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

Bethany Speer, 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 2016-029. 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-5000-65352
April 2016

Contract No. DE-AC36-08GO28308

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

Bethany Speer, 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 2016-029. 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-5000-65352
April 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").

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 California. 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 Tony Jimenez, Tyler Stehly, Christopher Mone, and Michael Maness of NREL for analysis and modeling assistance.

Executive Summary

Construction of the first offshore wind farm in the United States began in 2015, 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) has commissioned the National Renewable Energy Laboratory (NREL) to analyze two hypothetical, large-scale deployment scenarios for California: 16 GW of offshore wind by 2050 (Scenario A) and 10 GW of offshore wind by 2050 (Scenario B). The results of this analysis can be used to better understand the general scales of economic opportunities that could result from offshore wind development. Assumptions for this analysis come from projected electricity demand in California, 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 (BOS) model. Figure ES-1 shows the hypothetical deployment scenarios beginning with small-scale demonstration projects in 2020.

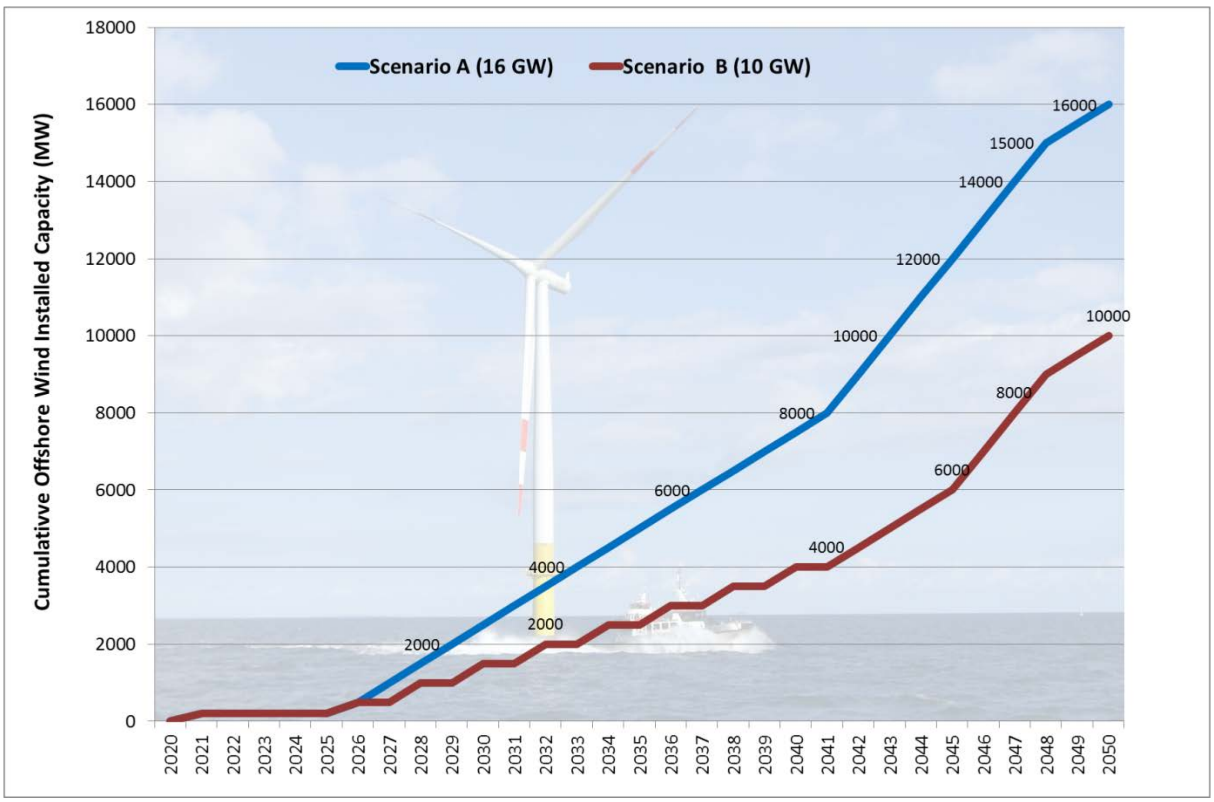

Figure ES-1. Two California offshore wind deployment scenarios modeled between 2020 and 2050

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

Scenario A has more turbines that are installed at a faster rate with more components produced and services procured locally. Scenario B has fewer turbines installed and less local manufacturing and services. Both Scenarios A and B demonstrate that offshore wind could contribute to the economic development of California in the near term, with even greater impacts seen in later years (2040–2050).

Results show total state gross domestic product (GDP) impacts of $16.2 billion in Scenario B or $39.7 billion in Scenario A for construction; and $3.5 billion in Scenario B or $7.9 billion in Scenario A 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. Establishing an in-state supply chain that can provide even a modest portion of the material and labor for floating offshore wind installations can dramatically increase the economic impact of offshore wind deployment within California.

Table ES-1 and Figures ES-2 and ES-3 show jobs estimates from the construction and operation of offshore wind projects in California during these years:

Table ES-1. Estimated California Jobs from Offshore Wind Projects in Year 1, 2030, and 2045

Year	2020/21 (Construction 2020; Operations 2021[1])	2030	2045
Higher Deployment Scenario (A)			
Construction Phase Jobs	1,320	5,790	23,780
Operations Phase Jobs	50	680	4,270
Lower Deployment Scenario (B)			
Construction Phase Jobs	1,320	4,260	14,890
Operations Phase Jobs	50	380	1,720

Note: Construction jobs 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.

[1] Construction jobs are shown for 2020. Operations do not begin till 2021, so operations jobs are shown for 2021.

