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BVGassociates

Virginia offshore wind port readiness evaluation

Report 2: Port utilization scenarios

A report to the Virginia Department of Mines, Minerals and Energy

May 2015

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BVG Associates

BVG Associates is a technical consultancy with expertise in wind and marine energy technologies. The team probably has the best independent knowledge of the supply chain and market for wind turbines in the UK. BVG Associates has over 150 person years experience in the wind industry, many of these being “hands on” with wind turbine manufacturers, leading RD&D, purchasing and production departments. BVG Associates has consistently delivered to customers in many areas of the wind energy sector.

Apex Companies

Apex Companies (Apex) delivers planning, engineering, environmental, and consulting services to clients across the United States and abroad. Apex has been at the forefront of port and site selection for the first purpose-build offshore wind support facility in the United Sates located in New Bedford, Massachusetts.

Offshore Design Engineering

Offshore Design Engineering (ODE) is an international engineering contractor to the offshore oil, gas and renewable energy markets providing comprehensive range of consultancy, engineering, project and construction management and operations and maintenance services. ODE have been involved in the development of some 400MW of offshore wind encompassing a majority of current UK projects, plus providing considerable ongoing engineering and management support to North American and German markets.

Timmons Group

Timmons Group provides civil engineering, environmental, geotechnical, geospatial/geographical information systems (GIS) technology, landscape architecture and surveying services to a diverse client base. Timmons Group is headquartered in Richmond, Virginia.

Global Wind Network

Global Wind Network (GLWN) is an international supply chain advisory group with a mission to increase the domestic content of North America’s wind energy installations, onshore and offshore. GLWN’s manufacturing engineering and wind supply chain expertise has been significantly leveraged these past two years with key projects specific to offshore wind component production for the US Department of Energy, the National Renewable Energy Labs, Lawrence-Berkley Labs, the Massachusetts Clean Energy Center, and the New Bedford (MA) Economic Development Council.

Clarendon Hill Consulting

Clarendon Hill Consulting (CHC) provides inter-disciplinary consulting services in environmental and urban planning, port infrastructure and vessel analysis for the offshore wind industry and GIS, as well as general project management.

The views expressed in this report are those of BVG Associates and its partners. The content of this report does not necessarily reflect the views of Virginia DMME.

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Executive summary

BVG Associates led a team commissioned by The Virginia Department of Mines, Minerals and Energy to evaluate 10 Virginia ports for their readiness to accommodate seven different offshore wind manufacturing and construction activities:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing
- Submarine cable manufacturing, and
- Construction staging.

The team also evaluated five Virginia commercial shipyards for their readiness to manufacture offshore substations.

This report is the second of three in this study, and presents port utilization scenarios for offshore wind manufacturing and construction staging. The other two reports present an evaluation of 10 Virginia ports and a review of potential high-impact investment opportunities.

Potential for an offshore wind cluster

Virginia has strong potential for hosting offshore wind manufacturing and construction staging activity. Several ports have the right characteristics to enable manufacturing clusters. These clusters of activities could deliver important logistics benefits and economies of scale on infrastructure investment. They could also attract second and third tier suppliers to the region, especially to nacelle assembly.

Five distinct scenarios

Virginia's ports offer a lot of flexibility for locating offshore wind manufacturing and construction staging facilities. The five scenarios presented in this report are indicative of how Virginia's infrastructure can support offshore wind activity. The implementation cost of each scenario is summarised in Table 0.1. Each scenario incorporates all the facilities considered, but in a different geographical configuration. Other scenarios exist where only some facilities are established, or where lower-capacity facilities are established.

Potential to create more than 1,500 direct jobs

Locating all six manufacturing activities in Virginia would generate more than 1,500 direct manufacturing jobs (sustained full time equivalent employees), many of which would be highly-paid trade workers. The top two job creators – foundation manufacturing and blade manufacturing – could together generate more than 800 direct jobs. Figure 0.1 summarizes the direct job creation by activity and job classification. Indirect and induced labor would significantly increase the local benefit.

Table 0.1 Summary of port utilization scenarios and implementation costs.

Story	Scenario	Ports	Implementation cost
Super-port	1	Portsmouth Marine Terminal	$11 million to $25 million
Cluster ports	2	Portsmouth Marine Terminal Newport News Marine Terminal	$15 million to $36 million
Cluster ports	3	Portsmouth Marine Terminal Peck Marine Terminal	$14 million to $38 million
Cluster ports	4	Newport News Marine Terminal Peck Marine Terminal	$11 million to $33 million
Distributed port network	5	Portsmouth Marine Terminal Newport News Marine Terminal Peck Marine Terminal Virginia Renaissance Center	$20 million to $50 million

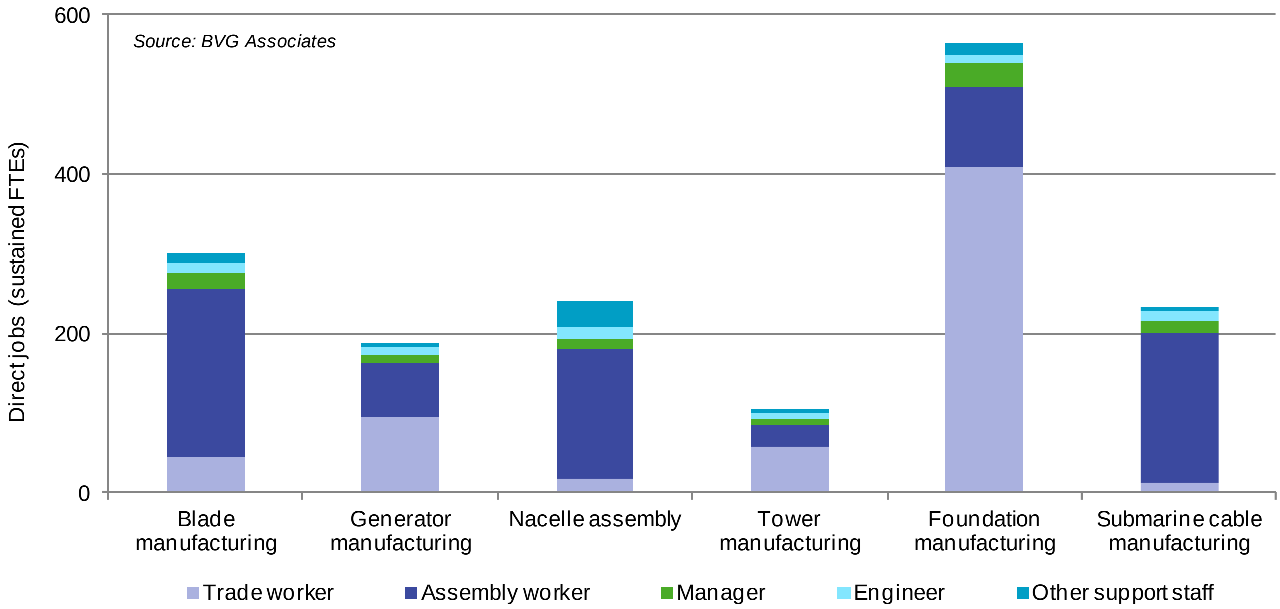

Figure 0.1 Summary of offshore wind manufacturing direct jobs by classification.

1. Introduction

The Commonwealth of Virginia Department of Mines, Minerals and Energy (DMME) commissioned BVG Associates (BVGA) and its partners to evaluate the readiness of Virginia's ports to support offshore wind farm manufacturing and construction.

This is the second of three reports setting out the results of the analysis. Table 1.1 lists these reports.

Table 1.1 Reports produced as part of the Virginia offshore wind port readiness evaluation study.

