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2018 Massachusetts Offshore Wind Workforce Assessment

A Report By

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Foreword

For more than a decade the Commonwealth of Massachusetts has been setting the stage for development of a U.S offshore wind industry with its nation-leading and historic renewable energy policies and ambitious greenhouse gas reduction targets. The Massachusetts Clean Energy Center (MassCEC) has led the charge by funding advanced research to assess environmental impacts and economic development opportunities, measuring wind resources, convening stakeholders, and building critical infrastructure like the New Bedford Marine Commerce Terminal and the Wind Technology Testing Center.

As a result of legislation passed by the Massachusetts legislature and signed by Governor Charlie Baker in August 2016, Massachusetts utilities will solicit proposals to construct 1,600 megawatts of cost-effective offshore wind by 2027. The legislation is designed to result in the construction of multiple offshore wind projects off the coast of Massachusetts in the coming years. In addition to helping meet the Commonwealth's GHG emission reduction mandate and powering over one million Massachusetts homes, these projects will bring significant economic opportunities for Massachusetts businesses while creating thousands of jobs.

The purpose of this report is to highlight the opportunities for Massachusetts residents and businesses to work in this emerging industry, and to identify recommendations and key strategies to better position our educational institutions and training centers to develop and serve a burgeoning offshore wind workforce.

The three offshore wind developers competing to build projects in the federal wind energy areas south of Martha's Vineyard have extensive experience and financial backing and are pursuing projects with other states including Rhode Island, Connecticut, New York, New Jersey, Delaware, and Maryland. This interest should result in a significant pipeline of offshore wind projects up and down the East Coast that will require a workforce capable of planning, constructing, deploying, and servicing offshore wind farms. The developers' commitment to deploy their Massachusetts projects from the MassCEC New Bedford Marine Commerce Terminal will be one of the largest drivers of economic and job impacts in the Commonwealth. Massachusetts has a skilled workforce with a rich history of working in the marine environment, making it well-suited to meet the diverse needs of the offshore wind industry – from project development to manufacturing, fabrication, installation, and operations and maintenance.

To ensure that our workforce can fully participate in this emerging industry and benefit from the associated economic development, it is imperative that Massachusetts workers have the training and credentials required to compete for these well-paying jobs. To that end, MassCEC has supported this analysis of the workforce needs and opportunities associated with the development of large-scale offshore wind projects.

Specifically, the report describes the jobs associated with planning, constructing and servicing offshore wind projects and provides information on the education, skills and health and safety credentials typically required for each job. It also provides an overview of regulatory frameworks for offshore worker health and safety, outlining the respective roles of the various federal agencies with jurisdiction over offshore wind worker health and safety. Importantly, the report also assesses the Commonwealth's capacity to provide the technical and safety training that workers will need and provides recommendations about how the Commonwealth can prepare to meet those needs.

The emerging offshore wind sector is poised to create thousands of job opportunities across a wide range of sectors and we are confident that our proud maritime heritage, robust innovation sector, and skilled workforce will help lead Massachusetts towards a brighter clean energy future.

Steve Pike
Chief Executive Officer
Massachusetts Clean Energy Center

Executive Summary

This report presents the results of a comprehensive workforce and economic analysis that estimates the labor needs and economic impacts associated with the planning, construction, and maintenance of offshore wind (OSW) energy in the Massachusetts and Rhode Island/Massachusetts Wind Energy Areas (WEAs). Informed by the experience of the OSW industry's emergence in Europe, dozens of in-depth interviews, and a detailed economic analysis, this report is designed to provide state and regional policymakers with actionable recommendations they can use to maximize the economic benefits of the emerging OSW industry for Massachusetts, its communities, and its workforce.

The report is organized into seven primary sections:

1. Development of an Offshore Wind Farm: Describes the various phases of a wind farm's development.

2. Jobs of Offshore Wind: Provides an overview of the types of OSW occupations involved in each phase.

3. Estimate of Job Impacts and Economic Impacts: Utilizes the National Renewable Energy Laboratory's (NREL) Jobs and Economic Development Impact (JEDI) OSW model to estimate the number of jobs and economic impacts resulting from the development, construction, and operations and maintenance (O&M) of 1,600 MW of offshore wind.

4. Offshore Wind Workforce Gap Analysis: Estimates the degree to which the Massachusetts workforce is prepared to fill OSW positions as the wind farms are developed.

5. Health and Safety Regulatory Agencies and Industry Standards: Provides an overview of the federal agencies with jurisdiction over offshore wind worker health and safety as well as private sector training programs used by European OSW developers.

6. Massachusetts OSW Workforce Training Capacity: Assesses the state's existing OSW training capacity to determine what types of workforce training and education programs are needed.

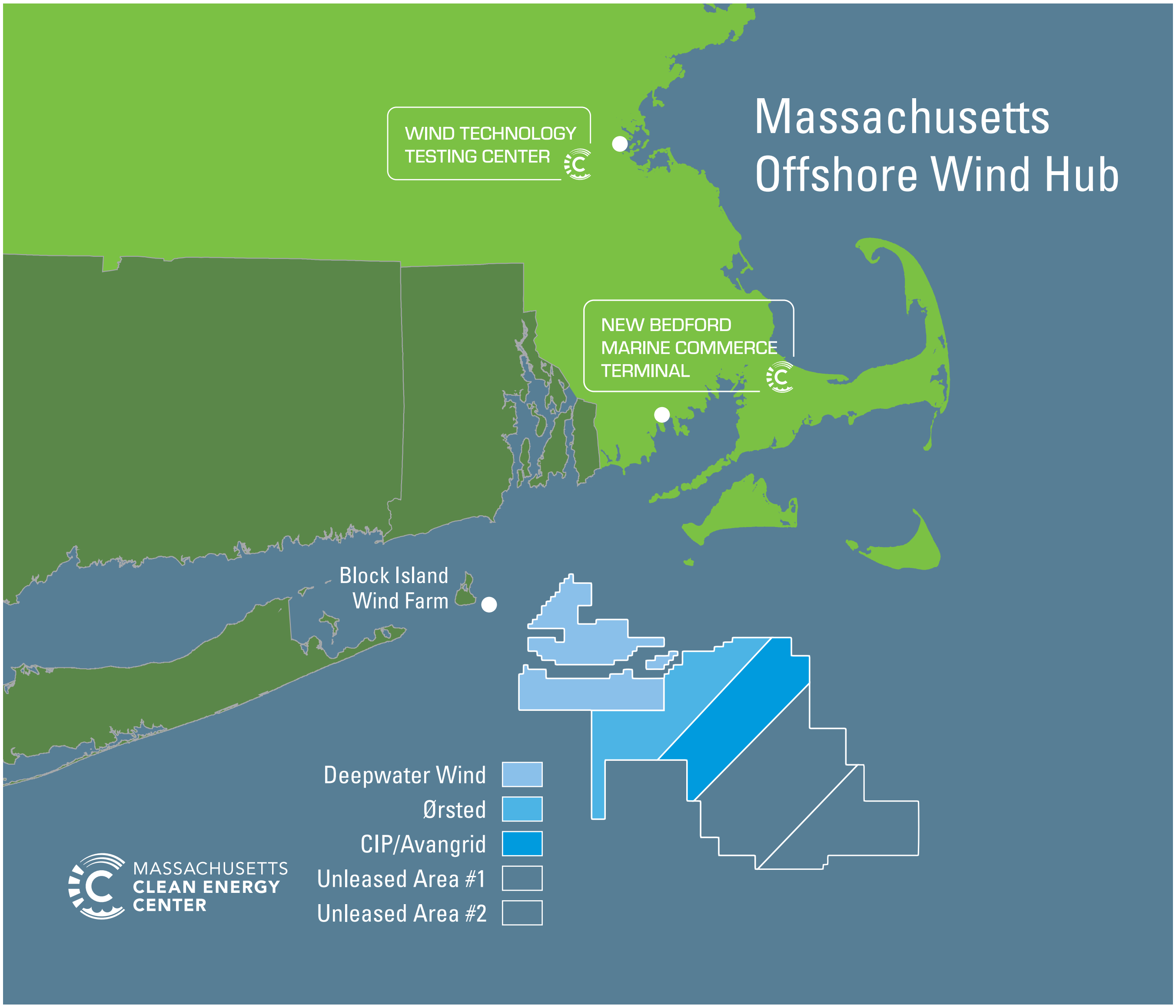
7. Conclusions and Recommendations.

MASSACHUSETTS WIND POTENTIAL

According to DOE's National Renewable Energy Laboratory (NREL), Massachusetts waters have the largest technical offshore wind potential of any state in the contiguous U.S. Since 2009, Massachusetts has been leading an intensive public engagement effort with the U.S. Bureau of Ocean Energy Management (BOEM) to establish lease areas for offshore wind. To date, this effort has involved over 100 public meetings with federal, state, Native American tribal, and local government officials, fishermen, environmentalists, and the general public. As of the publication date of this report, three offshore wind developers have lease agreements to build projects in the federal waters south of Martha's Vineyard, Massachusetts:

- Deepwater Wind
- Ørsted (Bay State Wind)
- Copenhagen Infrastructure Partners (CIP)/Avangrid (Vineyard Wind)

BOEM has announced plans to conduct a competitive auction among qualified offshore wind developers of the two unleased areas in the Fall of 2018.



OVERVIEW OF OFFSHORE WIND JOBS

The development of an OSW farm requires the support of a diverse group of workers in a variety of occupations in each of the three phases: Planning and Development, Construction, and Operations and Maintenance (O&M). Water transportation workers will be in high demand throughout all phases. These workers play a crucial role by transporting people and materials to the wind farm and patrolling the exclusion zone during construction. Engineering occupations are also crucial throughout all three phases and are concentrated in supervisory roles, requiring a deep understanding of how turbine systems function and interact. Engineers are supported by teams of engineering technicians, who, among other tasks, collect site assessment data during the planning and development phase and perform maintenance during the O&M phase.

Professional and scientific occupations, including civil, mechanical, electrical, and environmental engineers, geoscientists, zoologists and wildlife biologists, budget analysts, legal professionals, and cost estimators, and others are required throughout the project, but play a leading role during the planning and development phase. These occupations support wind farm development through activities such as site assessments, negotiation of power purchase agreements, regulatory compliance, and development of plans to mitigate environmental impacts. These occupations require not only a familiarity with energy production and regulation, but also an understanding of the political and economic conditions in Massachusetts and the ecosystem in the lease area, and are therefore likely to be filled from within Massachusetts.

Trade workers play a significant role during the construction of the wind farm, including electricians, steel workers, pile drivers, crane operators, painters, longshoremen, machine operators, commercial divers, construction laborers, and others. These skilled workers will play a central role in the construction, assembly, and deployment of offshore wind projects. As much assembly as possible is performed onshore, but some trade workers perform their duties offshore as part of the final installation and commissioning of the wind farm.

Although the Construction phase is primarily associated with short-term, project-based work, workers employed during this phase will be perfectly suited to perform similar functions on subsequent projects or may be able to transition into long-term O&M occupations, since they will acquire much-needed experience working offshore and with turbine systems during the Construction phase. The O&M phase extends throughout the 25-year life of the wind farm and produces well-paying jobs for O&M technicians performing routine and reactive maintenance, back-office jobs in planning, administration, and supervision, and jobs in water transportation that bring engineers and technicians to and from the wind farm.

ESTIMATED JOB CREATION OF THE 1,600 MW BUILDOUT

The project team utilized NREL's JEDI OSW model to estimate the number of jobs resulting from the planning, construction, and O&M of 1,600 MW of OSW.[1] Currently, few specifics are known about the development parameters for individual OSW projects in Massachusetts since the industry is still nascent in the U.S. and because most of the project specifics are redacted in the formal developer bids submitted in late 2017. Accordingly, the project team assumed that there will be four 400 MW installations staggered every two years to maintain a manageable number of projects. Low, Medium, and High scenarios were then modeled for each of the four projects.

Construction activity related to the deployment of 1,600 MW of OSW is estimated to create between 2,279 and 3,171 direct job-years.[2] In total, construction activities are estimated to support between 6,878 and 9,852 job-years, which includes direct, indirect (supply chain), and induced impacts (see Table 1).[3]

TABLE 1
JOB-YEARS DURING CONSTRUCTION
LOW AND HIGH SCENARIOS FOR MASSACHUSETTS

	Project Development & Onsite Labor (Direct)	Turbine & Supply Chain (Indirect)	Induced	Total
Project 1	514 – 842	560 - 846	568 - 773	1,642 - 2,461
Project 2	572 – 823	580 - 952	577 - 800	1,729 - 2,575
Project 3	591 – 780	586 - 921	573 - 762	1,750 - 2,463
Project 4	602 – 726	589 - 899	566 - 728	1,757 - 2,353
Total	**2,279 - 3,171**	**2,315 - 3,618**	**2,284 - 3,063**	**6,878 - 9,852**

Source: JEDI; Public Policy Center.

Once each project is producing power, a total of 35 to 64 direct jobs will be generated and sustained annually over the life of each wind farm project, for a total of between 140 to 256 jobs annually for all four projects. In total, O&M activities are estimated to annually support between 964 to 1,748 job-years, which includes direct, indirect (supply chain), and induced impacts (see Table 2).

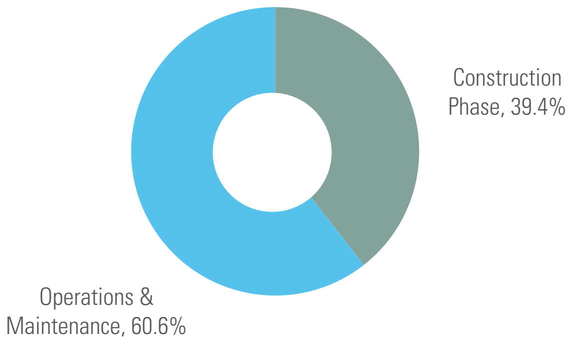
TABLE 2
ANNUAL JOB-YEARS DURING O&M
LOW AND HIGH SCENARIOS FOR MASSACHUSETTS

	Project Development & Onsite Labor (Direct)	Turbine & Supply Chain (Indirect)	Induced	Total
Project 1	35 - 64	166 - 303	68 - 124	269 - 491
Project 2	35 - 64	149 - 269	62 - 112	246 - 445
Project 3	35 - 64	137 - 247	57 - 104	229 - 415
Project 4	35 - 64	129 - 234	55 - 99	219 – 397
Total	**140 – 256**	**581 - 1,053**	**242 - 439**	**964 - 1,748**

Source: JEDI; Public Policy Center.

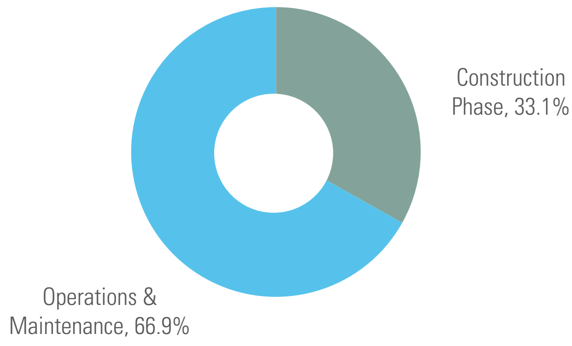
O&M jobs represent the greatest potential for long-term employment in Massachusetts, as O&M jobs are most likely to be filled by local workers and may last the entire duration of the wind farm's 20- to 25-year design life. In the Low scenario, O&M will account for 60.6 percent of the total job-years over the lifetime of the wind farm, while in the High scenario, O&M will account for 66.9 percent of the total job-years (see Figure 1 and Figure 2).

FIGURE 1
LIFETIME JOB-YEARS: CONSTRUCTION VERSUS O&M
LOW SCENARIO



Source: JEDI; Public Policy Center.

