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

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

This report is available from the Bureau of Ocean Energy Management by referencing OCS Study BOEM 2016-032. 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-5000-65481
April 2016

Contract No. DE-AC36-08GO28308

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

Tony Jimenez, David Keyser, and
Suzanne Tegen
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 2016-032. 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-5000-65481
April 2016

Contract No. DE-AC36-08GO28308

NREL prints on paper that contains recycled content.

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 on economic potential in the state of Hawaii. In particular, we thank Sara Guiltinan and Doug Boren for their guidance. In addition, we thank Walt Musial and Aaron Smith of the National Renewable Energy Laboratory (NREL) for their advice and review as well as Tyler Stehly and Michael Maness of NREL for analysis and modeling assistance. We thank Warren Bollmeier with the Hawaii Renewable Energy Alliance for local knowledge on Hawaii's power system, policies, and community. In addition, we are grateful for reviews by Karin Haas, Dave Corbus, and Brian Smith of NREL.

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 the East Coast and mid-Atlantic. However, floating platforms, which have yet to be deployed commercially, will likely need to be anchored to the deeper seafloor if deployed in Hawaiian waters. Although no commercial floating wind power plants yet exist, six megawatt-scale demonstration projects have been deployed or are under construction in other countries with generally good success.[1]

To analyze the employment and economic potential for floating offshore wind off Hawaii's coasts, the Bureau of Ocean Energy Management commissioned the National Renewable Energy Laboratory (NREL) to analyze two hypothetical deployment scenarios for Hawaii: 400 MW of offshore wind by 2050 and 800 MW of offshore wind by 2050. The results of this analysis can be used to better understand the general scale of economic opportunities that could result from offshore wind development. Assumptions for this analysis come from projected electricity demand in Hawaii, the estimated offshore wind resource, 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 model.

The 400-MW scenario assumes one 400-megawatt (MW) project installed in 2025; and the 800-MW scenario assumes an additional 400-MW project installed in 2030, for a combined 800 MW in Hawaii. Note that both of these scenarios are hypothetical and are not intended to be forecasts of actual deployment. Actual deployment of offshore wind turbines requires more thorough siting assessments and stakeholder engagement that consider a wide range of potential environmental and conflicting use impacts (e.g., the Hawaiian Islands Humpback Whale National Marine Sanctuary shown in Figure ES-1).

The effects highlighted in this report can be used in 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 inform stakeholders in other states about the potential economic impacts of floating offshore wind technology development.

[1] Four floating offshore wind turbines have been installed to date, and two projects are under construction. See Appendix.

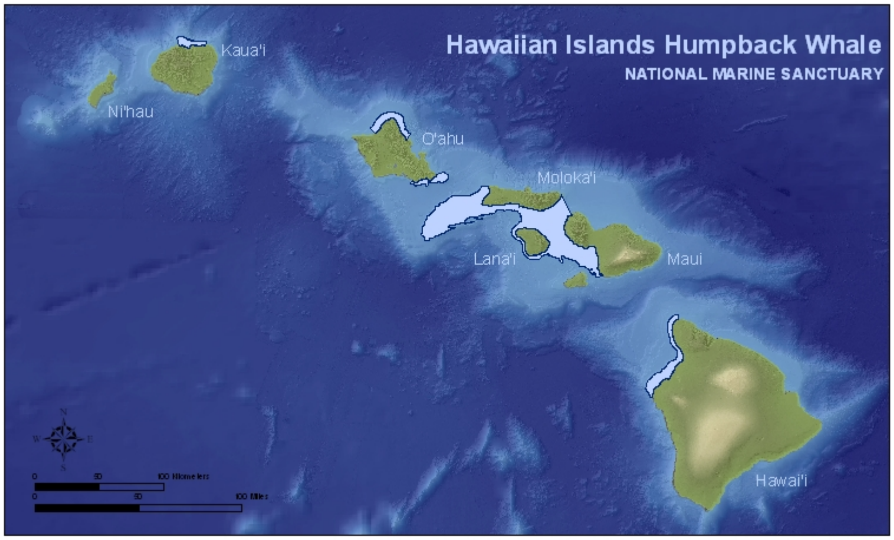

Figure ES-1. Hawaiian land and ocean showing water depth and Humpback Whale National Marine Sanctuary (highlighted).

Image from the National Oceanic and Atmospheric Administration[2]

For the first 400-MW installation in 2025, we assume that the turbine size is 8 MW. The second 400-MW installation, in 2030, is assumed to use 10-MW turbines. Because there are larger turbines, each producing more power than the 8-MW ones for the same total nameplate capacity (400 MW), the 2030 installation will require fewer turbines and therefore fewer workers.

Results show total state gross domestic product (GDP)[3] impacts of $348 million in the 800-MW scenario or $203 million in the 400-MW scenario for the construction phases; and $993 million in the 800-MW deployment or $539 million in the 400-MW project for the operations phases. Another key finding from this work is the sensitivity of the results to the magnitude of the in-state supply chain. If it were practical and possible to establish an in-state supply chain that could provide even a modest portion of the material and labor for floating offshore wind installations, it could increase the economic effect of offshore wind deployment within Hawaii.

