U.S. Offshore Wind Workforce Assessment

Jeremy Stefek, Chloe Constant, Caitlyn Clark, Heidi Tinnesand, Corrie Christol, and Ruth Baranowski

National Renewable Energy Laboratory

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List of Acronyms

ACDE/ANSI	Association of Commercial Diving Educators/American National Standards Institute
BOSIET	Basic Offshore Safety Induction and Emergency Training
COD	commercial operation date
CTV	crew transfer vessel
DOE	U.S. Department of Energy
FTE	full-time equivalent
GW	gigawatt
GWO	Global Wind Organisation
HSE	health, safety, and environmental
I-O	input-output
JEDI	Jobs and Economic Development Impact
K-12	kindergarten through 12^{th} grade
MassCEC	Massachusetts Clean Energy Center
MW	megawatt
NCCCO	National Commission for the Certification of Crane Operators
NREL	National Renewable Energy Laboratory
NSPS-THSOA	National Society of Professional Surveyors-The Hydrographic Society of America
O&M	operations and maintenance
OPITO	Offshore Petroleum Industry Training Organization
ORBIT	Offshore Renewables Balance-of-system and Installation Tool
OSHA	Occupational Health and Safety Administration
ROV	remotely operated vehicle
SOV	service operation vessel
WTIV	wind turbine installation vessel

Executive Summary

A total of 40 gigawatts (GW) of offshore wind capacity is currently in different phases of development in the United States (Musial et al. 2022). Achieving this level of buildout would meet state procurement requirements and fulfill the Biden administration's goal of 30 GW by 2030 and represents a significant opportunity to create jobs, grow a supply chain, revitalize working waterfronts, and help decarbonize the U.S. electric grid.

Offshore wind energy projects are complex and require an extensive, varied, and well-trained workforce. Educational institutions, state governments, labor organizations, and others are working to understand the opportunities and requirements of the industry and to develop education and training programs to meet those needs. However, gaps remain in fully understanding and meeting workforce requirements at a national level.

This report provides estimates of the current and future workforce needs of the industry (demand), identifies relevant occupations and requirements, highlights emerging educational institutions, training programs, and initiatives that can contribute to meeting workforce needs, and identifies workforce gaps (supply). It then recommends actions to bridge workforce gaps and support key stakeholders such as industry, state and local governments, educational organizations, and unions in their efforts to attract, educate, train, and retain a domestic workforce to support this burgeoning industry.

Demand: Workforce Needs To Meet 2030 Offshore Wind Energy Goals

To meet the target of 30 GW of U.S. installed offshore wind capacity by 2030, average annual employment levels (full-time equivalent [FTE]/year) are estimated at 15,000 and 58,000 based on 25% and 100% domestic content scenarios, respectively. Averages are computed for period of 2024 to 2030 (Figure ES-2). This estimate only includes the direct and indirect offshore wind jobs associated with development, manufacturing, installation, and operation of offshore wind energy plants, and the estimates do not include additional jobs in communities supported by offshore wind activity, also known as induced impact jobs. In any given year, actual employment requirements could be higher or lower than these levels based on industry demand or variability in domestic content; however, average employment throughout this period is generally expected to fall in this range. In addition, the total workforce need is expected to start toward the bottom of the range and grow over time as the offshore wind energy industry develops.

We model these scenarios through a mixed process-based and input-output economic impact framework to estimate jobs, assuming a deployment pipeline of awarded, soon-to-be-awarded, and anticipated lease areas for fixed-bottom and floating offshore wind projects sufficient to reach 30 GW by 2030 as detailed in "The Demand for a Domestic Offshore Wind Energy Supply Chain" (Shields et al. 2022). The fixed-bottom capacity is assumed to be installed on the East Coast and the floating capacity on the West Coast, assuming there are no constraints to reaching the 30-GW target (Figure ES-1).

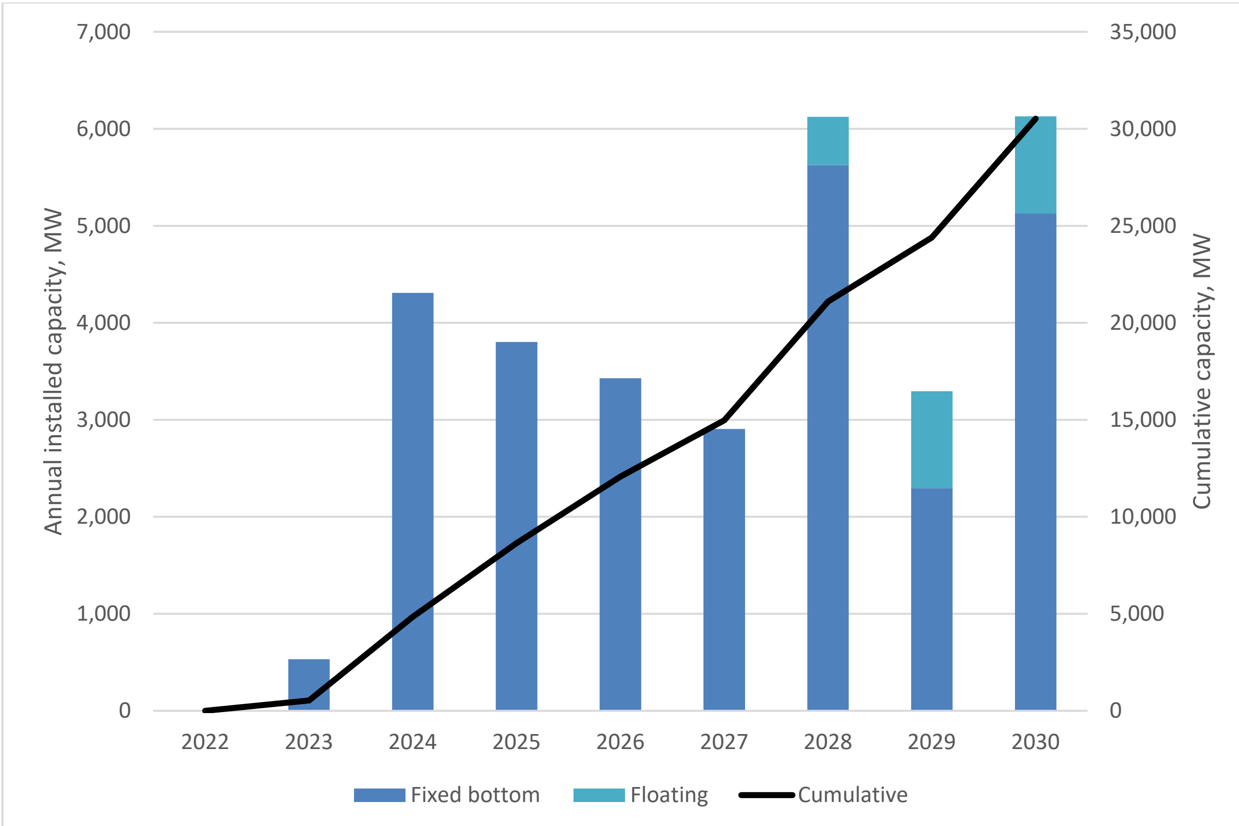

Figure ES-1. The total annual and cumulative installed capacity that represent multiple offshore wind energy projects that are modeled to estimate workforce needs (MW = megawatts)

Specific job numbers are estimated in the following five industry segments:

- **Development**. Jobs associated with site assessment, plant design, permitting, financing, project management, and other preconstruction activities.
- **Manufacturing and supply chain**. Jobs for various components produced at multiple tiers of the manufacturing process, from engineering and design of components to production
- **Ports and staging**. Jobs involved in ports and staging, such as terminal crews and logistics and management roles located portside
- **Maritime construction**. Jobs operating at sea to install projects, including the marine crew, engineers, and installation crews
- **Operations and maintenance (O&M)**. Jobs that involve operating and maintaining a project during its lifetime, including wind technicians and plant managers.

Figure ES-2 shows the potential workforce range over time through 2030 for each industry segment.

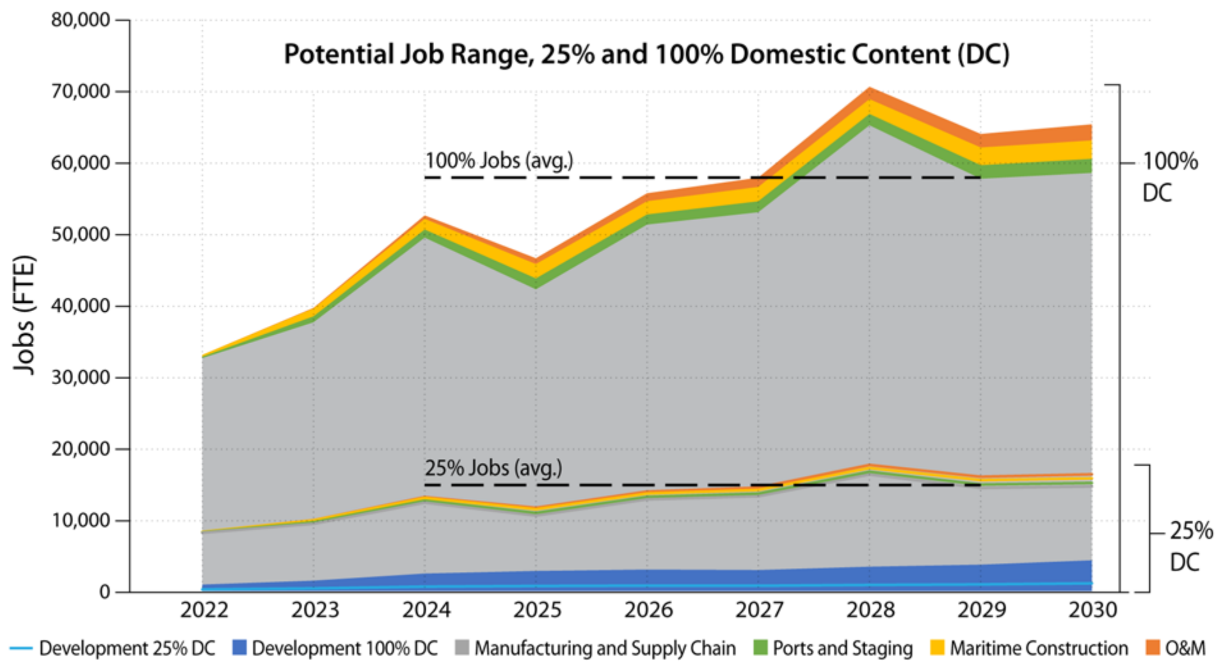

Figure ES-2. Potential job estimates across industry segments to support a project pipeline of 30 gigawatts of offshore wind energy by 2030, assuming a domestic workforce lower bound of 25% and an upper bound of 100%. Also shows a range of average employment each year between 2024 and 2030.

The industry will likely use a smaller domestic workforce for wind power plants installed between 2022 and 2025, but as manufacturing and supply chain plants are built, U.S.-flagged offshore wind vessels support installation activities, and the U.S. offshore wind labor market matures, the increase in domestic content will grow the workforce for wind plants installed beyond this timeframe. Based on our assessment of workforce demand, key conclusions for each industry segment include the following:

- **Development**. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 800 and 3,200 based on 25% and 100% domestic content scenarios, respectively. Job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. The workforce need is likely closer to the upper limit because the United States has professionals and training programs to support a domestic workforce. Project development is underway, and many development jobs for initial offshore wind projects have been hired. Roles will continue to increase between 2022 and 2025 due to the development of multiple, concurrent projects, and will need to be met as soon as possible.
- **Manufacturing and supply chain**. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 12,300 and 49,000 based on 25% and 100% domestic content scenarios, respectively. Job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. The largest contribution is factory-level workers; therefore, the greatest potential for employment is by using U.S.-based suppliers to produce subcomponents, parts, and materials for offshore wind energy components. The extent to which domestic jobs are realized depends on the building

of U.S. manufacturing facilities and those facilities leveraging a U.S. supply chain to source subassemblies, parts, and materials.

- **Ports and staging**. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 400 and 1,600 based on 25% and 100% domestic content scenarios, respectively. Job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. Ports are centralized infrastructure located near coastal communities, which could support efforts to hire from local and disadvantaged communities as the number and size of offshore wind projects grows. The largest contribution of workers is from terminal crews involved in staging components and loading vessels. Ports supporting offshore wind energy activities will support economic development in industrial waterfront communities by creating jobs.
- **Maritime construction**. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 500 and 2,100 based on 25% and 100% domestic content scenarios, respectively. Job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. Because of different installation strategies and vessel availability, the level of domestic workforce is highly uncertain. Maritime construction workforce needs are estimated to develop slowly between 2022 and 2026, as we expect the initial offshore wind projects may use installation strategies with foreign-flagged installation vessels with a larger international workforce. However, if Jones-Act compliant vessels are built to meet future development demand, we expect an increase in the domestic workforce need.
- **O&M**. Assuming domestic content scenarios of 25% and 100%, the near-term average annual employment levels (FTE/year) is between 100 and 500 in 2024, but this could grow in the longer term to between 600 and 2,300 in 2030. O&M jobs will begin ramping up to support offshore wind energy plants in 2023−2024. O&M roles are needed throughout the wind plant's life; therefore, workforce needs are cumulative, increasing based on the number, size, and commissioning year of projects.

Supply: Developing the Offshore Wind Energy Workforce for Tomorrow

Meeting future workforce demand efficiently is best served by a coordinated, regional approach. This approach will enable stakeholders to build consensus around offshore-wind-energy-specific role requirements; collaborate on new and existing programs to provide comparable offshore-wind-focused training and education; and coordinate the mobilization of workforce in related fields to support industry needs. An adaptable approach will also enable workers to bring the appropriate skills and experience to the right geographic locations at the right quantities and times to match the stage of development for offshore wind projects. Notably, equitably developing a diverse workforce will require intentional efforts. Finally, creating opportunities within the communities most impacted by offshore wind energy development will support future deployments of offshore wind plants and associated infrastructure.

Roles and Competency Requirements

Most offshore wind energy industry roles require specialized training and relevant experience in a skilled trade, whereas only some roles require advanced degrees (e.g., bachelor's degree or higher). These advanced degrees often support development and engineering roles that have longer educational lead times but are needed at an earlier stage of deployment. Hiring from adjacent industries (i.e., maritime, oil and gas, and land-based wind energy industries) is one opportunity to supply the offshore wind industry with workers with applicable experience. Nevertheless, attracting and teaching workers from these industries the necessary new skills (e.g., upskilling) will require a transition period and concerted efforts. Key considerations of education requirements, skills, and experience for the many wide-ranging roles, with varying training needs, include:

- **Job roles requiring basic and skilled trades in construction and manufacturing are the largest contribution of workers across industry segments** (as compared to professionals and engineering roles), such as factory-level workers who manufacture offshore wind energy components, terminal crews who load vessels at ports, and construction crews on vessels. These skilled construction jobs are in high demand across renewable and other industries, which may increase the hiring difficulty for the offshore wind industry.
- **The types, numbers, and geographic locations of jobs vary during an offshore wind power plant's life and, when considered across the pipeline of projects across the United States, can lead to large variability** in workforce demand. Therefore, workers should be trained and hired strategically to alleviate potential peaks and troughs of workforce demand. For example, jobs related to installation activities are temporary, but a large deployment pipeline allows workers to move to other projects if those projects are properly timed.
- **Based on discussions with stakeholders, general awareness of the types and breadth of workforce roles required is low.** Widespread understanding of the roles and their requirements will help attract workers and aid in modifying existing or developing new education and training programs. While there is a strong focus on training wind turbine technicians based on the programs we have identified, **the offshore wind energy industry has a wide range of roles.** This report identifies 113 distinct roles, from finance and engineering to maritime and trades that will need to be considered in developing the workforce.
- **Workforce roles are often characterized differently by companies, organizations, and stakeholders.** This characterization can create confusion regarding the training and qualifications needed for these roles. Key roles and requirements, especially for those seeking specific credentials, should be standardized and communicated among training organizations and adjacent industries. For example, offshore wind technician is often characterized broadly and sometimes inconsistently. Having standardized role definitions, requirements, or credentials would ensure appropriate programs are developed that meet industry requirements.
- **Some roles are expected to be in high demand at the same time as other industries** (i.e., construction). Understanding the workforce needs of related industries will enable stakeholders to plan for potential gaps and leverage related training and education programs and initiatives.

Education and Training Programs

Many organizations are already providing or developing training and education programs to support an offshore wind energy workforce. We identified 44 offshore-wind-energy-focused programs during the development of this report, including successful partnerships that bring together industry, education, training, and states, like the National Offshore Wind Institute and the Offshore Wind Training Institute. NREL maintains the Offshore Wind Workforce

[Education and Training Database](#) to make it easy to quickly find institutions and programs that will help energize students about an offshore wind powered future and related concepts. However, additional program development will likely be needed to meet demand over time, particularly to train skilled tradespeople, provide safety training to offshore workers at sea, and leverage workers' transferable skills to support the offshore wind industry.

Table ES-1 identifies key training gaps in each industry segment based on magnitude and timing of workforce need, presence of education and training programs, and requirements for offshore-wind-specific training, certificates, or skill sets. Red indicates that one or more of these gaps may be present and is explored in more detail in this report. Areas left blank indicate workforce programs that do not train workers for roles in that specific industry segment.

Table ES-1. Alignment and Gaps of Workforce Programs That Educate and Train Occupations Across Industry Segments

Industry Segment	Full-Time Equivalents (FTEs)		Workforce Programs				
Workforce Requirements	Average Annual Jobs, 25% Domestic Workforce	Average Annual Jobs, 100% Domestic Workforce	Safety Training	Community Colleges	Union-Led Training	Maritime Academies	University Programs
Development	800	3,200		Yellow		Green	Green
Manufacturing and Supply Chain	12,300	49,000					
Regional professionals							Green
Factory-level management			Yellow				Yellow
Design and engineering							Green
Quality and safety			Yellow	Yellow			Yellow
Factory-level worker	*	*	Yellow	Red	Red		
Facilities maintenance			Yellow	Green			
Ports and Staging	400	1,600					
Marine crew			Red	Yellow	Yellow	Green	
Terminal crew	*	*	Red	Red	Red		
Logistics management			Yellow	Green			Green
Facilities management			Yellow	Green			Green
Vessels	500	2,100					
Marine crew			Red	Yellow	Red	Green	
Project crew			Red	Yellow		Green	Yellow
Construction crew	*	*	Red	Red	Red		
Operations and Maintenance	600	2,300					
O&M crew	*	*	Red	Green	Green		Green
Plant operations			Yellow	Green			Green

Meeting Workforce Requirements:
- Green: No gaps or gaps being addressed
- Yellow: Some potential gaps
- Red: One or more key gaps
- Blank: Program has limited contribution to workforce development
- * Largest worker contribution

Note: Average annual jobs represent a range of potential employment each year between 2024 and 2030 to support a project pipeline of 30 gigawatts of offshore wind energy by 2030

According to our assessment of workforce programs for the offshore wind energy industry the following critical gaps may exist:

- **Additional community college and union-led training programs such as apprenticeships may be needed to meet the workforce need for manufacturing factory-level workers, port terminal crews, and vessel construction crews**. Basic and skilled tradespeople who support these installation and manufacturing roles will be in high demand for the offshore wind energy industry. These workers are also in high demand in other industries and require years of experience, which is often provided through apprenticeship programs. Developing training programs together with planned facilities will ensure that a trained, local workforce is available when and where needed.

- **The standardization of safety certifications for people working at sea to build and operate projects is required to ensure training programs meet desired industry requirements for vessel crews, port terminal crews, and O&M crews**. There are no officially adopted offshore wind energy industry safety training standards in the United States, but organizations are working on aligning existing U.S. standards and training requirements with the industry and developing and certifying programs and facilities to support standards such as the Global Wind Organisation Basic Safety and Sea Survival Training. Without agreeing on the necessary safety standards, a vessel operator may be unwilling to hire a domestic crew who they feel are not appropriately trained to conduct job tasks at sea.
- **To transition workers from maritime, oil and gas, and other industries and enable existing generalized professionals to use their prior knowledge and experience**, education and training institutions should develop programs that provide the needed offshore-wind-industry-specific knowledge, education, and experience.

There are notable strengths among current workforce programs, including:

- **Community colleges are already establishing offshore wind energy programs focused primarily on offshore wind technician and safety training, in partnership with other organizations**. Existing wind technician training programs can provide between 100 and 125 graduates annually. Assuming existing programs are scaled up and new programs added in line with the project development pipeline, this is not a short-term immediate gap.
- **The United States has a robust network of university programs to educate students in professional, engineering, and management roles**. The skills for these types of roles are generally transferable among industries, so the development of new degree programs is not as critical as in other segments. However, research has shown that industry organizations often prefer direct experience in wind energy (Stefek et al. 2022), so additional offshore-wind-specific coursework could be created to supplement existing degree programs to help meet this need.

Recommendations – Key Actions To Bridge Supply and Demand

Education and Training Programs

Current training programs and facilities have largely been developed with industry and/or state engagement and investments. Key considerations and recommendations regarding the development of education and training programs include:

- **To bridge workforce gaps efficiently and maintain consistency across education and training programs, workforce development coordination should continue and be expanded**. These efforts would support alignment between supply and demand through time and between states and regions. They should focus on ensuring programs are developed that meet industry requirements; are consistent; are developed in the right geographies and scales to meet but not exceed demand; and leverage funding and knowledge. Collaboration is typically best when it includes partnerships with state and local governments and industry, which provide funding, assistance with establishing facilities, and networking opportunities.

- **Aligning and standardizing safety training for offshore wind energy workers is one of the highest priorities to ensure an adequately trained workforce is available to build projects**. Currently, there is no official industry training standard; however, early support from states and cooperation with industry, academic organizations, training providers, and unions have proven successful in bridging gaps between the Global Wind Organisation and existing programs and increasing the program development rate.
- **Aligning training requirements and times with expected demand will be a substantive challenge in the near term as the industry expands**. Many of the additional development-segment roles that are needed in the nearer term require bachelor's- and master's-level credentials and relevant experience. Many of the skilled trade roles that will be needed in high numbers during manufacturing and installation require multiyear training/apprenticeship programs and in some cases years of experience. Accelerating training programs timing or increasing on-the-job training may be important for aligning domestic workers with these roles and bridging the most critical gaps. If this does not happen, it may result in an increased use of foreign workers to fill the gaps.
- **Many existing education and training programs could be adapted or expanded to address offshore-specific topics**. For example, university engineering programs could include optional offshore wind energy course work or union training programs could partner with industry and community colleges to offer complementary offshore-wind-specific training. These additive programs could also support upskilling existing workers. Although some of these programs are already being developed, there are many more that could be adapted and leveraged in this way.
- **U.S. and global entities should collaborate to structure trainings**, leveraging lessons from the international offshore wind industry while providing U.S.-specific context.
- **Engaging students in renewable energy from an early age and including offshore wind, particularly in coastal communities, will be important in supporting the development of a trained workforce**. Although not investigated explicitly as a workforce program, primary and secondary educational programs will play a key role in generating awareness and interest and providing the educational foundation for pursuing further education and training for the future offshore wind energy industry.

Workforce Initiatives

As the U.S. offshore wind workforce develops, programs and initiatives that create a diverse workforce and target communities most impacted by offshore wind development, including a transition from fossil-fuel industries, will help jump start the industry and ensure equitable distribution of jobs and economic benefits. Key considerations and recommendations relating to these initiatives include:

- **Focusing on the local workforce to offer an opportunity to simultaneously ensure communities impacted by offshore wind development are benefiting economically** while meeting workforce requirements. Economic development organizations are actively engaged in many of the states along the East Coast to ensure a role for their states and coastal communities in offshore wind energy development. Connecting local workforce initiatives and education and training programs with infrastructure investments in manufacturing factories, ports, and O&M is key to involving local community members.

- **Continuing and expanding partnerships with unions can support the supply and training of the required workforce**. Unions are playing an active role in developing the offshore wind workforce as the industry grows, both in supplying a local workforce and ensuring jobs in the industry offer competitive salary and benefits.
- **Supporting apprenticeship programs for individuals to gain necessary skills for trade careers.** Preapprenticeship programs can help individuals prepare to participate in formal apprenticeship programs. Unions have indicated that these types of programs are a key mechanism that they use to attract and train underserved populations to enter the union workforce.
- **Repurposing oil and gas manufacturing facilities to accelerate segments and involve different geographic regions in domestic offshore wind energy manufacturing** while transitioning jobs from the oil and gas industry. While these facilities are typically located in the Gulf of Mexico region, the skilled workforce could benefit projects in the Atlantic region, as demonstrated in the construction of the Block Island Wind Farm. Workers in development and installation roles could also be transitioned, leveraging their offshore knowledge with additional wind energy training.
- **Recruiting and upskilling members of marine industries could help fill peaks in installation requirements while benefitting these members when they are the most impacted.** While offshore wind power plant construction could impact some marine industries (i.e., fishing), it may also present opportunities for vessels to support installation, such as for survey or guard vessels.
- **Treating diversity and inclusion initiatives that aim to attract underrepresented and underserved populations as a high priority by all stakeholders** involved in developing the offshore wind energy workforce.
- **Assessing and tracking requirements for diversity and local labor, as they are increasingly becoming part of project agreements and state offshore wind requirements**, to ensure they achieve their desired outcomes to promote a more equitable workforce.

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1 Introduction

With 42 megawatts (MW) of installed capacity, the United States offshore wind energy industry can be considered emerging; however, it is set for rapid expansion in the coming years with a project development and operational pipeline of nearly 40 gigawatts (GW) in different phases of development (Musial et al. 2022). This growth is supported by national- and state-level targets and commitments, including the Biden administration's national offshore wind target to reach 30 GW of installed offshore wind capacity by 2030 while developing a domestic workforce (The White House 2021), and state-level procurement commitments.

Although the growth of the offshore wind energy industry represents an opportunity to create jobs, offshore wind projects are complex, requiring an extensive, varied, and well-trained workforce. Educational institutions, state governments, labor organizations, and others are taking action to understand the opportunities and requirements of the industry and to develop education and training programs to meet those needs. However, gaps remain in fully understanding and meeting workforce needs at a national level.

This "U.S. Offshore Wind Workforce Assessment" estimates future offshore wind energy job opportunities (demand) and identifies existing relevant occupations and requirements, emerging educational institutions, training programs, and initiatives that can contribute to meeting workforce needs (supply). It then recommends actions to bridge gaps and support key stakeholders, such as offshore wind energy businesses; state and local governments; educational organizations; and unions, in their efforts to attract, educate, train, and retain a domestic workforce to support this burgeoning industry.