FIGURE 2
LIFETIME JOB-YEARS: CONSTRUCTION VERSUS O&M
HIGH SCENARIO

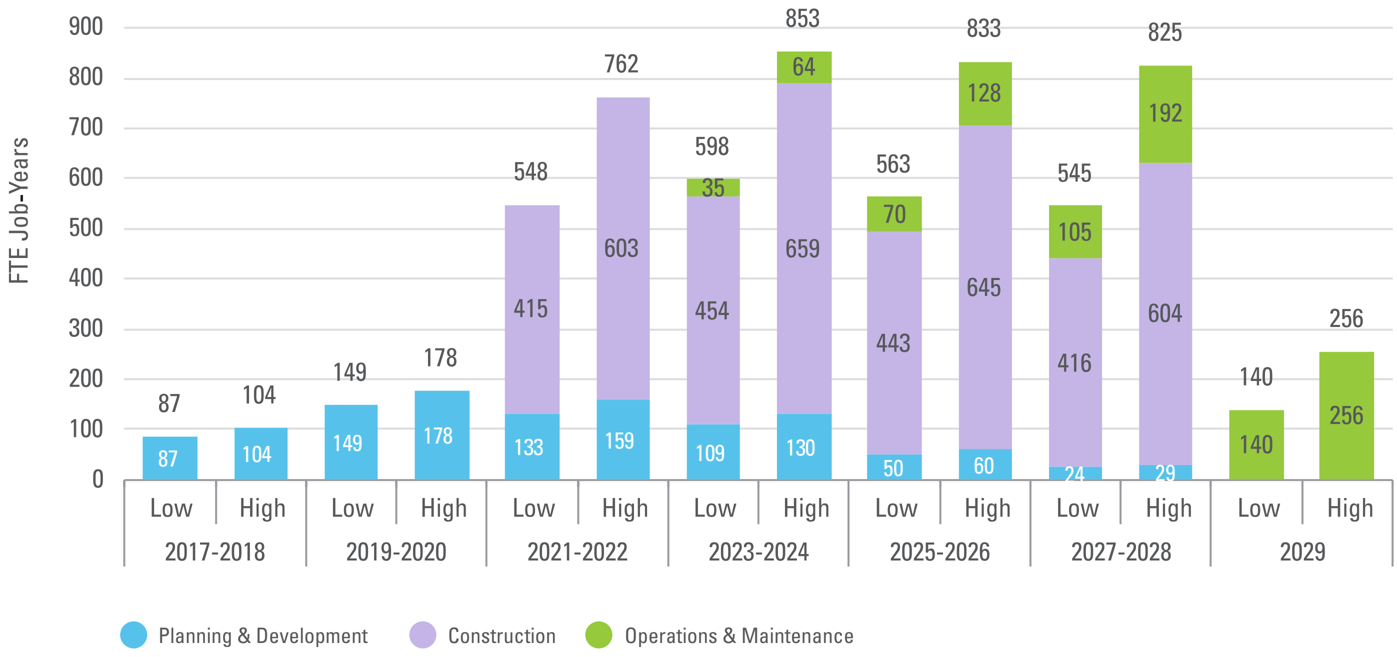


Source: JEDI; Public Policy Center.

Job-Years by Phase

Figure 3 presents the distribution of direct job-years by phase from 2017 to 2029 based on the Low and High scenarios. Job-years are expected to peak during 2023–2024, when Project 2 is in the construction phase, Projects 3 and 4 are in the planning and development phase, and Project 1 enters the O&M phase. O&M activities will continue to increase until all 1,600 MW come online, at which point the job-years for these installations are expected to plateau for the duration of the life of the wind farms. Please note that jobs associated with local manufacturing of offshore wind foundation and turbine components are not included in these scenarios.

FIGURE 3
JOB-YEARS 2017–2029: LOW AND HIGH SCENARIOS



Source: JEDI; Public Policy Center.

Net New Job-Years by Occupation by Year

While the JEDI model's results are helpful in understanding the total number of job-years, the model does not provide results by occupational category. Consequently, the project team apportioned the model's job-year estimates to a typical offshore wind occupational matrix, which was developed from key informant interviews, site visits to European wind farms and service ports, and an extensive literature review.

The estimates in Table 3 represent the new job-years for an occupation during each two-year period from 2017 to 2030 using the Medium scenario total produced by the JEDI model.[4] Note that while O&M occupations are low in total numbers, the job-years associated with these jobs extend beyond the timeframe of Table 3, with each lasting for at least the 20- to 25-year life of the wind farm.

TABLE 3
BIENNNIAL NEW JOB-YEARS BY OCCUPATION, 2017-2030 [5]
MEDIUM SCENARIO

Occupations	2017-18	2019-20	2021-22	2023-24	2025-26	2027-28	2029-30	Total Job-Years
Planning & Development	**94**	**160**	**142**	**116**	**54**	**26**		**592**
Engineering	33	33	33	33				132
Surveying and Scientific Monitoring	11	22	22	22	11			88
Finance	11	10						21
Permitting		22	22					44
Legal	6	6						12
PR and Marketing	5	11	5					21
Machine Maintenance and Port Services	11	22						33
Site Managers			26	27	26	26		105
Water Transportation Workers	6	12	12	12	6			48
Other	11	22	22	22	11			88
Construction			**520**	**569**	**556**	**522**		**2167**
Project Engineers			18	20	20	18		76
Construction Managers			45	49	49	45		188
Machine Maintenance and Port Services			11	22	11	11		55
Water Transportation Workers			108	110	109	108		435
Trade Workers			323	352	351	325		1351
Longshoremen/Stevedores			45	49	49	45		188
Structural Iron & Steel Workers			90	98	98	91		377
Electricians			60	66	65	61		252
Material Moving Machine Operators			45	49	49	45		188
Other Installation Technicians			30	33	33	30		126
Laborers			53	57	57	53		220
Other			15	16	16	15		62
Operations & Maintenance				**47**	**47**	**47**	**47**	**188**
Site/Plant Managers				8	8	8	8	32
Project Engineers				6	6	6	6	24
Water Transportation Workers				6	6	6	6	24
O&M Technicians				24	24	24	24	96
Other				3	3	3	3	12
Total Annual Job-Years	**94**	**160**	**662**	**732**	**657**	**595**	**47**	**2947**

Source: JEDI; Public Policy Center.

Workforce Gaps

The estimates in Table 3 were used as a baseline to identify workforce gaps. While Massachusetts is well prepared to support the OSW industry for many occupations, there are several high priority occupations in OSW for which the Commonwealth will need to produce or attract new talent. These occupations constitute a large percentage of the total OSW workforce and are in relatively short supply.

Skilled Trade Workers

Workers in skilled trades and those with skills that could transfer to long-term O&M occupations are underrepresented in the Massachusetts workforce. For instance, each project is expected to have a large demand (measured as the share of job-years) for iron and steel workers and construction welders. Massachusetts already has a low supply of workers in these occupations relative to the nation, which was corroborated by key informant interviews. For example, the Block Island Wind Farm, with only 5 turbines, required a smaller workforce yet welders still had to be drawn from neighboring states to support that project. Moreover, while some trade workers, such as electricians, are well represented in the Massachusetts workforce, many will need additional training to work in an offshore environment.

O&M Technicians

O&M technicians are needed throughout the lifespan of a wind farm to perform routine and emergency maintenance on the turbines. Typically, developers and turbine manufacturers provide additional technology-specific training, but require their new installation and O&M workers to have already completed Global Wind Organization (GWO) Basic Safety Training and to comply with the recently developed Basic Technical Training standard. There are not yet workforce or educational programs with the accreditation and the facilities required to help close this gap in Massachusetts. Considering that O&M work is not anticipated to begin until 2021 or later, there is an opportunity for the Commonwealth to maximize the local economic benefits of OSW developments by preparing workers for O&M and related job opportunities by supporting the development of these types of educational and training resources.

Water Transportation Workers

As OSW farms are located offshore, it is not surprising that water transportation workers will be in high demand throughout all phases. These workers play a crucial role in all phases by transporting people and materials to the wind farm and patrolling the project site during the construction phase. The demand for water transportation workers is expected to peak between approximately 2023 to 2026, when the project construction phases overlap. The short-term demand for these workers is likely to outstrip the state's existing supply of maritime workers, who would need to be incentivized to leave established industries such as commercial fishing to work in OSW. Additionally, there will be an increased need for port and machinery services, which will increase the demand for diesel mechanics and other marine equipment maintenance occupations in the ports used by developers, construction crews, and O&M teams.

Training Needs and Opportunities to Develop the Workforce Pipeline

European OSW developers active in the Massachusetts market will require health and safety training for onshore and offshore construction workers and maintenance technicians. Consequently, investing in health and safety training programs and facilities will be essential to enabling a local workforce to participate in and benefit from the development of an OSW industry in Massachusetts.[6] Federal agencies charged with regulating offshore and maritime workplace safety have yet to develop specific guidelines for the OSW industry. Outside of the development of new regulations, the U.S. Coast Guard, Occupational Safety and Health Administration (OSHA), and BOEM have guidelines in place for worker safety at sea, in construction, and in longshoring, which all apply to OSW. Fortunately, the major developers and manufacturers involved in the Massachusetts OSW industry have experience in industry developed safety standards through their European connections, such as the Global Wind Organization (GWO) and BZEE (Bildungszentrum für Erneuerbare Energien).

Currently, no existing Massachusetts training or educational institutions offer the full suite of GWO technical or health and safety training programs anticipated to be in demand. However, several Massachusetts institutions, including Bristol Community College and the Massachusetts Maritime Academy, are both geographically proximate to the Massachusetts lease areas and substantively well-positioned to qualify for full accreditation by the appropriate international credentialing bodies with relatively modest strategic investments in key courses of study and physical facilities. Capital needs associated with health and safety training include offshore crew transfer training platforms, helicopter simulators for crew transfer and sea survival training, and facilities for training at heights and working in confined spaces.

Notably, the U.S. is home to a very limited number of private training providers with credentials from one of the industry-recognized credentialing bodies. In fact, only six private U.S. training organizations are GWO or BZEE certified, and none of these are located in the Northeast. There are seven Massachusetts higher education institutions that provide training programs in wind energy, renewable energy programs, or training programs related to the wind industry, but not necessarily programs tailored to OSW.

Accordingly, the credentialing of training providers is critical to establishing an effective workforce development strategy. OSW work can be very dangerous and the equipment is very expensive, therefore, developers and turbine manufacturers highly value workers with both the required technical competencies and industry-recognized credentials for health and safety training. It is therefore very important for OSW companies and economic and workforce development practitioners to develop clear career pathways for workers who seek to attain those credentials.

The European experience makes it clear that integrated partnerships between industry organizations, trade unions, and community college and vocational school systems will be needed for the creation of an adequate pipeline of workers with the skills, experience, and credentials needed to work in the OSW industry.

Organized labor will also play a key role in the Massachusetts workforce development pipeline to support the emerging OSW industry due to the heavy presence of skilled trade labor in the OSW construction workforce. Organized labor, which already invests heavily in worker training, will need to work closely with industry to calibrate their training to meet the needs of offshore wind.

Employing best practices from Europe to expand existing training systems will provide Massachusetts with an advantage in creating and improving the regional workforce for the OSW industry as it develops, minimizing the need to import workers from neighboring states and countries. For instance, the traditional career pathway into many trades is through an apprenticeship, which typically includes on-the-job experiences over a multi-year period of employment. Union apprenticeships often also require several hundred hours of classroom instruction and most programs are completed after four years of full-time commitment. Consequently, it may be several years before a full pipeline of OSW trade workers are trained through the existing apprenticeship system.

Estimated Economic Output of the 1,600 MW Buildout

The project team utilized the JEDI offshore wind model to estimate the economic output resulting from the development of 1,600 MW of wind energy off the Massachusetts coast. Again, four 400 MW installations staggered every two years were assumed and Low, Medium, and High scenarios were then modeled for each project.

The estimated direct impact on state economic output as a result of the construction of 1,600 MW of offshore wind energy ranges from $678.8 million to $805.1 million. In total, the projects are estimated to generate a total impact between $1.4 billion to $2.1 billion, which includes direct, indirect (supply chain), and induced impacts (see Table 4).

TABLE 4
ECONOMIC OUTPUT IN MASSACHUSETTS FOR CONSTRUCTION
LOW AND HIGH SCENARIOS

	Project Development & Onsite Labor (Direct) ($M)	Turbine & Supply Chain (Indirect) ($M)	Induced ($M)	Total ($M)
Project 1	$161.9 - $208.3	$87.1 - $173.3	$95.7 - $129.6	$344.7 - $511.2
Project 2	$170.0 - $205.5	$90.2 - $208.3	$96.9 - $133.5	$357.1 - $547.3
Project 3	$172.6 - $199.4	$91.1 - $199.8	$95.9 - $127.0	$359.6 - $526.2
Project 4	$174.3 - $191.9	$91.6 - $196.7	$94.7 - $121.3	$360.6 - $509.9
Total	**$678.8 - $805.1**	**$360.0 - $778.1**	**$383.2 - $511.4**	**$1,422.0 - $2,094.6**

Source: JEDI; Public Policy Center. Values are in millions of 2015 dollars. Totals may not add due to rounding.

It is estimated that O&M activities will result in between $3.7 million to $6.7 million in direct annual output for each 400 MW project, or $14.8 million to $26.8 million for all 1,600 MW of offshore wind. In total, O&M activities are estimated to create a total impact of between $201.1 million to $364.3 million annually when one considers their direct, indirect, and induced impacts (see Table 5).

TABLE 5
ANNUAL ECONOMIC OUTPUT IN MASSACHUSETTS FOR OPERATIONS & MAINTENANCE
LOW & HIGH SCENARIOS

	Project Development & Onsite Labor (Direct) ($M)	Turbine & Supply Chain (Indirect) ($M)	Induced ($M)	Total ($M)
Project 1	$3.7 - $6.7	$41.0 - $74.6	$12.1 - $22.0	$56.8 - $103.3
Project 2	$3.7 - $6.7	$36.7 - $66.2	$11.0 - $19.9	$51.4 - $92.8
Project 3	$3.7 - $6.7	$33.7 - $60.8	$10.2 - $18.5	$47.6 - $86.0
Project 4	$3.7 - $6.7	$31.9 - $57.8	$9.8 - $17.7	$45.3 – $82.2
Total	**$14.8 - $26.8**	**$143.3 - $259.4**	**$43.1 - $78.1**	**$201.1 – $364.3**

Source: JEDI; Public Policy Center. Values are in millions of 2015 dollars. Totals may not add due to rounding.

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List of Acronyms

Abbreviation	Meaning
AWEA	American Wind Energy Association
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
BZEE	Bildungszentrum für Erneuerbare Energien
BST	Basic Safety Training
BTT	Basic Technical Training
CAD	Computer Assisted Design
CAPEX	Capital Expenditure
COE	Cost of Energy
CTV	Crew Transfer Vessel
DC	Direct Current
DoE	U.S. Department of Energy
DOER	Massachusetts Department of Energy Resources
DoI	U.S. Department of the Interior
DPU	Massachusetts Department of Public Utilities
EBS	Emergency Breathing Systems
EPA	U.S. Environmental Protection Agency
EWEA	European Wind Energy Association
FTE	Full-Time Equivalent
GW	Gigawatt
GWO	Global Wind Organisation
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
JEDI	Jobs and Economic Development Impact Model
LCOE	Levelized Cost of Electricity

LQ	Location Quotient
MassCEC	Massachusetts Clean Energy Center
MW	Megawatt
MWh	Megawatt-hour
NREL	National Renewable Energy Laboratory
NVQ	National Vocational Qualifications
O&M	Operation and Maintenance
OCS	Outer Continental Shelf
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditures
OSHA	Occupational Safety and Health Administration
OSW	Offshore Wind
RQF	Regulated Qualifications Framework
SCADA	Supervisory Control & Data Acquisition
SMS	Safety Management System
SOV	Service Operation Vessel
TSS	Traffic Separation Schemes
TWh	Terawatt-hour
USACE	United States Army Corps of Engineers
USCG	U.S. Coast Guard
WEA	Wind Energy Area
WTTC	Wind Technology Testing Center

1 Introduction

The ocean has always provided a bounty to those living and working in Massachusetts. From Native Americans' and early settlers' subsistence fishing to modern-day mariners, the waters off the coast of Massachusetts have provided opportunities to prosper from and enjoy the fish and shellfish found beneath their waves. The ongoing development of the offshore wind industry captures a new bounty, from the winds that blow so steady and powerfully over the waves.

