JANUARY 17, 2020

HAMPTON ROADS ALLIANCE

# OPPORTUNITIES FOR DEVELOPING THE OFFSHORE WIND ENERGY INDUSTRY IN HAMPTON ROADS

MANGUM economics

4201 DOMINION BOULEVARD, SUITE 114
GLEN ALLEN, VIRGINIA 23060
804-346-8446
*MANGUMECONOMICS.COM*

# Table of Contents

# About Mangum Economics, LLC

Founded in 2003, Mangum Economics is a Virginia based firm that specializes in producing objective economic, quantitative, and qualitative analysis in support of strategic decision making. Mangum Economics is located in the Innsbrook Corporate Office Park, in Glen Allen.

Much of our recent work relates to economic development, data centers, renewable energy, tax and regulatory policy, and terrestrial and subsea fiber.

Examples of typical studies include:

- *Potential Impact of the Development of the Offshore Wind Energy Industry on Hampton Roads and Virginia*, September 28, 2020.
- *The Economic Contribution of Utility Scale Solar Development to Virginia*, for the Maryland, Delaware, and Virginia Solar Energy Industry Association, May 2020
- *Potential Impact of Large Data Center Development in Maryland*, for the Maryland Chamber of Commerce, March 2020.
- *The Impact of Data Centers on the State and Local Economies of Virginia*, for the Northern Virginia Technology Council, January 2020.
- *Opportunities for Southern Virginia to Participate in the Cloud Economy*, for Mid-Atlantic Broadband Communities Corporation, April 2019.
- *Spotsylvania Solar Energy Center: Economic and Fiscal Contribution to Spotsylvania County*, for S-Power, February 2019.
- *Potential Impact of a Data Center Incentive in Illinois*, for the Illinois Chamber of Commerce, November 2018.
- *The Economic and Fiscal Contribution that Volvo Group North America made to Maryland, Mississippi, New York, North Carolina, Pennsylvania, Tennessee, and Virginia in 2016*, for Volvo Group North America, April 2018.

## The Project Team

David Zorn, Ph.D.
*Economist*

Nick Norboge, Ph.D.
*Consultant*

A. Fletcher Mangum, Ph.D.
*Founder and CEO*

Alexander Nikolov
*Research Assistant*

# Introduction

The Hampton Roads Regional Alliance commissioned Mangum Economics to produce this report on strategies and opportunities for the development of the offshore wind energy industry in the Hampton Roads area.

The offshore wind energy industry is a completely new industry that is coming to America. It is only a matter of time and place. Until now, the industry has not had any significant footprint anywhere in the country. Hampton Roads is certain to be one of the port areas on the East Coast of the U.S. that hosts the new industry. Hampton Roads will be less than 30 miles from the largest offshore wind farm planned for the United States – Dominion Energy's $7.8 billion, 2.6-gigawatt (GW) commercial Coastal Virginia Offshore Wind (CVOW) project. And Avangrid is starting to develop a $7.5 billion, 2.5-GW Kitty Hawk project off North Carolina near the border with Virginia. All else equal, Hampton Roads will provide the most efficient ports to support and service the development, manufacturing, installation, and operation of these projects. However, all else is not equal. There are significant frictions that will keep the economy of Hampton Roads from absorbing all $15 billion of the expenditures needed to construct those two projects. In a previous report, we estimated that less than ten percent of the total construction cost of the commercial CVOW project would go to Virginia businesses.[1] Avangrid estimates that a little over ten percent of the total construction cost of the Kitty Hawk project would go to Virginia businesses.[2] This report is intended to assist the Hampton Roads Regional Alliance to grow the offshore wind energy industry in the region so that Hampton Roads is able to capture more of the jobs and economic activity from offshore wind energy projects beyond just the two that are very near to Virginia Beach.

We begin by briefly reviewing the major drivers of economic growth associated with the offshore wind industry. Next, we describe how those major drivers of economic growth are likely to affect the Hampton Roads economy. Next, we briefly outline the challenges to the development of the offshore wind industry in Hampton Roads. Finally, we identify what we believe are the best opportunities for Hampton Roads to secure new investment and employment from the offshore wind industry. Hampton Roads Regional Alliance has requested that this report provide broad recommendations for economic development activities and not a prospect or target list. The information provided here has been gleaned from conversations with industry representatives, industry publications, company financial reports, and government reports from the United States and the United Kingdom.

[1] Mangum Economics, *Potential Impact of the Development of the Offshore Wind Energy Industry on Hampton Roads and Virginia*, September 28, 2020.
[2] Avangrid Renewables, *Economic Impact of Kitty Hawk Offshore Wind*, undated. It is consistent to estimate that a higher percentage of total construction costs for the Kitty Hawk project than the CVOW project will go to Virginia businesses because the Kitty Hawk project is about three years behind the CVOW project and more offshore wind energy businesses should be located in Virginia three years from now.

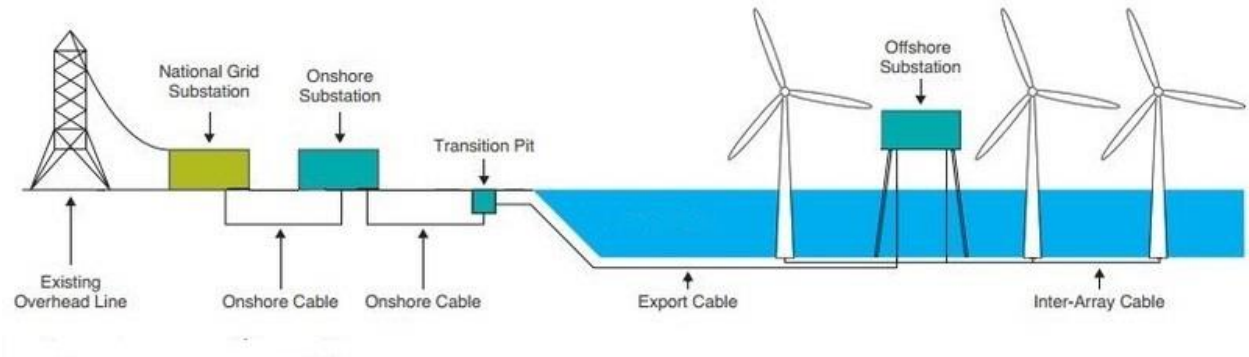
## Major Drivers of Offshore Wind Energy Industry Economic Development

This section identifies industries that contribute the most to the economic activity related to offshore wind farms. The greater the expenditures on a given industry, the more economic activity that will be generated by that industry.

There are two major stages of offshore wind projects – construction and operation. Both stages have significant potential to contribute to local economic development. Where the offshore wind energy construction businesses are located, they are very visible. The enormous physical size of the infrastructure draws attention to itself and makes the development impact easy to appreciate. However, the economic development impact of construction is highly dependent on having a reliable pipeline of new projects. Reliable pipelines are easier to project than to experience. In reality, the ebbs and flows of financial conditions, variations in regulatory regimes, and successes and failures at winning bids on projects make the local economic impact of the construction stage of offshore wind uncertain.

In contrast, the operational stage of offshore wind is much less noticeable in terms of its local footprint, however, it is far more stable in terms of the jobs and revenue that it provides locally. Offshore wind farms need regular maintenance and very large ones will require some degree of maintenance on an almost daily basis.

The construction and operation of a wind farm involve scores of different industries. Some, like the wind turbine manufacturers, are extremely obvious. Others, like oceanographic research, are less obvious. In our previous report on the potential impact of offshore wind development on Hampton Roads, we estimated the cost of constructing and operating a large wind farm off the coast of Hampton Roads. Our proprietary estimates were based on research on the industry, data from offshore wind construction projects in the United Kingdom, and information from industry sources. For the purposes of this report, we have roughly aggregated those cost estimates by type of industry in order to identify the industries and types of businesses that have the greatest impact for economic development purposes.