This assessment (see Figure 1) provides a detailed, national-level analysis to inform the development of an offshore wind energy workforce by:

- Estimating the job opportunity space across development, manufacturing and supply chain, ports and staging, maritime construction, and operations and maintenance (O&M)
- Detailing the occupational roles for different groups in each industry segment
- Assessing educational needs across the five industry segments
- Creating and maintaining an inventory of existing and planned training and education programs and facilities
- Identifying opportunities and challenges for attracting and training an offshore wind energy workforce.

Figure 1. A conceptual organization of the assessment

2 Workforce Demand

Estimating the workforce needs for the offshore wind energy industry is critical to understanding how educational institutions, unions, and other workforce development initiatives can train and prepare workers for the future.

Current employment in the industry is limited because it is relatively new in the United States. For example, total employment in the domestic wind energy industry was 120,164 workers in 2021, with the offshore wind sector accounting for 877 workers (U.S. Department of Energy [DOE] 2022b). Going forward, the offshore wind industry will create additional jobs, including engineers, management, land-based and offshore skilled trades, and professional services, which have unique skills, education, and experience to meet industry needs.

To meet the target of 30 GW of U.S. installed offshore wind capacity by 2030, average annual employment levels (full-time equivalent [FTE[1]] are estimated at 15,000 and 58,000 based on 25% and 100% domestic content scenarios, respectively. Averages are computed for period of 2024 to 2030 (Figure 2).[2] In any given year, actual employment requirements could be higher or lower than these levels based on industry demand or variability in domestic content which is the percentage of domestic workers, vessels, suppliers, or businesses supporting industry segments; however, average employment throughout this period is generally expected to fall in this range. In addition, the total workforce need is expected to start toward the bottom of the range and grow over time as the offshore wind energy industry develops. Figure 2 indicates that job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content.

[1] A full-time equivalent (FTE) means one job is the equivalent of one person working 40 hours per week, year-round or 2080 hours. Two people working full time for 6 months equals one FTE. Two people working 20 hours a week for 12 months also equals one FTE.

[2] This estimate includes only the offshore wind jobs associated with development, manufacturing, installation, and operation of offshore wind energy plants (both direct and indirect). However, the estimates do not include additional jobs in communities supported by offshore wind activity, also known as induced impact jobs. For example, 33,000 additional jobs in communities by 2030 was reported in (The White House. 2021) as part of an estimate of 30 GW of offshore wind by 2030 induced impacts jobs.

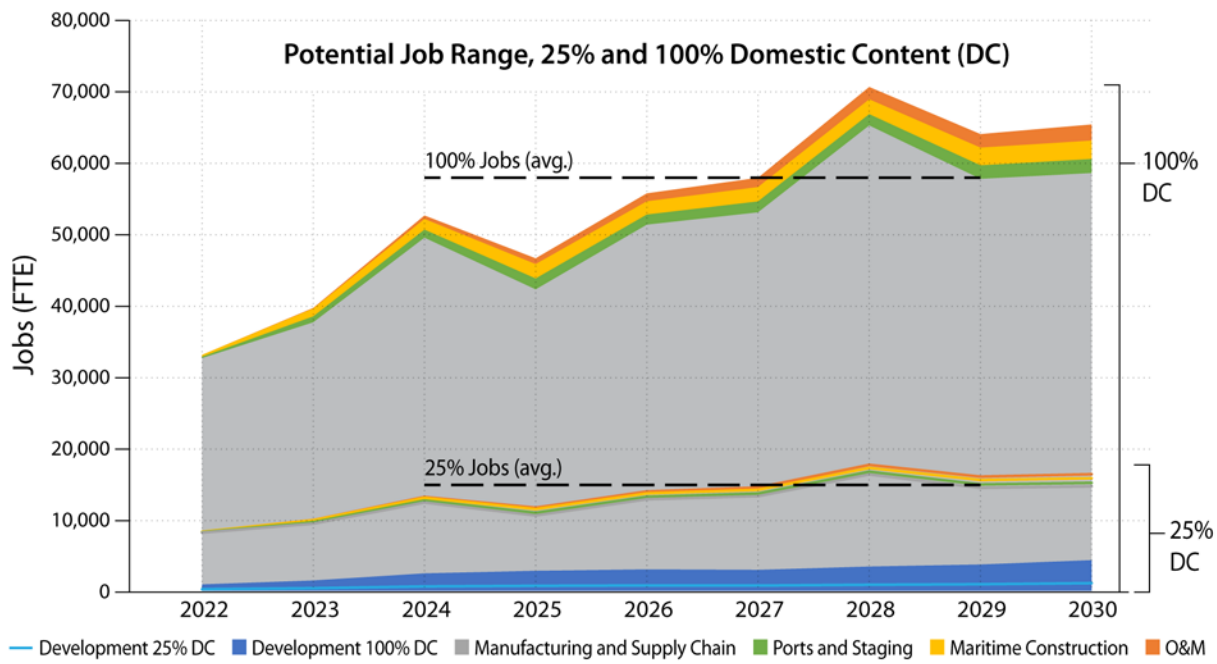

Figure 2. Potential job estimates across industry segments to support a project pipeline of 30 gigawatts of offshore wind energy by 2030, assuming a domestic workforce lower bound of 25% and an upper bound of 100%. Also shows a range of average employment each year between 2024 and 2030.

Modeling the offshore wind energy project pipeline helps estimate the workforce needs at a national level and shows how it develops across projects. Many of the workers who support a single offshore wind power plant, typically for a specific role, will also support other plants over time performing that same role. Therefore, to quantify the number of jobs for this assessment, we estimated the workforce need for individual offshore wind energy projects, based on specific site, technology, and installation characteristics. We used a combination of a process-based and input-output (I-O) economic impact analysis, which expands the capabilities offered by the Jobs and Economic Development Impact (JEDI) model, to estimate the number of jobs for each segment. We also modeled a pipeline of projects under construction, announced, or planned on the East and West Coasts that contribute to the goal of 30 GW of offshore wind by 2030 based on information in the "Offshore Wind Market Report: 2021 Edition" (DOE 2021b) and component demand in "30 GW by 2030: A Supply Chain Roadmap for Offshore Wind in the United States" (Shields et al. 2022). These per-plant jobs are then plotted over time to show the workforce needs for the entire industry between 2022 and 2030. The pipeline of projects and a detailed methodology including key assumptions is provided in Appendix A.

These workforce estimates include the direct and indirect workers representing several occupations and roles across five segments of the offshore wind energy industry:

- **Development**. Includes mostly professional roles (e.g., biologists, policy experts, project managers, community planners) that occur prior to installation of the offshore wind power plant, such as those associated with site assessment, plant design, financing, project management, and permitting review.

- **Manufacturing and supply chain**. Includes the jobs to fabricate and assemble components, subassemblies, parts, and materials from multiple tiers of the manufacturing process. Roles range from engineering and component design to factory-level workers working production lines.
- **Ports and staging**. Includes terminal crews, logistics, and management-related roles located portside. Many port jobs are laborers and trade workers who support offshore wind plant construction and installation.
- **Maritime construction**. Includes all workers on a vessel operating at sea to install offshore wind energy components, including the marine crew, engineers, and construction crews. Many maritime construction jobs are laborers and trade workers who support offshore wind plant construction and installation.
- **Operations and maintenance**. Includes wind technicians and associated operating plant management.

The largest U.S. workforce opportunity is in manufacturing offshore wind components while developing a robust domestic supply chain to supply the major component factories of subassemblies, parts, and materials. Figure 3 shows the size of the contribution of each industry segment assuming all labor, components, and suppliers are sourced from the United States.

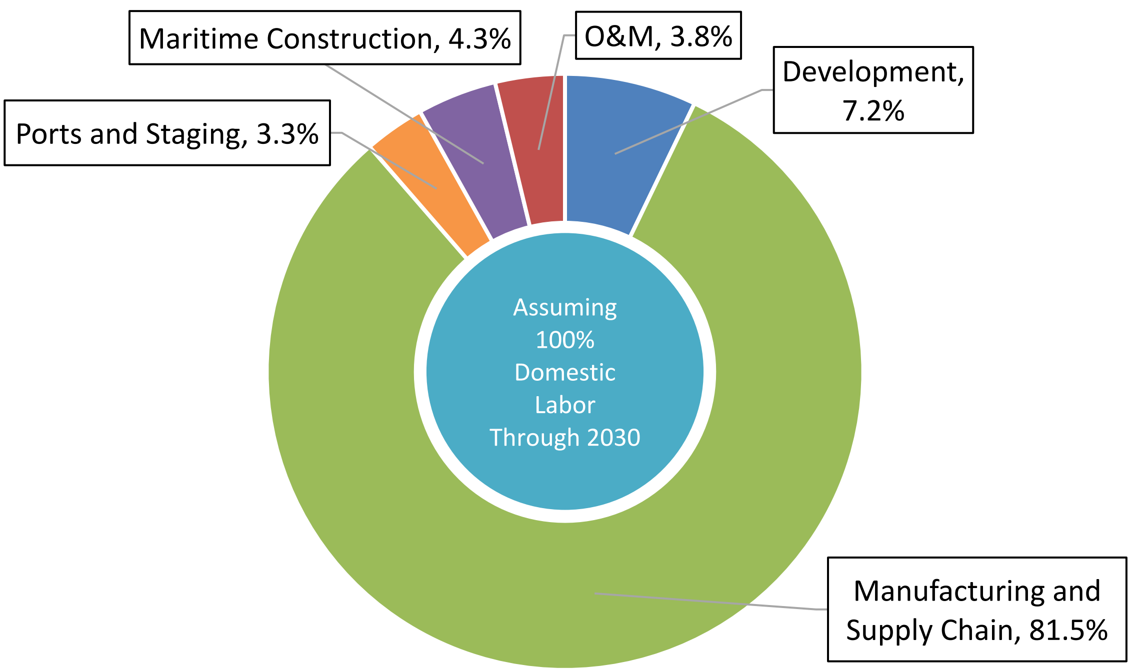

Figure 3. The largest opportunity space for the offshore wind energy workforce is in manufacturing and supply chain, which depends on developing domestic capabilities

While manufacturing and supply chain represents the greatest opportunity space for jobs, development, ports and staging, and O&M represent largest contributions in the short term (2022-2025), especially when considering the timing of workforce need (e.g., manufacturing facilities will develop over time) and the likelihood of different segments supporting a domestic workforce. Offshore wind power plants built in the mid-2020s to 2030 will increasingly use more domestic resources. Workforce needs from each plant are expected to increase over time as manufacturing and supply chain plants are built, U.S.-flagged[3] offshore wind vessels support installation activities, and the U.S. offshore labor market matures.

Each industry segment contributes to the job opportunity based on the offshore wind pipeline but has unique considerations into the types of workers, certainty of domestic content, and insights about the workforce demand.

2.1 Development

Before a project is initiated, there is significant development work involved in understanding the market and available technologies, identifying and evaluating opportunities, and participating in lease auctions and power purchase agreements. This work is primarily done by developers within wider teams that are not exclusive to a specific project and with support from consultants and advisors. Once a project is initiated, a small, dedicated project team is formed, which grows as the project progresses to a team of approximately 30-50 people. This team manages and oversees the project during a 3- to 5-year period and hires contractors to conduct environmental assessments, project design, interconnection studies, and other development activities.

Development jobs include mostly professional roles (e.g., biologists, engineers, policy experts, project managers, community planners) that occur prior to installing the offshore wind power plant, such as those associated with site assessment, plant design, financing, project management, and permitting review. A list of development roles, descriptions, education, and experience requirements is provided in Appendix B.

Figure 4 shows the average range of potential growth in development-segment jobs within the offshore wind energy industry. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 800 and 3,200 based on 25% and 100% domestic content scenarios, respectively. The figure indicates that job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. For example, in 2024, the near-term potential job need is between 600 and 2,400, but this could grow in the longer term to between 1,100 and 4,300 in 2030.

[3] A U.S.-flagged vessel is any ship registered (or having national status) subject to the laws of the United States.

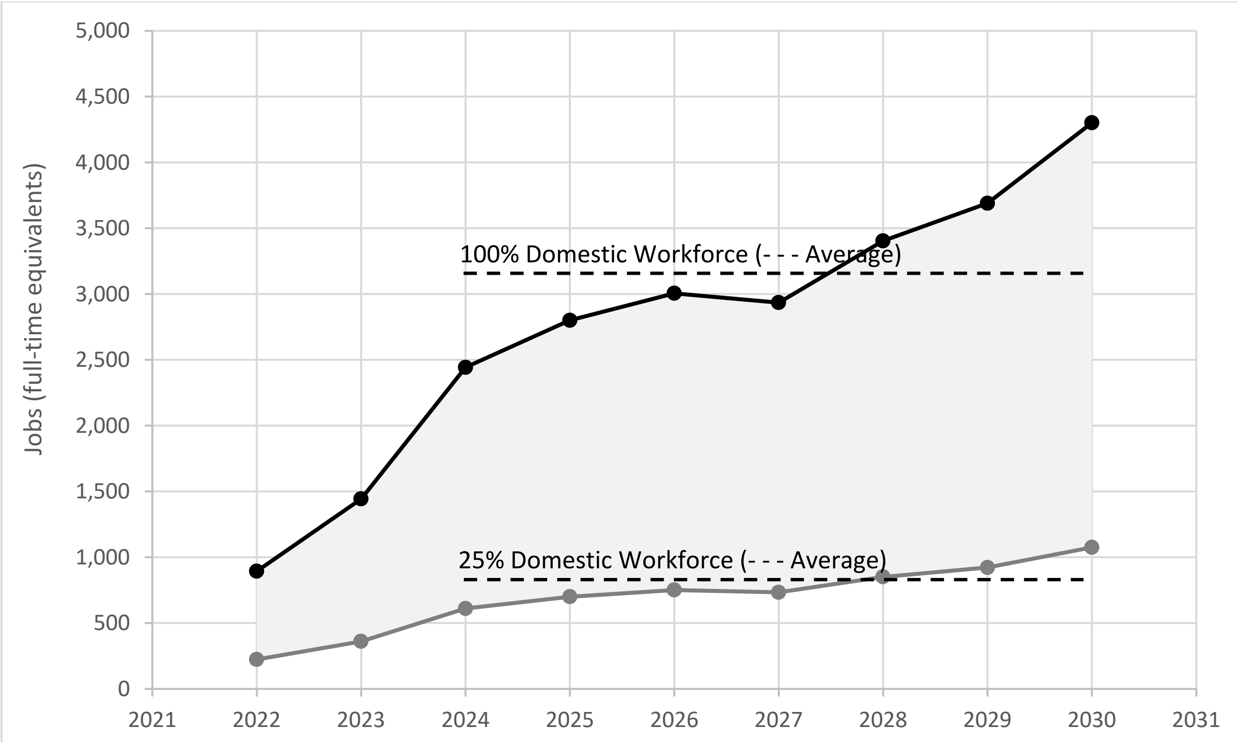

Figure 4. Number of jobs over time (FTE-year) related to development of offshore wind power plants to meet pipeline demands

Our assessment indicates there is more certainty that many of these workers could be hired domestically and the workforce need has the potential to be closer to the 100% range.[4] The United States has existing professionals working in the land-based and other renewable energy industries, in addition to other fields. Existing education programs could also add an offshore wind energy component to support a domestic workforce.

The workforce need during the development stage of an offshore wind plant project can vary significantly in both number and types of roles as the development progresses from project initiation to the final investment decision ahead of construction. Development jobs are among the first roles developers hire to assist with the offshore wind energy deployment process. While significant deployment efforts are already underway and many development roles for initial offshore wind projects have been hired, as indicated by the large ramp up in 2022 and 2023 (Figure 4), workforce needs will continue to increase through 2025 as multiple, concurrent projects are developed across the project pipeline. Workers in the development segment are expected to support multiple projects and processes throughout the project life cycle, and therefore workforce need is consistent over time from 2025 to 2030.

[4] NREL has been hosting offshore wind workforce network advisory group meetings and conducting expert elicitations to receive information about workforce opportunities and gaps.

2.2 Manufacturing and Supply Chain

The largest opportunity for employment in the U.S. offshore wind energy industry is in manufacturing components and the associated supply chain. Several manufacturing facility announcements have been made; however, these facilities will take a few years to start producing components. The extent to which domestic jobs are realized depends on the building of U.S. manufacturing facilities and those facilities leveraging a U.S. supply chain to source subassemblies, parts, and materials.

Manufacturing and supply chain estimates include all job roles associated with the assembly, fabrication, or production of offshore wind components, subassemblies, parts, and materials, including management, assembly, trade workers, and engineers. Roles can be grouped into professionals, factory-level management, design and engineering, quality and safety, factory-level workers, and facilities maintenance. A list of manufacturing and supply chain roles, descriptions, education, and experience requirements is provided in Appendix B.

If component production occurs at a port, the jobs associated with producing those components are categorized under manufacturing and supply chain and not under ports and staging. Further, manufacturing and supply chain estimates do not include jobs associated with building the facilities, only those associated with producing offshore wind components.

Figure 5 shows the average range of potential growth in manufacturing and supply chain-segment jobs within the offshore wind energy industry. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 12,300 and 49,000 based on 25% and 100% domestic content scenarios, respectively. The figure indicates that job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. For example, in 2024, the near-term potential job need is between 12,000 and 47,500, but this could grow in the longer term to between 13,600 and 54,000 in 2030. The workforce estimate represents all the jobs (in FTEs) to fabricate and assemble all the components, subcomponents, parts, and materials for all tiers of the manufacturing and supply chain, and not solely major component (e.g., blades, towers, nacelles, monopiles, cables) fabrication and assembly.

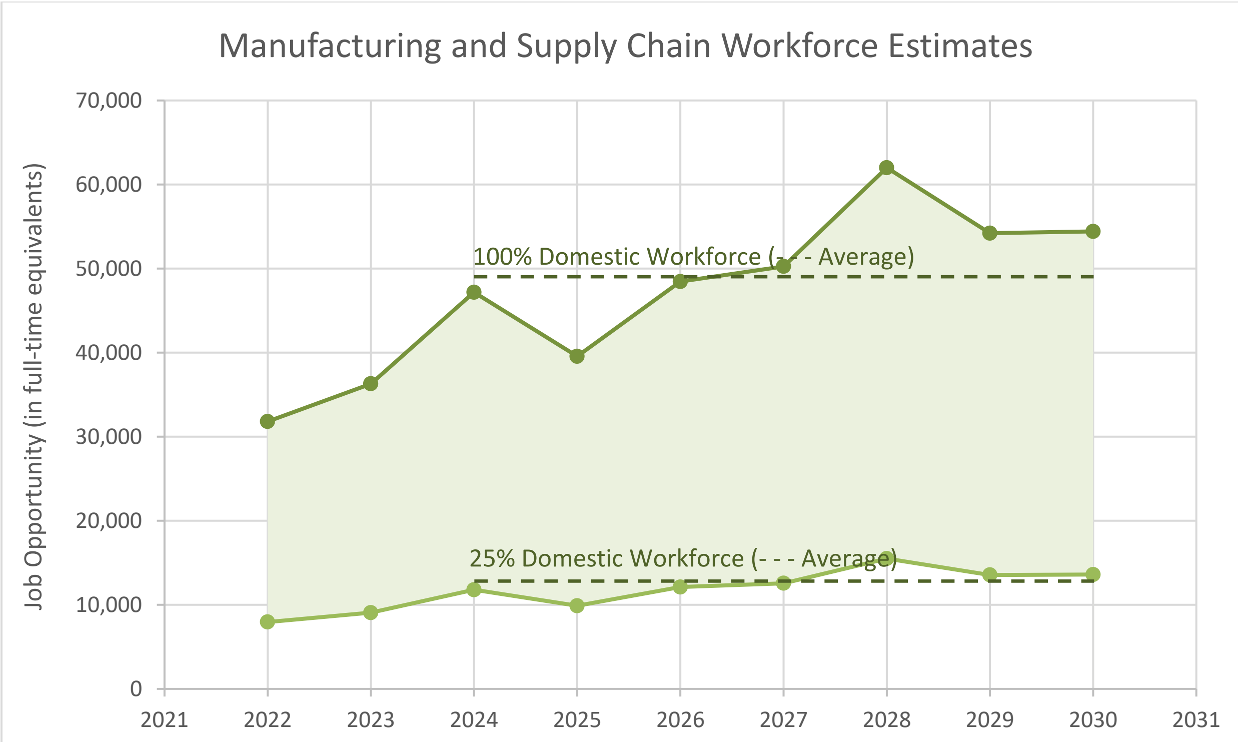

Figure 5. Number of jobs over time (FTE-year) for producing all components needed to meet the demands of the offshore wind energy pipeline

Our assessment indicates there are a number of different factors that will determine how and when the offshore wind supply chain with develop in the United States, so the timing and magnitude of the required workforce is less certain than other segments.[5] The workforce opportunity will depend on the level of domestic content each component achieves and will vary over time as new manufacturing plants are built and suppliers provide subcomponent, parts, and materials (Shields et al. 2022).

Timing is critical for workforce development in the manufacturing and supply chain industry segment. The number of jobs is expected to increase throughout this decade (2022-2030) at different rates for each component. For example, monopile[6] facilities may start production much sooner than nacelle assembly facilities. It is likely that the initial components will be imported into the United States while U.S. manufacturing and supply chain facilities are built, suppliers are contracted to provide parts and materials, and a domestic workforce is trained and hired. Educational institutions, unions, original equipment manufacturers, and developers could work together to ensure workers are adequately trained and ready to hire as U.S. manufacturing begins production (Shields et al. 2022).

[5] The National Renewable Energy Laboratory (NREL) has been hosting offshore wind workforce network advisory group meetings and conducting expert elicitations to receive information about workforce opportunities and gaps.
[6] A monopile is one type of offshore wind energy foundation, typically a hallow steel cylinder driven into the seabed. Turbine components are installed on the monopile.

The largest contribution of workers for the manufacturing and supply chain segment is at the factory level (those who are doing the physical processes involved in production). Because the total estimates for this industry segment are high, there is a need to train and hire a significant workforce. These workers typically have training in basic and skilled trades, such as welders and electricians, which are high-demand skill sets across renewable energy and other industries.

Table 1 lists the contribution of each wind turbine component to the total manufacturing and supply chain workforce estimates (Figure 5) and the percentage breakdown of direct and indirect jobs for each component.[7] The workforce contribution provides the breakdown of job opportunity for each component from the total manufacturing and supply chain job estimates. Direct jobs include workers who fabricate or assemble final components at a manufacturing plant and indirect jobs who produce parts or materials for a major component.

Table 1. Breakdown of the Job Estimate Contribution of Offshore Wind Energy Components in 2026 Overlaying Workforce Development Assumptions

Includes job potential for fixed-bottom and floating technologies to meet demands of the offshore wind pipeline.

Component[8]	Workforce Contribution (%)	Direct Job Contribution (%)	Indirect Job Contribution (%)
Rotor blades	7.5%	48.3%	51.9%
Nacelle	38.7%	35.6%	64.4%
Towers	10.2%	43.7%	56.4%
Monopiles	8.8%	34.3%	65.7%
Transition piece	5.4%	34.3%	65.7%
Jacket	3.4%	34.3%	65.7%
Gravity-based foundation	2.7%	38.5%	61.5%
Semisubmersibles	14.9%	34.5%	65.5%
Substation topside	0.3%	71.3%	28.7%
Array cable	2.7%	38.4%	61.6%
Export cable	5.4%	38.4%	61.6%

The largest U.S. offshore wind energy workforce opportunity can be achieved through supply chain development as the indirect impacts represent the largest contribution to support domestic jobs (Shields et al. 2022). For most components, the indirect jobs have the higher contribution percentage, therefore, if the United States activated a robust supply chain to provide parts and materials for the major components, it would support more jobs. In addition, it would allow more states and regions to participate in the offshore wind supply chain and receive economic benefits.

[7] The table percentages are based on the job estimates, which assume all labor, subcomponents, parts, and materials are sourced from the United States (e.g., 100% domestic content).
[8] A description of these components can be found in "The Demand for a Domestic Offshore Wind Energy Supply Chain" (Shields et al. 2022) report.

The nacelle has the largest workforce opportunity out of all the offshore wind components; however, to achieve a higher domestic content and workforce will require the fabrication and assembly of the many subcomponents internal to the nacelle (e.g., generators, gearboxes, power converters) and activating their individual supply chains for parts and materials (Shields et al. 2022).

Fabricating metal components, such as towers and offshore substructures (e.g., monopiles, jackets, gravity-based foundations), also represents a significant workforce opportunity with workers using similar metalworking skill sets. Fabricating secondary steel, with roles such as welding, was identified as a potential challenge to meeting the workforce need for producing so many metal components.

2.3 Ports and Staging

The revitalization and development of ports along the coasts to support the offshore wind energy industry will create thousands of new jobs and spur economic growth near portside communities. Of the 22 East Coast ports and 13 West Coast ports, only a few have sufficient capabilities to support offshore wind energy activities, and several are actively investing in infrastructure upgrades (Shields et al. 2022). In communities neighboring port developments, focusing on the local workforce offers an opportunity to meet workforce needs while ensuring communities impacted by offshore wind energy developments realize economic benefits.

These ports will serve as hubs for assembly, operations, and maintenance for the wind turbines, and some may include manufacturing facilities as well. Ports and staging jobs include terminal crews, logistics and management, and facilities management located portside, and marine crew roles. A list of ports and staging roles, descriptions, education, and experience requirements is provided in Appendix B.

Ports on the U.S. coasts can support the U.S. offshore wind industry through staging components, supporting vessel loading, and general operations. The timing of port and vessel jobs is strongly connected because workers load components from the port to the vessel for installation.

Figure 6 shows the average range of potential growth in ports and staging-segment jobs within the offshore wind energy industry. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 400 and 1,600 based on 25% and 100% domestic content scenarios, respectively. The figure indicates that job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. For example, in 2024, the near-term potential job need is between 300 and 1,100, but this could grow in the longer term to between 500 and 2,000 in 2030.