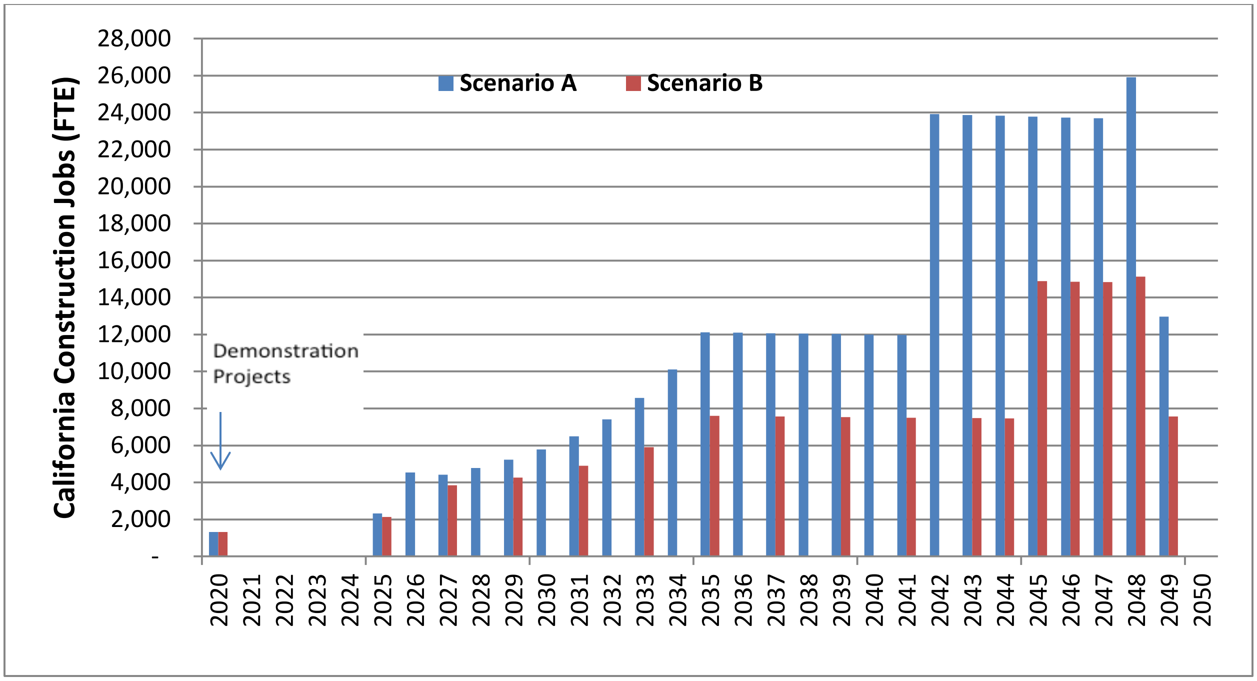

Figure ES-2. California's annual construction-phase jobs supported in Scenario A and Scenario B

Note: Total jobs include on-site, project development, supply chain, and induced jobs.

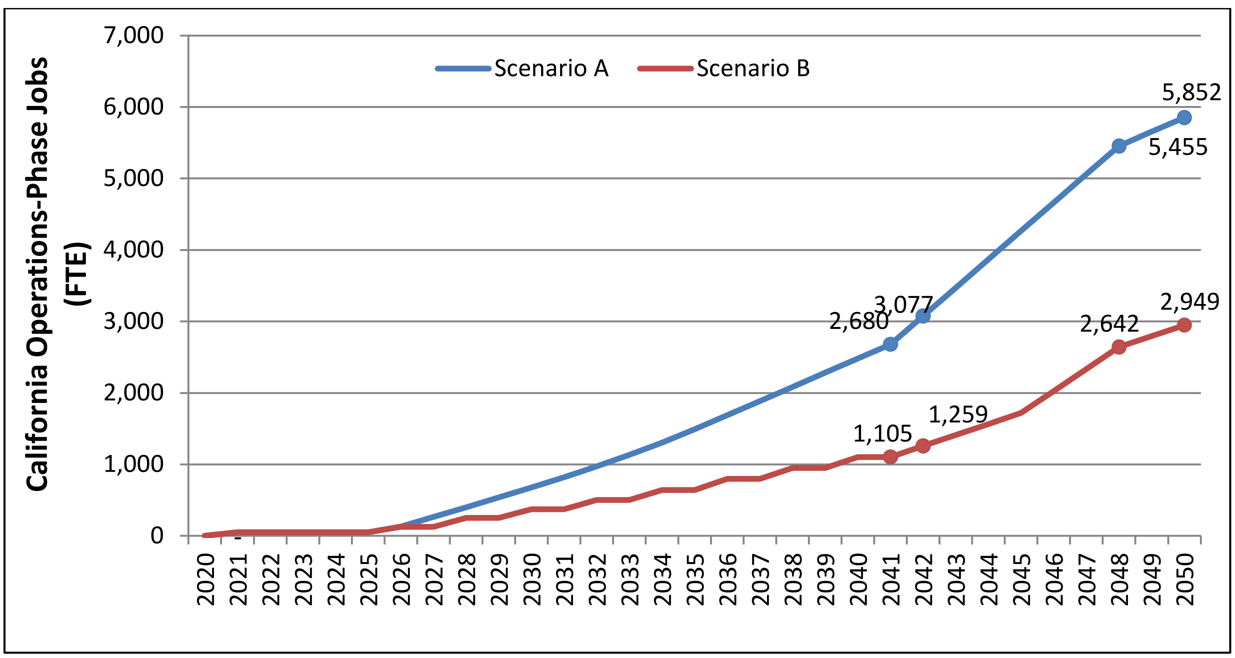

Figure ES-3. California's annual operations-phase jobs supported by offshore wind during the analysis period

Note: Total jobs include on-site, supply chain, and induced jobs.

Table of Contents

Figures and Tables

1 Introduction

California has the technical wind energy resource potential to power at least 100,000 megawatts (MW) off of its coast (Musial et al., forthcoming).[2] As highlighted in Figure 1-1, California's offshore wind resource is especially strong in the northern part of the state. California also has infrastructure assets that could be attractive to project developers. For example, existing ports could potentially be leveraged for existing grid interconnections or other operations.

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 California. The analysis examined two deployment scenarios in the 2020–2050 timeframe: a higher deployment scenario totaling 16 GW and a lower deployment scenario at 10 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 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 California offshore development and renewable energy experts, and ongoing work within 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 Balance of System (BOS) model. This work builds off of similar analyses of the economic potential of offshore wind development off of the coasts of Oregon (at both the state and coastal county levels) and Hawaii (Jimenez et al. 2016a; Jimenez et al. 2016b; Jimenez et al. 2016c).

The potential offshore wind capacity and generation scenarios in this report are based on analysis of the wind resource off the coast of California and the best-fit offshore wind technologies given water depths, wind conditions, and other factors. These estimates are not an approximation for 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.

