Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios

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NATIONAL RENEWABLE ENERGY LABORATORY

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Executive Summary

Offshore wind has tremendous potential in the United States as a clean, renewable source of electricity. This report uses the offshore wind Jobs and Economic Development Impacts (JEDI) model[1] and provides four case studies of potential offshore wind deployment scenarios in different regions of the United States: the Southeast, the Great Lakes, the Gulf Coast, and the Mid-Atlantic. Researchers worked with developers and industry representatives in each region to create potential offshore wind deployment and supply chain growth scenarios, specific to their locations. These scenarios were used as inputs into the offshore JEDI model to estimate jobs and other gross economic impacts in each region.

Study results show that in addition to being a promising source of electricity, offshore wind also has the potential to drive regional economic development. How significant of a driver depends on how much offshore wind capacity is deployed. Specifically, the results from the four regional case studies describe how and to what extent increased investment in offshore wind technology and labor force development could translate into increased employment in the offshore wind industry.

To obtain the best regional assumptions for this report, the four scenarios (combining deployment, labor force, and regional supply chain development) were constructed specifically for each region, and this affects the analysis results. The scenarios vary in terms of their levels of relative deployment potential as well as assumptions about the local workforce and supply chain. Sourcing components locally reduces transportation costs, times, and risks and increases the economic impacts to the local economy. One study showed that the total construction costs of a hypothetical 588-megawatt (MW) offshore wind farm built off the coast of Virginia with turbines imported from Europe would be 17% more expensive than building the same wind farm with turbines manufactured locally (VCERC 2010).

Differences in the scenarios (e.g., local content assumptions) result in regional economic comparisons that are not "apples to apples." In other words, it is not appropriate to compare regional results on a dollars- or jobs-per-megawatt basis, given the actual and modeled regional variances. Table ES-1 shows ranges of jobs per megawatt in the four regions we examined, but it cannot be used as a nationwide average due to the variance in regional model inputs, differences in real regional wind conditions, and the fact that all regions of the country were not included.

Table ES-1. Regional Ranges of Jobs Per Megawatt from Offshore Wind in Four Regions

Results (Jobs/MW)	Low Scenario	Moderate Scenario	High Scenario
Regional ranges	14 - 27	17 - 28	25 - 31

In the Southeast region, offshore wind energy development has the potential to support between 14 and 44 full-time equivalent (FTE) jobs/MW during construction periods and 1.6 and 1.7 FTE ongoing (operations phase) jobs/MW. Many large ports in the Southeast region could be used as staging areas and for component manufacturing, such as the Port of Virginia, Port of Charleston,

[1] For more detailed information on the Offshore Wind JEDI model, please see the model user reference guide at www.nrel.gov/docs/fy13osti/58389.pdf

and Port of Savannah. There is existing economic activity in industries similar to offshore wind in the Southeast, so the regional workforce and infrastructure could contribute to offshore wind in the future.

In the Great Lakes region, the lack of tides and decreased corrosiveness of freshwater compared to saltwater present advantages; however, the main concerns are logistical. Lock and other seaway constraints, as well as farther average distances from shore for the potential turbines (compared to ocean projects), are likely to increase costs. On average in the Great Lakes, there could be between 6 and 27 FTE jobs/MW installed and 0.7 and 0.8 FTE jobs/MW for the projects' ongoing operation.

According to a report published by the National Renewable Energy Laboratory (NREL), more than 30% of the total U.S. offshore wind potential in the 0- to 30-m depth is concentrated in the Gulf of Mexico (Musial and Ram 2010). The offshore oil and gas industry in the Gulf of Mexico uses approximately 3,700 offshore structures to extract one-fourth of the total U.S. oil production and one-eighth of natural gas (Kaiser 2010). Given the similarity between the foundations and substructures needed for offshore wind development and those used by the oil and gas industry, the existing manufacturing workforce and infrastructure could add to the percentage of local labor and materials used in the development of offshore wind or speed the development of a local supply chain. Our analysis shows that offshore wind deployment has the potential to support between 25 and 29 FTE jobs/MW during construction and 1.3 FTE jobs/MW on an ongoing basis, for operations and maintenance.

The Mid-Atlantic region is home to some of the largest ports and logistics infrastructure in the United States, including the Port of New York and New Jersey, the Port of Baltimore, the Port of Philadelphia,[2] and the Port of Virginia. The Mid-Atlantic region is home to a large number of companies and manufacturers that have the potential to support the offshore wind supply chain. During construction phases, we estimated that jobs in this region could range from 12 to 30 FTE jobs/MW, and the average for the ongoing jobs was 1.2 FTE jobs/MW.

In each of the four regions, this research found that an offshore wind industry in the United States has the potential to support thousands of jobs due to robust workforce requirements, even at relatively conservative levels of deployment and domestic supply chain growth.

[2] The Port of Philadelphia can access the Atlantic Coast via the Delaware River.

List of Acronyms & Abbreviations

AWEA	American Wind Energy Association
BOEM	Bureau of Ocean Energy Management
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
FTE	full-time equivalent
GAO	U.S. Government Accountability Office
GW	gigawatt
GWh	gigawatt-hours
I-O	input-output
JEDI	Jobs and Economic Development Impact model
JMU	James Madison University
kW	kilowatt
M	meter
MW	megawatt
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
RPS	renewable portfolio standard

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1 Introduction

Offshore wind has the potential to play a significant role in U.S. electricity generation. The National Renewable Energy Laboratory (NREL) estimates more than 1,000 gigawatts (GW) of electricity-generating potential in U.S. waters between 0 and 30 meters (m) deep[3] and more than 4,200 GW total capacity in all coastal water[4] (Musial and Ram 2010; Lopez et al. 2012). In its National Offshore Wind Strategy Guide,[5] the U.S. Department of Energy (DOE) established a scenario that deployed 54 GW of offshore wind-generating capacity by 2030 and 10 GW by 2020 (Beaudry-Losique et al. 2011). Although as of this publication no commercial offshore wind development has occurred in the United States, five offshore wind projects are in advanced stages of development. From a global perspective, most offshore development is located in Europe's North Sea.

Deployment in line with goals established by DOE would require significant investment. At the time of publication, an average offshore wind plant could cost approximately $5,600 per kilowatt (kW) to install. The 2011 installed cost of a typical 3.6-megawatt (MW) turbine would be more than $20 million (Tegen et al. 2013). Because of the large expenditures, developers and other businesses related to the offshore wind industry have the potential to play an important role in U.S. regional economies. Valuable insights into the scale and scope of local economic development driven by offshore wind can be gained by analyzing these potential impacts. The intent of this analysis is to use reasonable deployment numbers to estimate the potential economic impacts of different levels of offshore wind development, not to predict deployment scenarios.

There is extensive literature that analyzes the potential development and economic impact of land-based wind installations and the land-based wind industry in the United States.[6] Empirical studies of regional economies where wind development has occurred show that the deployment of wind power systems has an impact (Brown et al. 2012). Researchers at Lawrence Berkeley National Laboratory performed an analysis of development and trade data showing that a land-based wind supply chain has developed in the United States. Indeed, the land-based wind industry had a measurable impact on the U.S. economy even when it only contributed 3.3% of the nation's electricity (Wiser and Bolinger 2012).[7]

Yet while the technology is similar, there are many differences between offshore and land-based wind installations. Each has different logistical and labor force requirements, and each operates under different regulations. Each technology influences material suppliers and manufacturers differently and has different infrastructure requirements. These are only a few examples from a

[3] It's generally easier and less expensive to install wind turbines in shallower waters.
[4] This potential is for areas with an average wind speed of 7 m/s or greater at 90-m elevation that are up to 50 nautical miles from the U.S. coast.
[5] http://energy.gov/eere/wind/downloads/national-offshore-wind-strategy-creating-offshore-wind-energy-industry-united
[6] Sample publications include Brown, Pender, Wiser, Lantz, & Hoen 2012; DOE 2008; Druckenmiller 2012; U.S. Government Accountability Office (GAO) 2004; Lantz & Tegen 2008; Pedden 2006; Wei, Patadia, & Kammen 2010.
[7] The U.S. Energy Information Administration estimates that wind power contributed 4.1% to the United States electricity supply in 2013 and 3.3% in 2012.

multitude of differences. This offshore wind-specific analysis captures the unique impacts that a burgeoning offshore wind industry could have in regions of the United States.

This report introduces the Offshore Wind Jobs and Economic Development Impact (JEDI) model[8] and explores potential economic development impacts of offshore wind development in four regions of the United States: the Southeast, the Great Lakes, the Gulf of Mexico, and the Mid-Atlantic. In doing so, the authors ("we") introduce the first estimates of economic impacts from offshore development using the Offshore Wind JEDI model.

The Department of Energy selected the regions in this report based on areas that could deploy fixed-bottom (monopile or jacket) offshore wind platform technology. There are other domestic regions with offshore wind potential farther out from shore for which a floating platform would be necessary (due to the water depth), such as the Northeast. To deploy offshore wind in the United States, policymakers and stakeholders need to address a number of issues including transmission, policy, environmental impacts, siting and permitting, comparative assessments of alternative generation options, and education and outreach. The JEDI model assesses specific gross economic impacts to the regions. Many of the above important issues are mentioned in this report but are not thoroughly discussed or analyzed. The results offered in each regional section stem from the aggregation and analysis of the information collected from local experts and may not reflect the point of view of each of the third parties interviewed. There are two states that are included in two different regions: Pennsylvania in the Great Lakes and Mid-Atlantic regions, and Virginia in the Mid-Atlantic and Southeast regions.

1.1 Potential Barriers to Offshore Wind Power Development

Offshore wind projects worldwide have not been developed in locations where they have a significant exposure to hurricanes and other tropical events (Musial et al. 2013a). Therefore, there is no empirical evidence regarding the effect this additional risk factor would have on the structural design of turbines and foundations, and ultimately on total installation costs. Hurricanes do not preclude the development of the offshore wind industry; however, an increase in cost and possibly a lower energy production per unit of installed capacity may be expected (Navigant Consulting 2013).

Beyond concerns about hurricanes, there are additional barriers to offshore wind project development. Property owners and others oppose offshore wind development for aesthetic reasons, logistical complications with fisheries and vessel traffic, military and civilian air traffic, radar, environmental concerns, transmission, and grid interconnection. This report focuses on scenarios in which the successful deployment of offshore wind projects overcomes these barriers, in the future. For more information on barriers to offshore wind power development, see Musial and Ram 2010.

1.1.1 State Government Policies and National Activities

Policies identified as effective in advancing offshore wind deployment at the state level include (but are not limited to) renewable portfolio standards (RPSs), especially with an offshore wind

[8] To view the Offshore Wind JEDI user reference guide, go to www.nrel.gov/docs/fy13osti/58389.pdf

section, feed-in tariffs, and low-interest loans (Navigant Consulting 2013). Some states also have emissions policies that could see offshore wind as a favorable clean energy option.

The Bureau of Ocean Energy Management (BOEM) operates a number of offshore renewable energy programs.[9] BOEM grants leases, easements, and rights-of-way for orderly, safe, and environmentally responsible renewable energy development activities (BOEM 2013). In 2013 and 2014, BOEM released "Wind Energy Areas" in certain coastal areas (Musial et al. 2013b), including states in the Mid-Atlantic and Southeast. Developers can use these maps and an auction process to bid on leases for offshore wind development.

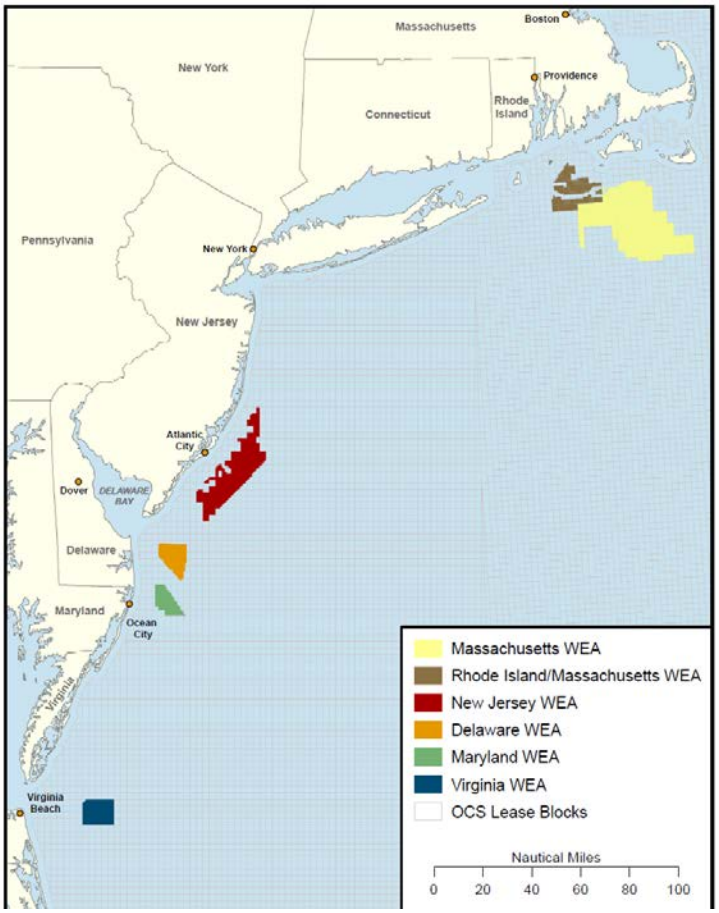

Figure 1. Atlantic Outer Continental Shelf Wind Energy Areas

Source: Bureau of Ocean Energy Management 2014[10]

[9] www.boem.gov/Renewable-Energy-Program/index.aspx

[10] www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/Smart_from_the_Start/Wind_Energy_Areas0607.pdf

1.2 Regional Scenarios Vary, Making Comparisons Difficult

For each region, we performed in-depth interviews with local stakeholders. Each scenario's assumptions vary due to wind resource and capacity deployed, which preserves the unique regional aspects but makes inter-regional jobs-per-megawatt comparisons more complicated. The deployment scenarios in each region (combining deployment, cost reduction, and within-region supply chain development) are very different. In one region (the Southeast), we had enough information for multiple variations on scenarios, whereas in the other three, we obtained data for low-, medium-, and high-deployment scenarios.

1.3 Methodology

For each case study, researchers worked with regional energy groups and industry representatives to create potential offshore wind deployment scenarios and corresponding construction and operating costs. Each case considers unique regional features that could play roles in the establishment and growth of an offshore wind industry. Each region has a unique wind resource as well as a different regional supply chain and labor force, so scenarios vary greatly by location.