According to the NREL, Massachusetts waters have the largest technical offshore wind potential of any state in the contiguous U.S., with a net technical resource of over 1,000,000,000 megawatt-hours (MWh) per year.[7] By comparison, Massachusetts consumed 54,500,000 MWh of electricity in 2014.[8] Theoretically, if all this wind energy could be captured, it could generate over 18 times the state's existing electricity consumption.

In 2009, Massachusetts issued its first comprehensive Ocean Management Plan for state waters, identifying areas appropriate for OSW development.[7] Then in 2013, the Bureau of Ocean Energy Management (BOEM) held its first competitive offshore commercial wind lease sale, auctioning off 164,750 acres within the "area of mutual interest" identified by Rhode Island and Massachusetts in a Memorandum of Understanding between the two states in 2010. Two of the lease areas in the Massachusetts Wind Energy Area (WEA) were auctioned off in 2015 and there are two remaining lease areas which are expected to be auctioned in the fall of 2018. While there are not any wind farms currently operating within these WEAs, development is accelerating thanks to a 2016 bill passed by the Massachusetts State Legislature and signed into law by Massachusetts Governor Charlie Baker requiring the state's major electric utilities to solicit 1,600 megawatts of OSW power by 2027.

OSW development companies operating in the area include Bay State Wind,[8] Deepwater Wind,[9] and Vineyard Wind.[10] General Electric, which is now headquartered in Massachusetts, designed and manufactured the five 6 MW turbines used for the first OSW farm in the United States, Block Island Wind in Rhode Island.

Additionally, Massachusetts is home to two critical pieces of OSW innovation infrastructure: the Wind Technology Testing Center and the New Bedford Marine Commerce Terminal.

- **Wind Technology Testing Center (WTTC):** Built and owned by MassCEC, the WTTC is the nation's first facility capable of testing wind turbine blades up to 90 meters in length. The WTTC also offers a full suite of certification tests for tested blades, as well as the latest wind turbine blade testing and prototype development methodologies to help the wind industry advance the technology while driving down costs.
- **The New Bedford Marine Commerce Terminal:** Built and owned by MassCEC, the New Bedford Marine Commerce Terminal is a 29 acre multi-purpose facility designed to support the construction, assembly, and deployment of offshore wind projects, as well as handle bulk, break-bulk, container shipping, and large specialty marine cargo. The first of its kind in North America, the Terminal has been engineered to sustain mobile crane and storage loads that rival the highest load-bearing ports in the nation. The majority of the Terminal, including along the bulkhead, can support 4,100 pounds per square foot of uniform loading and crane loads of up to 20,485 pounds per square foot..

Elsewhere in the U.S., states with access to offshore WEAs are at varying stages of development.[11] The maturing European OSW industry provides helpful insight into what kind of economic and labor market impacts Massachusetts can expect from this emerging industry.

2 Development of an Offshore Wind Farm

2.1 OFFSHORE WIND PROJECT PHASES

The development and construction of an OSW farm proceeds in phases. At the most basic level, these phases are planning and development, construction, and O&M. Other phases that might be considered as separate from or as a subset of these most basic phases include manufacturing, pre-assembly and installation, commissioning, and decommissioning. The following sections provide a high-level overview of the work required in the life of a typical offshore wind farm project.

2.1.1 PLANNING AND DEVELOPMENT

The planning and development phase covers the activities that precede the start of wind farm construction. These activities are managed by the wind farm developer. It involves mostly professional and scientific/technical jobs. The first step involves identifying and selecting potential sites for an OSW project. Important factors that require thorough examination include wind strength and occurrence, the characteristics of the seabed, and the possible environmental impacts. During this phase, firms engage in extensive stakeholder outreach to seek input in determining the favorability of such a project in the area. The final step of this phase includes obtaining permitting from all necessary bodies, including from local, state, and federal agencies, and it requires that all permits and contracts are secured, with a clear and reliable source of funding.

2.1.2 CONSTRUCTION

The construction phase is frequently divided into subsections that relate to specific aspects of the project, such as pre-assembly, installation, and commissioning. The construction of an OSW farm is dependent on favorable weather, sea conditions, and time of year restrictions regarding marine mammals. In order to take full advantage of the limited construction season, developers tend to conduct the activities related to the construction phase subsection in tandem, thus maintaining a continuous flow of turbine components ready to deploy.

Pre-Assembly & Installation

Construction begins with the installation of the so-called "balance-of-plant," which is managed by the developer and includes the onshore and offshore substations, array cables, export cables, and turbine foundations. Once all of these components are in place, the OEM installs the wind turbine components. Before the tower and other components can be installed, often they are first brought to a local facility for "pre-assembly." In order to reduce costs and complexity associated with offshore assembly, much of this work is conducted in a marshalling or staging port. The tower, for example, often arrives in pieces and without many of its internal components. When it arrives, it is welded or bolted together and parts such as the elevator and power cables are installed. Finally, all the components are transported via vessels or barges to the wind farm where they are installed using specialized installation vessels. This phase will involve a mix of engineering and supervisory-level jobs and trade workers and general labor jobs.

Commissioning

The commissioning phase begins when all wind turbine components have been installed. Commissioning typically includes the testing and inspecting of all components and making the final electrical connections. During this phase, the staff ensures compliance with design-phase documentation, inspects all engineering aspects, and tests the electrical components. Once each wind turbine is connected to the grid, power generation commences and the O&M crew takes over the wind farm.

2.1.3 OPERATIONS & MAINTENANCE

During the O&M phase, the turbines, foundations, cables, and other components are inspected regularly and any necessary repairs and upkeep are performed. This is the longest phase, extending for the full life of a wind farm: approximately 25 years. This work falls into three categories: operations, preventive maintenance, and reactive maintenance. Operations refers to the high-level management of the wind farm, such as environmental monitoring and site administration, and represents a very small portion of all O&M activities. Preventive maintenance, which is scheduled, includes routine inspections and repair or replacement of parts showing sufficient wear. Reactive maintenance, which is unscheduled, includes the repair or replacement of parts that have failed or been damaged. Depending on the distance from port and other factors, O&M can occur via Crew Transfer Vessel (CTV), which returns to port at the end of the work day; CTV with helicopter support; or Service Operation Vessel (SOV), which spends most of its time anchored near the wind farm and provides spare parts storage and crew accommodations.

3 The Jobs of Offshore Wind

The development of an OSW farm requires the support of a diverse group of workers in a variety of occupations. Throughout all the phases, there is a concentration in engineering occupations in supervisory roles, as managers in the planning and development, construction, and O&M phases. These engineers are supported by teams of technicians, who collect site assessment data during the planning and development phase and perform maintenance during the O&M phase. Trade workers play a significant role during the construction of the wind farm, as skilled welders and electricians are needed to assemble and commission the turbines. Although the construction phase jobs are short-term, many of the workers employed during this phase will be well prepared to transition into long-term roles in the O&M phase, since they have experience working offshore and are familiar with turbine systems. During every phase of OSW development, water transportation and supportive services are engaged to ferry workers and equipment to and from the OSW farm site and to maintain construction machinery.

This section provides a brief overview of the types of jobs involved with each phase of an offshore wind farm including the occupational skills, job functions, and educational requirements associated with each job.

3.1 SUPPORT SERVICES AND TRANSPORTATION OCCUPATIONS

There will be a demand for water transportation and support services throughout all phases of an OSW farm's development. The majority of employment in these occupations is concentrated in water transportation, which will be based in the ports chosen by the developer and the turbine manufacturers as staging and deployment areas for the wind farm's construction.[12] Table 6 outlines the education requirements for these occupations, all of which require practical, hands-on training on equipment and vessels used in the maritime and construction trades.

TABLE 6
CREDENTIALS AND REQUIREMENTS FOR OCCUPATIONS IN SUPPORT SERVICES & TRANSPORTATION

Occupations	Common Education Credentials	Professional License	Average Annual Wage
Machine Maintenance and Port Services			
Bus/Truck Mechanics & Diesel Engine Specialists	Postsecondary Training or Associate's	N	$54,880
Ship Engineers	Postsecondary Training	N	$90,120
Site Managers			
Construction Managers	Bachelor's	Y	$109,900
Architectural & Engineering Managers	Bachelor's	Y	$145,000
Water Transportation Workers			
Captains, Mates, & Pilots of Water Vessels	Postsecondary Training or Associate's	Y	$38,670
Sailors & Marine Oilers	Postsecondary Training	N	$38,670
Ship Engineers	Postsecondary Training or Associate's	N	$90,120

Source: U.S. Bureau of Labor Statistics (2016, wages); O-Net; RenewableUK; U.S. Department of Energy.

Massachusetts is home to a robust maritime economy, and the majority of the occupations in supportive services and transportation are temporary and will most likely be contracted out to existing companies. While there are existing educational and training programs in place for producing marine workers, additional training may be required to gain expertise in navigating a marine construction environment at the scale of an OSW farm.

Occupations in Supportive Services & Transportation include:

Machine Maintenance and Port Services Occupations

This category includes a variety of support occupations related to port operations and vessel and construction machinery maintenance. Experience and requirements are related to the level of service performed. For instance, vessel mechanics should be certified diesel mechanics with experience working on ships and larger vessels.

Site Managers

These supervisors oversee and coordinate the delivery and storage of primary and secondary turbine components, and the quayside staging and pre-assembly of components. This position requires previous experience as a supervising engineer, logistics management, contract labor and construction or architectural management, and a master's degree in an engineering or construction-related field.

Water Transportation Workers

Water transportation workers include all vessel crews, such as captains, mates, and ship engineers, responsible for transporting turbine components to the wind farm site, piloting vessels performing surveying and monitoring duties, and operating cable laying ships, guard ships, tugboats, and barges. Workers would need to be trained in general sea safety techniques and have experience in piloting ships in a working industrial harbor and specific training on how to operate in a marine construction environment. Typically, water transportation workers do not need to possess post-secondary educational credentials unless they are operating a vessel with specialized construction equipment on board, such as a cable laying ship or a dredging barge.

3.2 PLANNING AND DEVELOPMENT

A number of professional occupations are involved in the planning and development phase of an OSW project, such as marine scientists and engineers. Based on the experience of OSW farm development in the U.K., it is anticipated that developers will import people with experience in OSW for initial leadership and supervisory roles, at least during planning and development of the first, and possibly second, projects. For example, in the case of Block Island Wind Farm, Deepwater Wind contracted with onshore and offshore survey scientists: onshore survey scientists were local, geophysical surveyors were both local and imported, geotechnical surveyors were from the Gulf of Mexico, and engineering, cable survey, and permitting employees were all local.

TABLE 7
CREDENTIALS AND REQUIREMENTS FOR OCCUPATIONS IN PLANNING & DEVELOPMENT

Occupations	Common Education Credentials	Professional License	Average Annual Wage
Engineering			
Civil Engineers	Master's	Y	$91,930
Mechanical Engineers	Master's	Y	$94,500
Electrical Engineers	Master's	Y	$108,990
Marine Engineers & Naval Architects	Master's	Y	$98,370
Electrical and Electronic Engineering Technicians	Associate's	N	$65,370
Mechanical Engineering Technicians	Associate's	N	$56,110
Surveying and Scientific Monitoring			
Environmental Engineers	Bachelor's	N	$88,800
Geoscientists	PhD	N	$84,310
Natural Sciences Managers	PhD	N	$172,000
Zoologists & Wildlife Biologists	PhD	N	$83,340
Atmospheric & Space Scientists	PhD	N	$103,770
Mechanical Engineering Technicians	Associate's	N	$56,110
Geological & Petroleum Technicians	Associate's	N	$56,450
Finance			
Financial Manager	Master's	Y	$138,610
Budget Analysts	Bachelor's	Y	$77,480
Cost Estimators	Bachelor's	Y	$74,200
Permitting			
Compliance Officers	Bachelor's	N	$83,030
Permitting			
Lawyers	J.D.	Y	$158,760
Paralegals & Legal Assistants	Associate's	N	$55,250
PR and Marketing			
Market Research Analysts & Marketing Specialists	Master's	N	$79,030

Source: U.S. Bureau of Labor Statistics (2016, wages); O-Net; RenewableUK; U.S. Department of Energy

Occupations in planning and development include:

Engineering Occupations

Employees in engineering occupations design the wind farm and offshore/onshore substations, and determine how and where to connect transmission lines within the wind farm and to the grid. Supervisory and lead positions require a master's degree in electrical, civil, or mechanical engineering, professional licensure, and experience working with electric utilities, power generation, and/or high voltage systems. Engineering technicians provide support and should possess at least an associate's degree in an engineering field.

Surveying and Scientific Monitoring Occupations

Survey Scientists are active throughout planning and development, early in the construction process, and periodically during the O&M phase. They are needed for a variety of activities, including gaining an understanding of the seafloor at the wind farm site and along the cable route to the shore; ensuring that developments do not violate environmental regulations and that negative impacts on the ecosystem are minimized or avoided altogether; and analyzing weather, climate, atmospheric, and ocean conditions to assist with siting. Managerial and lead roles require an advanced degree (master's or Ph.D.) in a related field, such as environmental science or engineering, oceanography, wildlife biology, zoology, and atmospheric science or meteorology. Technicians support surveying and monitoring operations by collecting field data through observation or by installing and monitoring meteorological and oceanographic data collection equipment.

Finance Occupations

OSW financial analysts prepare initial assessments of financial risk involved in OSW projects and monitor project expenses to ensure alignment between actual costs and projections. Supervisory positions require a master's degree in finance, accounting, economics, or business; familiarity with the construction industry or energy markets; and experience running the financial operations of a large organization. Support staff responsible for assisting with financial analysis typically have a bachelor's or master's degree in finance, business administration, or accounting.

Permitting Occupations

In order to support the development of a wind farm, permitting workers assist developers in complying with state and federal regulations related to the construction and operation of an OSW farm, as well as local ordinances and zoning codes related to onshore facilities. They could also develop health and safety standards and site management plans. Permitting occupations require a minimum of a bachelor's degree in environmental engineering, land use planning, or landscape architecture, and experience in community engagement, stakeholder management, and compliance monitoring.

Legal Occupations

Lawyers are needed to develop power purchasing and transmission agreements, draft supply chain contracts, and help with permitting requirements. They also work with turbine manufacturers to finalize warranties for turbine equipment and the legal agreements that manage the day-to-day activities of workers in the subsequent phases of construction and O&M. Lawyers require a Juris Doctor (JD) or Master of Laws (LL.M.) degree and experience in power purchase agreements, environmental standards, performance contracts, and federal and state regulatory law. Lawyers are typically assisted by paralegals, who would need some post-secondary training in legal research and practices.

Public Relations and Power Marketing Occupations

Employees in public relations and power marketing occupations meet and negotiate with power purchasers to finalize power purchase agreements; prepare research to support the marketing of the power produced by the OSW farm; forecast sales trends to help build organizational strategies and marketing programs; host public information sessions; and answer requests for media interviews. Positions involved in power marketing require a master's degree in finance or engineering, and an expert-level understanding of the New England energy markets and factors driving the global wind energy market. Public relations workers require a bachelor's or master's degree in communications or public relations and experience in the field.

3.3 CONSTRUCTION OCCUPATIONS

Construction occupations are involved in cable laying, building the offshore and onshore substations, the pre-assembly and testing of turbine components at the staging port, the installation of the turbines at sea, and the commissioning of the turbines, which involves cable attachment and high voltage wiring. Supervisory roles in the construction phase will most likely be filled by workers experienced with OSW farm construction. However, they will be managing teams of local workers performing the day-to-day tasks of assembling components at the staging area, which includes installing secondary turbine materials (such as elevators, internal electrical components, ladders, and platforms), preparing the wind farm site for construction, erecting towers, and attaching nacelles and blades. Offshore experience gained during the construction phase will expose many workers to the skills and training required for employment in O&M. Table 8 demonstrates the credentials, requirements, and average wage for construction occupations.