In addition to strong offshore wind resources and existing infrastructure, California also has significant electricity demand and a political history of supporting renewable energy. California's updated Renewable Portfolio Standard, signed on October 7, 2015, requires that 50% of each utility's retail sales come from renewable energy by December 31, 2030 (DSIRE 2015). As a result of previous iterations of this policy and also due to other incentives and market drivers, California has become a leader in the United States in terms of installed renewable energy capacity, with the highest amounts of solar photovoltaics (PV), biomass, geothermal, and concentrating solar power, and the second highest amounts of land-based wind and hydropower, by state (Beiter 2015).

[2] 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.

California produced about 68% of its electricity in 2014 from in-state power plants or from California-utility-owned power plants that are out of state. About 7.7% (or 6,715 megawatts) of the installed capacity of these plants was from solar photovoltaic systems (SEIA/GTM 2014; California Energy Commission 2015). Given the diurnal generation profile of solar PV, even this level of penetration can significantly impact grid operations because of large peaks of generation in the afternoon when the sunlight is most direct. The generation profile of offshore wind may be complementary to solar PV and could help Californians reach higher penetrations of renewable electricity without curtailment of solar power. Offshore wind speeds tend to peak in the evenings when Californians are typically increasing electricity usage in their homes. When combining the load profiles of solar PV and offshore wind, a more steady generation profile might be achieved. Offshore wind could help offset demand for additional fossil fuel baseload plants and help California meet its Renewable Portfolio Standard objectives.

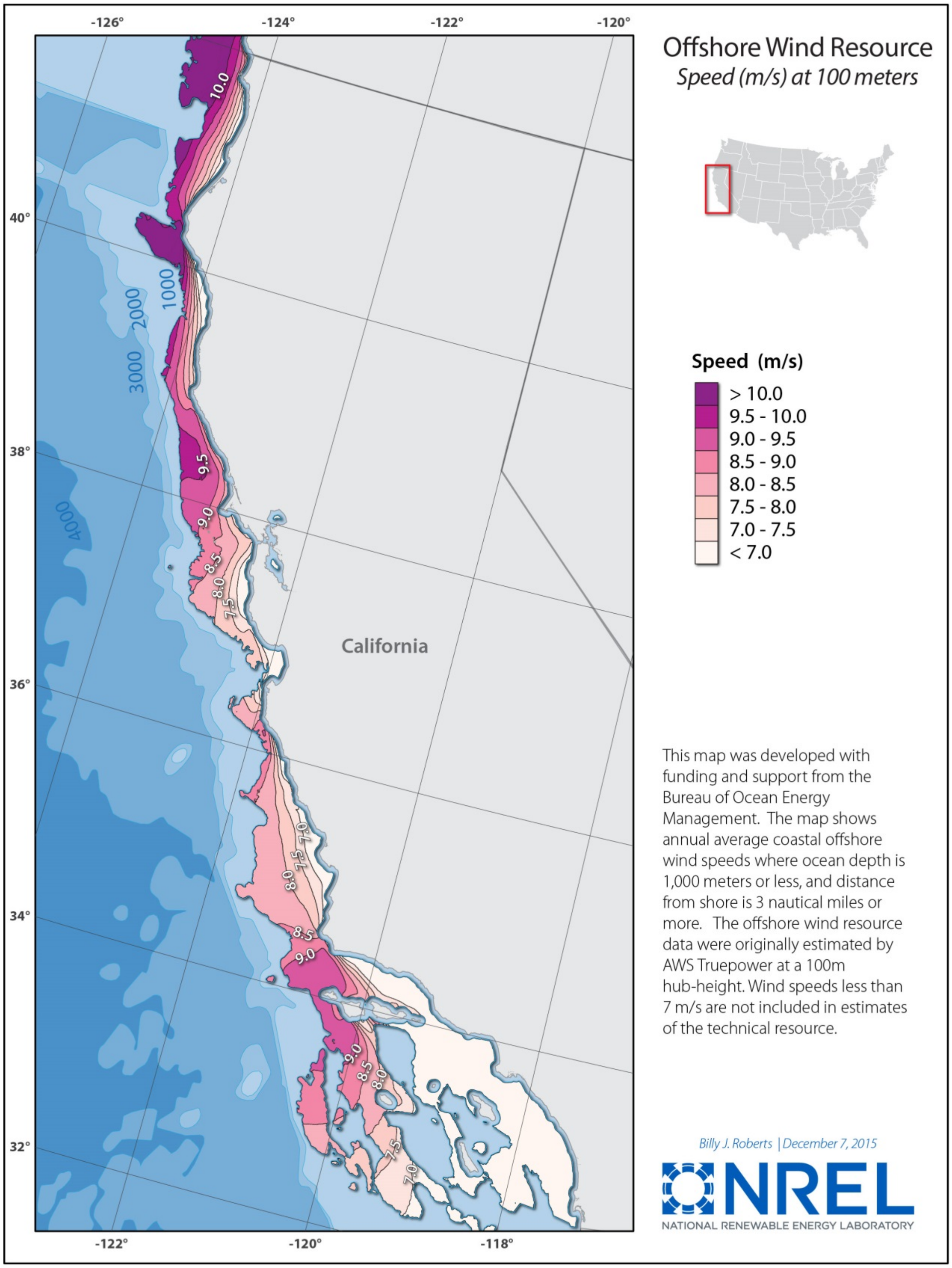

Figure 1-1. California offshore wind speeds at a height of 100 meters

Source: NREL, with data from AWS Truepower

Offshore wind technology for deep water is still in the prototype development stages. However, NREL estimates that 95% of the technical resource area off the coast of California is over waters with depths that exceed 60-meters, it is not feasible to use proven fixed bottom offshore wind platform technologies at most sites. Based on recent studies, fixed bottom offshore wind structures are less economical in waters above 60-meters deep than floating systems. Compared to Europe, California has a much smaller area of shallow seafloor. While no commercial[3] 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).