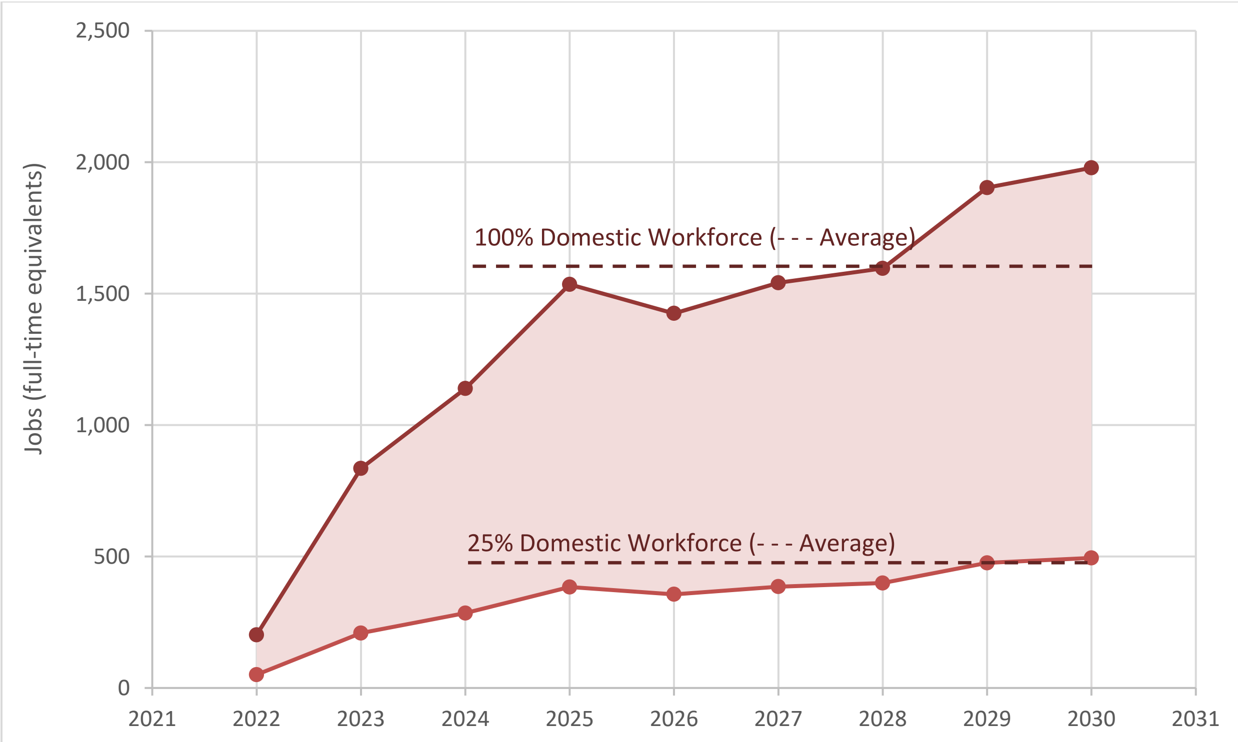

Figure 6. Number of jobs over time (FTE-year) related to ports and staging activities for offshore wind power plants to meet the demands of the offshore wind pipeline

Our assessment indicates that a port is a stand-alone infrastructure that requires a local workforce from nearby communities to operate and the United States has a skilled workforce currently operating these existing ports. Therefore, there is a higher likelihood of a domestic workforce developing in this segment for the offshore wind industry, with job estimates potentially falling on the upper end of the range, closer to the 100% domestic content job estimates.[9]

The largest contribution of workers for the ports and staging segment is from terminal crews involved in staging components and loading vessels (Table B-9). These workers typically have training in basic and skilled trades, which are high-demand skill sets across renewable energy and other industries.

Additional economic development through job creation is likely in industrial waterfront communities near ports that are upgrading their infrastructure to support offshore wind energy development. A 2018 assessment found existing U.S. ports generate 652,078 direct jobs with an average salary of $62,800. An additional 501,555 indirect jobs and 1,056,942 induced jobs supported by port-related activities can also increase economic opportunity through workers spending earnings in communities (Martin 2019). While offshore will likely add a small fraction to these jobs, the offshore wind is an opportunity to increase port utilization.

[9] NREL has been hosting offshore wind workforce network advisory group meetings and conducting expert elicitations to receive information about workforce opportunities and gaps.

2.4 Maritime Construction

Installing offshore wind energy components at sea requires a workforce that can operate vessels and install large industrial structures, machines, and cables in challenging ocean environments. Several different types of vessels, with unique capabilities, are required to complete installation activities for offshore wind power plants.

The maritime construction workforce can support multiple offshore wind projects. In the United States, the workforce need largely depends on the number and type of vessels available, the number of crew members on a vessel, and the duration of installation.

Each vessel has workers on board comprising a marine, project, and construction crew. The number of workers in each crew type are categorized for each vessel used in this study are depicted in Figure 7. Total crew on board each vessel, along with major assumptions used to arrive at that total, are itemized in Table A-1. These totals and worker types were validated with industry-provided data from offshore wind plant developers, union leaders, maritime and offshore safety trainers, educators, offshore wind personnel and logistics experts, and vessel operators. Assumptions associated with worker on board totals are listed in Appendix A. A list of maritime construction roles, descriptions, education, and experience requirements is found in Appendix B.

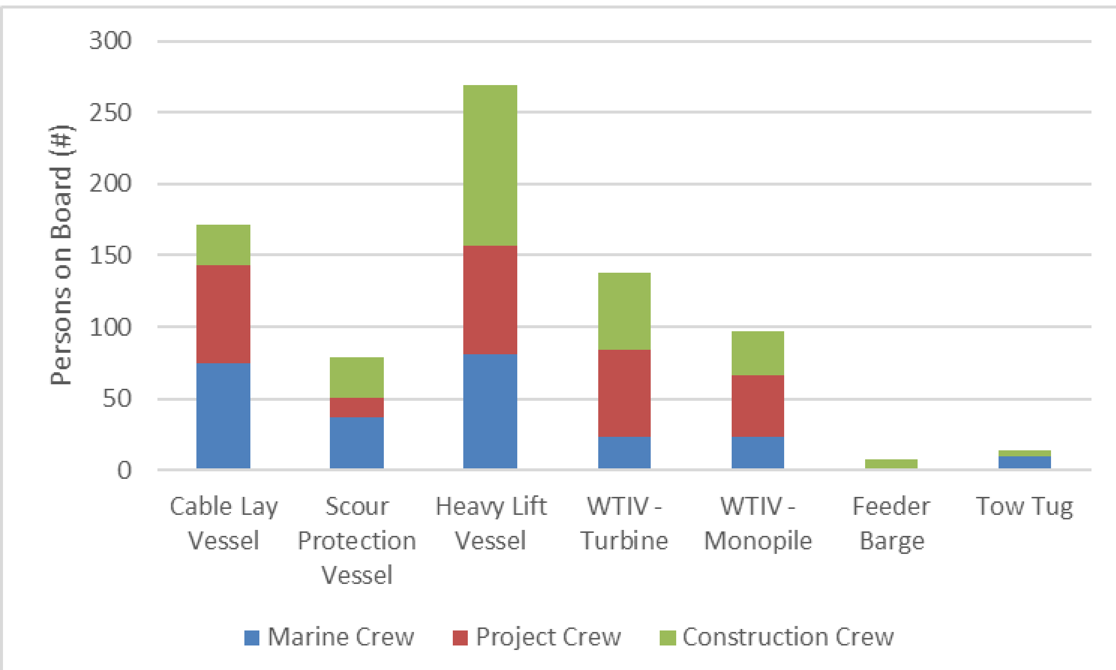

Figure 7. Number of persons on board for each vessel, categorized by crew type

(WTIV = wind turbine installation vessel)

Jobs related to vessels are also included in ports and staging and operations and maintenance industry segments. Job roles like pilots typically operate from the portside (Section 2.3). For operating offshore wind energy plants, jobs estimates are included in Section 2.5 including those workers on service operation vessels and crew transfer vessels.

Figure 8 shows the average range of potential growth in maritime construction-segment jobs within the offshore wind energy industry. Average annual employment levels (FTE/year) from 2024 to 2030 are estimated at 500 and 2,100 based on 25% and 100% domestic content scenarios, respectively. The figure indicates that job growth is not flat across this period but is expected to grow in parallel with the industry and at a rate dependent on using domestic content. For example, in 2024, the near-term potential job need is between 400 and 1,500, but this could grow in the longer term to between 650 and 2,600 in 2030.

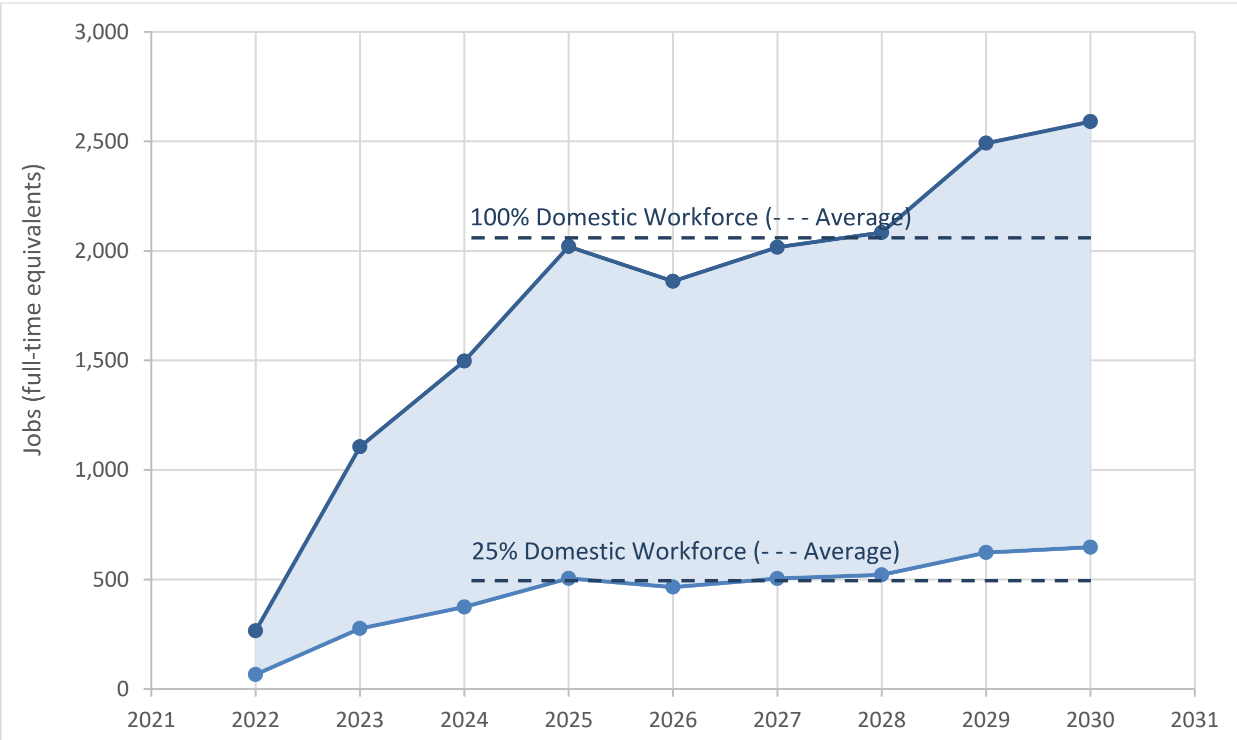

Figure 8. Number of jobs over time (FTE-year) related to maritime construction activities using a fleet of vessels to install the offshore wind pipeline

Figure 9 shows the contribution of each vessel type to the job estimates provided in Figure 8. For this analysis, a standardized installation strategy provides an approximate estimate of the workforce needs over time for a fleet of vessels.[10] The standardized strategy for fixed-bottom offshore wind includes the processes to install monopiles using a wind turbine installation vessel (WTIV), wind turbine components (e.g., nacelles, blades, towers) using a WTIV, offshore substations using a heavy-lift vessel, feeder barge, and tow tug combination, a scour protection vessel, and a cable lay vessel to install array cables and export cables. The strategy for floating

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[10] The installation strategy for offshore wind energy projects may change over time and use different vessels to complete tasks such as substructure and wind turbine installation. To provide a high-level and reasonable approximation, we used a standard fleet of vessels to complete the same tasks. However, we modeled the unique characteristics (e.g., distance to shore, wind turbine size, plant capacity, and cable type) for each plant in the pipeline of projects, which impacts the process and times estimated by NREL's Offshore Renewables Balance-of-system and Installation Tool (ORBIT). For more information on the ORBIT balance-of-system costs model visit https://www.nrel.gov/docs/fy20osti/77081.pdf.

offshore wind includes all of the same vessels except for the wind turbine components and substructure, which instead uses tow tugs to pull those components to sea.

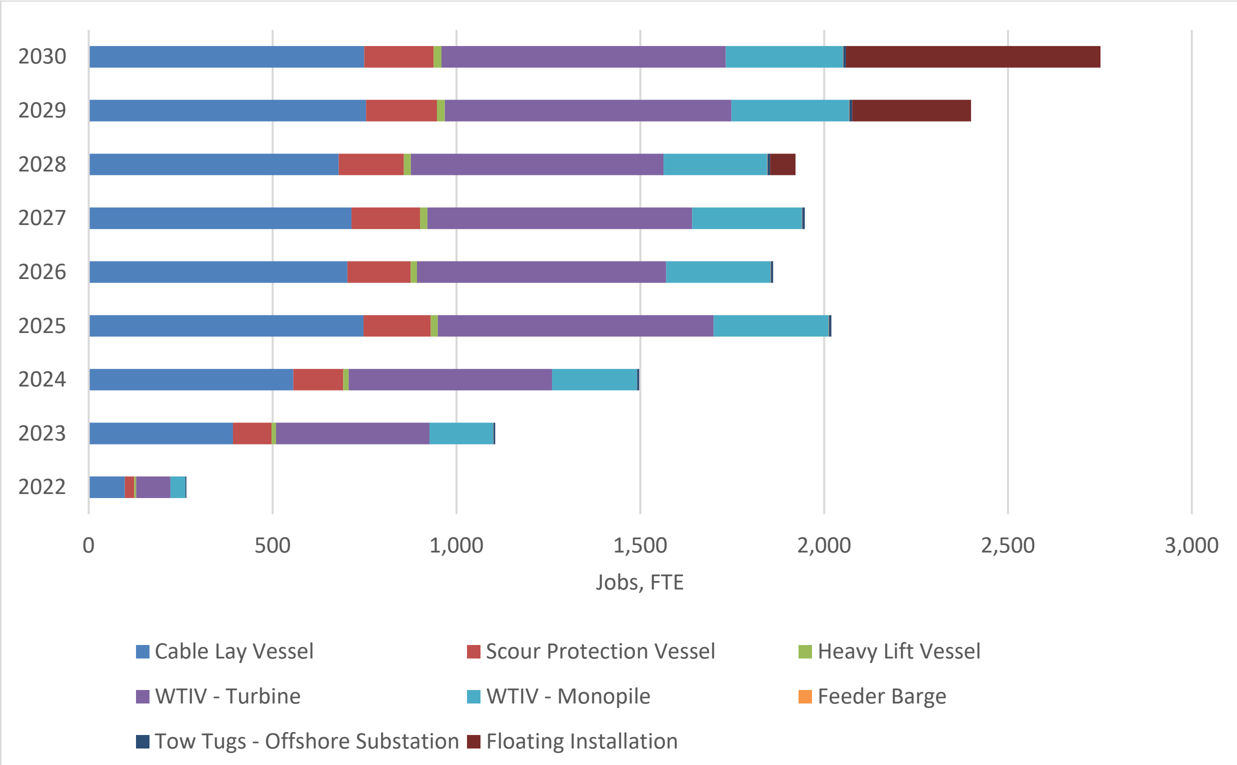

Figure 9. Job contribution of each vessel type based on the installation hours each person on board works

NREL developed a custom, process-based model to forecast workforce demand over time for different vessel types based on achieving 30 GW of offshore wind energy by 2030. This model, referred to as the Offshore Wind Vessel Workforce Estimator, expands upon the capabilities of the Offshore Wind JEDI model by combining job modeling, occupation, and salary data with detailed installation strategies and process times from the National Renewable Energy Laboratory's (NREL's) Offshore Renewables Balance-of-system Installation Tool (ORBIT).[11] The processes and times to complete installation are paired with labor requirements (Figure 7) to provide an estimation of workforce needs over time based on the project pipeline.

Our assessment indicates that there is uncertainty about how many maritime construction workers will be hired domestically versus from a foreign country to support U.S. offshore wind energy installations. This uncertainty arises from where vessels will be flagged, developers trying to develop alternate means of meeting project deadlines, uncertainty around vessel fleet availability (especially given regulations), and potentially extended installation times as a result of project delays from using different types of vessels. Therefore, the size of the domestic workforce will fall somewhere between the job opportunity range presented in Figure 8, and

[11] User documentation and more information about the ORBIT model is available at https://www.nrel.gov/docs/fy20osti/77081.pdf.

likely increasing toward the upper range as more Jones-Act-compliant installation vessels are built or unique installation strategies use U.S. workers.[12] In 2022, there are no U.S.-flagged wind turbine installation vessels and only one under construction. The construction of these vessels typically takes 3−4 years from commitment to deployment.

2.5 Operations and Maintenance

The O&M workforce includes long-term jobs that ensure electricity is generated by the offshore wind plant. Many positions manage, oversee, and conduct monitoring, testing, repair, and maintenance of wind turbines and their components. O&M jobs also include marine crews who transport technicians to operate and maintain offshore wind turbines as well as onshore staff who provide management and engineering support.

Figure 10 shows the average range of potential growth in O&M-segment jobs within the offshore wind energy industry. O&M roles are needed over the lifetime of the operating wind plant; therefore, the workforce needs are cumulative, increasing over time based on the number of projects, size of those projects, and year they are commissioned. Assuming domestic content scenarios of 25% and 100%, the near-term average annual employment levels (FTE/year) is between 100 and 500 in 2024, but this could grow in the longer term to between 600 and 2,300 in 2030.

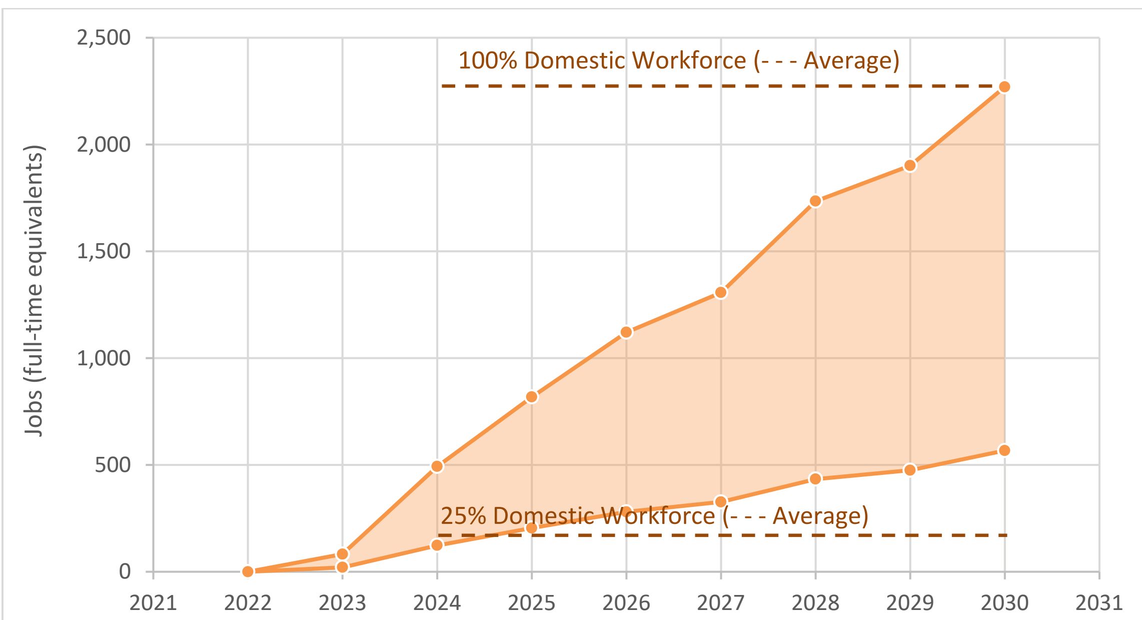

Figure 10. Estimated number of O&M workers for service operations vessels, crew transfer vessels, and onshore based on an offshore pipeline on a per-plant or per-turbine basis

[12] The Jones Act (46 United States Code § 55102) requires any vessel transporting cargo by water between U.S. port and an offshore wind energy plant be built and registered in the United States.

Our assessment indicates there is a high certainty that O&M jobs will be sourced from the United States, especially offshore technicians and marine crew.[13] The upper end of the range, 100% domestic content, is more indicative of the number of jobs to expect from the O&M industry segment. Many developers have announced headquarters or hub facilities to operate one or more projects. The location of these jobs could be in coastal communities near the operating wind power plant.

Job estimates are broken down into onshore and crew on two types of vessels (service operation vessels, or SOVs, and crew transfer vessels, or CTVs) based on the plant's O&M approach (Figure 11). The O&M workforce will continue to grow after 2030 according to the deployment timeline of additional offshore wind plants. O&M jobs will begin supporting offshore wind plants once wind plants are operating (planned for 2023−2024), but companies may begin hiring earlier.

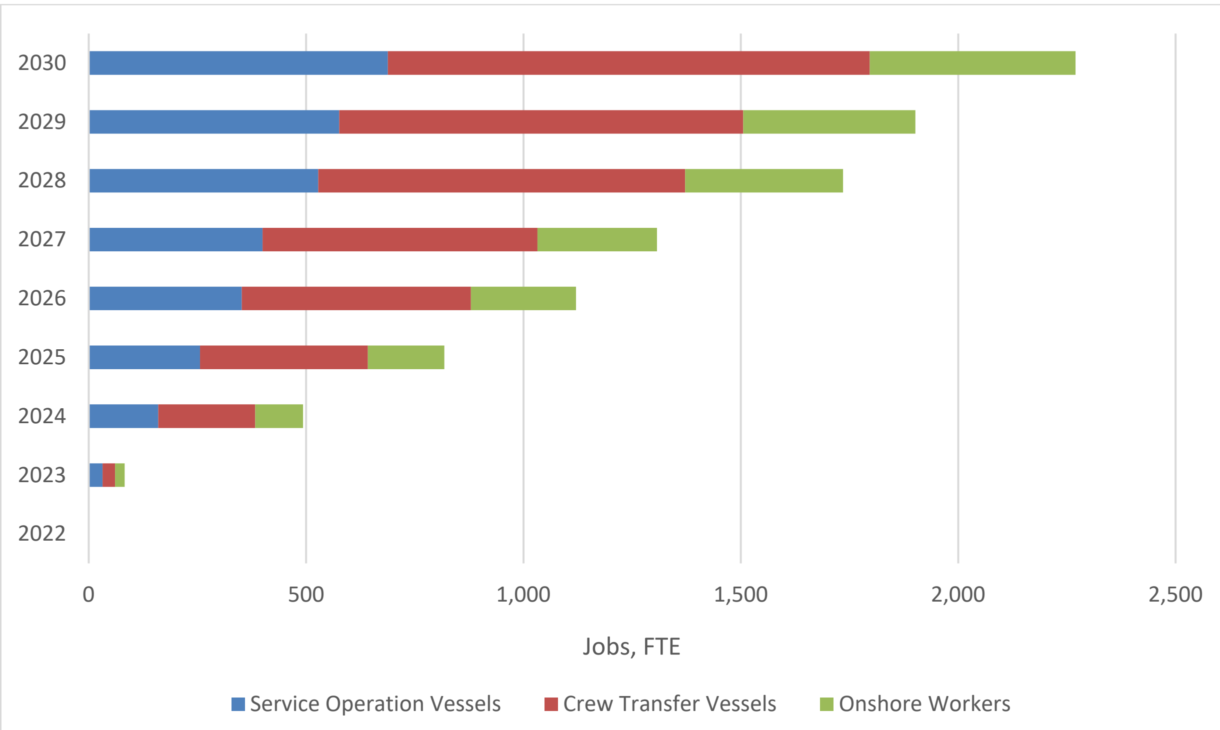

Figure 11. Job contribution of each vessel type based on the operations of offshore wind energy plants

Some roles (such as marine crew or onshore office staff) are reported on a per-plant basis, because they are mostly independent of project capacity, whereas other roles (such as turbine technicians) are more dependent on the number of wind turbines in the plant. The workforce requirements for SOV, CTV, and onshore are based on the commercial operation date (COD) for

[13] NREL has been hosting offshore wind workforce network advisory group meetings and conducting expert elicitations to receive information about workforce opportunities and gaps.

each plant in the pipeline each year. CTVs also have additional workforce requirements on a per-turbine basis.

Figure 12 shows a breakdown of the different types of O&M workers as estimated number in Figure 10 and Figure 11. O&M jobs can be categorized into two types, O&M crew workers and wind plant operation workers. O&M crew workers include technicians and marine crew. O&M crew technicians include offshore staff who are transported by vessels to repair components at the offshore wind plant location by the marine crew. Wind plant operation O&M roles include onshore staff who work at a headquarters in engineering, management, and oversight. A list of O&M roles, descriptions, education, and experience requirements is provided in Appendix B.

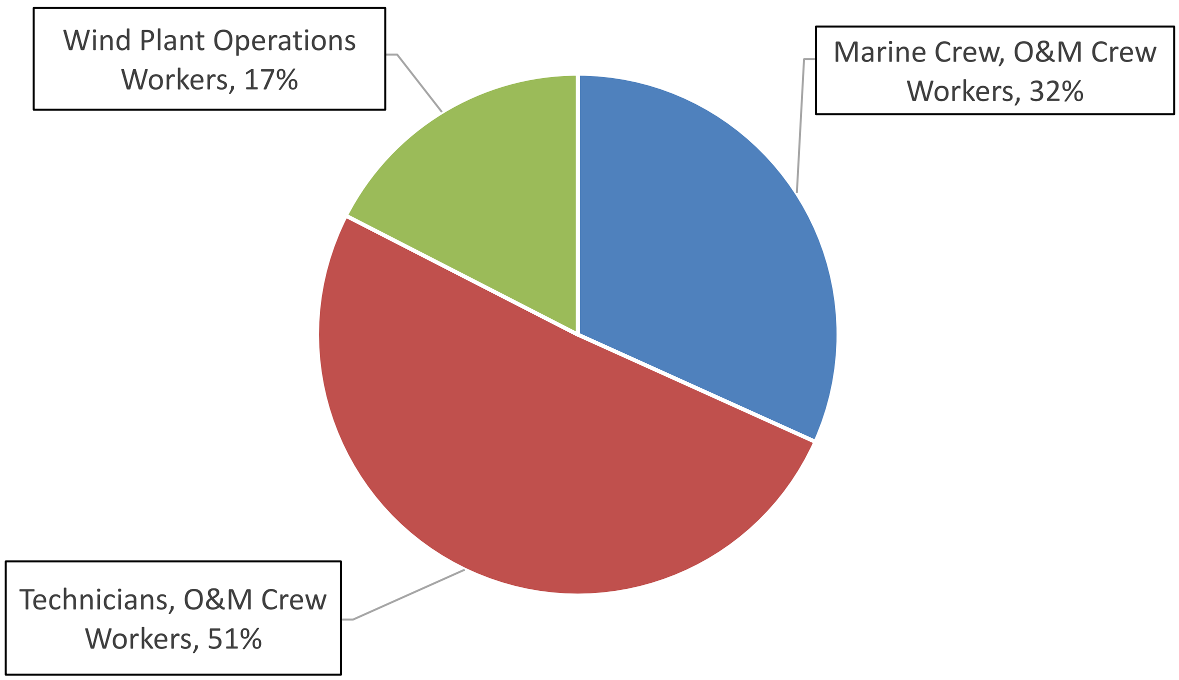

Figure 12. Breakdown of the types of long-term O&M workers supporting offshore wind energy plants

3 Workforce Supply

Meeting the future offshore wind energy workforce demand efficiently will require a coordinated, regional approach. This approach will enable stakeholders to build consensus around offshore-wind-specific role requirements, collaborate on new and existing programs to provide comparable offshore-wind-focused training and education, and coordinate the mobilization of the workforce in related fields to support offshore wind industry needs. An adaptable approach will also enable workers to bring the appropriate skills and experience to the right geographic locations at the right quantities and times to match the stage of development for offshore wind energy projects. Notably, equitably developing a diverse workforce will require intentional efforts. Finally, creating opportunities within the communities most impacted by offshore wind industry development will support future deployment of offshore wind power plants and associated infrastructure.