Table ES-1 and Figure ES-2 show jobs estimates from the construction and operations of offshore wind projects in Hawaii during these years.

[2] See http://hawaiihumpbackwhale.noaa.gov/documents/images/boundary3.jpg (2016).
[3] 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 JEDI models, but it is referred to as GDP throughout this report.

Table ES-1. Snapshot of Annual Estimated Jobs from Hawaii's Offshore Wind Developments

Year	First Year (2025 for Construction; 2026 for O&M)	2030	2050
800-MW Scenario			
Construction-Phase Jobs	**1,660**	**1,200**	**-**
Operations-Phase Jobs	**190**	**340**	**340**
400-MW Scenario			
Construction-Phase Jobs	**1,660**	**-**	**-**
Operations-Phase Jobs	**190**	**190**	**190**

Note: Construction job totals are in full-time equivalent (FTE). One FTE is the equivalent of one person working full time (i.e., 40 hours per week) or two people working half-time. Jobs are rounded to the nearest 10. O&M = operations and maintenance.

Figure ES-2 shows the estimated employment impacts of a 2025 installation individually as well as combined with a 2030 installation over time. The impacts of the installation that take place in 2030 are somewhat smaller than those of the 2025 installation for two main reasons. As stated, one is that the later installation assumes larger and fewer turbines, resulting in reduced employment and other jobs and economic impacts. The second reason is because the later installation benefits from increased experience and efficiency. Deploying 400 MW of floating offshore wind installations in Hawaii and assuming a minimal in-state supply chain could (see Table 3-2 for in-state supply chain assumptions):

- Add a total of \$145–\$205 million to Hawaii's GDP during the construction phase.
- Support a total of 1,200–1,700 construction-phase FTE, one-year jobs (on-site, supply chain, and induced).
- Support approximately 155–185 ongoing operations-phase jobs (on-site, supply chain, and induced). Assuming a 25-year project lifetime, the cumulative operations-phase employment impact is 3,900–4,700 job-years (full-time jobs multiplied by the number of years the job lasts).
- Add approximately \$18–\$22 million annually in operation-phase additional state GDP, for a cumulative impact of \$450–\$540 million during the project's 25-year lifetime.

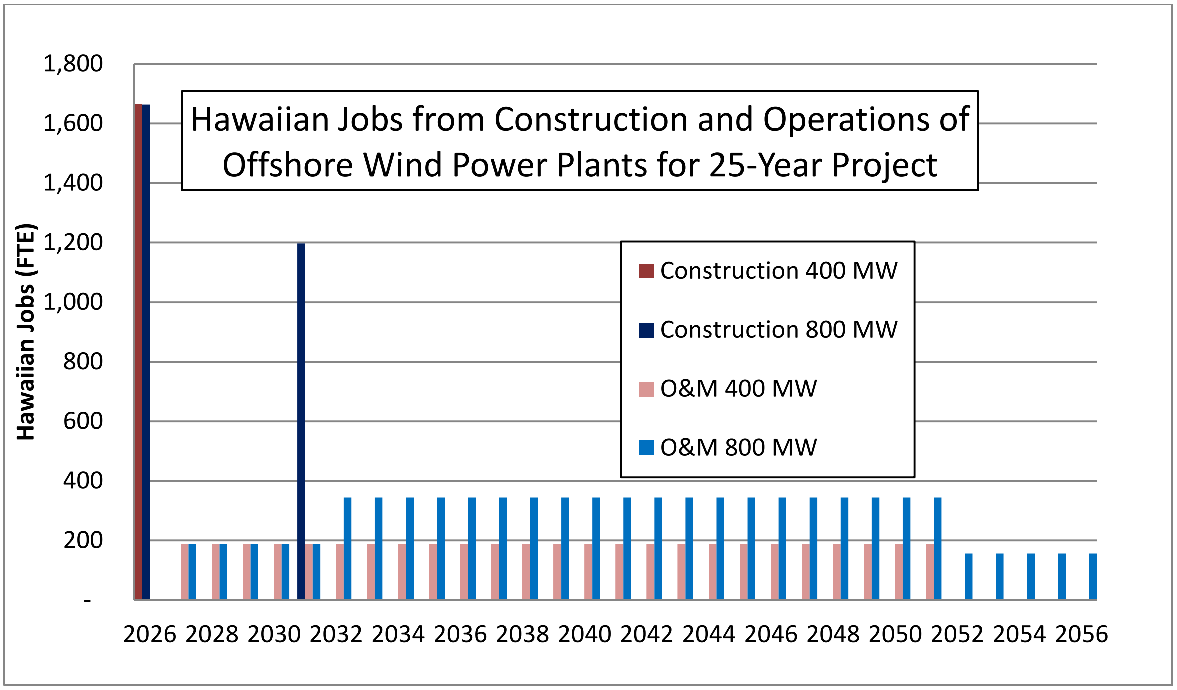

Figure ES-2. Hawaiian jobs from construction and operations of 400 MW (red) or 800 MW (blue) of offshore wind between 2026 and 2056

