

Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios

Tony Jimenez, David Keyser, Suzanne Tegen,
and Bethany Speer
National Renewable Energy Laboratory



This report is available from the Bureau of Ocean Energy Management by referencing OCS Study BOEM 2016-030. The report may be downloaded from BOEM's Recently Completed Environmental Studies - Pacific webpage at <http://www.boem.gov/Pacific-Completed-Studies/>.

This study was funded by the U.S. Department of the Interior, Bureau of Ocean Energy Management through Interagency Agreement M14PG00038 with the U.S. Department of Energy.

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Strategic Partnership Project Report
NREL/TP-5000-65421
May 2016

Contract No. DE-AC36-08GO28308



Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios

Tony Jimenez, David Keyser, Suzanne Tegen,
and Bethany Speer
National Renewable Energy Laboratory

Prepared under Task No. WFHA.1000



This report is available from the Bureau of Ocean Energy Management by referencing OCS Study BOEM 2016-030. The report may be downloaded from BOEM's Recently Completed Environmental Studies - Pacific webpage at <http://www.boem.gov/Pacific-Completed-Studies/>.

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Strategic Partnership Project Report
NREL/TP-5000-65421
May 2016

Contract No. DE-AC36-08GO28308

NOTICE

This study was funded, in part, by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific Region, Camarillo, CA, through BOEM Interagency Agreement Number M14PG00038. The report has been technically reviewed by BOEM and it has been approved for publication. The views and conclusions contained in this report are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This manuscript has been authored by employees of the Alliance for Sustainable Energy, LLC (“Alliance”) under Contract No. DE-AC36-08GO28308 with the U.S. Department of Energy (“DOE”).

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Acknowledgments

We would like to thank the Bureau of Ocean Energy Management (BOEM) and the U.S. Department of Energy for funding the model used in this work under Interagency Agreement number 14-1944 (BOEM M14PG00038). We thank BOEM for funding this research and report about economic potential in the state of Oregon. In particular, we thank Doug Boren, Sara Gultinan, and Frank Pendleton for their guidance. We thank Julie Peacock of the Oregon Department of Energy, Jason Busch of the Oregon Wave Energy Trust, Ben Maples of RES Americas, and Aaron Smith and Kevin Banister from Principle Power for their advice and review. In addition, we thank Walt Musial, Tyler Stehly, Philipp Beiter, and Mike Maness of the NREL for their technical assistance and Karin Haas, Dave Corbus, and Brian Smith of NREL for their review.

Executive Summary

Construction of the first offshore wind power plant in the United States began in 2015, off the coast of Rhode Island, using fixed platform structures that are appropriate for shallow seafloors, like those located off of the East Coast and mid-Atlantic. However, floating platforms, which have yet to be deployed commercially, will likely need to anchor to the deeper seafloor if deployed off of the West Coast.

To analyze the employment and economic potential for floating offshore wind along the West Coast, the Bureau of Ocean Energy Management (BOEM) commissioned the National Renewable Energy Laboratory (NREL) to analyze two hypothetical, large-scale deployment scenarios for Oregon: 5,500 megawatts (MW) of offshore wind deployment in Oregon by 2050 (Scenario A), and 2,900 MW of offshore wind by 2050 (Scenario B). These levels of deployment could power approximately 1,600,000 homes (Scenario A) or 870,000 homes (Scenario B). Assumptions for this analysis come from projected electricity demand in the Northwest, the estimated offshore wind resource, and discussions with industry, as well as ongoing work at NREL to better characterize the current and future cost breakdowns of floating offshore wind systems. Many of the cost inputs come from NREL's internal Offshore Wind Balance of System (BOS) model. Figure ES-1 shows the hypothetical deployment scenarios beginning with small-scale demonstration projects in 2020.

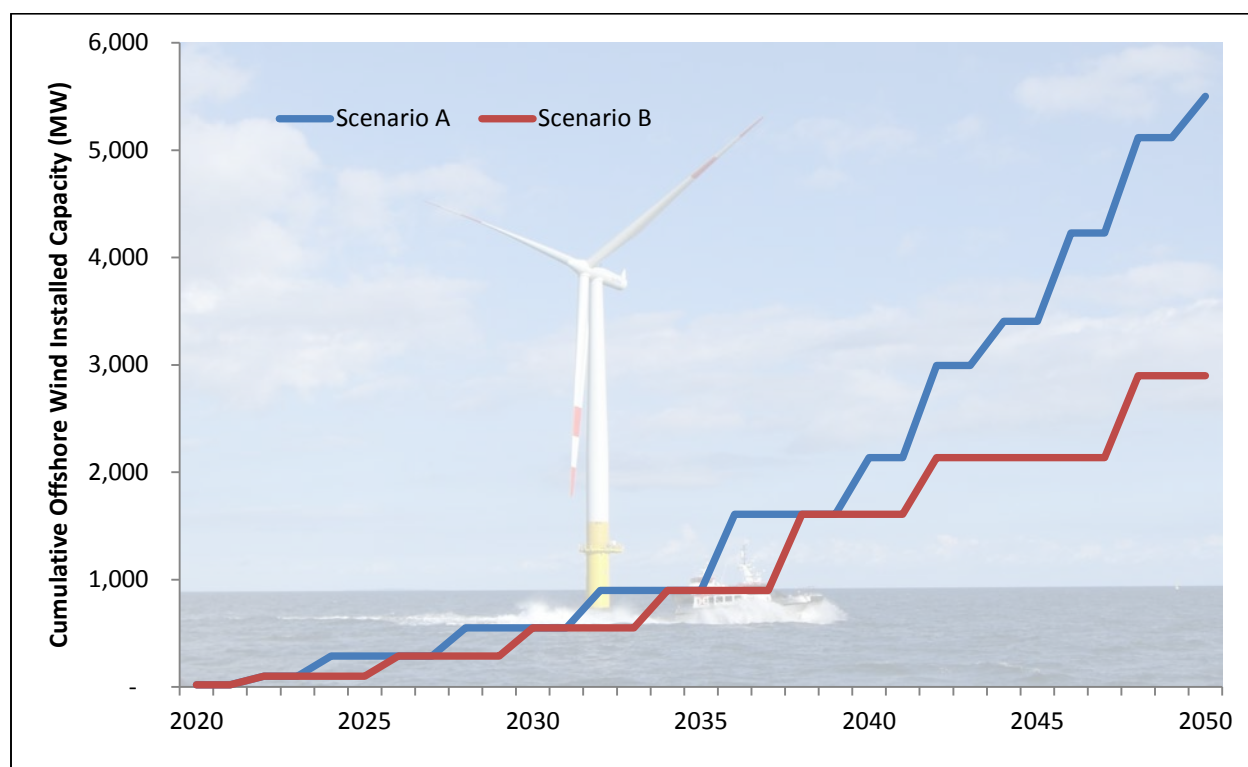


Figure ES-1. Two Oregon offshore wind deployment scenarios modeled between 2020 and 2050

Photo: Siemens Turbine, Baltic Sea, NREL/PIX 26995

For each of the two scenarios, we examined two sets of values for the Oregon content, meaning that in one case, there is more Oregon labor and there are more Oregon parts and equipment.

Results from examining two sets of local content values show that the estimated economic impacts vary greatly depending upon the local labor and equipment used for the offshore wind energy projects and supply chain.

The impacts highlighted here can be used in state and regional planning discussions and can be scaled to get a sense of the economic development opportunities associated with other deployment scenarios. In addition, the analysis can be used to inform stakeholders in other states about the potential economic impacts of this scale of floating offshore wind technology development.¹

According to the Scenario A analysis, deploying 5,500 MW of floating offshore wind in Oregon and assuming a modest in-state supply chain could:

- Support between \$4.6 billion and \$5.7 billion in construction-phase economic activity to Oregon’s gross domestic product (GDP)² between 2020 and 2050.
- Support between 44,000 and 66,000 full-time equivalent (FTE)³ construction-phase job-years (Figure ES-2) between 2020 and 2050. A job-year is one full time job for one year. For example, 1 person working full time for 10 years or 2 people working full time for 5 years each total 10 job-years. See Figure ES-2.
- Support 21,000–30,000 operations-phase job-years during the analysis period (2020–2050).
- Support an estimated 300 long-term operations-phase jobs in 2030; 1,200 long-term jobs in 2040; and 2,300–3,400 long-term jobs after the analysis period (Figure ES-3). Long-term jobs last for the duration of the offshore wind project.
- Add a total of \$2.2 billion–\$3.2 billion in operations-phase additional state GDP during the analysis period and \$250 million–\$350 million annually after the end of the analysis period.

Figure ES-2 shows construction phase jobs in Oregon with both local content cases. “High LC” represents the high in-state content, and “low LC” represents low in-state content assumptions. Spikes in construction-phase jobs correspond to installation activity. Figure ES-2 shows the ongoing jobs due to O&M phase activities. Unlike construction-phase jobs, which are short term, operations-phase jobs are enduring, lasting for the lifetime of the facility. The number of operations-phase jobs starts out small but increases over time as the number of installed offshore wind projects increases.

One key finding from this work is the sensitivity of the results to the magnitude of the in-state supply chain. Establishing an in-state supply chain that can provide even a modest portion of the material and labor for floating offshore wind installations would dramatically increase the economic impact of offshore wind deployment within the state.

¹ NREL has performed similar research analyzing the impact of floating offshore wind deployment for the Oregon coastal counties, California, and Hawaii.