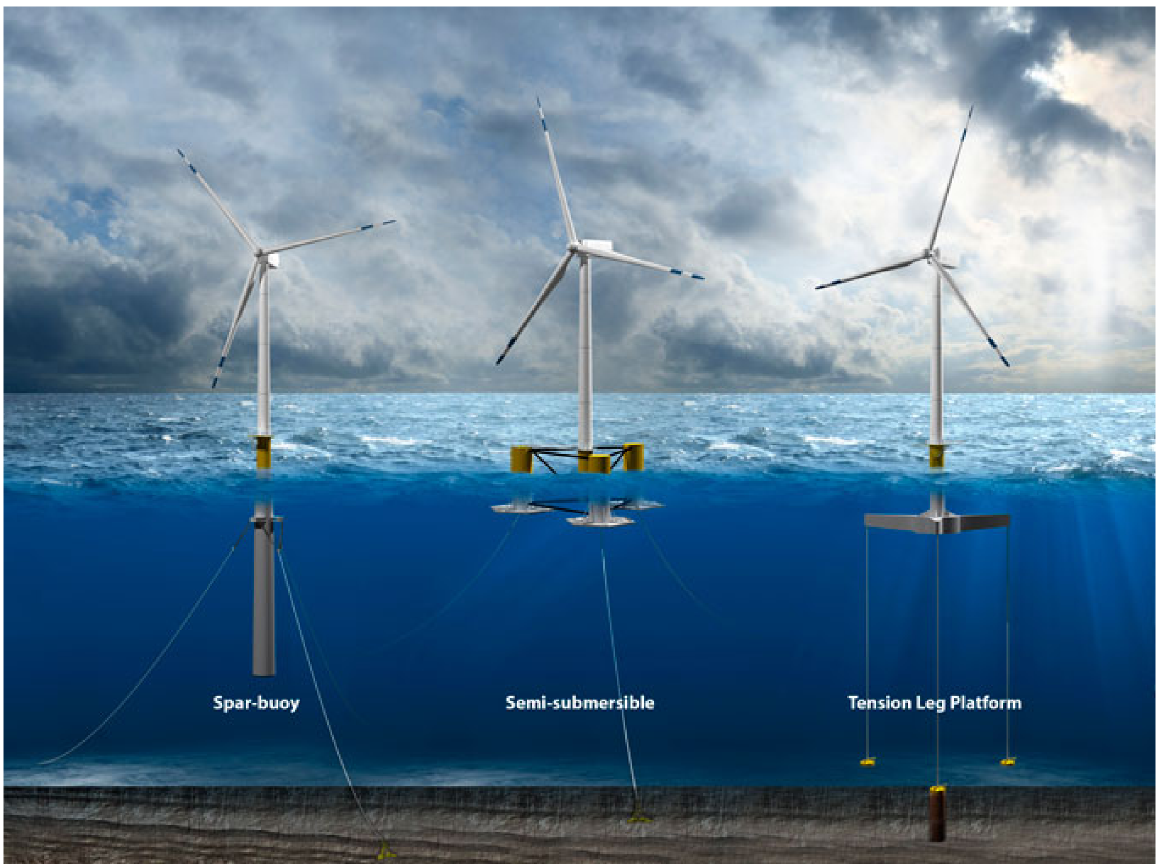

Figure 1-2. Illustration of types of offshore wind turbine platforms

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.[4] The Offshore Wind Jobs

[3] 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.

[4] The first offshore wind farm in the United States is expected to be installed off of Block Island in Rhode Island in 2016; however, this is a fixed-bottom (not floating) offshore wind project.

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.

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, 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 from related expenditures. 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, at the orchard where the apple was grown, and throughout the apple 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.[5]

There are several assumptions in JEDI that 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.[6]

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

- *Onsite 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, and permitting.
- *Induced* impacts arise when onsite 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.

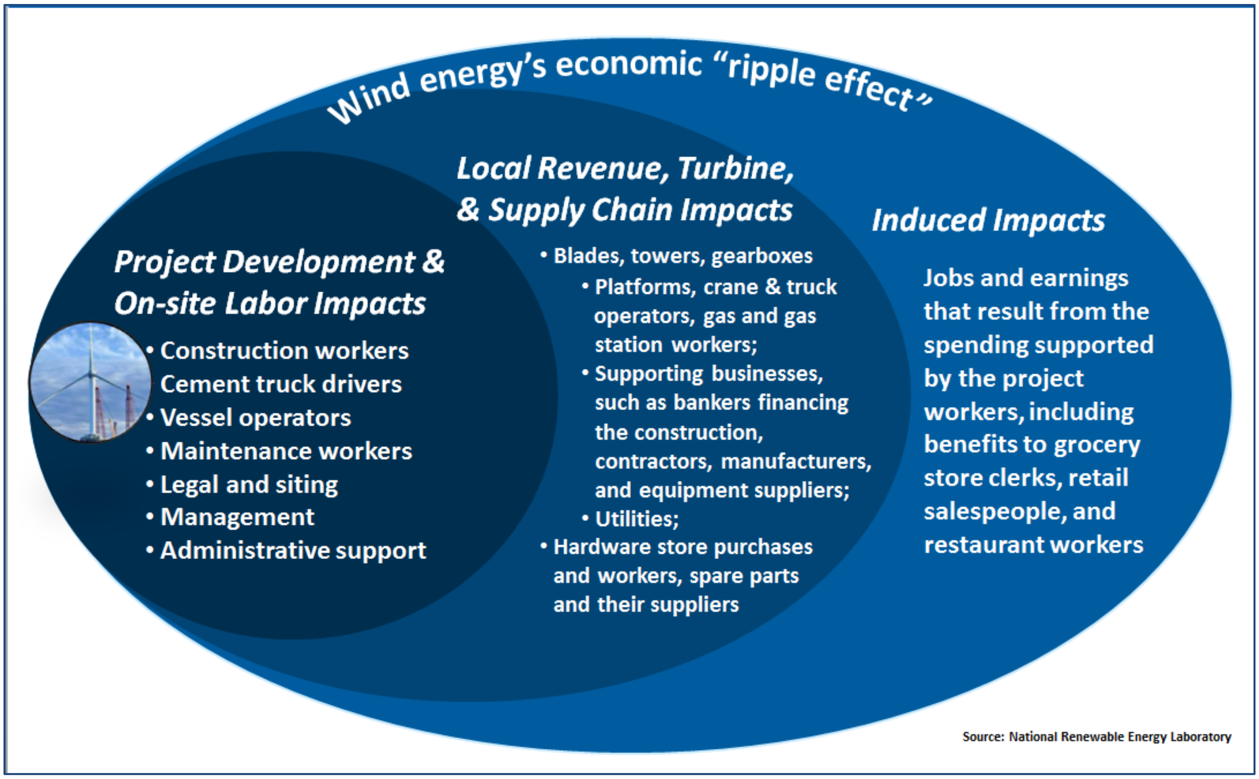

Figure 2-1. JEDI model economic ripple effect: sample jobs in offshore wind

Source: NREL

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 each both total 10 job-years. This is a useful term when describing cumulative or total employment impacts over a multi-year period.
- *Earnings* are wages and salaries as well as supplements, such as health insurance and employer contributions to retirement funds.
- *Gross Domestic Product (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 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 California projects, including taxes.

