine visibility is mixed.
- Community leaders are concerned primarily about affordable housing and the effect of climate change on their communities. They are very reliant on commercial fisheries and do not want to see them negatively affected. Offshore wind interests them insofar as it intersects with these issues.

3.1 Ongoing research opportunities

The areas with the greatest need for additional research are the ecological effects of floating OSW, the interactions of planned arrays with current commercial fishing activities and gathering additional input from tribes and other historically under-represented communities. As the OSW development process matures, more details will emerge about where and how many turbines will be placed in the Gulf. Additionally, the technologies used for floating arrays will continue to mature, and observations from existing research and commercial arrays will provide more information about how those technologies interact with ocean ecology and other ocean users. Additional research could address the following topics:

- Calculating meaningful estimates of potential impacts on commercial fisheries, which requires the following information:
  - The specific areas of the ocean where turbines will be installed, the configuration of the turbines, mooring technology, and inter-array cabling
  - Corridors, technology, and depth of ocean-to-shore transmission cabling
  - Levels and specific types of harvesting currently happening in areas where arrays and transmission are proposed. Sources such as the Northeast Ocean Data portal (https://www.northeastoceandata.org) and the Department of Marine Resources have data of this nature.
  - The proximity of realistic alternative areas to harvest

Some of this information will become available when BOEM announces the lease areas (predicted for mid-2023). At that point, it will be possible to determine potential overlaps between wind arrays and harvesting areas to produce a high-level estimate of potential impacts.

The more information that is available about the harvesting activities happening in those areas, the better the impact estimates will be. A collaborative research study with members of the fishing industry that gathers data about the locations, species, and magnitude of harvesting occurring in the proposed lease areas would help inform the design and siting of arrays to minimize impacts and understand how to design and site arrays to minimize the negative impacts on other ocean users.

As developers specify precise locations for arrays and the designs and layouts of those arrays, more precise estimates of ecological and economic effects will be feasible. At this point, details such as array locations, foundation distances, inter-array cabling, mooring technology, and ocean-to-shore transmission locations and depths will be known with a high degree of specificity. This is also the point when permitting studies often occur and offer an opportunity to develop these estimates.

Researchers can apply publicly available economic multipliers to estimate the indirect and induced economic activity that would also be impacted by changes to fishing activity. This would provide an apples-to-apples comparison to the economic impact calculations presented in Section 2.1 of this report.

The following is a list of additional research opportunities that could be conducted to build on this report:

- **How electrification and changes to the electricity generation mix will affect the energy burdens of low- and moderate-income households.**
- **Continued engagement with Indigenous and other historically marginalized communities and frontline communities to ensure they have ample opportunity to voice concerns and participate in decision-making.**
- **Utilize the Research Array to investigate interactions with wildlife and compatibility with commercial fishing activities.**

The Roadmap process continues to fund additional studies. As the Research Array comes online, it will also be a resource for additional research into potential interactions with wildlife and commercial fishing operations.

BOEM continues to fund additional research on OSW, floating technologies, and unique ecological impacts in the GoM [155]. These efforts include research on North Atlantic right whales and other protected species; behavior effects from sound generated by offshore construction; and marine, migratory, and federally listed bird impacts.

A collaboration between Maine Sea Grant, the Department of Energy, and NOAA is funding additional research on community engagement and the coexistence of offshore energy generation and Northeast fishing and coastal communities (https://seagrant.umaine.edu/2022/05/19/sea-grant-doe-noaa-fisheries-fund-six-projects-for-the-coexistence-of-offshore-energy-with-northeast-fishing-and-coastal-communities/).