Table of Contents

List of Figures

List of Tables

1 Introduction

There is considerable potential for the development of offshore wind power to generate electricity off the coast of Hawaii. Estimates from the National Renewable Energy Laboratory (NREL) show more than 28 gigawatts (GW) of technical offshore wind resource potential capacity, with approximately 100 Terawatt hours per year (TWh/yr) of technical resource potential (Musial et al., 2016, forthcoming) in waters less than 1000-m deep. The estimate of the potential energy production is simply the capacity potential that could be installed using —not an approximation of what actually will be built.[4] The raw estimate does not factor in siting restrictions or other uses for the offshore space that will be necessary, such as shipping lanes and environmentally sensitive areas. Figure 1-1 shows the estimated Hawaii offshore wind resource at 90 meters (m) as well as National Marine Sanctuary areas.

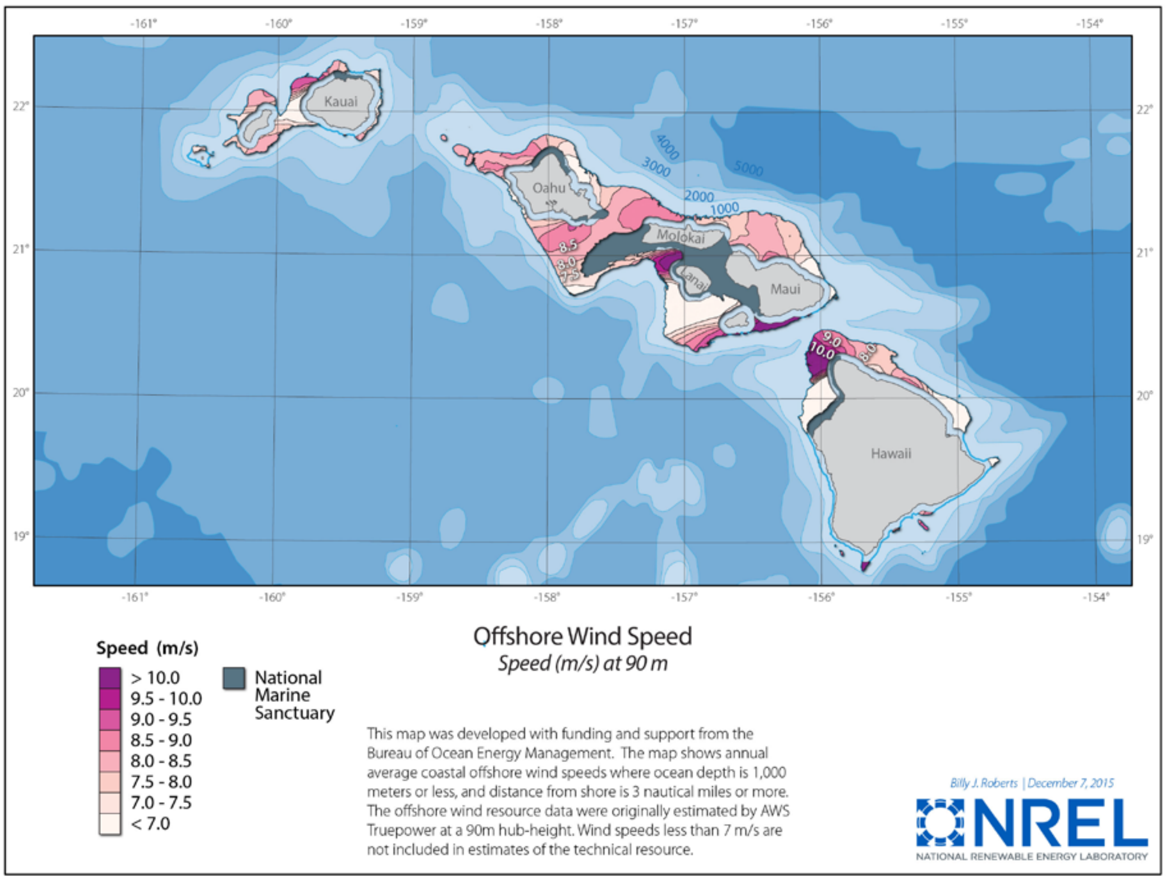

Figure 1-1. Hawaii offshore wind resource with National Marine Sanctuaries in dark green shading

To better understand the potential economic impacts of a large-scale deployment of floating offshore wind technology, the Bureau of Ocean Energy Management commissioned NREL to conduct this economic impact analysis of utility-scale floating offshore wind deployment in Hawaii. The analysis examined two deployments in the 2020–2050 time frame: one 400-MW

[4] For example the JEDI scenarios assumed in this report would utilize only about 3% of this technical resource area.

project installed in 2025 and another scenario consisting of the 400-MW, 2025 deployment as well as an additional 400-MW project installed in 2030. Note that the 400-MW and the 800-MW scenarios are hypothetical and are not intended to be forecasts of actual deployment.