Each case study utilizes the Offshore Wind JEDI model. The model is one element in a suite of JEDI input-output (I-O) models. JEDI models provide estimated economic impacts that are supported by investment in a number of energy technologies. Funded by DOE, NREL and MRG & Associates created the Offshore Wind JEDI model to incorporate the unique aspects of offshore wind development into an economic impact tool that can be accessed and used by the public.[11]

I-O models are widely recognized tools that are used to estimate economic impacts associated with investments or expenditures. These models map how economy sectors such as businesses, households, workers, capital, and governments interact with one another via purchases and sales at a single point in time. Because sectors are related to one another, an increase in demand for one can lead to an increase in demand for another. An increase in demand for steel towers, for example, results in increased demand for iron ore.

JEDI and other I-O models estimate economic impacts that are supported by changes in demand for goods and services produced by industries and households. Goods or services produced by households include labor and property (such as land) that is sold or leased to industries. JEDI estimates changes in demand for these goods and services with data from the project scenario.

The JEDI project scenario is a set of data that describes a project. Each project contains two sets of line item expense categories such as equipment (blades, towers, turbines, etc.), materials and services, and labor. One set covers the project construction, the other covers operations and maintenance (O&M) of a project. JEDI models contain default project scenario and cost data, but

[11] All publicly available JEDI models can be downloaded from www.nrel.gov/analysis/jedi

analysts with knowledge of project details can change these defaults to better represent the scenario being analyzed.[12]

The JEDI model also allows a model user to specify which portions of expenditures are made within the region of analysis. For example, the model allows users to specify whether wind turbine blades were manufactured in the state where the project is being built or outside the state (assuming the state is the region of analysis). The JEDI model uses expenditures made within the region of analysis, or "local expenditures," to estimate economic impacts. The JEDI model does not estimate economic impacts outside the region of analysis (e.g., generator parts from China).

1.4 Caveats, Limitations, and Sensitivities

As with all economic models, there are caveats and limitations to the use of the JEDI model. Results from JEDI models are gross, not net. JEDI calculates economic activity that would be supported by demand created by project expenditures. Other changes in an economy take place that JEDI does not consider. These include supply-side impacts such as price changes, changes in taxes or subsidies, or utility-rate changes. The JEDI results presented in this analysis represent estimates at a single point in time and should not be interpreted as a forecast. For more information on caveats, limitations, and sensitivities, please see Appendix A.

1.5 Results

The JEDI model reports economic impact estimates for two phases: (1) construction and (2) O&M. Construction-phase results are one-time totals that span the equivalent of approximately 1 year.[13] O&M results are presented on an annual basis and ongoing for the life of the facility.

All impacts are based on expenditures and local content data contained within the project scenario. JEDI organizes effects into different categories based on how the user-specified project scenario supports the impact. The workers who install a wind turbine, for example, are onsite. The workers who manufactured that turbine are part of the supply chain (not onsite). Installers and manufacturers earn wages and spend money within the region of analysis, which supports further economic activity (e.g., the construction workers eat lunch at local sandwich shops). The three categories of impacts used by JEDI are[14]:

- **Project development and onsite labor impacts** represent economic activity that is either directly involved with a project's development and implementation or that occur onsite. These impacts typically occur in the construction, maintenance, engineering and professional services, and port staging sectors.

[12] Further information about the Offshore Wind JEDI model, data, and methodology can be obtained from the user reference guide, available at www.analysis.nrel.gov/jedi
[13] If, for example, JEDI reports a construction-phase impact of 50 workers to build a project that takes 2 years to complete, this is the equivalent of an average of 25 workers per year (50 / 2 = 25). If the same project required 3 years to complete, the average would be 17 (rounded) workers per year.
[14] I-O models typically organize impacts into direct, indirect, and induced effects. JEDI categories differ from these. Project development and onsite labor impacts include less-than-direct effects from project expenditures, and turbine and supply chain impacts are more broad than the indirect effects from project expenditures. The Offshore Wind JEDI User Reference Guide (www.nrel.gov/analysis/jedi) contains more information about these differences.

- **Turbine and supply chain impacts** represent economic activity that is supported by purchases for a project or business-to-business services. These include locally manufactured inputs such as blades and locally procured equipment used to manufacture those blades, such as resin and fiberglass.
- **Induced impacts** accrue as money circulates in an economy. Households spend earnings from project development and onsite labor impacts as well as turbine and supply chain impacts. The portion of these earnings spent within the region of analysis is known as induced impacts. These effects commonly occur in the retail sales, child care, leisure and hospitality, and real estate sectors.

JEDI reports three metrics for each type of impact: jobs, earnings, and gross output. Each metric has a specific definition that informs how it should be interpreted.

- **Jobs** are expressed as full-time equivalent (FTE). One job is the equivalent of one person working 40 hours per week, year-round. Two people working full-time for 6 months equal one FTE. Two people working 20 hours per week for 12 months also equal one FTE. An FTE could alternately be referred to as a person-year or job-year. Jobs, as reported by JEDI, are not limited to those who work for an employer; they could include other types of workers such as self-employed ("sole proprietors").
- **Earnings** include any type of income from work, generally an employee's wage or salary and supplemental costs paid by employers such as health insurance and retirement.[15]
- **Gross output** is the total amount of economic activity that occurs within an economy (within the region of analysis). It is the sum of all expenditures. A scenario in which a developer purchases a locally manufactured $500,000 blade that utilized $100,000 of locally procured fiberglass represents $600,000 in gross output.

[15] It could also be other non-wage compensation for work performed, such as proprietor earnings.

2 The Regions

This analysis includes case studies of potential deployment and associated economic impacts in four regions of the United States: the Mid-Atlantic, the Great Lakes, the Gulf of Mexico, and the Southeast (Atlantic). Analysts worked with regional stakeholders, including academics, government officials, industry representatives, and offshore wind experts to develop analysis scenarios that best reflect conditions within the study region. These four regions were chosen due to the water depth and the near-term deployment potential. Other regions of the country could also experience offshore wind deployment, but areas like the Northeast and Northwest have greater water depths, so the regions in this analysis are most suited to an analysis of fixed-bottom technologies. The current JEDI model does not accommodate floating offshore wind turbine systems.

Table 1. Regions of Analysis

Mid-Atlantic	Great Lakes	Gulf of Mexico	Southeast
Virginia	Illinois	Alabama	Georgia
District of Columbia	Indiana	Louisiana	North Carolina
Maryland	Michigan	Florida	South Carolina
Delaware	Minnesota	Mississippi	Virginia
Pennsylvania	New York	Texas	
New Jersey	Ohio		
	Pennsylvania		
	Wisconsin		

Some of the most common factors that influenced deployment levels for this research were offshore wind resources, load growth, local supply chains, and electricity prices. Analysts also considered regional electricity, current offshore wind activity, and other conditions unique to each region.

Each region also has different socioeconomic conditions. Population and employment characteristics and trends can influence expectations about future electricity demand. For three of the regions studied, we analyzed three scenarios, based on low, medium, and high deployment. For the Southeast region, we analyzed five scenarios, based on a combinations of varying levels of deployment (or “growth levels”), regional investment, and costs. We were able to perform a more in-depth analysis in the Southeast due to collaboration with James Madison University and their extensive network in the region. Researchers there had already investigated offshore wind deployment and the offshore wind potential in the region.

2.1 Wind Resources

Wind resources vary within regions, and this will likely be a factor in siting decisions made by developers. In the Gulf of Mexico, for example, average wind speeds are greater off the coast of Texas than onshore (Figure 2). This is one of the major considerations in evaluating resources, however. The potential installed capacity also depends on a number of other factors.

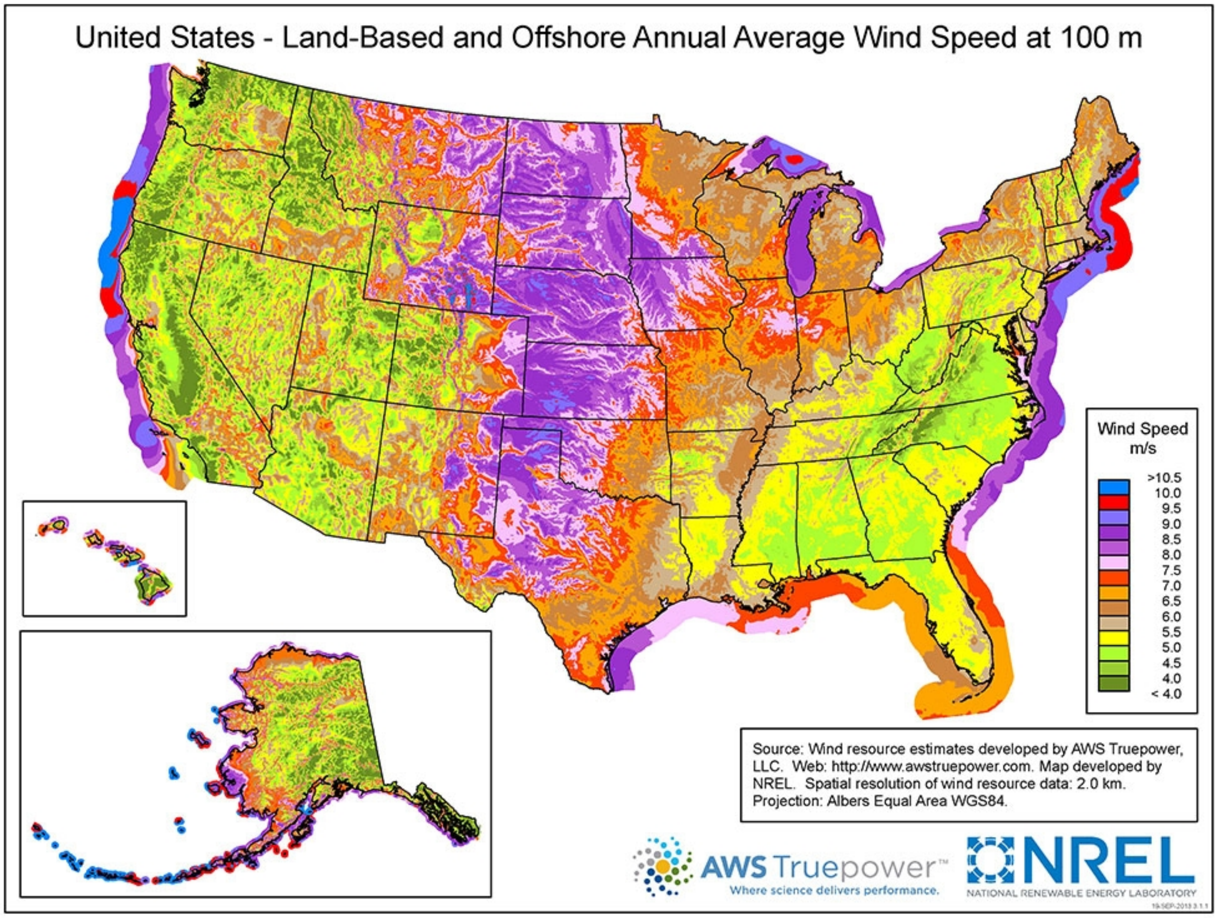

Figure 2. Offshore wind resource map (NREL 2013)

The total potential capacity for offshore wind in the United States is estimated to be 4,224 GW (Lopez et al. 2012). This estimate is based on shallow and deep water resource availability and quality, power generation system performance, topographic limitations, and environmental and land-use constraints. It does not necessarily represent the total amount of renewable energy capacity that might actually be deployed because it doesn't take other considerations into account, like economic feasibility, policy, electricity demand, etc. Table 2 shows the potential capacity and production in U.S. waters for each of the four regions considered in this study. To put the numbers in Table 2 into context, the United States used 4,058,209 gigawatt-hours (GWh) of electricity in 2013 and has 1,168 GW of installed capacity (EIA 2014). The nation currently has 61.1 GW of land-based wind power developed, even though the potential capacity is more than 10,000 GW (Wiser and Bolinger 2013). Not all of the potential capacity will be developed.

Table 2. Regional Offshore Wind Potential within 50 Nautical Miles from Shore

Region	Potential Annual Energy Production (GWh)	Capacity Potential (GW)	Area (km2)
Mid-Atlantic	1,075,939	264	52,726
Great Lakes	3,032,659	742	148,387
Gulf of Mexico	2,346,618	625	124,985
Southeast	2,393,706	587	117,388

Source: Lopez et al. 2012

2.2 Electricity Prices

Higher regional (wholesale) electricity rates and higher-quality offshore wind resources could allow offshore wind to better compete in many coastal areas (Musial and Ram 2010). The higher revenues associated with higher electricity prices generally increase returns on investment and encourage construction of new power generation assets, including those with a relatively high installed capital cost like offshore wind.

Wholesale prices are a good indicator of the payments for generated electricity that offshore wind producers can expect to receive. Generally speaking, higher yearly average wholesale prices are more common in the Mid-Atlantic, whereas hubs in the Southeast and the Gulf of Mexico have two of the lowest average prices in the country. This makes offshore wind attractive as a generation source in the Mid-Atlantic to operators seeking to maximize their level of compensation for generated electricity but does not preclude its deployment in the Southeast or Gulf of Mexico. Other factors that influence returns on investment and, by extension, deployment opportunities – like capital and operational costs – are addressed for each region in the following sections of this report.

Offshore wind technology costs are likely to continue to decline due to technological innovation, manufacturing efficiency, improved O&M strategies, and better resource assessment (Lantz et al. 2012). NREL experts analyzed 25 offshore wind scenarios discussed in 12 studies and found that projections within the 20th to 80th percentile predict a cost decline of 17% to 47% between 2010 and 2030 (Tegen et al. 2013).

There are sources of low-cost competition for offshore wind electricity such as natural gas electric generation. An abundant supply of natural gas in the United States is creating a downward pressure on its price, and analysts predict that low prices will continue throughout the 2020-2030 decade (EIA 2013a). However, wind power costs during generation remain relatively constant throughout the life of each plant. Changes in fuel costs for natural gas plants, on the other hand, represent a long-term unknown. Even though natural gas prices are projected to remain low through the 2020s, a recent study found that wind power can provide protection against many of the natural gas scenarios contemplated by the U.S. Energy Information Administration (EIA) beyond 2030 (Bolinger 2013).

2.3 Populations and Economies

The size of a population and growth trends are important indicators of potential future load growth and potential future employment. While individual use of electricity can change, for example, with efficiency improvements, the sheer size of a population is and will continue to be a key determinant of infrastructure investments. Industries are also significant electricity consumers. In 2011, residential households consumed 38% of electricity in the United States, while commercial and industrial users consumed 62% (EIA 2013b).

Developing offshore wind sites close to where electricity will be consumed is also advantageous to producers because it allows for shorter transmission distances. If costs must be incurred to develop transmission infrastructure, then developers will want to minimize these expenses. However, even in the absence of transmission development costs, shorter transmission distances are more efficient and allow for a greater portion of the electricity that is produced to be purchased by end users.