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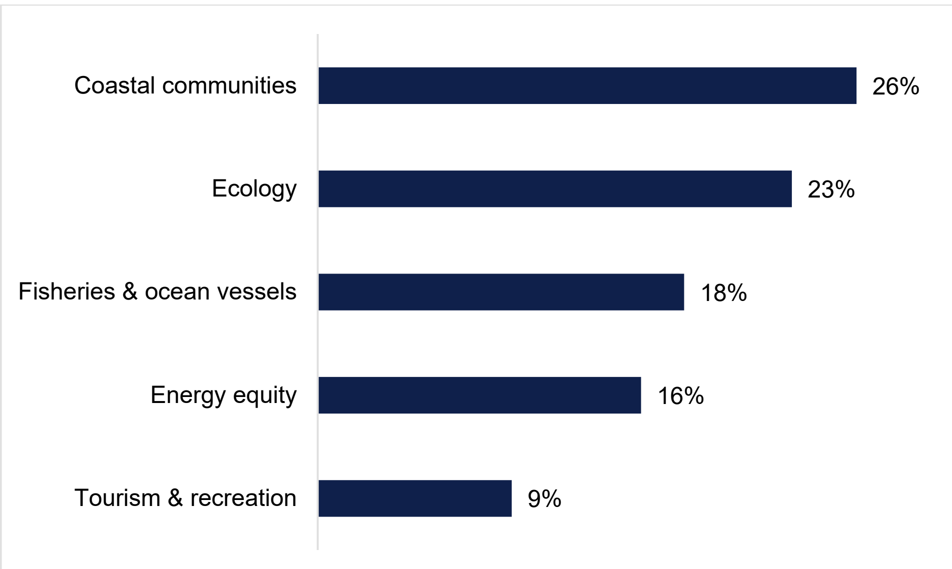
APPENDIX A. DETAILED METHODOLOGY

Literature review

To provide a complete accounting of the socio-economic benefits and costs of increased OSW development in the GoM, the DNV team completed a literature review of existing research supported by the University of Maine and other advisable resources. We reviewed 176 sources covering the current state and trends of the OSW industry and experiences from more mature developments in other parts of the United States and Europe (see Bibliography). Specific topic areas included coastal communities, tourism and recreation, fisheries and other ocean users, ecology, and energy equity and environmental justice. Figure 4-1 shows the percent of the reviewed sources that cover each of the major topics.

Figure 4-1. Literature review topic breakdown



Assessed potential ecological and wildlife impacts – Using publicly available data, literature, and technical reports, DNV completed an ecological impact analysis on the existing environmental conditions and biological resources to identify gaps in the literature, review key potential ecological risks and benefits that may result from OSW development in the GoM, and provide recommendations for addressing these gaps and risks. Potential impacts and benefits and recommendations were assembled based on the Bureau of Ocean Energy Management (BOEM) and other agency guidance documents, the most current literature, and permitting documentation from other OSW energy projects in the region. Additional considerations for impacts that are yet to be encountered due to the novel nature of floating OSW infrastructure in the GoM and future potential climate change impacts were also assessed.

The research team completed the bulk of the literature review in November, 2021. The research team reviewed 148 references by that time. Since then, an additional 28 sources have been added to address specific questions from reviewers. No comprehensive literature review has been attempted since November, 2021.

In-Depth Interviews

To bolster our literature review and other research with information regarding the latest activity in the state and help support the research conducted for this Task, DNV completed 64 interviews between January 2022 and April 2022 and included a variety of perspectives from individuals spread out around the state.

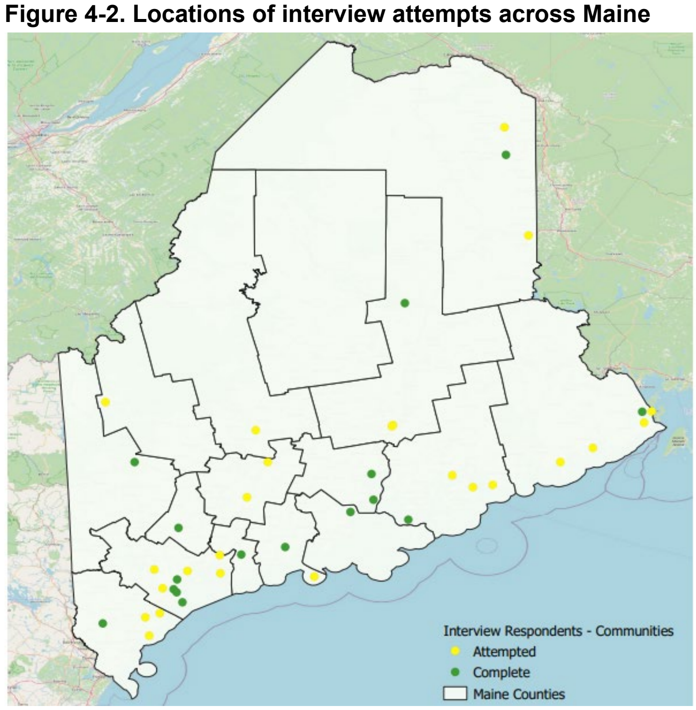
Following our literature review, the DNV team developed interview guides that incorporated questions to help understand the existing culture the tourism, fishing and coastal/non-coastal communities in Maine. The team met with several Fishery Working Group members, the Department of Maine Resources (DMR) and other prominent fishing representatives in the state to help bring a local, personalized list of questions to guide these conversations. These initial conversations helped the team develop interview guides that provided the DNV team with a baseline understanding of existing issues and conversations happening in Maine which were used to help understand what benefits OSW can bring and what existing challenges OSW could help alleviate.