Results highlighted in this report show that offshore wind could contribute to economic development in Hawaii in both the near and long term. Local sourcing of materials and labor would greatly increase the gross economic impact of offshore wind energy deployment in Hawaii, but in-state sourcing of large equipment is unlikely due to Hawaii's remote location. Report results can be used in state and regional planning discussions and can be scaled to get a sense of the economic development opportunities associated with deployment scenarios. Assumptions for this analysis were developed based on interviews with the offshore wind industry and Hawaii offshore development and renewable energy experts. In addition, there is ongoing work within NREL to characterize the current and future cost breakdowns of floating offshore wind power plants. Many of the cost inputs come from NREL's Offshore Wind Balance of System (BOS) model. This work builds on similar analyses of the employment and economic potential of offshore wind development off the coasts of Oregon (at both the state and coastal county levels) and California (Jimenez et al. 2016; Jimenez, Keyser, and Tegen 2016; Speer et al. 2016).

The potential offshore wind capacity and generation scenarios in this report are based on analyses of the wind resource off the Hawaiian Islands and the best-fit offshore wind technologies given water depths, wind conditions, and other factors.

Although no commercial[5] floating wind power plants yet exist, six megawatt-scale demonstration projects have been deployed or are under construction in several countries around the world with generally good success. See Appendix. Figure 1-2 illustrates three generic floating platform technology classes. Spar buoys and semisubmersible 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 U.S. Department of Energy's *Offshore Wind Market Report* (Smith 2015).

[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.

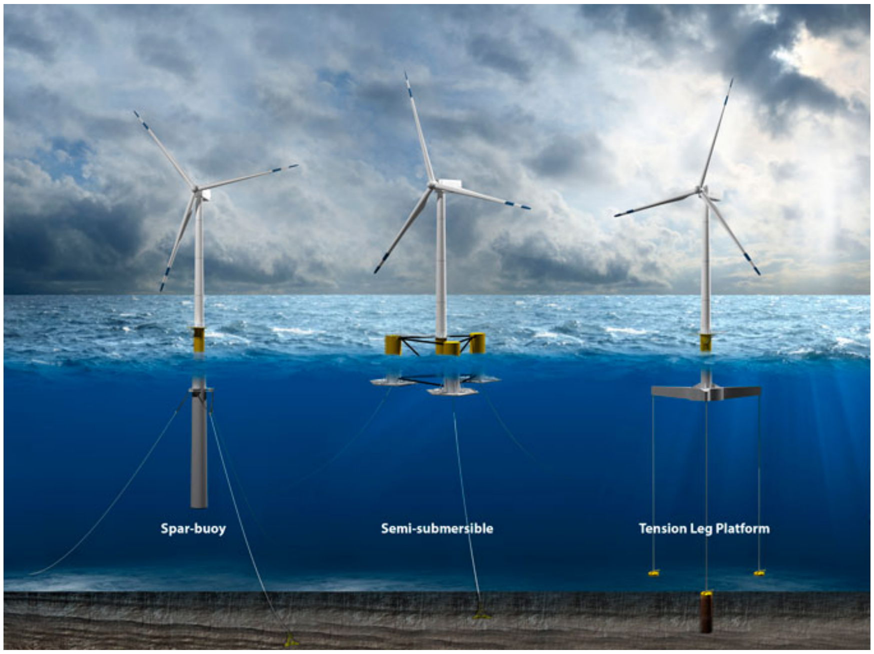

Figure 1-2. Types of offshore wind turbine platforms.

Illustration by Josh Bauer, National Renewable Energy Laboratory

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. NREL's 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 the utilization of an engineering cost model that estimates gross employment and economic impacts. This report explains the assumptions and methods used to estimate the potential jobs and gross economic impacts that could come from two scenarios in the state of Hawaii.

2 Methodology

Gross economic impacts presented in this study were generated using NREL's Offshore Wind JEDI model. JEDI models are 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).

JEDI, like other input-output (I-O) models, is used to 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) 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 from related expenditures. If a consumer goes to the grocery store and buys a domestically grown pineapple, for example, this supports portions of jobs at the local grocery store, at the orchard where the pineapple was grown, and throughout the grower's supply chain, all within a given distribution system.

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 operations of offshore wind facilities are not considered. These impacts that JEDI does not consider include displaced investments 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]

[6] Balance -of -systems costs include non-hardware costs for wind turbine operations, 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.

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 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: on-site, 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 the 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.