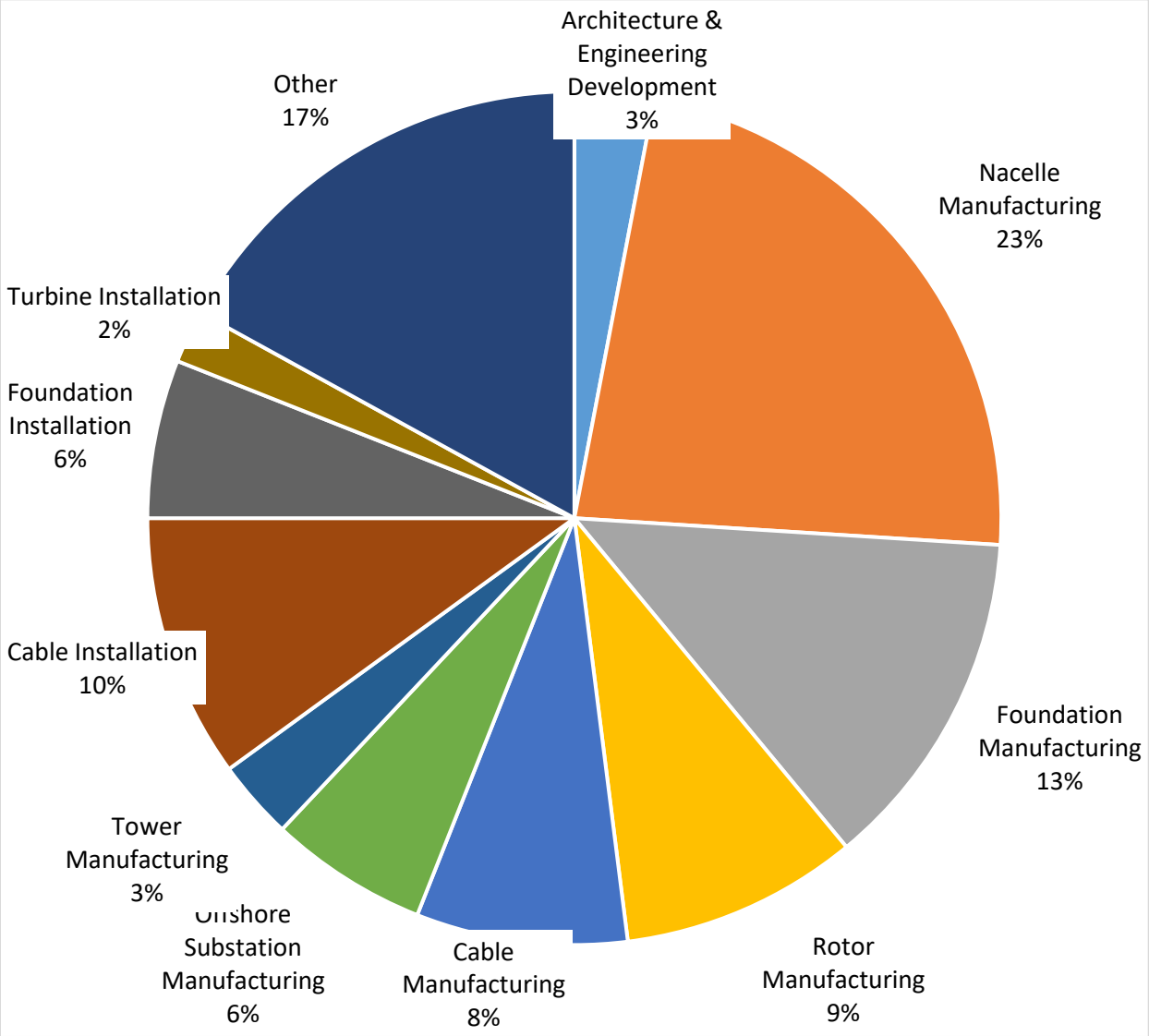


## CONSTRUCTION INDUSTRIES

There are three phases of construction for an offshore wind energy project: development, manufacturing, and installation. Figure 1 shows the ten categories of construction expenses that account for two percent or more of the total project construction cost.

- Total development phase costs account for six percent of the total construction cost with about half of that amount associated with architecture and engineering.
- Manufacturing of all components accounts for 74 percent of the total cost with turbine nacelles being the largest single expense category.
- Total installation costs account for 20 percent of the total construction cost with cable installation accounting for half of all installation expenditures.

Figure 1. Ten Largest Categories of Offshore Wind Farm Construction Total Expenditures



These ten largest construction categories can be simplified further for economic development purposes into four major categories:

- Turbine manufacturers,
- Foundation and tower manufacturers,
- Cable manufacturers/installers, and
- Offshore structural installers.

## Turbine Manufacturers

On any individual offshore turbine, the nacelle and rotor are made by the same company, although it is common for the different major parts to be made in different ports. For example, a rotor might be made in the U.K. while the nacelle and tower are made in Denmark. Although larger turbines are more efficient at generating electricity, wind and weather conditions can impose limitations on the size and composition of the nacelles and blades. Turbines account for the largest single percentage of the cost of a project and the size, weight, and style of the turbines impose certain engineering requirements on the rest of the infrastructure. Therefore, the turbine manufacturers have a very heavy influence on the other businesses in most of the other parts of the offshore wind industry.

## Foundation and Tower Manufacturers

Foundations and towers made for offshore wind turbines can be similar to structural elements manufactured for the offshore oil and gas industry. Currently, there are basically five types of foundations:

- Steel monopile foundations that are driven into the seabed at ocean depths of less than 100 feet.
- Concrete and steel gravity foundations that sink into soft seabeds at ocean depths of less than 100 feet.
- Steel tripod bottomed foundations that do not need to be driven into the seabed as deeply as monopiles but can be used in ocean depths up to 300 feet.
- Steel jacketed foundations that are driven deep into the seabed for use in ocean depths up to 300 feet.
- Floating foundations for ocean depths in excess of 130 feet.

Floating foundations may not provide enough stability for large turbines. Monopile foundations, which generally will be well suited to the conditions on the East Coast of the United States, are the least expensive foundations to manufacture and can be transported for significant distances. Therefore, the businesses that produce monopile foundations will face global competitive pressure.

## Cable Manufacturers/Installers

Like offshore turbine manufacturing, subsea cable manufacturing is a very concentrated industry. Usually, the manufacturers own and operate the vessels that install the cable offshore. Customs and

Border Protection has determined that the Jones Act (which requires U.S.-built and U.S.-crewed vessels for transportation of goods in U.S. waters) does not apply to cable laying vessels. Therefore, cable laying vessels are generally foreign-flagged vessels primarily operating out of foreign ports. This means that unless cable manufacturing facilities are built in Hampton Roads (which is unlikely), the local economic impact of cables associated with the construction stage will come from providing services to the foreign-flagged installation vessels when they are in port.

### Offshore Structural Installers

The installation of offshore infrastructure (primarily foundations and turbines) requires specialized vessels and trained crews that are Jones Act-compliant or foreign-flagged specialized vessels that work with Jones Act-compliant feeder barges. Globally, there are only about two dozen vessels that are designed to install offshore wind turbines, and none are Jones Act-compliant. Dominion Energy has commissioned the nation's first Jones Act-compliant installation vessel, and other companies have stated that they plan to build vessels. U.S. crews will also need to be trained for those U.S. made vessels. Even for projects that choose to rely on U.S. feeder barges collaborating with foreign-flagged vessels, installation will require the staging of all components of the installation at a U.S. port. So, no matter what vessels are used for installation, local port facilities and port workers will be essential for installation on the East Coast.