This study is of potential impacts within the State of California, so reported results do not include impacts outside of California. The percentage of expenditures made on components within California 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, the 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 fishing and military.

3 Scenarios

We analyzed two scenarios for the construction and operation of hypothetical offshore wind projects between the years 2020 through 2050 to estimate potential employment and other economic impacts in California. Scenario A assumes a cumulative installed capacity of 16 GW and Scenario B, a cumulative installation of 10 GW. The deployment scenarios are the result of consultations with technical experts and offshore wind energy leaders, California energy demand projections, and the California offshore wind resource.

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 timespan. Beyond the smaller projects (200–300 MW), we assume larger projects on the order of 500 MW are built. Figure 3-1 illustrates this cumulative capacity schedule.

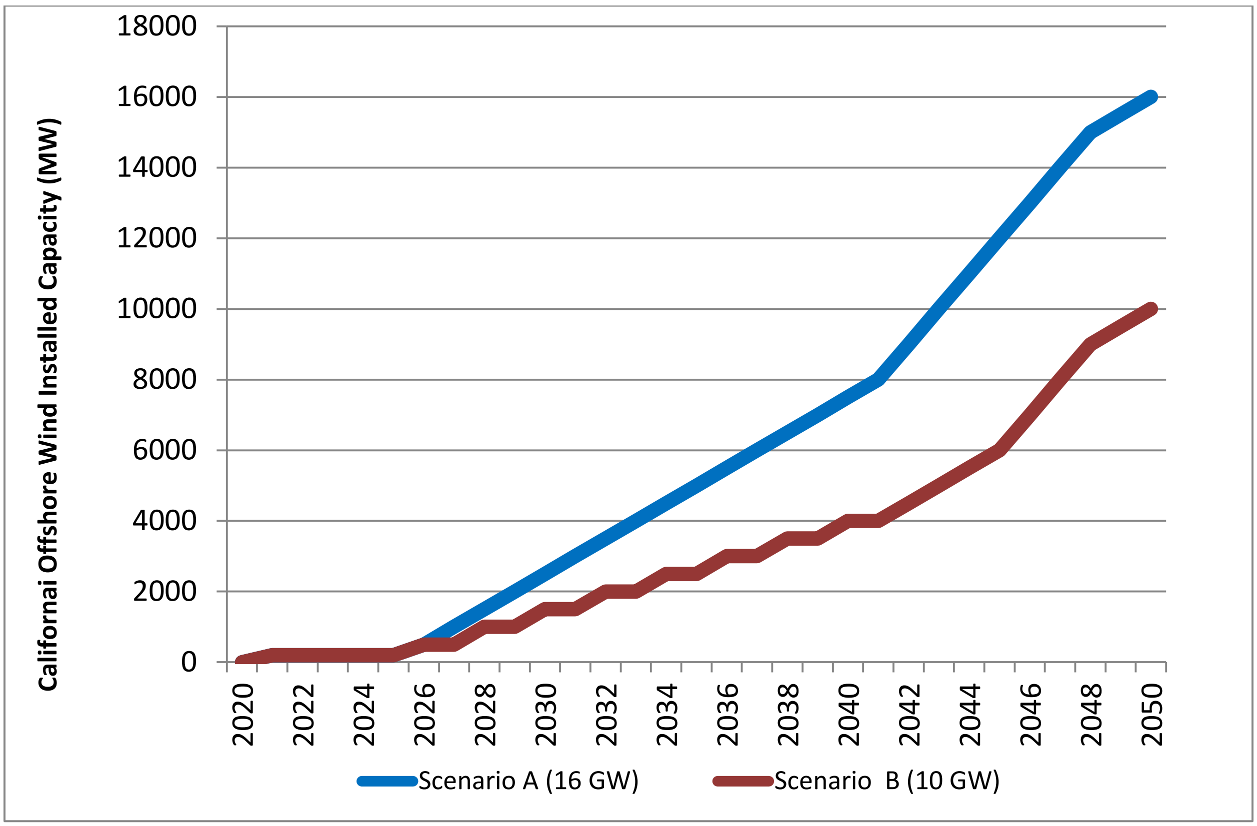

Figure 3-1. California offshore wind deployment under both growth scenarios

JEDI model defaults come from the NREL BOS model, which is used to calculate the expenditure values used in this analysis. The assumptions used for distance to port, distance to grid, and water depth are based on internal analysis and are averages across the potential California offshore wind sites, with potential O&M ports approximately 47 kilometers (km) to 127 km from the hypothetical project sites. The distance to grid is roughly between 40 km and 100 km and the water depth is an estimated 100 meters to 1,000 meters. Thus, we use a constant distance to port of 80 km, distance to grid of 67 km, and average water depth of 558 meters.

Local content assumptions were determined based on interviews with California market experts and analysis of offshore wind economic activity and capacity within the state. Scenario A assumes higher local content compared to Scenario B, based on the more rapid market growth demonstrated by the greater cumulative installed capacity that would incentivize increased levels of supply chain growth. For example, nacelle/drivetrain, blade, and tower manufacturers may have stronger business cases to build facilities in California if there is local demand. Tables 3-1 and 3-2 include the local content assumptions for Scenarios A and B for construction and O&M, respectively. Year 0 is the year projects begin in which there is almost no California content, or "local content." Local content is assumed to increase through the life of the project. Table 3-2 shows the local content growth from year 0 to about 2035, where much of the local content stabilizes due to multiple deployments

Table 3-1. Local (California) Content Assumptions – Construction

Construction Costs	**California Share**		
Construction Expenditure Items	**Year 0**	**Scenario A**	**Scenario B**
Turbine Equipment			
Nacelle/Drivetrain	0%	50%	25%
Blades	0%	100%	50%
Towers	0%	100%	100%
Ground transportation (to project staging area/port)	0%	0%	0%
Warranty cost	0%	0%	0%
Materials and Other Equipment			
Basic construction (concrete, rebar, gravel, mooring lines, etc.)	60%	80%	70%
Foundation (including anchors or alternatives for fixed bottom types only)	10%	65%	30%
Substructure	0%	55%	25%
Project collection system	0%	0%	0%
HV cable (project site to point of grid interconnection)	5%	30%	15%
Onshore substation	5%	45%	30%
Offshore substation	5%	40%	25%
Labor Installation			
Foundation	5%	65%	30%
Substructure	5%	65%	30%
Erection/Installation	5%	65%	30%
Project collection	5%	65%	30%
Grid interconnection (including substation)	5%	65%	30%
Management/Supervision	0%	45%	15%
Insurance During Construction			