3.1 Roles and Competency Requirements

Beyond quantifying the labor market demand to realize the U.S. offshore wind development pipeline, this report aims to provide additional detail on the roles that will be needed to support the industry within the five industry segments and identify the required competencies of these occupations. We gathered information on occupations, descriptions, and competencies using job postings and verified this data by interviewing industry experts.

3.1.1 General Roles

Throughout the lifetime of offshore energy projects, support, professional, and management occupations are critical elements of the workforce. Across these occupations, the skills required are generally transferable between industries. However, knowledge of and experience with the unique challenges associated with offshore wind energy will be beneficial and possibly required for many professional and management roles. These roles can often be located anywhere and do not necessarily need to be local to a specific project.

3.1.2 Development

During development, specific roles related to engineering design; environmental science and monitoring; permitting and regulatory; and stakeholder engagement are required. Although these roles often include transferable skills from other industries, knowledge of and experience in offshore wind and engagement with local impacted communities are particularly valuable. In addition, experience with information and data science is becoming increasingly important for many planning roles. Most of the roles during this development stage require advanced degrees. Given the near-term requirements to support the growing development pipeline, the high education requirements, and value of experience, development roles should be a key focus of offshore wind workforce development in the immediate term.

Table B-1 in Appendix B outlines key development-stage roles and their education and experience requirements. Appendix D spotlights two key development roles of a marine services technician and a permitting coordinator.

3.1.3 Manufacturing and Supply Chain

As noted in Section 2, manufacturing and supply chain occupations have the largest potential demand if U.S.-based suppliers are used to produce subcomponents, parts, and materials for offshore wind energy components. In addition, many of these roles are also in high demand in other industries; therefore, it should be a high priority for workforce development efforts to attract and retain workers in these roles. While job estimates include direct component manufacturing and indirect supplier jobs, this supply assessment focuses on primary component manufacturing (e.g., blade, tower, nacelles, substructures, cables) and the types of workers and employment structures within those factories.

Manufacturing and supply chain occupations can be categorized into six main types: regional professionals, factory-level management, design and engineering, quality and safety, factory-level worker, and facilities maintenance.

A list of roles, education, and experience necessary for component manufacturing facilities adds context to these requirements and can be divided into the following six categories:

- **Regional professional** roles, which represent those working at the corporate level as part of operations
- **Factory-level management** roles, which are responsible for the management and oversight of the factory and are involved in plantwide processes, such as operations, management, or production
- **Design and engineering** occupations, which are responsible for designing and testing components
- **Quality and safety** occupations, which are responsible for the quality of produced materials and products, as well as the safety and health of the workers
- **Factory-level workers**, or those doing the physical processes involved in production
- **Facilities maintenance** roles, which may include repairs or ensuring cleanliness and hygiene of the plant.

The roles for each of these categories are summarized in Table B-2 through Table B-7 in Appendix B.

In addition to these categories of roles, there are additional unique roles and considerations relevant for each component manufacturing process or plant that are detailed in the following subsections.

Workforce Requirements for Blade Manufacturing

Within the blade manufacturing process, there are some specialized occupations in design and engineering, as well as at the plant level. In design and engineering, product engineers require an advanced degree in structural or mechanical engineering disciplines, and often have high competency in computer-aided design processes. They often interact with other component working groups to ensure their blade design is consistent with the overall wind turbine design. Similarly, blade test engineers have special knowledge in materials and testing procedures for blades; knowledge and experience with composite materials, embedded sensing, and ultimate and fatigue load testing. For plant-level workers, specialties mainly are specific to manufacturing with composite material and nongeometric shapes. For example, a blade production worker that focuses on finishing processes might require training or experience with carpentry or fiberglass repair, which differs from the skills needed in a steel-only component. Plant-level workers in blade manufacturing typically require at minimum a GED or high school (HS) diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

Workforce Requirements for Nacelle Manufacturing

Although the nacelle assembly process is similar to the blade manufacturing process, including the types of occupations required, some additional unique skill sets are needed. For example, specialized skill sets are required for occupations in design and engineering, as well as at the plant level. In design and engineering, like in blade design, product engineers must have an advanced degree in engineering, and often have high competency in computer-aided design processes. However, because of the number of electrical and mechanical components in the nacelle, a greater number of electrical and mechanical engineers are required on the design team. Nacelle test engineers have special knowledge and experience in electrical and mechanical system testing and standards. For plant-level workers, specialties include electrical package installation, mechanical assembly, and fabrication skills associated with metal alloys, which are sometimes automated (requiring automated machine operation experience). Plant-level occupations in the nacelle assembly field typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

Workforce Requirements for Tower Manufacturing

Within the tower manufacturing process, there are some specialized roles for plant-level workers. Plant-level workers include rollers, millers, welders, and coaters. Rollers roll precut steel plates, prepare the rolled plates for welding, and bond and calibrate the hulls in the roller. They need experience in metalworking and with overhead cranes. Millers use robotic saws to mill grooves for welding activities. After the steel plates are rolled, operators and submerged arc welders make weld connections on rolled steel plates using automatic or semiautomatic welding machines. They require experience in machine or manual welding, and typically the original equipment manufacturer provides specialized weld training that is unique to tower production. Finally, coaters prep and paint the tower segment surfaces. These tower segments are typically manufactured at the plant, transported to the port, and welded together into one piece before they are ready to load onto a vessel for installation at sea. All these roles typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

Workforce Requirements for Transition Piece Manufacturing

The fabrication and manufacturing of transition pieces[14] requires unique skill sets that are specific to electrical and structural design and assembly, as well as metal fabrication and

[14] A transition piece binds the blades, nacelle, and tower to a monopile foundation. It is usually a tubular steel structure.

finishing. In design and engineering processes, transition pieces require mainly structural design, as well as electrical considerations to connect array cables with the wind turbine's electrical system. Design and testing engineers, therefore, require advanced degrees in structural and electrical engineering, as well as knowledge and experience with relevant design standards and testing. For plant-level workers, fabrication and assembly skills specific to electrical package installation are needed, as well as steel part fabrication skills (e.g., welding, blasting, polishing, and finishing). All of these plant-level roles typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

Workforce Requirements for Monopile Manufacturing

The monopile manufacturing process is similar to the tower manufacturing process because workers are trained for heavy steel fabrication. For manufacturing monopiles, there are some specialized roles for plant-level workers, including rollers, millers, welders, and coaters. Rollers roll precut steel plates, prepare the rolled plates for welding, and bond and calibrate the hulls in the roller. As a result, the workers need experience in metalworking and with overhead cranes. Millers use a robotic saw to mill groves for welding activities. After the steel plates are rolled, the operator and submerged arc welders make weld connections on rolled steel plates using automatic or semiautomatic welding machines. These roles require experience in machine or manual welding, and typically the original equipment manufacturer provides specialized welding training that is unique to monopile production. Finally, coaters prepare and paint the monopile surface. All of these roles typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

Workforce Requirements for Jacket Structure Manufacturing

The fabrication and manufacturing of jacket substructures, whether used for wind turbine or substation foundations, require unique skill sets that are specific to metal fabrication and finishing, and similar to tower and monopile manufacturing. Workers fabricate steel structures by rolling, milling, welding, and painting them. All of these roles typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

The U.S. Gulf of Mexico has plants capable of manufacturing jacket substructures. Because these manufacturing plants have more experience with manufactured jacket substructures for oil and gas, it is uncertain if these facilities are equipped for serial production of jackets for offshore wind energy. However, fabricators in the Gulf of Mexico did manufacture the jackets for the Block Island Wind Farm. This experienced workforce in the Gulf of Mexico region, with skills from the oil and gas industry, could be utilized in the offshore wind industry (Musial et al. 2020).

Other foundation types such as gravity-based foundations may also require unique skill sets including workers who are experienced in steel fabrication and cement and concrete product manufacturing.

Workforce Requirements for Substation Topside Manufacturing

Manufacturing a topside requires skill sets that are similar to transition piece manufacturing and center around structural and electrical design and electrical and steel fabrication and assembly. The substation, however, has a larger, more complex electrical system, thereby often requiring a greater number of worker hours to complete its fabrication. Topside fabricators and assemblers typically require a GED or high school diploma for those in rolling, welding, and coating roles, whereas specific training is typically needed for electricians and any other specialized technicians. Oversight positions typically require an advanced degree in engineering.

Workforce Requirements for Cable Manufacturing

Cable manufacturing focuses on array and export cables. The main difference between the two cable types is that array cables are typically rated at a lower voltage (current practice is 66 kilovolts), whereas export cables are a higher voltage (typically 220 kilovolts) and come in several designs, such as a three-core alternating current cable rated at 220 kilovolts, and a direct current cable design.

Within the array and export cable manufacturing process there are some specialized roles for plant-level workers.[15] These workers include several different machine operators specific to the cable manufacturing process. Machine operators complete the following processes in cable manufacturing: extruder, drawing, stranding, assembly, screening, jacketing, rewind line, and testing. Workers gain proficiency in machines that complete these specialized processes to manufacture cables at a low-to-medium voltage or high voltage. All of these roles typically require at minimum a GED or high school diploma. Many of these roles require more than a GED/HS diploma but less than a 4-year degree as detail in Table B-2 through B-7 in Appendix B, such as a technical degree and prior manufacturing experience.

3.1.4 Ports and Staging

Port and staging occupations can be categorized into four main types: marine crew, terminal crew, port and logistics management, and facilities management.

The marine crew comprises 1) the staff who work on the shipping vessel that brings the materials and products to be stored and deployed for the offshore wind installation or maintenance, 2) the staff who work on the tugboats that help guide the shipping vessel into the harbor and correct terminal, and 3) the pilot who meets the vessels offshore with his pilot boat and the necessary tugboats and helps the shipping vessel navigate into the harbor. These occupations are vessel-based, and therefore require education and experience that aligns with their role on board. These roles can vary in requirements from little experience (those lower in command who may be working toward an experienced-based certification) to specialized training and extensive experience (such as a pilot, captain, or mate). These roles and requirements are detailed in Table B-8 in Appendix B.

The port terminal crew includes those occupations that are involved with docking the shipping vessel, as well as receiving, inspecting, and documenting the material and products at the

[15] Array and export cable manufacturing are similar processes, just different cables sizes. Therefore, we consolidated the workforce role and requirements here.

terminal and transporting the material and products to the marshalling area. These occupations are further described in Table B-9 in Appendix B. Appendix D spotlights the key role of crane operator.

While the marine crew and terminal crew are responsible for the offshore wind energy project materials and products arriving at the port and being transported to their marshalling or staging area, the port and logistics management occupations and the facilities management occupations are responsible for port logistics, management, and facility maintenance. Port management occupations are responsible for managing the port and may operate independently of the customer, materials, or goods. Logistics management roles are responsible for most logistics processes of the material or product. Facilities management occupations are responsible for the maintenance, repair, cleanliness, and hygiene of port facilities. These occupations are further described in Table B-10 and Table B-11 in Appendix B.

3.1.5 Maritime Construction

Occupational requirements for installation vessels can generally be grouped into three categories; the marine crew responsible for vessel-specific operating activities, the project crew who oversee the installation activities, engineering, and crew safety and quality control, and the construction crew who complete the installation.

Although the functional competencies for a role may depend on the specific installation process being completed, there are many roles and competencies that are general across installation activities as represented in Table B-11 through Table B-13 in Appendix B.

Given that these jobs operate in an offshore environment, offshore-specific health, safety, and environmental (HSE) training is required for all of these roles (e.g., Basic Offshore Safety Induction and Emergency Training (BOSIET) or Global Wind Organisation (GWO) safety training).

Maritime Construction Workforce Role Requirements for Monopile and Transition Piece Installation (Wind Turbine Installation Vessel)

Unique to the foundation installation process are select vessels roles in the engineering and management crew, as well in the installation crew. Within the engineering and management crew, representatives of the developer and the foundation manufacturer that are familiar with the foundation technology and can coordinate the quality and installation of that technology are necessary. It is ultimately up to the foundation manufacturer and developer to determine which workers are on the vessel, such as foundations package manager and the project engineers. Different representatives are detailed in Table B-11. Within the monopile and transition piece installation crew, all positions are specific to the foundation installation process.

The foundations package manager represents the foundation company and implements the foundation delivery and installation strategy and is expected to have several years of experience with the company to best represent them offshore. Further, this manager is expected to have at least a bachelor’s degree and applicable licensing in a relevant engineering discipline, such as civil engineering. Additional requirements include offshore-specific HSE training, such as Helicopter Underwater Escape Training (HUET), BOSIET, and GWO training. A spotlight on the role of foundations package manager is included in Appendix D. Multiple project engineers may be on the vessel during foundation installation, representing both the foundation company and the developer. The foundation project engineer supports the foundation package manager in carrying out the foundation delivery strategy and coordinates between the marine and installation crews, as well as the developer clients, to ensure successful installation and communicate progress and changes to the design, installation, or schedule. The developer project manager represents the developer's interest on board and coordinates between the foundation manufacturer and the developer onshore offices to communicate progress and changes to the design, installation, or schedule. Both project managers are expected to have a bachelor's degree in a construction, engineering, or business management field. The surveyors aid in the accurate placement of the foundation, and are also expected to have a bachelor's degree, along with a National Society of Professional Surveyors-The Hydrographic Society of America (NSPS-THSOA) hydrographer certification and offshore-specific HSE training.

The installation process requires crew members who are specially trained to lift, place, and drive the monopile into the seafloor, and who are all certified in offshore-specific HSE. Crane operators need to be certified by the National Commission for the Certification of Crane Operators (NCCCO) and have experience in lifting in offshore conditions. Riggers and roustabouts need to have an Offshore Petroleum Industry Training Organization (OPITO) rigging and lifting certification. These roles are expected to be filled with individuals who have received their GED/high school diploma. The pile driver is expected to be NCCCO-certified as a dedicated pile driver, while the commercial diver is expected to have obtained Association of Commercial Diving Educators/American National Standards Institute (ACDE/ANSI) commercial dive certification along with specialist training (e.g., underwater welding). Both the pile driver and diver are expected to have, at minimum, an associate degree or vocational training to ensure their specialized skill competency. Supervisors for these skilled positions must meet the relevant training and certifications, and potentially have more experience in offshore conditions. For example, a heavy-lift supervisor has the same required competencies as heavy-lift operators but is able to manage a team of operators based on their level of experience and competency.

Maritime Construction Workforce Role Requirements for Turbine Installation (Wind Turbine Installation Vessel)

Wind turbine installation requires many of the same roles and requirements as foundation installation due to the common use of the WTIV, but there are some critical differences (see Table B-13 and Table B-14). First, the foundation package manager and the foundation project manager are replaced by the turbine package manager and the turbine project manager, who represent the wind turbine manufacturer and maintain similar responsibilities but are specialists in the turbine packages, rather than the foundation packages. Second, rather than pile drivers, wind turbine technicians are employed on the vessel. These technicians are specially trained in the particular turbine package and employed on board to ensure the turbine subsystems are mechanically and electrically connected and functioning after their placement on the foundation. Wind turbine technicians are expected to have an associate degree or vocational training that prepares them for their role, as well as offshore-specific HSE training. Furthermore, some wind turbine manufacturers may require in-house technical training with their turbines.

Maritime Construction Workforce Requirements for Cable Installation

Unique to the cable installation process and vessel are select positions in engineering and management, as well the installation crews (see Table B-11 for position descriptions). These unique positions are mostly required for the accurate management and placement of the electrical cable, along with connecting the cable with the wind turbines, substation, or onshore terminal.

Within the engineering and management crew, the construction manager, cable lead engineer, and the developer project manager work together to manage and coordinate between clients, suppliers, and crew to ensure the proper delivery, handling, and installation of the cable. If design, crew, schedule, or installation changes must be made, the three managers work together with their onshore counterparts and the other companies involved to communicate and resolve those changes. These managers are expected to have at least a bachelor's degree and offshore-specific HSE training, and usually need significant experience in project management and construction work in offshore settings. Also, in the engineering and management crew, a team of surveyors and remotely operated vehicle (ROV) pilots ensure the accurate placement of the cable on the ocean floor. The surveyors are expected to also have a bachelor's degree, along with a NSPS-THSOA hydrographer certification and offshore-specific HSE training. The ROV pilots are required to have a GED/high school diploma, and their pilot/technician grade 1 ROV piloting certificate and offshore-specific HSE training. Depending on the seniority of the ROV pilot, they could be required to already have finished their apprenticeship and have several years of piloting experience (the lead ROV pilot) or they could be completing their apprenticeship as part of their work experience (ROV pilot trainee). Additionally, because of the size of the ship and the length of time spent offshore, paramedics are common to have on board this vessel. The offshore paramedics are required to have their GED/high school diploma, a paramedic license, and their offshore medic certification.

Within the installation crew, the unique positions the cable installation vessel includes are technicians and electrical engineers who are responsible for the electrical connection of the cable to the wind turbine electrical system. The electrical engineers are required to have their bachelor's degree and relevant engineering license, as well as offshore-specific HSE training. The wind turbine technicians are required to have their associate degree or a vocational training equivalent to ensure they have their certification. They also are required to have offshore-specific HSE training.

Maritime Construction Workforce Requirements for Offshore Substation Installation

For offshore substation installation, workforce roles and requirements are specialized throughout the marine, engineering and management, and installation crews (see Table B-11 for role description and requirements). Depending on the heavy-lift vessel type, there is a series of additional considerations around submerging the vessel; balancing weight and ballasting; operating one or more heavy-lift cranes simultaneously; and managing a larger crane operator team.

Although the basic requirements remain the same, the marine crew is specialized for the vessel type and required to have experience with the particular vessel and its mechanisms. Additionally, the heavy-lift vessel requires the assistance of tugboats, ensuring the safe voyage of the heavy-lift vessel, and potentially aiding in crew transfer. The tugboat marine crew is smaller but requires members to be more generalists in their abilities to ensure all operations are completed satisfactorily.

The main differences in roles and requirements within the engineering and management team include the presence of the substation lead engineer, who represents the substation manufacturer offshore and leads a team of electrical engineers for the installation of the substation so that it is electrically connected to the rest of the wind power plant, and the testing of the substation components before final commissioning. The electrical engineers are required to have their bachelor's degree and relevant engineering licenses, along with electrical HSE and offshore-specific HSE training.

Lastly, within the installation crew, the heavy-lift crane operators have a different responsibility scope on the heavy-lift vessel than some of the other vessels. Although basic education and training requirements are similar to heavy-lift crane operators on other vessels, this position requires more experience specializing in heavy-lift vessel crane operation offshore, and a proven track record of successful lift operations on these vessels due to the higher level of coordination with the marine crew and deck crew.

Maritime Construction Workforce Requirements for Scour Protection Installation

Scour protection installation is a specific process with a specialized vessel, and thus has specialized workforce roles and requirements throughout the marine, engineering and management, and installation crews.[16] Depending on the vessel used to place the scour protection, there are additional considerations around vessel placement and control, scour protection material transport and placement, and coordination with specialized teams.

Within the marine crew, although the basic requirements remain the same, the crew is specialized for the vessel type and required to have specific experience with the particular vessel and its mechanisms. Because of the importance of vessel placement and control for the proper placement of scour protection, ongoing coordination between the marine navigation crew and the ROV and survey teams is critical.

Within the engineering and management team, the materials control, surveying, and ROV teams are unique to this vessel and process. Materials controllers are critical to ensuring the safe and accurate onloading, conveyance or lifting on the ship, and offloading of material, as well as the quality of that material. The materials controller is expected to have a GED/high school diploma and some experience handling materials in industrial settings, along with offshore-specific HSE training. The survey and ROV teams then coordinate closely to ensure the proper placement of the ship, the fall pipe or crane, as well as the scour protection once it lands on the ocean floor.

[16] Scour protection is the process of laying rock or other material to prevent erosion of the seabed around a fixed structure, like a monopile.

Although basic requirements remain the same as described in Table B-11, a proven track record of successfully coordinating scour protection installation is preferred.

If using a fall pipe vessel to install scour protection, the installation crew must be specialized for that onboard equipment. The fall pipe technician assists with the installation and deinstallation of the fall pipe and must have a GED/high school diploma, an OPITO rigging and lifting certification, as well as offshore-specific HSE training. The backhoe operator loads the scour protection rock on the conveyor belt for deposition into the fall pipe and must have a GED/high school diploma, NCCCO crane operator certificate, and offshore-specific HSE training.

3.1.6 Operations and Maintenance

O&M occupations can generally be categorized into two types: O&M crew and wind plant operation. Although the marine crew is similar to other vessels already reviewed in this report, the scope of responsibilities is significantly different. SOV and CTV marine crew responsibilities mainly comprise navigating, operating, and maintaining the vessels, as well as carrying the O&M crew to the project site. The SOV requires more crew, and crew that are more experienced in specialized vessel operation due to the role the SOV plays in maintenance activity. Crew members that operate an SOV must actively position the vessel during select operational activities. Conversely, the CTV crew can be smaller and does not require experience with specialized vessel operation, because the CTV is mainly transporting the O&M crew to the service operation vessel offshore.

Within the O&M crew, there are three workers—wind turbine technician, onshore (office) staff, and foundation and support structure maintenance engineers—with specialized skill sets for O&M processes, described in more detail in Table B-15 in Appendix B. First is the wind turbine technician. Although these technicians are also employed in installation processes, those who are performing O&M processes must have training for major and advanced repairs and troubleshooting, as well as digital tools training. They may also have specific training as required by the wind turbine manufacturer or operator. Details on the role of offshore wind technician are included in Appendix B. Second, the onshore (office) staff supports the offshore O&M team, and generally requires at least an associate degree and several years of relevant experience to implement wind power plant operation staff directions and support planning and logistics. Lastly, the foundation and support structure maintenance engineers are structural specialists expected to have a bachelor's degree and engineering license in civil or structural engineering, surveying, or a related field. They must also have several years of relevant experience and be trained in offshore-specific HSE protocols. Further, specific training may be required by the foundation manufacturer or operator.

Onshore, there is a wind power plant operations team that determines an operations plan and coordinates the execution of that plan for the offshore crew. This engineering, management, and oversight crew includes specialists with higher degrees, licenses, and field expertise, such as environmental science, computer science and data science, or business management. For example, data scientists are becoming increasingly valuable as smart asset management approaches for optimizing operations and maintenance are being implemented. These occupations are described in more detail in Table B-16 in Appendix B.

3.2 Education and Training

Education and training organizations have recognized the need for programs to address offshore wind workforce requirements and have been developing and instituting a wide variety of new programs and facilities, including entry-level courses, GWO safety training, offshore wind technician courses, general introductions to offshore wind, and graduate-level classes on the technical aspects of offshore wind energy system design. We identified 44 offshore-wind-energy-focused programs during the development of this report. We have also created an online database of offshore-wind-energy-focused programs with information on their offerings and links to further information.[17]

However, there remain potential gaps in meeting the workforce demand as outlined in this report. Table 2 identifies key training gaps in each industry segment based on magnitude and timing of workforce need, presence of education and training programs, and requirements for offshore-wind-specific training, certificates, or skill sets. Red indicates that one or more of these gaps may be present and is explored in more detail in this report. Areas left blank indicate workforce programs that do not train workers for roles in that specific industry segment.

Appendix C details the qualitative methodology to determine the alignment and gap assessment in Table 2.

[17] https://openei.org/wiki/Offshore_Wind_Workforce/Education_and_Training_Database

Table 2. Alignment and Gaps of Workforce Programs That Educate and Train Occupations Across Industry Segments

Industry Segment	Full-Time Equivalents (FTEs)		Workforce Programs				
Workforce Requirements	Average Annual Jobs, 25% Domestic Workforce	Average Annual Jobs, 100% Domestic Workforce	Safety Training	Community Colleges	Union-Led Training	Maritime Academies	University Programs
Development	800	3,200		Yellow		Green	Green
Manufacturing and Supply Chain	12,300	49,000					
Regional professionals							Green
Factory-level management			Yellow				Yellow
Design and engineering							Green
Quality and safety			Yellow	Yellow			Yellow
Factory-level worker	*	*	Yellow	Red	Red		
Facilities maintenance			Yellow	Green			
Ports and Staging	400	1,600					
Marine crew			Red	Yellow	Yellow	Green	
Terminal crew	*	*	Red	Red	Red		
Logistics management			Yellow	Green			Green
Facilities management			Yellow	Green			Green
Vessels	500	2,100					
Marine crew			Red	Yellow	Red	Green	
Project crew			Red	Yellow		Green	Yellow
Construction crew	*	*	Red	Red	Red		
Operations and Maintenance	600	2,300					
O&M crew	*	*	Red	Green	Green		Green
Plant operations			Yellow	Green			Green

Meeting Workforce Requirements:
- Green: No gaps or gaps being addressed
- Yellow: Some potential gaps
- Red: One or more key gaps
- (blank): Program has limited contribution to workforce development
- * Largest worker contribution

Note: Average annual jobs represent a range of potential employment each year between 2024 and 2030 to support a project pipeline of 30 gigawatts of offshore wind energy by 2030

This section summarizes the gaps and opportunities for workforce programs to train workers for many of these role types, with some being relevant across workforce programs. Each workforce program in Table 2 has a subsection within this section assessing its unique position to educate and train the different types of workers identified in the role and requirement tables in Appendix B. In addition, beyond developing new programs, there are many opportunities for companies, organizations, and education institutions to incorporate offshore wind energy content into their existing programs, coursework, and activities to increase awareness of related career options and help prepare the future workforce to meet the anticipated project pipeline.