Although offshore substations account for six percent of the total cost of constructing a large offshore wind farm, we have not included that industry in the list of industry categories that are likely to make a significant contribution to economic development. Offshore substations are used to collect the power generated by many offshore turbines before transmitting the energy to shore. Each offshore wind farm needs only one or two offshore substations. On large wind farms, the ratio of turbines to offshore substations is roughly 100 to 1. Because there is low need and demand for offshore substations, they are not likely to be a significant driver of economic development.

## OPERATIONS AND MAINTENANCE INDUSTRIES

Once an offshore wind farm begins operation, the bulk of the economic development impact that it generates comes from expenditures for maintenance and repair of the infrastructure. The major turbine manufacturers offer maintenance and repair service contracts for the equipment that they have manufactured. These contracts are generally regarded as the most profitable parts of the companies' businesses. Other independent companies also offer maintenance and repair services. Except for some unusual circumstances, the vessels used for maintenance and repair services will need to be Jones Act-compliant. It will be most efficient to have regular maintenance services provided by businesses located fairly near the wind farm being maintained. Less frequent major repair services can be efficiently provided by businesses located farther away from the wind farm.

## Drivers of Economic Development in Hampton Roads

This section identifies industries that are key to enabling the Hampton Roads area to absorb a large part of the economic development impact that the offshore wind industry will create.

Merely having a wind farm (even a very large one) in the waters near an area will not necessarily result in significant local economic development. This is one of the most important lessons from the experience in the United Kingdom (U.K.). The U.K. has more installed offshore wind energy capacity than any other nation.[3] In fact, the U.K. has 27 percent more installed offshore wind energy capacity than Germany, the European country with the next largest amount of installed capacity. The U.K.'s first offshore wind farm was commissioned in 2000 (Blyth Offshore, 4 MW) followed by a second facility in 2003 (North Hoyle, 60 MW).

However, almost 20 years later, most of the supply chain supporting that development remains in continental Europe. Because many of these suppliers (located in Denmark, Norway, and Germany) had direct access to the U.K. through the North and Baltic Seas, manufacturers of large offshore wind components were able to relatively easily transport those structures to offshore U.K. locations, many of them within 400 nautical miles. The U.K. has initiated a number of efforts to attract more of the offshore wind supply chain into the country. However, it remains clear that the offshore wind industry has installed many projects in U.K. waters without having a large footprint on U.K. soil.

Each of the four phases of offshore wind activity (development, manufacturing, installation, and operation) involves different types of businesses that would impact the Hampton Roads economy in different ways. The larger the proportion of expenditures in each phase that go to categories of businesses that already exist in the Hampton Roads economy, the greater the immediate economic benefit to the Hampton Roads economy from new offshore wind activity.

Input-output multipliers are used to estimate the extent to which economies absorb the benefits of new expenditures. Often when people consider economic development impacts, they look at very high nationwide multipliers that can be vastly misleading with respect to the impact on regional economies. For example, a national employment multiplier of seven for manufacturing means that for every one local manufacturing job created by a project there are six other jobs supported *somewhere in the U.S.* For this reason, the appropriate multipliers to use for gauging the impact on regional economies such as Hampton Roads are those that are specific to the industries and the regional geography being studied.

Table 1 depicts the employment and expenditure multipliers for the four phases of every offshore wind project (development, manufacturing, installation, and operation). These multipliers reflect the structure of the Hampton Roads economy in 2018 (the most recent year for which data are available)

[3] Global Wind Energy Council, *Global Wind Report 2019*.

and are based on data that are specific to the industries involved in each phase and to the regional footprint of those industries within Hampton Roads specifically.

Table 1. Hampton Roads Input-Output Multipliers by Offshore Wind Activity Phase

| Project Phase | Hampton Roads Input-Output Multiplier |
|---|---|
| Development | 1.8 |
| Manufacturing | 1.6 |
| Installation | 2.2 |
| Operation | 1.7 |

Looking at Table 1, the multiplier of 1.8 for development indicates that for every one job from an industry directly involved in the development of the offshore wind farm, an additional 0.8 jobs are supported elsewhere in the regional economy of Hampton Roads. Similarly, for every one dollar of expenditures from an industry directly involved in the development of the offshore wind farm, an additional $0.80 in expenditures is generated elsewhere in the regional economy of Hampton Roads.

For the manufacturing phase, for every one job from an industry directly involved in the manufacturing of the offshore wind farm, an additional 0.6 jobs are supported elsewhere in the regional economy of Hampton Roads; and for every one dollar of expenditures from an industry directly involved in the manufacturing of the offshore wind farm, an additional $0.60 in expenditures is generated elsewhere in the regional economy of Hampton Roads. Likewise, for the installation phase one direct installation job supports an additional 1.2 jobs, and one dollar of direct installation expenditures generates an additional $1.20 expenditures; and for the operational phase one direct operational job supports an additional 0.7 jobs, and one dollar of direct operational expenditures generates an additional $0.70 expenditures.

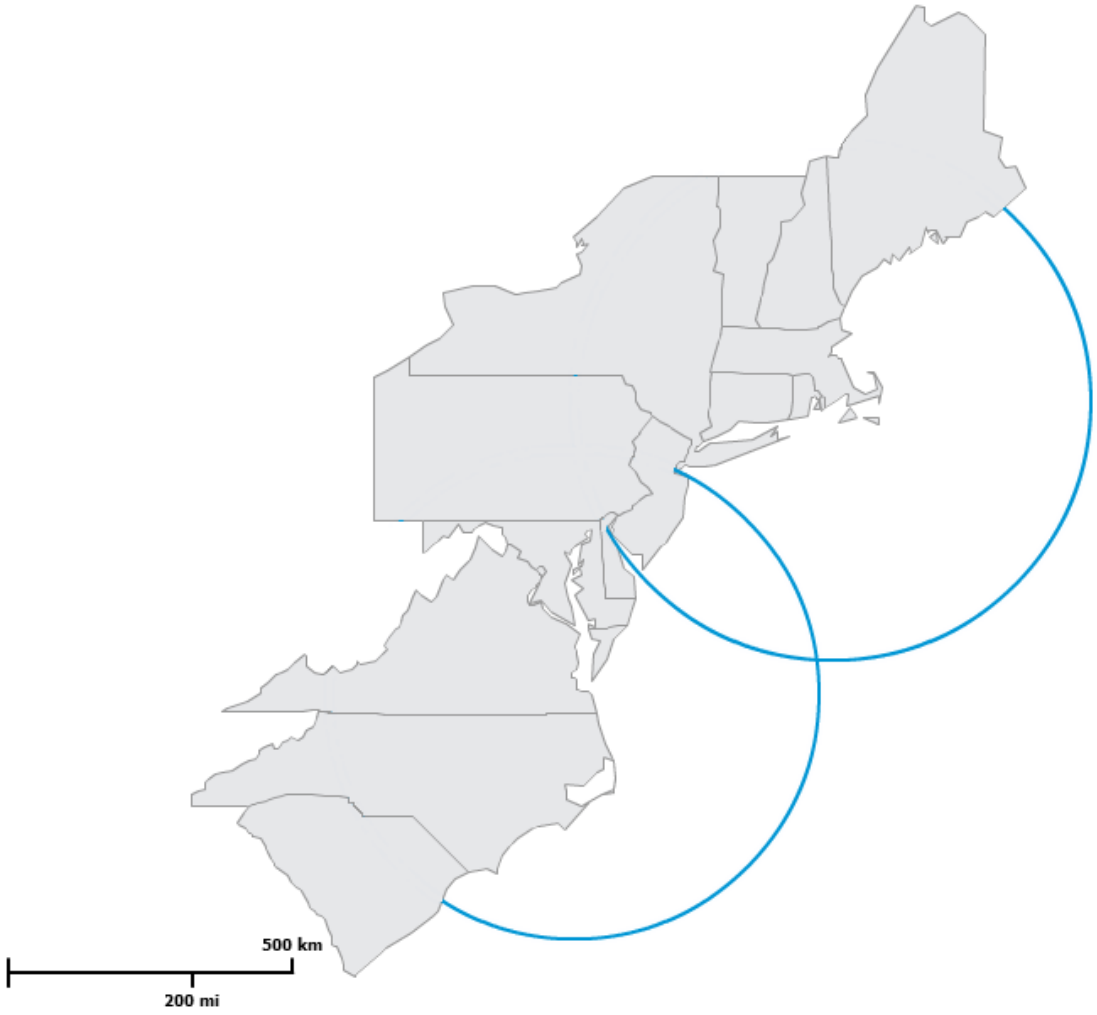
As shown in Table 1, these regional multipliers indicate that businesses involved in the installation phase of an offshore wind project that work out of ports in Hampton Roads will have the greatest impact on the region. The reason for this is that there are many businesses already located in the Hampton Roads area that are able to support and supply the influx of vessels and workers that would be needed to install the offshore infrastructure. Those businesses include the area's marine logistics and transportation, vessel and port services, and hospitality industries.