Of the regions included in this analysis, the Great Lakes has the largest population (Table 3). Its population of more than 82 million represents about a quarter of the U.S. population. From 2001 to 2011, the population remained nearly the same, despite average nationwide growth of nearly 1% annually. The Southeast is the least populous region, with more than 32 million residents. It was the fastest-growing region with annual growth averaging 1.5% (U.S. Census Bureau 2013).

Table 3. Population and 10-Year Average Annual Growth Rates by Region

Region	Population (2011)	Population Annual Average Growth, 2001 – 2011	Percentage of U.S. Population (2011)
Mid-Atlantic	37,049,834	0.6%	12%
Great Lakes	82,038,050	0.0%	26%
Gulf of Mexico	57,069,952	1.4%	18%
Southeast	32,241,295	1.5%	10%
United States	311,587,816	0.9%	

Source: U.S. Census Bureau Intercensal Population Estimates, 2013

Population change is generally correlated with employment opportunities (Greenwood and Hunt 1989), making a region's economic characteristics equally relevant.

Regional labor markets are also relevant to any company seeking to hire local workers. Employment figures by industry show the number of workers in industries similar to offshore wind. Recent up- or down-turns and unemployment figures can signal the relative availability of a local labor force. The gross economic impact numbers in this report remain the same regardless of whether a worker is hired from within a region or migrates to that region to work, yet this is an important distinction for local planners and residents (Cutler and Davies 2007).

All regions in this analysis exhibited positive average annual employment growth from 2001 to 2011 that was greater than the U.S. average (Table 4). The fastest growth occurred in the Gulf of Mexico, and the Southeast had the highest unemployment rate in 2011. Unemployment was the lowest in the Mid-Atlantic region.

Table 4. Employment and Unemployment by Region

Region	Employment (2011)	Average Employment Change (2001–2011)	Unemployment Rate (2011)
Mid-Atlantic	21,776,417	0.6%	7.9%
Great Lakes	47,904,384	0.2%	8.6%
Gulf of Mexico	31,211,988	1.3%	8.9%
Southeast	17,881,305	0.9%	9.2%
United States	138,756,000	0.0%	8.9%

Sources: Bureau of Economic Analysis (2013), Bureau of Labor Statistics (2013)

3 Case Study: Mid-Atlantic Region

The Virginia Center for Wind Energy at James Madison University and NREL analyzed this more in-depth case study of offshore wind power developed off the coasts of Virginia, New Jersey, Delaware, Maryland, and Pennsylvania. The Mid-Atlantic region presents an ample wind resource, and many states within this region are striving to become major players in this upcoming industry. The region has relatively high electricity rates, which could encourage utilities and taxpayers to develop and pay for offshore wind.

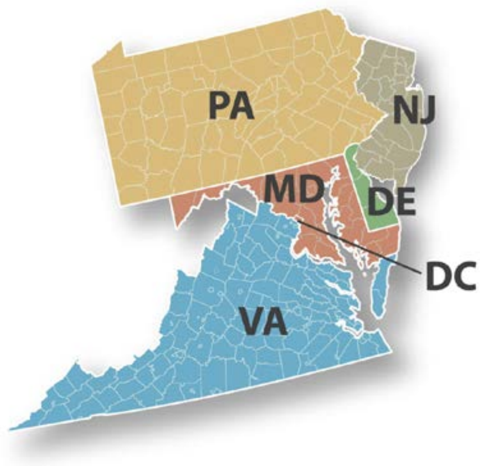

Figure 3. Map of the Mid-Atlantic region

3.1 Physical Characteristics and Infrastructure of the Mid-Atlantic

To assist the development of offshore wind energy in this region, BOEM established renewable energy task forces in Virginia, Maryland, Delaware, and New Jersey to facilitate intergovernmental communications regarding outer continental shelf renewable energy activities.[16]

The Mid-Atlantic region is home to some of the largest and most industrious ports and logistics infrastructure in the United States, including the Port of New York and New Jersey, the Port of Baltimore, the Port of Philadelphia,[17] and the Port of Virginia.

In general, the Mid-Atlantic region is home to a large number of companies and manufacturers that have the potential to support the offshore wind supply chain. However, it is important to note that no studies or reports identifying the supply chain capabilities of the states of Delaware and New Jersey could be identified, and the results displayed in Table 5 can be used as a general indication of current infrastructure.

Each company identified was sorted into one or more of five broad categories, depending on the products and services offered:

[16] www.boem.gov/Renewable-Energy-Program/State-Activities/Index.aspx
[17] The Port of Philadelphia can access the Atlantic Coast via the Delaware River.

- Electronics: power transmission equipment, transformers, industrial control systems, etc.
- Manufacturing and assembly: large wind turbine components such as turbine blades, nacelles, towers, foundations
- Materials and safety equipment: composites, paints, resins, plastics, bridges, bolts, nuts, concrete, and other similar materials
- Installation, logistics, and transportation: erection, port facilities, shipbuilding and repair, railroads, and O&M
- Services: engineering, legal, financial, educational, and outreach.

Table 5. Supply Chain Companies and Firms Identified in the Mid-Atlantic Region

	Maryland	Delaware	New Jersey	Virginia	Pennsylvania
Electronics	1	0	3	2	15
Manufacturing & assembly	17	0	1	6	17
Installation, construction, materials	13	2	1	5	28
Maintenance, logistics, transportation	16	0	4	34	6
Services	6	2	6	34	4
Total	53	4	15	81	70

3.2 Scenarios

The inputs used for the JEDI model in these offshore scenarios include market and deployment, regional investment, and cost reduction. For each category, three distinct estimates of the way input variables change over time were developed. These estimates determine regional economic activity and the number of jobs the industry can support. Scenarios run from 2015 up to 2030 for offshore wind energy in the Mid-Atlantic, and we ran the JEDI model for each year.[18]

3.2.1 Market and Deployment

For market and deployment, we created a conservative, a moderate, and an aggressive approach to offshore wind turbine deployment in the Mid-Atlantic region. In these scenarios, it is assumed that all wind power plants are constructed in New Jersey, Virginia, Delaware, and Maryland; Pennsylvania's contribution to the Mid-Atlantic offshore wind industry was assumed to be through regional content via the Port of Philadelphia.

For low market and deployment, development of new offshore wind power plants was assumed to be very conservative, with the market being dominated by pilot/demonstration projects and

[18] While the scenarios were developed from 2015 up to 2030, we performed the JEDI analysis for the years 2020 through 2030. Offshore wind installations are expected to be built before 2020, so we developed these scenarios to reflect this point of view.

small-scale wind power plants; industry growth is slow, reaching 400 MW in 2030. During this period, around 12% of all new power plants in the region are from offshore wind, meaning that it would still be a niche technology to complement conventional generating technologies.

For medium market and deployment, a moderate-level offshore wind development in the region was assumed; therefore more consistent growth is observed, reaching 750 MW in 2030. By 2030, the offshore wind market would have represented around 30% of all new power plant installations in the Mid-Atlantic region, establishing offshore wind as a mainstream technology.

For high market and deployment, an aggressive level of offshore wind power plant deployment was assumed, in which the majority of new power-generating plants derived from offshore wind facilities, reaching a market of 1,400 MW by 2030. Around 62% of all new power plants in the region are expected to be from offshore wind energy, meaning that it has become the dominant generating technology in the Mid-Atlantic. In addition to adding more generating capacity to the region, outdated and inefficient power plants would be decommissioned and replaced with newer technologies such as offshore wind, particularly because the offshore wind market approaches and exceeds the historical growth rate from 2027 through 2030.

Table 6. Mid-Atlantic Region Cost and Capacity Scenarios (2012 $)

Deployment Scenario	Cost ($/kW)		Deployed Capacity (MW)	
	2020	2030	2020	2030
Low (A)	5,840	5,460	366	3,196
Medium (B)	5,600	4,830	1,912	7,832
High (C)	5,360	4,230	4,100	16,280

3.2.2 Regional Investment

Three estimates for regional supply chain development were considered. The higher the regional share percentage in a specific line item, the more money is being circulated into the regional economy, thereby supporting more regional jobs.

We examined each individual component separately when determining its potential for regional sourcing. The regional share of many of these components and services, like concrete or legal services, was not expected to change over time because they are widely available in the region. More specialized goods and services, like foundations and turbine blades, are expected to vary over time. Specialized goods and services may not be fully available in the region initially, meaning a percentage of the investment must be outsourced.

For the low regional investment path, it was assumed that the development of the regional supply chain is minimal due to uncertainties in the industry. However, due to the sufficient presence of manufacturers, developers, and services, some regional contributions are expected.

The medium regional investment path was assumed to be similar to the low path in the early days of the industry, but in this case significant growth in the regional supply chain was assumed after 2020. Each year, more manufacturers, developers, and services will relocate to the region or expand their facilities to accommodate the offshore wind industry.

The high regional investment path assumed immediate and significant regional investment into the offshore wind industry, resulting in a rapid development of the supply chain. Nearly all components and services are regionally sourced by 2030.[19] Table 7 summarizes the regional investment "paths" for the regional scenarios.

Table 7. Low, Medium, and High Regional Investment Paths for the Dynamic Components for Offshore Wind in the Mid-Atlantic

	Low Investment		Medium Investment		High Investment	
Component	2020	2030	2020	2030	2020	2030
Nacelle/drivetrain	32%	68%	35%	95%	65%	100%
Blades & towers	13%	71%	25%	95%	30%	95%
Substructures & foundation	11%	30%	20%	50%	30%	85%

Source: Navigant 2013

3.2.3 Costs

The EIA established a baseline cost for offshore wind in 2015 to be around $5,975/kW in 2010 dollars[20] and made adjustments to the baseline for each state. For the Mid-Atlantic region, the average expected cost for an offshore wind power plant is around $6,040/kW,[21] but there is significant variance among the states. For instance, Virginia enjoys the lowest expected capital costs at around $5,724/kW, whereas New Jersey is the most expensive at $6,736/kW. The higher costs of living and large population densities in the northern states led to higher construction cost estimates for New Jersey and Delaware relative to other states.

Figure 4 depicts a pie chart showing the typical capital costs for offshore wind in the Mid-Atlantic region in this JEDI analysis. Approximately 51% of the total cost is associated with turbine equipment such as blades, nacelles, and foundation, along with other materials and equipment such as concrete, safety equipment, and other equipment. Labor and development costs comprise the majority of the remainder at approximately 34% of the total cost. The remainder of capital expenditures is distributed among financing, insurance, tax, and other miscellaneous costs.

[19] A linear scaling system was applied for *Regional Investment* percentages between 2021 and 2024, and 2026 to 2029.
[20] In April 2013, the EIA updated the baseline capital costs for offshore wind to $6,230 in 2012 dollars, which accounts for the rate of inflation over these 2 years and not an increase in the cost relative to 2010 dollars.
[21] To date, no cost estimates are available for Pennsylvania.

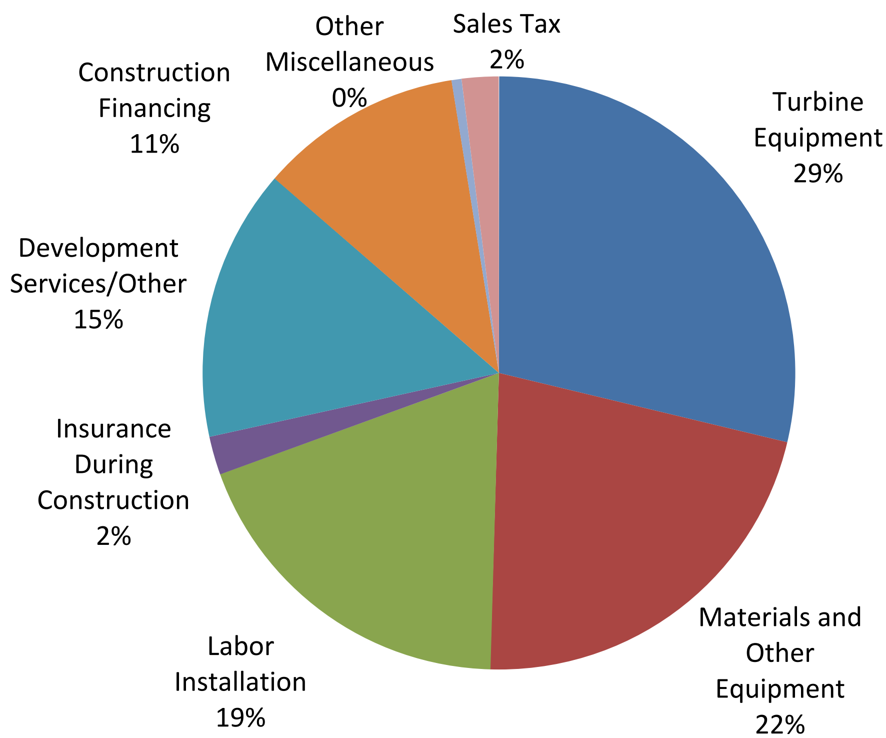

Figure 4. Capital expenditure cost distribution for offshore wind in the Mid-Atlantic region

Three simple cost-reduction models were established for application to the JEDI model, which may occur due to technological advancements, economies of scale, and other factors, such as improvement in manufacturing and deployment efficiency. These estimates establish upper and lower bounds for cost reduction in the Mid-Atlantic.

Under the low-cost reduction path, limited development in offshore wind energy technologies, manufacturing efficiencies, and deployment efficiency was assumed. A cost reduction of 3.5% every 5 years was applied to the baseline, resulting in an overall cost reduction of around 10% by 2030. Under the medium-cost reduction path, a more aggressive cost-reduction model was applied, representing more significant technological advances and more efficient manufacturing, assembly, and deployment of offshore wind turbines. A cost reduction of 7.2% every 5 years was applied, resulting in an overall cost reduction of around 20%. Under the high-cost reduction path, optimal technology improvements and efficiency were assumed. It was also assumed that favorable federal and state policies help further reduce the capital costs of offshore wind power plants. The average cost of offshore wind is assumed to decrease by 11.2% every 5 years, for an overall cost reduction of around 30%.

3.3 Results

3.3.1 Construction Period

Under Scenario A, the offshore wind industry supports approximately 1,100 FTEs in 2020, increasing to more than 8,200 FTEs in 2030. In other words, the industry is expected to support nearly eight times more labor after 10 years, despite the conservative assumptions made in this scenario. Many of the jobs supported are in supply chain and induced impacts, with comparatively little from project development and onsite labor.

Scenario B would support significantly more FTEs throughout the modeling period, increasing from around 6,000 FTEs in 2020 to more than 22,100 FTEs in 2030 (i.e., more than three times total FTEs over Scenario A).

Under Scenario C, JEDI analysis suggests that the offshore wind industry would support nearly 18,000 FTEs in 2020 and more than 42,000 FTEs in 2030, for a total of around 330,000 FTEs in construction over this period (which is more than double that supported by Scenario B). Figure 5 depicts the estimated construction-phase jobs supported by Scenarios A, B, and C.