One or more key gaps need to be addressed (shaded red in Table 2) are to train crews for work at sea and meet the number of skilled trade workers for the offshore wind energy industry.

Safety training is a significant gap for many ports and staging, maritime construction, and O&M crew requirements because workers who perform installation and O&M activities at sea require specialized safety training. Currently, there is no official industry training standard; however, GWO standards are the most widely adopted. Developers, maritime academies, community colleges, unions, vessel operators, and federal agencies should collaborate and form censuses on a safety standard. These stakeholders should then communicate that standard to community colleges, maritime academies, or union-led training programs, which may be well-placed to provide safety training so that vessel operators have confidence in hiring domestic U.S. workers to conduct job installation tasks safely at sea.

In addition, supplying the magnitude of skilled trade workers needed is a critical gap for manufacturing and supply chain factories, ports and staging terminals, and vessel maritime construction crew (several red gaps in Table 2). Community colleges and union-led training apprenticeship programs are some of the best positioned to support training and education for these roles, since they already provide it for similar roles in other industries. However, these programs will need to be expanded to ensure sufficient workers, especially in a job market that is competitive for skilled trades.

Many role groupings are identified as having partial gaps (shaded yellow in Table 2) because there are already some programs existing that partially meet the requirements but that there is additional knowledge or training required specific to offshore wind. Unique coursework, degree, trainings, or programs may need to develop to supply workers with education or experience to succeed in offshore wind energy roles. Community college, union-led training, and universities all have an opportunity to support addressing these gaps by expanding or linking existing programs. Transitioning workers from maritime, oil and gas, and other industries and enabling existing generalized professionals to use their prior knowledge and experience may also be key to filling these gaps.

Maritime academies and universities have been at the forefront of training and program development so many gaps for engineer, management, and professional roles are being addressed, as indicated by the green shading in Table 2. Furthermore, community colleges and unions have placed emphasis program development to support O&M roles, such as wind technicians. Therefore, assuming existing programs are scaled up and new programs continue to be added in line with the project pipeline needs, this is not a large of a gap for engineer, management, and professional roles to support the offshore wind industry.

Collaboration among education and training institutions, industry, government entities, and community organizations will also be critical to establishing programs and developing a qualified and diverse workforce. As the offshore wind pipeline develops, established networks and programs can support new partners, share knowledge, and develop solutions to mitigate challenges and concerns that arise. Examples of existing successful partnerships include organizations like the National Offshore Wind Institute and the Offshore Wind Training Institute. Collaborations with industry organizations may also help encourage internships, apprenticeships, and extracurricular activities like competitions and that can be supported by federal, state, and local government.

Although initial wind energy project activity is happening along the East Coast, both coasts and the Gulf of Mexico have offshore wind resource potential. As the offshore wind energy market expands to these additional regions, local training programs will be needed to meet the demand for a local skilled workforce. Like the East Coast, there will be opportunities for the integration of offshore wind into existing programs and the creation of new programs where warranted. Incorporating offshore-wind-energy-specific coursework into local and regional programs will help prepare a specialized workforce that is ready to support these types of projects in their region.

Safety Training

Standardized safety training for workers who perform installation and operation activities at sea has been identified as one of the highest- priority areas to address to ensure that an adequately trained workforce is available to build projects.[18] This prioritization is in response to the large number of workers that will need this training as well as current availability of courses in the United States. GWO estimates that more than 25,000 workers will need to receive basic safety training to meet the installation pipeline through 2025 (GWO 2021).

Currently, there is no official industry training standard; however, GWO standards are the most widely adopted. GWO is a nonprofit group of manufacturers and offshore wind energy project owners who join to "understand and reduce the risk associated with safety hazards in the wind industry" for land-based and offshore wind. GWO sets guidelines, based on risks encountered in the wind turbine generator environment, that are incorporated into training curricula by GWO-certified training providers. This GWO certification ensures that standards are met.

Organizations across the Eastern Seaboard are already rising to the challenge to develop and certify these programs and facilities to support them. As of August 2022, there are at least seven publicly announced programs across six states that offer, or plan to offer, the full suite of GWO Basic Safety Training modules, including Sea Survival. GWO also reports a pipeline of almost 100 community colleges, maritime academies, and universities across North America that are seeking certification. However, many organizations have reported that the process for obtaining this certification can be long and difficult and have expressed concerns that it could prove to be a bottleneck for training the workforce. Given the importance of certification for upholding safety standards, efforts should be made to ensure programs can be developed and certified in a timely manner to meet demand without compromising quality.

The Occupational Health and Safety Administration (OSHA) dictates that the offshore wind energy industry must provide training on occupational hazards and risks and mitigate those risks. However, OSHA does not specify training requirements. Many existing training programs in the United States offer safety training that may meet or even exceed the GWO standards, and are aligned with OSHA requirements, but may not generally be accepted by the offshore wind industry globally. GWO certification is designed to specify unique training for the risks of the offshore wind environment and is also aligned with OSHA standards.

During development of the initial safety training programs in the United States, early support from the state and cooperation with industry, academic organizations, training providers, and unions has helped bridge gaps between GWO and existing programs and increase the development rate. For example, Massachusetts is supporting multiple programs to develop GWO-certified curricula, including Bristol Community College's National Offshore Wind Institute and Massachusetts' Maritime Academy. For Massachusetts Maritime Academy, funding was provided by Massachusetts Clean Energy Center (MassCEC), Vineyard Wind LLC, and North Atlantic States Carpenters Training Fund to offer training to members of Pile Drivers and

[18] Based on discussions at an Offshore Wind Workforce Summit held in July 2020 as well as feedback from the advisory group of the Offshore Wind Workforce Network.

Divers Local 56. Continued cooperation and partnerships in this vein may ensure programs are developed efficiently to meet the high demand.

Community Colleges

Associate degrees offered by community colleges can support the offshore wind industry both by feeding into four-year university degree programs and as a foundation for those interested in pursuing technician roles. Seven community colleges across five states currently offer, or plan to offer, curricula specifically focused on offshore wind energy. These programs largely focus on offshore wind technician and safety training but vary in terms of how advanced they are, with some programs taking a strong lead in offshore wind workforce development. For example, Bristol Community College offers an Offshore Wind Technology Associate Degree and has established the National Offshore Wind Institute and a partnership between Suffolk County Community College, Sunrise Wind, and several unions have established the National Offshore Wind Training Center on Long Island. There are not gaps identified for O&M education and training because established programs are expected to meet nearer term demand in this area, and it is expected that new and expanded programs will develop over time.

However, there are a number of areas where community colleges could support in addressing key gaps, particularly for skilled trades. It is also worth noting that many community college programs are not explicitly offshore-wind-energy focused but could be expanded to meet the requirements for working in offshore wind. DOE's WINDExchange[19] initiative includes a map identifying educational and training programs that focus on wind industry occupations, and many of the coastal locations might be well-suited to also address offshore wind requirements. For example, given the large overlap in skills and education requirements between land-based and offshore wind technologies, land-based wind programs, particularly those located near the coast, could consider adding offshore modules or partnering with other organizations offering complementary offshore wind training.

Community colleges can also help develop the manufacturing-sector workforce. It is difficult to plan and train factory-level workers before the facility capacity and location is known, so many plant operators will wait to hire until manufacturing facilities are built.[20] However, existing community college programs can be leveraged, and new programs developed in parallel to planned manufacturing facilities to ensure a well-trained workforce is available.
For example, Hudson Valley Community College offers several certificates and associate degrees in areas like advanced manufacturing, mechanical and electrical engineering, and construction and maintenance that can train workers for the anticipated wind tower manufacturing facility at the Port of Albany.

The same is true for jobs related to ports and staging and maritime construction; however, these roles will require additional training, which is a gap in current coursework for these areas.

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[19] https://windexchange.energy.gov/training
[20] Insight based on feedback from subject matter experts during a January 18, 2022, meeting of the offshore wind workforce network advisory group.

Union-Led Training

Many unions are actively involved in building out the offshore wind energy industry in the United States—in fact, several were involved in building the first two U.S. offshore wind energy projects and others have agreements to build upcoming projects.

In contrast to the past development of other renewable energy industries in the United States, unions will play a prominent role in ensuring a qualified workforce is available to support the growing offshore wind energy industry. This will be particularly valuable in addressing critical gaps for high-demand roles needed by the offshore wind industry and already represented and supported by unions, for example, welding. Many states are considering or are already employing project labor agreements that have requirements for local and unionized labor and provisions for training and recruitment, though this may depend somewhat on whether a state has right-to-work laws. Industry is also working together and forming partnerships with unions to support their project. For example, Vineyard Wind and the Southeastern Massachusetts Building Trades Council have signed a labor agreement for what will be the first industrial-scale offshore wind power plant in the United States that allocates $500,000 to a special fund to support recruitment and training opportunities for underserved communities (Vineyard Wind undated).

Ørsted also confirmed its commitment to using union labor and already has agreements in place with unions in Massachusetts, Rhode Island, Connecticut, and New York (Ørsted 2020). In addition, the company has been working with unions to form training partnerships to ensure the union members have the training they need to work in offshore wind energy (Governors' Wind & Solar Energy Coalition 2020).

Dominion Energy agreed to negotiate a project labor agreement with the Virginia State Building and Construction Trades Council, The International Brotherhood of Electrical Workers, and the Laborer's International Union of North America to perform the onshore electrical interconnection work for the first stage of the Coastal Virginia Offshore Wind project (Dominion Energy, 2021). Table 3 lists some of the activities that unions are engaging in to support the offshore wind energy industry in the United States today.

Table 3. Some of Many Offshore-Wind-Energy-Related Activities Currently Being Undertaken by Unions in the United States

Union Name	Existing Offshore Wind Industry Connections	Existing Partnerships
American Federation of Labor and Congress of Industrial Organizations (AFL-CIO)	Participating in discussions with DOE, establishing diversity and inclusion programs	DOE
North America's Building Trades Unions (NABTU)	Existing contracts, future contract negotiations, participating in discussions with DOE	Ørsted, Dominion Energy, DOE
International Brotherhood of Electrical Workers	Worked on existing projects, existing contracts, training center development, partnership with JDR Cable Systems (Vineyard Wind interarray cable installation) for high-voltage training	Ørsted, NABTU, Business Network for Offshore Wind, Massachusetts Clean Energy Center, Vineyard Wind, Deepwater Wind, JDR Cable Systems
International Brotherhood of Teamsters	Contracts to build wind plants	Ørsted, NABTU
Laborers' International Union of North America	Contracts to build wind plants	Ørsted, NABTU, Atlantic Shores, Dominion Energy
United Association	Contracts to build wind plants	Ørsted, NABTU
International Association of Sheet Metal, Air, Rail and Transportation Workers	Contracts to build wind plants	Ørsted, NABTU
International Union of Operating Engineers	Contracts to build wind plants	
International Association of Bridge, Structural, Ornamental, and Reinforcing Iron Workers	Worked on existing projects, registered apprenticeship program, part of training center, participating in discussions with DOE	Ørsted, NABTU, DOE, Bay State Wind, Bristol Community College, Massachusetts Maritime Academy
International Union of Painters and Allied Trades	Contracts to build wind plants	Ørsted, NABTU
United Steel Workers	Partnership to develop manufacturing facility	US Wind
Communications Workers of America	Participating in discussions with DOE	
United Brotherhood of Carpenters and Joiners of America	Training investments for offshore-wind-energy-specific skills	
Utility Workers Union of America	Involved in many of the transmission and substation buildouts along the coasts	Bay State Wind, Bristol Community College, Massachusetts Maritime Academy

Union Name	Existing Offshore Wind Industry Connections	Existing Partnerships
Seafarers International Union	Two seafarer-contracted companies have a joint venture to provide customized terminal design, project management, warehousing, logistics, supply chain management, and equipment maintenance	
Union of Pile Drivers and Divers	Capital Skills Grant recipient from Massachusetts Clean Energy Center and Vineyard Wind; used funds to sponsor training of approximately 45 individuals with the Massachusetts Maritime Academy and offer a 4-year apprentice program that includes wind training (Mass CEC, 2022) Appear to be involved in the union labor agreement to build Vineyard Wind	

In order to ensure a qualified workforce is available, labor unions are focused on integrating offshore-wind-energy-specific skills into their existing network of training and apprenticeship programs as well as developing training programs focused on offshore wind requirements.

Most registered apprenticeship programs in the building and construction trades are run by a Joint Apprenticeship Training Committee comprised of equal representation from the union and its signatory contractors. This structure helps to ensure training meets documented industry demand, and that the training adapts over time as new technologies, products, and practices enter the market or new regulations take effect. The union and contractors contribute to the program, often with little to no public funding needed, such that apprenticeship is practically free for apprentices who in fact are employed and working in addition to taking courses (hence the motto “earn-while-you-learn"). Pre-apprenticeship, or apprenticeship readiness programs, have been established to build a committed and diverse pool of candidates that are prepared for the rigors of registered apprenticeship. Apprenticeship and pre-apprenticeship programs are likely to play a key role in developing the skilled workforce needed to construct or install offshore wind energy projects; the advantage of apprenticeship for workers is that they are trained and experienced in a wide range of projects and are thus not dependent on offshore wind energy projects alone for their livelihood. While apprenticeship is aimed primarily at new workers and imparting fundamental knowledge and skills, specialized or customized courses and on-the-job training for journey-level workers can help upskill the incumbent workforce to meet the unique demands of offshore wind energy. Joint Labor-Management apprenticeship programs in the manufacturing sector share many of the characteristics described above, though unilateral, employer-only sponsored apprenticeship programs may be more commonplace in manufacturing than in construction. In addition, it is worth noting that there are far fewer registered apprenticeship programs in manufacturing than in construction (U.S. Department of Labor 2021), which may mean a greater level of effort is required to develop quality training programs to support the manufacturing and supply chain-segment of the offshore wind industry.

Despite all of these efforts, challenges exist in establishing the role of unions in the offshore wind industry. For example, there may not be alignment between occupational structures and training standards, like for the role of an offshore wind technician wherein the training requirements may span multiple existing training programs. Or, for example, when considering work on electrical infrastructure like a substation, IBEW members perform similar work across substations in North America, but role and training terminology across the offshore wind energy industry may make this connection less clear. Close cooperation among unions, industry, and other educational and training organizations, in particular in understanding their respective areas of expertise, will help facilitate the integration of unions into the offshore wind energy industry in the United States.

One possible gap for unions is whether they have adequate transparency and visibility into industry's plans to develop manufacturing facilities and the general pipeline, as well as projected numbers for other related industries they support. This visibility will enable unions to grow their recruitment and training programs and facilities strategically to match the needs of the offshore wind industry together with other industries. There are already workforce shortages for some trades; for example, offshore wind energy projects are expected to have a large demand for iron and steel workers and construction welders. Massachusetts has conducted a study (MassCEC 2021) indicating there is already a low supply of workers in these occupations relative to the nation. To address this gap, unions will have to work closely with industry as well as local and state economic development groups to understand the pipeline and make plans accordingly. For example, crane operators are in high demand with specific NCCCO training requirements. As a result, some unions are already preparing for NCCCO certification, such as the International Union of Operating Engineers, which supported the crane operations of the Block Island Wind Farm. They offer several training courses in preparation of a NCCCO certification at their International Training & Education Center in Texas.

Maritime Academies

Maritime academies offer curricula and training designed to support traditional ocean-based industries, so they are well-suited to support the offshore wind energy industry. There are seven maritime academies in the United States, and six are currently offering or developing offshore-wind-specific courses or programs, indicating they are already addressing workforce requirements. Maine Maritime, Massachusetts Maritime Academy, SUNY Maritime, California State University Maritime Academy, Mid-Atlantic Maritime Academy, and the U.S. Naval Academy offer or will offer programs focused on offshore wind energy. For example, Massachusetts Maritime Academy developed an "Introduction to Offshore Wind" course and opened a facility designed for offshore wind crew transfer training in partnership with logistics company Crowley Maritime (The Maritime Executive 2021).[21]

Maritime academies also offer a link between offshore wind and traditional maritime industries that can be leveraged for less wind-specific roles; for instance, for vessel occupations.

[21] https://maritime-executive.com/article/crowley-launches-offshore-wind-training-program-with-mass-maritime

University Programs

NREL identified more than 50 universities that offer some form of offshore wind energy courses as part of their curricula. NREL maintains the [Offshore Wind Workforce Education and Training Database]() to make it easy to quickly find institutions and programs that will help energize students about an offshore wind powered future and related concepts.

While community colleges and vocational programs are often designed to create a workforce entering the skilled trades in construction and manufacturing, universities are predominantly focused on creating a workforce on the professional level, providing the education required for engineers, professional support roles, and scientists and researchers, among others.

As with community colleges, the curricula offered by these university programs vary widely. For example, some of the programs currently offered that have some element of offshore wind energy content range from offshore wind energy engineering, renewable energy interdisciplinary minor to a Master of Science in offshore wind energy engineering. The wide variety of these programs means it can be difficult to assess the extent to which they are addressing workforce requirements. However, these programs do have the potential to create awareness and interest in the offshore wind industry and can potentially be expanded to further meet requirements as the industry develops. In addition, existing engineering programs, in particular offshore engineering or offshore energy, are well-suited to address many of the requirements of the offshore wind industry and serve as a good foundation for an offshore-wind-specific supplement.

Many universities have made significant efforts to develop the offshore wind energy industry. Some notable highlights include the University of Maine, which leads the DeepCwind Consortium with the aim of ensuring that the state develops into a national leader for offshore wind energy. The University of Maine is currently developing the Aqua Ventus floating offshore wind demonstration project. The University of Maine also hosts the interdisciplinary Advanced Structures and Composites Center, which is involved in the research and development of floating offshore wind platforms. It also runs the Windstorm Challenge, a science, technology, engineering and mathematics competition aimed at middle and high school students in which students are asked to "design and construct a scale-model floating wind turbine platform, test the design under wind and wave conditions, and deliver a sales-pitch-style presentation to a panel of judges." The challenge also offers opportunities for internships at the Advanced Structures and Composites Center.

The University of Rhode Island was heavily involved in the development process for the Block Island Wind Farm. The university was responsible for facilitating collaboration on the first U.S. offshore wind plant by providing scientific support and feeding into the Ocean Special Area Management Plan that determined the final plant site location. The University of Rhode Island is also home to the Rhode Island Sea Grant program, which is designed to develop sustainable long-term use of coastal and marine resources and leads the DOE-sponsored National Sea Grant Offshore Wind Energy Liaison initiative connecting the Sea Grant program with offshore wind energy activities. For example, the Northeast Sea Grant Consortium has awarded six projects aimed at advancing social science and technology research on offshore renewable energy in the Northeast United States (DOE 2022a).

Universities are also beginning to develop unique joint partnerships with industry. For example, Ørsted has been partnering with academia and state-level governments and has reached a memorandum of understanding with Stockton University and Rutgers University to collaborate on the creation of a professional and technical development program.

Kindergarten Through 12th Grade Education

Based on NREL's review of publicly announced programs and efforts, curricula and programs focused on offshore wind energy at the kindergarten through 12th grade (K-12) level are currently limited and created as independent initiatives rather than standardized or coordinated efforts. However, despite high demands on often limited school budgets, efforts to introduce younger students to renewable energy and offshore wind in particular will likely create interest that may carry through to their future education and career decisions.

Of the few programs that exist, WindWinRI is a high school certificate program for students who are interested in working in the offshore wind energy industry. This program is a result of a state-led initiative and partnership between Rhode Island's Labor and Job Training Department with the North Kingstown Chamber of Commerce. WindWinRI is a comprehensive program that introduces high school students to a new and burgeoning industry while helping them develop skill sets tailored for offshore wind and earning college credits (Anzilotti 2018). In this program, secondary school students take courses on specific skills desired by the offshore wind industry, including welding, electrical systems, and marine safety. Additionally, this program was designed to create a pathway into an industry that many students may not know exists. Although only available in a select few Rhode Island schools, there are plans to raise funding to expand the program to more high schools within the state.

MassCEC has also provided grant funding to K-12 education, focused primarily on high schools and not necessarily programs in and of themselves. For example, Adult Continuing Education Martha's Vineyard was awarded a grant to expand their offshore wind technician certificate program to encourage high school dual enrollment and explore the possibility of incorporating marine science and technology topics into the high school's Career and Technical Education Program (MassCEC undated[a]).

Other K-12 programs with a predominant focus on land-based wind energy are now expanding into offshore wind. For example, the REcharge Academy, an educator renewable energy training program, recently included a minor offshore wind focus. The academy combines materials from Recharge Labs, WindWise, KidWind, the National Energy Education Development Project, WhiteBox Learning, and Vernier. The 2021 virtual REcharge Academy was conducted in partnership with the University of Rhode Island Coastal Resources Center, WindWinRI, and the North Kingstown Chamber of Commerce and, incorporated more offshore wind content. The National Energy Education Development Project, supported by DOE and the Bureau of Ocean Energy Management, has also updated its ocean and wind energy curricula to include offshore wind energy.[22]

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[22] For more information, visit https://www.need.org/.

Project developers can also play a role in spurring interest among K-12 students and providing incentives, resources, and educators. Atlantic Shores provided an offshore wind lesson to schools near their lease area, ran an essay contest, and provided Science, Technology, Engineering, Arts and Mathematics (STEAM) programs with prizes (Atlantic Shores Offshore Wind undated). Although STEAM programs at the K-12 level are generally important, ensuring there are strategies to help demonstrate the career opportunities these studies can open, like in the offshore wind energy industry, will be critical in creating sustained interest among students. Through collaboration and some standardization, successful K-12 programs like those outlined here can be expanded and replicated to spread awareness and inspire the offshore wind energy workforce of the future.

Partnerships

Collaboration among governments, industry, academic institutions, labor unions, and community-based organizations is key to addressing offshore wind energy workforce needs efficiently, effectively, and equitably by preparing a workforce that meets the technical, geographic, and timeline needs for anticipated wind projects. To better understand existing partnerships, NREL asked representatives of education and training institutions to provide information about their programs, who they partner with, and to describe how they partner with identified entities. Representatives from 19 out of 25 (76%) entities responded to the partnership questions and identified 49 partner organizations from industry; federal, state, and local governments; other educational and training institutions; unions; and nongovernmental community organizations.[23] More than two-thirds of respondents indicated that they are currently partnering with other educational institutions to develop, implement, or support aspects of their program. Just over 70% are partnering with state or local governments, and 75% of respondents indicated that they partner with industry. One-third of respondents are collaborating with unions.

Educational and training institutions are partnering with industry in a variety of ways. Besides providing funding to develop education and training programs, industry representatives provide guest instructors or speakers and support the development of curricula and programs through guidance, review, feedback, and participation on advisory committees. They are helping to train instructors, contribute data for use in coursework, and support outreach and marketing efforts. Industry is increasing student experience and knowledge by partnering with educational institutions to provide student internship opportunities and sponsor capstone projects and experiential programs.

Partnerships with state and local governments primarily include funding, networking opportunities, and assistance with establishing training facilities and acquiring equipment. Representatives from education and training institutions indicated that they are collaborating with federal government entities on research topics and to bring guest speakers into classrooms.

Educational and training programs are working together to develop, implement, and support offshore wind energy programs by providing guidance on program development, access to equipment, and collaboration on research topics. A few schools have established transfer

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[23] Respondents primarily included education institutions offering credential, certificate, associate, bachelor, and graduate degree programs, as well nongovernmental organizations.

agreements to increase educational opportunities for students, whereas others are supporting the development of programs by providing funding at community colleges. Another common way education and training institutions are partnering is by promoting offshore wind programs at partner institutions, such as advertising programs, referring students, and conducting recruitment to underrepresented students.

Unions are partnering with educational and training institutions by participating in curriculum advisory committees and collaborating on workforce development.

Current projects and programs are concentrated in the Northeast; however, as the offshore wind energy market expands beyond the East Coast, established programs, working groups, and other types of partnerships will offer efficiencies and lessons learned for the development of new programs and workforce opportunities in other geographies.

In order to facilitate partnerships across stakeholders and regions across the United States, NREL has formed an Offshore Wind Workforce Network to bring together stakeholders to learn from one another and work together to solve challenges in developing a well-trained, domestic offshore wind workforce. [24]

3.3 Pathways and Initiatives

In addition to training and education programs, it is important to look at key pathways and initiatives to intentionally develop a diverse and qualified workforce that benefits local communities. Table 4 outlines some key ways to address the needs of the five industry segments. These approaches are not comprehensive but areas of high priority on which to focus. Appendix C details the qualitative methodology to determine the workforce development opportunities in Table 4.

[24] More information about the Offshore Wind Workforce Network can be found at https://openei.org/wiki/Offshore_Wind_Workforce/Network.

Table 4. Important Initiatives and Pathways To Facilitate Hiring of Offshore Wind Energy Industry Occupations

Industry Segment (Workforce Requirements)	Full-Time Equivalents (FTEs): Average Annual Jobs, 25% Domestic Workforce	Full-Time Equivalents (FTEs): Average Annual Jobs, 100% Domestic Workforce	Diversity and Inclusion Initiatives	Revitalizing Ports and Manufacturing Facilities	Local Workforce and Economic Development	Adjacent Maritime Industries	U.S. Military Veterans	Oil and Gas Workers
Development	800	3,200	Primary	Limited	Primary	Secondary	Secondary	Primary
Manufacturing and Supply Chain	12,300	49,000						
Regional professionals			Primary	Secondary	Secondary	Limited	Primary	Secondary
Factory-level management			Primary	Primary	Primary	Limited	Primary	Primary
Design and engineering			Primary	Secondary	Primary	Limited	Primary	Secondary
Quality and safety			Primary	Primary	Primary	Limited	Primary	Primary
Factory-level worker	*	*	Primary	Primary	Primary	Secondary	Primary	Primary
Facilities maintenance			Primary	Primary	Primary	Secondary	Primary	Primary
Ports and Staging	400	1,600						
Marine crew			Primary	Primary	Primary	Primary	Primary	Primary
Terminal crew	*	*	Primary	Primary	Primary	Primary	Primary	Primary
Logistics management			Primary	Primary	Primary	Limited	Primary	Limited
Facilities management			Primary	Primary	Primary	Limited	Primary	Secondary
Vessels	500	2,100						
Marine crew			Primary	Secondary	Secondary	Primary	Primary	Primary
Project crew			Primary	Secondary	Secondary	Primary	Primary	Primary
Construction crew	*	*	Primary	Primary	Secondary	Primary	Primary	Primary
Operations and Maintenance	600	2,300						
O&M crew	*	*	Primary	Primary	Primary	Primary	Primary	Primary
Plant operations			Primary	Primary	Primary	Primary	Primary	Primary

Meeting workforce requirements: Primary Pathway; Secondary Pathway; Limited Pathway; * Largest worker contribution

Note: Average annual jobs represent a range of potential employment each year between 2024 and 2030 to support a project pipeline of 30 gigawatts of offshore wind energy by 2030

Oil and Gas Workers

Many workforce segments of other industries have transferrable skills to offshore wind including oil; natural gas; aerospace and defense; land-based wind; military or armed forces; and adjacent maritime industries. As the country looks to meet more of the energy and transportation needs with renewable energy, there will be a related impact to jobs in the fossil-fuel industry. The oil, natural gas, and chemicals industries have experienced significant job fluctuations and loss over the past decade and are likely to see more of the same going forward. The just transition of oil-and-gas workers into renewable energy, and offshore wind in particular, may help address some of these issues.