Number	Title
Report 1	An evaluation of 10 ports
Report 2	Port utilization scenarios
Report 3	High-impact investment opportunities

Report 1

The first report presents an evaluation of 10 Virginia ports (see Figure 1.1) that have available or under-used waterfront infrastructure. We considered their use for seven distinct offshore wind activities:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing and staging
- Submarine cable manufacturing, and
- Construction staging.

We concluded that the following five Virginia ports have the potential to accommodate one or more offshore wind activities:

- Portsmouth Marine Terminal
- Newport News Marine Terminal
- Peck Marine Terminal
- Virginia Renaissance Center (ex-Ford Plant), and
- BASF Portsmouth.

We also evaluated Virginia's commercial shipyards for their readiness to manufacture offshore substations. Our analysis identified four suitable shipyards, with no need for significant infrastructure upgrades.

Report 2

This second report presents offshore wind port utilization scenarios for the five aforementioned Virginia ports. It also characterizes the direct jobs that would be created at the ports for each facility. It does not consider indirect and induced labor or labor during construction of facilities.

Section 2 describes the methodology for determining the port utilization scenarios and for characterizing direct job creation.

Section 3 presents several scenarios in which we accommodate all seven offshore wind activities in the five ports.

Section 4 reports the number and type of jobs associated with the operation of each facility, as well as the training and education requirements for those jobs.

We tested and verified our evaluation through detailed consultation with experienced industry suppliers. We are grateful to the following companies that contributed:

- Adwen (a joint venture between Gamesa and Areva)
- Alstom Power
- Blade Dynamics
- Bladt Industries (Bladt)
- Keystone Engineering
- LM Wind Power (LMWP)
- MHI Vestas Offshore Wind (MVOW)
- Oceaneering
- Prysmian
- Senvion

Report 3

Report 3 considers the various port utilization scenarios in a wider context, including potential competition from other regional ports and the impacts of a local supply chain on the cost of energy of offshore wind projects.

This final report also identifies and prioritizes the high-impact port infrastructure investment opportunities that will be open to the Commonwealth of Virginia in the future.

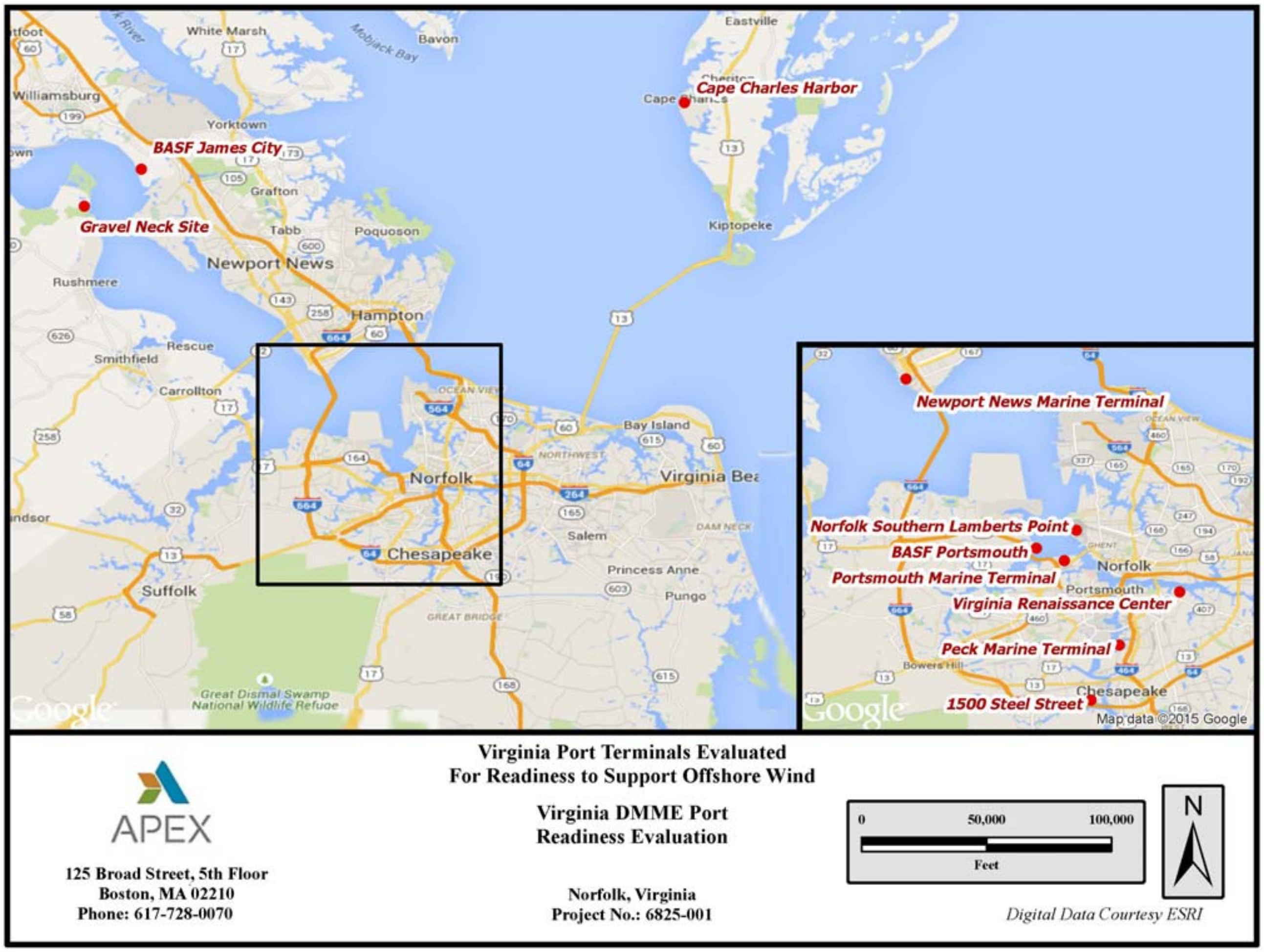

Figure 1.1 Map showing the ports considered in the evaluation.

2. Methodology

2.1. Offshore wind market

Overall market assumptions

We developed an offshore wind market forecast to characterize the potential future demand for Virginia-based construction staging ports and wind farm component manufacturing facilities.

In establishing the requirements for port infrastructure, we were asked by Virginia DMME to assume a manufacturing volume for 100 offshore wind turbines per year. This volume represents a 20% to 50% share of the potential offshore wind market in the 2020's serviceable from Virginia. We projected a serviceable market size of 2,000 to 5,000 turbines over 10 years starting in 2020. We made the following assumptions when developing this market forecast:

- Full build-out of current US East Coast BOEM Wind Energy Areas and Call Areas between 2020 to 2035 (total of 10 to 20 GW)
- Each area will be developed in tranches of no less than 500MW
- The market for Virginia ports to support construction staging is limited to wind farms within 250 nautical miles of Cape Henry, Virginia (approximately one day's transit from Virginia ports for a wind turbine installation vessel)
- The market for wind farm component manufacturing facilities based in Virginia ports is all of the US East Coast, and
- The average turbine rating is 6MW to 8MW.

Anticipated trends in the development of construction staging ports

We assume the first utility-scale US East Coast offshore wind farms are likely to be built with imported components (including turbines, foundations and cables) and only use local construction staging ports. Based on the overall market assumptions set out above, we forecast a market demand for construction staging ports of 500MW per year in 2023 to 2027, within the catchment area of Virginia. From 2028, we forecast this market demand to increase to 1,000MW per year.

Anticipated trends in the development of US-based manufacturing facilities

We assume the demand for domestically manufactured components will lag the overall market by approximately two years. Based on the overall market assumptions, we forecast a market demand of 500MW per year for domestically manufactured in the early years, increasing to 1500 MW per year in the late 2020's.

We assumed that manufactured components will be ordered two years in advance of wind farm construction.

2.2. Port development stages

European ports servicing the offshore wind industry have typically been developed and adapted in stages, rather than all at once. We expect a similar development pattern for Virginia ports. We defined four development stages: first mover, first followers, second followers, and additional developments.