Port areas up and down the East Coast of the U.S. and also in the U.K. have worked to identify existing local businesses that can participate in the offshore wind energy supply chain. However, it is important to understand that the greatest economic development advantage that offshore wind projects offer to local economies is industrial diversification – adding new industries and businesses to the local economy. The Hampton Roads economy is heavily oriented to the defense manufacturing and service industries, and the hospitality industries. Therefore, business additions from any of the industries in the

development, manufacturing, installation, or operations phases will help to diversify the Hampton Roads economy. And the opportunities to attract and recruit such additions could be significant.

In general, the potential service area of ports for the offshore wind industry is described as being within 250 nautical miles. That distance is considered the distance that many service vessels could travel in one day's time. Figure 2 shows the areas within 250 nautical miles of Portsmouth, Virginia and New Bedford, Massachusetts. The Port of New York is located at the northern edge of the radius from Portsmouth, Virginia. Those three ports, among others, are vying to serve the nascent offshore wind industry in the United States. The 250 nautical mile distance may be especially relevant for operations and service vessels, however, in many ways, it is not a hard limit for the reach of a port in the offshore wind industry. We know from the North Sea experience that ports in Denmark and Germany have served offshore wind farms in the U.K. over 400 nautical miles away, even though there are large port areas in nearby England and Scotland. So, businesses that locate in Hampton Roads will have opportunities to serve offshore wind farms from the Carolinas and north to Maine.

Figure 2. 250 Nautical-Mile Radii from Portsmouth, Virginia and New Bedford, Massachusetts



## Challenges for the Offshore Wind Industry in Hampton Roads

In this section, we identify some major challenges to Hampton Roads becoming a major offshore wind energy port. Hampton Roads has many advantages for offshore wind, including a port with deep and wide channels, no air-draft restrictions from the port facilities to the sea, almost immediate access to the open ocean, relatively lower costs of doing business, a right-to-work policy regime, state support for necessary port upgrades, and the creation of the Mid-Atlantic Wind Training Alliance. Those strengths have been noted in a number of reports.[4]

However, Hampton Roads also faces several major challenges. If Hampton Roads is to become a major offshore wind port on the East Coast of the U.S., it will be necessary for businesses in Hampton Roads to serve offshore projects outside of Virginia waters all along the eastern seaboard. This means that Hampton Roads' ability to become a major offshore wind port will necessarily be impacted by events outside of Virginia. In the remainder of this section, we list the most significant of those events.

### FEDERAL-LEVEL POLICY UNCERTAINTIES

In 2019 and 2020 there were a number of policy changes at the federal level that caused a dramatic change in the prospects for the development of the U.S. offshore wind industry along the East Coast of the U.S. Older tariffs on a number of products related to offshore wind were extended on imports from China and proposals have been made that would add tariffs on wind towers from Canada, Indonesia, Korea, and Vietnam. The effect of these tariffs would be to increase the cost of construction and disrupt established supply chains.

On the regulatory front, as part of its approval process, the Bureau of Ocean Energy Management (BOEM) has ordered more extensive environmental impact assessments for offshore wind projects than were previously required. This change is expected to delay all projects by one year, but that expectation may prove to be optimistic because BOEM has also announced that it intends to evaluate offshore wind projects sequentially and only one at a time. So, if the evaluation of one project takes longer than expected, and if similar delays happen with subsequent evaluations, the cumulative effect of those delays could have a significant negative impact on the pace of offshore wind project development everywhere in the United States.

Additionally, Customs and Border Protection has issued a number of rulings on its interpretation of the Jones Act (requiring that merchandise transported between two points in the United States be done on U.S.-built and U.S.-crewed vessels). The rulings have not always been consistent and at times would have made offshore construction impossible until a full fleet of Jones Act-compliant vessels were built. Such regulatory uncertainty makes project planning very difficult and discourages potential vendors from bidding on projects in the U.S. that may or may not ultimately be constructed.

[4] An excellent summary of most of Hampton Roads' advantages is provided in BVG Associates, *The Virginia Advantage: The roadmap for the offshore wind supply chain in Virginia*, December 2018.

Finally, in September 2020, President Trump signed an Executive Order that would extend a moratorium on offshore leasing activity in the waters off of North and South Carolina, Georgia, and Florida. This Executive Order not only affected oil and gas operations but also offshore wind projects. Moreover, that moratorium has now been extended to 2032. This policy is especially damaging to Hampton Roads' prospects for becoming a major East Coast offshore wind port. This is because businesses in Hampton Roads businesses are geographically well-positioned to serve offshore wind projects off the coast of the southern Atlantic states that have been affected by the moratorium. At the same time, wind industry businesses located farther north from Virginia and the southern states covered by the moratorium are not as well-situated to serve the moratorium area, and therefore, they are less affected by that policy.

In addition, wind speeds at 200 meters above sea level (offshore turbine height) are roughly similar from Long Island, New York south to Ocracoke, North Carolina. And from there, winds still have significant strength south to Edisto Island, South Carolina. If businesses in Hampton Roads are limited to serving offshore wind projects north of North Carolina, they will always face stiffer competition from businesses located in New England than they would in serving offshore wind projects further south. And businesses looking to locate for the first time on the East Coast would likely want to position themselves farther from the southern edge of the area where offshore wind projects are permitted.

## STATE-LEVEL POLICY UNCERTAINTIES

In addition to being affected by federal policies, Hampton Roads' ability to become a major port serving offshore wind projects along the East Coast of the U.S. will be significantly impacted by policies and activities in other East Coast states. For example, Connecticut, Maryland, Massachusetts, New Jersey, New York, and Rhode Island have implemented local purchase requirements that would make it more difficult for businesses in Hampton Roads to serve some parts of the offshore wind projects in those states. And more generally, expectations for local economic development related to offshore wind can cause their own difficulties. In September 2020, despite the general supportive approach from the New Jersey state legislature, the President of the New Jersey State Senate asked the state public utility commission to suspend the approval of Ørsted's project off Atlantic City for failure to follow through on local economic development promises. Such controversies could create uncertainties about the state-level policy environment for offshore wind development that make businesses reluctant to make major investments on the East Coast of the U.S. until circumstances are clearer and more predictable.