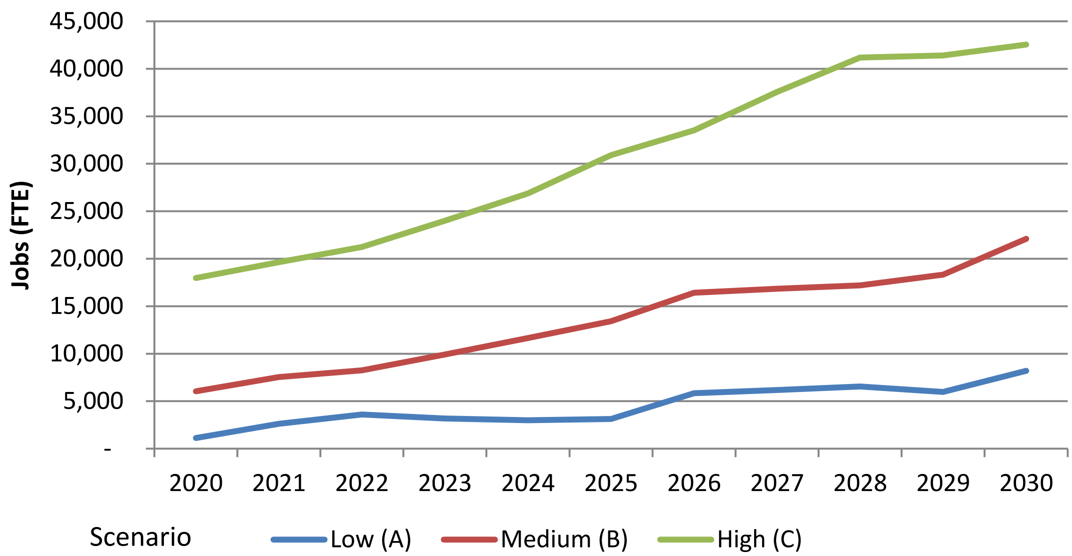

Figure 5. Estimated construction-phase jobs supported under each scenario (Mid-Atlantic region)

Table 8. Estimated Number of Jobs Supported by Construction under Each Scenario (Mid-Atlantic Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total FTE Jobs/MW
Low (A)	2020	230	460	440	12
	2030	1,490	3,610	3,100	20
	Annual Average 2020-2030	770	1,770	1,710	16
Medium (B)	2020	1,320	2,440	2,290	15
	2030	4,250	9,550	8,300	29
	Annual Average 2020-2030	2,630	5,740	5,060	23
High (C)	2020	3,120	7,890	6,950	18
	2030	9,410	17,360	15,790	30
	Annual Average 2020-2030	6,240	12,850	11,531	25

3.3.2 Operations and Maintenance Period

The O&M phase of an offshore wind power plant is much less labor-intensive than the construction phase; therefore the total number of FTEs supported was expected to be significantly lower. Jobs supported during the O&M phase last throughout the lifetime of the power plant, which is typically around 25 years. In other words, jobs supported during this phase are typically ongoing opportunities.

The JEDI model outputs for FTE supported under the low, medium, and high scenarios are given in Figure 6. The low-deployment / high-cost scenario (A) is projected to support the fewest FTEs, with almost 4,000 FTE over 3.2 GW generating capacity by 2030, whereas JEDI analysis of the higher-deployment/lower-cost scenarios (B and C) gives an estimate of around 9,500 and 20,000 FTEs respectively. In this analysis, all O&M expenditures are assumed to be regional, so the normalized FTE per megawatt is a consistent 1.2 FTE/MW for all three scenarios from 2020 through 2030.

Similarly to the construction phase, many of the jobs supported are expected to be turbine and supply chain, while significantly fewer jobs are supported in the project development and onsite labor sector. The difference in jobs supported between the sectors is much larger during the O&M phase than the construction phase. In Scenario B, between 1.8 and 2.2 jobs in turbine and supply chain are supported for every job in project development and onsite labor during construction. During O&M, this ratio increases to around 8 jobs in the supply chain for every job in project development.

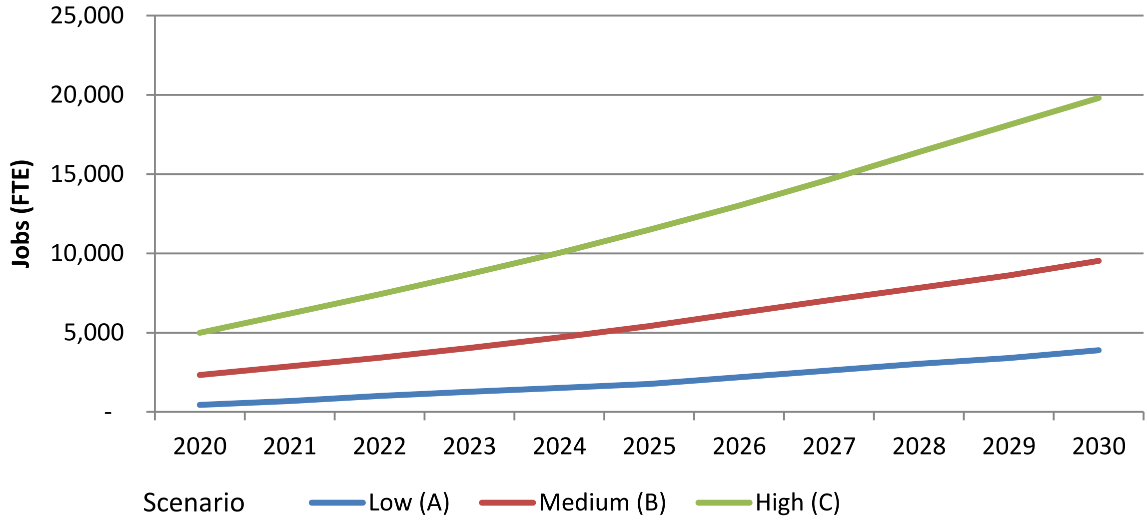

Figure 6. Annual estimated total O&M jobs supported under each scenario (Mid-Atlantic region)

Table 9. Estimated Number of Jobs Supported by O&M under Each Scenario (Mid-Atlantic Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total FTE Jobs/MW
Low (A)	2020	30	250	160	1.2
	2030	280	2,220	1,390	1.2
	Annual Average 2020-2030	140	1,130	710	1.2
Medium (B)	2020	170	1,330	830	1.2
	2030	680	5,440	3,410	1.2
	Annual Average 2020-2030	410	3,220	2,020	1.2
High (C)	2020	360	2,850	1,780	1.2
	2030	1,420	11,300	7,080	1.2
	Annual Average 2020-2030	850	6,790	4,250	1.2

3.3.3 Earnings and Output

As the industry grows, JEDI indicates higher combined earnings and outputs for all three scenarios, as shown in Tables 10 and 11. The larger portion of the money in earnings and output is expected to be in turbine and supply chain, whereas project development is expected to have the smallest portion. For earnings, between 44% and 49% of the money is expected to be in supply chain, whereas around 24% to 30% would be allocated in onsite labor and project development. This is roughly equivalent to a 2:1 ratio; that is, for every dollar in project development, approximately $2 would be in turbine and supply chain.

This difference is even larger for output; between 54% and 62% of the output was in turbine and supply chain. For project development and onsite labor impacts, JEDI projected only around 12% to 18% to be in this sector. In dollar terms, this means that for every dollar in project development, roughly four dollars are in turbine and supply chain.

Table 10. Estimated Earnings and Output Supported by Construction under Each Scenario (Mid-Atlantic Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Low (A)	2020	$30	$60	$40	$120	$30	$70
	2030	$210	$300	$290	$1,070	$180	$490
	Annual Average 2020-2030	$120	$180	$150	$560	$100	$270
Medium (B)	2020	$190	$280	$190	$670	$130	$360
	2030	$600	$760	$750	$2,970	$470	$1,300
	Annual Average 2020-2030	$370	$500	$450	$1,730	$290	$450
High (C)	2020	$450	$680	$610	$2,370	$390	$1,090
	2030	$1,340	$1,590	$1,360	$5,390	$900	$2,480
	Annual Average 2020-2030	$890	$1,140	$1,000	$3,970	$660	$1,810

Table 11. Estimated Earnings and Output Supported by O&M under Each Scenario (Mid-Atlantic Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Low (A)	2020	$4	$4	$20	$60	$9	$30
	2030	$30	$30	$180	$560	$80	$220
	Annual Average 2020-2030	$20	$20	$90	$290	$40	$110
Medium (B)	2020	$20	$20	$110	$340	$50	$130
	2030	$80	$80	$430	$1,370	$200	$540
	Annual Average 2020-2030	$50	$50	$260	$810	$120	$320
High (C)	2020	$40	$40	$230	$720	$410	$280
	2030	$170	$170	$900	$2,850	$100	$1,130
	Annual Average 2020-2030	$100	$100	$540	$1,710	$250	$680

3.4 Summary of Economic Impacts

The Mid-Atlantic region has the potential to support a robust offshore wind industry; there is a good shallow wind resource, particularly in Virginia and New Jersey. The wind energy areas currently being promoted by the BOEM are located relatively close to major population and infrastructure centers, where electricity is in high demand. The region is home to some of the largest and most industrious ports on the East Coast, with the necessary equipment and expertise to handle large wind turbine components. These make the region very attractive for offshore wind power plant development.

The JEDI model was used to provide estimates of the magnitude of economic impacts using three distinct scenarios, representing conservative, moderate, and aggressive development of the industry in the region. Scenario A is a conservative scenario, and JEDI analysis projects fewer jobs and slow regional growth. Scenario C, the aggressive scenario, projects the highest economic impacts but would require the supply chain to develop at a very rapid pace due to the large number of wind turbines to be deployed annually that are regionally sourced. These two scenarios represent an upper and a lower bound of what the wind industry could look like in the Mid-Atlantic.

Scenario B offers moderate development of the industry and supply chain, and JEDI analysis suggests that the industry would be able to support approximately 8,000 FTEs in 2020 to approximately 31,000 FTEs in 2030 regionally. While the results of this study are only estimates intended to create a general profile of what the offshore industry could look like, the results presented in Scenario B seem to offer sufficient economic returns to encourage further growth.

However, since an offshore wind industry does not yet exist in the United States, these results should be considered preliminary and should be updated as further developments occur and information improves.

4 Case Study: Great Lakes Region

In collaboration with NREL, Professor David Loomis[22] and the Great Lakes Wind Collaborative conducted an analysis of the economic impacts of potential offshore wind development in the Great Lakes region. This case study reflects their analysis and findings. The Great Lakes region includes states that touch Lakes Superior, Michigan, Huron, Erie, and Ontario: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania[23], and Wisconsin, as shown in Figure 7.

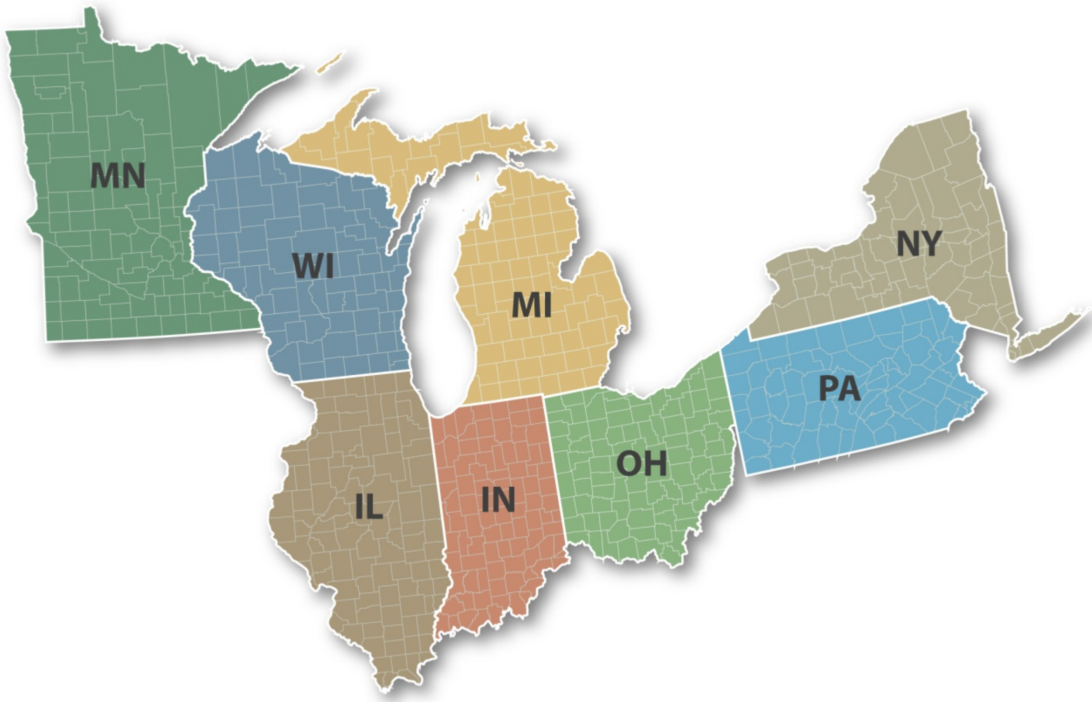

Figure 7. Map of the Great Lakes region

4.1 Physical Characteristics and Infrastructure of the Great Lakes

The diversity, freshwater, and inland location of the Great Lakes set projects within the Great Lakes region apart from similar projects in the Atlantic Ocean, Gulf of Mexico, or Pacific Ocean. Water depth can vary greatly from site to site. Ocean depths can vary but typically not as much as in the Great Lakes. Lakes are filled with freshwater, which freezes at a higher temperature than sea water yet is not as corrosive as the saltwater found in the ocean. There are fewer port options for potential offshore wind projects in the Great Lakes than projects off the U.S. seaboard. Potential wind sites in the Great Lakes are usually farther from shore than potential sites off the coast of the United States. Lakes do not experience tides; relatively consistent water depth decreases maintenance costs.

[22] Department of Economics, Illinois State University
[23] Note that Pennsylvania is included in both the Great Lakes region and the Mid-Atlantic region.

In addition, lock constraints can make transporting offshore wind system boats and equipment between the Great Lakes and the Atlantic difficult. The Saint Lawrence Seaway, which connects the Great Lakes with the Atlantic, cannot accommodate vessels wider than 80 ft. or those that need freshwater depth of more than 26.5 ft. Freshwater is less buoyant than saltwater, so a boat able to navigate in 26.5 ft. of ocean water may not be able to operate in freshwater of the same depth. The 80-ft. width limit, however, is likely the most problematic in transporting offshore wind ships and equipment. Barges capable of traversing the Saint Lawrence Seaway exist, but they are not as common as suitable barges that are too wide for the canal (Garrett et al. 2012).