Prior to conducting the interviews, the DNV interview team was provided with background information collected from these initial interviewees to gather a baseline understanding of these communities and the importance Maine and these industries have on their families, culture, and community. Interviewers were then trained by senior staff members on how to conduct these interviews and practiced in pairs interviewing each other internally to understand the flow of conversation and ask important follow up questions. Staff members shadowed senior staff prior to conducting their own interviews.

These interviews with the following groups included the following topics:

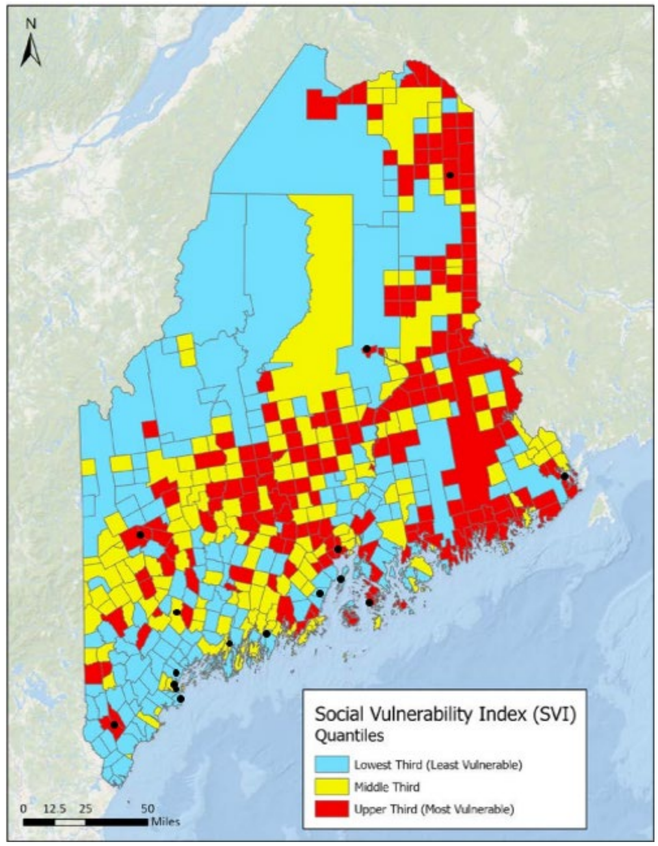
- **Tourism and recreation industries –** Interviews were conducted with Tourism and Recreational agencies, associations, and businesses throughout Maine. Large agencies representing the tourism and recreational industries were able to speak generally of the industries in Maine. Private tourism and recreational businesses were interviewed from different sectors of the industries utilizing the GoM that could potentially be impacted by OSW. These sectors include the birding, whaling, and boating industries among others. These interviews included questions about their perspectives on top tourism and recreation attractions along the GoM, why Maine is special for these activities, current issues the industries are facing, and what areas of tourism and recreation could be most impacted by OSW development (including topics such as increased construction, impacts to rental homes, and increased ocean use)
- **Fishing and other ocean users –** Included in this group of interviewees are fishermen and lobstermen, Fisheries Working Group Members, Lobster Zone Council Members, and individuals' part of other applicable groups and associations. These interviews included questions about their role in the fishing industry and their history and background fishing in the community and to the extent it dates back to their family history and their way of life. These interviews also touched on understanding the existing issues fishermen face, challenges they are experiencing to date, and what additional benefits and or challenges might arise from future OSW development and potential solutions to mitigate and added challenges.