² GDP is the sum of: the value of production (i.e., the amount of revenue beyond expenditures paid to other industries), payments to workers, payments to investors, and net tax payments. This is labeled “value added” in the Jobs and Economic Development Impacts (JEDI) models, but is referred to as GDP throughout this report.

³ An FTE job is considered one person working full time or the equivalent (e.g., 2 people working full time for 6 months each).

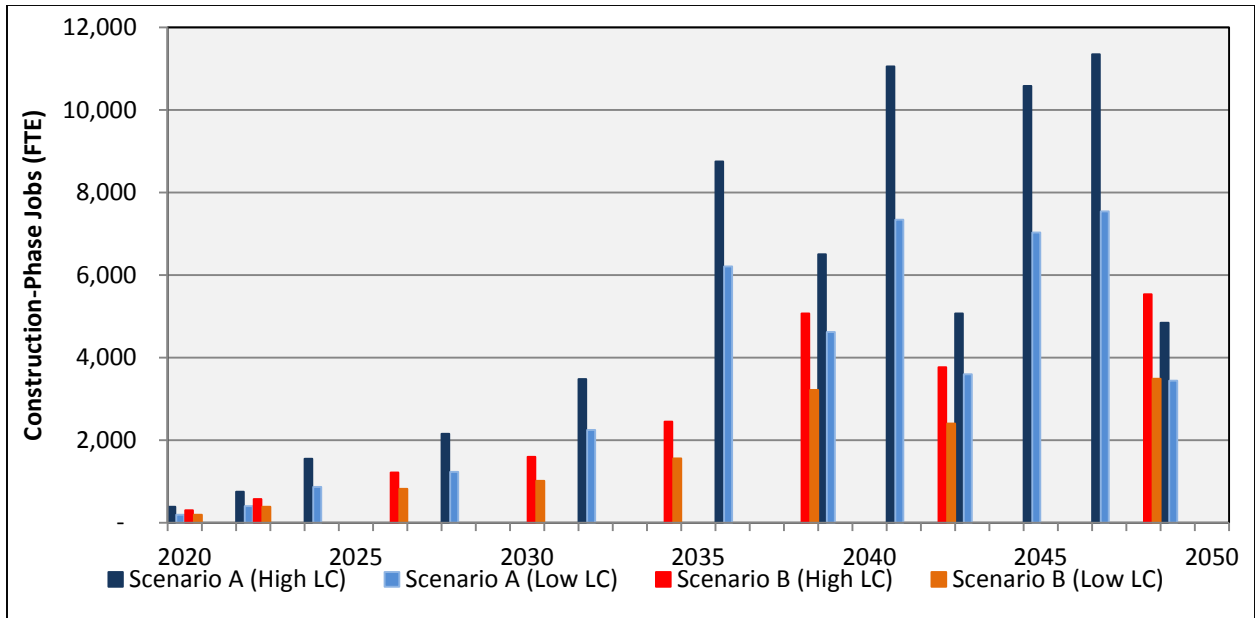


Figure ES-2. Annual construction phase jobs supported in Scenario A and Scenario B with high and low local content

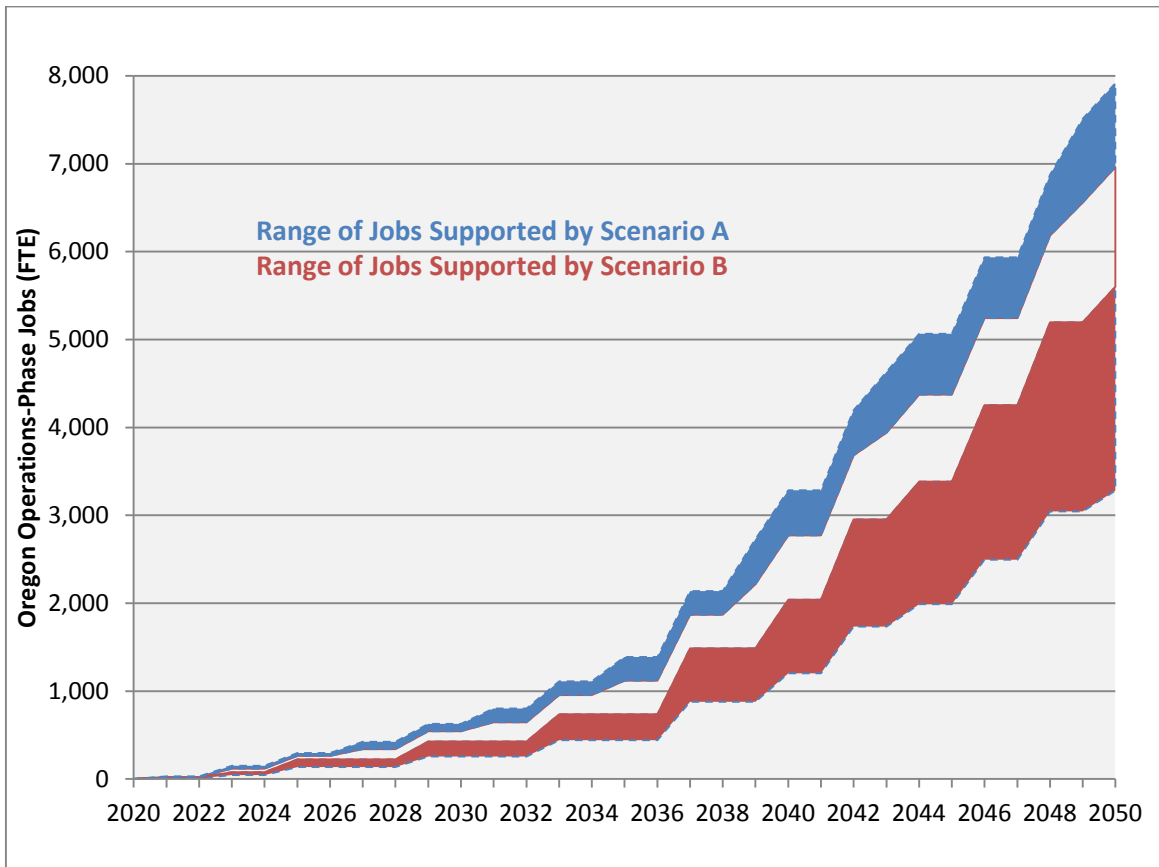


Figure ES-3. Oregon's operations-phase jobs (FTE) supported by offshore wind projects during the analysis period, showing ranges from low to high local content

Table of Contents

1	Introduction	1
2	Methodology	5
3	Scenarios	9
4	Results	17
	4.1 Construction Phase.....	17
	4.1.1. Job Years.....	19
	4.2 Operations and Maintenance: the Operations Phase	19
5	Conclusion	23
6	References	24
	Appendix A. Floating Offshore Wind Projects Installed or Under Construction	25

Figures and Tables

Figure ES-1.	Two Oregon offshore wind deployment scenarios modeled between 2020 and 2050	iv
Figure ES-2.	Annual construction phase jobs supported in Scenario A and Scenario B with high and low local content	vi
Figure ES-3.	Oregon’s operations-phase jobs (FTE) supported by offshore wind projects during the analysis period, showing ranges from low to high local content	vi
Figure 1-1.	Oregon offshore wind resource	2
Figure 1-2.	Illustration of types of offshore wind turbine platforms	3
Figure 2-1.	JEDI model economic ripple effect: sample jobs in offshore wind	7
Figure 3-1.	Offshore wind deployment for both growth scenarios	9
Figure 3-2.	Scenarios with high and low percentages of local content over time.....	15
Figure 4-1.	Annual construction-phase jobs supported in Scenario A and Scenario B	17
Figure 4-3.	Oregon’s range of operations-phase jobs supported by offshore wind during the analysis period, with ranges showing low to high local content.....	20
Table 3-1.	Analysis Cost Assumptions.....	11
Table 3-2.	Local (Oregon) Content Assumptions—Construction	13
Table 3-3.	Local (Oregon) Content Assumptions—O&M	14
Table 4-1.	Average Annual Construction-Phase Impacts by Decade	18
Table 4-2.	Approximate Average Annual Earnings for Construction Phase Jobs (\$ 2014)	19
Table 4-3.	O&M Impacts for Selected Years	21
Table 4-4.	Average Annual Earnings for O&M-Phase Jobs (\$ 2014)	21
Table A-1.	Floating Offshore Wind Projects.....	25

1 Introduction

Oregon has the technical wind energy resource potential to power approximately 60 MW off of its coast (Musial et al., forthcoming).⁴ Figure 1-1 shows Oregon’s offshore wind resource. The estimate of potential energy production is simply the capacity potential from the wind and technology—not an approximation of what actually will be built. The raw estimate does not factor in important siting restrictions or other uses for the offshore space that will be necessary, such as shipping lanes and environmentally sensitive areas.

To better understand the potential economic impacts of large-scale deployment of floating offshore wind technology, the Bureau of Ocean Energy Management (BOEM) commissioned the National Renewable Energy Laboratory (NREL) to conduct this economic impact analysis of large-scale floating offshore wind deployment in Oregon. The analysis examined two deployment scenarios in the 2020–2050 timeframe: a higher deployment scenario totaling 5.5 GW and a lower deployment scenario at 2.9 GW. It should be noted that both scenarios are hypothetical and are not intended to be forecasts of actual deployment.