For example, one pathway into the renewable energy industry for a segment of the oil-and-gas workforce may be through oil-and-gas companies that are already expanding into renewable energy. Many of the traditional fossil-fuel organizations in Europe have moved into the offshore wind industry—including Ørsted, Equinor, and Shell—and the same trend could happen in the United States.

The following list highlights some of the technical skills and occupations native to the oil-and-gas industry that are in demand on wind energy projects, many of which can apply to offshore wind energy (Airswift 2020):

- Geotechnical engineering
- Surveying

- Marine engineering
- Foundation package managers
- Fabrication managers/superintendents
- Client site representatives
- Offshore construction specialists
- Offshore HSE reps
- HSE site reps
- Quality assurance/quality control professionals–welding, non-destructive testing, coating
- Installation managers
- Cable installation engineer and site representatives
- Subsea engineers
- Environmental surveyors.

However, although there are many transferable skills between the oil-and-gas and offshore wind energy industries, challenges and considerations related to transitioning workers remain that need to be addressed, including the geographic concentration of the existing workforce, the potential pay gap for many of the roles, the need for wind-turbine-specific safety training, and the overall magnitude of the workforce that will need to find new jobs as the fossil-fuel industry declines.

Current U.S. oil-and-gas jobs do not necessarily align geographically with the offshore wind project pipeline, particularly in the near term. Much of the offshore oil-and-gas industry is along the Gulf Coast, and although the Bureau of Ocean Energy Management has begun exploring offshore wind energy in the Gulf of Mexico—with announcements for two draft wind energy areas (U.S. Department of the Interior 2022)—the near-term project pipeline is concentrated on the East Coast. As a result, workers looking to transition from oil and gas to offshore wind may need to relocate.

Another consideration often cited by former oil-and-gas workers who have transitioned into the renewables industry is the discrepancy in pay, with renewable energy often paying less than similar positions in oil and gas (Saul 2021). This discrepancy has been true for the green energy industry generally (Domonoske 2020) and may extend to the offshore wind industry as well. In addition, while many oil-and-gas workers have had safety training specific to the offshore oil-and-gas industry, these workers will require wind-turbine-specific safety training, which is provided in programs such as from the GWO.

Finally, the largest workforce need for the offshore wind industry is less than the potential magnitude of workers that may be seeking to transition from the oil-and-gas industry in the coming decade and should be communicated accordingly.

U.S. Military Veterans

Another group of individuals that is often cited when discussing the future offshore wind workforce is U.S. military veterans. Veterans make up a larger portion of the clean (or advanced) energy workforce as compared to the overall economy (DOE Office of Policy 2020). Veterans are also disproportionately represented in fossil-fuel-related jobs, the same study shows; however, as described in the previous section, those jobs could be at risk as fossil fuels are replaced by carbon-free energy sources. As the offshore wind energy industry grows, veterans can transition from their previous industry by leveraging their existing technical skills and therefore contributing to the renewable energy sector.

Veterans' organizations have been successful in creating resources to help members understand how their skills could apply to the wind industry. In particular, the civilian-to-military occupation translator,[25] which maps roles in military service to roles in energy and other industries, is a helpful resource that could be expanded to include offshore-wind-energy-specific roles.

The Helmets to Hardhats program is a prime example of a partnership between labor unions and construction industry contractor associations aimed at helping veterans, transitioning active-duty military service members, National Guard and Reservists secure a quality career in the construction industry via registered apprenticeship. In 2007, the initiative expanded with the creation of the Wounded Warrior program that focuses on serving disabled veterans by connecting them to careers in the construction industry as well as careers that support construction.[26] By guiding participants to the best-in-class career pathway in the construction trades, veterans and others are well served by gaining skills and experience suited to a wide array of projects and thus not dependent on offshore wind energy projects alone for a livelihood.

Adjacent Maritime Industries

Another useful workforce segment to address when developing pathways into the offshore wind energy industry are the adjacent maritime and fishing industries. Maritime industries include aquaculture, seafood processing, commercial diving, and marine transportation. These industries are already located along the coasts, with workers possessing transferrable skills or having the ability to upskill or retrain for the offshore wind industry.

One potential opportunity is the use of maritime workers temporarily during peaks of installation activities when offshore workforce requirements are at their highest and there is potential for disruption to fishing and other maritime industries. In addition, fishing vessels could be used to support installation activities as well as operations and maintenance for the project lifetime. In Europe, some fishing vessels have been used as survey and guard vessels during the development and construction of projects, then return to fishing once construction is complete. This approach could be replicated in the United States, with recent efforts underway—Ørsted and Eversource announced that they will be working with marine services provider Sea Services North America and its partner fishermen to provide scouting vessels and monitoring services (South Fork Wind 2021).

There is also current activity focused on recruiting and teaching members from the fishing industry the necessary additional skills (i.e., upskilling) in Massachusetts, according to two of the recent grants awarded by MassCEC. In addition, the Commercial Fisheries Center of Rhode Island and the University of Rhode Island Fisheries Center were funded to develop industry-standardized professional requirements for the safety and inspection of vessels for use in offshore wind energy, allowing fishermen to gain necessary skills to participate in the industry.

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[25] https://www.troopstoenergyjobs.com/roadmap/explore/
[26] For more information on this program, visit: https://helmetstohardhats.org/about-us/

Another program between the Massachusetts Fishermen's Partnership and the Northeast Maritime Institute is designed to recruit and prequalify commercial fishermen for enrollment in dedicated training and certification programs at the Northeast Maritime Institute. The program will provide formal training to fishermen to obtain their merchant mariner credentials (Offshore Engineer 2020).

Role of Local Workforce and Economic Development

Focusing on the local workforce can offer an opportunity to simultaneously meet workforce requirements while ensuring communities most impacted by offshore wind energy deployments are benefiting economically. Economic development organizations and states are actively engaged on the East Coast to ensure their role in offshore wind energy development. These efforts can also serve as an effective model for other states to follow.

Programs that are being led by state-based organizations along the East Coast include new training programs and institutions, testing facilities, port development and revitalization, new manufacturing facilities, electrical infrastructure development, workforce analysis and grants, communities of practice (where a group of people with the same interest or concern come together to work on it), and offices focused on supporting diversity and energy justice. Table 5 provides some of the various funding agencies and what their funds support.

Table 5. Agencies That Provided Funds To Support Local Workforce Development

(Sources: MassCEC undated[b]; New York State undated)

Funding Agency	Funding Amount	Application of Funds
Rhode Island Commerce	$800,000	Catalyze developments throughout Rhode Island and improve the municipal development process
Rhode Island Department of Labor and Training	unknown	The Business Network for Offshore Wind's workforce development program: READY 4 OFFSHORE WIND
The Virginia Growth and Opportunity Foundation (Virginia Department of Housing and Community Development)	$529,788	Grants to build the offshore wind energy supply chain in Virginia
Maryland Energy Administration	$2.8 million	Funding is focused on supporting local businesses including those that are small and minority- and women-owned and that are involved in the expansion of clean, renewable, offshore wind energy
Massachusetts CE C	$3.8 million	Workforce development grants
New York State Energy Research and Development Authority	$20 million	Workforce development training grants
New Jersey Economic Development Authority	$4.5 million	Support offshore wind energy workforce development projects and challenges, including the New Jersey Wind Turbine Technician Training Challenge and New Jersey Offshore Wind Safety Training Challenge Established the Wind Institute for Innovation and Training

Revitalizing Ports and Manufacturing Facilities

There are at least 12 ports across seven states along the East Coast that are supporting offshore wind energy development. In New York alone there will be five active ports supporting the industry. At least one of these ports will not only create jobs but will serve a community that is largely immigrant and working class and has been economically stressed for years (Pereira 2021). Several of these are new ports that are being developed on former fossil-fuel sites and investing capital into the local region during construction or renovation activities on the scale of hundreds of millions of dollars.

Similar to the development of ports, component manufacturing offers an opportunity to create new jobs, which could support a just transition for workers and communities facing job loss so long as quality jobs are created in the process. Many of these manufacturing facilities will have a significant impact on the communities that surround them and could contribute to substantial economic growth in those areas. Developing a domestic supply chain offers the greatest number of job opportunities in offshore wind, as outlined above. Accordingly, workforce development efforts should focus on the manufacturing sector.

Several of the state-based economic development organizations have been involved in the planning and funding for the development of these facilities to support the industry and are well-positioned, together with local unions and training and education organizations, to craft training programs to help meet the corresponding workforce needs. For example, Hudson Valley Community College has been preparing to meet offshore wind workforce requirements in anticipation of the wind tower manufacturing facility at the Port of Albany (Hudson Valley Community College 2021).

The Gulf of Mexico region will also be a significant focal point for the development of a U.S. offshore wind energy manufacturing industry. The region has established itself as a world leader in marine activity for manufacturing, offshore engineering design, training, shipping, offshore construction, and energy production. As the offshore wind industry continues to develop along the East Coast and the rest of the country, the Gulf of Mexico is expected to play a key role by leveraging supply chain and manufacturing facilities (and corresponding workforce) that were developed for oil and gas.

The "Demand for a Domestic Offshore Wind Energy Supply Chain" report outlines these opportunities in more detail (Shields et al. 2022).

Diversity and Inclusion Initiatives

All stakeholders involved in offshore wind workforce development have expressed interest and commitment to encouraging participation of underrepresented and underserved populations and practicing environmental justice in the U.S. offshore wind energy industry. Many stakeholders see the development offshore wind energy as an opportunity to improve diversity and inclusion in the workforce in traditional economic sectors (viz., construction and manufacturing) while addressing the racial wealth gaps in the communities that will be impacted by offshore wind projects and associated infrastructure.

New York, New Jersey, and Massachusetts all have provisions in their most recent solicitations or request for proposals to increase workforce diversity and ensure environmental justice. Recent solicitations in New York and New Jersey contained equity provisions that support the development of a local workforce by requiring developers to provide workforce training and support minority-owned businesses. For example, in the latest solicitation in New York, there is a requirement that proposers "must agree to undertake efforts to maximize contract and subcontract opportunities for Minority and Women Owned Business Enterprises and Service-Disabled Veteran-Owned Businesses" (New York State Energy Research and Development Authority 2022). As a result of these requirements in New York and New Jersey, organizations have pledged to benefit disadvantaged communities and incorporated environmental justice initiatives into their research, grants, and workforce training programs.

In 2021, the Massachusetts CEC issued a request for proposals, specifically aimed at increasing inclusion and diversity in the offshore wind energy workforce by funding and developing programs that increase access to training and employment for underserved populations in the greater Boston area. In addition to the new requirements for request for proposals, Massachusetts awarded $1.6 million in grants to eight offshore wind workforce training programs in 2021. Each grant was awarded to a program that focuses on a specific obstacle, such as a barrier to women, people of color, low-income individuals, and other targeted priority groups entering the industry.

However, some stakeholders have expressed concerns that there may be tensions in the development of the offshore wind energy workforce with potentially conflicting priorities to use minority- and women-owned businesses as well as support and prioritize union and local labor. [27]Although unions are actively working to increase diversity amongst their members, many have historically been predominantly white male workers, and many minority- and women-owned businesses do not currently employ union labor (Shemkus 2021). Therefore, this is another key area that will benefit from close coordination between industry, states, unions, and representatives for minority- and women-owned businesses.

Many individual unions have also developed and implemented programs and expressed strong commitments to continue increasing the diversity of their members, and state that cultivating a diverse union workforce is critical for the long-term success of the union labor force. For instance, construction trades unions administer or participate in pre-apprenticeship, or apprenticeship readiness programs that focus explicitly on workforce diversity and inclusion. In addition, the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) has numerous initiatives to support increased diversity in their member unions as well as requirements to audit diversity throughout its ranks.

Some of these programs are focused on increasing awareness of jobs in the unions, others are targeted at increasing the advancement of women and members of color into leadership positions. Apprenticeship is the primary career pathway for individuals to enter a skilled trade or craft, and preapprenticeship programs can help disadvantaged and underrepresented individuals prepare for the rigors of formal, registered apprenticeship programs.

While the stakeholders outlined in this section, and others across the industry, have set intentions and made commitments to increasing and supporting a diverse workforce, it is not clear how

[27] Based on feedback from the advisory group of the Offshore Wind Workforce Network.

these goals will be tracked or reported. Having transparency and communicating progress toward goals will be critical to ensuring that the benefits the industry is intending to provide to underserved and marginalized workers will come to fruition.

In addition, if the industry wants to attract workers from underserved communities, innovative approaches may need to be developed and implemented. There are many examples from other industries that could be explored and leveraged—initiatives that provide supportive services (e.g., transportation and childcare grants) or offer stipends for training and relocation. One example comes from technology company Interapt in Louisville, Kentucky. Rather than attracting skilled workers from technology hubs like Boulder or San Francisco, the organization decided to recruit and train local residents who were interested in learning new skills. The program required participants to pass an initial test, and then paid them to go through thousands of hours of training (Solman 2021).

Another example is preapprenticeship programs to help individuals enter the industry by preparing them to participate in formal apprenticeship programs. Hallmarks of quality preapprenticeship programs include facilitated entry for applicants, simulated experiences, supportive services such as transportation and childcare, and a focus on recruiting and preparing diverse candidates (U.S. Department of Labor undated); job or career placement activities are also critical to ensure that training results in quality employment. Unions have indicated that preapprenticeship programs are a key mechanism to attract and train underserved populations to enter the union workforce. The latest workforce report from MassCEC includes preapprenticeship programs in their key findings and suggests that Massachusetts expand these types of programs (MassCEC 2021). MassCEC further committed to this goal by funding the organization Building Pathways in 2021 to support preapprenticeship programs and wrap-around services like transportation and childcare.

Another opportunity for innovation could come from more robust skills mapping across industries to outline in more detail what skills are required for which roles and where there is overlap with other industries in order to support workers as technologies and the economy shift. This mapping could help facilitate additional pathways for underserved students and workers to build careers that enable long-term self-sufficiency. For example, the Asian American Civic Association’s Green Automotive Maintenance Skills diesel technician training program offers a clear pathway for graduates who have many transferable skills required by the offshore wind energy sector. Yet, there is still a need for additional support and coordination to ensure this transfer happens (Ehsieh 2021). This kind of skills mapping could benefit many of the workers described earlier, including oil and gas, fishing, and eventually those involved in building offshore wind farms.

4 Conclusion

As the growth of offshore wind energy in the United States continues to accelerate, focus on workforce development to support it is getting increased attention from local, state, and federal government, industry, academic and training institutions, unions, and community organizations. To meet the target of 30 GW of U.S. installed offshore wind capacity by 2030, average annual employment levels (FTE/year) are estimated at 15,000 and 58,000 based on 25% and 100% domestic content scenarios, respectively, depending on how many U.S.-flagged vessels support the industry and the development of a domestic manufacturing and supply chain. Many of these jobs will be required concurrently and in occupations that are already in high demand.

Greater communication, consensus-building, and coordination between stakeholders at the local, state, regional, and national level are critical to maximizing the employment potential of offshore wind and developing a domestic offshore wind energy workforce. To support this development, we provide the following recommendations.

Recommendation #1: build consensus around the roles and requirements needed for an offshore wind energy workforce, and clearly communicate those roles and requirements to all stakeholders, including:

- Finding general agreement on the roles (and corresponding characteristics and requirements) within the industry by convening the Offshore Wind Workforce Network and conducting further stakeholder engagement
- Communicating the consensus on roles (e.g., via O*Net or similar, career mapping, and so on) so that related training organizations and adjacent industries are aware of them
- Encouraging GWO to work with existing safety training providers to ensure they are adhering to U.S. standards so these trainings can be leveraged for the offshore wind energy industry.

Recommendation #2: continue to conduct detailed assessments of existing programs, trainings, and workers to identify gaps in training, skills, education, or experience. These programs should then be communicated broadly to all stakeholders to raise awareness of existing resources and possibilities for training alignment. As a result, we recommend:

- Assessing existing certification and training programs in key areas to determine whether additional training and standardization are required to serve the offshore wind energy industry
- Adapting and expanding the curricula and training already offered by related programs (e.g., at maritime academies) in lieu of creating new programs
- Training workers in skilled trades for manufacturing facilities as well as professional roles regardless of if they are offshore-specific. There is opportunity, such as at community colleges, to train workers in more general skill sets.
- Hiring people who have a desire and tolerance to work in unique offshore environments will ensure that they will be successful in their roles. Although many skill sets are similar between some land-based industries and those needed for offshore wind, working offshore may not be for everyone.

Recommendation #3: prioritize the most immediate workforce needs for training alignment, expansion, and development, including:

- Hiring and training workers strategically, based on the offshore wind deployment pipeline and regional needs. States should conduct more detailed state-level assessments to identify how they can support regional offshore wind energy workforce goals. This approach will help mitigate the potential peaks and valleys of workforce demand (e.g., jobs related to installation activities, such as ports and vessels, are temporary, so a large deployment pipeline means workers can move on to other projects).
- Supporting specific skill sets for heavy metal fabrication, monopiles, and towers to fulfill the workforce needs of announced manufacturing plants
- Establishing workforce training programs for manufacturing and the supply chain through additional policies and programs.

Recommendation #4: document existing program offerings and coordinate the development and expansion of programs to ensure these efforts are implemented for the most needed programs and in the most relevant locations. The development and expansion of programs could be coordinated across local, state, regional, and national entities and can be the basis for strategic partnerships. As a result, we recommend:

- Partnering with offshore wind and supporting industries, such as manufacturing, to ensure that educational and training courses and content align with offshore wind industry requirements and regional needs
- Providing offshore-wind-specific education and training to prepare workers for domestic offshore wind energy industry. U.S. entities should collaborate with international entities to leverage lessons learned from the international offshore wind industry while providing U.S.-specific content.
- Encouraging unions, industry, and other stakeholders to partner to map training programs and organizations to the requirements of the offshore wind energy industry
- Exploring virtual training options (versus building expensive training facilities).

Recommendation #5: encourage collaboration between offshore wind workforce stakeholders to create a diverse, equitable pipeline for future workforce needs. These efforts should include building pathways to transition workers from parallel industries to offshore wind, retaining offshore wind workers in various roles within the industry to improve job and local workforce retention, and creating outreach programs that enable future workforce supply. Specifically, we recommend:

- Introducing younger students (K-12) to renewable and offshore wind energy to create interest that may carry through to their future education and career decisions
- Encouraging academic programs at all levels to work closely with industry to create internship, apprenticeship, and other pathway opportunities into the offshore wind industry, such as sponsor capstone projects and experiential programs
- Recruiting workers involved in the installation phase to continue in the industry by working in O&M. This approach can help ensure that the experience gained during

installation is carried through to operations as well as smooths out the installation workforce demand over time.

- Encouraging collaboration between marine industries and training organizations to help workers transition into (and out of) offshore wind energy jobs, which may also help smooth out the peaks and valleys of installation workforce needs.

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Appendix A. Pipeline and Methodology

The authors modeled a pipeline of offshore wind energy projects (Appendix B) based on information in the "Offshore Wind Market Report: 2021 Edition" (Musial et al. 2021) and component demand in "The Demand for a Domestic Offshore Wind Energy Supply Chain" (Shields et al. 2022). We estimated the number of jobs for each plant in this pipeline and needs over time between 2022 and 2030. [28] The pipeline represents projects under construction, announced, or planned that contribute to the goal of 30 gigawatts of offshore wind by 2030, including fixed-bottom and floating projects (Figure A-1). The model plants add up to 28 gigawatts of installed capacity on the East and West Coasts by 2030.

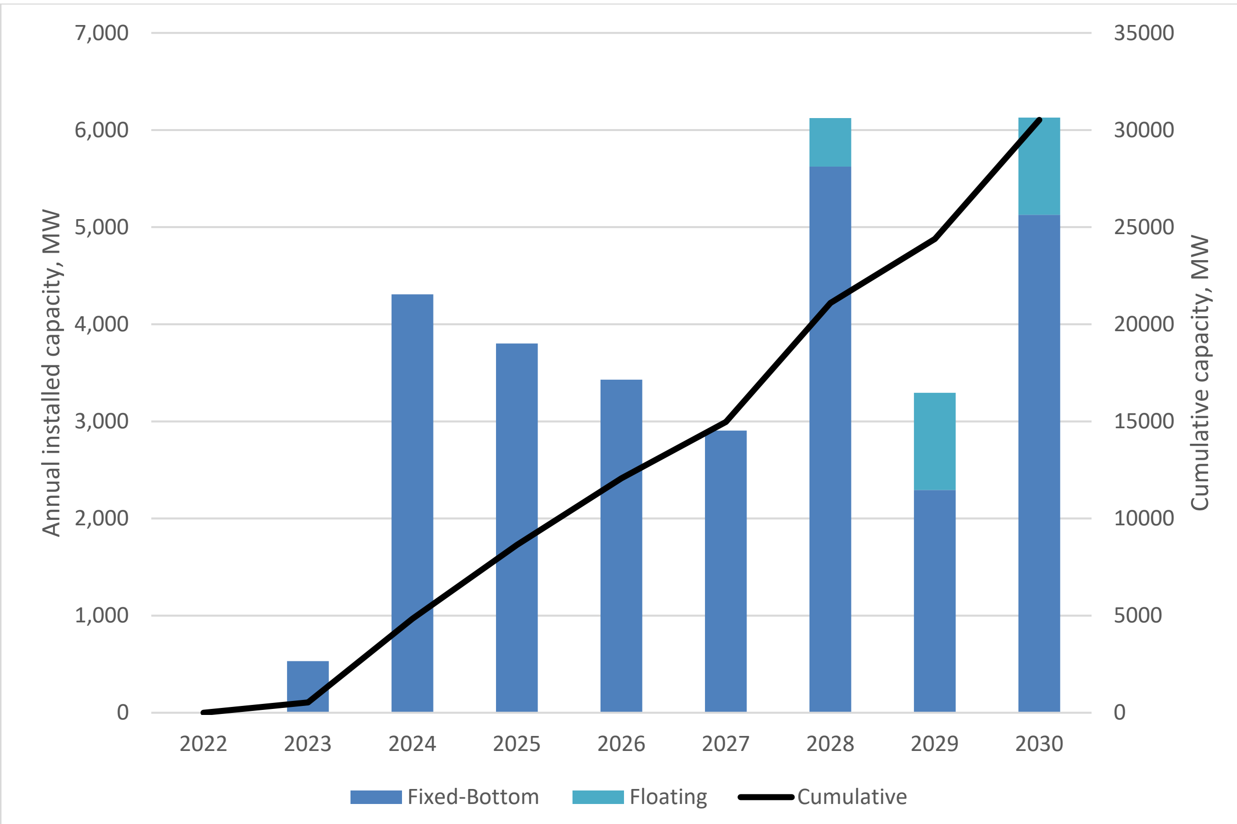

Figure A-1. The fixed-bottom capacity is expected to be installed on the East Coast and the floating capacity on the West Coast, assuming there are no constraints to reaching 30 gigawatts of offshore wind energy by 2030

(MW = megawatts)

We modeled each plant in the offshore wind pipeline using specific site, technology, and installation characteristics. Example characteristics include site depth, distance to shore, turbine

[28] We estimated the number of jobs up to 2030 because the project pipeline and turbine technologies and installation strategies are more uncertain past 2030. The estimates to 2030 would represent the workforce need that would be sustained going forward, with additional hiring based on the growth of the industry at that time.

rated capacity, number of wind turbines, and other attributes that account for different plant and labor costs.

We developed an input-output (I-O) economic impact model, based on the Job and Economic Development Impact (JEDI) model, to conduct an analysis by-parts framework for all components to assess the job impacts of each industry segment. The primary inputs include the pipeline demand, total cost, and domestic content assumptions that provide sensitivities for how much labor and material is sourced from the United States. IMPLAN economic data provide direct and indirect I-O multipliers to estimate the employment impacts.[29] The estimates in this assessment includes only the offshore wind jobs associated with development, manufacturing, installation, and operation of offshore wind energy plants (both direct and indirect). However, the estimates do not include additional jobs in communities supported by offshore wind activity, also known as induced impact jobs.

NREL also developed a custom, process-based model to forecast workforce demand over time for different vessel types based on achieving 30 GW of offshore wind energy by 2030. This model, referred to as the Offshore Wind Vessel Workforce Estimator, expands upon the capabilities of the Offshore Wind JEDI model by combining job modeling, occupation, and salary data with detailed installation strategies and process times from the National Renewable Energy Laboratory's (NREL's) Offshore Renewables Balance-of-system Installation Tool (ORBIT).

For the workforce estimates over time, we also applied a 3-year average over the job (full-time equivalent [FTE]) estimates for the workforce sensitivity and general workforce development assumption to smooth out the variance that occurs when a plant uses the workforce for their project or component manufacturing.

Limitations to the scope of this analysis include:

- The estimates are on a national level and do not indicate the region or states where the workforce will likely develop
- The general workforce development assumption is a standard set of domestic content assumptions for each offshore wind industry segment to provide a more reasonable workforce development pathway. The domestic content may not factor in all Jones-Act considerations for vessels or manufacturing or supply chain announcements.[30]

Limitations of the input-output (I-O) process-based and economic impact models include:

[29] More information and a public version of the JEDI model is available at: https://www.nrel.gov/analysis/jedi/.
[30] The Jones Act (46 United States Code § 55102) requires any vessel transporting cargo by water between U.S. port and an offshore wind energy plant be built and registered in the United States. The Jones Act also requires 100% American crew on U.S.-flagged vessels (at least 75% US citizens and up to 25% green card holders), the percentage of ownership of the vessel that is required to be American, and the percentage of materials that are required to be American.

- These models use fixed, proportional relationships between economy sectors. Factors that could change economic sectors, such as price changes that lead households to change consumption patterns, are not considered.

- The process-based model relies on assigning job roles to discrete installation tasks. Some workers may not be represented and are therefore not accounted for in the job estimates.