Figure 4-2. Locations of interview attempts across Maine



- **Coastal and non-coastal communities –** Interviews were conducted with locals around the State along the coast and those inland, in the Downeast, mid-coast, and southern part of Maine (Figure 4-2). Most (14 out of 17) respondents represented municipal governments and had positions such as Town Managers, Economic and Community Development staff, and Planning and Development staff. Three of the 17 completed interviews were with respondents that represented trade organizations such as chambers of commerce. These interviews included questions about their community's historical and cultural benefits, existing problems facing the community and their future, and possible scenarios of different implications of how OSW development could impact their community (including topics such as maritime jobs, ocean use, and general perceptions of OSW being introduced to their culture). Environmental justice and social vulnerability scores for the interviewed communities were not readily available at the town level from the Maine Community Resilience Partnership website (https://www.maine.gov/future/climate/community-resilience-partnership), the Maine Climate Council (https://www.maine.gov/future/initiatives/climate/climate-council) and its equity working group, or EJScreen (ejscreen.epa.gov). A visual overlay (Figure 4-3) of the completed interviews with the Maine state vulnerability index map [170] indicated that 7 of the completed interviews occurred in areas within the upper third tercile (most vulnerable) of the social vulnerability index. Another three of the completed interviews were in areas win the middle tercile of the social vulnerability index.

Figure 4-3. Visual overlay of completed interviews



- **Tribes –** The original research scope did not include communication with Indigenous tribes. Upon input from the Roadmap working groups, the research team added interviews with tribal representatives to the research plan. Tribal contact information was obtained from the working group members who made the recommendations and from GEO. The research attempted to reach four Indigenous tribes but was unable to make contact with any.

The interviews were conducted by phone. The study protocol required at least three attempted contacts before considering a potential respondent unreachable. Callers left voicemails when possible. Table 4-1 summarizes the attempted and completed interviews. The overall completion rate was 45%, which is well above current national averages (<6%) for phone surveys [173].

Table 4-1. Evaluation interview summary

Interviewee group	Attempted Interviews	Completed Interviews
Coastal and non-coastal communities	42	16
Fisheries and ocean users	53	31
Tourism and recreation groups/organizations	43	17
Indigenous tribes	4	0
Total interviews	**142**	**64**

Quantitative estimates

DNV conducted three types of quantitative socioeconomic impact estimates: 1) economic impacts on jobs and wages, 2) the social costs of avoided carbon emissions, and 3) the health costs of other avoided air pollutants. DNV utilized two OSW scenarios to establish specific amounts of installed OSW capacity and determine what type of generation that capacity would displace.

Offshore wind scenarios

DNV described the state of the OSW industry, the most likely implications for Maine, and identified several potential wind development scenarios in previous reports [153] [157]. Five assumptions informed the scenario development:

- There is expected to be a continued prohibition on OSW development in state waters.
- Offshore wind development will be focused in federal waters.
- 100% of the technology deployed will be floating OSW turbines due to the characteristics and depth of the ocean floor in Federal waters of the GoM.
- The theoretical maximum potential of OSW generation in the GoM is assumed to be 155 MW in 2030, 5 GW in 2040 and 20 GW in 2050. [10]
- The levelized cost of energy for floating OSW will be cost competitive with fixed-bottom OSW by 2050.

The socioeconomic analyses focus on the two Diverse Portfolio scenarios developed in the previous research. These scenarios both assume aggressive decarbonization efforts in the region and provide a low and high estimate of OSW needs. Anchoring the socioeconomic analyses on these two scenarios gives readers a sense of the range of outcomes that are likely to occur over the next several decades.

The base case demand, diverse portfolio scenario projects Maine's OSW capacity needs to grow from 155 MW in 2030 to 2,086 MW by 2050. Regional needs will grow from 155 MW in 2030 to 3,312 MW in 2050. The "decarbonization" (high) demand scenario differs from the base case scenario at the regional level. In the decarbonization scenario, regional OSW requires quicker ramp up – 1,619 MW by 2040 – and are ultimately higher – 11,216 MW by 2050. The needs for Maine specifically are the same in both scenarios [153].