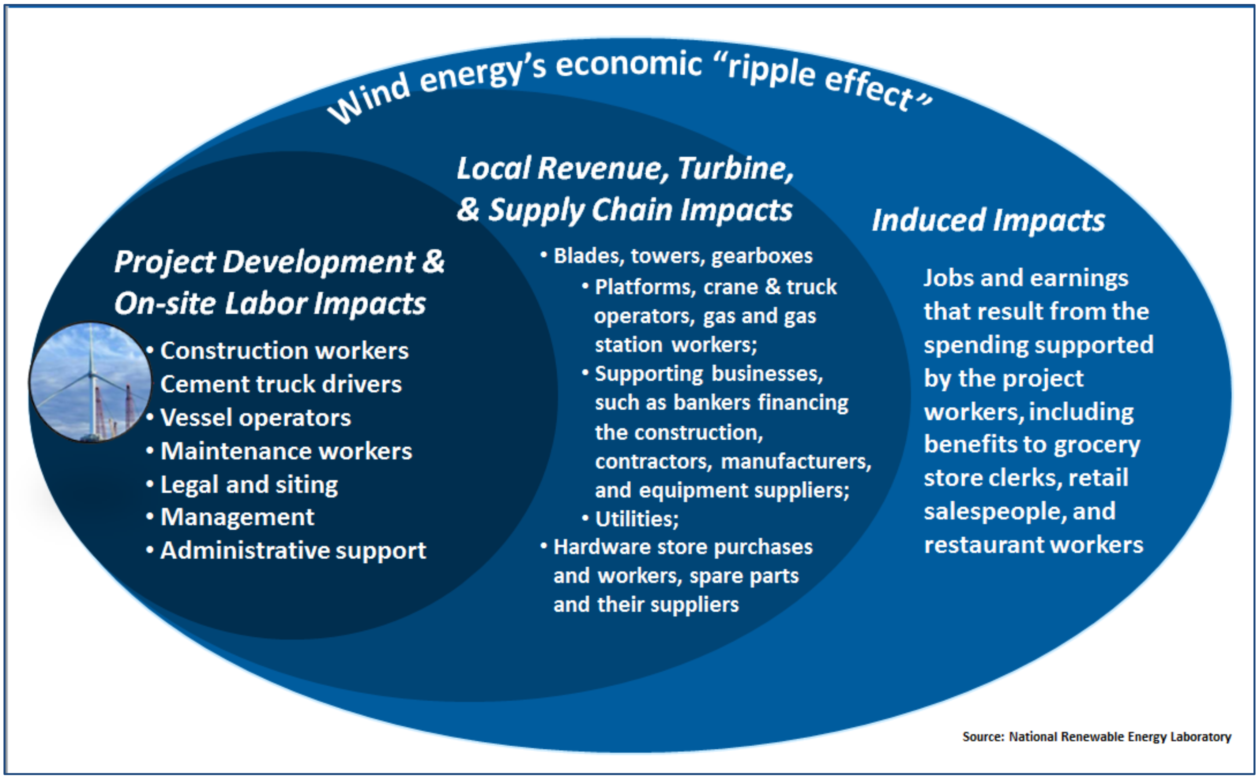

Figure 2-1. JEDI model economic ripple effect: sample jobs in offshore wind.

Image from NREL

JEDI reports four impact metrics: jobs, earnings, 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 1 year. For example, one person working for 10 years or 5 individuals working for 2 years each both total 10 job-years. This is a useful term when describing cumulative or total employment impacts throughout 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* within JEDI, but for the sake of clarity, we use *GDP* throughout this report.)
- *Output* is a level of overall gross economic activity. It is the sum of an industry's contribution to GDP and its expenditures on inputs that are purchased from other businesses within the analysis area (in this case, the state of Hawaii).

All JEDI results are reported within the region of analysis. This study is of potential impacts within the state of Hawaii, so reported results do not include jobs or other impacts outside of Hawaii. The percentage of expenditures made on components within Hawaii was estimated based on interviews with offshore wind technical experts and others familiar with the economy within the state and research on the current capacity within the state to produce components and other inputs.

JEDI reports results during two time periods: construction and O&M. Construction-period estimates are for the equivalent of 1 year. Average impacts for projects that take more or less than 1 year are simply the construction impacts divided by the number of years the project takes. O&M impacts are estimated as 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

This analysis examines two hypothetical floating offshore wind deployments, capital and operating cost assumptions, and the proportion of the various material, services, and labor categories that are sourced from within Hawaii, referred to as the "local content." Table 3-1 shows assumptions for the two deployments.

Table 3-1. Assumptions for Hawaii's Offshore Wind Deployments in 2025 and 2030 (2014$)

Installation Year	2025	2030
Project Size (MW)	400	400
Turbine rated power (MW)	8	10
Distance from port (km)	40	40
Distance from shore (km)	40	40
Water depth (m)	550	550
Turbine capital cost ($/kW)	$1,683	$1,636
BOS capital cost ($/kW)	$3,351	$2,516
Total capital cost ($/kW)	$5,202	$4,293
Annual O&M ($/kW)	$148	$119
Project lifetime (years)	25	25

Due to the different technology assumptions (e.g., rated power), these two installations have different costs and therefore different impacts. It is assumed that fewer Hawaiian laborers will be needed for the construction phase of the 2030 wind power plant because fewer turbines would be necessary in 2030.