- *First movers* are the offshore wind activities with the greatest need for local port facilities and the lowest requirement for future market certainty
- *First followers* are the offshore wind activities with a strong need for local port services, but increased need for market certainty, relative to the first movers, before investing in factories or other facilities at the port
- *Second followers* are the activities with less need for local port services than the first followers. Second followers can be expected to only invest in port facilities once the market is largely de-risked
- *Additional* offshore wind activities are those that supply to a larger, global market and can therefore make port investment decisions independently from demand in the local or regional market

Table 2.1 Port development stages.

Development stage	Need for local port facilities	Need for local market certainty
First mover	High	Low
First followers	Moderate to high	Moderate to high
Second followers	Moderate to low	Moderate to high
Additional	Varies	Varies

2.3. Implementation cost and time line

In Report 1, we assess the time and cost needed to establish any of the offshore wind activities at the five Virginia ports with strong potential to support the offshore wind. This analysis considered each combination of port and offshore wind activity in isolation, creating an "a la carte" selection of implementation cost and time lines. These estimates are summarized below in Table 2.2.

Scenario implementation cost estimates were prepared for the scenarios described in Section 3, based on these findings.

Table 2.2 Implementation summary for five Virginia ports. The grey cells indicate an activity not suitable at the port. $$ = implementation cost; [calendar icon] = Time line; [person icon] = construction jobs

	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center	BASF Portsmouth
Blade manufacturing	**$$:** $3.0 million-$10.8 million [calendar icon]: 23 months [person icon]: 15.2 FTE-years	**$$:** $2.9 million-$7.9 million [calendar icon]: 15 months [person icon]: 10.6 FTE-years	**$$:** $2.4 million-$8.7million [calendar icon]: 7 months [person icon]: 2.5 FTE-years	**$$:** $1 million-$5 million [calendar icon]: 2 months [person icon]: 1.6 FTE-years	**$$:** $13.3 million-$37.2 million [calendar icon]: 3.5 years [person icon]: 14.5 FTE-years
Generator manufacturing	**$$:** $3.0 million-$10.8 million [calendar icon]: 23 months [person icon]: 15.2 FTE-years	**$$:** $2.9 million-$7.9 million [calendar icon]: 15 months [person icon]: 10.6 FTE-years	**$$:** $1.3 million-$7.2 million [calendar icon]: 6 months [person icon]: 0.7 FTE-years		**$$:** $9.9 million-$32 million [calendar icon]: 3 years [person icon]: 12.8 FTE-years
Nacelle assembly	**$$:** $4.7 million-$16.5 million [calendar icon]: 2.5 years [person icon]: 25.2 FTE-years	**$$:** $4.5 million-$12.1 million [calendar icon]: 2.5 years [person icon]: 16.7 FTE-years	**$$:** $2.7 million to $13.8 million [calendar icon]: 12 months [person icon]: 4.2 FTE-years		**$$:** $13.9 million to $37.9 million [calendar icon]: 3.5 years [person icon]: 14.8 FTE-years
Tower manufacturing	**$$:** $5.9 million-$18.9 million [calendar icon]: 2.5 years [person icon]: 27.4 FTE-years	**$$:** $5.7 million-$14.5 million [calendar icon]: 20 months [person icon]: 18.9 FTE-years	**$$:** $5.1 million to $6.8 million [calendar icon]: 4 months [person icon]: 1.4 FTE-years		**$$:** $13.9 million to $44.7 million [calendar icon]: 4 years [person icon]: 16.3 FTE-years
Foundation manufacturing	**$$:** $5.4 million to $12.5 million [calendar icon]: 25 months [person icon]: 19.2 FTE-years	**$$:** $5.3 million to $13.8 million [calendar icon]: 19 months [person icon]: 17.6 FTE-years			**$$:** $9.3 million to $31.8 million [calendar icon]: 2.5 years [person icon]: 12.4 FTE-years
Submarine cable manufacturing	No upgrades required	No upgrades required	**$$:** $900,000 to $1.3 million [calendar icon]: 1 month [person icon]: 0.5 FTE-years	**$$:** $900,000 to $1.3 million [calendar icon]: 1 month [person icon]: 0.5 FTE-years	**$$:** $12.5 million to $38.9 million [calendar icon]: 2.5 years [person icon]: 14.7 FTE-years
Substation manufacturing	*Substation manufacturing readiness was evaluated at commercial shipyards. No upgrades are required.*				
Construction staging	**$$:** $7.3 million to $17.3 million [calendar icon]: 2.5 years [person icon]: 27.3 FTE-years	**$$:** $7.1 million to $14.4 million [calendar icon]: 2.5 years [person icon]: 21.6 FTE-years			**$$:** $13.5 million to $38.9 million [calendar icon]: 3.5 years [person icon]: 14.7 FTE-years

2.4. Clustering

The port utilization scenarios presented in this report demonstrate varying degrees of clustering, or co-location, of offshore wind activities. Clustering tends to maximize supply chain and logistics efficiency, especially in the handling of finished goods, by:

- Requiring less overall storage space for finished goods
- Requiring less overall waterside infrastructure development, and
- Requiring fewer vessel port calls and handling activities.

Clustering also tends to attract second and third tier suppliers and establish a relevant skills base.

When developing cluster scenarios, we considered common vessel requirements and common waterside infrastructure as the primary driver for which activities are the most logical to co-locate, as well as taking account of European trends.

2.5. Stories and scenarios

The port utilization scenarios were developed by first establishing “stories”. Stories are the big-picture overview and scenarios are more detailed instances of a story. Each story can have one or more scenarios. An example of a story is a “cluster port,” where several manufacturers co-locate. A scenario would be one specific combination of manufacturers creating a cluster.

2.6. Job characterization

We developed a jobs characterization profile for each of the seven major offshore wind component manufacturing and construction staging activities, which are:

- Blade manufacturing
- Tower manufacturing
- Generator manufacturing
- Nacelle assembly
- Foundation manufacturing
- Submarine cable manufacturing, and
- Construction staging.

The jobs characterization comprises the number of direct jobs (measured in full time equivalent employees (FTEs)), number of shifts, classification of jobs, and educational and training requirements. For each of the activities, the manufacturing facility jobs are mapped to a job classification, an educational requirement, and a skill requirement. The job characterization was validated by our industrial partners, four publically available resources, and several previous projects completed by GLWN and BVGA.

Job Classifications

For each activity, the jobs were classified as manufacturing workers or support staff. Manufacturing workers were further categorized as:

- Assemblers, or
- Trade workers.

Support staff members were further categorized as:

- Administrative and clerical assistants
- Engineers (industrial, manufacturing, plant, product, or quality)
- Finance managers
- Finance assistants
- Floor supervisors
- Human resource or safety managers
- Operations managers
- Plant or general managers
- Production, control and logistics (PC&L) managers, or
- Sales, purchasing, and logistics (SP&L) operators

Education and Skill Requirements

For each activity, we examined the manufacturing process steps and analysed the education, industry skills, and professional certifications required for that process. The levels educational levels are:

- High School Diploma
- Post-Secondary Professional Certificate (Journeyman, Trade/ Technical Programs)
- Associate's Degree
- Bachelor's Degree
- Post-Bachelor Professional Certification (e.g., CPA, PE, LEED)
- Master's Degree, Ph.D., or Law

To characterize the required skills further, we identified five post-secondary professional certificates and technical programs:

- **CNC Machining**: Beginner and advanced CNC programs that are offered at most community and technical colleges

- **American Welding Society's (AWS) Welding Certificates**: Certification through the AWS, which is normally required for all welding operators, inspectors and supervisors
- **Composite Technology Certificate**: Typically a four-day program "Composite Production Processing", offered by the National Composite Center
- **Certified Composite Technician (CCT)**: Certification through the American Composites Manufacturers Association (ACMA)
- **Quality Control Inspector Certificate**: International Organization for Standardization (ISO) Materials and Process training, and
- **Six Sigma Certificate:** Green Belt or Black Belt certificates offered through independent certifying agencies.