The results highlighted in this report can be used in state and regional planning discussions and can be scaled to get a sense of the economic development opportunities associated with various offshore wind deployment scenarios. In addition, the analysis can be used to inform stakeholders in other states about the potential economic impacts of this scale of floating offshore wind technology development. Assumptions for this analysis were developed based on interviews with the offshore wind industry and Oregon offshore development and renewable energy experts, and ongoing work at NREL to characterize the current and future cost breakdowns of floating offshore wind farms. Many of the cost inputs come from NREL’s Offshore Wind BOS model. This work builds off of similar analyses of the economic potential of offshore wind development off of the coasts of California and Hawaii as well as an analysis of the Oregon coastal county economies (Speer et al. 2016; Jimenez et al. 2016a; Jimenez et al. 2016b).

The potential offshore wind capacity and generation scenarios in this report are based on analysis of the wind resource off the coast of Oregon and the best-fit offshore wind technologies given water depths, wind conditions, and other factors. These estimates are not an approximation of the amount of wind projects that will be built and they do not factor in important considerations such as siting restrictions, permitting issues, or environmentally protected or sensitive areas. Figure 1-1 shows Oregon’s offshore wind speeds at a height of 100 meters.

In 2016, the Oregon State Legislature passed Senate Bill 1547, titled “Elimination of Coal from Electricity Supply,” which revised the state’s renewable energy target to 50% by 2040. It also requires that utilities no longer purchase coal starting in 2035. Offshore wind is one renewable energy resource option that could help Oregonians meet their renewable energy target by 2040.

⁴ We list technical potential, which is based strictly on resource—not on policy, permitting, or other important considerations. Not all of this resource will be developed. The technical resource estimate excludes water depth greater than 1,000 meters, wind speeds below 7 meters per second, and conflicting use (e.g., marine sanctuaries). See Musial et al., forthcoming.

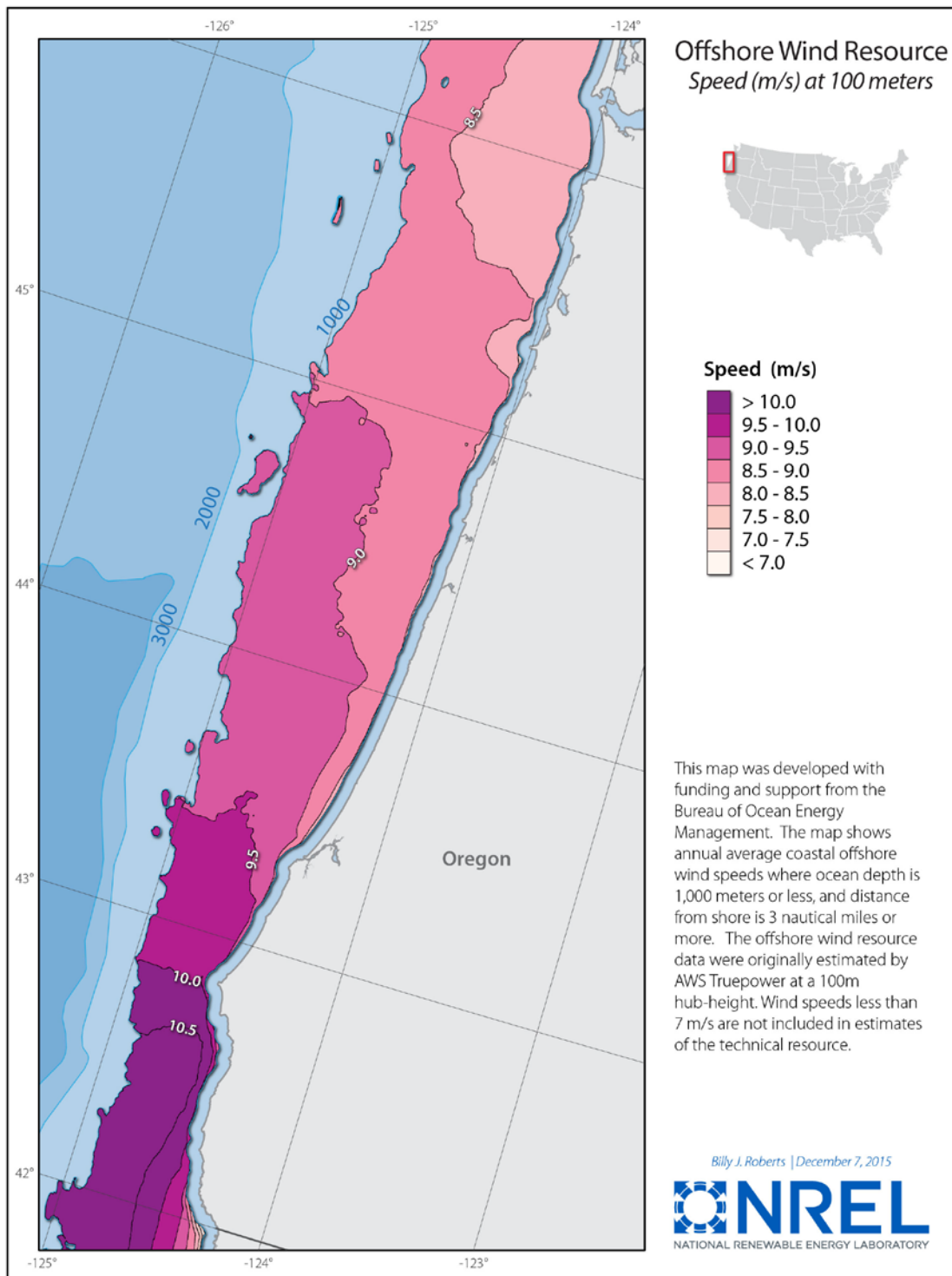


Figure 1-1. Oregon offshore wind resource

Source: NREL

Offshore wind technology for deep water is still in the development stages. Due to the significant depth of the ocean floor off the coast of Oregon, it is not feasible to use proven fixed-bottom offshore wind platform technologies at most sites. Fixed bottom offshore wind structures only work in waters that are less than 60 meters deep. Based on recent studies, fixed bottom offshore wind structures are less economical than floating systems in waters deeper than 60 meters. Compared to Europe, Oregon has a much smaller area of shallow seafloor. While no commercial⁵ floating wind farms yet exist, five megawatt-scale demonstration projects have been deployed in several countries with generally good success. Figure 1-2 illustrates three generic floating platform technology classes. Spar buoys and semi-submersible platforms have been deployed in all of the projects, whereas tension-leg platforms have not yet been deployed. Additional information about offshore wind technology can be found in the Department of Energy's (DOE's) *Offshore Wind Market Report* (Smith 2015). The Appendix lists floating offshore wind projects that have been installed or are under construction as of April 2016.



Figure 1-2. Illustration of types of offshore wind turbine platforms

Source: Illustration by Joshua Bauer, NREL

Economic models are useful to estimate the economic impacts of projects built with new technologies and where there is no or very little market experience. The Offshore Wind Jobs and Economic Development Impacts (JEDI) model is one such tool, with parameters established through consultations with offshore wind experts, other reports, European project data, NREL's BOS model, and utilization of an engineering cost model that estimates gross employment and economic impacts.

⁵ Several floating offshore wind turbines have been installed to date; however, none of these projects has been deployed at the commercial scale. See Appendix A.

The scenarios in this report show that offshore wind could be a contributor to economic development in Oregon in both the near and long term, with more significant development occurring in later years. Substantial local sourcing of materials and labor could greatly increase the gross economic impact of offshore wind energy deployment in Oregon. This report explains the assumptions and methods used to estimate the potential jobs and gross economic impacts that could come from these two scenarios in the state of Oregon.

2 Methodology

Gross economic impacts presented in this study were generated using NREL's Offshore Wind JEDI model. JEDI models are commonly used to estimate gross economic impacts from the development and operations and maintenance (O&M) of energy projects (Billman and Keyser 2013; Tegen et al. 2015).

Input-output (I-O) models such as JEDI characterize an economy in terms of inputs purchased and outputs produced by sectors. Sectors include businesses, governments, households, investors, and the rest of the world (through imports and exports). Businesses are modeled as making a set of expenditures for inputs (such as business-to-business services, raw materials, utilities, etc.) and selling an output. All inputs are outputs of another sector. For example, if a generator manufacturer purchases copper wire, this wire is an input to the generator manufacturer and an output from the copper wire manufacturer.

By accounting for all inputs and all outputs within a region, I-O models can estimate economic impacts that are supported by expenditures that extend beyond that expenditure. If a consumer goes to the grocery store and buys a domestically grown apple, for example, this supports portions of jobs at the local grocery store, within the distribution system, at the orchard where the apple was grown, and throughout the apple grower's supply chain.

Although JEDI models typically contain default data from actual installations, in the case of emerging technologies such as floating platform offshore wind, default data must come from other sources. The version of the Offshore Wind JEDI model used in this analysis contains an integrated version of the NREL BOS model for offshore wind.⁶

Several assumptions in JEDI should be considered when analyzing results:

- JEDI results are gross, not net. This distinction means that impacts not immediately related to the construction and operation of offshore wind facilities are not considered. These impacts that JEDI does not consider include displaced investment such as what would occur if, for example, a natural gas power plant were built instead of an offshore wind facility.
- JEDI implicitly assumes fixed prices within any given year. This assumption means that the model assumes that any amount of goods and services will always be available and can be purchased at the same price regardless of the quantity purchased.
- Impact results assume that producers continue to use the same sets of inputs in the same proportions and that consumers purchase the same sets of goods and services, also in the same proportions, as those contained in IMPLAN.⁷

For the purposes of this analysis, the JEDI model also assumes that projects are sited appropriately and successfully constructed and operated. JEDI estimates outcomes from what are

⁶ Balance of systems costs include non-hardware costs for wind turbine operation, such as site assessment and permitting.