## OCEAN ENERGY INEXPERIENCE

The offshore wind energy industry in Europe developed out of the offshore oil and gas industry that was already well established in the North Sea. In contrast, federal restrictions on oil and gas leasing on the East Coast of the U.S. have made offshore energy a non-starter here. As a result, there are essentially no offshore energy businesses on the East Coast of the United States. That means that the port facilities, offshore service businesses, and workers experienced working on offshore infrastructure that would have developed to serve those offshore energy businesses do not exist to serve the offshore wind industry. That lack of ocean energy experience makes the Jones Act a much greater constraint on

offshore wind development on the East Coast because, if there had been offshore oil and gas activity on the East Coast like there has been in the Gulf of Mexico, then there would likely already be Jones Act-compliant vessels operating out of Hampton Roads.

## OFFSHORE INDUSTRY WEAKNESS

Despite the dramatic global increase in plans for offshore wind energy projects, the companies in the offshore wind industries are not in financially strong positions. Because the industry is relatively young and more and more offshore wind projects are being announced around the world, there is a general perception that the offshore wind industry is robust, thriving, and profitable. However, while the potential market demand for offshore wind turbines is large, orders from the U.S. are being delayed because of the policy delays mentioned above.

Additionally, turbine manufacturers are in keen competition with each other to produce new and larger capacity turbines that can reduce the cost of installation and of generating electricity. Turbines have already reached a size where producing turbines with larger capacities requires new materials, new engineering, new technologies, and new mechanics. It is not just a matter of making the existing turbines in a bigger size. The research and development activities necessary to accomplish that task are costly in terms of identifying and testing new materials, engineering, mechanics, and technologies. Production of prototypes for testing requires large capital expenditures. Additionally, once a new design is settled on (because the parts and materials are different than in previous designs), new suppliers must be identified, and new supply agreements must be negotiated. So, the cost of developing a new supply chain adds to the cost of developing a new design.

This coincidence of delayed orders, vigorous competition, and increased R&D costs is straining the financial positions of the manufacturers. All have laid off workers in the last year in order to reduce expenditures, and yet many of the companies are still operating at a loss or with small profits. The same is true for many of the other businesses in the offshore energy supply chain. Companies are laying off workers and selling off capital assets to raise cash, and they are combining because there is not enough demand to support all of the existing capacity. This financial weakness means that offshore wind businesses are not financially able to easily invest millions of dollars in new facilities in new markets on the expectation of someday getting a return on their investment.

## ATTENTION GIVEN TO NEW YORK AND NEW ENGLAND

When it comes to the potential for offshore wind energy development in the U.S., the global offshore wind industry generally focuses its attention on New York and New England. Mentions of New York and Massachusetts at industry conferences, in trade literature, and in more general news vastly outnumber mentions of projects in the Mid-Atlantic or Carolinas. In part, this is because America's first wind farm was built in New England and the first application to BOEM for a large-scale project was there. Another reason appears to be that New York and Massachusetts are devoting a lot of public resources via economic development authorities and collaborations with local trade associations to "talking up" those states and nearby offshore wind activities.

# Opportunities for Additions to Hampton Roads

This section describes the industries that could potentially contribute to the economic development of Hampton Roads by investing in operations in the area. The individual businesses identified illustrate the types of companies in those industries that could be attracted to Hampton Roads because of the development of the offshore wind industry on the East Coast. We have not included firms that already have a significant presence in Hampton Roads. This section is not intended to be a target list for economic development, but rather an indication of the types of firms that may be attracted to Hampton Roads.

## REPURPOSING OFFSHORE OIL AND GAS OPERATIONS

The offshore oil and gas industry in the United States is highly concentrated in the Gulf of Mexico. Across all phases of development, that industry offers interesting opportunities with strong potential for offshore wind in Hampton Roads.

### The North Sea Experience

An important piece of background information on the offshore wind energy industry is that much of it spun off from the offshore oil and gas industry in Europe. Businesses and port areas that served the rigs operating in the North Sea transitioned to serving offshore wind farms there. Denmark's carbon-fuel utility, Dong Energy, became Ørsted, one of the world leaders in renewable energy development. The Equinor employees who built the world's first floating wind farm situated in Scotland are the same ones who built Statoil's oil and gas platforms, before Norway's biggest petroleum company changed its name. The multinational oil and gas company, Royal Dutch Shell plans to build two wind offshore farms in the Netherlands. These companies and many others had extensive experience operating offshore energy infrastructure, which was valuable in the new offshore wind farms. And the fact that the oil and gas industry ports and vessels were already located near the new offshore wind farms made those assets extremely useful for the new industry.

### Advantages for the Offshore Wind Industry in the United States

Although there are no offshore oil and gas ports or vessels on the East Coast of the United States, the offshore oil and gas industry in the U.S. still offers a number of important benefits to offshore wind operations on the East Coast.

Most importantly the need for Jones Act-compliant vessels is an enormous challenge for the offshore wind industry. The offshore oil and gas industry already operates a large number of Jones Act-compliant vessels in the Gulf of Mexico. These vessels are suited for transporting workers, parts, and equipment from port to offshore energy infrastructure. If necessary, vessels originally built for use by the oil and gas industry in the Gulf of Mexico could be converted so that they are repurposed for use in the offshore wind industry. The Romanian marine engineering and naval architecture firm, GLO Marine has done just

that. The company engineered the conversion of two oil and gas service vessels for use in the offshore wind industry. The ships were able to be converted far faster than laying a brand-new keel. Obviously, Hampton Roads has shipyards and other firms that are capable of performing the conversion work on vessels.

The offshore oil and gas companies also have a large number of highly trained American employees with extensive experience in offshore operations. The industry in the Gulf of Mexico directly employs roughly 10,000 people on offshore oil and gas platforms. Many of these U.S. workers are skilled mechanics, electricians, engineers, and builders with experience working at sea. Many of these jobs are not directly translatable to offshore wind.

The point is not that U.S. offshore oil service companies are offshore wind service companies with another name. But that U.S. offshore oil service companies can provide some of the essential U.S. vessels and U.S. workers needed by the U.S. offshore wind industry. As the International Energy Agency has noted, "The oil and gas industry will be critical for some key capital-intensive clean energy technologies [including offshore wind] to reach maturity. … Scaling up these technologies and bringing down their costs will rely on large-scale engineering and project management capabilities, qualities that are a good match to those of large oil and gas companies."[5]

## Advantages for Gulf of Mexico Energy Services Companies

A number of global oil and gas service companies are headquartered in the United States, mainly in Louisiana and Texas. They have developed technologically advanced equipment and methods for dealing with challenging environments and mechanical problems. The challenge for the offshore oil services industry is that the combination of low oil prices and weakening demand for fossil fuels is increasingly leaving the industry's expertise underemployed. Within the last few months, Schlumberger (the largest oil services firm) announced layoffs of 21,000 employees – one-quarter of the firm's workforce. Baker Hughes, Halliburton, and Weatherford have also laid off thousands of workers in 2020.

Offshore wind's need for Jones Act-compliant vessels and trained workers offers the offshore oil and gas service businesses opportunities to diversify into a related industry with strong growth potential. Adding completely new revenue streams by reallocating some excess capacity would help to stabilize the business of the offshore energy services companies. Oil and gas companies like Dong Energy, Statoil, and Royal Dutch Shell have successfully diversified into offshore wind.

While it is likely that offshore wind will eventually gain a foothold in the Gulf of Mexico, that region is much farther behind the East Coast in terms of identifiable offshore wind activity. The offshore oil services companies in the Gulf of Mexico could gain industry-specific experience working on the East Coast of the U.S. that would translate to the Gulf of Mexico and other areas.