TABLE 8
CREDENTIALS AND REQUIREMENTS FOR OCCUPATIONS IN CONSTRUCTION

Occupations	Common Education Credentials	Professional License	Average Annual Wage
Project Engineers			
Civil Engineers	Master's	Y	$91,930
Mechanical Engineers	Master's	Y	$94,500
Electrical Engineers	Master's	Y	$108,990
Industrial Health & Safety Engineers	Bachelor's	Y	$98,310
Marine Engineers & Naval Architects	Bachelor's	Y	$98,370
Construction Managers			
Construction Managers	Bachelor's	Y	$109,900
Architectural & Engineering Managers	Bachelor's	Y	$145,000
Trade Workers			
Longshoremen/Stevedores	Apprenticeship/ Postsecondary Training	N	$31,400
Iron & Steel Workers/Construction Welders	Apprenticeship/ Postsecondary Training	Y	$70,350
Electricians	Apprenticeship/ Postsecondary Training	Y	$66,130
Material Moving Machine Operators	Apprenticeship/ Postsecondary Training	Y	$27,080
Elevator Installers & Repairers	Apprenticeship/ Postsecondary Training	Y	$89,910
Commercial Divers	Apprenticeship/ Postsecondary Training	N	$54,750
Construction Laborers	High School or GED	N	$53,750

Source: U.S. Bureau of Labor Statistics (2016, wages); O-Net; RenewableUK; U.S. Department of Energy

Occupations in Construction include:

Project Engineers

Project engineers are responsible for overseeing specific aspects of the construction process. For example, electrical engineers oversee cable and power transmission installation, civil engineers oversee tower erection, mechanical engineers oversee nacelle installation, and naval engineers oversee foundation deployment. The engineering team will most likely consist of individuals with multidisciplinary backgrounds in engineering as well as specialists. Additionally, engineering technicians, possessing an associate's or bachelor's degree in engineering, oversee engineering activities on site and coordinate with construction managers. Typically, project engineer positions require a master's in an engineering subfield with experience working on large-scale construction projects, preferably in a marine environment or in power generation. Project engineers will occasionally be required to make site visits to inspect progress or troubleshoot.

Industrial Health and Safety Engineers

Differing from project engineers, industrial health and safety engineers develop and implement systems for quality assurance/control, and maintain worksite compliance with health and safety standards and workplace safety regulations. These positions require a knowledge of turbine systems and the OSW construction process to understand the limitations of components and potential hazards, and a master's degree in engineering with experience in Industrial health and safety monitoring on a large-scale construction project.

Construction Managers

Construction managers oversee the day-to-day activities on the wind farm site during construction to ensure alignment between project goals and actual progress toward project completion. This position requires knowledge of marine construction techniques and experience working in an offshore construction site, an associate's or bachelor's degree in engineering, experience managing teams of contract trade workers, and, if working offshore, sea safety and crew transfer training.

Trade Workers

This category includes structural steel and ironworkers, electricians, material moving machine operators, painters, and longshoremen. Trade workers are responsible for a variety of specific duties, including unloading, assembling, and loading, installing the structural, high-voltage electrical, mechanical, and secondary systems within the turbines, at substations, and at onshore connection sites, and operating construction equipment, such as welding torches, cranes, pile drivers, forklifts, or underwater robots. Typically, trade workers are part of a recognized labor union, which maintains standards for membership. These can include the completion of professional training and certification programs, which could be obtained through a vocational school, community college or union program, or provided by the turbine manufacturers.

3.4 OPERATIONS AND MAINTENANCE OCCUPATIONS

The O&M phase is the longest phase of a wind farm's life and typically extends for 25 years. During the O&M phase, teams of technicians perform regularly scheduled and emergency maintenance to keep the turbines producing energy efficiently, and to ensure that other components, such as foundations and cables, are in working order.

Table 9 outlines the requirements and average annual wages for the occupations in this phase. Additionally, engineers and technicians typically receive training from the turbine manufacturers on proprietary equipment, such as the turbine nacelle and the Supervisory Control & Data Acquisition (SCADA) monitoring system.

TABLE 9
CREDENTIALS AND REQUIREMENTS FOR OCCUPATIONS IN OPERATIONS & MAINTENANCE

Occupations	Common Education Credentials	Professional License	Average Annual Wage
Site/Plant Managers			
Power Plant Operators	Bachelor's	N	$75,820
Transportation, Storage, & Distribution Managers	Associate's	N	$105,810
Project Engineers			
Electrical Engineers	Bachelor's	N	$108,990
Mechanical Engineers	Bachelor's	N	$94,500
Quality Engineers	Bachelor's	N	$91,930
Industrial Health & Safety Engineers	Bachelor's	N	$98,310
Water Transportation Workers			
Captains, Mates, & Pilots of Water Vessels	Postsecondary Training or Associate's	Y	$60,480
Sailors & Marine Oilers	Postsecondary Training	N	$38,670
Ship Engineers	Postsecondary Training or Associate's	N	$90,120
O&M Technicians	Postsecondary Training or Associate's	Y	$67,000 [13]

Source: U.S. Bureau of Labor Statistics (2016, wages); O-Net; RenewableUK; U.S. Department of Energy

Occupations in O&M include:

Site/Plant Managers

These O&M managers direct all O&M activities and daily activities of power generation, coordinate teams of technicians, contractors, and equipment suppliers, and manage the supply of components that OSW O&M operations must maintain to service turbines. Plant managers require experience in the power industry, monitoring complex systems operations, or field service operations, as well as possess a background in engineering, and preferably a bachelor's degree. Site managers do not require a post-secondary education, but they do need to be aware of the safety regulations and have experience managing the logistics of an industrial supply chain.

Project Engineers

Project engineers have a diverse array of responsibilities depending on their field during the O&M phase.

Electrical Engineers are primarily responsible for remotely monitoring the OSW plant's electrical systems and power production levels during the O&M phase to ensure that the turbines are functioning properly and efficiently. This position requires a bachelor's or master's degree in electrical engineering, experience working in the electrical transmission or generation industry, experience with SCADA or other supervisory control systems, and training from turbine equipment manufacturers on proprietary software and hardware.

Mechanical Engineers support the maintenance team by developing and executing a service and maintenance plan, and supervising a team of technicians, occasionally offshore. This position requires at least a bachelor's degree in mechanical engineering, some multidisciplinary engineering knowledge, and previous experience in a project engineering or project control position, as well as training on servicing proprietary equipment, crew transfer, and sea safety.

Quality Engineers assist the O&M team with developing and maintaining quality control standards for turbine operation and maintenance. This position requires a bachelor's or master's degree in engineering with a concentration in civil, electrical, or mechanical engineering, and an understanding of how the different systems of a turbine interact to produce energy efficiently, and what interventions improve energy production.

Industrial Health and Safety Engineers develop and maintain compliance for safely performing maintenance on the turbines, crew transfer, and warehouse duties. This position requires a knowledge of turbine systems and the duties of O&M workers to understand the limitations of components and potential hazards, and a bachelor's degree in engineering with experience in industrial health and safety monitoring.

O&M Technicians

O&M technicians account for the bulk of the O&M workforce. They conduct both routine and emergency maintenance on all equipment inside the nacelle after receiving training from the manufacturer. Becoming an O&M technician requires a high school diploma and knowledge of turbine mechanical, hydraulic, and electrical systems. Willingness and physical stamina to work in hazardous conditions is also a major requirement. Trade workers and construction laborers who worked on the construction of the wind farm are considered well qualified to transition into this role.

4 Estimating the Job and Economic Development Impacts of Massachusetts Offshore Wind

The project team utilized NREL's JEDI model to estimate the number of jobs and economic impacts resulting from the development of 1,600 MW of offshore wind.[14] A detailed description of the methodology is provided in Appendix A. Economic impacts measure how spending associated with an industry flows through an economy. For example, employee wages and purchases made from suppliers circulate through the economy and create impacts greater than the initial spending, that is, the original expenditures are multiplied.

Measuring these ripple effects in the economy provides a complete picture of an offshore wind farm's economic contribution to an impact area. The JEDI model quantifies these impacts by applying user input and model defaults to IMPLAN, an input-output model that traces a project's purchases of goods, services, and labor through an economic area. The JEDI model expresses these impacts as Project Development and On-Site labor Impacts (commonly referred to as Direct Impacts), Turbine and Supply Chain Impacts (commonly referred to as Indirect Impacts), and Induced Impacts (see Figure 4).

FIGURE 4
EXAMPLES OF OFFSHORE WIND IMPACTS

Project Development and On-site Labor Impacts (Direct Impacts)	Turbine and Supply Chain Impacts (Indirect Impacts)	Induced Impacts
Construction workers	Blades, towers, nacelles	Driven by spending of employee earings, including supply chain earings.
Regulatory experts	Transportation & Warehousing	For example, increased business at local restaurants, hotels, retail, establishments, convenience stores, etc.
Longshoreman	Equipment suppliers	
Heavy machine operators	Fuel	
Engineers	Habor support services	
Water transportation workers	Waste management	
	Hotels & Motels	
	Utilities	
	Equipment and tool suppliers	

While the JEDI model enables the user to run a simple analysis using model defaults, it also encourages users to "incorporate project-specific values in place of the default values." Currently, few specifics are known about the development parameters for individual OSW projects in Massachusetts, both because the industry is still nascent in the U.S. and because project details are still mostly unknown. Although bids have been submitted by each of the developers, the bids include a great amount of redacted information, particularly concerning specifics about the size and number of turbines and contract terms and pricing, while the dozens of appendices that are provided to the Massachusetts Department of Energy Resources (DOER) are heavily redacted at this point in time.

Consequently, the project team developed Low, Medium, and High scenarios for the full 1,600 MW buildout. Each of these scenarios includes assumptions and estimates throughout the Planning and Development, Construction, and O&M phases that are based on information gathered from key informant interviews, site visits to European wind farm developments and ports, an extensive literature review, and scenarios developed by the NREL in its report, Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios.[15]

The scenarios and assumptions are based on four primary elements:

1. Development Timeline and Project Size

2. Turbine Size and Foundation Type

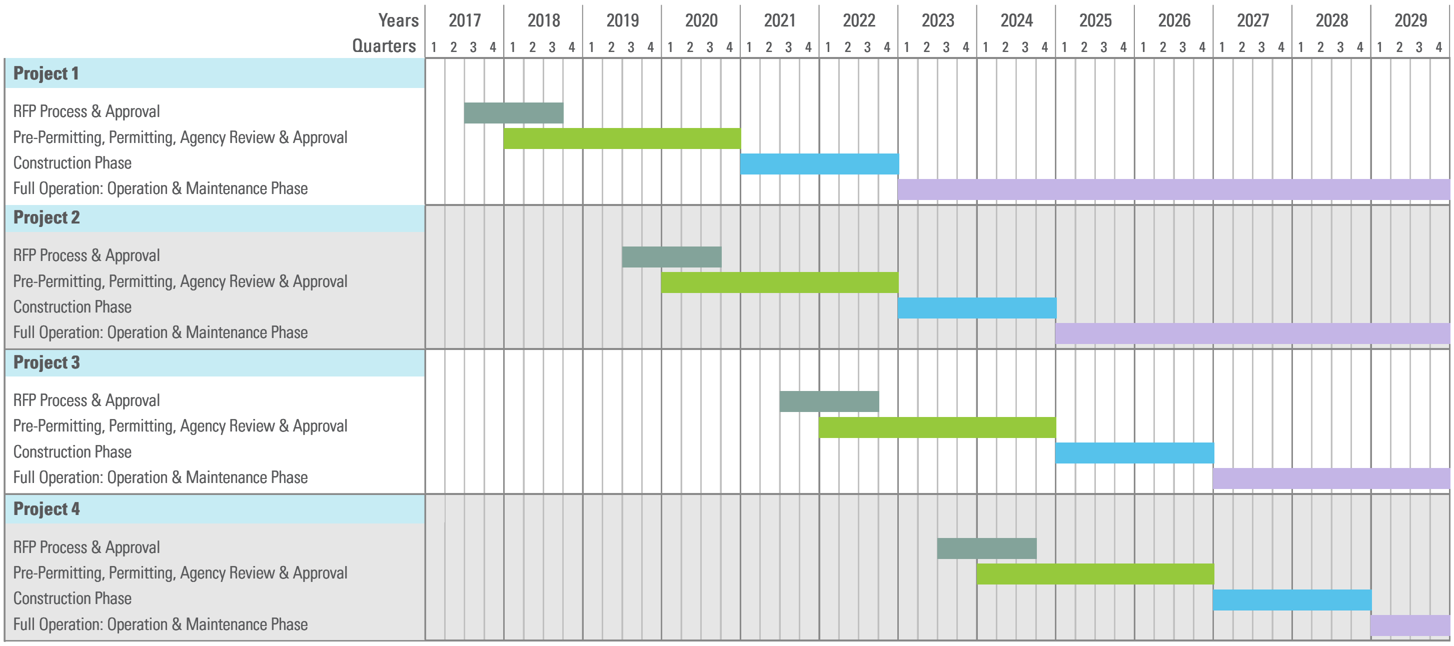
3. Supply Chain Investment

4. Cost-Reduction Estimates

4.1 DEVELOPMENT TIMELINE AND PROJECT SIZE

To maintain a manageable number of scenarios, four 400 MW installations, staggered every two years were assumed. This installation scenario fits within the 83C legislation, which requires utilities to solicit 1,600 MW by June 30, 2027.[16] The scenario also assumes a three-year permitting and environmental review period for each project, which will occur partially concurrent with the RFP process, and a two-year development and construction period for each project.[17] Figure 5 presents the estimated timetable for the four development scenarios.

FIGURE 5
ESTIMATED MASSACHUSETTS OFFSHORE WIND FARM DEVELOPMENT TIMETABLE



4.2 TURBINE SIZE AND FOUNDATION TYPE

As companies push the technological boundaries to lower the cost of energy, it is likely that a 10, 12, or even 15 MW turbine will be available for deployment in Massachusetts during the 1,600 MW buildout. However, the decision on turbine size is a product of several factors, including water depth, scouring rates, blade size, and foundation technology, and some of these factors are still being studied by developers. Consequently, the project team chose to be conservative and assumed that 8 MW turbines would be deployed in the Massachusetts lease areas throughout the project period.[18]

There are three primary foundation types: monopile, jacket, and gravity.[19] Eighty-eight percent of the foundations installed in Europe in 2016 were monopile foundations, and monopiles cumulatively represent 81 percent of all installed foundations in Europe.[20] Monopiles have traditionally been suited for water depths that range from 0 to 30 meters, but industry is advancing monopile technology to accommodate deeper water depths. Water depths range from about 30 meters to 65 meters across the federal wind energy areas beginning 14 miles south of Martha's Vineyard. In addition, the condition of the seabed and other parameters such as turbine size and weight and blade size and length dictate the type of foundation that can be installed.

The JEDI model's default cost estimates are not valid for monopiles in water depths greater than 30 meters, since this type of construction was not technically possible when JEDI was originally developed. Consequently, the project team used jacket foundations as inputs to the JEDI model, since jacket foundations can be installed in waters up to 60 meters in depth. However, it is important to note that at least two of the developers are exploring the use of monopiles in waters deeper than 30 meters. The difference in job impacts between jacket and monopile foundations can range from between 5-10 percent, depending on the specific details of the project, with jacket foundations having higher impacts.

4.3 SUPPLY CHAIN INVESTMENT

The project team developed Low, Medium, and High supply chain scenarios that anticipate the state's supply chain developing and maturing as projects move from the planning & development to construction phases, as additional OSW projects enter the pipeline in other states, as suppliers expand and adapt products, and as new suppliers relocate or start businesses in the region.[21] A key step in this process was to determine which activities must occur at the port, which could possibly take place locally, and which will likely rely on foreign expertise, production, and manufacturing capacity. The parameters of each scenario were informed by interviews with industry leaders, the experience in the United Kingdom, and a systematic consideration of the factors affecting the share of local content and labor that will be used to develop and operate 1,600 MW of OSW in Massachusetts. More details about the supply chain assumptions can be found in Appendix C.