⁷ IMPLAN, the "Impacts analysis for PLANing" is a proprietary software and data tool for conducting input-output economic analysis. IMPLAN is published by MIG, Inc. Further information about IMPLAN can be found at <http://www.IMPLAN.com>.

assumed to be successful projects, not dollars spent on negotiations, extraordinary legal issues, or siting difficulties. This means that offshore wind developers have worked with the appropriate federal and state agencies, local communities, and stakeholder groups to address siting, permitting, and operational concerns.

JEDI models parameterize projects in terms of expenditures made within a region of analysis for specific line items. The model applies these expenditures to economic multipliers from an I-O model to calculate gross impacts at the site of the facility and throughout the economy. NREL used its offshore BOS model to estimate capital expenditures associated with installation activities and other BOS costs for input into JEDI. The model was built using data provided to NREL by DNV GL, which investigated the major contributions to U.S. offshore wind project BOS costs. Model data have been supplemented with additional industry data. Industry data covered the key cost drivers and trends, provided typical values and expected ranges, and included assumptions made based on current technology and best practices. The data reflect active offshore wind projects in Europe, along with modifications based on the offshore and land-based wind industry in the United States.

The model is capable of calculating budget-level estimates related to:

- Development costs, including those pertaining to project management, engineering, permitting, and site assessment
- Ports and staging costs, e.g., storage rental, crane rental, and port entrance and docking fees
- Support structure costs for primary steel, secondary steel, and transition pieces
- Electrical infrastructure costs for array cables, export cables, and the offshore substation
- Vessels costs, such as for a heavy lift vessel, jack up vessel, or offshore barge
- Decommissioning costs stemming from cable removal and scour removal.

JEDI reports three types of gross economic impacts: onsite, supply chain, and induced (Figure 2-1).

- *On-site labor* impacts are those that are most closely associated with an offshore wind project. During construction, these are workers who work at the site of the facility or are directly involved with it. During O&M, these are workers who are directly involved with operating and maintaining the wind facility.
- *Turbine and supply chain* impacts are supported by the purchases made by either the construction company (during the construction phase) or the operator (during the operations phase). These include procurement of manufactured components, consulting services, and other materials as well as permitting.
- *Induced* impacts arise when on-site and supply chain workers spend money within the geographic area of analysis. These often include impacts (fractions of FTE jobs) at retail stores, health care facilities, restaurants, and hotels.

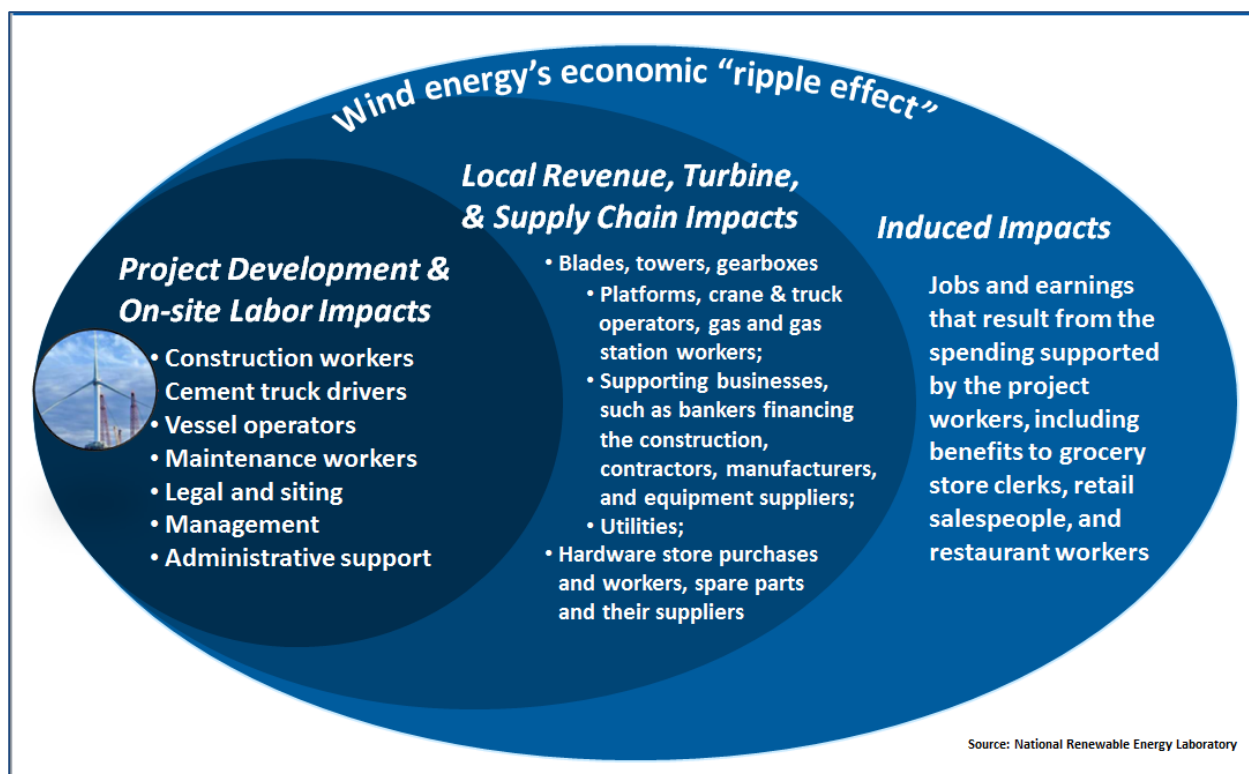


Figure 2-1. JEDI model economic ripple effect: sample jobs in offshore wind

JEDI reports four impact metrics: jobs, earnings, gross domestic product (GDP), and output.

- *Jobs* are FTE workers. One FTE is the equivalent of one person working full time (i.e., 40 hours per week). One person working 20 hours per week is 0.5 FTE. A related term used in this report is the *job-year*. A job-year is one person (working full time) for one year. For example, one person working for 10 years or 5 individuals working for 2 years both total 10 job-years. This is a useful term when describing cumulative or total employment impacts over a multiyear period.
- *Earnings* are wages and salaries as well as supplements, such as health insurance and employer contributions to retirement funds.
- *GDP* is an industry's value of production or, in other words, the amount of revenue beyond expenditures paid to other industries. *GDP* includes payments to workers, investors, and the government (in the form of taxes). (Note: This is labeled *value added* in the JEDI model, but for the sake of clarity, we use *GDP* throughout this report.)
- *Output* is the sum of overall economic activity (including GDP, plus expenditures on inputs). In other words, it is the market value of the goods and services produced by these Oregon projects, including taxes.

All JEDI results are reported within the region of analysis. By default, this could be at a state level or national level. This study is of potential impacts within the state of Oregon, so reported results do not include impacts outside of Oregon. The percentage of expenditures made on components within Oregon was estimated based on interviews with offshore wind technical

experts and others familiar with the economy within the state and analysis of the current capacity within the state to produce components and other inputs.

JEDI reports results over two time periods: construction and O&M. Construction period estimates are for the equivalent of one year. Average impacts for projects that take more or less than one year are simply the construction impacts divided by the number of years the project takes. O&M impacts are estimated on an annual and are assumed to be supported for the life of the project.

As stated, the JEDI model assumes that projects are sited appropriately and successfully constructed and operated (including permitting with federal and state agencies, local communities, and stakeholder groups to alleviate siting and operational concerns). In reality, the deployment process takes years due to siting considerations. For offshore projects, there are very important issues regarding shipping lanes, marine sanctuaries, and other uses of the offshore area such as for fishing and the military.

3 Scenarios

We analyzed two scenarios for the construction and operation of hypothetical offshore wind projects between the years 2020 and 2050 to estimate potential employment and other economic impacts in Oregon. The deployment scenarios are the result of consultations with technical experts and offshore wind energy leaders, Oregon energy demand projections, Oregon offshore wind resource, and load growth estimates from DOE’s *Wind Vision Study* (DOE 2015).

For Scenario A, we examine half of the total Oregon deployment modeled in the DOE *Wind Vision* resulting in cumulative installations of 5.5 GW of offshore wind by 2050. Scenario B follows a slower growth path than the first, resulting in 2.9 GW over the same period. Figure 3-1 shows expansion under each scenario. Scenarios A and B both assume smaller initial projects in early years, with project development ramping up in 2025 and remaining fairly steady throughout the analyzed period. Beyond the smaller projects (200–300 MW), we assume larger projects on the order of 500 MW are built.