JEDI model defaults come from the NREL BOS model, which is used to calculate the expenditure values used in this analysis. Offshore wind technology continues to advance, and turbine size is increasing (Smith 2015). The 2025 installation is assumed to use 8-MW turbines, whereas the 2030 installation is assumed to use 10-MW turbines due to technology innovation. Both capital costs and O&M costs are assumed to decline over time. Inputs to this model include turbine rated power, distance to port, and distance to grid.

We used averages among potential Hawaiian offshore wind sites to estimate water depth, distance to grid, and distance to port. We modeled grid distance as 40 kilometers (km), distance to port as 40 km, and water depth as 550 m. Due to the high cost of construction in Hawaii, (compared to the continental United States) both BOS costs and O&M costs are increased by 35% more than the continental U.S. values.[8]

Local content is determined based on input from experts with knowledge of both offshore wind and the Hawaiian economy as well as evaluations of existing economic activity and capacity within Hawaii. Local content is assumed to be the same for both the 2025 and 2030 installations. These local content assumptions are summarized in Table 3-2 for construction and Table 3-3 for O&M.

[8] This estimate of the increased costs comes from conversations with the offshore wind industry and Hawaiian wind energy experts.

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

Construction Expenditure Items	Hawaii Share
Turbine equipment	0%
Materials and other equipment	0%
Labor installation	
Foundation	60%
Substructure	60%
Erection/installation	60%
Project collection	60%
Grid interconnection (including substation)	60%
Management/supervision	60%
Insurance during construction	
CAR/third-party liability/business interruption, etc.	0%
Development services/other	
Engineering	20%
Legal services	20%
Public relations	90%
Ports and staging	35%
Site certificate/permitting	50%
Air transportation (personnel or materials)	10%
Marine transportation (personnel or materials)	80%
Erection/installation (equipment services)	50%
Decommissioning bonding	0%
Construction financing (AFUDC)	
Interest during construction	0%
Due diligence costs	15%
Bank fees	0%
Other miscellaneous	20%

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

Annual O&M Costs	Hawaii Share
Labor	
Technician salaries	100%
Monitoring & daily operations staff and other craft labor	80%
Administrative	100%
Management/supervision	90%
Materials and services	
Water transport	100%
Site facilities	100%
Machinery and equipment	20%
Subcontractors	20%
Corrective maintenance parts	5%

The levels of local content are uncertain, most notably for specialized offshore wind components, in large part due to uncertainties around the requirements for specialized labor skills and ports. 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. The port itself may need to undergo infrastructure improvements to be able to handle the size and weight of offshore components (Tetra Tech 2010; Navigant 2014; Cotrell et al. 2014). These could be located in Hawaii, but it is also conceivable that components come from Mexico, California, Washington, Oregon, or transported across the Pacific. Similarly, vessels capable of installing offshore wind facilities would either need to be built in or mobilized to Hawaii. Vessels and crews may temporarily relocate to Hawaii, but these would not be considered "local" in this analysis because they are permanently based elsewhere.

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.[9] 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 assumes that no turbine equipment and only a small proportion of the BOS equipment are sourced from within Hawaii. The proportion of manufactured equipment that is ultimately sourced from Hawaii will depend upon global, national, and local market forces.

[9] 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.

4 Results

The overall picture of jobs from each offshore wind deployment is depicted in Figure 4-1. Jobs are presented for each year of the analysis in bar chart format. The 400-MW jobs are in red, and the 800-MW jobs are in blue.