Data sources and validation

We referenced four primary sources in developing the jobs characterization:

- *Wind Energy Workforce Development: A Roadmap to a Wind Energy*, by I. Baring-Gould
- *A National Skills Assessment of the U.S. Wind Industry in 2012*, by M. Leventhal and S. Tege
- *On-line Wind Career Map*, US Department of Energy
- *Potential Economic Impacts from Offshore Wind in the United States – The Southeast Region*, by The Virginia Center for Wind Energy, National Renewable Energy Laboratory (NREL) and the US Department of Energy.

Baseline data for manufacturing and assembly processes, and associated jobs, was developed using recent offshore wind supply chain projects completed by project team members GLWN and BVGA, including:

- *Offshore Wind Manufacturing and Supply Chain: A Competitiveness Analysis*, prepared for the US Department of Energy
- *Offshore Wind Supply Chain Initiative, prepared* for the Massachusetts Clean Energy Center
- *Offshore Wind Regional Supply Chain*, prepared for The New Bedford (MA) Economic Development Council, and
- *Competitive Analysis of Domestic Suppliers - Foundation Manufacturing*, prepared for the LEEDCo Icebreaker project.
- *Socioeconomic analyses,* prepared for RWE Innogy's Atlantic Array, Centrica's Race Bank, E.ON Climate and Renewables' Rampion, and EDF Energy Renewables and Eneco's Navitus Bay, and
- *Supply chain analyses,* prepared for five UK Round 3 developers representing a total of nearly 6 GW.

Data was reviewed and validated by project industrial partners.

3. Port utilization scenarios

This section presents port utilization scenarios for offshore wind manufacturing and construction staging activities in Virginia.

There are logistical benefits from the co-location of activities and we have developed three "stories" which represent different degrees of co-location:

- **Super-port,** where all seven offshore wind activities are co-located a single port
- **Cluster ports,** where all activities are co-located in two ports, and
- **Distributed port network,** where all activities are spread across three or more ports so that each location hosts no more than three activities.

For each story, we have devised one or more scenarios in which all seven offshore wind activities take place in Virginia ports.

There is currently no super-port in Europe that accommodates all seven activities considered in this analysis. There are a number of possible reasons for this:

- A lack of available infrastructure with the required technical and commercial parameters
- Suppliers preferring to remain at their existing production sites
- The challenges of upgrading infrastructure before obtaining commitment from multiple tenants, or getting a number of tenants to commit at the same time, and
- The commercial complexity of agreeing the shared use of infrastructure.

We discuss these issues as they relate to Virginia in Report 3.

Note: None of the port utilization scenarios includes BASF Portsmouth, whose implementation cost is approximately $30 million to $50 million. There is adequate space in the other ports under different utilization scenarios, which have much lower implementation costs. BASF Portsmouth is more likely to be used for offshore wind if the there is both a major constraint on port services in the region and a highly de-risked offshore wind industry, neither of which is presently the case.

3.1. Port development stages

Table 3.1 summarizes our assumptions about the expected stages of port development.

We expect the first mover to be construction staging, as a port location near a wind farm project has a strong cost benefit. The market trigger would be a project, or series of projects, having a combined capacity of at least 500MW.

We expect blade and tower manufacturing to be the first followers, with manufacturing investments triggered by an unmet demand for 500MW worth of components per year, with visibility of demand for approximately five years. These facilities can both be used for manufacture of products for onshore wind farms and could be provided by independent players able to supply to multiple turbine manufacturers.

We expect generator manufacturing and nacelle assembly to typically be second followers, as they require a larger and more stable market demand than the first followers to trigger an investment in new manufacturing facilities.

Foundation and submarine cable manufacturing could lead or lag the other activities by several years, as they are dependent on the global (and not necessarily the local) market demand.

These stages are indicative only. Depending on specific needs and opportunities, almost any facilities could lead or follow any others.

Table 3.1 Port development stages (indicative).

Port development stages	Offshore wind activity	Market trigger for investment (indicative)	Timing to complete port upgrades
First movers	Construction staging	Visibility for first 500 MW (can be met by multiple projects)	Port ready for 2023
First followers	Blade manufacturing Tower manufacturing	500 MW/year beyond manufacturer's existing capability	Port ready for 2023
Second followers	Nacelle assembly Generator manufacturing	1000 MW/year for five or more years in the US market	Port ready for 2025-2026
Additional activities	Foundation manufacturing Submarine cable manufacturing	Foundations: 500 MW/year beyond manufacturer's existing capability Cables: varies widely by manufacturer	Varies. Earliest port ready by 2021

3.2. Super-port

Few ports in the world offer the required parameters to be a super-port. Those characteristics are:

- Proximity to a thriving offshore wind market
- More than 200 acres of available quayside space
- Deep-water access
- No overhead navigational restrictions, and
- Existing waterside infrastructure.

The main logistical benefits of co-locating manufacturing and construction staging activities comes from avoiding the need to double-handle components and the shared use of infrastructure.

While no super-ports currently exist, a few cluster ports have emerged in Europe, most notably: Bremerhaven and Cuxhaven in Germany, and Hull in the UK (see Table 3.2). These cluster ports represent bold investments in port infrastructure for offshore wind but were enabled by proximity to a growing and stable offshore wind market. It is also notable that the two German ports are state owned.

Scenario 1: Portsmouth Marine Terminal (super-port)

Portsmouth Marine Terminal (PMT) offers a unique opportunity to create an offshore wind super-port by co-locating all of the manufacturing and construction staging activities considered. None of the other ports in the study has sufficient space to be a super-port.

Figure 3.1 shows an indicative layout of activities within PMT.

Table 3.3 summarizes this scenario. We estimate the total upgrade cost to range from $11 million to $25 million.

This scenario carries the lowest port infrastructure upgrade cost of any scenario analyzed. The upgrades can be phased in over time, in response to market demand. The likely first phase would be upgrades for construction staging, which is estimated to cost between $7 million and $17 million.

Table 3.2 European offshore wind cluster ports.

Location	Activities	Tenants
Port of Bremerhaven (Germany)	Nacelle assembly Blade manufacturing Foundation manufacturing Construction staging	Adwen Senvion Weserwind RWE Innogy
Port of Cuxhaven (Germany)	Tower manufacturing Foundation manufacturing (no longer operational) Construction staging	Ambau Cuxhaven Steel Construction E.ON
Port of Hull (UK) *not yet operational*	Nacelle assembly Blade manufacturing Construction staging Tower manufacturing (expected)	Siemens (to be confirmed)
Le Havre (France)	Generator manufacturing Construction staging	ABB (to be confirmed)
Cherbourg (France)	Blade manufacturing Construction staging	LMWP (to be confirmed)
Lindø (Denmark)	Nacelle assembly Foundation manufacturing	Siemens MVOW Bladt