4.4 COST-REDUCTION ESTIMATES

The main driver for growth in the OSW industry has been a significant decline in power-generation costs, driven primarily by advances in technology. Cost reductions have been aided by government financial support in the U.K., Germany, and Netherlands to address the security of electricity supply and decarbonization of electricity production. Such efforts have driven innovation in the sector, which has brought costs down while boosting performance and efficiency. The Levelized Cost of Electricity (LCOE) from offshore wind, which averaged about $240 (U.S.) per megawatt-hour (MWh) in 2001, fell to approximately $170/MWh by the end of 2015. Recently, the price has dropped even further, bringing the LCOE down to $126/MWh in the second half of 2016.[22] According to Bloomberg New Energy Finance, larger turbines, improved construction knowledge, and competitive bidding through auctions in Denmark and the Netherlands have driven the drop in price. In September of 2016, two OSW projects in Danish waters were awarded to a company making a record-breaking bid of $67 per MWh.[23]

Technological improvements and improved logistics will remain a key ingredient in lowering energy costs. The cost of financing can also be expected to decline as more projects enter the pipeline and investors perceive less risk in financing future projects.

A larger pipeline will also spur supply chain efficiencies and lead to a more experienced workforce for subsequent projects, which becomes more efficient as workers learn by doing.[24] State investments in infrastructure and workforce development may also help to reduce costs. In addition, DOER's RFP requires "that Long-Term Contracts resulting from any subsequent solicitations must include a levelized price per megawatt hour, plus associated transmission costs, that are less than the previous solicitation," thus, future cost-reductions are all but certain.[25]

The Massachusetts Offshore Wind Future Cost Study conducted by the University of Delaware Special Initiative on Offshore Wind reports that "costs will continuously lower throughout a build out during the decade, due to ongoing technology and industry advances and the effects of making a Massachusetts market visible to the industry."[26] The Initiative's model predicts that the LCOE for a 2,000 MW build-out in Massachusetts will decline from 16.2 cents in 2023 to 11.5 cents in 2029, or 4.8 percent per year.[27] However, Bloomberg predicts a price of 12 cents during the first round of the Massachusetts 83C procurement process. This result is supported by an economic spatial model developed by KIC InnoEnergy and BVG Associates and reports from the U.S. Department of Energy (DoE) and U.S. Department of the Interior, which estimate an average cost reduction of approximately 5 percent can be achieved annually between 2015 and 2030 in the U.S. Notably, this model was based on the nation as a whole and not Massachusetts exclusively. [28,29] Similarly, BVG Associates estimates a 2 percent annual reduction in undiscounted expenditure in OSW, although these estimates are based on expected learning rates only.[30]

Accordingly, the project team developed Low, Medium, and High cost-reduction scenarios for both capital and operating costs to reflect anticipated decreases in costs as each project is developed. These reductions are primarily based on estimated learning rates and other cost reduction effects presented in the Delaware study and supported by information gleaned from literature reviews and key informant interviews. Note that the Delaware report is the only cost study to date that focuses exclusively on OSW rates for Massachusetts. Under the Low-Cost Reduction scenario, a 1.0 percent annual cost reduction in development and construction was applied. The Medium Cost reduction estimate applies a 3.5 percent annual cost reduction rate, while the High Cost Reduction applies a 5.0 percent annual rate.

4.5 ESTIMATED JOB CREATION AND ECONOMIC DEVELOPMENT BENEFITS

The JEDI model reports results for two phases: Construction and Operations.

Construction: This category includes payroll expenditures for employees working in Construction Related Services (e.g., engineers, scientists, regulatory experts, legal) and Construction and Interconnection Labor (e.g., the employees who actually construct the wind farm, such as construction laborers, crane operators, longshoremen, ship operators).[31] Importantly, JEDI results for the construction phase represent cumulative totals over the entire construction period. Therefore, the results are not affected by the duration of a project. For example, results are the same whether a project takes one year or three years to construct, that is, the actual construction duration of a project has no effect on the reported impacts.

Operations: This category includes the activities necessary to keep the wind farm operating efficiently after it is constructed. JEDI results for Operations are annual estimates.

The JEDI impacts for the Construction and O&M phases are expressed in terms of the job-years and output generated by the construction of a wind farm for the area of analysis (in this case, Massachusetts):

Job-Years: Refers to the years of full-time equivalent (FTE) employment created by the wind farm project, including wage and salary employees and self-employed persons. One FTE is the equivalent of one person working full time for one year (2,080 hours), thus, two half-time employees would equal one FTE. Importantly, this means that the number of jobs reported by JEDI does not equal the number of people working on the project, as not all employees will be full-time and one person may work for multiple years. [32]

Output: Represents the total estimated dollar value of goods and services, or sales, produced in the economy as a direct result of the wind farm project.

4.5.1 CONSTRUCTION PERIOD IMPACTS

Job-Years

The JEDI model estimates that the development of 1,600 MW of OSW in Massachusetts will generate between 6,878 and 9,852 job-years during the Construction phases, including an estimated 2,279 and 3,171 job-years in direct Project Development and Onsite Labor (see Table 12).

TABLE 11
JOB-YEARS DURING CONSTRUCTION
LOW AND HIGH SCENARIOS FOR MASSACHUSETTS

	Project Development & Onsite Labor (Direct)	Turbine & Supply Chain (Indirect)	Induced	Total
Project 1	514 - 842	560 – 846	568 – 733	1,642 – 2,461
Project 2	572 – 823	580 – 952	577 – 800	1,729 – 2,575
Project 3	591 – 780	586 – 921	573 – 762	1,750 – 2,463
Project 4	602 – 726	589 – 899	566 – 728	1,757 – 2,353
Total	**2,279 – 3,171**	**2,315 – 3,618**	**2,284 – 3.063**	**6,878 – 9,852**

Source: JEDI; Public Policy Center.

Output

The estimated direct impact on state economic output as a result of the construction of 1,600 MW of offshore wind energy ranges from $678.8 million to $805.1 million. In total, the projects are estimated to generate a total impact between $1.4 billion to $2.1 billion, which includes direct, indirect (supply chain), and induced impacts (see Table 12).

TABLE 12
ECONOMIC OUTPUT IN MASSACHUSETTS FOR CONSTRUCTION
LOW AND HIGH SCENARIOS

	Project Development & Onsite Labor (Direct) ($M)	Turbine & Supply Chain (Indirect) ($M)	Induced ($M)	Total ($M)
Project 1	$161.9 - $208.3	$87.1 - $173.3	$95.7 - $129.6	$344.7 - $511.2
Project 2	$170.0 - $205.5	$90.2 - $208.3	$96.9 - $133.5	$357.1 - $547.3
Project 3	$172.6 - $199.4	$91.1 - $199.8	$95.9 - $127.0	$359.6 - $526.2
Project 4	$174.3 - $191.9	$91.6 - $196.7	$94.7 - $121.3	$360.6 - $509.9
Total	**$678.8 - $805.1**	**$360.0 - $778.1**	**$383.2 - $511.4**	**$1,422.0 - $2,094.6**

Source: JEDI; Public Policy Center. Values are in millions of 2015 dollars.

4.5.2 OPERATIONS & MAINTENANCE PERIOD IMPACTS

Annual FTE Job-Years [33]

Once each project is producing power, a total of 35 to 64 direct job-years will be generated and sustained annually over the life of each wind farm project, for a total of 140 to 256 job-years annually for all four projects. In total, O&M activities are estimated to annually support a total of 964 to 1,748 job-years, which includes direct, indirect (supply chain), and induced impacts (see Table 13).

TABLE 13
ANNUAL JOB-YEARS DURING O&M
LOW AND HIGH SCENARIOS FOR MASSACHUSETTS

	Project Development & On-site Labor (Direct)	Turbine & Supply Chain (Indirect)	Induced	Total
Project 1	35 - 64	166 - 303	68 - 124	269 - 491
Project 2	35 - 64	149 - 269	62 - 112	246 - 445
Project 3	35 - 64	137 - 247	57 - 104	229 - 415
Project 4	35 - 64	129 - 234	55 - 99	219 – 397
Total	**140 – 256**	**581 - 1,053**	**242 - 439**	**964 - 1,748**

Source: JEDI; Public Policy Center.

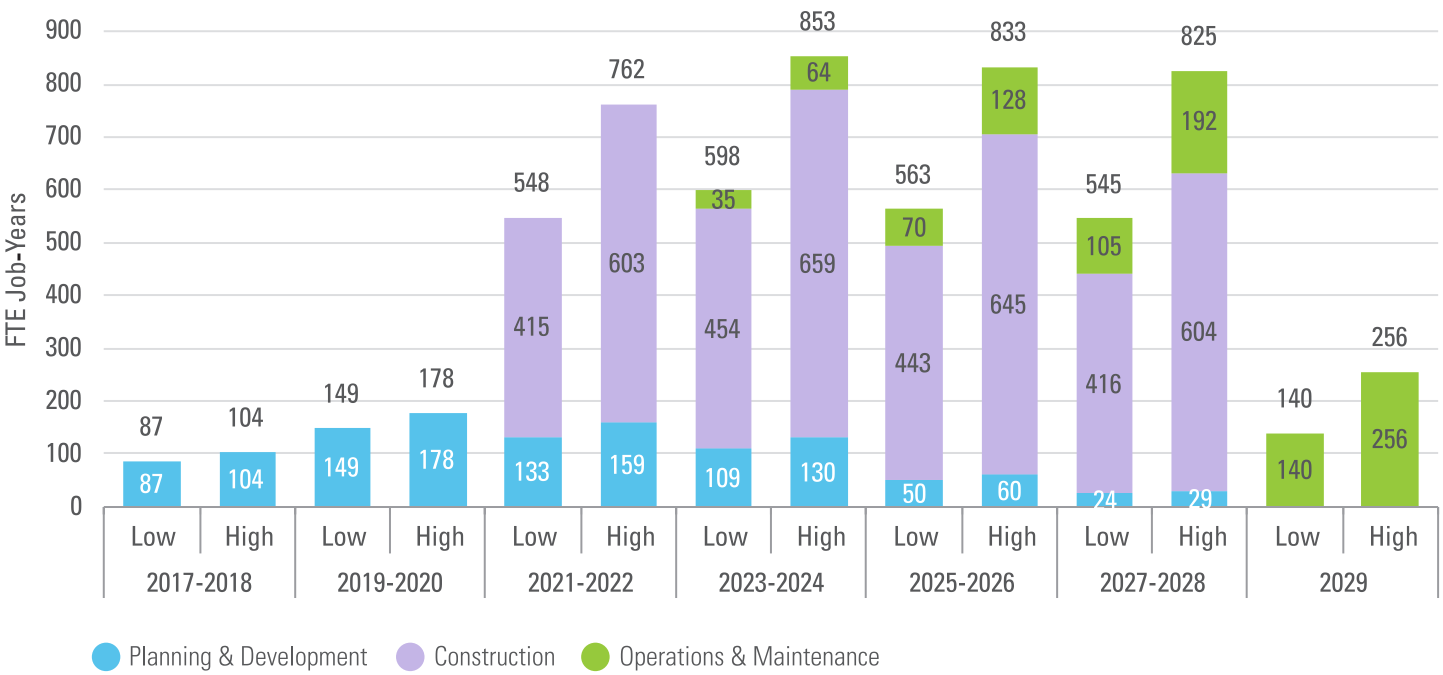
Output

It is estimated that O&M activities will result in between $3.7 million to $6.7 million in direct annual output for each 400 MW project, or $14.8 million to $26.8 million for all 1,600 MW of offshore wind. In total, O&M activities are estimated to create a total impact of between $201.1 million to $364.3 million annually when one considers the direct, indirect, and induced impacts (see Table 14). If a supply chain is developed to produce the replacement parts for O&M, it is expected that these impacts will increase over time.

4.5.3 JOB-YEARS BY PHASE, 2017–2029

Figure 6 presents the distribution of job-years by phase from 2017 to 2029 based on the Low and High scenarios. Job-years are expected to peak during 2023–2024, when Project 2 is in the construction phase, Projects 3 and 4 are in the Planning & Development phase, and Project 1 enters the O&M phase. O&M activities will continue to increase until all 1,600 MW have come online, at which point the job-years for these four projects are expected to plateau for at least the next 19 years.[34] Please note these numbers are exclusive of any offshore wind foundations or turbine components being manufactured locally.

FIGURE 6
JOB-YEARS 2017–2029: LOW AND HIGH SCENARIOS

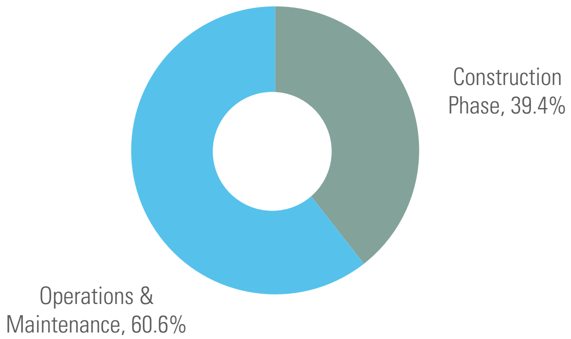


Source: JEDI; Public Policy Center.

4.5.4 LIFETIME JOB-YEARS: CONSTRUCTION VERSUS OPERATIONS

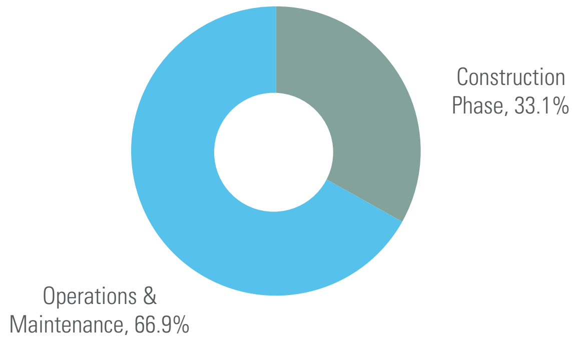
While construction activities contribute to the greatest number of job-years during the 2017-2029 time frame, most of these jobs do not extend beyond the construction phase of each project. Conversely, most O&M occupations represent full-time employment over a 25-year period. In the Low scenario, O&M will account for 60.6 percent of the total job-years over the lifetime of the wind farm, while O&M will account for 66.9 percent of the total job-years in the High scenario (see Figure 7 and Figure 8).[35]

FIGURE 7
LIFETIME JOB-YEARS: CONSTRUCTION VERSUS O&M LOW SCENARIO



Source: JEDI; Public Policy Center.

FIGURE 8
LIFETIME JOB-YEARS: CONSTRUCTION VERSUS O&M HIGH SCENARIO



Source: JEDI; Public Policy Center.

4.6 LOCAL MANUFACTURING JOB CREATION POTENTIAL

The economic impact estimates presented in the previous section are modeled on scenarios in which none of the primary components are sourced in Massachusetts during the 1,600 MW buildout in the Low scenario and a small amount of secondary foundation parts are be sourced locally in the High scenario. Primary components include the major turbine equipment such as nacelles, blades, towers, and foundations, which account for approximately 40 percent of total capital expenditures for an OSW project.[36]

Given the high transportation cost to import larger components such as towers and foundations, it is likely that some manufacturing capacity will eventually be developed in the United States. This is particularly true as other Atlantic states actively pursue entry into the industry by requiring the procurement of electricity from offshore wind.

In addition, the bids submitted in response to Request for Proposals pursuant to the Massachusetts General Laws Section 83C of Chapter 169, while heavily redacted, do hint that some capital equipment—particularly foundations or towers—may be manufactured in Massachusetts in the near term.

Consequently, several scenarios were developed to estimate the potential scale of opportunity for Massachusetts if blade, tower, or foundation manufacturing facilities are located in the state. Importantly, the impact estimates are calculated only for the 1,600 MW buildout, when in reality any large Massachusetts manufacturing facility will be supplying components to wind farms up and down the Atlantic coast and possibly beyond. The purpose of this section, therefore, is to estimate the additional job impacts that may occur from locally manufactured blades, foundations, and towers to supply Massachusetts' 1,600 MW buildout.