The majority of these differences would likely make offshore wind development in the Great Lakes more expensive than comparable ocean-based projects. The lack of tides and decreased corrosiveness of freshwater compared to saltwater slightly mitigate but do not outweigh these increased expenses.

4.2 Scenarios

For the Great Lakes region, the Great Lakes Wind Network utilized its network to research potential deployment scenarios, along with regional content estimates. NREL and Illinois State University performed interviews with regional experts to obtain data on the supply chain and manufacturing capabilities.

4.2.1 Deployment Scenarios

This analysis considers three growth scenarios: low, moderate, and high growth (Table 12). The low scenario (A, which is also high cost) represents mostly pilot projects and small installations, culminating in a total of 1,000 MW installed. The medium scenario (B) assumes slightly faster growth with moderate cost reductions. The high scenario (C) assumes rapid growth of the industry, relatively high levels of deployment, and further cost reductions.

Growth in the low scenario increases from 250 MW by 2020 to 1 GW by 2030. The medium scenario begins with 500 MW by 2020 and grows to 2 GW by 2030, and the high scenario increases from 1 GW by 2020 to 5 GW by 2030. All scenarios begin with a $6,632/kW construction cost, with 2030 costs ranging from $4,642/kW to $5,969/kW. All scenarios assume a constant annual O&M cost of $133/kW.

Table 12. Great Lakes Region Cost and Capacity Scenarios (2012 $)

Deployment Scenario	Construction Cost ($/kW)		Deployed Capacity (MW)	
	2020	2030	2020	2030
Low (A)	$6,632	$5,969	250	1,000
Medium (B)	$6,632	$5,306	500	2,000
High (C)	$6,632	$4,642	1,000	5,000

This study only considers deployment in the Great Lakes in water that is shallow enough for jacket substructures. Many sites in Lake Superior and Lake Michigan, in particular, would likely require floating technology. At the time of this publication, the Offshore Wind JEDI model is not capable of estimating economic impacts of installations that use floating substructures.

4.2.2 Regional Content

Each growth scenario is positively correlated with the development of an offshore wind supply chain within the Great Lakes region (Table 13, Table 14). This assumes that if there is more offshore wind development, it is likely that suppliers such as turbine manufacturers will choose to invest in facilities in the Great Lakes region, and developers will choose to purchase goods that are produced and services that are provided by companies with a local presence.

Table 13. Great Lakes Local Content Assumptions (Construction) for Each Deployment Scenario

	Low (A)		Medium (B)		High (C)	
	2020	2030	2020	2030	2020	2030
Nacelle/drivetrain	0%	0%	0%	50%	0%	75%
Blades & towers	0%	25%	0%	50%	21%	75%
Materials & other equipment	1%	4%	3%	23%	23%	42%
Construction labor	0%	1%	0%	51%	50%	75%
Development services/other	32%	42%	53%	53%	53%	64%
Total construction local content	9%	15%	12%	40%	28%	57%

Table 14. Great Lakes Local Content Assumptions (O&M) for Each Deployment Scenario

	Low (A)		Medium (B)		High (C)	
	2020	2030	2020	2030	2020	2030
Labor	61%	79%	68%	98%	79%	100%
Materials & services	51%	51%	51%	51%	51%	51%
Total O&M local content	51%	53%	52%	54%	53%	55%

The low scenario portrays both the lowest level of regional content that can be purchased within the Great Lakes region as well as lowest deployment considered in this case study. As such, it can be considered a lower bound. Similarly, the high scenario portrays both the greatest deployment and the most content that can be purchased within the Great Lakes region. It can be considered an upper bound.

4.3 Results

4.3.1 Jobs

Figure 8 shows the estimated number of total annual construction jobs supported by project construction from 2020 to 2030.

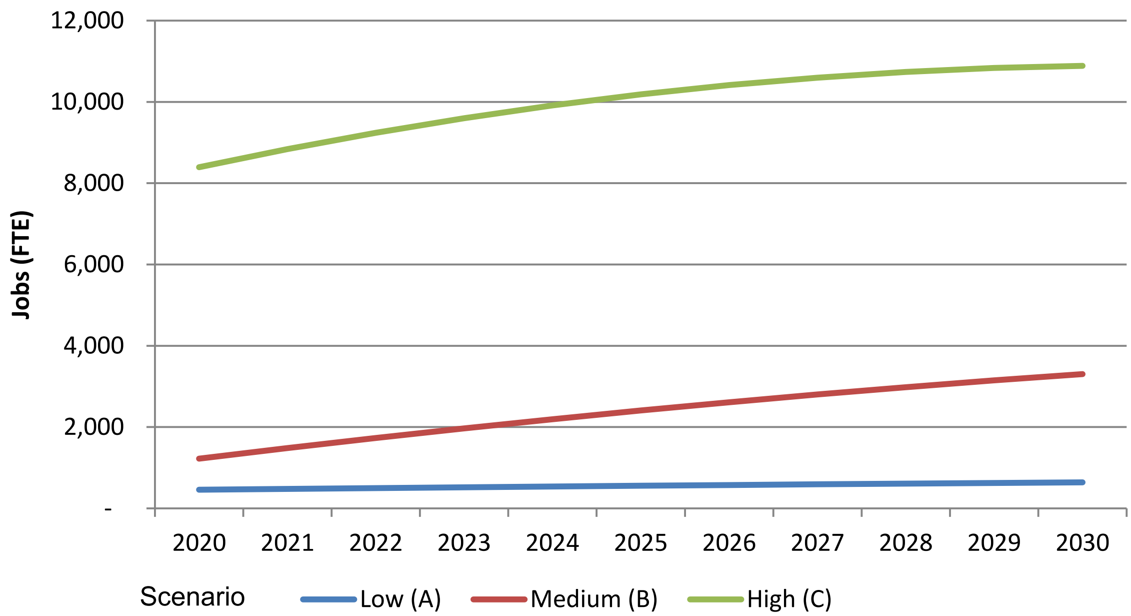

Figure 8. Estimated construction-phase jobs supported under each scenario (Great Lakes region)

Table 15. Estimated Number of Jobs Supported by Construction under Each Scenario (Great Lakes Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Jobs/MW
Low (A)	2020	100	160	190	6
	2030	100	280	260	9
	Annual Average 2020-2030	100	220	230	7
Medium (B)	2020	210	510	500	8
	2030	700	1,340	1,270	22
	Annual Average 2020-2030	470	960	920	16
High (C)	2020	2,220	2,990	3,180	21
	2030	2,250	4,480	4,170	27
	Annual Average 2020-2030	2,270	3,890	3,800	25

Table 15 also shows estimated job impacts per megawatt for each scenario during construction. Jobs range from a total of 6/MW under the low scenario in 2020 to 25/MW under the high scenario by 2030.

During their operational phase, offshore wind farms in this analysis are estimated to support between 0.7 and 0.8 jobs/MW, regardless of time period (Table 17). All scenarios assume that almost all workers who operate and maintain the sites live within the Great Lakes region. The biggest difference among different scenarios is how much content (such as replacement parts) is sourced locally. These differences are not large enough to significantly influence impacts per megawatt.

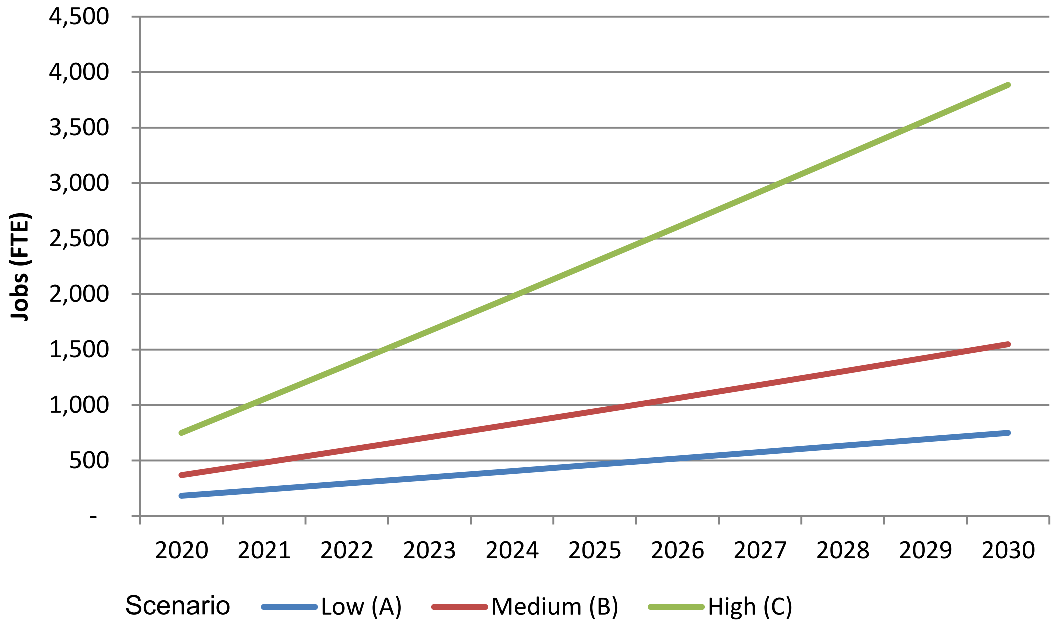

Figure 9. Annual estimated total O&M jobs supported under each scenario (Great Lakes region)

Table 16. Estimated Number of Jobs Supported by O&M under Each Scenario (Great Lakes Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Jobs/MW
Low (A)	2020	10	100	60	0.7
	2030	70	420	260	0.7
	Annual Average 2020-2030	40	260	160	0.7
Medium (B)	2020	30	210	130	0.7
	2030	170	850	530	0.8
	Annual Average 2020-2030	90	530	330	0.8
High (C)	2020	70	420	260	0.7
	2030	420	2,130	1,330	0.8
	Annual Average 2020-2030	240	1,270	790	0.8

4.3.2 Earnings and Output

Compensation for jobs supported by potential offshore wind development in the Great Lakes region is above average and doesn't vary significantly among scenarios. In 2011, workers in the Great Lakes region were compensated an average of $53,959 annually (BEA 2013). Under all three scenarios, the average earnings[24] of project development and onsite workers is approximately $140,000. Supply chain workers earn $70,000 in Scenarios B and C and $60,000 in Scenario A. Workers in induced jobs earn slightly less than average, around $50,000. As induced jobs include many low-paid retail and service sector workers, this is to be expected.

Earnings for most O&M workers are also estimated to be above average. Onsite positions earn an average of $110,000 in Scenario A, and the increased local portion of management workers in Scenarios B and C pushes average earnings up to $120,000. Supply chain earnings are an average of $70,000 in all scenarios, and induced earnings are an average of $50,000.

Table 17. Estimated Earnings and Output Supported by Construction under Each Scenario (Great Lakes Region, 2012 $ Millions)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total
Low (A)	2020	$30	$30	$30	$90
	2030	$30	$60	$40	$130
	Annual Average 2020-2030	$30	$40	$30	$110
Medium (B)	2020	$70	$100	$70	$240
	2030	$130	$350	$180	$660
	Annual Average 2020-2030	$100	$230	$130	$470
High (C)	2020	$420	$710	$460	$1,590
	2030	$390	$1,210	$600	$2,210
	Annual Average 2020-2030	$410	$1,010	$550	$1,970

Totals may not sum due to rounding.

Development of offshore wind in the Great Lakes region is estimated to support between $90 million and $1.6 billion by 2020 and $110 million to $2.2 billion in output by 2030 (Table 17). Annual average output estimates from 2020 to 2030 range from $110 million to $1,970 million. The majority of this output is in supply chain and business-to-business activity.

Operation of offshore wind plants supports between $30 million and $140 million of output in 2020 (Table 18). By 2030 this increases to $140 million to $710 million. This analysis only

[24] "Average earnings" is defined as the sum of all annual earnings from 2020 to 2030 divided by the sum of annual FTE jobs (or FTE job-years) over the same time period.

pertains to impacts estimated to occur between 2020 and 2030, but impacts from the operation of facilities continue for the life of the facility.

Table 18. Estimated Earnings and Output Supported by O&M under Each Scenario (Great Lakes Region, $ 2012 Millions)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total
Low (A)	2020	$2	$20	$9	$30
	2030	$8	$90	$40	$140
	Annual Average 2020-2030	$5	$60	$20	$90
Medium (B)	2020	$3	$50	$20	$70
	2030	$20	$180	$80	$280
	Annual Average 2020-2030	$10	$110	$50	$170
High (C)	2020	$8	$90	$40	$140
	2030	$50	$460	$200	$710
	Annual Average 2020-2030	$30	$270	$120	$420

Totals may not sum due to rounding.

4.4 Summary of Economic Impacts

Offshore wind development in the Great Lakes has the potential to support significant economic activity. In the medium scenario presented in this report, project construction is estimated to support 25 (2020) to 41 (2030) FTE jobs/MW. These jobs will earn approximately $74,000 annually.

On an ongoing basis, these projects are estimated to support 0.8 (2020) to 1.1 (2030) jobs/MW—a figure that increases as a local supply chain develops. These workers are estimated to earn between $67,000 and $63,000 annually.

These figures represent theoretical installations and supply chain growth. They are estimates based on the structure of the Great Lakes economy in 2010. Employment in the region has shifted away from manufacturing and toward sectors like health care. Supply chain growth that could support offshore wind development could take advantage of existing infrastructure and manufacturing workers, but current manufacturing declines may cause manufacturing workers to change occupations or migrate out of the region.

5 Case Study: Gulf of Mexico Region

NREL conducted an analysis of the potential economic impacts of offshore wind development in the Gulf of Mexico region. NREL researchers contacted industry experts, government officials, representatives from trade associations, and university researchers who offered their insights into the offshore wind development potential in the region. Results offered in this section stem from the aggregation and analysis of the information collected from local experts and may not necessarily reflect the point of view of each of the third parties interviewed. The Gulf of Mexico region is defined in this analysis as all states that surround the Gulf of Mexico: Texas, Louisiana, Mississippi, Alabama, and Florida, including its Atlantic coast, as shown in Figure 10.