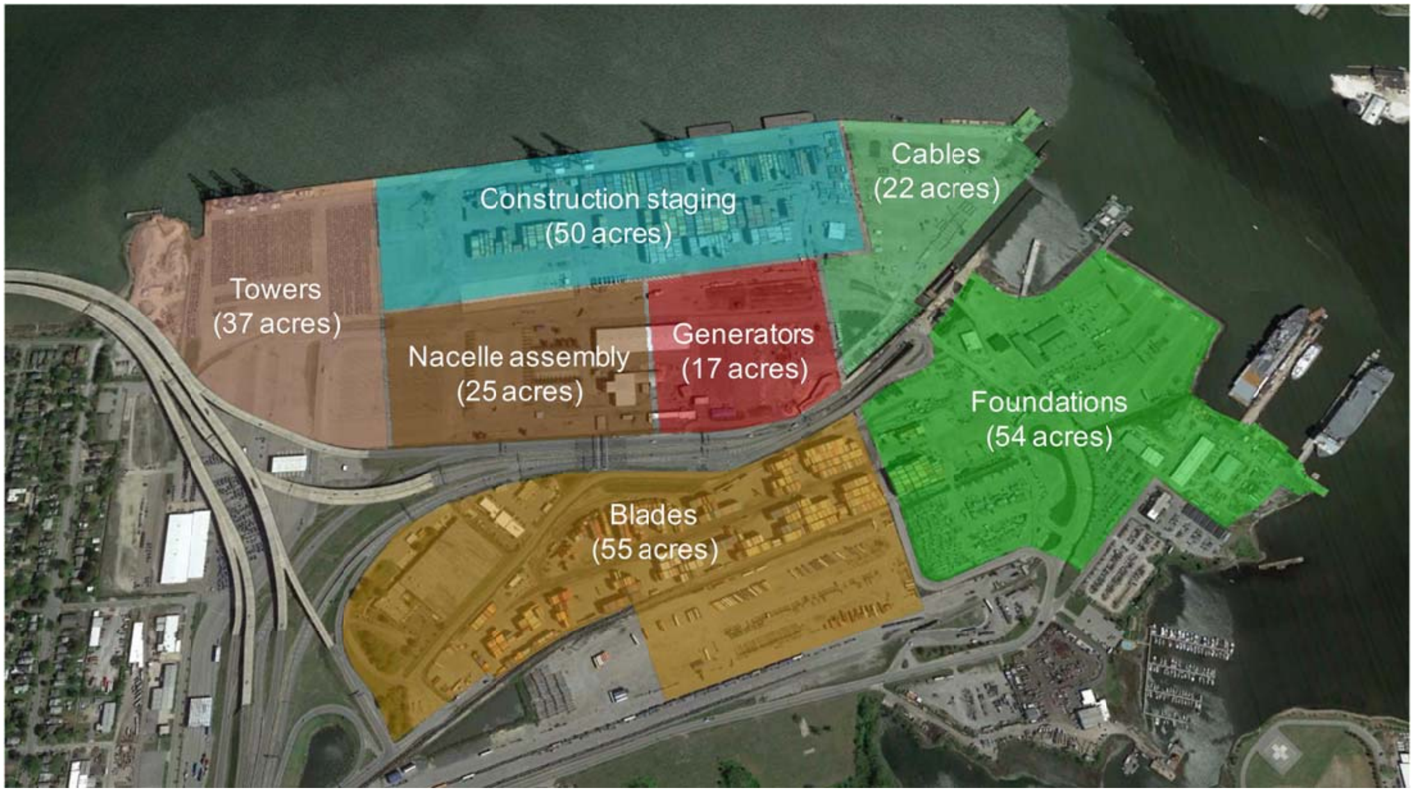

Figure 3.1 Example facility layout for super-port at Portsmouth Marine Terminal.

Table 3.3 Super-port at Portsmouth Marine Terminal (Scenario 1).

Port development stage (indicative)	Offshore wind activity	Required parcel size (acres)	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center
1st mover	Construction staging	50	✓	-	-	-
1st follower	Tower manufacturing	37	✓	-	-	-
1st follower	Blade manufacturing	55	✓	-	-	-
2nd follower	Nacelle assembly	25	✓	-	-	-
2nd follower	Generator manufacturing	17	✓	-	-	-
Additional	Foundation manufacturing	54	✓	-	-	-
Additional	Submarine cable manufacturing	22	✓	-	-	-
Space used / Space available (acres)			260 / 287	0 / 165	0 / 63	0 / 70
Upgrade cost			**$11 million to $25 million**			

3.3. Cluster ports

PMT, Newport New Marine Terminal (NNMT) and Peck Marine Terminal (Peck) are all good candidates for cluster ports, as they have the space and vessel access to accommodate several offshore wind manufacturing and construction activities.

We developed three clustering scenarios based on co-locating activities with common vessel and waterside infrastructure needs. There are additional possibilities and we expect the implementation cost and time line to be similar for those scenarios.

Scenario 2: Portsmouth Marine Terminal and Newport News Marine Terminal (cluster ports)

In this scenario, PMT and NNMT are used as cluster ports. The first movers are located at PMT and the followers at NNMT. The opposite is also possible and would have similar implementation costs.

Figure 3.2 shows an example layout of facilities at NNMT.

Table 3.4 summarizes Scenario 2. We estimate the implementation cost for the first movers at PMT is between $9 million and $20 million. For followers at NNMT, we estimate the implementation cost is between $6 million and $16 million.

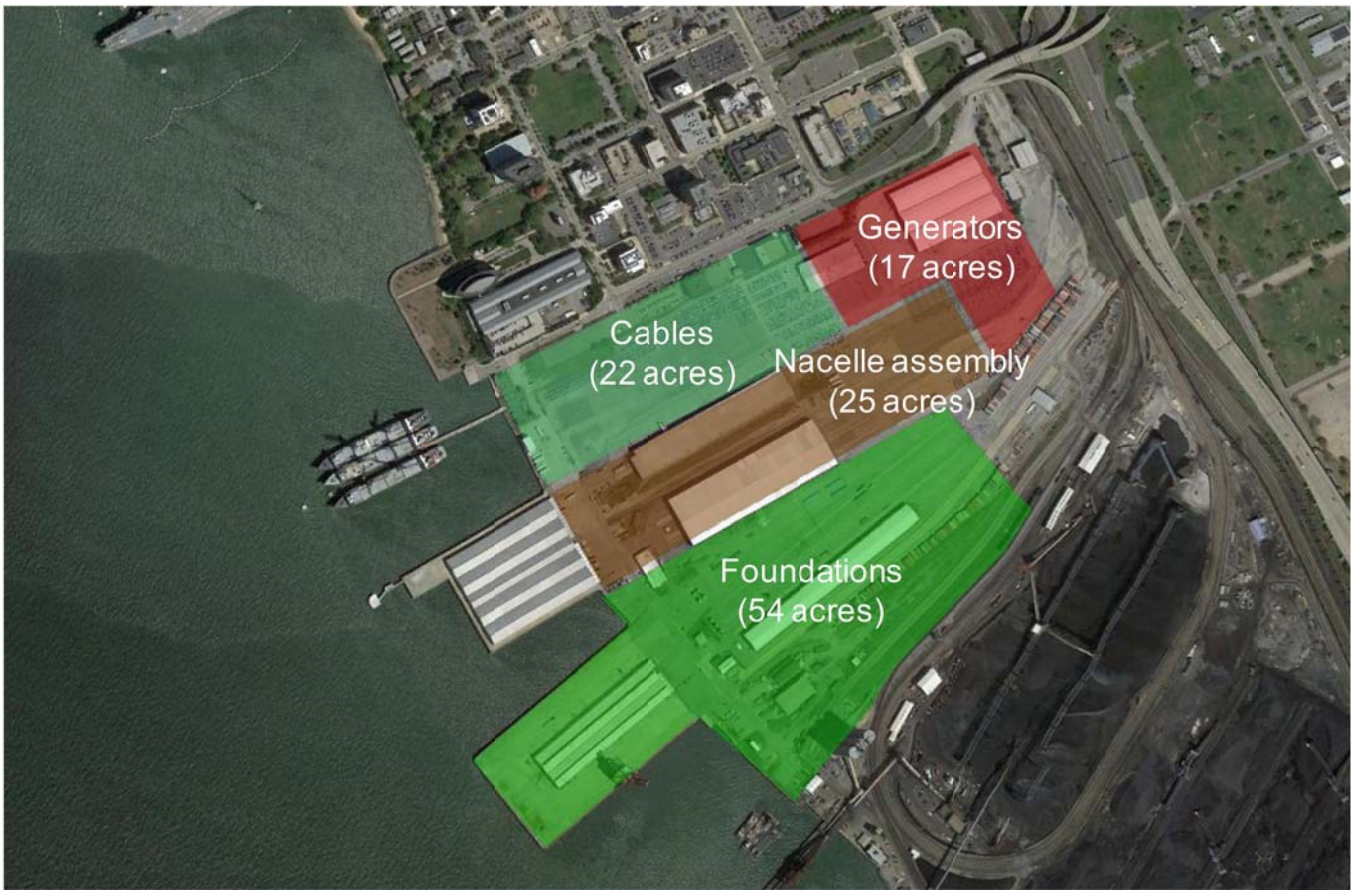

Figure 3.2 Nominal facility layout for cluster port at Newport News Marine Terminal.