- Results represent the gross job impacts for offshore wind energy, not net impacts or impacts to other related industries.[31]

Specific job numbers are estimated in five industry segments, using project-specific costs, industry aggregations, and timing assumptions:

- Development. The plant project costs associated with construction operations, site assessment activities, and design and installation are multiplied through an I-O methodology assigning the costs into a professional services sector industry aggregation. To account for when these jobs occur over time, 33% of the labor hours (in full-time equivalents) are allocated each year across two years before the commercial operation date (COD) and 33% are allocated the year of the COD.

- Manufacturing and supply chain. We developed an I-O economic impact model based on the Jobs and Economic Development Impact methodology to conduct an analysis-by-parts framework for all components to assess the direct and indirect impacts of manufacturing and the supply chain. The primary inputs include the supply chain throughput, total production cost for each component, and domestic content assumptions that provide sensitivities for how much labor and material are sourced from the United States. IMPLAN economic data provide direct and indirect I-O multipliers to estimate the employment impacts of expenditures from component production. These assumptions are detailed in Shields et al. (2022).

- Ports and staging. The Offshore Renewables Balance-of-system and Installation Tool (ORBIT) calculates the time a port is used to support offshore wind energy installation and multiplies it through a monthly port rate. These costs are multiplied through an I-O methodology assigning the costs into a transportation sector industry aggregation. To account for when these jobs occur over time, 50% of the labor hours (in FTEs) are allocated to 1 year before COD and 50% are allocated the year of COD.

- Maritime Construction. Workforce estimates are based on a process-based assessment of FTE workers for several types of installation vessels. We developed a process-based model, referred to as the Offshore Wind Vessel Workforce Estimator, which combines job modeling, occupation, and salary data and assigns job roles based on detailed installation strategies and process times from ORBIT. Because vessels can only install in

[31] Other macroscopic economic changes may take place that the Jobs and Economic Development Impact model does not consider, including supply-side impacts, such as price changes, changes in taxes or subsidies, tariffs on foreign steel, or utility rate changes. The model also does not incorporate far-reaching effects, such as those due to greenhouse gas emissions, displaced investment, or potential side effects of a project such as recreation or tourism.

certain weather conditions, there are environmental considerations for when wind turbines are installed. Further, depending when installation begins in a given year, 75% of the labor hours (in FTEs) are allocated to 1 year before COD and 25% the year of COD. Total workers on board and major assumptions used to arrive at those totals are itemized in Table A-1. We validated these totals, along with roles onboard, with industry-provided data. ORBIT assumes vessel strategies for activities, thus we included workers on board support vessels for certain activities in the worker on-board table. For example, cable laying in ORBIT assumes a simplified strategy, so we included workers on board from support vessels to align our worker on-board numbers with industry-provided data. Some vessels were not included in strategies because they were not directly related to the activity, although they were indicated in industry-provided data, such as bubble curtain vessels and environmental monitoring vessels.

Table A-1. Worker On-Board Totals, by Vessel Type, With Major Assumptions Listed

Vessel	Workers On Board	Notes
Cable lay vessel	172	Because ORBIT accounts for a simplified cable lay vessel strategy, we included vessel workers involved in cable laying from a cable-lay vessel, pre-lay grapnel vessel, survey vessel, trenching support vessel, technical teams, pull-in vessel, and offshore support vessel in this worker total to align our numbers with industry data and strategies. Worker totals may vary depending on the strategy used.
Scour protection vessel	79	This worker total relies on a fallpipe vessel strategy. Worker totals will vary significantly with the strategy employed.
Heavy-lift vessel	269	This heavy-lift vessel is based on substation installation activities.
Wind turbine installation vessel	97 (monopiles) 138 (wind turbines)	We modeled both monopile and wind turbine installation with a wind turbine installation vessel strategy. The greatest difference in workers between the two processes comes from the presence of foundation workers, welders, or turbine workers given the task needs. We do not include bubble curtain vessels for pile driving, nor environmental monitoring or survey ships that may accompany monopile or turbine installation activities.
Feeder barge	7	Feeder barges are used in conjunction with tow tugs to transport materials to the installation site.
Tow tug	14	Tow tugs are used in this study to direct feeder barges and transfer crew to the installation site.

- Operation and maintenance (O&M). A literature review provided information on the number of onshore jobs per plant and number of offshore jobs per plant on service operation vessels. In addition, we modeled a separate number of jobs per turbine for maintenance activities for crew transfer vessels. We multiplied the number of plants and turbines in the offshore wind pipeline by these O&M job estimates to determine the full workforce need. We assume that 100% of the O&M workforce starts at COD for each project.

Appendix B. Workforce Roles and Requirements

Workforce roles, descriptions, education, and experience requirements for each sector—development; manufacturing and supply chain; ports and staging; maritime construction; and operations and maintenance—are described in this appendix.

To define different roles and requirements within job categories, we developed descriptions of occupations and the required competencies from direct job postings for the occupations described, which we corroborated with industry interview data. We based competency requirements on functional rather than foundational competencies. Functional competencies are occupation- or process-specific and measure the ability to demonstrate performance to the standards required of a particular job occupation, scope of work, or package (e.g., monopile package installation versus substation package installation), whereas foundational competencies are related to "soft skills," and work readiness generally required of employers.

B.1 Development Workforce Roles and Requirements

Table B-1 lists the different types of roles, a description of the role, and education and experience requirements that make up the development job estimates in Section 2.1.

Table B-1. Development Occupation Descriptions and Requirements

Role	Description	Education and Experience Requirements
Financial analyst/controller*	Provides financial advice and financial reporting	Bachelor's degree in accounting or finance Relevant experience in financial analysis or accounting preferred
Commercial analyst*	Models project costs and returns Monitors power markets and policy support	Bachelor's degree, Master of Business Administration (MBA) preferred Several years' experience in relevant quantitative experience, such as market analysis
Finance manager	Structures and executes project finance and mergers and acquisitions transactions	Master's degree or higher professional education in finance, economics, or engineering/MBA Several years relevant experience in finance
Insurance specialist*	Performs contractual risk management related to insurance provisions, including taking out necessary insurance and managing insurance claims	Master's or higher professional education in risk management, insurance, or law Several years relevant experience in insurance, preferably with utility-scale renewable energy
Counsel*	Supports general counsel and commercial and procurement teams in preparing for and negotiating key agreements	Juris Doctor Several years relevant experience in law, preferably with utility-scale renewable energy

Role	Description	Education and Experience Requirements
Procurement specialist*	Manages supplier relations Manages contracts including preparing for and negotiating supply contracts, claims, variation, and delivery	Bachelor's degree in business, engineering, law, or supply chain Relevant experience in procurement preferred
Regulatory/ permitting coordinator**	Manages permitting of the offshore wind plant and associated infrastructure Liaises with federal, local, and state officials, landowners, and other stakeholders	Bachelor's degree in relevant business or engineering field Several years relevant experience in offshore renewables, oil and gas, telecommunications, or large energy infrastructure projects
Public relations/ stakeholder specialist*	Engages with and acts as a representative to relevant stakeholders including local communities and state and local government	Bachelor's degree Local knowledge and relationships preferred
Environmental scientist, biologist, geophysicist, subsea engineer, oceanographer**	Monitors and analyzes specific aspects of the environment and potential effects of a wind power plant	Master's or higher professional education in environmental science, oceanography, or other relevant field
Engineer**	Designs/supports the design and implementation of the wind power plant and associated infrastructure	Master's or higher professional education in a relevant engineering degree Several years of relevant experience in engineering or other quantitative field, experience in offshore wind/oil and gas preferred
Project manager*	Manages development activities across a project	Bachelor's degree, business or engineering degrees preferred Several years' experience in project management
Administrator	Supports day-to-day project operations	Relevant experience in administrative work
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

B.2 Manufacturing and Supply Chain Workforce Roles and Requirements

Table B-2 through Table B-7 lists the different types of roles, a description of the role, and education and experience requirements that make up the manufacturing and supply chain job estimates in Section 2.2.

Table B-2. Description and Requirements for Regional Professional Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Regional corporate executive*	• Directs, plans, and coordinates operational activities for their region • Devises policies and strategies to meet company goals	• Bachelor's degree in business, finance, or organizational leadership fields, advanced degrees such as an MBA preferred • Significant experience in leadership and management in the energy industry
Administrator	• Supports day-to-day project operations	• Relevant experience in administrative work
Sales and marketing manager and team*	• Develops customer relations • Identifies, qualifies, and closes business opportunities • Develops and leads strategic sales plan • Communicates and achieves sales targets	• Bachelor's or advanced degree in business, marketing, finance, or related field • Industry sales and management experience
Business development manager and team**	• Positions the company and current/future products for key contracts through developing close customer business relationships • Leads or assists with preparing and submitting bids, quotes, or proposals by defining business cases and competitive approaches • Leads or assists with driving cross-function problem-solving teams to address commercial, technical, or manufacturing issues associated with key accounts • Identifies key potential new markets and work across the organization to develop a business strategy	• Bachelor's degree in business or engineering degree, advanced degree in business administration, finance, or related field preferred • 5 years of industry experience (minimum)
Research and development manager and team**	• Plans and leads the execution of all product development activities from conception through certification • Collaborates closely with the commercial teams to determine new development opportunities • Advises the rest of the executive team on research and development opportunities, needs, and progress	• Master's degree or higher professional education required in a quantitative field, such as engineering, computer science, and so on • Experience in plant and project management

Role	Description	Education and Experience Requirements
	• Leads activities with third-party contractors, consultants, and service providers	
Manufacturing and sourcing manager and team**	• Builds strategic partnerships • Selects suppliers, negotiate contracts and pricing, and manage contracts • Works closely with legal counsel to lead vendor negotiations • Evaluates company spend on a regular basis to help prioritize sourcing initiatives and cost-saving opportunities	• Bachelor's degree in relevant engineering or business field • Several years of experience in strategic sourcing management (minimum)
Human resources manager and team	• Builds internal relationships • Cultivates culture and employee engagement and oversee human resource processes • Oversees learning, development, and talent recruitment programs • Works with business unit leaders to define and implement productivity tracking tools and reporting • Administers performance management program • Coordinates with counsel and other business units to manage public relations and promote the company internally and externally	• Bachelor's degree in a relevant field such as public relations, communications, and so on • Significant experience in human resources management
Counsel**	• Supports general counsel and commercial and procurement teams in the preparation and negotiation of key agreements	• Juris Doctor • Several years of law experience, preferably with utility-scale renewable energy
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-3 Description and Requirements for Factory-Level Management Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Production Engineer**	• Defines and controls production process including tooling and equipment • Validates design specifications and shop floor applications of new products, tools, or equipment	• Master's or higher professional education in relevant engineering field • Experience in the wind energy industry or manufacturing setting
Manufacturing engineer**	• Develops, monitors, and improves manufacturing processes to meet and improve key performance indicators • Oversees manufacturing of product and delivery to customer • Oversees inventory management from procurement, receiving, cycle counts, and forecasting • Supports service material needs • Ensures tooling and fixtures are delivered to manufacturing to support needs	• Bachelor's degree in relevant engineering field • Experience in a manufacturing and supervisory role
Plant manager**	• Ensures the plant achieves operational and financial metrics, including on-time delivery, workforce planning, compliance, safety, and cost; responsible for developing close relationships with customers	• Bachelor's degree • Experience in plant and project management
Operations manager**	• Manages production supervisors and processes in manufacturing shop operations, sourcing materials and management, technical (lean manufacturing and process engineering), and health, safety, and environment (HSE)	• Bachelor's degree in relevant engineering or business field • Experience in a manufacturing setting
• ***Knowledge or training specific to offshore wind energy technology or industry recommended** • ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-4. Description and Requirements for Design and Engineering Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Design engineer**	• Designs new offshore components, develops tools, certification, validation, and industrialization • Handles warranty cases • Specializes in electrical, structural, controls, or mechanical components • Implements codes and standards as related to the product and installation environment	• Bachelor's, master's, or Ph.D. degree in relevant engineering field, depending on leadership level • Relevant engineering licenses • Experience based on leadership level
Testing engineer**	• Tests components and subcomponents to support product design and validation • Works with design and nondestructive testing teams to streamline and improve testing procedures	• Master's or higher professional education in relevant engineering degree • Relevant engineering licenses
Supply chain analyst**	• Creates processes and methods to gather supply chain data to support production. Plans and implements supply chain optimization, after conducting data analysis to identify improvements. Develops requirements and standards, and tracks inventory	• Bachelor's degree in business analytics, supply chain, or equivalent

***Knowledge or training specific to offshore wind energy technology or industry recommended**
****Knowledge or training specific to offshore wind energy technology or industry required**

Table B-5. Description and Requirements for Quality and Safety Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Quality assurance (QA)/quality control (QC) officer/specialist**	• Defines the quality standards and guidelines for the project and identifies quality issues during installation	• Bachelor's degree • Several years relevant experience • Specialized training in quality management
QA inspector*	• Sets up and operates measuring systems to rapidly and accurately define complex, nongeometric shapes • Performs inspection analysis, scheduling, and reporting	• High school diploma/GED • Experience in QA/QC
QC engineer*	• Ensures that products are designed, built, and produced in accordance with customer specifications and quality requirements	• Bachelor's degree • Knowledge of manufacturing codes
Safety officer/advisor	• Provides support, advice, and guidance on all aspects of compliance with HSE processes and practices	• Bachelor's degree in relevant field

Role	Description	Education and Experience Requirements
		• Relevant industrial safety certifications
Purchasing manager/assistant**	• Purchases the materials, equipment, and tools needed to manufacture products • Works with logistics manager to source materials and understand factory needs	• Bachelor's degree in relevant field • Experience in business, supply chain, or other relevant field
Logistics manager	• Optimizes regional logistics and internal material flow • Evaluates purchasing, planning, and warehouse core data • Improves supply chain development, supplier performance, capacity, and cost • Identifies cost opportunities and excitation in the factory, supply chain, and transportation • Decreases obsolete inventory • Mitigates supply chain risk	• Bachelor's degree in relevant field • Relevant experience in supply chain management • Six-Sigma training • Lean manufacturing training
Nondestructive test and inspection technician*	• Implements nondestructive testing procedures as directed by the testing engineer and QA/QC officer	• High school diploma/GED • Nondestructive testing training • Training/coursework in composite materials
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-6. Description and Requirements for Factory-Level Worker Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Materials handler	• Handles the ordering and supply chain of materials • Manages the material flow from receiving to manufacturing processes	• High school diploma/GED
Production supervisor*	• Ensures production team members have the right tools, resources, skills, and knowledge to perform their duties safely, ensures quality and safety, communicates with senior plant leaders	• Bachelor's degree in business or engineering • Experience in a manufacturing setting
Manufacturing associate/operator – welder, machine setter, assembler	• Designs new components, develops tools, certifies, validates, and industrializes products • Operates workstation tools and equipment based on assigned processes;	• High school diploma/GED • National manufacturing certification (such as National Association of Manufacturers, National Occupational Competency Testing Institute,

Role	Description	Education and Experience Requirements
	can include automated cell/machinery operation • Designs, builds, and assembles carts, trays, standards, and other equipment to support workstation tooling and equipment • Performs layout operations to verify part dimensions • Assembles/disassembles machine parts, as required • Specializes in cutting and trimming; polishing; painting and finishing; plasma cutting; welding; assembling; blasting; heavy lifting	and National Institute for Metalworking Skills) • Training, depending on scope of work (e.g., National Commission for the Certification of Crane Operators [NCCO])
Electrical technician**	• Prepares, assembles, and inspects electrical packages and components • Installs electrical packages and components • Coordinates with design team to assemble electrical packages to specifications	• Associate degree or vocational training for electricians or in electrical engineering
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-7. Description and Requirements for Facilities Maintenance Roles Within Supply Chain and Manufacturing

Role	Description	Education and Experience Requirements
Maintenance supervisor	• Oversees the preventative and corrective maintenance plans, processes, and team members that work with facility equipment, machinery, and facilities	• Associate degree or vocational training • Experience in manufacturing and supervisory role
Maintenance technician/engineer	• Performs the preventative and corrective maintenance of equipment, machinery, and facilities	• High school diploma/GED • Experience in manufacturing setting
Cleaning staff	• Maintains facility cleanliness and hygiene	• None
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

B.3 Ports and Staging Workforce Roles and Requirements

Table B-8 through Table B-11 lists the different types of roles, a description of the role, and education and experience requirements that make up the port job estimates in Section 2.3.

Table B-8. Port Marine Crew Role Descriptions and Requirements, Including Shipping Vessel, Tugboat, and Pilot Boat Crew

	Role	Description	Education and Experience Requirements
Shipping Vessel Crew	Captain/master	• Responsible for every aspect of the voyage and vessel	• Associate degree (or vocational training • Significant experience leading a crew and navigating a vessel • License issued by the U.S. Coast Guard
	Mate (chief/first, second, third)	• Manages and trains the deck crew • Inspects and maintains equipment inventory • Orders needed repairs • Aids in captain duties when necessary	• Associate degree or vocational training • License issued by the U.S. Coast Guard
	Boatswain/bosun	• Oversees the deck crew	• High school diploma/GED • Relevant vessel crew leadership experience • 6−12 months training on a U.S.-flagged Jones-Act-compliant vessel (6 months for small vessels, 12 months for large or construction vessels) • U.S. Coast Guard license
	Seamen (able-bodied and ordinary)	• Watches for obstructions, measures water depth, turns wheel on bridge, or uses emergency equipment as directed • Maintains and operates ship	• High school diploma/GED • 6−12 months training on a U.S.-flagged Jones-Act-compliant vessel (6 months for small vessels, 12 months for large or construction vessels) • U.S. Coast Guard license
	Ship engineer	• Operates and maintains engines, boilers, deck machinery, and electrical, sanitary, and refrigeration equipment aboard the ship	• Associate degree or vocational training • Licensing for specific responsibilities (e.g., electrical engineering license)
	Engine room rating	• Assists the Office of the Watch • Maintains main propulsion and various systems onboard vessels • Assures a clean, safe work environment	• Engine Room Rating Certificate of Competency
	Electro-technical officer	• Maintains, repairs, diagnoses, installs, and tests electrical and electronic equipment on the vessel (on call)	• Associate degree or vocational training • Several years of relevant sea experience • License issued by U.S. Coast Guard
	Head tunnelman/ tunnelman	• Supervises the crew assisting in the O&M of the off-the-shelf, unloading machinery; responsible for the	• High school diploma/GED

	Role	Description	Education and Experience Requirements
		performance of the vessel during the unloading process • Assists preparing and testing of all gates prior to cargo loading and ensures that the environmental management procedures are followed	
	Crew services	• Provides catering, maintains crew quarters, and ensures health and welfare of crew during vessel deployment	• High school diploma/GED
Tugboat Crew	Captain/master	• Manages every aspect of the voyage and vessel	• Associate degree (or vocational training) • Significant experience • License issued by the U.S. Coast Guard
	Mate (chief/first, second, third)	• Manages and trains the deck crew • Inspects and maintains equipment inventory • Orders needed repairs • Aids in captain duties when necessary	• Associate degree or vocational training • License issued by the U.S. Coast Guard
	Boatswain/bosun	• Oversees the deck crew	• High school diploma/GED • Relevant vessel crew leadership experience • 6−12 months training on a U.S.-flagged Jones-Act-compliant vessel (6 months for small vessels, 12 months for large or construction vessels) • U.S. Coast Guard license
	Ship engineer	• Operates and maintains engines, boilers, deck machinery, and electrical, sanitary, and refrigeration equipment aboard the ship	• Associate degree or vocational training • Licensing for specific responsibilities (e.g., electrical engineering license)
Pilot Boat Crew	Pilot	• Steers ships in and out of berths, through hazardous conditions, and in boat traffic with own vessel • Coordinates with tugboat crew to navigate and guide the shipping vessel to the correct port terminal	• Associate degree or vocational training • Significant experience piloting • License issued by U.S. Coast Guard
***Knowledge or training specific to offshore wind energy technology or industry recommended **Knowledge or training specific to offshore wind energy technology or industry required**			

Table B-9. Port Terminal Crew Role Descriptions and Requirements

Role	Description	Education and Experience Requirements
Laborer	• Supports material handling activities, performs assigned tasks, and monitors and maintains equipment, building, and grounds	• None
Rigger/ roustabout	• Assists with lifting operations, handles ropes and cables, port side	• High school diploma/GED • Offshore Petroleum Industry Training Organization (OPITO) rigging and lifting certification
Longshoreman	• Prepares cargo for transport, which may include engaging and disengaging locks, placing or removing dunnage, and using lashing materials	• Transporter worker ID card • 2 years general laborer experience (required)
Main/auxiliary crane operator	• Operates mechanical boom and cable or tower and cable equipment to lift and move materials, machines, or products	• High school diploma/GED • NCCCO training
Foreman, heavy-lift supervisor	• Oversees receiving, lifting, and transport crew • Directs and monitors terminal activity to ensure it is consistent with environmental safety and health, port, and customer standards	• Associate degree or vocational training • Heavy-lift operator certifications (if applicable)
Truck driver	• Offloads containers at port and transports within port to marshalling areas directly	• Must possess a valid Class A commercial driver's license and have minimum 2 years commercial driver's license-A driving experience • Must be 23 years old (minimum for insurance) • Must have a good driving record • Drug test and background check required • U.S. Department of Transportation physical required • Transportation Worker Identification Credential card preferred, not required • Port experience preferred
Customs officer	• Screens and documents goods when they arrive from a foreign country and confiscates illegal materials and goods	• Bachelor's degree • 1-year experience in security, driver's license, proof of U.S. citizenship, pass a drug test and criminal background check • Entrance exam from U.S. Customs and Border Protection
Port police	• Responsible for the safety and security of all passengers, cargo, and vessel operations at the port, requires	• Associate degree or vocational training • Basic police academy training

Role	Description	Education and Experience Requirements
	considerable public and community contact and cooperation • Initiates actions designed to respond to long-term or continuing criminal or safety problems, and responds to individual criminal activity	• Field training successfully completed with field training officer
QA/QC manager/ specialist**	• Defines the quality standards and guidelines for the projects and identifies quality issues during receiving and transport • Manages the QA/QC team	• Bachelor's degree • Relevant safety certifications • At least 3 years of experience in QA/QC
QA/QC inspector*	• Sets up and operates measuring systems to define and assess quality of received materials and goods rapidly and accurately • Conducts inspection analysis, scheduling, and reporting	• High school diploma/GED • Experience in QA/QC
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-10. Port and Logistics Management Role Descriptions and Requirements

Role	Description	Education and Experience Requirements
Port/terminal manager	• Manages all operations of the terminal and port • Manages and maintains key performance indicators for all terminals and its employees • Directs and oversees consistent application of all U.S. Department of Transportation regulations and Federal Motor Carrier Safety Administration programs	• Master's or higher professional education preferred; bachelor's degree required • 2 years of experience in terminal management
Operations supervisor	• Manages administrative duties related to port/terminal/vessel operations • Reconciles cargo manifests, both inbound and outbound • Assists in vessel, terminal, stevedoring operations to ensure compliance with cargo handling guidelines and requirements • Communicates and coordinates with vessels, vessel planners, trade management, customer service, accounting, suppliers, and contractors to optimize performance	• Bachelor's degree preferred • 2 years of experience in vessel/port operations and customer service
Safety officer	• Provides support and guidance on all aspects of compliance with the	• Master's or higher professional education preferred; bachelor's degree required

Role	Description	Education and Experience Requirements
	Safety, Health and Environmental processes and practices	• Relevant safety certifications
Marketing	• Researches conditions in local, regional, national, or online markets • Gathers information to determine potential sales of a product or service, or plan a marketing or advertising campaign • May gather information on competitors, prices, sales, and methods of marketing and distribution • May employ search marketing tactics, analyze web metrics, and develop recommendations to increase search engine ranking and visibility to target markets	• Bachelor's degree • 3−5 years experience
Information technology personnel	• Designs information technology infrastructure via cloud and on-premises technologies • Creates and manages database infrastructure • Supports and improves existing business processes and transforms the delivery of new services • Leverage DevOps tools, concepts, and continuous integration pipelines to build fast, reliable, and secure infrastructure services and solutions	• Master's or higher professional education preferred; bachelor's degree required • 8 years of experience in technical computer work
Human resources personnel	• Responsible for employee recruitment, management, and training • Own conflict management, benefits, and job status change processes	• Bachelor's degree • 1 year of experience in human resources
Administrative personnel	• Provides administrative support to the ports planning and development, facilities, projects, and human resources programs • Provides front desk and telephone coverage duties to the ports administration offices	• Associate degree or vocational training • 5 years of experience in administration or equivalent
Freight forwarder/ customs broker	• Arranges for containers to be filled with material at the manufacturing facility, transported to the origination port, and transported to the marshalling harbor	• Bachelor's degree • 3-5 years of experience in industry and customer service
Logistics/materials manager*	• Manages the processes and equipment/materials team to support all vessel activities	• Associate degree or vocational training • Structural, mechanical, and civil understanding

Role	Description	Education and Experience Requirements
	• Leads the logistics teams during process execution	• Able to interface with engineers
Material coordinator (onshore and offshore)*	• Monitors processes from manufacturing to delivery • Specifies all critical materials and equipment and develops plans to ensure on-time delivery	• Bachelor's degree • Global Wind Organisation training • Experience in vendor management, inventory logic and systems, and transporting via multimodal methods
Inspection/expediting manager*	• Implements and maintains physical distribution procedures, work authorizations, dispatching and expediting procedures and marshalling area, storage, and terminal scheduling and loading procedures	• Associate degree or vocational training
Data control manager	• Documents records at all phases, from procurement to installation, including testing, certifications, and all interfaces	• High school diploma/GED • Experience in database and inventory management on a variety of systems
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-11. Port Facilities Management Crew Role Descriptions and Requirements

Role	Description	Education and Experience Requirements
Maintenance and facilities supervisor	• Oversees the repair and preventative maintenance plans, processes, and team members that work with equipment, machinery, and facilities	• Bachelor's degree • Experience in facilities management
Maintenance engineer	• Repairs and conducts preventative maintenance of equipment, machinery, and facilities • Maintains vessels and completes records	• Associate degree or vocational training • May have skill, expertise, and certifications in welding, electrical, or mechanic work
Cleaning staff	• Maintains facility cleanliness and hygiene	• None
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

B.4 Maritime Construction Workforce Roles and Requirements

Occupational requirements for maritime construction vessels can generally be grouped into three categories: 1) the marine crew responsible for vessel-specific activities and crew safety, 2) the project crew who oversees the project management, quality control, and installation of specific packages (e.g., wind turbine, foundation, substation, or cable specialist crews), and 3) construction crew who supports installation (e.g., with activities like crane operations, welding, and so on).