Construction Costs	California Share		
Construction Expenditure Items	**Year 0**	**Scenario A**	**Scenario B**
CAR/third-party liability/business interruption, etc.	10%	20%	10%
Development Services/Other			
Engineering	5%	90%	30%
Legal services	10%	90%	30%
Public relations	90%	100%	90%
Ports and staging	10%	85%	30%
Site certificate/Permitting	25%	85%	65%
Air transportation (personnel or materials)	0%	0%	0%
Marine transportation (personnel or materials)	10%	60%	25%
Erection/Installation (equipment services)	10%	70%	60%
Decommissioning bonding	50%	75%	60%
Construction Financing (AFUDC)[7]			
Interest during construction	0%	0%	0%
Due diligence costs	15%	25%	20%
Reserve accounts (MRA/DSRA)	0%	0%	0%
Bank fees	15%	30%	20%
Other Miscellaneous	10%	70%	20%

Table 3-2. Local (California) Content Assumptions – O&M

Annual Operating and Maintenance Costs	California Share		
Operational Costs	**Year 0**	**Scenario A**	**Scenario B**
Labor			
Technician salaries	50%	100%	100%
Monitoring & daily operation staff and other craft labor	50%	75%	50%
Administrative	100%	100%	100%
Management/Supervision	10%	100%	90%
Materials and Services			
Water transport	20%	75%	50%
Site facilities	100%	100%	100%
Machinery and equipment	5%	25%	10%
Subcontractors	1%	25%	10%
Corrective maintenance parts	5%	25%	10%

[7] AFUDC is an abbreviation of Allowance for Funds Used During Construction.

We assume fairly significant portions of local content for construction and operating costs for both Scenarios A and B owing to California's large and diverse economy and, as mentioned previously, its significant energy sector. Before the economic downturn in 2008, California's annual GDP was $1.9 trillion (BEA 2015). The economy had recovered by 2011, and over the last 5 years has seen an approximate average annual growth rate of 4%. The durable goods manufacturing sector is especially strong, with a growth rate of 7% over the past year reaching $145 billion in GDP in 2014.

Both Scenarios A and B assume that large equipment will be produced in California, including nacelles/drivetrains and towers. Smaller equipment is also assumed to be produced in California along with other materials and services. We assume that the level of local content stabilizes by 2035. In Scenario A, the construction-phase overall California content for labor and equipment grows from 18% to 54%. This Sparkline shows the increases over time from 18% to 54% from 2025 (after demonstration projects) to 2050 . The Scenario A operations-phase California content ranges from 26% to 52% with a steadier ramp . The Scenario B construction-period California content grows from 16% to 35% . And Scenario B operations-phase local content ranges from 18% to 38% .

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 California's coast; ports could also be located elsewhere along the Pacific Coast (e.g., Washington, Oregon, or Mexico) or across the Pacific, in Asia. Vessels capable of accommodating the larger components would need to be built in California or be sent to the California area. If crews to staff ports, shipyards, or vessels move to California temporarily, these would not be considered Californian 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.[8] 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.

[8] 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

4.1 Construction Phase

As shown in Figure 4-1, we estimate that annual construction jobs ranging from 2,000 to 26,000 could be supported in California from 2025 to 2050. Each job in Figure 4-1 is the equivalent of one full-time job for one worker for one year. For modeling purposes, the actual construction is assumed to last for one year, although in reality, construction may take longer.

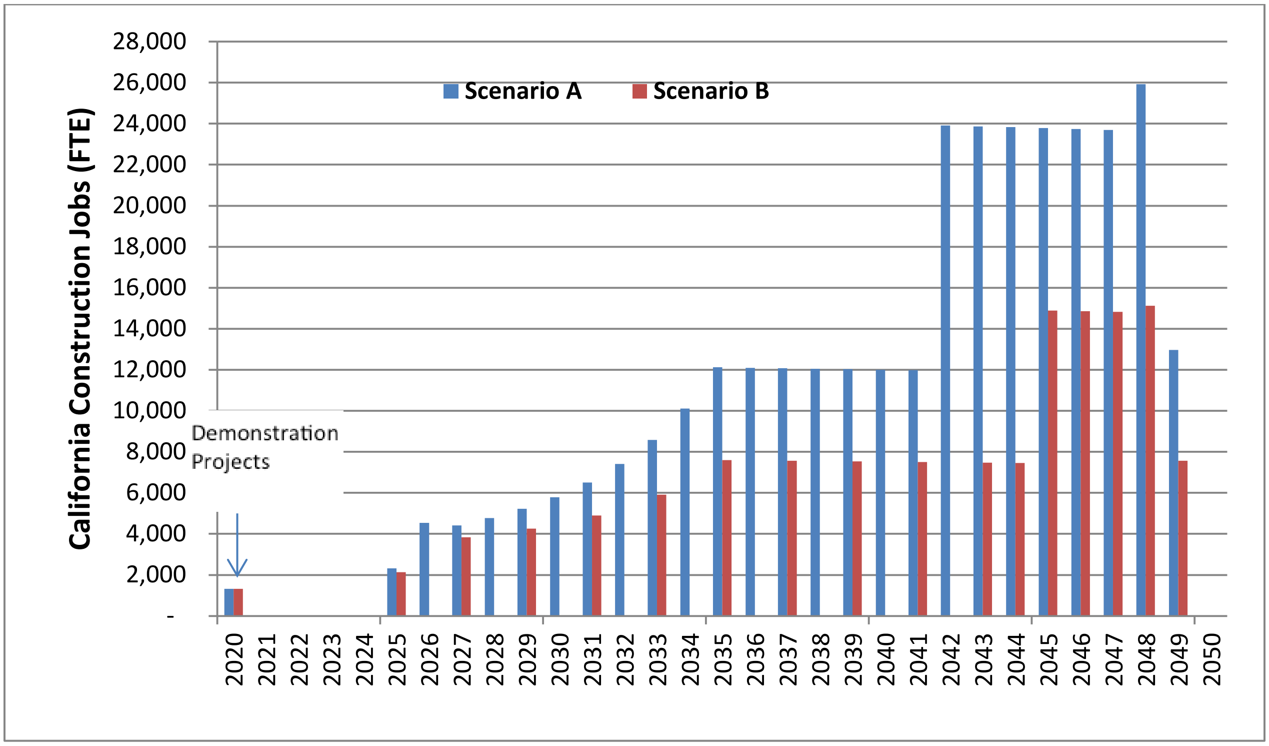

Figure 4-1. Construction-phase California Jobs for both scenarios

Note: Both scenarios begin with smaller scale demonstration projects in 2020.