Table 3.4 Cluster ports at Portsmouth and Newport News Marine Terminals (Scenario 2).

Port development stage (indicative)	Offshore wind activity	Required parcel size (acres)	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center
1st mover	Construction staging	50	✓	-	-	-
1st follower	Tower manufacturing	37	✓	-	-	-
1st follower	Blade manufacturing	55	✓	-	-	-
2nd follower	Nacelle assembly	25	-	✓	-	-
2nd follower	Generator manufacturing	17	-	✓	-	-
Additional	Foundation manufacturing	54	-	✓	-	-
Additional	Submarine cable manufacturing	22	-	✓	-	-
Space used / Space available (acres)			142 / 287	118 / 165	0 / 63	0 / 70
Upgrade cost			**$9 million to $20 million**	**$6 million to $16 million**	**0**	**0**

Scenario 3: Portsmouth Marine Terminal and Peck Marine Terminal (cluster ports)

Peck is well suited for generator manufacturing and nacelle assembly. Co-locating these two activities will reduce logistic costs. In this scenario, PMT hosts the remaining activities. Table 3.5 summarizes Scenario 3.

Table 3.5 Cluster ports at Portsmouth and Peck Marine Terminals (Scenario 3).

Port development stage (indicative)	Offshore wind activity	Required parcel size (acres)	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center
1st mover	Construction staging	50	✓	-	-	-
1st follower	Tower manufacturing	37	✓	-	-	-
1st follower	Blade manufacturing	55	✓	-	-	-
2nd follower	Nacelle assembly	25	-	-	✓	-
2nd follower	Generator manufacturing	17	-	-	✓	-
Additional	Foundation manufacturing	54	✓	-	-	-
Additional	Submarine cable manufacturing	22	✓	-	-	-
Space used / Space available (acres)			218 / 287	0 / 165	42 / 63	0 / 70
Upgrade cost			**$9 million to $20 million**	**0**	**$5 million to $18 million**	**0**

Scenario 4: Newport News and Peck Marine Terminals (cluster ports)

This scenario is similar to Scenario 3 but NNMT replaces PMT. Table 3.6 summarizes Scenario 4.

Table 3.6 Cluster ports at Newport News and Peck Marine Terminals (Scenario 4).

Port development stage (indicative)	Offshore wind activity	Required parcel size (acres)	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center
1st mover	Construction staging	50	-	✓ (40 acres)	-	-
1st follower	Tower manufacturing	37	-	✓	-	-
1st follower	Blade manufacturing	55	-	✓ (45 acres)	-	-
2nd follower	Nacelle assembly	25	-	-	✓	-
2nd follower	Generator manufacturing	17	-	-	✓	-
Additional	Foundation manufacturing	54	-	✓ (43 acres)	-	-
Additional	Submarine cable manufacturing	22	-	-	✓ (21 acres)	-
Space used / Space available (acres)			0 / 287	165 / 165	63 / 63	0 / 70
Upgrade cost			**0**	**$8 million to $20 million**	**$3 million to $13 million**	**0**

3.4. Distributed port network

A distributed port network is a natural starting point for an emerging or uncertain regional offshore wind market, as it is the most commercially agile approach to port investment (although it loses economies of scale). With this approach, each manufacturer, port owner or wind farm developer can make investment decisions in isolation and minimize their (or the port's) total at-risk investment.

We have presented one logical distributed port network scenario but many other scenarios are possible and we would expect them to have similar implementation costs and time lines. The parcel size and physical characteristics of Virginia Renaissance Center make the site well suited to blade manufacturing. Likewise, Peck is well suited to tower manufacturing.

Scenario 5: Portsmouth, Newport News, and Peck Marine Terminals and Virginia Renaissance Center (distributed port network)

This scenario uses PMT to host construction staging. The first followers are distributed between Peck (tower manufacturing) and Virginia Renaissance Center (blade manufacturing).

Table 3.7 Distributed port network at Portsmouth, Newport News and Peck Marine Terminals and Virginia Renaissance Center (Scenario 5).

Port development stage (indicative)	Offshore wind activity	Required parcel size (acres)	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center
1st mover	Construction staging	50	✓	-	-	-
1st follower	Tower manufacturing	37	-	-	✓	-
1st follower	Blade manufacturing	55	-	-	-	✓
2nd follower	Nacelle assembly	25	✓	-	-	-
2nd follower	Generator manufacturing	17	✓	-	-	-
Additional	Foundation manufacturing	54	-	✓	-	-
Additional	Submarine cable manufacturing	22	-	-	✓	-
Space used / Space available (acres)			92 / 287	54 / 165	59 / 63	55 / 70
Upgrade cost			**$8 million to $18 million**	**$5 million to $12 million**	**$6 million to $18 million**	**$1 million to $2 million**

3.5. Port utilization summary

The five scenarios presented in this report are indicative of the many ways in which Virginia's infrastructure can support offshore wind activity. The implementation cost of each scenario is summarised in Table 3.8.

Table 3.8 Summary of port utilization scenarios and implementation costs.

Story	Scenario	Ports	Implementation cost
Super-port	1	Portsmouth Marine Terminal	$11 million to $25 million
Cluster ports	2	Portsmouth Marine Terminal Newport News Marine Terminal	$15 million to $36 million
Cluster ports	3	Portsmouth Marine Terminal Peck Marine Terminal	$14 million to $38 million
Cluster ports	4	Newport News Marine Terminal Peck Marine Terminal	$11 million to $33 million
Distributed port network	5	Portsmouth Marine Terminal Newport News Marine Terminal Peck Marine Terminal Virginia Renaissance Center	$20 million to $50 million

4. Direct manufacturing jobs

This section summarizes the employment activity generated by each offshore wind manufacturing activity, based on the production of 100 wind turbines per year. This includes:

- The number and classification of manufacturing and support staff jobs (measured FTEs)
- The required education levels
- The required skill and certificates, in addition to education degree level.

This analysis does not consider indirect and induced jobs and jobs relating to the construction of facilities.

The numbers of jobs, though not rounded, are indicative. Different suppliers use different manufacturing methods with different labor quantity and grade requirements and in time, efficiency continues to improve, reducing labor requirements.

4.1. Blade manufacturing

Figure 4.1 Vestas blade facility, Windsor Ontario.

Job classifications

To manufacture 300 blades in one year (to support the installation of 100 turbines), we estimate that a total staff of 300 FTEs is needed. Table 4.1 shows a breakdown of job classifications for the 300 workers. The manufacturing staff is divided equally among three shifts, when at full capacity. The support staff is divided across the three shifts with 25 servicing first shift and 10 each, second and third shifts.

Educational requirements

Since the majority of the workers in a blade plant are assemblers, the primary education level is a high school diploma.