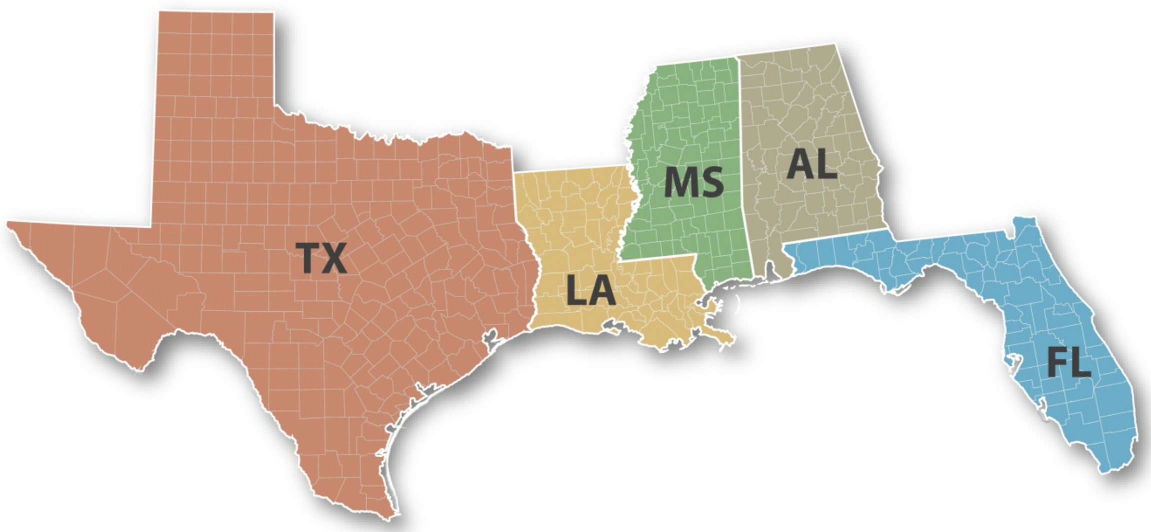

Figure 10. Map of the Gulf of Mexico region

5.1 Physical Characteristics and Infrastructure of the Gulf of Mexico

According to a report published by Musial and Ram, more than 30% of the total U.S. offshore wind potential in the 0- to 30-m depth is concentrated in the Gulf of Mexico (Musial and Ram 2010). Increases in sea depth have been identified as one of the main drivers of offshore wind cost increases (van der Zwaan et al. 2012). The abundant potential in shallow waters found in the Gulf could help lower costs per unit of electricity produced.

The offshore oil and gas industry in the Gulf of Mexico uses about 3,700 offshore structures to extract one-fourth of the total U.S. oil production and one-eighth of natural gas (Kaiser 2010). Given the similarity between the foundations and substructures needed for offshore wind development and those used by the oil and gas industry, the existing manufacturing workforce and infrastructure could add to the percentage of local labor and materials used in the development of offshore wind or speed the development of a local supply chain. Consequently, the costs of foundation fabrication and overall installation expenses would be lower than in regions where higher levels of imported labor and materials would be needed.

Ship fabrication and repair yard infrastructure in the Gulf of Mexico represent an advantage for the region compared to the rest of the United States. Most of the supply chain elements related to the construction of large-scale vessels needed for the installation of offshore wind turbines are present in the region, including 18 of the 26 largest shipyards in the country (Douglas-Westwood 2013; Colton 2013).

5.2 Scenarios

A wide variety of sources was used to obtain information about the Gulf of Mexico region. Interviews with local engineering companies, developers, manufacturers, the Texas state government, and researchers from academia were helpful in understanding regional trends and issues. This section includes information from reports published by domestic and international companies and government entities. The cumulative installation scenarios were based on numbers published by the Navigant Consortium for the years 2020 and 2030 (Navigant Consulting 2013).

5.2.1 Deployment Scenarios

The low-growth scenario used conservative assumptions about the rate of offshore wind deployment in the region. Installed capacity per year for this scenario ranged between 49 MW for 2021 to 158 MW in 2030. Comparatively, the annual installed capacity ranged between 187 and 606 MW for the moderate scenario and 213 and 690 MW for the high-growth scenario. In the moderate- and high-deployment scenarios, it was assumed that some installations would be in place before 2020.[25] Table 19 summarizes the estimates used as inputs for the JEDI model.

Table 19. Scenario Inputs (Gulf of Mexico Region, 2012 $)

Deployment Scenario	Cost ($/kW)		Capacity (MW)	
	2020	2030	2020	2030
Low (A)	$5,800	$4,930	60	1,000
Medium (B)	$5,400	$4,050	400	4,000
High (C)	$5,220	$3,400	900	5,000

Construction and operation costs in the Gulf of Mexico for 2020 were based on a hypothetical 500-MW offshore wind plant conceptualized by the Navigant Consortium[26] to estimate costs and economic impacts in the North Atlantic region (Navigant Consulting 2013; Hamilton 2013). Line-item costs in 2020 were then modified to reflect the conditions prevalent in the Gulf of Mexico. O&M costs were kept constant through the period analyzed because no significant sources of changes in costs for this area, like technology advancements, were identified.

[25] This report does not include economic impact estimates from construction prior to 2020.
[26] This theoretical plant would be built off the north Atlantic coast in 2018 at a depth of 20 to 30 m, using 3- to 5-MW turbines with a jacket substructure.

We selected a 17% decrease in construction costs between 2020 and 2030 as a baseline for the three scenarios based on a recent NREL publication on present and future costs of wind energy (Tegen et al. 2012). The baseline cost reduction results from the downward pressure on prices worldwide from higher levels of manufacturing automation, turbine technology improvements, and increased industry efficiency (Lantz et al. 2012). For the moderate scenario, we selected a cost reduction of 25% between 2020 and 2030, which is in line with the estimates that the Navigant Consortium reports (Hamilton 2013).

The low-growth scenario considers a more conservative baseline cost reduction rate of 13%, plus a decrease in costs of 2% due to a lower local content use. The combined cost reduction rate for the high-growth scenario is 35%, which is the result of a higher baseline cost reduction rate of 22%, plus 13% coming from local content increases. The next section discusses cost reductions related to local content levels in detail.

5.2.2 Regional Content

Ten of the 15 leading U.S. ports (by tonnage) are located in the Gulf of Mexico. In 2011, approximately 40% of all waterborne traffic in the United States was shipped or received in a port located in one of the five states in the Gulf of Mexico (Navigation and Civil Works Decision Support Center 2012). The Gulf's dense waterway infrastructure (e.g., ports and inland waterways) could lower operation and maintenance costs, which are correlated to the distance between offshore wind turbines and the ports used for maintenance.

The percentage of labor and components that could be sourced locally was estimated through interviews with local experts, including consultants, university faculty, developers, and industry advocates.

Table 20. Detailed Local Content Estimates by Selected Expenditure Categories (Gulf of Mexico Region)

	A (Low)		B (Moderate)		C (High)	
Years	2020	2030	2020	2030	2020	2030
Local content						
Equipment						
Nacelle/drivetrain	0%	0%	0%	20%	0%	40%
Blades	0%	15%	0%	55%	20%	65%
Towers	0%	35%	30%	65%	40%	100%
Materials & other equipment						
Basic construction (concrete, rebar, gravel, etc.)	80%	80%	80%	80%	80%	80%
Foundation & substructure	100%	100%	100%	100%	100%	100%

The presence of the offshore oil and gas industry in the Gulf of Mexico could make it easier for the region to design, manufacture, and install offshore wind foundations and substructures from the start. On the other hand, more specialized components like nacelles and blades require manufacturing infrastructure that currently does not exist in the region. Land-based wind power component manufacturers, while numerous in Gulf states, may need to invest significant amounts of capital to re-tool their factories or build new ones closer to the coast to produce offshore wind turbine components (Hamilton 2013).

The percentage of local turbine content in Gulf of Mexico installations will not necessarily depend on the current land-based wind power manufacturing infrastructure. The amount and timing of annual offshore wind installations is an important contributing factor. Manufacturers may choose to site their plants in regions of the United States in which deployment occurs earlier and at greater levels. It may not be cost effective for component manufacturers to invest in facilities in the Gulf of Mexico when comparable facilities exist, for example, along the Atlantic coast. In that scenario, a percentage of the orders from the Gulf of Mexico would be fulfilled from manufacturing plants located in other regions within the United States. Therefore, early deployment trends in the Gulf of Mexico and other regions could influence the amount of local content for installations in the Gulf. Local content figures used in this analysis take this into account because offshore wind deployments occur earlier and at a faster pace in the North Atlantic than in the Gulf in the majority of scenarios considered by experts (Hamilton 2013).

5.3 Results

5.3.1 Construction Period

Figure 11 shows the estimated total number of FTE jobs supported each year between 2020 and 2030 by construction under each scenario. This represents the number of jobs supported by capacity that is completed in the year indicated.

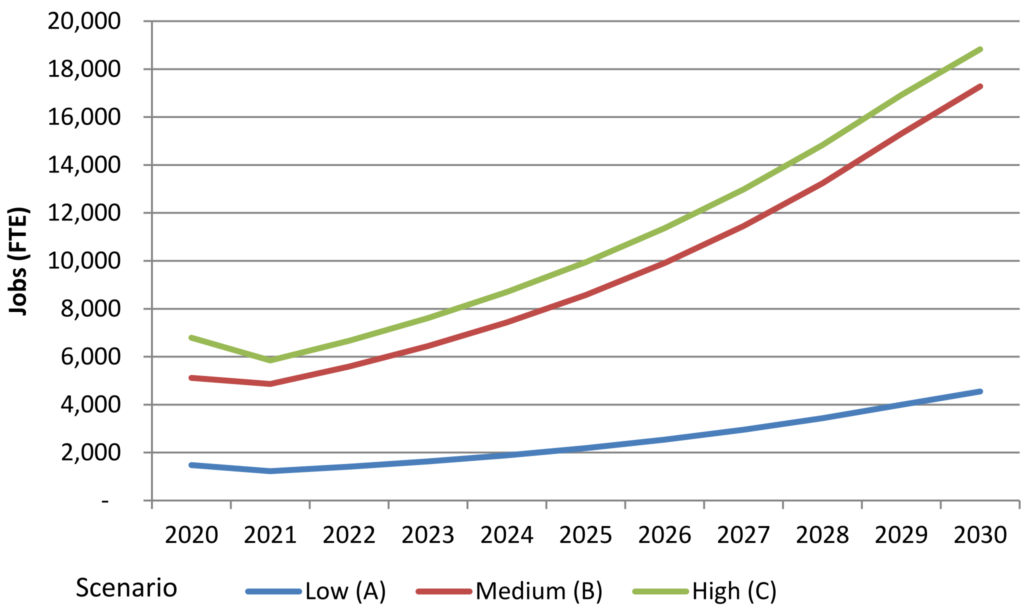

Figure 11. Estimated construction-phase jobs supported under each scenario (Gulf of Mexico region)

Table 21 summarizes job impacts in the initial and final years for each scenario analyzed. Lower-growth scenarios support fewer jobs, and so do scenarios with lower levels of local content. The total number of construction jobs supported in 2020 ranges from 1,480 to 6,800, depending on the scenario. For 2030, job numbers increase from 4,550 in the low-growth scenario to 18,830 in the scenario in which the most rapid growth is experienced.

Table 21. Estimated Number of Jobs Supported by Construction under Each Scenario (Gulf of Mexico Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Jobs/MW
Low (A)	2020	390	580	520	25
	2030	1,270	1,720	1,560	29
	Annual Average 2020-2030	680	950	860	27
Medium (B)	2020	1,340	2,000	1,780	26
	2030	4,800	6,580	5,900	29
	Annual Average 2020-2030	2,570	3,700	3,290	28
High (C)	2020	1,740	2,700	2,360	27
	2030	5,400	7,030	6,400	27
	Annual Average 2020-2030	2,960	4,240	3,760	28

In this case study, however, the number of jobs per megawatt installed does not necessarily increase with greater local content and deployment. This is because the higher-growth scenarios assume increases in labor productivity. This is most noticeable when comparing the medium and high scenarios because it causes the number of jobs per megawatt to be lower in the medium scenario (in 2020 and 2030) or the same (average 2020 – 2030) as the high scenario.

O&M jobs, while not as numerous as construction jobs, grow at a faster rate because they are proportional to the cumulative capacity installed, whereas construction jobs depend on the capacity installed each year (Figure 12).

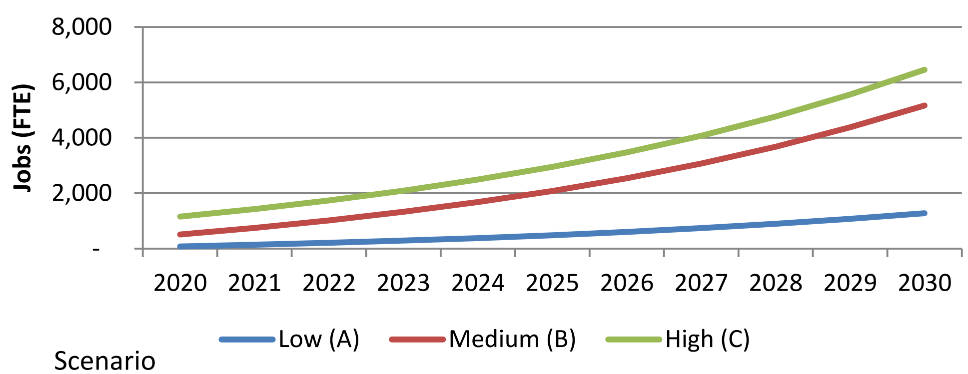

Figure 12. Annual estimated total O&M jobs supported under each scenario (Gulf of Mexico region)

The number of O&M jobs per megawatt does not vary among scenarios (Table 22). This case study assumes that most O&M labor will come from the Gulf Region regardless of scenario, and other variations are minor enough to not cause significant differences.

Table 22. Estimated Number of Jobs Supported by O&M under Each Scenario (Gulf of Mexico Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced
Low (A)	2020	3	50	30
	2030	60	780	440
	Annual Average 2020-2030	30	340	190
Medium (B)	2020	20	310	170
	2030	270	3,140	1,760
	Annual Average 2020-2030	120	1,450	810
High (C)	2020	60	700	390
	2030	340	3,920	2,200
	Annual Average 2020-2030	170	2,000	1,120

5.3.2 Earnings and Output

Earnings levels during construction range from a total of $110 million to $500 million in 2020 to $350 million to $1,460 million in 2030 (Table 23). These earnings levels represent well-compensated jobs, with average annual earnings (including benefits) of $140,000 annually for onsite workers. Supply chain job holders are estimated to earn approximately $60,000, and earnings from induced jobs are approximately $40,000.

Table 23. Estimated Earnings and Output Supported by Construction under Each Scenario (Gulf of Mexico Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Low (A)	2020	$50	$70	$30	$140	$20	$70
	2030	$180	$210	$100	$414	$70	$210
	Annual Average 2020-2030	$90	$120	$50	$230	$40	$120
Medium (B)	2020	$190	$240	$110	$490	$80	$240
	2030	$670	$780	$390	$1620	$260	$800
	Annual Average 2020-2030	$360	$430	$220	$910	$150	$440
High (C)	2020	$240	$300	$160	$670	$110	$320
	2030	$750	$850	$420	$1,750	$280	$860
	Annual Average 2020-2030	$410	$480	$250	$1,060	$170	$510

The construction phase of the project is anticipated to support between $280 million and $990 million in output in the Gulf of Mexico in 2020, increasing to $834 million to $3,460 million in 2030 (Table 23). The largest portion of this—about half—is in the supply chain category under all scenarios.