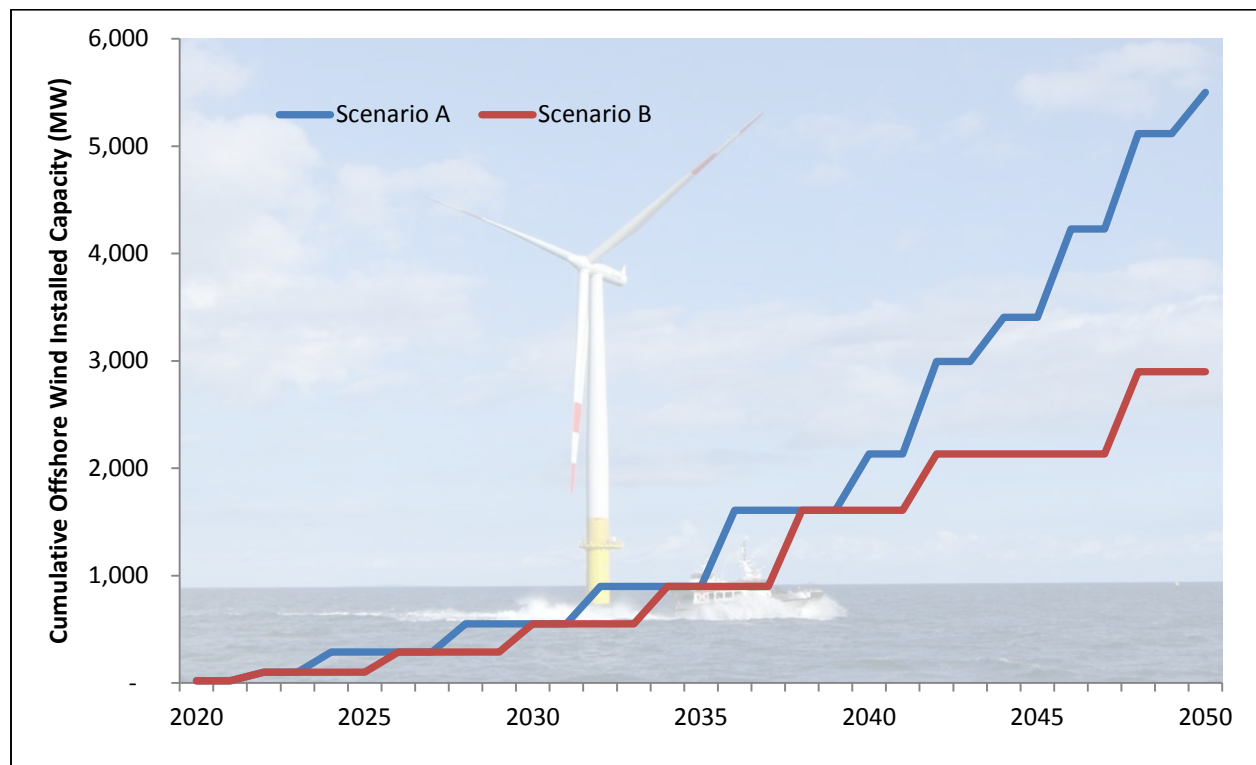


Figure 3-1. Offshore wind deployment for both growth scenarios

Source: NREL/7489066

Both expansion scenarios differ from the *Wind Vision* deployment scenario in that they assume small, initial pilot projects and result in fewer projects deployed by 2050. Oregon offshore wind facilities in the *Wind Vision* were selected to minimize energy costs while maintaining a prescribed level of wind-generated electricity and meeting demand for electricity. The offshore wind facilities in the study, therefore, are built in order of their modeled economic viability.

Beyond the pilot projects, we assume that facilities of similar sizes to those in the *Wind Vision* study are built, using our own deployment schedules.⁸

We use averages across potential Oregon offshore wind sites to estimate water depth, distance to the grid, and distance to port. The two potential ports—Astoria and Coos Bay—are approximately 30 kilometers (km) to 150 km from potential sites. Distance to grid is approximately 20 km to 60 km, and water depth ranges from 50 meters (m) to 1,000 m. We model grid distance as 40 km, distance to port as 90 km, and water depth as 525 m.

Both capital expenditures and operational expenditures values are based on recent unpublished work conducted of behalf of BOEM in which we analyzed multiple offshore wind costs and future scenarios. Installations completed through 2026 are assumed to use 8 MW turbines, while installations completed after 2026 are assumed to use 10-MW turbines. Costs do not vary between the scenarios. Both capital costs and O&M costs are assumed to decline over time. For the current analysis, unit (\$/MW) turbine costs are assumed to continue to decline beyond 2030. In contrast, BOS costs are assumed to remain flat after 2030. BOS costs are calculated using the BOS model. Inputs to this model include turbine rated power, distance to port, and distance to the grid. Cost assumptions are summarized in Table 3-1. Due to its small size, the 20-MW project installed in 2020 has a noticeably higher unit capital cost than the succeeding projects.

⁸ Resulting capacities (A = 5.5 GW and B = 2.9 GW) are achieved by decelerating expansion, not by reducing wind facility sizes.

Table 3-1. Analysis Cost Assumptions

Year	Installations (Scen A) (MW)	Installations (Scen B) (MW)	Turbine Cost (\$/kW)	Total CAPEX (Scen A) (\$/kW)	Total CAPEX (Scen B) (\$/kW)	Total Annual OPEX (\$/kW)
2020	20	20	\$1,732	\$11,282	\$11,282	\$137
2021	0	0	\$1,723			\$131
2022	80	80	\$1,713	\$5,873	\$5,873	\$126
2023	0	0	\$1,703			\$120
2024	189	0	\$1,693	\$5,067		\$115
2025	0	0	\$1,683			\$110
2026	0	189	\$1,674		\$5,047	\$105
2027	0	0	\$1,664			\$101
2028	262	0	\$1,655	\$4,619		\$96
2029	0	0	\$1,645			\$92
2030	0	262	\$1,636		\$4,600	\$88
2031	0	0	\$1,626			\$88
2032	349	0	\$1,617	\$4,596		\$88
2033	0	0	\$1,608			\$88
2034	0	349	\$1,599		\$4,577	\$88
2035	0	0	\$1,590			\$88
2036	708	0	\$1,580	\$4,559		\$88
2037	0	0	\$1,571			\$88
2038	0	708	\$1,562		\$4,540	\$88
2039	526	0	\$1,554	\$4,454		\$88
2040	0	0	\$1,545			\$88
2041	861	0	\$1,536	\$4,490		\$88
2042	0	526	\$1,527		\$4,426	\$88
2043	409	0	\$1,519	\$4,366		\$88
2044	0	0	\$1,510			\$88
2045	823	0	\$1,501	\$4,458		\$88
2046	0	0	\$1,493			\$88
2047	888	0	\$1,484	\$4,425		\$88
2048	0	765	\$1,476		\$4,516	\$88
2049	384	0	\$1,468	\$4,382		\$88
2050	0	0	\$1,459			\$88

Local content assumptions differ in each scenario because we assume more rapid expansion would incentivize greater levels of supply chain growth. Potential wind blade manufacturers, for example, may be more likely to build a facility in Oregon if local demand for their products is greater.

For each deployment scenario we examined two sets of values for local content (LC), labeled “High LC” and “Low LC” respectively. Note that the set of values differ between deployment scenarios. In other words the High LC values are different between the scenario A and scenario B. As well, the Low LC values are different between Scenario A and scenario B.⁹

These local content assumptions are summarized in Table 3-2 for construction and Table 3-3 for O&M. In both tables, if there is one value for an item, that value is constant for the whole analysis period. If two values are given, the first value is the 2020 local share; the second value is the local share from 2035–2050. Figure 5 shows the growth in overall local content for both construction and O&M from the initial values in 2020 to the final values in 2035 and after.

If there is one value for an item, that value is constant for the whole analysis period. If two values are given, the first value is the 2020 local share; the second value is the local share from 2035–2050.

⁹ There is one instance (O&M Management and Supervision) where a particular value in the High LC set is lower than the corresponding value in the Low LC set for the same deployment scenario.

Table 3-2. Local (Oregon) Content Assumptions—Construction

	Oregon Share – Scen. A		Oregon Share – Scen. B	
	High LC	Low LC	High LC	Low LC
Construction Expenditure Items				
Turbine Equipment				
Nacelle/Drivetrain	0%	0%	0%	0%
Blades	0→15%	0→15%	0→5%	0→5%
Towers	0→40%	0%	0→10%	0%
Ground Transportation (to project staging area/port by vessel)	20→50%	0%	10→25%	0%
Warranty Cost	0%	0%	0%	0%
Materials and Other Equipment				
Basic Construction (concrete, rebar, gravel, mooring lines, etc.)	60→70%	60→70%	60%	60%
Foundation (including anchors/alternatives for fixed bottom types only)	50→85%	10→55%	10→50%	10→20%
Substructure	0→55%	0→55%	0→20%	0→20%
Project Collection System	0%	0%	0%	0%
HV Cable (project site to point of grid interconnection)	0%	0%	0%	0%
Onshore substation (formerly converter station)	30→80%	0%	20→50%	0%
Offshore substation (formerly substation)	30→85%	0%	20→50%	0%
Labor Installation				
Foundation	35→85%	5→50%	20→50%	5→15%
Substructure	5→50%	5→50%	5→15%	5→15%
Erection/Installation	50→100%	5→50%	5→15%	5→15%
Project Collection	5→50%	5→50%	5→15%	5→15%
Grid Interconnection (including substation)	50→75%	5→50%	25→50%	5→15%
Management/Supervision	20→60%	0→40%	10→25%	0→10%
Insurance During Construction				
CAR/Third Party liability/business interruption, etc.	10%	10%	10%	10%
Development Services/Other				
Engineering	5→50%	5→80%	5→20%	5→20%
Legal Services	10→80%	10→80%	10→50%	10→20%
Public Relations	90→100%	90→100%	90%	90%