Under the assumption it will take some time for the offshore manufacturing, project development, and other service markets to develop, the vast majority of the jobs are supported toward the end of the scenarios, as indicated in Table 4-1. The following detailed breakdowns show average annual jobs, earnings, output, and GDP for both scenarios over the near, medium, and long term.

Table 4-1. Average Annual Construction Phase Impacts by Decade – Scenarios A and B ($ Millions, 2014)

		2020–2030		2030–2040		2040–2050	
	Scenario	**A**	**B**	**A**	**B**	**A**	**B**
Jobs	Onsite	260	100	1,130	280	2,340	860
	Supply Chain	1,350	550	5,490	1,670	11,280	4,940
	Induced	970	410	3,450	1,090	6,950	3,180
	Total	**2,580**	**1,060**	**10,070**	**3,040**	**20,570**	**8,980**
Earnings ($ Millions, 2014)	Onsite	$37	$14	$154	$14	$319	$121
	Supply Chain	$111	$45	$461	$45	$949	$411
	Induced	$56	$24	$199	$24	$400	$182
	Total	**$204**	**$82**	**$815**	**$82**	**$1,668**	**$714**
Output ($ Millions, 2014)	Onsite	$44	$16	$186	$46	$382	$138
	Supply Chain	$445	$177	$1,885	$572	$3,903	$1,700
	Induced	$158	$67	$560	$177	$1,125	$513
	Total	**$646**	**$260**	**$2,631**	**$795**	**$5,410**	**$2,351**
GDP ($ Millions, 2014)	Onsite	$39	$15	$165	$42	$341	$127
	Supply Chain	$173	$71	$705	$214	$1,436	$622
	Induced	$100	$42	$356	$112	$715	$326
	Total	**$313**	**$128**	**$1,226**	**$368**	**$2,491**	**$1,074**

Table 4-2 summarizes average job earnings, which vary depending on the skills required and role in the project. Onsite workers earn approximately $130,400 to $139,700, supply chain workers $79,500 to $81,600, and jobs in induced industries earn just over $55,000 in both scenarios, annually. The variances in the averages between the two scenarios reflect the different pools of workers and economic activity estimated to occur in California over the 2020–2050 timespan.

Table 4-2. Average Annual Earnings of Onsite, Supply Chain, and Induced Workers ($ 2014)

	Scenario A	**Scenario B**
Onsite	$130,422	$139,725
Supply Chain	$81,593	$79,452
Induced	$55,389	$55,209
Overall	**$76,986**	**$75,746**

In addition to supporting jobs and earnings, construction of offshore wind projects in California could result in broader economic activity. For example, there could be between an estimated $1 billion to $2.5 billion of annual in-state GDP impacts from 2040–2050, and between an estimated $2.4 billion to $5.4 billion in overall economic outputs.

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 bars shown in Figure 4-1. When calculated in job-years, Scenario A's construction activity would support approximately 327,000 job-years over the 2020–2050 time frame, and Scenario B's construction activity would support approximately 135,000 job-years between 2020 and 2050.

4.2 Operations Phase

Most of the jobs impacts in California 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 in 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 3,000 in Scenario B to nearly 6,000 in Scenario A. However, when calculated in job-years, the O&M phase of Scenario A supports 562,000 job-years, and Scenario B's O&M phase supports 258,000 job-years that continue beyond the period of analysis. O&M jobs 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.

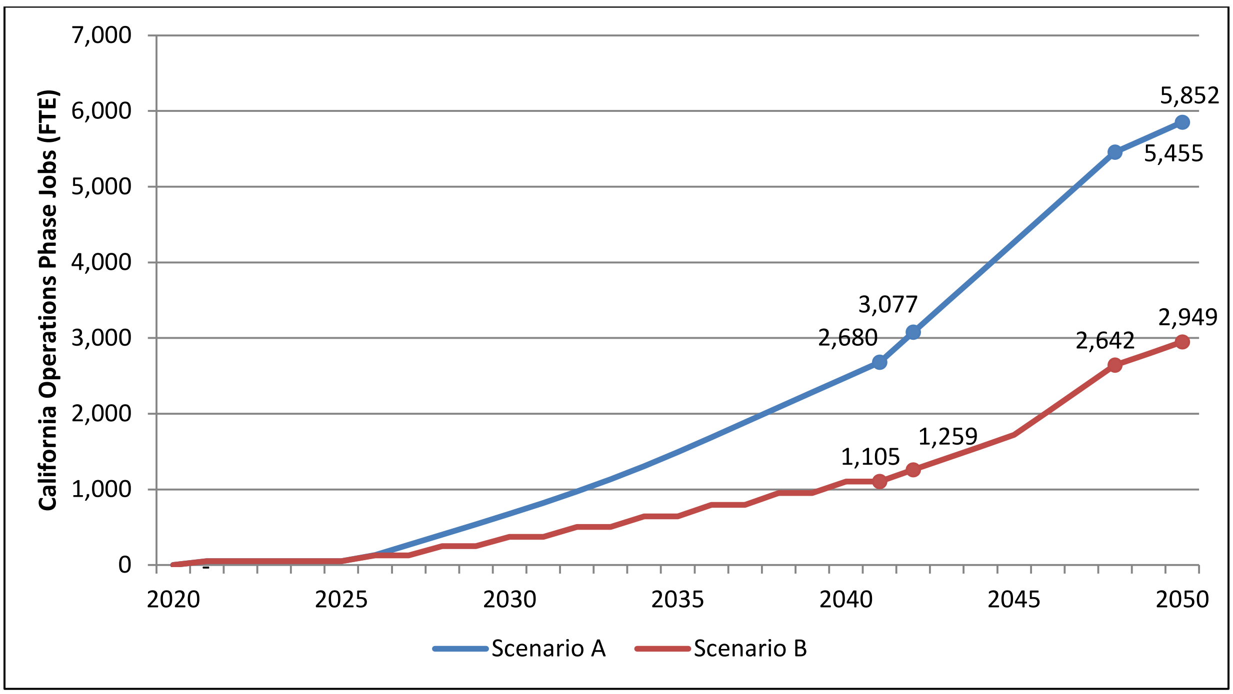

Figure 4-2. California's operations-phase FTE jobs supported by offshore wind

An additional $400 (Scenario B) to $700 million in GDP (Scenario A), and $600 million (Scenario B) to $1.2 billion (Scenario A) in annual economic output could be supported by operations, maintenance, and other operations-phase employment, such as environmental monitoring and legal work (see Table 4-3 below for further details).