[5] International Energy Agency, *The Oil and Gas Industry in Energy Transitions: World Energy Outlook special report*, January 2020.

Finally, because there has been no offshore oil and gas activity off the East Coast of the U.S., oil and gas services companies do not already have a presence here. However, Hampton Roads would provide an excellent base of operations for those companies on the East Coast. Companies from Texas and Louisiana will appreciate operating from a right-to-work state, like Virginia. Virginia's lower cost of doing business relative to other East Coast states will be beneficial for establishing new locations. And the ease of access from the Hampton Roads port areas to the open ocean will be what these companies are used to when operating in the Gulf of Mexico.

## DEVELOPMENT

During the development phase, among other activities, environmental, geological, and hydrological surveys are conducted. Once the environmental and geological studies are complete, the engineering and design of the wind farm are performed. This work develops the overall configuration of the wind farm system, including layout design, turbine selection, foundation type, electrical design, installation methods, operational strategy, and other key elements of the project. The following companies are involved in offshore work of this type.

CGG is a global geoscience technology leader. It provides a broad range of data, products, services and equipment for natural resource geophysics, geology, data science, and geospatial research of the seabed. It is headquartered in Cedex, France.

ION is a global technology company, headquartered in Houston, that delivers digital insights on the ocean floor for the offshore energy, ports, and defense industries. The company's traditional focus has been on the petroleum exploration and production industry. However, it is diversifying its business into relevant adjacent markets such as offshore logistics and marine robotics. ION is a very asset-light company, which would allow it to easily serve projects in the Hampton Roads area, but which also means that it would have a limited impact in terms of economic development in Hampton Roads.

TGS-NOPEC Geophysical has corporate headquarters in Oslo and operational headquarters in Houston. The company provides global subsurface seismic, magnetic, gravity, multibeam, and coring data and advanced processing, imaging, interpretation, and integration services to the energy industry. It has provided services not only in established operational areas but also in new and emerging areas.

MIND Technology offers exploration, survey, and (through its subsidiary, Klein Marine Systems) defense services for the marine environment. Its range of sensors, vessels, and expertise are used for mapping the ocean floor for hazards and seismic conditions. It has a wide range of towed sonar instruments that are used to search and identify items and conditions on the seabed. MIND Technology is headquartered in The Woodlands, Texas.

## TURBINE (NACELLE AND ROTOR) MANUFACTURING

Attracting wind turbine manufacturing facilities to a local area is the goal of every major port on the East Coast of the United States and in the United Kingdom. These are advanced manufacturing facilities with technologically advanced equipment and processes and high paying skilled jobs. Because of the size of the equipment that they produce, these facilities result in significant investments in major port infrastructure, vessels, and logistics.

Turbine nacelles and rotor assemblies (blades and hubs) will usually be supplied by the same company, though the nacelles can be manufactured in different locations from the rotors. These turbine companies are the most important companies in offshore wind manufacturing. Securing local investment by turbine manufacturers is important to growing the offshore wind industry in the local economy. A turbine manufacturer has many suppliers of separate components (e.g., bearings, structural and fabricated steel, fiberglass and resin, towers, sensors, specialized coatings, pitch and yaw control systems, communication technologies, and electrical components).[6] Small components can easily be shipped from distant manufacturing locations. Therefore, only very large components and large major components that are specialized for a single turbine manufacturer are likely to locate in port areas around the turbine manufacturers. The supply chain for the turbine manufacturers will, to some degree, be attracted to locate near the assembly facility; however, the turbine manufacturers will not locate facilities based on convenient access to suppliers.

There are only a few manufacturers of offshore wind turbines. Siemens Gamesa Renewable Energy (Spain) has produced 3.3 GW of fully commissioned offshore wind capacity – far more than its closest competitors.[7] MHI Vestas (a Danish joint venture of Mitsubishi Heavy Industries and Vestas Wind Systems)[8] ranked next with 1 GW of commissioned offshore capacity, followed by three Chinese competitors (Shanghai Electric Windpower Group, Xinjiang Goldwind Science & Technology Co., and Envision Energy). The Chinese companies produce almost exclusively for the Chinese market which for the foreseeable future probably will consume all of their productive capacity. GE Renewable Energy (a French division of General Electric) accounted for 390 MW of commissioned offshore capacity.

Siemens Gamesa, Vestas, and GE are the only turbine manufacturers that, in the near term, might possibly begin manufacturing in the United States for the offshore market. Siemens Gamesa and GE have recently introduced the availability of very large capacity turbines to reduce the overall cost of producing electricity from offshore wind. Siemens Gamesa's 14-222 D turbine can achieve 15-MW capacity, while GE's Haliade-X turbine can achieve 13-MW capacity. Vestas has had a 10-MW turbine available for some time.

---

[6] For a description of some of the components of turbines, see BVG Associates, *Guide to an Offshore Wind Farm: Updated and extended*, April 2019.

[7] The information in this paragraph comes from the report by Bloomberg New Energy Finance, *2019 Global Wind Turbine Market Shares*, February 2020.

[8] On October 29, 2020, Vestas Wind Systems purchased Mitsubishi Heavy Industries' 50 percent share of the joint venture, MHI Vestas. Since 2014, MHI Vestas operated exclusively in the offshore industry, whereas Vestas operated exclusively in the onshore industry.

It is important to understand that the offshore turbine industry is highly competitive, and the companies routinely report profits near, or even below, zero from their offshore wind business. Even with the ability to borrow at very low interest rates, the construction of new manufacturing facilities would be a strain on the finances of any of the companies.

GE Renewable Energy has trailed far behind Siemens Gamesa and Vestas in the offshore wind market. Perhaps GE's most notable success in offshore wind energy was supplying the 6-MW turbines for the only offshore wind farm in the U.S. at Block Island, Rhode Island. However, GE was recently selected to supply its new 13-MW turbines for a 2.5-GW project in the North Sea. In December 2020, the Vineyard Wind project selected GE as its preferred supplier, replacing Vestas which had previously been named as the preferred supplier. GE has also been named the preferred supplier for two of Ørsted's projects: Skipjack (Maryland) and Ocean Wind (New Jersey). Altogether, GE has almost 4 GW of orders for its Haliade-X turbine in the northern Atlantic Ocean – all scheduled for delivery by the mid-2020s. That is ten times the capacity of offshore turbines that GE has ever produced. The Haliade-X turbine is produced in Saint-Nazaire, France. GE is also building its turbine factory in China to build Haliade turbines for the Pacific region.

It is likely that, because the Saint-Nazaire nacelle manufacturing facility has just finished being retooled to produce these new turbines and GE is building a factory in China, building an additional new nacelle manufacturing facility in the U.S. would be difficult to justify financially. It will probably take years of orders to recover the cost of the investment in France and China. And GE Renewable Energy is a financially weak business. In October 2020, the division recorded a very small quarterly profit for the first time in almost two years, but the profits were generated from the onshore side of the business.

Vestas is the global leader in wind energy manufacturing overall, but almost all of its production has gone to the onshore wind industry. Its current coastal production facilities are located throughout continental Europe, and in the U.K., China, India, Argentina, and Brazil. It has onshore wind production facilities (nacelles, blades, and towers) in Colorado.

For the offshore market, the company has been focusing on 10-MW floating turbines that are most suitable for use in deepwater locations that are common in the Pacific and that may be useful for new wind farms in the Mediterranean Sea and the Gulf of Maine. It is working to develop a larger capacity turbine to remain competitive in the offshore market. As mentioned previously, the offshore division of Vestas has not been in a financially strong position. In August 2020, the company laid off 400 offshore wind workers in Europe, cut executive pay by ten percent, and narrowed its production to only projects that were already under contract. However, now that the offshore division has been reunited with the onshore wind part of Vestas (which has been stronger financially), the company may have the resources to give the offshore division the financial support that it needs to invest in the design and production of much larger turbines.