	Oregon Share – Scen. A		Oregon Share – Scen. B	
	High LC	Low LC	High LC	Low LC
Construction Expenditure Items				
Ports and Staging	50→90%	10→75%	10→20%	10→20%
Site Certificate/Permitting	25→75%	25→75%	25→50%	25→50%
Air Transportation (personnel or materials)	0%	0%	0%	0%
Marine Transportation (personnel or materials)	40→80%	10→40%	30→50%	10→15%
Erection/Installation (equipment services)	10→60%	10→60%	10→50%	10→50%
Decommissioning Bonding	50→60%	50→60%	50%	50%
Construction Financing (AFUDC)				
Interest During Construction	0%	0%	0%	0%
Due Diligence Costs	15%	15%	15%	15%
Bank Fees	15%	15%	15%	15%
Other Miscellaneous	10→50%	10→50%	10→20%	10→20%

Table 3-3. Local (Oregon) Content Assumptions—O&M

	Oregon Share – Scen. A		Oregon Share – Scen. B	
	High LC	Low LC	High LC	Low LC
Annual Operating and Maintenance Costs				
Operational Costs				
Labor				
Technician Salaries	50→100%	50→100%	50→100%	50→100%
Monitoring & Daily Operation Staff and Other Craft Labor	75→90%	50→75%	50%	50%
Administrative	100%	100%	100%	100%
Management/Supervision	10→80%	10→100%	10→70%	10→90%
Materials and Services				
Water Transport	20→75%	20→75%	20→50%	20→50%
Site Facilities	100%	100%	100%	100%
Machinery and Equipment	25→40%	5→25%	15→30%	5→10%
Subcontractors	10→40%	1→25%	1→30%	1→10%
Corrective Maintenance Parts	30→75%	5→25%	25→50%	5→10%

As shown in Figure 3-2, overall, maximum construction local content ranges from 28–40% in

Scenario A and 15–22% in Scenario B. Maximum overall O&M local content varies from 52 - 76% in Scenario A and 38 - 58% in Scenario B. Both scenarios assume that large equipment, other than blades, will not be produced in Oregon, and that project collection and cabling equipment will come from outside of the state. Figure 3-2 displays the data in the local content tables. Construction local content values are shown in each year there is construction; whereas the operational local content values increase with time and then remain steady after a consistent supply chain is established in 2035.

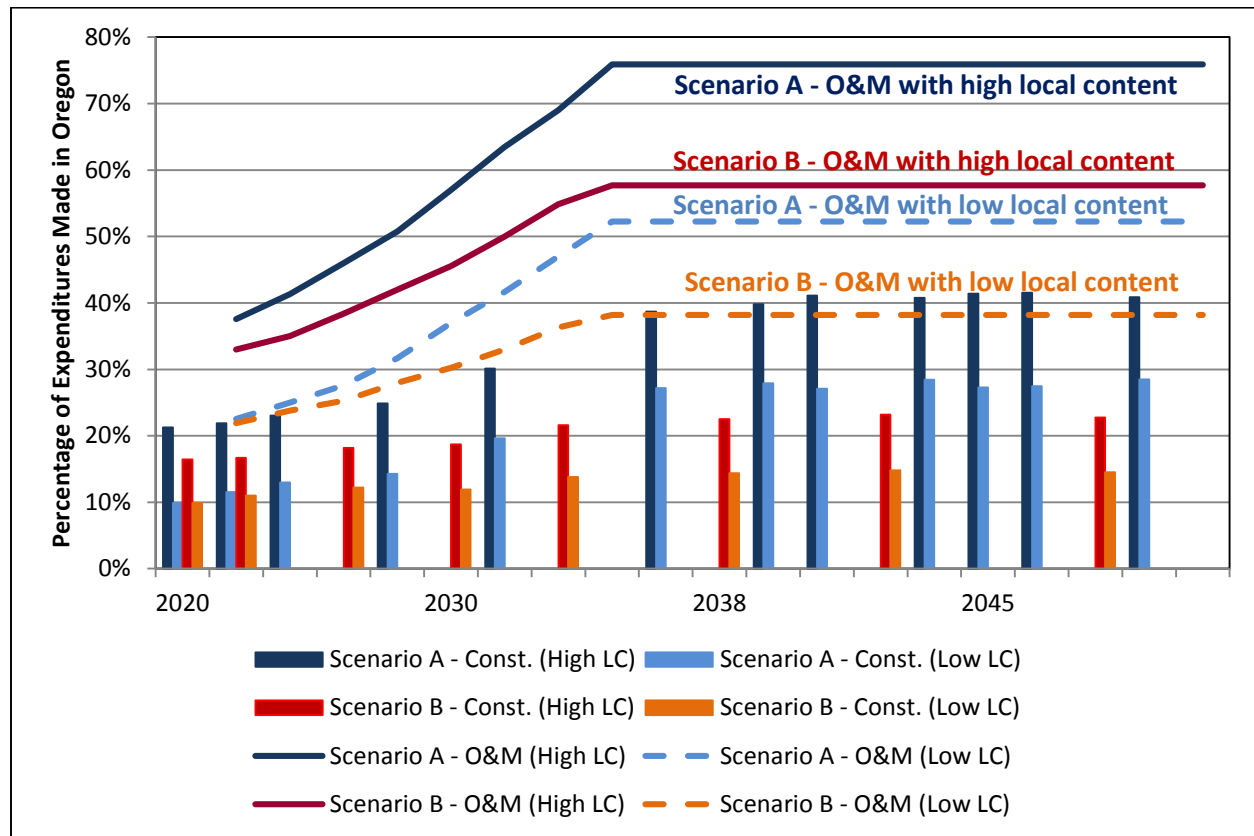


Figure 3-2. Scenarios with high and low percentages of local content over time

The levels of local content are uncertain, most notably for specialized offshore wind components, in a large part owing to uncertainties around the requirements for specialized ports and labor skills. Some of the larger and heavier components cannot be effectively moved over land and thus must be transported between the manufacturing location and staging port using ocean-faring vessels. Local ports may need to undergo infrastructure improvements to handle the larger and heavier components (Tetra Tech 2010; Navigant 2014; Cotrell et al. 2014). There are construction ports that already exist on Oregon’s coast; ports could also be located elsewhere along the Pacific coast (i.e., Washington, California, or Mexico) or across the Pacific, in Asia. Vessels capable of accommodating the larger components would need to be built in Oregon or be sent to the area. If crews to staff ports, shipyards, or vessels move to Oregon temporarily, these would not be considered Oregonian or “local” jobs.

At least two states—Massachusetts and Rhode Island—have used public funding to analyze opportunities to upgrade existing ports or to build new ports with the capacity to handle large

offshore wind components.¹⁰ This type of analysis demonstrates how local demand for components could have important economic implications because offshore wind companies could be incentivized to locate near the ports.

Manufacturing is another sector in which economic activity can occur as a result of offshore wind deployment. This analysis conservatively assumes that a relatively small proportion of the turbine and BOS equipment is sourced from within Oregon. However, the Oregon manufacturing base has the latent capability (plant facilities and skilled labor) to supply a larger proportion of the turbine and BOS equipment than is assumed in the analysis.¹¹ The proportion of manufactured equipment that is ultimately sourced from within Oregon will depend upon global, national, and local market forces.

¹⁰ Port improvements can involve physical repairs and upgrades to infrastructure, including piers, decks, cranes, terminals, and railways. For more information on recent improvements to a Rhode Island port, see: <http://www.ri.gov/press/view/10777>. A full analysis of opportunities to improve ports and infrastructure to support offshore wind in Massachusetts can be found here: <http://www.epa.gov/region1/superfund/sites/newbedford/518618.pdf>.

¹¹ Durable goods manufacturing in Oregon totaled over \$50 billion in 2014 (BEA 2015).

4 Results

4.1 Construction Phase

As shown in Figure 4-1, we estimate that annual construction jobs ranging from hundreds to over 11,000 could be supported in Oregon between 2020 and 2050. Each job in Figure 4-1 is the equivalent of one full-time job for one worker for one year. Although shown as annual jobs, construction of an offshore wind system typically takes longer than one year. The number of FTE jobs does not change in this case, but the jobs are spread across two years instead of one (instead of 6,000 jobs in one year, there would be 3,000 jobs in two years).

Under the assumption it will take some time for the offshore manufacturing, project development, and other service markets to develop, the majority of the jobs are supported toward the end of the scenarios, as indicated in Table 4-1.