Table 4-2. Maine and regional OSW capacity needs in diverse portfolio scenarios

Year	Base case demand (MW)		Decarbonization demand (MW)	
	Maine	New England	Maine	New England
2030	155	155	155	155
2040	305	305	305	1,619
2050	2,086	3,312	2,086	11,216

Both Diverse Portfolio scenarios assume that the region will pursue decarbonization aggressively enough that it will first look to renewables to fit capacity needs before developing additional fossil fuel generation. In 2030, both scenarios predict there will be sufficient hypothetical onshore renewable capacity to make up any that is not provided by OSW. However, by 2040 (and beyond), the scenarios assume that all hypothetical onshore capacity will be deployed, and therefore, anything not contributed by OSW would have to come from fossil fuels. Based on current fossil fuel generation mixes [29] in Maine (96%

[10] Includes GoM Floating Offshore Wind Research Array to be developed through a University of Maine collaboration with New England Aqua Ventus, LLC (NEAV), a joint venture between Diamond Offshore Wind, a subsidiary of the Mitsubishi Corporation, and RWE Renewables. The state's first pre-commercial-scale floating OSW project expected to contribute Class 1A renewable energy credits (RECs). The draft analysis does not include the University of Maine's Aqua Ventus I single-turbine 11 MW demonstration project.

natural gas) and the region (98% natural gas), DNV assumed the displaced fossil generation would be from combined-cycle natural gas turbines.

Economic impacts

DNV used the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) OSW tool to estimate the job creation and economic benefits for the total New England demand levels predicted in the two OSW scenarios detailed in Table 4-2. The JEDI tool is widely accepted by government agencies at federal, state, and local levels as well as private companies and international organizations as a reliable estimator of job and economic impacts from wind energy projects [96].

JEDI incorporates over 200 inputs such as technical characteristics, project costs, and local materials and labor shares to output impact results. NREL provides default values for these inputs based on information gathered from developers and industry experts on the average specifications and costs of existing projects [96]. DNV obtained supplemental data for induced job multipliers from the Economic Policy Institute to aid in calculating induced jobs during the operations phase.

JEDI is intended to estimate jobs resulting from specific, individual projects, and it cannot model projects with capacities much larger than 1 GW. To overcome this limitation, for years when the scenarios predicted more than 1 GW of installed capacity, DNV created multiple 1 GW projects and summed the outputs. In cases where the prediction was not an even GW, we ran one additional model for the project size necessary to add up to the total installed capacity. For example, the base demand scenario predicts 3,312 MW (3.312 GW) installed capacity in 2050. DNV created three 1GW projects and a fourth, 312MW project and summed those outputs together to derive the economic impacts for that scenario.

The JEDI model allows users to adjust many parameters. For the Maine-specific JEDI analysis, DNV used the following parameters.

- 15 MW semisubmersible OSW turbines. Turbines of this size are expected for OSW installations starting around 2030 [100].
- A grid layout with 7 turbine-diameter spacing (NREL default values).
- A floating-type turbine installation due to Maine's coastal depths and bathymetry.
- The distance from the port to the site was assumed to be 40 kilometers (km) and the offshore substation to landfall was assumed to be 20 km. Maine state legislation L.D.-1619, no OSW projects are permitted in state waters. This ensures that any OSW project would be at least 3 nautical miles from the coast [37].
- The distance between the site and offshore substation is assumed to be 2 km, the distance from landfall to interconnection is assumed to be 10 km, and landfall trench length is assumed to be 3 km. These inputs were based on NREL average distances provided in the JEDI model.
- The depth at the project site is assumed to be 300 feet based on known characteristics of the GoM.
- Default NREL values for project costs, adjusted for inflation and DNV's projections of improved supply-chain efficiencies through 2050.

The JEDI model also allows adjustments to the portion of project spending that occurs in a local region ("local share"), to determine the economic impact of OSW development in the construction and operating periods of a project. There are 65 separate adjustable inputs that enable the model to reflect a very wide range of the local region's contribution to the offshore supply chain. Local share parameters include categories for: turbine components and labor, project development such as site assessments and permitting, soft costs such as commissioning and decommissioning operational expenditures, and financial parameters including project finance and taxes [95]. Adjustable inputs can range from 0% to 100% local share.

For this analysis, DNV interpreted "local" to be specific to the state of Maine, though there is some indication that some level of cross-state supply chain coordination for the OSW industry could enhance investment impact [50]. Additionally, DNV assumes that as the Maine OSW industry matures, there will be an investment in the local supply chain specific to component manufacturing, skilled workforce development, and specialized OSW construction and maintenance vessel fleets and ports to meet the local OSW demand. It is commonly accepted that local supply chain development is critical to avoiding cost limitations involved with importing large OSW components such as blades, towers, nacelles, and generators, and allows for more cost-effective projects [89].