Table 4-3. An Annual Snapshot of O&M Impacts in Years 2030, 2040, 2050 – Scenarios A and B (Millions, $2014)

		2030		2040		2050	
	Scenario	**A**	**B**	**A**	**B**	**A**	**B**
Jobs	Onsite	130	80	530	270	1,270	780
	Supply Chain	370	200	1,310	560	3,060	1,450
	Induced	170	90	640	270	1,520	720
	Total	**700**	**400**	**2,500**	**1,200**	**5,900**	**3,000**
Earnings ($ Millions, 2014)	Onsite	$14	$8	$62	$32	$152	$93
	Supply Chain	$29	$16	$105	$43	$247	$113
	Induced	$10	$6	$39	$16	$91	$44
	Total	**$54**	**$30**	**$205**	**$92**	**$491**	**$249**
Output ($ Millions, 2014)	Onsite	$14	$8	$62	$32	$152	$93
	Supply Chain	$86	$45	$316	$127	$751	$334
	Induced	$29	$16	$108	$46	$256	$122
	Total	**$129**	**$69**	**$486**	**$205**	**$1,159**	**$550**
GDP ($ Millions, 2014)	Onsite	$14	$8	$62	$32	$152	$93
	Supply Chain	$50	$27	$182	$75	$429	$196
	Induced	$19	$10	$69	$29	$163	$78
	Total	**$84**	**$46**	**$313**	**$136**	**$745**	**$367**

As indicated in Table 4-4, the difference between Scenarios A and B in the average earnings for O&M workers is negligible. Onsite workers earn approximately $116,000 to $117,000, supply chain workers $78,000 to $80,000, and induced industries workers $60,000 to $61,000 in annual wages, salaries, and employer-provided benefits.

Table 4-4. Average Annual Earnings of O&M Worker ($2014)

	Scenario A	**Scenario B**
Onsite	$116,844	$115,831
Supply Chain	$80,042	$77,546
Induced	$60,188	$60,667
Overall Average	$82,770	$82,923

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

5 Conclusion

The construction of offshore wind farms in California over the near- to long-term could contribute to economic development in the state, especially if significant portions of equipment and services were procured locally, as is assumed in this analysis. For example, offshore wind projects could support nearly 6,000 long-term California operations-phase jobs by the year 2050, in the high (16-GW) scenario; or nearly 3,000 jobs for the lower deployment (10-GW) scenario. Cumulative GDP impacts are estimated to be $39.7 billion (Scenario A) or $16.2 billion (Scenario B) for the construction phases and $7.9 billion (A) or $3.5 billion (B) in the operations phases.

Higher the levels of spending by developers and operators within California could result in greater gross economic impacts. 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 California. Given its offshore wind resources, potential for port development, and diverse economy—including a robust energy sector—there is strong potential for employment and economic activity from the construction and operation of new offshore wind projects in California.

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.

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. Accessed May 2015. http://www.nrel.gov/docs/fy13osti/56390.pdf.

California Energy Commission. 2015. "Energy Almanac: California Electricity Producers." Accessed October 21, 2015. http://energyalmanac.ca.gov/electricity/overview.html.

DSIRE (Database of State Incentives for Renewables and Efficiency). 2015. "California Renewables Portfolio Standard." Accessed October 21, 2015. http://programs.dsireusa.org/system/program/detail/840.

Bernstein, Brock B., Andy Bressler, Peter Cantle, Max Henrion, DeWitt John, Sarah Kruse, Daniel Pondella, Astrid Scholz, Tim Setnicka, and Surya Swamy. 2014. *Evaluating Alternatives for Decommissioning California's Offshore Oil and Gas Platforms: A Technical Analysis to Inform State Policy*. Oakland: California Ocean Science Trust. Accessed October 23, 2015. http://www.oceansciencetrust.org/wp-content/uploads/2015/04/oil-and-gas-decommissioning.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.

Jimenez, Tony, David Keyser, Suzanne Tegen, and Bethany Speer. 2016a. *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, Tony, David Keyser, and Suzanne 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.

Jimenez, Tony, David Keyser, and Suzanne Tegen. 2016c. *Floating Offshore Wind in Hawaii: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios*. NREL/TP-5000-65481. Golden, CO: National Renewable Energy Laboratory. Accessed February 2016. http://www.nrel.gov/docs/fy16osti/65481.pdf.

Musial, Walt, Donna 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.

SEIA/GTM (Solar Energy Industries Association/GTM Research). 2015. *U.S. Solar Market Insight 2014 Year in Review*. Washington, D.C.: Solar Energy Industries Association. Accessed October 9, 2015. http://www.seia.org/research-resources/solar-market-insight-report-2014-q4.

Tegen, S.; Keyser, D.; Flores-Espino, F.; Miles, J.; Zammit, D.; Loomis, D. (2015). *Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios.* National Renewable Energy Laboratory. NREL/TP-5000-61315. Accessed October 8, 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. Floating Offshore Wind Projects Installed or Under Construction

Table A-1. Floating Offshore Wind Projects (as of March 2016)

Project	Status	Turbine Capacity	Project Capacity (MW)	Water Depth (m)	Country	Foundation Type	Year Online
Hywind Demo	Installed	2.3 MW	2.3	220	Norway	Spar	2009
WindFloat Atlantic I	Installed	2 MW	2	50	Portugal	Semi-submersible	2011
Kabashima/ Goto	Installed	2 MW	2	91	Japan	Spar	2013
Fukushima Forward I	Installed	2 MW	2	120	Japan	Semi-submersible	2013
Fukushima Forward II	Under Construction	7 MW; 5 MW	12	120	Japan	1 Semi-submersible; 1 Spar	2015/6
Hywind Scotland Pilot Park	Under Construction	6 MW	30	120	United Kingdom	Spar	Expected 2016/2017