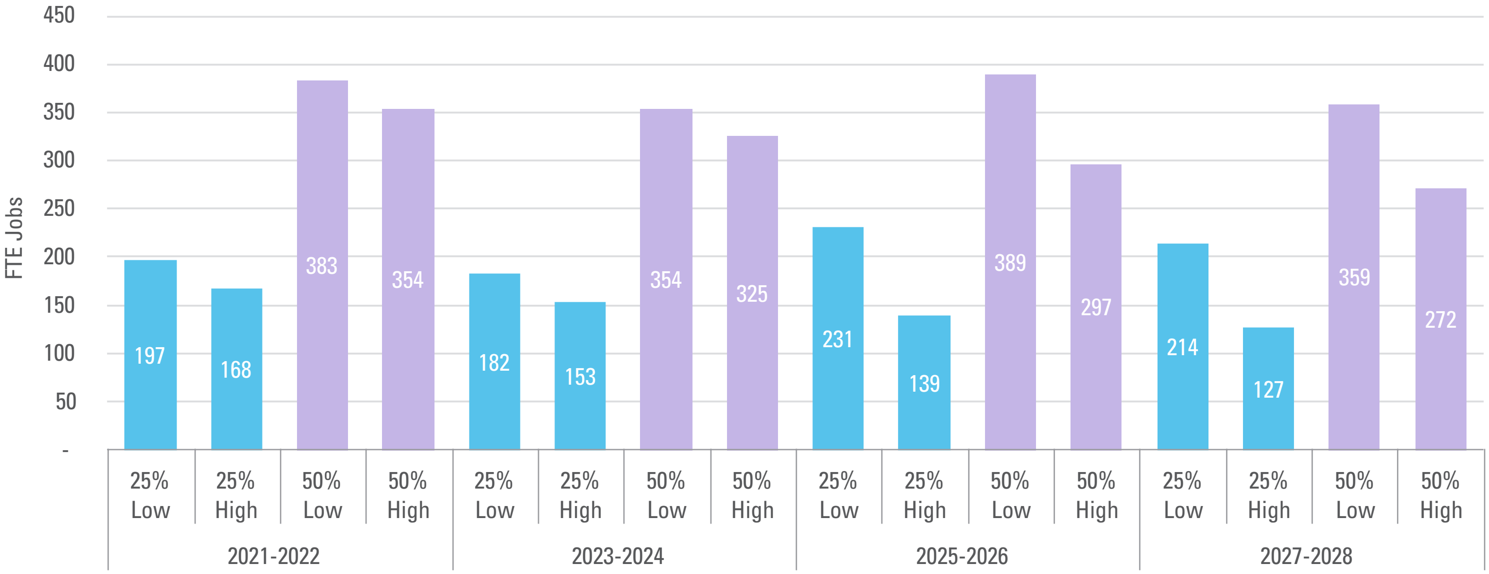
The analysis includes 25 percent and 50 percent local content scenarios for blades, towers, and foundations for the years 2021 through 2028.[37] Apart from these new local manufacturing assumptions, the JEDI model includes the same parameters as the original model estimates in the previous section so the reader can clearly see the additional job impacts that each component generates. While there may be a ramp-up period as the facilities come online, the scenarios were kept as simple as possible, particularly since there was no verifiable local content manufacturing information. Thus, we assume 25 percent and 50 percent local content for each year (2021 to 2028) for each of the four 400 MW projects. In addition, the JEDI model is run separately for each of the components (i.e. blades, towers, and foundations) so that the reader can see the degree to which each component drives potential job impacts. Importantly, the results that follow are not additive, for example, if both a blade and tower plant located in Massachusetts, the resulting impacts cannot simply be added together to arrive at an estimated impact.

4.6.1 BLADE MANUFACTURING

Table 15 displays job estimates for blade manufacturing in Massachusetts for the 1,600 MW buildout by project period for the Low and High scenarios. Because JEDI defines turbine component manufacturing (i.e. blades, foundations, and towers) as an indirect impact, these results include both the number of employees who will work in the blade plant and employees at supply chain businesses who furnish inputs to the blade plant.[38]

Notably, in some cases the number of jobs is lower in the High scenario for each component. While this may seem counterintuitive, it is a result of supply chain dynamics; the baseline High scenario reported in the previous section assumes much more local content for equipment such as cables, substation components, pilings, and secondary steel components. Accordingly, a blade plant, for example, will be sharing some of the same supply chain businesses for its inputs.

TABLE 15
ESTIMATED JOB IMPACT
BLADE MANUFACTURING IN MASSACHUSETTS FOR THE 1,600 MW BUILDOUT BY PROJECT YEAR
LOW (25%) AND HIGH (50%) SCENARIOS

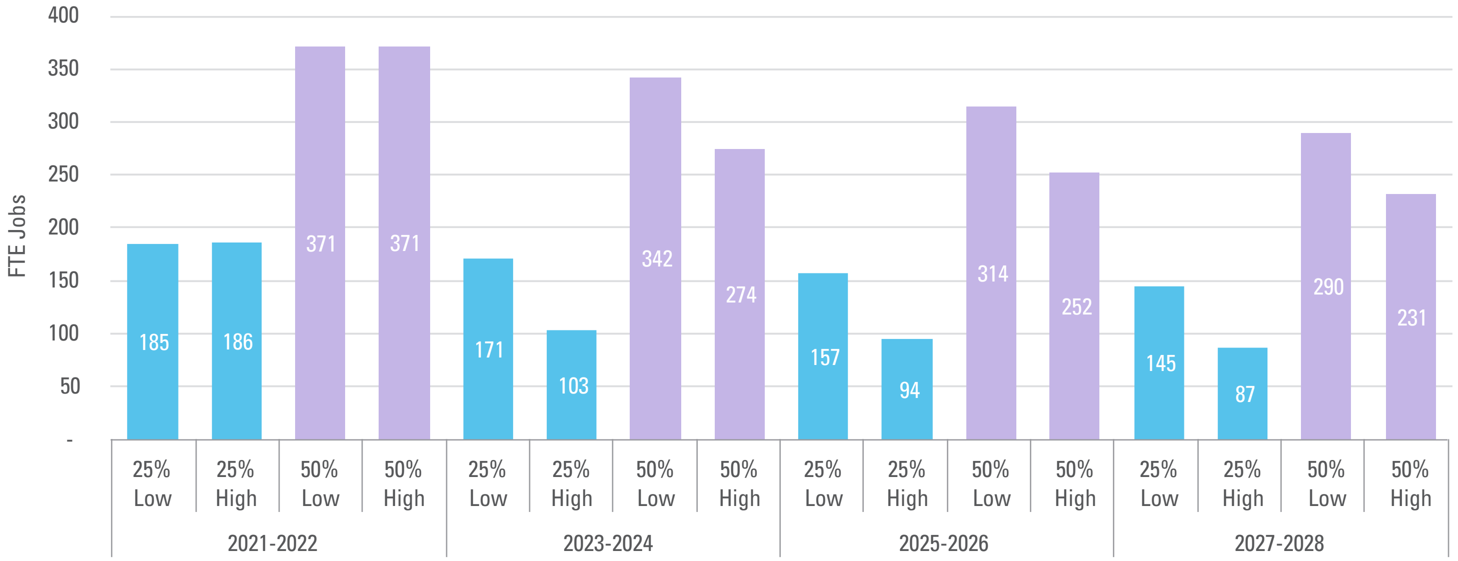


Source: JEDI; Public Policy Center.

4.6.2 FOUNDATION MANUFACTURING

Table 16 displays job estimates for foundation manufacturing in Massachusetts for the 1,600 MW buildout by project period for the Low and High scenarios. As noted in the previous section, these results include both the number of employees who will work in the foundation plant and employees at supply chain businesses who furnish inputs to the foundation plant.[39] In most cases the number of jobs is lower in the High scenario for reasons similar to the supply chain dynamics explained in the blade manufacturing section.

TABLE 16
ESTIMATED JOB IMPACT
FOUNDATION MANUFACTURING IN MASSACHUSETTS FOR THE 1,600 MW BUILDOUT BY PROJECT YEAR
LOW (25%) AND HIGH (50%) SCENARIOS

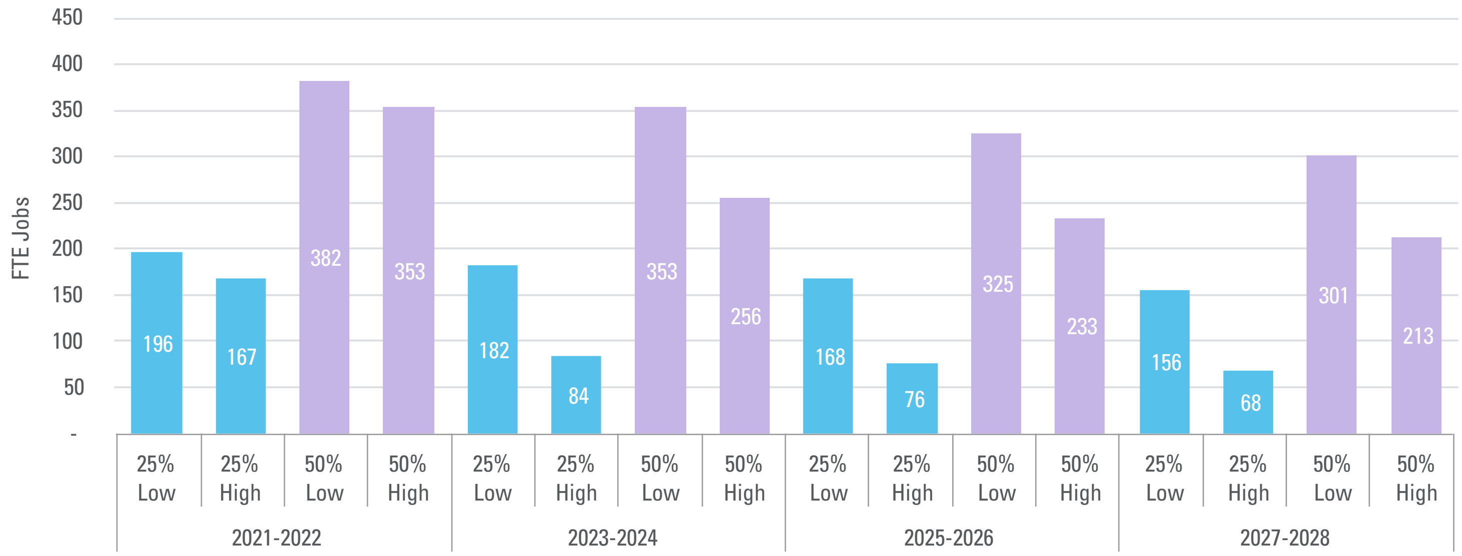


Source: JEDI; Public Policy Center.

4.6.3 TOWER MANUFACTURING

Table 17 displays job estimates for tower manufacturing in Massachusetts for the 1,600 MW buildout by project period for the Low and High scenarios. As noted in the previous section, these results include both the number of employees who will work in the tower plant and employees at supply chain businesses who furnish inputs to the tower plant.[40] In most cases the number of jobs is lower in the High scenario for reasons similar to the supply chain dynamics explained in the blade manufacturing section. This is particularly true for tower manufacturing, since the original impact model assumed a more significant proportion of local content in the High scenario in comparison to blade and foundation manufacturing.

TABLE 17
ESTIMATED JOB IMPACT
FOUNDATION MANUFACTURING IN MASSACHUSETTS FOR THE 1,600 MW BUILDOUT BY PROJECT YEAR
LOW (25%) AND HIGH (50%) SCENARIOS



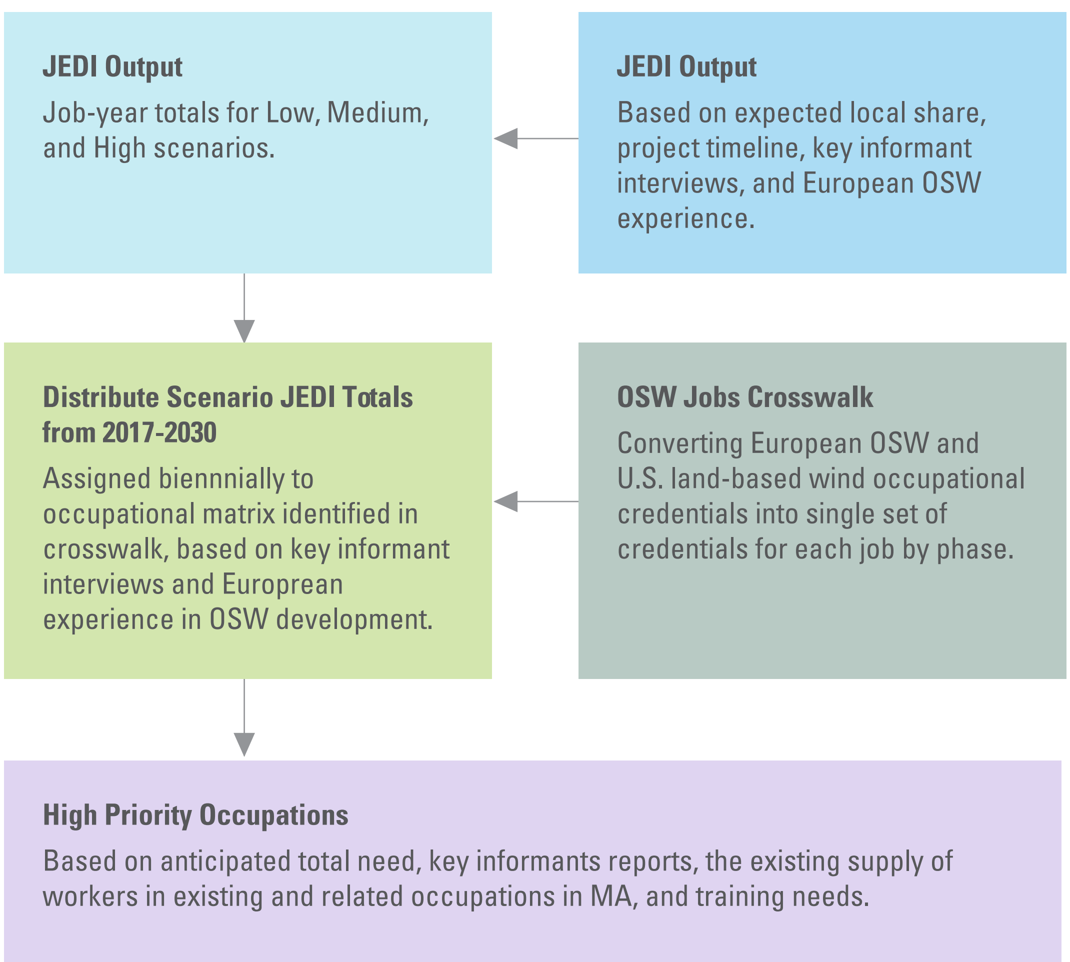
Source: JEDI; Public Policy Center.

5 Offshore Wind Workforce Gap Analysis

Determining the degree to which the Massachusetts workforce is prepared to fill OSW positions as they come online requires an understanding of the skill requirements of the OSW occupations and the existing skillsets of the Massachusetts workforce. Considering that the industry has yet to develop to a measurable extent in the U.S., the best sources for the skills and occupational requirements are the U.S. land-based wind industry and the European OSW industry.

Using insights gained through a crosswalk of U.K. to U.S. educational requirements, the JEDI model, an extensive literature review, and interviews with key informants, the project team assessed Massachusetts' OSW workforce capacity.[41] JEDI outputs provided the new job-years expected (labor demand) as projects move through the development pipeline. The project team allocated the total job creation estimates from JEDI biennially across each OSW occupation from 2017 to 2030.[42] The project team also examined the existing labor pool of Massachusetts workers in relevant occupations, workers with related skills, and the experience of key informants on other OSW developments (see Figure 9). High priority occupations were identified based on anticipated need relative to other OSW occupations, the current supply of workers in existing and related occupations in Massachusetts, key informants interviews, and OSW-specific training needs.

FIGURE 9
PROCESS FOR WORKFORCE GAP ANALYSIS



5.1 NET NEW JOB-YEARS BY OCCUPATION BY YEAR

The previous section provides an estimate of the number of job-years by occupation that will be supported by the construction and operation of 1,600 MW of OSW in Massachusetts. While these results are helpful in understanding the total volume of job-years, they do not provide detailed occupational estimates that are necessary to estimate skill and occupational demands. To address this, the project team apportioned the annual job-year estimates to a typical offshore wind occupational matrix, which was developed by information obtained through key informant interviews, and informed by visits to European wind farms and service ports, and an extensive literature review.