Currently, there are no regulations in Maine governing the local share of materials and labor that must be used for renewable energy projects.[11] Without such local share quotas, DNV chose two local share scenarios that display the range of economic benefits offered by OSW. To display this range, DNV elected to quantify a short-term and a long-term development scenario largely associated with JEDI input categories including turbine component costs, the balance of system costs, and electric infrastructure components for each of the previously specified generation scenarios (Table 4-3).

Table 4-3. Local shares in short-term and long-term development scenarios

Development scenario	Turbine components Balance of system Electric infrastructure	Ports and staging Vessels and labor Operational expenditure
Short term (low local content)	10% local share	30% local share
Long term (high local content)	50% local share	80% local share

This short-term scenario assumes a local content share of 10% for turbine components, system balancing, and electric infrastructure expenses. This 10% is also applied to several parameters that fall under the JEDI Local Share input categories of Assembly and Installation and Financial. The 10% input is meant to reflect a minimum local input for a variety of OSW supply chain needs in the short term based on the current minimal to non-existent OSW local manufacturing industry in the region. This 10% also reflects the beginning of a transition for the Maine OSW industry, moving away from a sole reliance on non-local supply chain contributions to provide a small portion of the components and associated labor needed to construct Maine's early OSW projects. Considerations that support a low short-term local share for these categories include:

- Most established OSW equipment suppliers are in Northern Europe. These firms are pursuing the design and production of offshore turbine foundations, monopiles, and other steel construction materials [98].
- The size of OSW turbine foundations would normally necessitate local production, but the lack of local production capacity could force imports. For the Cape Wind project, Mass Tank plans to partner with German-based EEW to make monopile foundations [98].
- Even with domestic onshore manufacturing content increasing, complex components such as nacelle internals would still likely need to be imported for the short term [98].

In the long-term scenario for JEDI, DNV increased the local share for turbine components, balance of system, and electric infrastructure components to 50%. This increase reflects what a more mature local supply chain could provide in local benefits pending investment in local component manufacturing and workforce development. DNV chose to limit local share contributions for these categories in the long-term development scenario to 50% to reflect what may be considered a maximum realistic local supply chain manufacturing contribution based on the following:

- The economic impacts estimate for the Aqua Ventus projects used an assumption of 70% local contribution to all non-turbine components [38] because of the unique construction methods planned for those arrays.

[11] Although there are some precedents. P.L. 2019 Ch. 477, which procured renewable resources giving 30% selection weight to economic benefits. For more info see: https://www.maine.gov/mpuc/regulated-utilities/electricity/rfp-awarded-contracts/class1a2020, and https://www.maine.gov/mpuc/regulated-utilities/electricity/rfp-awarded-contracts/class1a2021. L.D. 336 also calls for 50% local content for to be used for the Research Array.

- Ontario, Canada, implemented a local content wind requirement of 50% for some time until it drew backlash from the World Trade Organization. The requirement was subsequently canceled for large-scale projects and carried reduced thresholds for smaller projects [10].
- The U.K. government requires 50% of the supply chain to be local content by 2030. Currently, many major components and subsystems are manufactured outside the UK [145]. The Scottish ministry recently raised this requirement to 60% [156].
- In October 2005, a call for tenders was released by Quebec, Canada, for local wind farm development with 2,000 MW of wind capacity to be installed from 2009-2013. This call for tender required that 30% of the cost of the equipment be spent in the Gaspe Peninsula region and 60% of the entire project costs must be spent within Quebec Province. A previous tender released by Quebec pursued local content requirements for wind farms related to 1,000 MW of wind delivery between 2006 and 2012 as a way to aid the economic revitalization of the Gaspe Peninsula. The government insisted that Quebec's wind power development support local manufacturing and job creation by requiring that 40% of the total cost of the first 200 MW, 50% for the next 100 MW, and 60% for the remaining 700 MW. The government also stipulated that the turbine nacelles be assembled in the region, and that project developers include in their project bidding documents a statement from a turbine manufacturer guaranteeing that it will set up assembly facilities in the region. GE was subsequently selected to provide the turbines for a total of 990 MW of proposed projects upon its agreement to meet a 60% local content requirement and is currently establishing three manufacturing facilities in Canada [76].
- There is also evidence of significant potential for local supply of OSW turbine content based on the onshore wind turbine market, where 67% of land-based wind turbine content is supplied domestically. The Aqua Ventus offshore floating turbine components are being manufactured in Searsport, Maine [81]. While this demonstrates the state's ability to produce the necessary components for offshore turbines, at a larger scale, components associated with OSW turbine capacity may require aggressive domestic supply chain ramp-up to meet these specific needs [50]. Another stipulation of enhancing local content share is a stable and growing market for renewables as signified by clear auction requirements and strong feed-in tariff policies [12].