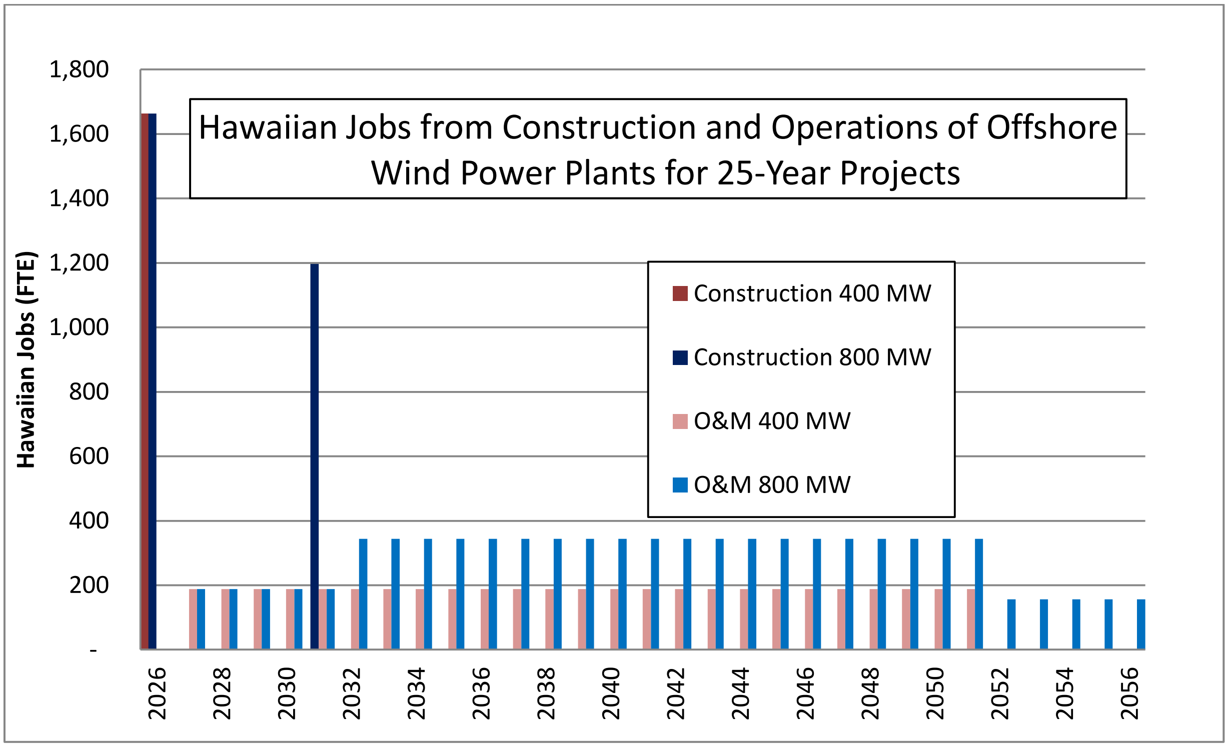

Figure 4-1. Hawaiian jobs from construction and operations of 400 MW (red) and 800 MW (blue) of offshore wind

4.1 Construction Phase

Model estimates show that utility-scale deployment of offshore floating wind turbines results in significant construction-phase impacts. The 2025 scenario supports a total of 1,700 FTEs, and the 2030 scenario supports 1,200 FTEs. Each modeled job shown in Table 4-1 lasts the equivalent of 1 year.[10] In reality, jobs can last longer than 1 year so the work could be spread out among additional years. The construction phases of both projects could support approximately 2,900 jobs that last for the equivalent of 1 year.[11]

[10] 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.
[11] Numbers are rounded to the nearest hundred. Table 4-1 shows jobs estimates without rounding.

Table 4-1. Construction-Phase Impacts in Millions of Dollars (2014$)

400 MW in 2025	**Jobs**	**Earnings**	**Output**	**GDP**
Project development and on-site labor impacts				
Construction and interconnection labor	450	$85		
Construction-related services	260	$23		
Subtotal project development and on-site labor impacts	710	$109	$140	$115
Turbine and supply chain impacts	462	$25	$74	$43
Induced impacts	491	$23	$70	$45
Total impacts	1,663	$157	$284	$203
400 MW in 2030	**Jobs**	**Earnings**	**Output**	**GDP**
Project development and on-site labor impacts				
Construction and interconnection labor	315	$59		
Construction-related services	174	$16		
Subtotal project development and on-site labor impacts	488	$75	$91	$79
Turbine and supply chain impacts	345	$18	$56	$33
Induced impacts	363	$17	$52	$33
Total impacts	1,197	$111	$199	$145
800 MW—Combined	**Jobs**	**Earnings**	**Output**	**GDP**
Project development and on-site labor impacts				
Construction and interconnection labor	765	$145		
Construction-related services	434	$39		
Subtotal project development and on-site labor impacts	1,199	$184	$231	$195
Turbine and supply chain impacts	807	$44	$131	$76
Induced impacts	855	$41	$121	$77
Total impacts	2,860	$268	$483	$348

Average earnings for these jobs vary depending on their relationship to the project. As shown in Table 4-2, on-site workers earn roughly $150,000 annually, whereas supply chain workers earn roughly $54,000 (in 2014 dollars). Earnings include wages and benefits. Induced jobs, which are concentrated in lower paying industries such as retail, earn an average of $48,000 annually. Slight differences in these averages between deployments reflect different pools of workers and economic activity estimated to occur in Hawaii during the 2020–2050 time span.

Table 4-2. Average Annual Earnings of On-Site, Supply Chain, and Induced Workers for Construction-Phase Jobs (2014$)

	400 MW	800 MW
On-Site	$153,000	$154,000
Supply Chain	$54,000	$54,000
Induced	$48,000	$48,000

In addition to supporting jobs and earnings, construction of offshore wind projects in Hawaii could result in broader economic activity. Construction-phase activity could increase Hawaii's annual GDP by $200 million (400 MW) and $350 million (800 MW). Recalling the definitions of value-added (GDP): value added is an industry's contribution 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.

4.2 Operations Phase

The total number of ongoing jobs supported by 2050 ranges from 160 (400 MW) to 340 (800 MW).[12] Table 4-3 uses a project lifetime of 25 years for the 2030 deployment, and thus it extends the time frame to 2055. Most of the job impacts in Hawaii would occur during the O&M phase of projects instead of during construction due to the longer-term nature of these jobs and higher levels of in-state spending.