The estimates in Table 18 represent the new job-years for an occupation during each two-year period from 2017 to 2030 using the Medium scenario produced by the JEDI model.[43] As noted earlier, employment is anticipated to peak in 2023-24. O&M occupations are low in total numbers, but the job-years associated with these jobs extend beyond the timeframe of Table 3, with each expected to last for 25 years following the commissioning of the wind farm.

TABLE 18
BIENNNIAL NEW JOB-YEARS BY GENERAL OCCUPATION, 2017–2030 [44]

Occupations	2017-18	2019-20	2021-22	2023-24	2025-26	2027-28	2029-30	Total Job-Years
Planning & Development	**94**	**160**	**142**	**116**	**54**	**26**		**592**
Engineering	33	33	33	33				132
Surveying and Scientific Monitoring	11	22	22	22	11			88
Finance	11	10						21
Permitting		22	22					44
Legal	6	6						12
PR and Marketing	5	11	5					21
Machine Maintenance and Port Services	11	22						33
Site Managers			26	27	26	26		105
Water Transportation Workers	6	12	12	12	6			48
Other	11	22	22	22	11			88
Construction			**520**	**569**	**556**	**522**		**2167**
Project Engineers			18	20	20	18		76
Construction Managers			45	49	49	45		188
Machine Maintenance and Port Services			11	22	11	11		55
Water Transportation Workers			108	110	109	108		435
Trade Workers			323	352	351	325		1351
Longshoremen/Stevedores			45	49	49	45		188
Structural Iron & Steel Workers			90	98	98	91		377
Electricians			60	66	65	61		252
Material Moving Machine Operators			45	49	49	45		188
Other Installation Technicians			30	33	33	30		126
Laborers			53	57	57	53		220
Other			15	16	16	15		62
Operations & Maintenance				**47**	**47**	**47**	**47**	**188**
Site/Plant Managers				8	8	8	8	32
Project Engineers				6	6	6	6	24
Water Transportation Workers				6	6	6	6	24
O&M Technicians				24	24	24	24	96
Other				3	3	3	3	12
Total Annual Job-Years	**94**	**160**	**662**	**732**	**657**	**595**	**47**	**2947**

Source: JEDI, authors' calculations.

5.2 MASSACHUSETTS WORKFORCE GAPS

The project team determined the Commonwealth's workforce gaps related to the occupations outlined in Section 4 and Table 18 using the location quotient (LQ) and total employment for each, the likelihood of workers in a particular occupation possessing skills specific to working offshore, insights gained from key informant interviews, and the project team's knowledge of existing programs to upskill workers.[45]

Several key findings emerged from the process:

- Investments in training programs and facilities focused on sea safety and crew transfer methods are essential to the development of an OSW industry in Massachusetts because even qualified individuals in high demand occupations, such as structural iron and steel workers or electricians, are not likely to have experience working offshore.
- Developing targeted recruitment programs may help encourage individuals with the desired skills and experience to transition into OSW employment, as European developers have done with veterans, commercial fishermen, and oil and gas workers.
- Massachusetts is specialized in the professional and scientific occupations needed for OSW (engineers, scientists, finance managers, legal professionals, etc.). Initially, these positions will be filled in part locally, but complemented with expertise from Europeans with experience in the industry. Over the long term, however, the Massachusetts workforce possesses the capacity to expand into these fields and meet emergent needs as more wind farms are planned and developed.
- An assessment of the manufacturing workforce needs of OSW was outside the scope of this research project, but it is well established that Massachusetts is home to a vibrant advanced manufacturing sector with particular strengths in computer & electronics and medical devices & equipment. For generations, the Commonwealth has benefitted from the presence of a highly skilled technical workforce with strengths in applied engineering, metalworking, and machining. However, like much of the rest of the nation, Massachusetts' manufacturers are contending with the challenge presented by an aging workforce. In a 2014 survey of 1,350 Massachusetts manufacturers, 33 percent reported difficulty hiring the production workers they need.[46] This contrast between the strong industry leadership in advanced manufacturing and the limited availability of production workers suggests the need to expand training and recruitment efforts, even in the absence of the opportunity presented by the emerging OSW industry.

5.2.1 HIGH PRIORITY OCCUPATIONS

This section highlights and expands upon the occupations that were defined as being "high priority" by considering the related supply and the expected future demand. High priority occupations are therefore occupations that:

- Require a significant number of workers as compared to other occupations;
- Have a low LQ, defined as a lower share of the total workforce as compared to the nation (LQ<1.0);
- May be required to perform their job function offshore or in hazardous conditions and therefore will require additional training beyond what has been traditionally expected;
- May be difficult to find enough workers for locally.

Using these criteria, the high priority occupations are:

- Water transportation workers
- Trade workers
- Operations and maintenance technicians

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- May be difficult to find enough workers for locally.

Using these criteria, the high priority occupations are:

- Water transportation workers
- Trade workers
- Operations and maintenance technicians

The employment data presented below provide the most recent snapshot of the Massachusetts labor market in order to demonstrate existing conditions in occupations that are crucial to the development and lifetime of OSW farms. While the Block Island Wind Farm experience demonstrates that labor unions are able to quickly source workers from other states to meet spikes in demand, this analysis does not systematically examine the regional labor market, since one of the primary goals of the 83C legislation is to create new economic opportunities for Massachusetts residents.

The tables presented below use LQs to demonstrate the extent to which these occupations are underrepresented as a share of the state workforce relative to the mix of occupations in the national workforce. The total size of the existing workforce for each occupation, and in some cases in related occupations, is also presented, and is based on annual employment for 2017. The estimated peak demand for an occupation, based on the FTEs as presented in Table 18 above, represents the period of highest demand for workers for each occupation, assuming the construction phase stays on the project schedule outlined in Table 5.

Importantly, the creation of new OSW positions in a given occupation does not mean that the incumbent workforce will transition into new positions in the OSW industry. This is especially true of trade workers, many of whom are already in high demand in the construction industry throughout the Northeast. Developers will most likely have to work with trade unions to bring in experienced workers from out-of-state in order to meet demand, as they did for the Block Island Wind Farm in Rhode Island.

In addition, many of the workers in the high priority occupations will be required to perform their duties offshore, and this will require both new entrants and incumbent workers to receive sea safety and other training that is uncommon outside of the marine trades. For example, a number of trade workers will spend the majority of their time offshore, and therefore, they are considered a higher priority to prepare for work in the OSW industry. Convincing workers in these high need occupations to leave their current jobs to work in the OSW industry, at least in the near term, may be challenging due to the need for additional training and credentialing.

Accordingly, meeting the need for workers in high priority occupations will require the coordinated effort of a variety of organizations within the state's education and workforce development system. Community colleges and technical schools could provide needed training to prepare new workers entering these occupations. Trade organizations and labor unions will play an important role in connecting incumbent trade w

orkers with the OSW-specific training as developers begin to finalize specific health and safety requirements. Perhaps most importantly, however, is the need for training facilities that mimic the conditions of OSW work, such as crew transfer training stations, height and rope work towers, and confined spaces. These facilities will allow even experienced workers to gain the new skills and credentials necessary to be both qualified and successful in the emerging OSW industry in the United States.

Water Transportation Workers

All three phases require water transportation workers, though during the construction phase they will be in particularly high demand. This is especially true if a Jones Act compliant jack-up vessel is not available (as expected for early projects), because the construction vessel will have to remain at the wind farm site and components will likely be ferried to it by feeder barges, requiring barge crews and tugboats. Key informant interviews suggest that local workers will fill the jobs on feeder barges and guard vessels, which in the U.K. were filled by workers from the commercial fishing industry. In the U.K., in some cases, fishing boats themselves would be engaged to act as guard boats. Conversely, during the initial project(s), a foreign wind turbine installation vessel will be staffed with crew from elsewhere.

The demand for water transportation workers over the course of the 1,600 MW buildout is estimated to peak at 128 workers (see Table 18). This estimate includes workers needed during one project's construction phase, two overlapping planning phases, and one O&M phase.[47] Currently, there are an estimated 1,116 water transportation workers employed in Massachusetts and the state's LQ for these occupations is 0.57, which indicates a low level of concentration in these occupations relative to the nation.

The demand for 128 water transportation workers represents approximately 11 percent of the existing workers who are currently employed in these occupations.

TABLE 19
WATER TRANSPORTATION WORKERS: PEAK DEMAND, EXISTING WORKFORCE, AND LQs

Occupation	Estimated Peak Demand	Existing Workforce	LQ
Water Transportation Workers	**128**	**1,116**	**0.57**
Sailors & Marine Oilers	-	409	0.49
Captains, Mates, & Pilots of Water Vessels	-	534	0.53
Ship Engineers	-	173	0.69

Source: JEDI, authors' calculations; EMSI.

There will also be a demand for water transportation workers during the O&M Phase (an estimated six jobs per 400 MW project). These workers will pilot and staff the crew transfer vessels (CTVs) that ferry technicians to and from the wind farm, and their services will be needed on a regular basis over the 25-year life of the wind farm.

Additionally, the increase in maritime traffic that OSW development will bring throughout every phase, from survey vessels to feeder barges and from tugboats to CTVs, will translate into an increased demand for workers in machine maintenance and port services occupations. While not identified as high priority occupation, approximately 88 job-years related to these occupations are expected throughout all phases of the OSW development period. While much of this demand can be absorbed by full-service ports like New Bedford or Boston, it is unclear at the time this report was prepared whether developers plan to utilize ports in other parts of the Commonwealth, such as Fall River or ports on the Cape and/or Islands. Regardless of the location of the staging and deployment area, an increased demand for marine equipment maintenance workers and other services can be expected.

Trade Workers

The trade workers identified here are currently underrepresented in the Massachusetts workforce and have most likely not been trained to perform their duties in an offshore environment.

The demand for iron & steel workers and construction welders over the course of the 1,600 MW buildout is estimated to peak at 98 workers (see Table 19). This estimate includes workers needed for one project's construction phase.[48] Currently, there are an estimated 1,859 iron & steel workers and construction employed in Massachusetts and the state's LQ for these occupations is 0.64, which indicates a low level of concentration in these occupations relative to the nation. The demand for 98 iron & steel workers and construction welders represents approximately 5 percent of the existing workers who are currently employed in these occupations. Local manufacturing of towers and/or foundations, as described in Section 5, would further increase the demand for iron & steel workers and construction welders.

TABLE 20
IRON & STEEL WORKERS AND CONSTRUCTION WELDERS: PEAK DEMAND, EXISTING WORKFORCE, AND LQs

Occupation	Estimated Peak Demand	Existing Workforce	LQ
Iron & Steel Workers and Construction Welders	**98**	**1,859**	**0.64**
Reinforcing Iron & Rebar Workers	-	322	0.51
Structural Iron & Steel Workers	-	1,239	0.69
Boilermakers	-	298	0.72

Source: JEDI, authors' calculations; EMSI.

Increasing the supply of Massachusetts-based trade workers may be simpler than it is for nonunion occupations, because trade unions typically provide training to enhance the skill of their members for work in new industries through apprenticeships and union training facilities. Because many apprenticeship programs are completed after four years of full-time commitment, some union workers will likely have to be imported from other states at the outset of the 1,600 MW buildout while new apprentices are being trained.

The demand for material moving machine operators over the course of the 1,600 MW buildout is estimated to peak at 49 workers (see Table 18).[52] This estimate includes workers needed for one project's construction phase. Currently, there are an estimated 1,219 material moving machine operators employed in Massachusetts and the state's LQ for these occupations is 0.96, which indicates a level of concentration in these occupations that is nearly similar to the nation. However, these workers play a crucial role moving large turbine components to and from dockside staging areas, and there will be an intense period of demand for them as construction ramps up.

TABLE 21
MATERIAL MOVING MACHINE OPERATORS: PEAK DEMAND, EXISTING WORKFORCE, AND LQs

Occupation	Estimated Peak Demand	Existing Workforce	LQ
Material Moving Machine Operators	**49**	**1,219**	**0.96**
Pile-Driver Operators	-	256	2.81
Earth Drillers	-	194	0.40
Ship Engineers	-	173	0.69
Crane & Tower Operators	-	560	0.48
Dredge Operators	-	32	0.69
Hoist & Winch Operators	-	44	0.70

Source: JEDI, authors' calculations; EMSI.

Operations and Maintenance Technicians

O&M technicians will be needed throughout the lifespan of the wind farm to perform routine and emergency maintenance on the turbines. By the end of the development of 1,600 MW, there will be an estimated demand for 96 O&M technicians, with an average of 24 jobs per 400 MW project (see Table 18). Many of the skills and training requirements for this position are unique to the OSW industry. Massachusetts does not currently have a measurable number of workers in the land-based wind industry, but related jobs involve similar skills (see Table 22). radio, cellular, & tower equipment installers & repairers, for instance, would have experience working at heights and with mechanical equipment, but still would require training in safety, crew transfer techniques, and maintaining the equipment to transition into the role of O&M technicians.

The demand for O&M technicians over the course of the 1,600 MW buildout is estimated to peak at 96 workers (see Table 22). This estimate includes the total workers needed during the O&M phase for each project. Currently, there are an estimated 7,810 people employed in related occupations in Massachusetts. The total LQ of 0.93 for related occupations indicates that these workers are almost equally represented in the Massachusetts workforce as in the nation. Developing a supply of workers to meet the anticipated demand may not be challenging once a training system is established. In addition to the list of related occupations, trade workers and construction laborers who worked on the construction of the wind farm are considered well qualified to transition into this role.

TABLE 22
O&M TECHNICIANS: PEAK DEMAND, EXISTING WORKFORCE, AND LQs

Occupation	Estimated Peak Demand	Existing Workforce	LQ
Operations and Maintenance Technicians	**96**	**7,810**	**0.93**
Wind Turbine Service Technicians	-	n/a[49]	n/a
Electrical/Electronic Repairers, Commercial & Industrial Equipment	-	1,900	1.11
Industrial Machinery Mechanics	-	3,770	0.45
Radio, Cellular, & Tower Equipment Installers & Repairers	-	468	1.24
Maintenance Workers, Machinery	-	1,672	0.73

Source: JEDI, authors' calculations; EMSI.

6 Health and Safety Regulatory Agencies and Industry Standards

As discussed in Section 6, the challenges and potential hazards associated with working offshore necessitate specialized health and safety training to create a workplace that is safe and injury free.[50] This section provides an overview of the factors that underlay the development and application of offshore wind worker health and safety guidance and regulations. It includes a brief overview of the federal agencies with jurisdiction over offshore wind worker health and safety as well as private sector training programs used by European offshore wind developers.

Not addressed in this section are the potential hazards associated with offshore wind farm construction, which have been covered in detail by other reports. Neither does the report provide prescriptive recommendations for keeping workers safe during construction, operation and maintenance, which is the purview of regulators, leaseholders, and their subcontractors, and is beyond the scope of the report.

Ultimately, the section does seek to identify specific health and safety trainings that are anticipated to be needed by the offshore wind industry in order to ensure that Massachusetts workers have the health and safety training and credentials required to perform in jobs in the emerging offshore wind sector.

6.1 FEDERAL AGENCIES WITH JURISDICTION OVER OFFSHORE WIND WORKERS

The federal agencies with potential jurisdiction over OSW worker health and safety include the Department of the Interior (DOI) through the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE), the U.S. Coast Guard (USCG), and OSHA. Other federal agencies have regulatory responsibilities for OSW farms, however, their roles do not routinely bring them into oversight of OSW worker safety. They include the US Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA).

While employers are advised to consult with each federal agency directly, Table 23 provides information on the specific jurisdictional and regulatory authority of the federal oversight bodies during OSW construction. This information was documented through extensive meetings and interviews with representatives of the federal agencies.