Vestas will need much larger production facilities than it uses now in order to make much larger turbines. With no existing facility that is already prepared to produce a new turbine, it would be easy for

Vestas to justify building a completely new nacelle and rotor manufacturing plant in the United States. However, Vestas can only afford to invest in a new U.S. facility if it can develop a new product and secure a sizeable U.S. order book for it. With Vestas losing out to GE to be the preferred supplier to the Vineyard Wind project in Massachusetts, Vestas would not seem to have a strong reason to pick one part of the East Coast over another, which could provide an opportunity for Hampton Roads.

If Vestas chose to locate in Hampton Roads, it could still supply projects into the Gulf of Maine. The transportation challenges would be double what they would be from a location like New Bedford, Massachusetts. Turbine manufacturers in the U.S. will be able to meet deadlines and delivery conditions for any location along the East Coast regardless of their location. The transportation of turbines up or down the East Coast will be simpler and faster than transporting them from Europe. However, without U.S. orders for a new turbine, a Vestas manufacturing plant on the East Coast is not in the foreseeable future.

As of 2020, Siemens Gamesa Renewable Energy is the global offshore industry market leader, and it offers the largest capacity turbine at 15 GW. Siemens was the company involved in the first offshore wind farm erected off Denmark in 1991. Siemens Gamesa has research and development centers in Denmark, Germany, Spain, India, and Colorado. Its factories are located in Denmark, Germany, Spain, the United Kingdom, Morocco, China, India, Brazil, Iowa, and Kansas.

Siemens Gamesa is likely to continue to lead the offshore wind industry for the foreseeable future. To date, offshore manufacturing and service contracts have been the profitable segments for the company, while the onshore market has not. During its latest financial report, the company indicated that it would focus more on being profitable than on securing orders in the onshore market. The company also plans to focus on new markets in the U.S. and Brazil. However, it is possible that, in the effort to keep costs down for the offshore market in order to maintain profitability, Siemens Gamesa may attempt to fulfill as many orders as possible out of its existing factories. A new nacelle manufacturing facility in the U.S. would likely cost over one billion dollars, which would have a significant impact on the company's bottom line. The company's less-complex blade manufacturing facility in Hull, U.K. cost over $400 million in 2018. Nevertheless, Siemens Gamesa is the only one of offshore turbine manufacturers to state that it is currently exploring plans to build a blade manufacturing plant in the U.S. or even a U.S. factory for its new 15-GW turbine.

TPI Composites, headquartered in Scottsdale, Arizona, is the only major independent producer of wind turbine blades. The company has supply agreements with GE, Nordex, and Vestas. It had two facilities in New England – an R&D center in Fall River, Massachusetts and a manufacturing plant in Warren, Rhode Island. However, in a cost-cutting measure, the Fall River facility, which was opened in 2011, was sold to an unidentified buyer in late 2019. The local advantage to hosting an independent blade producer is that it has a greater likelihood of serving more projects than an OEM blade manufacturer.

## OFFSHORE TOWER AND FOUNDATION MANUFACTURING

Foundations and towers have different specifications but involve similar materials and processes. In general, firms that can produce one can produce the other. In addition to the manufacturers listed below, the turbine manufacturing companies sometimes produce towers to support the turbines that they will install. It is notable that, for offshore applications, many of these manufacturers primarily serve the oil and gas industry.

Foundations and towers are extremely large, but they can also be affordably transported across large distances. To illustrate how portable towers and foundations are, foundations and jackets for the Seagreen wind farm in the North Sea off the coast of Scotland will be supplied by companies in the United Arab Emirates (Lamprell) and China (COOEC-Fluor Heavy Industries). Foundations for another project nearer to the coast of Scotland will be produced in Singapore (Saipem). This is in spite of the fact that BiFab has factories on the Scottish coast where so many offshore wind farms are located. In December 2020, BiFab entered into the Scottish equivalent of bankruptcy due to the fact that it has been unable to secure orders for its products.

Because of the size of foundations and towers, the biggest constraint on suppliers is the ability to produce at the water's edge. However, if production can be easily loaded onto a vessel, then it can be delivered globally. Businesses around the world have the skills, experience, and ability to supply these structural elements for offshore wind projects.

In the United States, companies including a number of firms involved in construction for the offshore oil and gas industry in the Gulf of Mexico have the technical ability to construct towers and foundations. There are a number of makers in North America that are located in landlocked areas. The premier examples are Broadwind Energy, Arcosa Wind Towers, and Marmen (Canada). If they wanted to compete for a share of the offshore wind business, they would need to relocate to port areas like Hampton Roads. However, given the continued growth in demand for onshore wind towers and the preference that offshore developers have for businesses with offshore expertise, companies that only have experience in the onshore wind market are likely only to locate to coastal areas if they manage to get a firm contract for a large offshore project.

Stiesdal Offshore Technologies is a fabricated steel manufacturer offering floating and fixed turbine foundations. The company's focus is on inventing low-cost floating foundations that can be used at any depth and without the need for specialized installation vessels. Stiesdal is partnering with Innogy and Royal-Dutch Shell for research and development. The company was founded by a former employee and executive of both Vestas and Siemens and an expert in wind energy technologies. The company's only location is in Denmark.

The Danish steel manufacturer, Welcon and the Canadian wind tower manufacturer, Marmen have signed a memorandum of understanding to develop a joint venture to build a facility somewhere in the

northeastern part of the U.S. to produce both towers and fixed & floating foundations for the offshore wind market in the United States.

CS Wind is a Korean company that is one of the largest producers of towers for onshore and offshore wind turbines. Its share of the global market is in large part due to its coverage of the Asian market, though the firm also has a factory in the U.K.

ASM Industries in Portugal specializes in fabricated steel for marine environments, especially offshore wind towers and foundations. The company has invested in the development of new floating, semi-submersible foundations that are best suited for deepwater applications.

ArcelorMittal is a European producer of fabricated steel products – the largest steel producer in the world. Siemens Gamesa has purchased offshore towers and foundations from the Luxembourg-headquartered firm. It has two plants in Pennsylvania.

Valmont SM manufactures and co-engineers heavy steel products for infrastructure applications, including wind turbine towers. Its production facility is in Denmark. Its parent company, Valmont Industries, is headquartered in Omaha, Nebraska.

Gulf Island Fabrication manufactures large offshore structures and vessels, mostly for the oil and gas industry, in Houma, Louisiana. Its headquarters are in Houston. It has produced jacket foundations for offshore wind turbines.

## CABLE MANUFACTURING AND INSTALLATION

The subsea power and telecommunications cable manufacturers generally install their products. The cable installation vessels do not need to be (and are not) Jones Act-compliant vessels. Non-Jones Act-compliant vessels can still operate out of U.S. ports. So, Hampton Roads could benefit from hosting and supplying foreign-flagged cable installation vessels. Such ships have crews of 100 or more.

Prysmian Group offers power and telecommunications cable designs, products, operating systems, and installation for almost every industry including offshore wind. It supplies medium-voltage inter-array cables, high-voltage alternating current (HVAC), and high-voltage direct current (HVDC) export cables. It also offers monitoring and maintenance services for cabling. The global firm is headquartered in Milan, Italy. Its high-voltage cables are produced in the town of Abbeville in western South Carolina. It currently operates three cable laying vessels, and a fourth will be added to the fleet in 2021.