DNV's short-term and long-term scenarios also informed the JEDI input categories that focus on ports and staging, vessels and labor, and operational expenses. For the short-term scenario, we applied a 30% local share assumption for these categories. This assumption was based on a consideration of Maine's strong maritime labor force, vessels, and ports, combined with the need for a specialized labor force, equipment, and infrastructure to complete installations. For example, there are presently no US-flagged vessels that can readily install 6 MW turbines in deep waters. Thus, construction in the GoM is likely to require foreign-flagged, specialized vessels to mobilize from Europe [25], even after controlling for the effects of the Jones Act.

For the long-term, DNV increased the local share assumption for Ports and staging, Vessels and labor, and Operational expenses to 80% to reflect what a mature local supply chain, including a skilled workforce, could provide in terms of local economic benefits.

Limitations

While the JEDI model is detailed in its considerations, it is only intended to provide estimates and not precise predictions. Additionally, the model's outputs are estimated as gross project benefits rather than net benefits. For example, connecting wind energy to the grid may offset the need for other energy sources, resulting in job loss in other sectors. The loss of jobs in other sectors or incremental job changes are not incorporated into JEDI model outputs [96], nor is it included in DNV's job creation numbers. The JEDI model also assumes fixed prices throughout the supply chain. Any changes in project costs, electricity prices, wages, or taxes are not considered. The results are not constrained by project resource availability or barriers [95].

Air quality

The air quality estimates used the same deployment and counterfactual scenarios to determine what type of generation would be displaced by OSW. DNV then utilized the EPA's AVERT [31] model to estimate avoided air pollution emissions from OSW deployment. AVERT was designed by the EPA to meet the needs of state air quality planners and other stakeholders. AVERT helps stakeholders assess the impacts of energy policies and programs by quantifying resulting changes in emissions of fine particulates, nitrogen oxides, sulfur dioxide, carbon dioxide, volatile organic compounds, and ammonia.

DNV utilized a second EPA tool, COBRA [154] to estimate the health cost effects of those amounts of emission reductions. COBRA takes changes in pollution emissions of fine particulates, sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds. COBRA allows the user to select a region and economic sector generating the emissions, and the amount of each type of pollutant reduced. It then outputs public health benefits for a wide range of health endpoints including: mortality, infant mortality, nonfatal heart attacks, respiratory hospital admissions, cardiovascular hospital admissions, acute bronchitis, upper respiratory symptoms, lower respiratory symptoms, emergency room visits for asthma, minor restricted activity days, work loss days, and asthma exacerbation. The tool allows the user to specify a locality where the benefits would accrue and a discount rate for the monetary value. The final output is a high and low estimate of annual dollars saved, in the specified locale, from the specified pollution sources.

DNV used this model by specifying emissions from the New England states (Maine, New Hampshire, Vermont, Connecticut, and Massachusetts) from the electric utility combustion sector. For output, DNV restricted the benefits to Maine only and specified a 3% discount rate.

Maine's electricity generation profile

Maine is already one of the leading states when it comes to the share of its generation that comes from renewables. According to the latest data available from the EIA [29], Maine already derives approximately 3/4ths of its electricity from non- fossil fuel sources, if one includes hydroelectric and biomass.

Based on Maine's current generation profile, the current ISO-NE interconnection queue, the State of Maine Renewable Energy Goals Market Assessment report [28] and six scenarios developed in the DNV Wind Energy Needs Assessment [157], DNV predicts that electricity generated by offshore wind is most likely to displace existing natural gas-fired generation. and six scenarios developed in the DNV Wind Energy Needs Assessment [157], DNV predicts that electricity generated by OSW is most likely to displace existing natural gas-fired generation.

- According to the October 2021 EIA report [29], almost all (96%) of Maine's and New England's (98%) current fossil fuel-fired generation comes from natural gas.
- The six scenarios developed in the Wind Energy Needs Assessment all assume rapid demand increase in Maine due primarily to the electrification of the transportation sector. DNV predicts that demand will outpace the ability of onshore renewables to keep pace. Therefore, if energy demand is not satisfied by OSW, it will have to be generated by some other source.

About DNV

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.