4.2.1. Job-Years

A job-year is equivalent to one person working full time for 1 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 bars shown in Figure 4-1. Table 4-3 shows the job-years and cumulative impacts from jobs in each project as well as the projects combined. Cumulative operations-phase employment ranges from 3,900 job-years (400 MW) to 8,600 job-years (800 MW).[13] Corresponding cumulative GDP impacts are $450 million to $990 million.

[12] Numbers are rounded to the nearest 10. For more detailed numbers, see Table 4-3.
[13] Numbers are rounded to the nearest 10. For more detailed numbers, see Table 4-3.

Table 4-3. O&M Impacts (Cumulative) in Job-Years and Millions of Dollars (2014$)

400 MW Installed in 2025 (2026–2050)	Job-Years	Earnings	Output	GDP
On-site labor impacts	628	$102	$102	$102
Local revenue and supply chain impacts	3,088	$200	$700	$348
Induced impacts	983	$48	$142	$90
Total impacts	4,698	$350	$944	$539
400 MW Installed in 2030 (2031–2055)	**Job-Years**	**Earnings**	**Output**	**GDP**
On-site labor impacts	628	$102	$102	$102
Local revenue and supply chain impacts	2,470	$160	$558	$278
Induced impacts	801	$39	$116	$73
Total impacts	3,898	$300	$776	$453
Combined	**Job-Years**	**Earnings**	**Output**	**GDP**
On-site labor impacts	1,256	$203	$203	$203
Local revenue and supply chain impacts	5,557	$360	$1,258	$626
Induced impacts	1,783	$86	$258	$163
Total impacts	8,597	$650	$1,719	$993

The average earnings of workers supported by O&M phase activities vary only slightly among the three scenarios. On-site workers earn roughly $160,000 annually, supply chain workers earn roughly $65,000 annually, and induced workers earn $48,000 annually. Overall, this translates to average jobs earning roughly $75,000 in wages, salaries, and employer-provided benefits (Table 4-4).

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

	400 MW	800 MW
On-Site	$162,000	$162,000
Supply Chain	$65,000	$65,000
Induced	$48,000	$49,000

Estimated annual GDP increases due to O&M and other operations-phase employment (including environmental monitoring, legal work, etc.) are $22 million and $44 million, respectively, for the 400-MW and 800-MW deployments.

The construction of offshore wind projects in Hawaii 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 Hawaii. JEDI does not account for the impacts on consumers, such as changes in utility or tax rates or other purchase prices.

5 Conclusion

Hawaiians could benefit greatly from having offshore wind as a new, local electricity resource. Results from this study show that offshore wind could support jobs and contribute to Hawaii's economic development. According to the modeled scenarios, the total impact of a 400-MW floating offshore in wind farm is roughly 5,000–6,500 job-years and $600–$750 million in additional state GDP. Construction-phase activities account for roughly 30% of the total impact, and operations-phase activities account for the remaining 70%. Average annual earnings for construction-phase workers would be more than $90,000, and average earnings for operations-phase workers would be $75,000.

Greater levels of spending made by developers and operators within Hawaii would support greater gross economic impacts. Higher levels of manufacturing in Hawaii could significantly increase the jobs and other economic development impacts, but the supply chain is unlikely to develop due to Hawaii's remote location and limited industrial base. Based on analysis of other locations, even the combined scenario is unlikely to be sufficient to stimulate significant supply chain growth. It is difficult to forecast what will actually happen due to advances in technology, changes in manufacturing, and uncertainty about domestic energy policy and both domestic and international economic growth during the analysis period.

Regardless of the specific technology or in-state content, there is a strong potential for economic development and employment from offshore wind in Hawaii, assuming projects are sited appropriately and operate as expected.

References

Beiter, Philipp. 2015. *2014 Renewable Energy Data Book*. DOE/GO-102015-4724. Golden, CO: National Renewable Energy Laboratory. Accessed January 2016. http://www.nrel.gov/docs/fy16osti/64720.pdf.

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. http://www.nrel.gov/docs/fy13osti/56390.pdf.

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

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.

Jimenez, T., D. Keyser, S. Tegen, and B. Speer. 2016. *Floating Offshore Wind in Oregon: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios*. NREL/TP-5000-65421. Golden, CO: National Renewable Energy Laboratory. Forthcoming.

Jimenez, T., D. Keyser, and S. Tegen. 2016. *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. http://www.nrel.gov/docs/fy15osti/61315.pdf.

Tetra Tech EC, Inc. 2010. *Port and Infrastructure Analysis for Offshore Wind Energy Development*. Prepared for Massachusetts Clean Energy Center. Boston: Tetra Tech EC. Accessed from http://images.masscec.com/uploads/attachments/Port%20and%20Infrastructure%20Analysis%20for%20Offshore%20Wind%20Energy%20Development/MA%20Port%20Study%20Final%20Report_4-20-10.pdf 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: Floating Offshore Wind Projects Installed or Under Construction

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