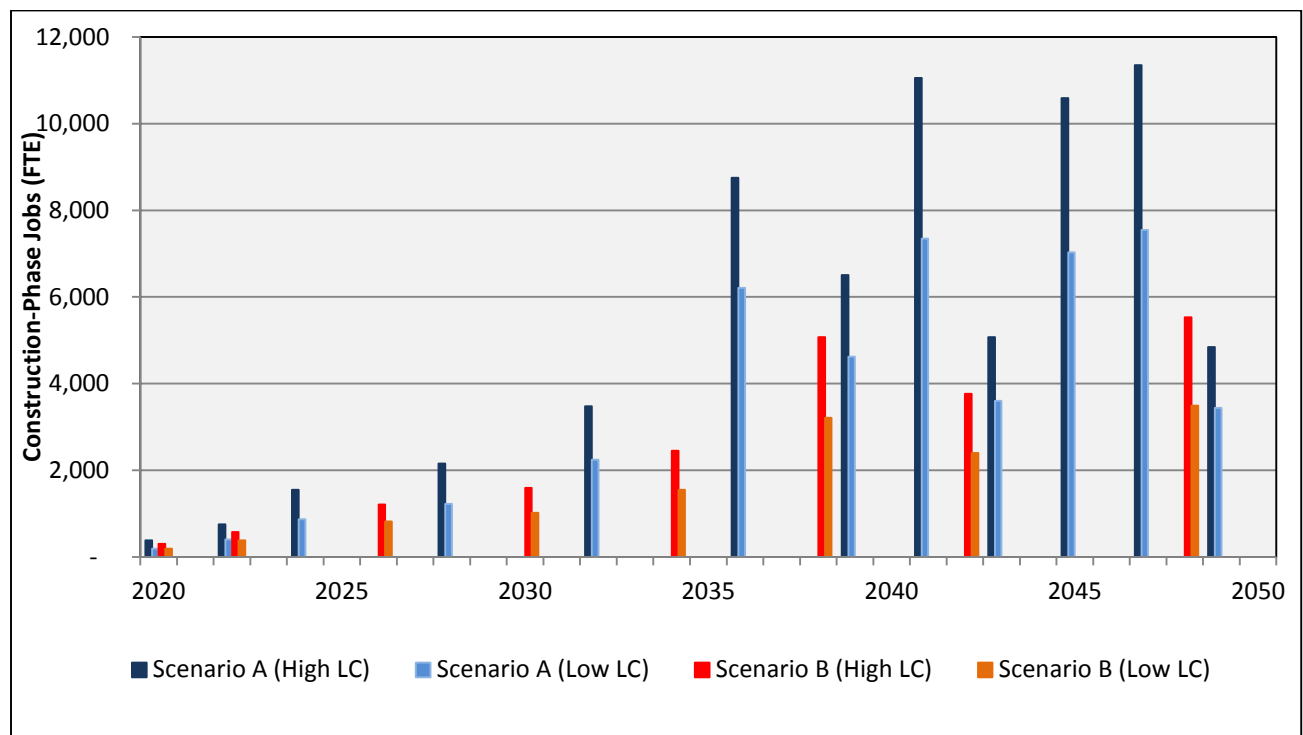


Figure 4-1. Annual construction-phase jobs supported in Scenario A and Scenario B

Most jobs and other impacts occur in the last half of the analysis period. Table 4-1 provides a more detailed breakdown of average annual jobs and other economic impacts during each of the three decades of the analysis period. By the last decade of the scenarios (2040–2050), average annual Oregon employment supported by offshore wind construction-phase activities is 2,600 jobs for Scenario A and 530 jobs for Scenario B. See Section 4.1.1 for job-year calculations.

Table 4-1. Average Annual Construction-Phase Impacts by Decade

	Scenario	2020–2030		2030–2040		2040–2050	
		A	B	A	B	A	B
Jobs	Onsite	30–60	20–40	140–200	50–100	310–410	50–100
	Supply Chain	150–250	130–200	680–980	320–490	1,500–2,300	320–500
	Induced	70–130	60–100	370–520	160–250	820 – 1,200	160–250
	Total	240–440	220–330	1,200 – 1,700	530–830	2,600 – 3,900	540–850
Earnings (\$ Millions, 2014)	Onsite	\$4–\$8	\$4–\$6	\$20–\$30	\$7–\$13	\$40–\$50	\$7–\$13
	Supply Chain	\$9–\$17	\$8–\$13	\$50–\$70	\$22–\$34	\$110–\$160	\$23–\$35
	Induced	\$3–\$6	\$3–\$4	\$20–\$20	\$7–\$11	\$40–\$50	\$7–\$11
	Total	\$17–\$30	\$15–\$23	\$80–\$120	\$36–\$58	\$190–\$270	\$37–\$59
Output (\$ Millions, 2014)	Onsite	\$6–\$12	\$5–\$8	\$30–\$40	\$10–\$17	\$50–\$70	\$9–\$17
	Supply Chain	\$40–\$80	\$38–\$61	\$230–\$340	\$100–\$160	\$500–\$800	\$100–\$170
	Induced	\$9–\$17	\$8–\$13	\$50–\$70	\$20–\$32	\$110–\$150	\$21–\$33
	Total	\$58–\$108	\$52–\$82	\$300–\$440	\$130–\$210	\$670–\$1,000	\$130–\$220
GDP (\$ Millions, 2014)	Onsite	\$5–\$9	\$4–\$6	\$20–\$30	\$8–\$14	\$40–\$60	\$8–\$14
	Supply Chain	\$15–\$25	\$14–\$20	\$70–\$100	\$34–\$51	\$170–\$240	\$35–\$52
	Induced	\$6–\$10	\$5–\$8	\$30–\$40	\$13–\$20	\$70–\$90	\$13–\$20
	Total	\$26–\$45	\$23–\$34	\$120–\$170	\$55–\$85	\$270–\$390	\$56–\$87

Average earnings for these jobs vary depending on their relationship to the project. As shown in Table 4-2, onsite workers earn roughly \$125,000–\$140,000 annually, while supply chain workers earn roughly \$70,000 (in 2014 dollars). As stated previously, earnings include wages and benefits. Induced jobs, which are concentrated in lower paying industries such as retail, earn an average of \$45,000 annually. Changes in these averages between scenarios reflect different pools of workers and different types of economic activity occurring within Oregon.

Table 4-2. Approximate Average Annual Earnings for Construction Phase Jobs (\$ 2014)

	Scenario A	Scenario B
Onsite	\$125,000	\$140,000
Supply Chain	\$72,000	\$69,000
Induced	\$45,000	\$45,000
Overall	\$70,000	\$69,000

Beyond jobs and earnings, by the last decade of the analysis (2040–2050) offshore wind construction-phase activity increases the annual Oregon GDP by an average of \$270 million to \$390 million per year (Scenario A) and \$56 million to \$87 million (Scenario B).

Recalling the definition of GDP in these scenarios: JEDI estimates the contribution of the offshore wind value chain (for these projects) to GDP. This is the value of production, or the amount of revenue beyond expenditures paid to other industries. It includes payments to workers and investors and net tax payments.

4.1.1. Job Years

A job-year is equivalent to one person (working full time) for one year. One person working for 10 years is expressed as 10 job-years; 5 individuals working for 2 years is also 10 job-years. Another way to look at this is to add up all of the same-colored bars shown in Figure 4-1. Model estimates show that large-scale deployment of offshore floating wind turbines, even with modest local content, results in significant construction-phase impacts. Scenario A, with the larger buildout and the higher local content, supports a total of 45,000–66,000 construction-phase job-years. Scenario B supports a total of 13,000–21,000 construction-phase job-years.¹²

4.2 Operations and Maintenance: the Operations Phase

Most of the jobs impacts in Oregon would occur during the O&M phase of projects, as opposed to during construction, due to the longer-term nature of these jobs and higher levels of in-state expenditures. When listed as job-years, the construction jobs and O&M jobs are easier to compare. The highest level of long-term jobs supported in the O&M phase could be from close to 2,300 in Scenario B to nearly 3,300 in Scenario A. However, when calculated in job-years, the O&M phases support 65,000–97,000 *job-years* and jobs that continue beyond the period of analysis. The offshore wind systems are assumed to last for 25 years. Figure 4-2 shows the increase in operations-phase jobs supported by the offshore wind projects within the analysis time frame.

¹² Construction that takes longer than a year would reduce the number of jobs at a single point of time but spread out the duration of those jobs.

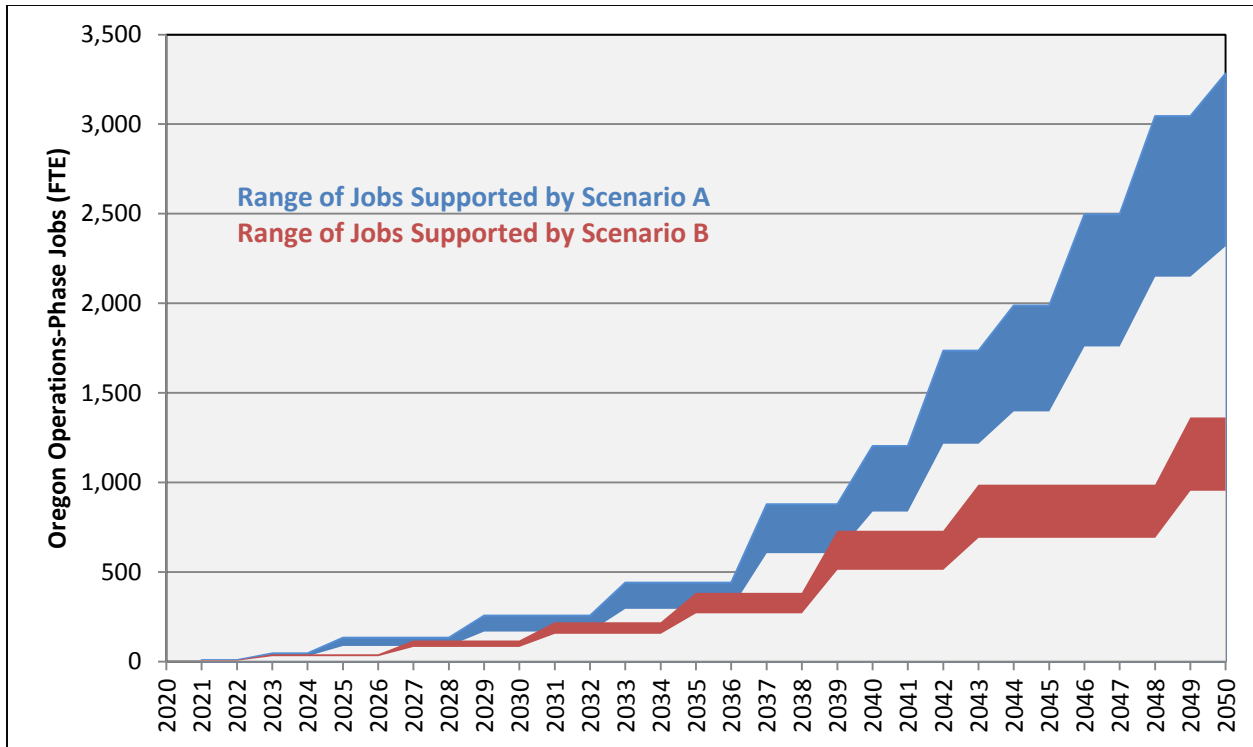


Figure 4-3. Oregon’s range of operations-phase jobs supported by offshore wind during the analysis period, with ranges showing low to high local content

After the analysis period, the number of supported operations phase jobs ranges from 2,300–3,400 for Scenario A and 900–1,400 jobs for Scenario B. By 2050, operations, maintenance, and other operations-phase employment (including environmental monitoring, legal work, etc.) could support an estimated \$250 million to \$340 million annually in state GDP in Scenario A or \$100 million to \$140 million in Scenario B. Table 4-3 shows these impacts in three different years: 2030, 2040, and 2050.