Output from O&M should be much lower than that supported by construction. In 2020, this analysis shows between $10 million and $210 million supported by O&M, increasing to a range of $230 million to $1,180 million by 2030 (Table 24). The largest portion of output is in the supply chain category in all scenarios.

Table 24. Estimated Earnings and Output Supported by O&M Activities under Each Scenario (Gulf of Mexico Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Low (A)	2020	< $1	< $1	$3	$10	$1	$4
	2030	$7	$7	$50	$170	$20	$60
	Annual Average 2020-2030	$3	$3	$20	$70	$8	$30
Medium (B)	2020	$3	$3	$20	$70	$8	$20
	2030	$30	$30	$200	$680	$80	$240
	Annual Average 2020-2030	$10	$10	$90	$310	$40	$110
High (C)	2020	$7	$7	$50	$150	$20	$50
	2030	$40	$40	$250	$840	$100	$300
	Annual Average 2020-2030	$20	$20	$130	$430	$50	$150

Total O&M earnings range from $5 million to $70 million in 2020 and $80 million to $390 million by 2030 (Table 24). These equate to overall average salaries of $60,000 for all jobs supported by O&M activities. Onsite workers receive the highest salaries, earning an average of $120,000 annually. Supply chain workers earn an average of $65,000 annually, and induced workers earn an average of $40,000 each year. These averages are consistent and similar across all scenarios.

5.4 Summary of Economic Impacts

Scenarios A, B, and C represent different levels of deployment, growth of a Gulf of Mexico supply chain, and offshore wind costs. Scenario C supports the most jobs and Scenario A the fewest. Scenario A is also the costliest on a per-megawatt basis, while local supply chain growth and efficiency improvements push costs down the most under Scenario C.

In the Gulf region, our analysis shows that offshore wind deployment has the potential to support an annual average of 2,490 to 10,960 jobs during construction periods (with an average of 25 to 29 jobs/MW) between 2020 and 2030, and 560 to 3,290 ongoing jobs on average between 2020 and 2030 (with an average of 1.3 jobs/MW). The results will depend on many factors, including number of projects and turbines installed, energy policy, and regional sourcing of goods and services.

6 Case Study: The Southeast Region

The Virginia Center for Wind Energy at James Madison University (JMU) and NREL performed the following analysis to estimate the expected economic impacts associated with offshore wind power developed off the coasts of Virginia[27], North Carolina, South Carolina, and Georgia, as shown in Figure 13.

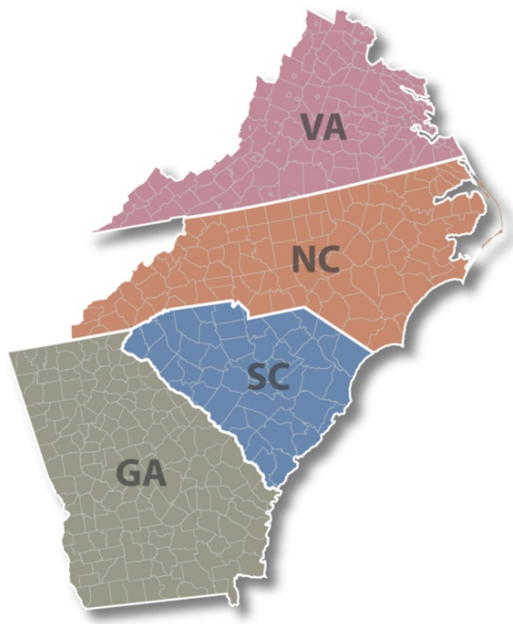

Figure 13. Map of the Southeast region

6.1 Physical Characteristics and Infrastructure

The Southeast could play a significant role in offshore wind development due to the substantial offshore wind resource, with Virginia, North Carolina, South Carolina, and Georgia representing 45% of the total East Coast resource (DOE 2008). The region is home to a highly skilled manufacturing and maritime workforce and employs thousands of people in the land-based wind industry, despite having almost no utility-scale wind energy facilities.[28]

There are many large ports in the Southeast region that could potentially be used as staging areas and for component manufacturing, such as the Port of Virginia, Port of Charleston, and Port of Savannah. Existing economic activity in industries similar to offshore wind in the Southeast suggests that the region could have relatively low business expenses, a competitive advantage that could also result in offshore wind component manufacturers choosing to locate in the region. The American Wind Energy Association (AWEA) estimates between 4,600 and 8,500 (from about 75,000 national) wind-related jobs in the Southeast in 2013. The EIA estimates that Virginia, North Carolina, South Carolina, and Georgia have lower construction costs for offshore wind energy than most of the East Coast states (EIA 2013d).

[27] Note that Virginia is included in both the Southeast and the Mid-Atlantic regions of the country.
[28] Southeastern Coastal Wind Coalition, 2014. www.secoastalwind.org/

6.2 Scenarios

Data for this study were acquired from interviews with state- and region-specific contacts who are engaged in activities that support and promote offshore wind development. The authors also used Web resources, reports from state and federal agencies and organizations, and appropriate databases to obtain information relevant to this effort.

Unlike the previous three case studies, for this region we examined five offshore wind deployment scenarios to accommodate varying future regional investment and technology cost potentials. This case study is more complex in its assumptions due to the availability of information provided through the JMU network.

6.2.1 Deployment Scenarios

Five combinations of deployment and market scenarios for offshore wind in the Southeast were developed (Table 25). These low, moderate, and high deployment scenarios reflect different levels of deployment but not necessarily different levels of growth in a regional offshore wind industry.

Table 25. Overall Scenarios Considering Growth, Regional Investment, and Cost (Southeast Region)

Deployment Scenario	Growth	Regional Investment	Cost	Explanation
A	Low	Low	High	Low growth and investment, high cost (LLH)
B	Medium	Medium	Medium	Moderate (MMM)
C	High	High	Low	High growth and investment, low cost (HHL)
D	Low	High	Medium	Low growth, high investment, moderate costs (LHM)
E	High	Low	Medium	High growth, low investment, moderate costs (HLM)

In the low-growth scenario, investment in the offshore wind industry is assumed to be very conservative. In this scenario it is likely that the first turbines deployed offshore will be small pilot projects intended primarily to support data gathering. Since the market is assumed to grow at a conservative pace (meaning a low level of deployment), it is also assumed that the majority of the region's capacity is in Virginia and North Carolina because these states are significantly further along in the federal leasing process. Moreover, the wind projects commissioned in this scenario are assumed to range between 150 and 250 MW in the initial years up to 2025. Larger wind projects of more than 300 MW of nameplate capacity are assumed to be commissioned after 2025.

The first years of the moderate-growth scenario (medium deployment level) are assumed to be similar to those of the low-market-growth scenario, featuring an initial phase of pilot projects. However, in this scenario, there is a consistent level of growth in the market, reaching 350 MW/year by 2025 and 600 MW/year by 2030.

The high-growth scenario (highest deployment) assumes that the offshore wind industry accelerates rapidly in the Southeast, representing a ceiling for turbine installations in the region.

In this case, the majority of added capacity is from offshore wind. In this more aggressive scenario, the industry would start with large-scale projects of more than 300 MW immediately and reach a build-in rate of 500 MW/year by 2020. Rapid market growth is assumed to continue for the next 10 years, reaching 900 MW/year in 2025 and 1,100 MW/year in 2030, about half of the average historical build-in rate for electricity in the region.

6.2.2 Regional Investment-Based Scenarios

Three regional investment scenarios for the Southeast were developed, each representing different levels of investment for offshore wind by local and regional companies. These scenarios reflect growth in a regional offshore wind industry such as component manufacturers or offshore wind training institutions. At higher levels of local and regional investment in offshore wind, there will be greater capital injected into the local economy and subsequent job creation. In this study, production outsourced to other regions or countries is considered to be lost or "leaked" dollars.

In the low regional investment scenario, the regional contribution to offshore wind projects would be minimal because of uncertainty in the industry among local firms; thus as of 2020, little of the capital being spent on offshore wind is injected into the local economy. Over the next 10 years, a very modest increase in regional manufacturing would be expected—the majority of components would be manufactured overseas. In particular, it is assumed that all project financing would be outsourced.

In the moderate regional investment scenario, the situation is similar to that of the low regional investment scenario in 2020, except that greater investment in the fabrication of substructures and foundations would be expected because of the region's capabilities of producing these components and the difficulty of transporting such large components from overseas. In this scenario, there would be a higher level of regional investment in the industry, thus advancing the regional supply chain. Roughly half of the production is assumed to be regional by 2030. As a result of supply chain development and increased certainty in the industry, some regional firms start to finance these projects.

The high regional investment scenario assumes a significant level of investment by local and regional companies in the industry, resulting in the development of a robust supply chain by 2030. The level of investment is higher than for the medium and low regional investment scenarios by 2020. By 2025, more than half of the components are assumed to be manufactured locally, and a supply chain that is almost entirely regional is developed by 2030. The industry is healthy enough by this point that regional institutions handle 75% of construction financing.

6.2.3 Cost-Based Scenarios

We developed three cost-based scenarios for use in the JEDI analysis. First we determined a baseline cost using data from the 2010 EIA Annual Energy Outlook report.

The low-deployment, low regional investment, high-cost scenario A (or LLH) assumes that there are limited developments in offshore wind energy technology, meaning that cost reduction is slow. A cost reduction of 3.5% every 5 years was applied to the baseline up to 2030. This leads to an overall cost reduction of around 10% during this 15-year period.

The moderate scenario B (or MMM) assumes that there are more technological advancements in offshore wind deployment technologies, thus resulting in a lower cost. The average cost of a wind turbine was assumed to decrease by 7.2% every 5 years, resulting in an overall cost reduction of around 20% over the 15-year period.

In the high-deployment, low-cost scenario C (or HHL), developments in offshore wind energy technologies are the most aggressive, thus driving down the average cost per kilowatt most dramatically. The average cost of offshore wind is assumed to decrease by 11.2% every 5 years, resulting in an overall cost reduction of 30% by 2030. Table 26 shows the costs per installed kilowatt for each scenario.

Table 26. Southeast Region Cost and Capacity Scenarios (2012 $)

Deployment Scenario	Cost ($/kW)		Capacity Deployed (MW)	
	2020	2030	2020	2030
Low Cost (C/HHL)	4,415	3,920	985	9,760
Medium Cost (B/MMM, D/LHM, E/HLM)	4,826	4,480	252	4,027
High Cost (A/LLH)	5,220	5,040	95	1,695

For reference: Scenarios list regional growth/investment/cost

6.3 Results

Five combinations of the deployment and market (growth), regional investment-based, and cost-based scenarios were developed. These are defined in Table 26 and referred to as Scenarios A (LLH), B (MMM), C (HHL), D (LHM), and E (HLM). In each case, the abbreviations correspond to the high, medium, or low listed in Table 25. The first letter refers to the growth scenario, the second to the regional investment, and the third to the cost. One-time construction-phase impact estimates presented in this report reflect estimated impacts that are deployed in the year indicated. O&M estimates reflect the total number of ongoing, annual O&M jobs supported in the year indicated.

6.3.1 Jobs

The JEDI model results provide a wide range of values for potential jobs from the different scenarios (Figures 14 and 15, Tables 27 and 28). Scenario A (LLH) results in the fewest number of jobs supported whereas Scenario C (HHL) represents the highest number of total jobs. The results show clearly that the level of regional investment impacts the number of jobs generated. While Scenarios A (LLH) and D (LHM) had the same offshore wind low level of deployment, the higher level of regional investment assumed in Scenario D (LHM) results in an average of more than 200 additional jobs annually between 2020 and 2030. Similarly, when comparing the results pertaining to Scenarios C (HHL) and E (HLM, which had assumed the same high level of deployment), this analysis shows that Scenario C (HHL) results in an annual average of approximately 15,000 more jobs from 2020 to 2030.

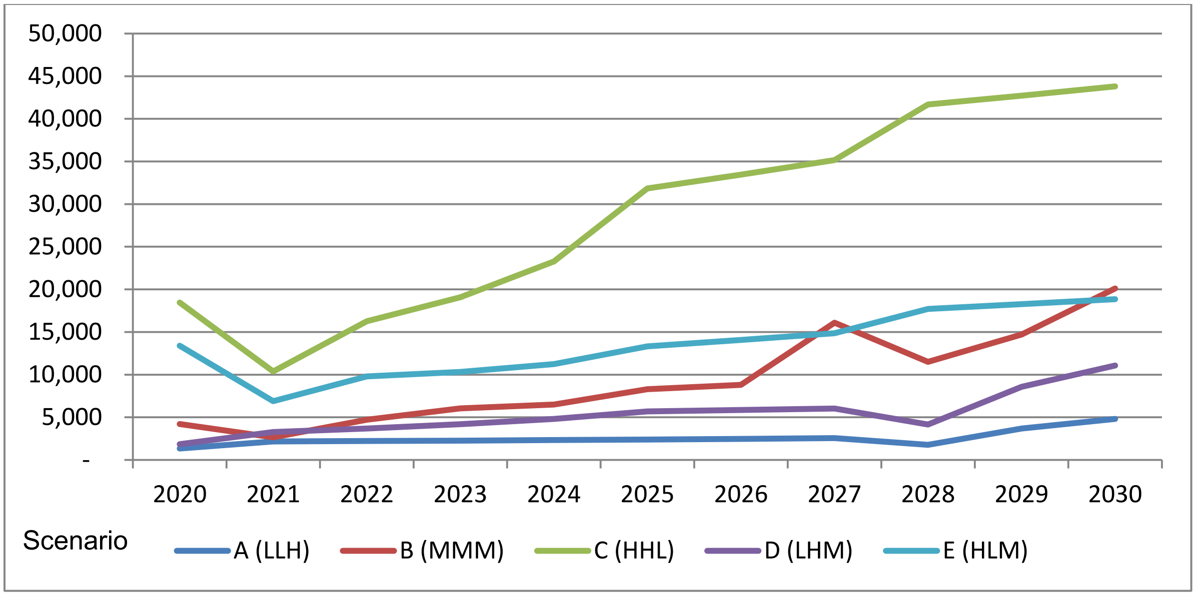

Figure 14. Estimated construction-phase jobs supported under each scenario (Southeast region)

The largest portion of the jobs generated in all scenarios, around 43%, was induced jobs that are supported by worker expenditures. Nearly as many jobs supported by the projects can be attributed to turbine and supply chain impacts.

Another widely reported metric to consider is the number of FTE jobs per megawatt supported under each scenario. From this perspective, Scenario E (HLM) generates the fewest number of jobs per megawatt installed, whereas Scenario D (LHM) results in the greatest number of jobs per megawatt installed. In 2020, the range of construction-phase FTEs per megawatt varies only between 13.6 in Scenario E (HLM) to 19.5 in Scenario D (LHM), primarily because the differences in regional investment are not as impactful as in later years. This analysis shows by 2030 a minimum of 17.1 FTEs/MW in Scenario E (HLM) and a maximum of 44.3 FTEs/MW in Scenario D (LHM). For Scenario B (MMM), the moderate scenario, around 16.7 FTEs/MW are supported in 2020, with the number increasing to 33.5 FTEs/MW by 2030.