Functional competencies for a role depend on the specific installation process being completed and the equipment being used. Roles and competencies across installation activities are represented in Table B-12 through Table B-14. Roles are further categorized for entry-, mid-, and high-level positions. Entry-level roles require minimum certifications and training, although some experience is usually preferred, and can also include apprentices or trainees. Mid-level roles often require additional certifications and training compared to entry-level roles, as well as greater experience (approximately 2−6 years) in a similar role, operating similar equipment, within a company, or specific to a vessel. High-level roles require high levels or continued retention of certification and training, along with significant experience (approximately 7−10 years) in a similar role, operating similar equipment, within a company, or specific to a vessel. In some marine and construction crew roles, relevant experience can be vessel- and equipment-specific. For instance, a captain, heavy-lift vessel crane operator, or fallpipe technician can all be vessel-specific roles, for which a worker would not be substituted without having the necessary familiarity and experience with that vessel and its equipment.

Given that the jobs outlined in Table B-12 through Table B-14 operate in an offshore environment, offshore-specific HSE training is required for all of these roles (for example, Basic Offshore Induction and Emergency Training or Global Wind Organisation safety training).

Table B-12 through Table B-15 lists the different types of roles, a description of the role, and education and experience requirements that make up the maritime construction job estimates in Section 2.4.

Table B-12. Maritime Construction Occupation Requirements for the Marine Crew.

Entry-Level Roles Are Highlighted in Light Blue, Mid-Level Roles Are Blue, and High-Level/Specialized Roles Are in Dark Blue.

Role	Description	Education and Experience Requirements
Captain/master	• Oversees every aspect of the voyage and vessel	• Associate degree (or vocational training • Significant experience • License issued by the U.S. Coast Guard
Mate (chief/first, second, third)	• Manages and trains the deck crew • Inspects and maintains equipment inventory • Orders needed repairs • Aids in captain duties when necessary	• Associate degree or vocational training • License issued by the U.S. Coast Guard
Boatswain/bosun	• Responsible for the deck crew	• High school diploma/GED • Relevant vessel crew leadership experience • 6-12 months training on a U.S.- flagged Jones-Act-compliant vessel (6 months for small vessels, 12 months for large or construction vessels) • U.S. Coast Guard license
Ship engineer	• Operates and maintains engines, boilers, deck machinery, and electrical, sanitary, and	• Associate degree or vocational training • Licensing for specific responsibilities (e.g., electrical engineering license)

Role	Description	Education and Experience Requirements
	refrigeration equipment aboard the ship	
Electro-technical officer	• Maintains, repairs, diagnoses, installs, and tests electrical and electronic equipment on the vessel	• Associate degree or vocational training • Several years of relevant experience • License issued by U.S. Coast Guard
Seaman (able-bodied and ordinary)	• Watches for obstructions, measures water depth, turns wheel on bridge, or uses emergency equipment as directed • Maintains and operates ship	• High school diploma/GED • 6-12 months training on a U.S.- flagged Jones-Act-compliant vessel (6 months for small vessels, 12 months for large or construction vessels) • U.S. Coast Guard license
Crew services, stewards	• Provides catering, maintains crew quarters, ensures health and welfare of crew during vessel deployment	• High school diploma/GED
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-13. Maritime Construction Occupation Requirements for the Project Crew.

Entry-Level Roles Are Highlighted in Light Blue, Mid-Level Roles Are Blue, and High-Level/Specialized Roles Are in Dark Blue.

Role	Description	Education and Experience Requirements
Lead project manager/ engineer**	• Represents the developer aboard and oversees that project activities are in accordance with developer plans • Coordinates with the marine, project, and construction teams during execution of installation • Coordinates changes in the design if needed with the onshore offices	• Bachelor's degree • Relevant engineering licenses • Several years of relevant experience • Experience in company
Lead package (wind turbine, foundation, substation, cable) manager/engineer**	• Represents package company aboard and interfaces with the client • Coordinates changes in the design if needed with the onshore offices and the client • Coordinates with developer client and other package managers to implement the package delivery strategy	• Bachelor's degree • Several years of relevant experience • Experience and leadership in company
Lead scour protection manager/engineer*	• Manages the fallpipe installation and rock deposition activities onboard the vessel • Leads operational teams during the installation	• Bachelor's degree • Relevant engineering licenses • Several years' experience with similar vessel equipment
Chief surveyor*	• Manages surveying crew • Leads surveying and monitoring efforts in rock placement or cable positioning	• Bachelor's degree • National Society of Professional Surveyors-The Hydrographic

Role	Description	Education and Experience Requirements
	• Coordinates with remotely operated vehicle (ROV) and ship navigation/positioning crew to align operations	Society of America hydrographer certification • Several years of experience in offshore surveying
ROV supervisor*	• Plans and coordinates ROV crew for surveying and sensing of fallpipe position in scour protection processes • Responsible for surveying, sensing, and mapping cable post-lay in cable-laying processes	• Associate degree or vocational training • Pilot/technician Grade 1 certificate
Package engineer/assistant engineer**	• Supports the wind turbine, foundation, substation, cable, or scour protection package manager/engineer in delivering the package delivery strategy	• Bachelor's degree • Relevant engineering licenses
Electrical engineer**	• Works onboard the offshore substation after it is lifted into place to finish installing and connecting it to the other electrical components of the array in offshore substation installation processes • Conducts cable installation, connection, and testing with turbine electrical components in cable installation processes	• Bachelor's degree • Relevant engineering licenses • Several year of experience in relevant electrical work (offshore electrical work preferred)
Associate surveyor*	• Manage placing of rock deposition or cable laying	• Associate degree or vocational training
Scour materials controller*	• Coordinates receiving of materials • Manages the material on board to ensure it is ready for deposition and being placed at an appropriate rate	• High school diploma/GED • Several years' experience
Wind turbine technician**	• Supports the installation of the towers, nacelles, and blades in wind turbine installation processes • Supports mechanical and electrical readiness of wind turbine prior to full commissioning • Prepares the cable for pull-in, pulls the cable into the destination turbine or substation, and terminates/tests the cable section in cable installation processes	• Associate degree or vocational training • Technician experience
HSE officer/advisor*	• Provides support, advice, and guidance on all aspects of compliance with HSE processes and practices	• Associate degree or vocational training; bachelor's degree preferred
QA/QC officer/specialist**	• Defines the quality standards and guidelines for the project and identifies quality issues during installation	• Bachelor's degree • Several years relevant experience • Specialized training in quality management

Role	Description	Education and Experience Requirements
Offshore paramedic	• Diagnoses and treats work-related injuries and illnesses among crew members	• High school diploma/GED • Paramedic license • Offshore medic certification
***Knowledge or training specific to offshore wind energy technology or industry recommended **Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-14. Maritime Construction Occupation Requirements for the Construction Crew.

Entry-Level Roles Are Highlighted in Light Blue, Mid-Level Roles Are Blue, and High-Level/Specialized Roles Are in Dark Blue.

Role	Description	Education and Experience Requirements
Construction project manager/engineer**	• Manages the construction team onboard the vessel • Leads operational teams during execution of construction	• Bachelor's degree • Relevant engineering licenses • Several years of relevant experience
Heavy-lift supervisor, surveyor, monitor	• Oversees lifting and piling activities • Monitors seabed and environmental conditions and positioning during pile driving	• Associate degree or vocational training • Heavy-lift operator certifications
Main/auxiliary crane operator	• Operates mechanical boom and cable or tower and cable equipment to lift and move materials, machines, or products	• National Commission for Certification of Crane Operators training • Several years of experience in similar vessel and equipment handling
Pile driver	• Drives monopiles into the seabed • Determines load-carrying capacities, gauging hammer performance, and accommodating lateral, compression, or tension loads	• Associate degree or vocational training
Commercial diver	• Works below surface of water to inspect, repair, remove, or install equipment and structures • Uses a variety of power and hand tools	• Associate degree or vocational training • Association of Commercial Diving Educators/American National Standards Institute commercial dive certification • Specialist training (e.g., underwater welding)
Heavy-lift crane operator	• Operates mechanical boom and cable or tower and cable equipment capable of heavy-lift and move operations for large materials, machines, or products	• Associate degree or vocational training • NCCCO training • Heavy-lift crane training and experience
ROV pilot	• Implements a plan, as directed, for the surveying and sensing of fallpipe position • Aids with ROV deployment	• High school diploma/GED • Pilot/technician Grade 1 certificate • Medical certification • Apprenticeship completed

Role	Description	Education and Experience Requirements
		• Several years' experience
Fallpipe technician	• Assists with the installation and deinstallation of the fallpipe • Operates machinery that lifts pipe segments and ROV in and out of the water	• High school diploma/GED • OPITO rigging and lifting
Backhoe operator	• Operates backhoe to load scour protection rock on conveyor belt for deposition in the fallpipe • May also operate other lift equipment on board	• High school diploma/GED; associate degree or vocational training preferred • NCCCO training
ROV pilot trainee/apprentice	• Aids ROV pilot in surveying and sensing of fallpipe position • Helps with deployment of ROV	• High school diploma/GED • Pilot/technician Grade 1 certificate • Medical certification
Rigger/roustabout	• Assists with lifting operations; handles ropes and cables	• High school diploma/GED • OPITO rigging and lifting certification
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

B.5. Operations and Maintenance Workforce Roles and Requirements

Table B-15 through Table B-16 lists the different types of roles, a description of the role, and education and experience requirements that make up the operation and maintenance job estimates in Section 2.5.

Table B-15. Description and Requirements for O&M Crew

Role	Description	Education and Experience Requirements
Marine crew	• The marine crew operates SOV and CTV vessels. • Many of the roles in Table B-12 support O&M marine crew activities.	• See Table B-12
Turbine technician**	• Supports the repair, maintenance, and inspection of wind turbines	• High school diploma/GED • Turbine technician training • Specialized technician training for major/advanced repairs and troubleshooting • Working at height and in confined spaces training • Working with digital tools training • High-voltage switching • Several years of relevant experience

Role	Description	Education and Experience Requirements
Foundation/support structure maintenance**	• Inspects, maintains, and repairs wind turbine support structures	• Bachelor's degree • Relevant engineering licenses • Several years of relevant experience
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Table B-16. Description and Requirements for the Wind Plant Operations Workers

Role	Description	Education and Experience Requirements
Plant operations manager**	• Oversees and coordinates the O&M team carrying out the O&M strategy, planning, and logistics	• Bachelor's degree in business management, engineering, or a related field • Several years of relevant experience
Marine services technician*	• Plans the environmental monitoring strategy according to policy and regulation • Responsible for the environmental monitoring plan execution	• Bachelor's degree in marine biology, environmental science, or related field • Several years of relevant experience
Maritime coordinator*	• Coordinates vessel operations • Acts as liaison and berth coordinator between the ports • Updates management and global operations execution branches • Monitors vessels and transfer of personnel • Maintains maritime logistics reports	• Bachelor's degree in nautical science or related field • Several years of relevant experience in maritime logistics
Operations engineer**	• Plans technical solutions for maintenance and repair • Monitors and analyzes operational data as it is generated to detect and troubleshoot needed repairs • Monitors performance and degradation of assets • Coordinates with external outfits for specialized repair	• Bachelor's degree in computer science, engineering, or related field • Advanced training or experience in data science
Onshore (office) staff*	• Supports the O&M planning and logistics onshore • Works under wind power plant operations staff	• Associate degree or vocational training • Several years of relevant experience
***Knowledge or training specific to offshore wind energy technology or industry recommended** ****Knowledge or training specific to offshore wind energy technology or industry required**		

Appendix C. Methodology for Workforce Program and Pathway Tables

C.1. Assessment of Workforce Programs That Educate and Train Occupations Across Industry Segments

The colors in Table ES-1 and Table 2B are an assessment of the effectiveness of a workforce program in meeting the education and training needs for each occupational category (e.g., regional professionals, factory-level management, and so on) in each industry segment.

1. By answering the following questions, a qualitative score was assigned to each workforce program that then determined the color assignment. How many workers are needed for each role?
2. Is there a short-, medium-, or long-term need for these occupations?
3. Are there existing education or training programs in the United States for these occupations?
4. Are there enough education or training programs to meet the current need?
5. For these occupations, is specific offshore wind energy technology or industry knowledge or required, recommended, or neither?
6. Do education programs have training or curriculum to fill this knowledge or training specific to offshore wind energy?
7. Do these occupations need specialized certification or licenses (e.g., to operate heavy machinery such as an electrical or engineering license)?

C.2. Assessment of Important Pathways To Facilitate Hiring of Offshore Wind Energy Industry Occupations

Primary Pathway. There are existing or planned initiatives or programs to hire workers from a particular pathway. This pathway is a clear entry point for the particular occupational category (e.g., regional professionals, factory-level management, and so on).

Secondary Pathway. It is possible to supply workers using this pathway but there are better pathways for this occupation to meet demand or new initiatives or programs will need to be created.

Limited Pathway. Workers may be sourced from this pathway but it is not well-aligned to supply workers.

Appendix D. High-Priority Role Spotlights

D.1 Marine Services Technician

A marine services technician, which may also be referred to as a wildlife surveyor or scientist, biologist, ecologist, or technician, ensures the successful completion of pre and postconstruction wildlife and vegetation surveys at wind energy project sites; conducts field surveys and habitat assessments; and prepares reports summarizing the results. People in this position may also monitor for potential marine life and construction interactions.

Education and Training

The role of a marine services technician requires a minimum of a bachelor's degree and advanced positions may require a master's degree or Ph.D. Relevant areas of study include biology (e.g., conservation, wildlife, marine), ecology, environmental science, natural resources, and other natural-sciences-focused topics. While many options exist for obtaining a degree in these fields, those wishing to pursue a career with offshore wind applications should select a program that includes offshore wind energy coursework or degree options.

Experience and Skills

To obtain a position as a marine services technician, employers prefer applicants who have experience conducting field studies and surveys. They should have experience using survey and monitoring software and equipment and potentially operating vessels. Species identification for both wildlife and vegetation, with expertise in specific locations or species, is highly valued. Other skills such as navigation using topographic maps, data collection, and writing will be necessary for this position. This position may require travel, working in remote locations, and physical endurance to be able to carry and maneuver equipment. Other requirements will likely include the ability to process and analyze data and calibrate, maintain, and operate equipment. Adhering to safety protocols and attaining offshore survey or safety certifications will also be required.

Existing Opportunities and Gaps

Positions in science are key to growing the offshore wind energy industry, particularly during the earlier stages of projects, when roles like marine services technician will be needed to support development and construction activities. Five[32] of the institutions that provided information on their programs indicated that they had existing programs that include offshore-wind-specific science content, and one additional university is in the process of incorporating offshore wind into its environmental science curriculum. As with engineering, there is an opportunity for other institutions to offer offshore science degree programs as well as incorporate offshore content into existing coursework so students can be prepared to support roles like marine services technician.

However, for the role of marine services technician, local, regional, and species expertise and experience are critical so, in addition to the potential for additional offshore wind coursework, it

[32] These institutions include Rowan University, Rutgers University, Stockton University, University of Massachusetts Dartmouth, University of Connecticut, and University of Rhode Island.

is important that these programs are located in the areas of offshore wind energy development and have coursework related to the key species and environments impacted by offshore wind.

Additional opportunities for educational institutions and industry to collaborate on curriculum and program development, as well as internship options, could allow for more scientists to graduate with the offshore wind experience necessary to support the anticipated growth of the industry.

D.2 Permitting Coordinator

The permitting coordinator is a professional role that supports offshore wind energy projects in the early-phase permitting, preconstruction, and construction phases of development. Primary processes include coordinating permitting schedules and ensuring related processes are completed in a timely manner.

The permitting coordinator role has the potential to include a variety of regulatory and environmental responsibilities and may also be referred to as a regulatory or permitting specialist, environmental and permitting specialist, or environmental compliance monitor. As such, this role may be required to secure and renew permits and licenses, as well as conduct research and review new or proposed environmental regulations; support and implement compliance solutions with applicable regulations; establish relationships with local, state, and federal agencies; interface with stakeholders; and prepare schedules and budgets for proposed projects.

Education and Training

A bachelor's degree in environmental or marine science; marine biology or ecology; biology; environmental policy; natural resources; environmental or land-use planning; geology; or related field is the minimum educational requirement for a permitting coordinator, although an advanced degree (master's or Ph.D.) is often preferred. Because offshore-wind-energy-specific education is not a requirement for this position, there are many options for obtaining a degree in a relevant field of study.

Though an offshore wind energy degree or coursework is not required, knowledge of and experience with the unique challenges associated with offshore wind is particularly important when it comes to regulatory and environmental issues and mitigation. There are few degree programs that provide offshore content in relevant topic areas, as well as credentials, certificate programs, and courses available to professionals seeking to focus on offshore wind within their line of work.[33]

Experience and Skills

To obtain employment as a permitting coordinator, most companies desire previous experience obtaining federal, state, and local permits. Familiarity with federal environmental and regulatory

[33] Institutions that offer degrees include Rowan University, Rutgers University, Tufts University, University of Connecticut, University of Delaware, and University of Rhode Island. Other education can be found through the Business Network for Offshore Wind, New York Institute of Technology, Rowan College of South Jersey, Stony Brook University, University of Massachusetts Amherst, and the University of Rhode Island.

policy such as the National Environmental Policy Act or state and local policy such as the California Environmental Quality Act may be required. Additionally, a working understanding of environmental mitigation requirements and strategies and a knowledge of environmental and regulatory issues is highly desired for this role.

Although offshore wind energy experience is preferred, it is not required for this role. Job postings indicated that prior experience with land-based wind, other renewable or offshore power generation technologies, onshore pipelines, transmission projects, or large infrastructure projects could meet the requirements for experience.

In addition to the experience preferred for this role, it is also important for potential employees to have the skills needed to build effective relationships and maintain a network of stakeholders, both internal (e.g., management) and external (e.g., federal, state, and local authorities, community members, and other relevant stakeholders).

Existing Opportunities and Gaps

A small number of the universities and organizations that provided information on their institutions and program offerings included degree programs that could prepare a future workforce of support, professional and management workers, and more specifically a permitting coordinator, with an offshore wind energy education. Together, with the concentration of institutions that responded in the Northeast, there are many opportunities for additional institutions to offer relevant degree programs, incorporate offshore wind content into degree programs and coursework, and provide regional diversity by offering these programs in other geographic areas of the United States.

Additional opportunities exist for industry to partner with educational and training programs to ensure that the offshore wind energy content incorporated into programs and coursework will adequately prepare the future workforce. Outside of curriculum, developing interdisciplinary activities at universities (such as competitions) could be expanded to include processes that require a variety of roles to increase opportunities to gain applicable experience.

D.3 Crane Operator (Portside and Offshore)

A crane operator is responsible for all phases of safely operating a crane within the guidelines of federal regulation standards as well as company standards. In wind energy applications, a crane operator is needed to replace large components like rotors, gearboxes, generators, nacelles, and damaged wind turbine blades. These tasks entail operating specific types of cranes to lift, move, position, and reposition wind turbine equipment at heights greater than 270 feet. The operator is required to unload crane accessories and work with riggers and other site employees to load and then position equipment. Following safety procedures and reporting on vehicle repair needs is vital to ensuring equipment is functional and the job is successfully completed.

This role requires specialized training that is usually completed at vocational/technical schools or training schools.

Education and Training

Crane operators must be certified by the National Commission for the Certification of Crane Operators (NCCCO). This certification applies to mobile crane operators, service truck crane operators, tower crane operators, overhead crane operators, articulating crane operators, and crane inspectors. The commission also offers certification for crane-related roles, such as rigger and dedicated pile driver. Additional endorsements or certification designations may be required for specific types of cranes including lattice boom crawlers, lattice boom trucks, and telescopic boom cranes.

Many U.S. training organizations specialize in training crane operators in preparation for NCCCO certification.[34] The full suite of Global Wind Organisation (GWO) safety training is currently offered or will be offered by seven programs across six states, primarily along the East Coast.

Experience and Skills

Experience operating specific types of cranes, erecting wind turbines, or installing wind turbine parts may be required for some positions. Additional requirements for crane operators include a current driver's license and a high school diploma or GED. Age limits, specific classes of driver's licenses, and proof of physical ability to perform the work may be required to become a crane operator.

Existing Opportunities and Gaps

More than 70 training options are listed on the NCCCO training providers' directory, and they are available in most U.S. regions. Specifically, only a few GWO training programs offer the full suite of certifications, including sea survival, and these are currently only available on the East Coast. Some unions are already preparing for NCCCO certification, such as the International Union of Operating Engineers, which supported the crane operations of the Block Island Wind Farm. They offer several training courses in preparation of a NCCCO certification at their International Training & Education Center in Texas.[35] As the offshore wind market expands beyond the Northeast and Mid-Atlantic regions, additional full-suite GWO programs will be required to meet regional demand for GWO trained workers. The need for these skilled workers may be an area of opportunity for existing crane operator training programs and would increase the regional availability of crane operators with full GWO training ready to enter the offshore wind energy workforce.

D.4 Foundations Package Manager

The foundations package manager is responsible for developing, delivering, and implementing the planning and execution of the foundations package on a wind power plant. Furthermore, they may be required to support efforts to tender, negotiate, and manage offshore supply, installation, and maintenance contracts; plan and implement delivery sites and logistics; comply with company and business engineering standards and technical acceptance criteria; and ensure quality and best practices and that excellent health, safety, and environment performance standards are applied.

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[34] The NCCCO does not endorse specific training options, but hosts a directory of training providers on their website, https://www.nccco.org/nccco/resources/training-resources/training-providers-directory.

[35] More than 60 International Union of Operating Engineers Local 57 members operated cranes at sea and supported cranes on land through a project labor agreement for the Block Island Wind Farm.

Education and Training

The role of foundations package manager requires a 4-year-plus degree in an engineering discipline such as civil, mechanical, structural, or ocean engineering. A bachelor's degree is the minimum education required for this role and is not necessarily specific to offshore wind energy, making it a requirement that can be met by universities across the United States. Though usually not required, it may be advantageous for those pursuing an advanced degree to focus their studies on offshore-wind-specific applications.

Experience and Skills

Employers prefer that a foundations package manager applicant in offshore wind energy have previous experience in offshore wind projects, offshore engineering, geotechnics, offshore wind turbine foundation dynamics, wind turbine generators, and submarine cable transport. Other experience, such as team management, contract management (engineering, procurement, construction, installation), and project management, may be beneficial.

Existing Opportunities and Gaps

Some engineering programs currently offer offshore-wind-energy-specific engineering degrees, certificates, and coursework that could meet the general requirements for a foundations package manager. Of the nearly 50 educational institutions that provided information about their programs, 11 indicated they had offshore-specific components to their engineering programs.[36] There is opportunity for these programs and other institutions to incorporate offshore-specific content and increase the number of degree programs available to students.

The current offshore wind engineering programs are concentrated in the Northeast and Mid-Atlantic areas. The expansion of programs to other regions such as southern states and the West Coast would provide additional opportunities for the future workforce to attain offshore-wind-energy-specific engineering education.

Many of the job postings reviewed required previous experience in offshore wind energy. While the U.S. offshore wind market develops, there have not been many opportunities for domestic workers to gain experience on an offshore wind energy project. Engineering programs that incorporate offshore-specific coursework could help bridge this gap while the market matures. Partnership between educational institutions and industry could also help increase the level of applicable experience that students achieve prior to graduation. In addition, there may be opportunities for offshore oil-and-gas workers to transition their experience over to offshore wind.

[36] These institutions include Clarkson University, Cornell University, Massachusetts Institute of Technology, Northeastern University, Rowan University, State University of New York Maritime College, Tufts University, University of Massachusetts Amherst, University of Delaware, University of Maine, and University of Rhode Island.

D.5 Offshore Wind Technician

Offshore wind technicians use specialized knowledge to manage, oversee, and conduct commissioning, testing, repair, and maintenance of wind turbines and their components. They perform maintenance and troubleshooting and repair mechanical, electrical, gearbox, and hydraulic systems; understand schematics; and apply appropriate diagnostic tools. Offshore wind technicians should be able to interpret fault reports, maintain power generation reports and service logs, and monitor wind turbine performance. Technicians inspect the exterior integrity of wind turbine towers, work at heights in excess of 300 feet and in confined spaces to complete inspections, and complete detailed inspection reports.

Further, there are often specialized offshore wind technician positions. One specialty role is a wind turbine blade technician, who perform blade repair and have specialized training and skills, such as certification for rope access.

This role completes specialized training offered through vocational/technical schools and community colleges; some companies may offer on-the-job training.

Education and Training

An offshore wind technician must have a driver's license and a minimum of a high school diploma or GED. Additional training such as a wind technician certificate or a 2-year degree in a relevant field such as mechanical, electrical, marine engineering or physics is preferred. A few offshore wind technician training programs are currently available in the Northeast, with at least one more known to be under development; additional programs are anticipated.[37]

For many companies, certifications such as those offered by GWO, including sea survival and rope access, are required. GWO training is available at a growing number of training centers and community colleges along the East Coast. Training from the International Rope Access Trade Association and the Society of Professional Rope Access Technicians is available at a few U.S. locations.[38]

Other certifications that may be required or highly beneficial are lockout/tagout, CPR/AED/First Aid, fall protection, and confined space. These are readily available in many locations.

Offshore wind technicians may also need specific training to operate and maintain advanced wind turbine models produced by a particular manufacturer.

Experience and Skills

Prior wind technician experience is preferred, although this requirement may be met with experience in relevant fields. Entry-level positions may help provide on-the-job experience.

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[37] Existing programs provided by the Atlantic Cape Community College and Farmingdale State College. A program under development is provided by the Rowan College of South Jersey.
[38] For more information, visit: https://www.globalwindsafety.org/trainingproviders/findttraningprovider, https://irata.org/course_venue_map, and https://sprat.org/sessions/.

It is beneficial for potential offshore wind technicians to have experience with specific wind turbine types as well as components, including hydraulic, electrical, mechanical, and composites. Additionally, an understanding of and experience with operations and maintenance power generation, transmission, and distribution is beneficial.

Applicants for offshore wind technician positions will have to meet certain physical fitness and weight requirements and be prepared to travel and work at heights and in adverse weather conditions.

Existing Opportunities and Gaps

As the offshore wind energy market expands, the need for offshore wind technicians will continue to increase. Additional training programs as well as diversification of program location will be required to meet the anticipated need for this role. There may be a possibility for existing land-based wind technician programs to expand their programs to include offshore wind technology, although not all program locations would be suitable for this expansion.

Because several wind turbine models will likely be deployed on the Atlantic Coast, training programs could engage with manufacturers to ensure technicians can operate and maintain their systems and streamline training.

The requirement for GWO training, including sea survival, provides a unique opportunity for existing training institutions to expand their offerings and for new training institutions and programs to be developed on or near U.S. coastlines.

There are additional opportunities for workers and companies in existing offshore wind energy industries to support, train, incorporate, or transition to offshore wind work.