Skills and certifications

Of the 255 manufacturing staff, 225 likely require a composite certification, such as the Certified Composites Technician (CCT) offered through the American Composites Manufacturers Association (ACMA). The ACMA program is recognized by the blade industry, for both manufacturing and maintenance, and has been adopted by blade manufacturers such as MVOW and LMWP. Blade manufacturing requires trade worker with a CNC Machining Certificate.

Table 4.1 Job classifications for blade manufacturing.

Classification	Direct jobs (sustained FTEs)
Trade worker	45
Assembly worker	210
Sub-total: manufacturing	255
Manager	21
Engineer	11
Other support staff	13
Sub-total: support staff	45
Total	**300**

Table 4.2 Educational requirements for blade manufacturing.

Degree	Number of workers
High school diploma or less	198
Post-secondary or trade certificate	57
Associate degree	21
Bachelor degree	24
Post-bachelor / professional certification	0
Master’s or PhD	0

Table 4.3 Additional training for blade manufacturing.

Additional training	Number of workers
CNC Machining Certificate (or similar)	30
AWS Welding Certificate	0
Composite Technology Certificate	225
Quality Control Inspector Certificate	33
Six Sigma – minimum Green or Black Belt	11

4.2. Generator manufacturing

Figure 4.2 Enercon 7.5MW generator manufacturing, Magdeburg, Germany.

Job classifications

There are three principal processes for the production of a turbine generator: stator and rotor production, stator assembly, and rotor assembly. To manufacture 100 direct drive (low speed) generator sets in one year (as used by Alstom and Siemens), we estimate a total staff of 188 FTEs is needed. Table 4.4 shows a breakdown of job classifications for the 188 workers. The manufacturing staff typically is divided equally between two operating shifts. The support staff is divided across the two shifts with 20 servicing the first shift and six, the second shift.

Educational requirements

A majority of the workers require post-secondary certification. This is primarily due to the skills required for the trade workers for the stator and rotor production. A minimum high school diploma is required for the assemblers, primarily working in stator and rotor assembly.

Skills and certifications

Of the manufacturing staff, 72 trade workers associated with the stator and rotor production require a post-secondary certificate. Operations with lathe or machining require a CNC Machining Certificate. Operations with material cutting, welding prep, joint welding, NDT (non-destructive testing) inspection, or heat treatment and annealing require the AWS Welding certificate, commonly for both line workers and supervisors. All inspector positions require quality control certification.

Table 4.4 Job Classifications for generator manufacturing.

Classification	Direct jobs (sustained FTEs)
Trade worker	94
Assembly worker	68
Sub-total: manufacturing	162
Manager	11
Engineer	9
Other support staff	6
Sub-total: support staff	26
Total	**188**

Table 4.5 Educational requirements for generator manufacturing.

Degree	Number of workers
High school diploma or less	68
Post-secondary or trade certificate	94
Associate degree	6
Bachelor degree	20
Post-bachelor / professional certification	0
Master’s or PhD	0

Table 4.6 Additional training for generator manufacturing.

Additional training	Number of workers
CNC Machining Certificate (or similar)	36
AWS Welding Certificate	36
Composite Technology Certificate	0
Quality Control Inspector Certificate	20
Six Sigma – minimum Green or Black Belt	9

4.3. Nacelle assembly

Figure 4.3 Alstom nacelle assembly, Amarillo, TX.

Job classifications

To assemble 100 nacelles in one year, we estimate that a total staff of 240 FTEs is needed. Table 4.7 shows a break-down of job classifications for the 240 workers, with the greatest number of staff being assemblers. The manufacturing staff is divided equally among two operating shifts. The support staff is divided across the two shifts with 41 servicing first shift, and 19 for second shift.

Educational requirements

A majority of the workers require only a high school diploma. This is attributable to nacelle manufacturing process primarily being served by assemblers and few skilled trade workers. Post-secondary certificates and higher education degrees are required for quality inspectors and various engineering and management staff.

Skills and certifications

For nacelle assembly, post-secondary Quality Control (QC) Inspector certification is required for the quality inspectors. Quality Mangers are expected to have both QC Inspector and Six Sigma Black certifications.

Table 4.7 Job classifications for nacelle assembly.

Classification	Direct jobs (sustained FTEs)
Trade worker	18
Assembly worker	162
Sub-total: manufacturing	180
Manager	13
Engineer	15
Other support staff	32
Sub-total: support staff	60
Total	**240**

Table 4.8 Educational requirements for nacelle assembly.

Degree	Number of workers
High school diploma or less	162
Post-secondary or trade certificate	38
Associate degree	30
Bachelor degree	10
Post-bachelor / professional certification	0
Master's or PhD	0

Table 4.9 Additional training for nacelle assembly.

Additional training	Number of workers
CNC Machining Certificate (or similar)	0
AWS Welding Certificate	0
Composite Technology Certificate	0
Quality Control Inspector Certificate	13
Six Sigma – minimum Green or Black Belt	1

4.4. Tower manufacturing

Figure 4.4 Broadwind Towers tower manufacturing, Manitowoc, WI.

Job classifications

To manufacture 100 towers in one year, we estimate that a total staff of 105 FTEs is needed. Table 4.10 shows a breakdown of job classifications for the 105 workers, with the greatest number of staff being skilled trade workers. The manufacturing staff is divided equally among two operating shifts. The support staff is divided across the two shifts with 16 servicing the first shift, and 5 for the second shift.

Educational requirements

A majority of the workers require post-secondary trade certification. This is primarily due to the welding skills required for the trade workers for tower production. A minimum high school diploma is required for the assemblers installing internal tower equipment, such as ladders and electronics, and painting and coating operations.

Skills and certifications

For tower production, AWS Welding Certification is required for a majority of the skilled trade workers. The AWS certification requires specific skills plus a combination of qualifying education and work experience. QC Inspector certification is required for all quality inspectors and the quality manager.

Table 4.10 Job classifications for tower manufacturing.

Classification	Direct jobs (sustained FTEs)
Trade worker	58
Assembly worker	26
Sub-total: manufacturing	84
Manager	9
Engineer	6.5
Other support staff	5.5
Sub-total: support staff	21
Total	105

Table 4.11 Educational requirements for tower manufacturing.

Degree	Number of workers
High school diploma or less	26
Post-secondary or trade certificate	58
Associate degree	6
Bachelor degree	15
Post-bachelor / professional certification	0
Master’s or PhD	0

Table 4.12 Additional training for tower manufacturing.

Additional training	Number of workers
CNC Machining Certificate (or similar)	4
AWS Welding Certificate	42
Composite Technology Certificate	0
Quality Control Inspector Certificate	13
Six Sigma – minimum Green or Black Belt	7

4.5. Foundation manufacturing

Figure 4.5 Bladt Industries jacket manufacturing, Aalborg, Denmark.

For the purposes of this report, “foundation manufacturing” is assumed to mean the production of the main lattice structure and transition piece of a jacket foundation, typically produced at a single facility or adjoining facilities.

Job classifications

To manufacture 100 jacket foundations and transition pieces in one year, we estimate that a total staff of 564 FTEs is needed. Table 4.13 shows a break-down of job classifications for the 564 workers. Of the 510 manufacturing staff, the main lattice production requires 303 FTEs and the transition piece 207 FTEs, equally divided across a three shift operation. Support staff for both operations is divided across the three shifts as follows: 28 servicing first shift; and 13 each for second and third shift.

Educational requirements

The majority of production for both the main lattice structure and the transition piece is in welding operations by skilled trade workers requiring post-secondary or trade certification. A minimum high school diploma is required for the carboline coating, galvanize spray, paint operations, and ancillary assembly operations.

Skills and certifications

For the main lattice and the transition piece production, production, AWS Welding certification is required for a majority of the skilled trade workers including welders, supervisors, and inspectors. AWS requires specific skills plus a combination of qualifying education and work experience. QC inspector certification is required for all quality inspectors and the quality manager.

Table 4.13 Job classifications for foundation manufacturing.