The JEDI results for total gross jobs supported during the O&M period do not vary significantly among scenarios. This is because the largest line-item expenditures are on goods and services, such as water transportation, which can already be procured in the Southeast region, and this analysis assumes a constant real price of $133/MW for O&M. Impacts from financing and taxes are not included.

In all scenarios, the number of O&M jobs supported increases from 1.6/MW in 2020 to 1.7/MW by 2030 (Table 28). Figure 15 plots these increases among scenarios. There are very slight deviations, with C (HHL) and E (HLM) being nearly the same and A (LLH) and D (LHM) being similar as well.

Table 27. Estimated Number of Jobs Supported by Construction under Each Scenario (Southeast Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total FTE Jobs/MW
Scenario A (LLH)	2020	220	530	590	14
	2030	750	1,960	2,090	19
	Annual Average 2020-2030	420	1,020	1,110	16
Scenario B (MMM)	2020	860	1,550	1,810	17
	2030	4,150	7,480	8,470	34
	Annual Average 2020-2030	2,000	3,450	3,980	24
Scenario C (HHL)	2020	3,310	7,180	7,960	19
	2030	9,120	16,260	18,420	40
	Annual Average 2020-2030	5,830	10,770	12,140	31
Scenario D (LHM)	2020	320	730	800	19
	2030	2,100	4,280	4,700	44
	Annual Average 2020-2030	1,020	2,080	2,290	34
Scenario E (HLM)	2020	2,270	5,250	5,870	14
	2030	3,210	7,500	8,160	17
	Annual Average 2020-2030	2,330	5,310	5,880	14

For reference: Scenarios list regional growth/investment/cost

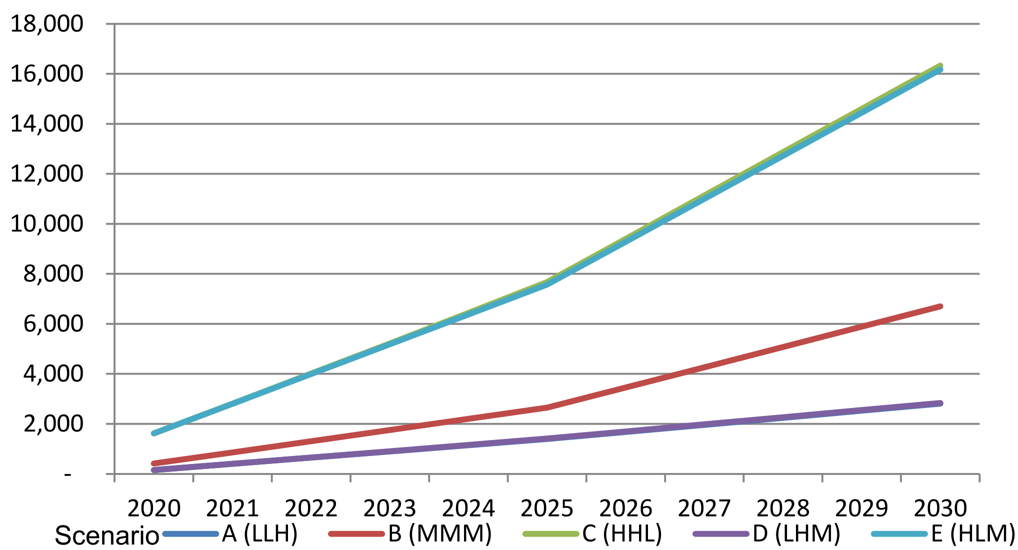

Figure 15. Annual estimated total O&M jobs supported under each scenario (Southeast region)

Table 28. Estimated Number of Jobs Supported by O&M under Each Scenario (Southeast Region)

Deployment Scenario	Years	Project Development & Onsite Labor	Supply Chain	Induced	Total FTE Jobs/MW
Scenario A (LLH)	2020	7	80	60	1.6
	2030	130	1,520	1,160	1.7
	Annual Average 2020-2030	70	780	590	1.7
Scenario B (MMM)	2020	18	230	170	1.6
	2030	330	3,610	2,760	1.7
	Annual Average 2020-2030	150	1,700	1,290	1.7
Scenario C (HHL)	2020	70	880	670	1.6
	2030	840	8,780	6,710	1.7
	Annual Average 2020-2030	420	4,510	3,440	1.7
Scenario D (LHM)	2020	7	80	60	1.6
	2030	150	1,530	1,170	1.7
	Annual Average 2020-2030	70	780	600	1.7
Scenario E (HLM)	2020	70	880	670	1.6
	2030	770	8,750	6,660	1.7
	Annual Average 2020-2030	380	4,490	3,410	1.7

For reference: Scenarios list regional growth/investment/cost

6.3.2 Earnings and Output

The earnings and gross economic output associated with project development and earnings associated with construction, as well as turbine and supply chain impacts, induced impacts, and total impacts, are presented in Table 29. Scenario C, with high growth and high regional investment, results in the greatest earnings and economic output. Scenario E with high growth and low regional investment follows in terms of earnings and output during early years (2020), but Scenario B with medium growth and regional investment passes Scenario E by 2030.

Table 29. Estimated Earnings and Output Supported by Construction under Each Scenario (Southeast Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Scenario A (LLH)	2020	$30	$50	$40	$120	$30	$90
	2030	$100	$160	$130	$490	$100	$320
	Annual Average 2020-2030	$60	$90	$70	$240	$60	$170
Scenario B (MMM)	2020	$120	$170	$100	$350	$90	$280
	2030	$470	$690	$520	$1,930	$420	$1,280
	Annual Average 2020-2030	$270	$350	$230	$860	$200	$610
Scenario C (HHL)	2020	$450	$660	$490	$1,760	$390	$1,210
	2030	$1,270	$1,460	$1,110	$4,340	$910	$2,790
	Annual Average 2020-2030	$810	$970	$740	$2,810	$600	$1,840
Scenario D (LHM)	2020	$40	$70	$50	$180	$40	$120
	2030	$290	$340	$290	$1,160	$230	$710
	Annual Average 2020-2030	$140	$170	$140	$550	$110	$350
Scenario E (HLM)	2020	$300	$520	$350	$1,190	$290	$890
	2030	$430	$640	$510	$1,850	$400	$1,240
	Annual Average 2020-2030	$310	$500	$360	$1,270	$290	$890

For reference: Scenarios list regional growth/investment/cost

The onsite labor impacts, local revenue and supply chain impacts, induced impacts, and total impacts associated with O&M are presented in Table 30. In 2020, the values are correlated with the level of growth defined for each of the five scenarios. By 2030, Scenario C (high growth, high regional investment, and low cost) exhibits the strongest growth, followed by Scenario E (high growth but low regional investment and medium cost).

Table 30. Estimated Earnings and Output Supported by O&M under Each Scenario (Southeast Region, 2012 $ Millions)

		Project Development & Onsite Labor		Supply Chain		Induced	
Deployment Scenario	Years	Earnings	Output	Earnings	Output	Earnings	Output
Scenario A (LLH)	2020	$1	$1	$6	$20	$3	$10
	2030	$20	$20	$100	$340	$60	$180
	Annual Average 2020-2030	$8	$8	$50	$180	$30	$90
Scenario B (MMM)	2020	$2	$2	$20	$50	$8	$30
	2030	$40	$40	$250	$820	$140	$420
	Annual Average 2020-2030	$20	$20	$120	$380	$60	$200
Scenario C (HHL)	2020	$8	$8	$60	$200	$30	$100
	2030	$100	$100	$610	$1,980	$330	$1,030
	Annual Average 2020-2030	$50	$50	$310	$1,020	$170	$530
Scenario D (LHM)	2020	$1	$1	$6	$20	$3	$10
	2030	$20	$20	$110	$340	$60	$180
	Annual Average 2020-2030	$9	$9	$50	$180	$30	$90
Scenario E (HLM)	2020	$8	$8	$60	$200	$30	$100
	2030	$90	$90	$600	$1,980	$330	$1,020
	Annual Average 2020-2030	$40	$40	$310	$1,010	$170	$520

For reference: Scenarios list regional growth/investment/cost

6.4 Summary of Economic Impacts

Development of offshore wind power will require significant investment and will affect the economy of the Southeast. Economic impacts would arise from direct work onsite as well as through an offshore wind supply chain or business-to-business services. In addition, impacts would include regional expenditures for goods and services made by offshore wind and related workers. Revenues in the form of royalty payments would also be generated, some of which would benefit state and local governments.

Scenario A with low growth and investment but high cost generates the lowest total gross FTEs regionally. It also produces the lowest economic return locally and regionally. A Sparkline showing this scenario between 2020-2030 indicates the estimated number of jobs in construction and operations, over time ranging from approximately 1,500 to 7,600 jobs. 

Scenario B with medium growth, investment, and cost represents a moderate case. The market growth and supply chain development may provide sufficient economic growth to entice regional industry support and supply chain development. This Sparkline indicates the estimated number of jobs over time from this scenario, ranging from approximately 4,600 to 26,800 jobs. 

Scenario C supports the highest number of gross FTE jobs but requires an exceptionally fast supply chain development to maintain local manufacturing and production. This scenario describes the great potential of offshore wind to support jobs and economic development for the region, ranging from approximately 20,000 to 60,100 jobs. 

Scenario D generated significantly more gross FTE jobs than did Scenario A because of aggressive regional investment in the industry. While the deployment and market development are limited, significant economic output is generated domestically, thus resulting in the highest number of FTE jobs per megawatt out of the five scenarios (34 FTE/MW) but not the highest number of jobs overall, due to limited deployment. This Sparkline shows job growth ranging from approximately 2,000 to 14,000 jobs. 

Scenario E, with a high level of deployment like Scenario C, resulted in far fewer gross FTE jobs than Scenario C because of a higher dependency on non-regional supply chain inputs. Moreover, this scenario presents the lowest number of FTE jobs per megawatt out of the five scenarios (15 FTE jobs/MW). Despite an aggressive deployment and market development, the region would not realize the full extent of potential economic impacts from development since many of the dollars would "leak" from the local economy. This Sparkline shows the trend over time from approximately 15,000 to 35,000 FTE jobs. 

In the Southeast region, offshore wind energy development has the potential to support between 420 and 5,830 annual jobs on average during construction periods and between 70 and 420 average ongoing jobs per year. Any level of development will require offshore wind-related improvements to infrastructure and will also bring jobs to the region. If there is enough wind power deployed to support a robust supply chain for offshore wind, the region would experience greater economic growth and perhaps vast improvements in infrastructure.

7 Conclusions

Regions around the United States will need to invest in energy infrastructure in the future to replace aging equipment or increase generating capacity to respond to demand for electricity. In coastal regions of the United States, offshore wind is one possible technology that could be used for additional capacity.

The offshore wind industry in the United States has the potential to support thousands of jobs, even at relatively conservative levels of deployment and domestic supply chain growth. Interviews with regional academics, industry professionals, and other energy experts informed the development of the scenarios presented in this analysis.

As stated above, each regional analysis was performed by interviewing local experts. The wind resource differs from region to region, as do the deployment scenarios. Factors that contribute to the varying results also include existing infrastructure (e.g., ports), labor (e.g., available labor pool, manual labor vs. mechanized), supply chain, and assumptions from regional experts in potential to deploy offshore wind. Results show average construction-phase FTE jobs per megawatt deployed of 14 to 31 (Table 31).

Table 31. Summary of Construction Cost and Job Estimates by Region

Region	Jobs/MW, Low Scenario	Jobs/MW, Moderate Scenario	Jobs/MW, High Scenario
Southeast	**16**	**24**	**31**
Great Lakes	**14**	**17**	**25**
Gulf of Mexico	**27**	**28**	**28**
Mid-Atlantic	**16**	**23**	**25**

These estimates generally correlate with three recently published studies, as shown in Table 32.[29] Scenarios included in this report tend to be conservative, with three low scenarios reporting jobs-per-megawatt figures less than the minimum from the literature (Bloomberg), and all reporting figures less than the maximum from the literature (Hagerman et al.).

Table 32. Comparison of Study Results with Other Published Results

Study	FTE Jobs/MW
Coad and Antunes (2010)	25-29
Hagerman et al. (2010)	39
Bloomberg New Energy Finance (2012)[30]	17

[29] Studies prior to 2010 exist but were excluded from this report. Significant progress is consistently being made to understand cost and logistical requirements of offshore wind energy, and recent studies better capture the present state of knowledge.

[30] This figure only represents direct or onsite jobs.

Ultimately, the number of jobs in the United States that are supported by offshore wind will depend on deployment of offshore wind plants and growth of a domestic supply chain. Both of these could influence the construction costs of offshore wind installations, which in turn could influence both deployment and subsequent domestic supply chain growth. Regardless of these nuances, when offshore wind is commercially deployed in the United States, the industry will require a robust workforce.

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Appendix A. JEDI Model Caveats, Limitations, and Sensitivities

As with all economic models, there are caveats and limitations to the use of JEDI. Input-output models in general utilize fixed, proportional relationships between economy sectors. Factors that could change economic sectors, such as price changes that lead households to change consumption patterns, are not considered.

JEDI provides estimates of economic impacts given the user-specified expenditures and economic conditions when input-output data were compiled. Impacts that extend into the future (such as O&M impacts) are assumed to do so if all else is constant. There can be any number of changes in a dynamic economy that JEDI does not consider, so these future results should not be considered a forecast. They simply reflect how a project might look if it were completed in the current economy under the user-specified cost and local content assumptions.

JEDI results are based on project inputs, and these inputs can change from project to project. This is especially true of nascent technologies or technologies that have not yet been widely deployed in the United States. If an analyst wishes to estimate impacts from a specific project, tailoring inputs to that project should produce more accurate results. JEDI does not evaluate whether inputs are reasonable, nor does it determine whether a project is feasible or profitable.

Results from JEDI models are gross, not net. JEDI calculates what economic activity would be supported by demand created by project expenditures. Other changes in an economy may take place that JEDI does not consider, including supply-side impacts such as price changes, changes in taxes or subsidies, or utility rate changes. JEDI also does not incorporate far-reaching effects such as greenhouse gas emissions, displaced investment, or potential side effects of a project such as recreation or tourism.

The order of magnitude of JEDI results is largely a function of a project's scale and how much is spent within the region being analyzed. Larger, more expensive projects tend to generate more jobs. These jobs may not be onsite; they might be further down the supply chain, or they might be a result of expenditures made by investors. Changes in assumed expenditures or local shares can have a large impact on estimates, depending on the expenditures and size of the change. The changes can vary from line item to line item.