Table 4-3. O&M Impacts for Selected Years

	Scenario	2030		2040		2050	
		A	B	A	B	A	B
Jobs	Onsite	30	10	150–160	110–120	430–450	210–230
	Supply Chain	100–160	50–70	460–720	270–430	1,300–2,000	490–790
	Induced	40–70	20–30	220–330	130–190	610–900	240–360
	Total	170–260	80–120	840–1,200	510–730	2,300–3,300	950–1,400
Earnings (\$ Millions, 2014)	Onsite	\$3	\$1	\$20–\$20	\$13–\$14	\$50 - \$60	\$30 - \$30
	Supply Chain	\$6–\$11	\$3–\$5	\$30–\$50	\$18–\$29	\$90–\$140	\$30–\$50
	Induced	\$2–\$3	\$1	\$10–\$15	\$6–\$9	\$30–\$40	\$10–\$17
	Total	\$12–\$17	\$6–\$8	\$60–\$80	\$38–\$51	\$170–230	\$70–\$96
Output (\$ Millions, 2014)	Onsite	\$3	\$1	\$20	\$13–\$14	\$50–\$60	\$30
	Supply Chain	\$19–\$33	\$9–\$15	\$100–\$160	\$52–\$89	\$260–\$430	\$100–\$170
	Induced	\$6–\$9	\$3–\$4	\$30–\$40	\$17–\$26	\$80–\$120	\$30–\$50
	Total	\$27	\$13–\$20	\$140	\$83–\$130	\$400–600	\$160–\$240
GDP (\$ Millions, 2014)	Onsite	\$3	\$1	\$20	\$13–\$14	\$50–\$60	\$30–\$30
	Supply Chain	\$10–\$17	\$5–\$8	\$50–\$80	\$29–\$46	\$140–\$220	\$50–\$90
	Induced	\$4–\$6	\$2–\$3	\$20–\$30	\$11–\$16	\$50–\$70	\$20–\$30
	Total	\$17–\$26	\$8–\$12	\$90–\$120	\$54–\$75	\$250–\$340	\$100–\$140

The average earnings of workers supported by operations-phase activities vary only slightly between the two scenarios. Onsite workers earn roughly \$120,000 annually, supply chain workers earn roughly \$66,000 annually, and induced workers earn about \$46,000 annually. Overall, this translates to average jobs earning slightly over \$70,000 in wages, salaries, and employer-provided benefits (Table 4-4).

Table 4-4. Average Annual Earnings for O&M-Phase Jobs (\$ 2014)

	Scenario A	Scenario B
Onsite	\$121,000	\$120,000
Supply Chain	\$68,000	\$67,000
Induced	\$46,000	\$46,000
Overall Average	\$71,000	\$72,000

The construction of offshore wind projects in Oregon would induce additional impacts that are not represented in this analysis, especially those in other states or countries. For example, other markets may supply goods and services, such as specialized crane parts or bearings, for projects

located in Oregon. JEDI does not account for the impacts on consumers, such as changes in utility or tax rates or other purchase prices.

5 Conclusion

Offshore wind would contribute to economic development in Oregon in the near future, and more substantially in the long term, especially if equipment and labor are sourced from within the state. According to the analysis, over the 2020–2050 period, Oregon floating offshore wind facilities could support 65,000–97,000 job-years and add \$6.8 billion–\$9.9 billion to the state GDP (Scenario A). Post analysis-period impacts are support of over 2,300–3,400 ongoing O&M jobs and \$240 million–\$350 million in additional annual state GDP while projects are operating.

Higher levels of spending made by developers and operators within Oregon could support greater gross economic impacts. Higher levels of manufacturing in Oregon could significantly increase the jobs and other economic development impacts. These impacts would grow further to the extent that Oregon-based suppliers export goods and services out of state. Improvements in technologies, manufacturing processes, and O&M practices, as well as policy changes and growth in domestic and international markets, among other factors, could significantly impact the development of offshore wind projects in Oregon.

Given Oregon’s strong offshore wind resources, regardless of the specific technology or local content, there is a strong potential for economic development and employment from offshore wind in Oregon, assuming projects are sited appropriately and operate as expected.

6 References

BEA (Bureau of Economic Analysis). 2015. “Regional Data – GDP & Personal Income. Gross domestic product (GDP) by state (millions of current dollars) – durable goods manufacturing.” Accessed July 2015. <http://bea.gov/regional/index.htm>.

Billman, L., and D. Keyser. 2013. *Assessment of the Value, Impact, and Validity of the Jobs and Economic Development Impacts (JEDI) Suite of Models*. NREL/TP-6A20-56390. Golden, CO: National Renewable Energy Laboratory. Accessed May 2015. <http://www.nrel.gov/docs/fy13osti/56390.pdf>.

Cotrell, J., T. Stehly, J. Johnson, J. O. Roberts, Z. Parker, G. Scott, and D. Heimiller. 2014. *Analysis of Transportation and Logistics Challenges Affecting the Deployment of Larger Wind Turbines: Summary of Results*. NREL/TP-5000-61063. Golden, CO: National Renewable Energy Laboratory. Accessed June 16, 2015. <http://www.nrel.gov/docs/fy14osti/61063.pdf>.

DOE (U.S. Department of Energy). 2015. *Wind Vision: A New Era for Wind Power in the United States*. Washington, D.C.: U.S. Department of Energy.

Jimenez, T., D. Keyser, and S. Tegen. 2016a. *Floating Offshore Wind in Hawaii: Potential for Jobs and Economic Impacts from Three Future Scenarios*. NREL/TP-5000-65481. Golden, CO: National Renewable Energy Laboratory. Accessed April 2016. <http://www.nrel.gov/docs/fy16osti/65481.pdf>.

Jimenez, T., D. Keyser, and S. Tegen. 2016b. *Floating Offshore Wind in Oregon Coastal Counties: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios*. NREL/TP-5000-65432. Golden, CO: National Renewable Energy Laboratory. Forthcoming.

Musial, W., and D. Heimiller. Forthcoming. *Offshore Wind Potential*. Golden, CO: National Renewable Energy Laboratory.

Navigant Consulting. 2014. *Offshore Wind Market and Economic Analysis*. DE-EE0005360. Washington, D.C.: U.S. Department of Energy.

Speer, B., D. Keyser, and S. Tegen. 2016. *Floating Offshore Wind in California: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios*. NREL/TP-5000-65481. Golden, CO: National Renewable Energy Laboratory. Accessed April 2016. <http://www.nrel.gov/docs/fy16osti/65481.pdf>.

Tegen, S., D. Keyser, F. Flores-Espino, J. Miles, D. Zammit, and D. Loomis. 2015. *Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios*. NREL/TP-5000-61315. Golden, CO: National Renewable Energy Laboratory. Accessed May 2015. <http://www.nrel.gov/docs/fy15osti/61315.pdf>.

Tetra Tech EC, Inc. 2010. *Port and Infrastructure Analysis for Offshore Wind Energy Development*. Boston: Massachusetts Clean Energy Center. Accessed July 1, 2015. http://images.masscec.com/uploads/attachments/Port%20and%20Infrastructure%20Analysis%20for%20Offshore%20Wind%20Energy%20Development/MA%20Port%20Study%20Final%20Report_4-20-10.pdf.

Appendix A. Floating Offshore Wind Projects Installed or Under Construction

Table A-1. Floating Offshore Wind Projects

Project	Status	Turbine Capacity (MW)	Project Capacity (MW)	Water Depth (m)	Country	Foundation Type	Year Online
Hywind Demo	Installed	2.3	2.3	220	Norway	Spar	2009
WindFloat Atlantic I	Installed	2	2	50	Portugal	Semi-submersible	2011
Kabashima/Goto	Installed	2	2	91	Japan	Spar	2013
Fukushima Forward I	Installed	2	2	120	Japan	Semi-submersible	2013
Fukushima Forward II	Under Construction	7 & 5	12	120	Japan	1 Semi-submersible; 1 Spar	Expected 2016
Hywind Scotland Pilot Park	Under Construction	6	30	120	United Kingdom	Spar	unknown