Classification	Direct jobs (sustained FTEs)
Trade worker	408
Assembly worker	102
Sub-total: manufacturing	510
Manager	30
Engineer	10
Other support staff	14
Sub-total: support staff	54
Total	**564**

Table 4.14 Educational requirements for foundation manufacturing.

Degree	Number of workers
High school diploma or less	102
Post-secondary or trade certificate	408
Associate degree	30
Bachelor degree	24
Post-bachelor / professional certification	0
Master’s or PhD	0

Table 4.15 Additional training for foundation manufacturing.

Additional training	Number of workers
CNC Machining Certificate (or similar)	0
AWS Welding Certificate	390
Composite Technology Certificate	0
Quality Control Inspector Certificate	63
Six Sigma – minimum Green or Black Belt	11

4.6. Submarine cable manufacturing

Figure 4.6 JDR Cable Systems submarine cable manufacturing, Hartlepool, UK.

Job classifications

Approximately 150km of medium voltage alternating current (AC) array cable and 50km high voltage AC export cable is needed to support the installation of 100 turbines. We estimate that a total staff of 234 FTEs is needed. Table 4.16 shows a break-down of job classifications for the 234 workers, with the greatest number of staff being assembly workers. The manufacturing staff is divided equally among three operating shifts. Support staff is divided across the three shifts as follows: 21 servicing first shift; and 6 each for second and third shift.

Educational requirements

A majority of the workers require only a high school diploma. This is attributable to the cable manufacturing process being highly automated, requiring lower skilled assemblers and few trade workers. Higher education degrees are required for quality inspectors, and engineering and management staff.

Skills and certifications

Submarine cable is produced in a continuous line with lengths that can exceed 100km. CNC Machining Certification is required for the electrical and mechanical maintenance crew, who are critical to ensuring continuous production. QC Inspector certification is required for all quality inspectors and quality managers. Six Sigma Black Belt is preferred for support staff engineers.

Table 4.16 Job classifications for submarine cable manufacturing.

Classification	Direct jobs (sustained FTEs)
Trade worker	12
Assembly worker	189
Sub-total: manufacturing	201
Manager	15
Engineer	11
Other support staff	7
Sub-total: support staff	33
Total	**234**

Table 4.17 Educational requirements for submarine cable manufacturing.

Educational attainment	Number of workers
High school diploma or less	189
Post-secondary or trade certificate	12
Associate degree	0
Bachelor degree	38
Post-bachelor / professional certification	0
Master’s or PhD	0

Table 4.18 Additional training for submarine cable manufacturing.

Post Secondary Certificate	Number of workers
CNC Machining Certificate (or similar)	12
AWS Welding Certificate	0
Composite Technology Certificate	0
Quality Control Inspector Certificate	15
Six Sigma – minimum Green or Black Belt	7

4.7. Construction staging

The structure of the construction staging workforce is likely to depend on whether it is working on a single, one-off wind farm or an ongoing pipeline of projects.

For a one-off wind farm, most of the onshore jobs will be short-term contracts. Responsibility for recruiting and training this workforce may rest on either the developer or the turbine manufacturer, depending on the contract structure.

For a pipeline of projects, a more permanent facility and workforce may be possible. In this case, it could be supported either by the turbine manufacturer alongside a manufacturing facility, or by a developer with a strong pipeline of projects in the region.

For the purposes of this analysis, we have assumed that the construction staging facility is operating over a number of years and supporting the construction of 100 turbines per year. Our analysis shows that the facility would employ approximately 220 workers, divided into two main groups:

- Approximately 150 blue-collar and white-collar staff for the assembly of wind turbine components. This involves preparing components for installation and moving them around the construction site. They work a variety of shift patterns depending on their role.
- Approximately 70 blue-collar marine installation and commissioning staff that will support and coordinated the loading of vessels.

There are also many more jobs created during construction that are associated with the vessels and the offshore construction and commissioning work. These workers are much more likely to be working on project-specific contracts, with no fixed base of operation.

4.8. Job characterization summary

Foundation manufacturing yields the most direct job opportunities (564 FTEs) and the greatest number of high-paying jobs (408 trade workers, 30 managers, 10 engineers) of all six offshore wind manufacturing activities.

Nacelle assembly yields 240 direct jobs, more than half of which are accessible to high school graduates without additional training or certification. Also, nacelle assembly historically produces a large number of indirect jobs through the extensive subcomponent and manufacturing services that feed into final nacelle assembly. Nacelle manufacturers typically purchase subcomponents as complete systems. These include brakes, bearings, gearboxes, drive motors, transformers, and power distribution, plus various other ancillary components such as brackets, crane systems, ducting, fiberglass housings, support frames, wiring harnesses, insulation and lighting. The overall jobs opportunities from nacelle assembly and its supply chain could easily render the greatest number of total jobs (direct and indirect) if a robust local supply chain is developed.

Generator manufacturing yields 188 direct jobs, half of which are high-paying trade workers.

Blade manufacturing and submarine cable manufacturing generate a large number of jobs, many of which are accessible to workers with a relatively low educational attainment level.

Tower manufacturing generates the least number of jobs out of the six manufacturing activities.

Figure 4.7 shows a summary of all six offshore wind manufacturing direct jobs by classification.

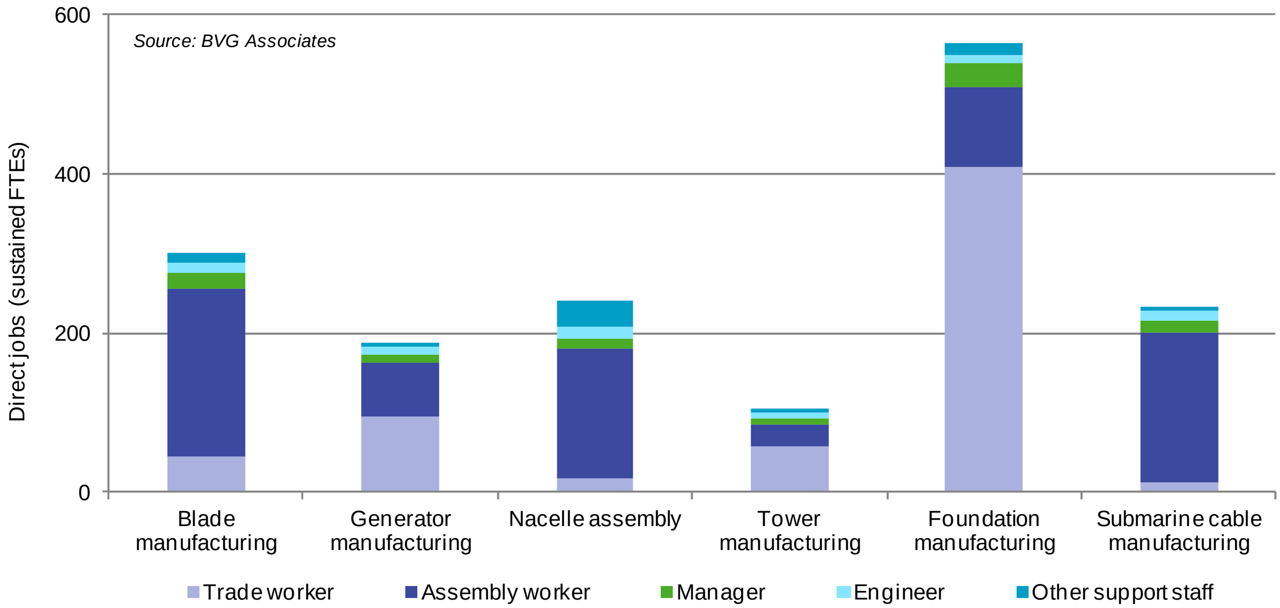

Figure 4.7 Summary of offshore wind manufacturing jobs by classification.