NKT, headquartered in Denmark, has been in the cable business since the 1800s. It provides a full range of offshore cabling solutions for marine applications. Most of its work has been in Europe. It operates a single cable-laying vessel.

Nexans is a power and telecommunications cable company. It produces high-voltage cables in a plant in Charleston, South Carolina from which it can easily be shipped to any location on the East Coast. It currently operates four vessels with a fifth to be added. Nexans has a supply agreement with Ørsted and Eversource for their offshore wind projects on the East Coast.

## FOUNDATION, TOWER, AND TURBINE INSTALLATION

According to the Bureau of Ocean Energy Management (BOEM), in order to comply with the Jones Act, the installation of bottom-founded, non-gravity foundations, towers, and turbines in U.S. waters must be done by vessels that are made and operated in U.S. ports and staffed with U.S. crews.[9] As of yet, there are no Jones Act-compliant wind turbine installation vessels afloat. Compliance will require not only the construction of new installation vessels in the United States (as Dominion Energy has commissioned) but also the training and support of American workers for installation projects.

Oceaneering, headquartered in Houston, provides engineered services primarily to the offshore energy industry. It serves the defense, entertainment, material handling, aerospace, science, and renewable energy industries. The company's survey experience and fleet of Jones Act-compliant vessels offer high-speed data transfer solutions to move survey data from vessels to shore. Its independent inspection, testing, and verification capabilities support structural quality assurance for foundations, towers, nacelle bedplates, and other large components. Oceaneering's engineering and design expertise supports the manufacture and installation of high-voltage power cables. It operates a fleet of vessels, ROVs, survey array spreads, and equipment for installation and seabed clearing. It offers robotic crawler inspections and subsea marine growth removal to meet the maintenance demands of large ocean installations.

[9] Kearns & West on behalf of BOEM, *Summary Report: Bureau of Ocean Energy Management's Offshore Wind and Maritime Industry Knowledge Exchange*, March 5-6, 2018.

## OPERATION AND MAINTENANCE

The maintenance of a wind farm facility typically involves the maintenance of the entire offshore wind farm infrastructure, including wind turbines, subsea cables, and offshore substations. The major wind turbine manufacturers (GE, Siemens Gamesa, and Vestas) all have divisions that offer maintenance and repair service contracts for the equipment that they produce.

Helix Energy Solutions is an international offshore energy services company, headquartered in Houston, that provides services to the offshore energy industry, specializing in robotics operations. The company also provides subsea cable burial and seabed clearing services for the offshore wind industry. The ROVs are designed to complement offshore construction. The firm also operates robotics support vessels.

Hornbeck Offshore Services is a leading provider of marine transportation services to exploration and production, oilfield service, offshore construction, and military customers. It has primarily focused on providing innovative, technologically advanced marine solutions to meet the evolving needs of the deep-water energy industry. The firm recently went through Chapter 11 bankruptcy-reorganization in order to reduce its debt. It is headquartered in Covington, Louisiana.

Sodexho Group, headquartered outside Paris, is a foodservice provider for institutions and organizations around the world. It has been a major provider of food service on crew vessels and offshore platforms for the petroleum industry.

ESS Support Services Worldwide is the specialty division of Compass Group providing catering and support services to offshore and remote sites. It offers rapid response to serve offshore employees. The company is the market leader in providing remote food service, housekeeping, and janitorial support assistance to clients in extreme environments.

Taylor's International, headquartered in Lafayette, Louisiana has 20 years of experience in providing remote offshore catering to the oil and gas industry around the globe. In addition to food service, the company offers a full range of logistical support, staffing, food management, and hospitality services.

Deutsche Windtechnik is a German company that offers independent onshore and offshore wind turbine operations and maintenance services globally. It offers maintenance, inspection, and repair services for turbines from all major and several smaller manufacturers. It also provides maintenance, repair, and operations services for electrical substations. The company has a health and safety training facility in Bremen, Germany and a system engineering training facility in Viöl, Germany. Its U.S. operations are headquartered in Houston.

ROBUR WIND is a German company that offers independent inspection, maintenance, and repair services for on- and offshore wind facilities. In July of 2020, it took over all of the business of the German offshore operations and maintenance company, REETEC, which was in the same line of business.

## Conclusion – Most Interesting, Unusual Opportunities

This report has identified a variety of types of businesses that could be attracted to initiate operations in Hampton Roads to participate in the offshore wind industry. The most obvious businesses to try to attract to the area are the turbine manufacturers. They are important to fostering a local offshore energy manufacturing supply chain that would dramatically diversify the Hampton Roads economy. We conclude this report by noting a few businesses that may not otherwise be considered but which we believe offer special potential for the future of the offshore wind industry and mutual benefit for Hampton Roads and the companies.

Most of the discussion about complying with the Jones Act surrounds the need for wind turbine installation vessels and contracting for the construction of new vessels. However, many Jones Act-compliant vessels (other than wind turbine installation vessels) will be needed throughout the East Coast for installation and operational activities. Hornbeck Offshore Services already owns and operates a fleet of over 75 Jones Act-compliant vessels. The need for those vessels in the Gulf of Mexico where they have traditionally operated is declining, and that has had a negative impact on the company. Offshore wind development on the East Coast offers a whole new market and use case for those vessels. Engineers and marine architects in Hampton Roads or in the Gulf of Mexico could design any necessary conversions of the vessels to meet the needs of the wind industry that differ from the oil and gas industry. It is notable that Hornbeck already provides services for military clients.

Oceaneering also has a fleet of Jones Act-compliant vessels and provides services that offshore wind developments need during the development, installation, and operations phases of the projects. It also offers services that would be useful for the subsea cable industry. The company already has operations in Virginia Beach that are primarily dedicated to naval contracting. The breadth of Oceaneering's service offerings is impressive, and its large international reputation would attract attention if it were to provide civilian, commercial services out of Hampton Roads.

The offshore wind industry is still very young. The technology and equipment involved are still evolving and transforming. Offshore turbines are not just bigger versions of onshore turbines. In fact, the offshore turbines that exceed 10 MW in capacity are significantly different from the smaller offshore turbines. The pressure to increase the efficiency of generating electricity offshore will continue to drive innovations in materials and mechanics. Currently, the biggest innovation still being developed is the floating foundation. As interest in placing wind turbines off the coast of the Carolinas and in the Gulf of Mexico grows, there will be pressure to develop turbines that can withstand frequent severe weather conditions. This could require different blade shapes, control mechanisms, and materials, among other innovations. Stiesdal Offshore Technologies is an extremely innovative company working to invent new ways to make the infrastructure less expensive to install and operate and where installations are less dependent on seabed conditions. If the Danish company were to open operations in Hampton Roads, it would place the area at the front of the offshore wind industry of the future, create an innovative

reputation for Hampton Roads in the industry, and generate connections to important offshore wind engineering, architecture, and design parts of the industry.

Offshore wind farms place large amounts of private infrastructure that is critical to the health, safety, and security of the American public in very unprotected areas of the globe. The open ocean is one of the most exposed and unguarded areas, far from law enforcement or national defense. This represents a significant risk not only to the owner and operator of the wind farm but to everyone that is dependent on the electrical grid that becomes dependent on the electricity generated offshore. Offshore and subsea infrastructure (power and telecommunications) have both cybersecurity and physical security risks from terrorism and other intentional damage. The major offshore wind companies offer cybersecurity services. However, these companies are not security specialists, and the physical security risks much harder to address and less frequently addressed. Klein Marine Systems, a subsidiary of MIND Technology, offers products and services for physical defense and protection of the marine environment. The company may be attracted to the potential contracting advantages of being located near the naval installations in Hampton Roads. Klein is headquartered in Salem, New Hampshire north of Boston.