TABLE 23
OSW FARM WORKER SAFETY REGULATORY JURISDICTION

Agency	Outer Continental Shelf (3-200 miles)	State Waters (within 3 miles)
DOI: BOEM/BSEE	All wind farm construction and operations activity within the wind energy lease area and associated easements, and rights-of-way, on the outer continental shelf; including the Safety Management System, which addresses all activities and facilities regardless of jurisdiction.	No jurisdiction
USCG	All vessels, including wind turbine installation vessels, feeders, tugs, barges, etc. between the marshalling port and wind energy lease area. Responsible for navigational safety and life and property on inspected vessels.	All vessels, including wind turbine installation vessels, feeders, tugs, barges, etc. between the marshalling port and wind energy lease area. Responsible for navigational safety and life and property on inspected vessels.
OSHA	Potential jurisdiction if activities are otherwise unregulated	Jurisdiction and regulations for specific hazards of OSW farms in state waters and the Great Lakes. Jurisdiction and regulations for activities taking place at ports including staging of equipment and turbine equipment and pre-commissioning.
USACE	Sets health and safety regulations for its contractors.	Lead federal regulatory agency for OSW projects in state waters. No jurisdiction over health and safety but does have health and safety regulations for its own contractors.

6.1.1 DEPARTMENT OF THE INTERIOR

The Department of the Interior (DOI) has broad jurisdiction over OSW farm planning, permitting, construction, and operation on the outer continental shelf (OCS) including worker health and safety.

DOI has taken several steps towards assuring a safe workplace for OSW farm workers but they have not developed prescriptive health and safety regulations. Instead, DOI has adopted a performance-based approach by requiring developers to submit a safety management system (SMS). The scope of the SMS covers all activities and all facilities described in and conducted under a lessee's site assessment plan, construction and operations plan, or general activities plan, regardless of jurisdictional boundaries. DOI is actively developing health and safety guidelines for OSW construction and O&M activities.

The purpose of the SMS is to provide a structured approach that developers can use to accomplish their health and safety performance objectives. This approach requires developers to identify hazards, manage risk through various tools and actions, and develop and implement policies and processes to reach goals. Specifically, DOI's SMS regulations require that developers demonstrate that their personnel are properly trained, although what this entails is left to industry to determine.[51]

6.1.2 UNITED STATES COAST GUARD

The USCG is responsible for maritime safety for both US-flagged and foreign vessels. Traditionally, USCG regulations address safe navigation practices and the safety of life and property on facilities (and vessels that service those facilities) engaged in exploring and exploiting mineral resources on the OCS. Through a memorandum of agreement (MOA), USCG works cooperatively with BOEM to clarify roles and responsibilities related to navigational risk and safety regulations for vessels associated with construction and servicing, though it does not specifically address OSW worker health and safety.[52]

The Coast Guard has published a Navigation and Vessel Inspection Circular (NVIC) that provides specific guidance for OSW farm developers. The most recent NVIC that applies is 02-07, "Guidance on the Coast Guard's role and responsibilities for Offshore Renewable Energy Installations (OREI)." [53] This NVIC provides guidance on marine navigation risk assessment and management concerns, specifically:

- Visual Navigation and Collision Avoidance
- Communications, Radar, and Positioning Systems
- Marine Navigational Marking
- Standards and Procedures for Shutdown in the Event of a Search and Rescue, Pollution, or Security Operation
- The Effects of Tides, Tidal Streams, and Currents
- Weather
- Ice
- Vessel Traffic Analysis
- Risk of Collision
- Analysis Potential Danger of OREI Structures to Vessels
- Assessment of Access to and Navigation Within, or Close to, an Offshore Wind Farm
- Impact on Search and Rescue
- Marine Environmental Protection/Response
- Example Risk Mitigation Strategies

The USCG issued a Commandant Instruction (16003_2A) in November 2016 that provides planning guidelines for "Port Approaches and Traffic Separation Schemes (TSS)" with recommendations for minimum distances of wind farms from a TSS.[54] The USCG called for buffer zones of two nautical miles from the "parallel outer or seaward boundary of a traffic lane" and five nautical miles from terminus of a TSS.[55]

6.1.3 OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

OSHA plays a primary role in enforcing safety regulations for land-based wind farms. OSHA also has jurisdiction and regulations for specific hazards of OSW farms in state waters and on the Great Lakes. Although OSHA has no jurisdiction offshore, the agency will be the lead regulatory authority at the OSW port and will be responsible for ensuring safe working conditions during the construction and assembly of wind turbine components quayside as well as the loading and deployment of vessels that will take components to the offshore construction site.[56]

OSHA offers a comprehensive set of health and safety regulations for longshoremen who work on the quayside lay-down yard and on vessels, which is an important facet of the offshore wind industry for loading, unloading, and assembly of components. The regulations included in Standard 1918, Safety and Health Regulations for Longshoring, cover:

- Personal Protective Equipment
- Working Conditions
- Handling Cargo
- Vessel's Cargo Handling Gear
- Opening & Closing of Hatches
- Cargo Handling Gear and Equipment Other Than Ship's Gear
- Working Surfaces
- Gear Certification

OSHA also is responsible for developing and enforcing workplace safety and health regulations for general industry (29 CFR 1910), the construction industry (29 CFR 1926), and the maritime and shipyard industry (29 CFR 1915, 1917, and 1918). Rules for all shipyard employment are contained in 29 CFR 1915. They include provisions for shipbuilding, ship repairing, and ship breaking including with regard to confined and enclosed spaces (Subpart B), scaffolds and ladders (Subpart E), and general working conditions (Subpart F). Aspects of marine terminal work are addressed by 29 CFR 1917 including the movement (loading and unloading) of cargo or materials within the terminal area accomplished with the use of shore-based cranes, or other cargo-handling equipment.

6.2 INDUSTRY STANDARDS FOR OFFSHORE WIND WORKER HEALTH AND SAFETY

As with other industries, OSW employers bear the responsibility for ensuring worker health and safety. However, it remains unclear at this time what specific strategies U.S. developers and operators will implement for meeting health and safety standards, especially since the regulatory bodies have yet to develop a cohesive set of regulations. The European OSW industry has adopted health and safety training according to standards developed by the Global Wind Organization (GWO), a non-profit association of wind turbine owners and manufacturers with the aim of supporting an injury-free work environment in the wind industry. Given the nascent state of the U.S. OSW industry and the evolving regulatory context, it is anticipated that developers in the near term may either adopt GWO or similar, equally effective OSW worker health and safety strategies, as these standards are well established in Europe and early entrants to the U.S. have ties to European OSW developers.

Deepwater Wind, based in Rhode Island, is the only developer with experience building, operating, and maintaining an OSW farm in the US. Because the five turbine Block Island Wind Farm is located in state waters, responsibility for offshore worker health and safety came under the jurisdiction of the Occupational Safety and Health Administration. As a result, the project does not provide complete insight into the regulations regarding the health and safety of OSW farm workers operating in federal waters, which fall under the DOI's jurisdiction. However, it does offer an example of how a successful strategy for ensuring OSW worker health and safety is developed and applied within the evolving U.S. regulatory context. Deepwater Wind implemented a health and safety protocol during the construction of their Block Island Wind Farm based on current standards from the U.S maritime and offshore oil and gas industries.

Ørsted and Copenhagen Infrastructure Partners(CIP)/Avangrid have mature safety cultures based on their experience building, operating and maintaining OSW farms in Europe. The same applies for offshore wind turbine manufacturers GE, MHI Vestas, and Siemens Gamesa, who are responsible for all activities associated with wind turbine pre-assembly, deployment, installation and commissioning.

As detailed above, DOI and other federal agencies with jurisdiction over OSW worker health and safety have not adopted prescriptive health and safety regulations including GWO Basic Safety Training. However, internationally, the GWO Basic Safety credential is the most widely accepted by developers and turbine manufacturers. Based on the European experience, Ørsted and Copenhagen Infrastructure Partners/Avangrid, as well as the offshore wind turbine manufacturers GE, MHI Vestas, and Siemens

Gamesa are expected to require specific workers to receive health and safety training according to GWO standards. Therefore, it is anticipated that there will be a demand for these training resources in Massachusetts.

6.2.1 GWO BASIC SAFETY TRAINING

GWO's stated objective is to "develop common industry training and best practice standards for health and safety as a vital and necessary way forward to reduce risks for personnel in the wind industry working on site and to reduce environmental risks."[57] GWO Basic Safety Training includes five modules:

1. Working at Heights and Rescue

2. First Aid

3. Sea Survival

4. Manual Handling

5. Fire Awareness

Working at Heights and Rescue training is designed to give the participants the necessary basic knowledge and skills to perform safe work at heights, alongside safe and comprehensive basic rescue from heights on an OSW turbine. The course involves information delivered in a classroom setting as well as practical exercises on a purpose built training tower. Training towers are 10-20 meters high and are equipped with the same equipment used in the field including ladders, hoisting systems, and escape hatches. Towers can be configured with multiple stations or facilities may have multiple towers to accommodate larger training groups.

First Aid training teaches participants safe and effective First Aid in a wind turbine environment. Upon completion of the training, participants will possess an awareness of the hazards encountered when working within the wind industry, how to control and mitigate these hazards, and be able to carry out First Aid safely in the field.

Sea Survival training teaches participants individual and collective survival techniques at sea. These include recognizing the dangers and symptoms related to hypothermia and drowning, understanding the advantages and limitations of the different life saving appliances, personal protective equipment, and use of personal fall prevention equipment commonly used offshore in the wind energy industry. The hands-on portion of this training is often done in a deep "survival pool" but can also be done in open water. The Sea Survival module also includes crew transfer training which addresses the safe and appropriate transfer to the OSW turbine structures in a dynamic ocean environment. It includes competencies such as understanding how to put on the appropriate survival suits and safety harnesses, hoisting techniques, rope work, and other transfer methods. This training enables workers to safely transfer from vessel to dock, vessel to foundation, and vessel to vessel. Mandatory training also focuses on understanding emergency and safety procedures.

Manual Handling training provides individuals with a solid understanding of how to perform manual labor tasks safely. Participants are required to perform exercises that demonstrate how to move a variety of objects in a simulated wind turbine environment that may be large, heavy, fragile and/or dangerous in a variety of other ways. This module educates participants in the dangers associated with manual handling such as the risk of developing muscular/skeletal injuries from job tasks, the correct handling of equipment, and identifying signs and symptoms of injuries related to poor manual handling techniques.

Fire Awareness training provides the basic knowledge and skills to prevent fires, conduct initial and appropriate judgment when evaluating a fire, manage evacuation of personnel, and efficiently extinguish an initial fire. Participants are required to identify causes, sources, and signs of a fire, demonstrate emergency escape procedures, and demonstrate correct use of fire extinguishing equipment in a wind turbine environment.

6.2.2 HELICOPTER UNDERWATER ESCAPE TRAINING

In addition to GWO Basic Safety Training Basic Safety Training, other trainings may be required by developers and turbine manufacturers in order to ensure OSW worker health and safety. If, for example, helicopters will be utilized to transport technicians to the wind farm, which is typical in Europe, employees will also be required to complete Helicopter Underwater Escape Training (HUET). HUET provides familiarization with helicopter safety procedures in various stages of the flight. Participants prepare for dry and wet emergency landings; practice the use of Emergency Breathing Systems (EBS); and practice abandoning a helicopter in various situations, including floating upright or capsized in the water, and with or without the use of an EBS. A deep pool equipped with a helicopter simulator (a.k.a. "heli-dunker," which is usually lowered into the pool using a hoist system or crane) is required.

There are currently no HUET training facilities in Massachusetts. The closest HUET training facility is located in Groton, CT and training is provided by Survival Systems USA. Although developing HUET training facility requires a substantial investment, it may be advantageous in light of industry's preference for a "one stop shop." The UMass Dartmouth School of Marine Science and Technology in New Bedford, MA has a 90,000-gallon test tank which has been identified as a potentially viable location for developing a local HUET training facility.

6.2.3 AMERICAN WIND ENERGY ASSOCIATION

The American Wind Energy Association (AWEA) was established in 1974 as a professional association for those involved in wind energy research and development. Through their Environmental, Health, and Safety (EHS) Committee and Subcommittees, AWEA promotes the safety and health of the wind energy industry workforce, seeks to achieve a safe workplace for all, and provides a forum for sharing of information and industry best practices as well as lessons learned. AWEA has developed Health and Safety Best Practice Guidelines for OSW Energy.[58] Through the Environmental, Health, and Safety Committee, which includes OSW developers and health and safety professionals, AWEA is actively working to develop more comprehensive health and safety standards for the U.S. OSW industry.

6.2.4 BZEE

BZEE, founded in 2000 by a consortium of German wind energy companies, focuses on closing the skills gaps between worker competencies and the needs of the wind industry. BZEE created the BZEE Academy in 2004 to link education and health and safety courses relevant to the OSW industry. BZEE's vision is to create a global network of certified training institutions offering courses aligned with its technical and safety training credentials that are recognized broadly throughout the wind industry. Currently, BZEE operates at 29 locations worldwide, where they offer training leading to wind energy-specific qualifications. BZEE certifies its network of training providers according to the International Standards Organization (ISO) "learning service provider" standard ISO-29990.

7 Massachusetts OSW Workforce Training Capacity

This section provides an assessment of the state's existing OSW training capacity in order to determine what types of workforce training and education programs are needed.

Worker training that provides both incumbent and new Massachusetts workers with appropriate credentialing and skill development is critical to maximizing the economic benefits to the state. Massachusetts will require a workforce with the appropriate industry-recognized credentials to maintain its national leadership position in the emerging OSW industry. The experiences in Europe and the U.K. clearly demonstrate the importance of relevant skills and technical competencies and underscore the need for a comprehensive workforce development pipeline.

As noted in Section 6, Massachusetts—for most occupations—is well prepared to support the OSW industry and has a workforce that aligns well with projected job creation. However, there are several "high priority" occupations in OSW for which the Commonwealth will need to produce or attract new talent. These occupations make up a large percentage of the total anticipated OSW workforce but represent a relatively smaller percentage of the existing Massachusetts workforce than the national average.

7.1 WATER TRANSPORTATION WORKERS AND TRAINING

The increase in maritime traffic associated with OSW development will result in an increased demand for workers in water transportation, machine maintenance, and port services occupations. Some of this demand can be absorbed in full-service ports like New Bedford or Boston, where existing workers have the required skills, knowledge, and abilities to fill those jobs. In some cases, workers can be retrained to meet the specific demands associated with careers in offshore wind.

Water transportation workers require a certain number of hours at sea on appropriate vessels to advance through the ranks, along with sufficient scores on licensure exams. There are existing Massachusetts-based educational and training programs in place for producing marine workers, such as the Massachusetts Maritime Academy, the Northeast Maritime Institute, New England Maritime Inc., and Marine Safety Training Inc. Training focused specifically on navigation in a marine construction environment at the scale of an OSW farm may need to be expanded. Additionally, new and incumbent workers must complete regular health and safety training, including refresher courses, in topics such as industry safety, equipment repairs, working in confined spaces, sea survival, and first aid.

7.2 TRADE WORKERS AND APPRENTICESHIP PROGRAMS

Trade workers in the OSW industry include Stevedores, Structural Iron & Steel Workers, Electricians, and Material-Moving Machine Operators, and others. Throughout the Commonwealth, trade workers are in high demand in the construction industry and are currently in short supply. Trade workers acquire skills most commonly at vocational/technical high schools, community colleges, and union apprenticeship programs. Many trade occupations require licenses and industry-recognized certificates from entities such as the federal Occupational Health and Safety Administration (OSHA).

As detailed in Section 6, iron & steel workers are in short supply in the Massachusetts workforce. Collectively, those occupations have a 0.69 location quotient, (i.e., Massachusetts has a low supply of these occupations relative to the nation). Expanding access to these careers would not only increase the supply of workers for OSW and other industries, it would also increase economic opportunities for Massachusetts residents seeking a well-paid alternative to careers that require a four-year college education.

The traditional career pathway into iron and steel working and other trades is through an apprenticeship. Typically, workers enter apprenticeships through a recognized labor union, which maintains standards for membership. Trade unions provide training to enhance the skill of their incumbent members and new employees for work in new industries.

Apprenticeship programs provide new workers with training leading to productive careers in trade occupations. Typically, apprenticeships include a combination of classroom instruction and on-the-job experiences over a multi-year period of employment. Through this system, apprentices acquire the necessary technical skills and abilities to perform entry-level tasks. An apprentice receives regular performance and progress evaluations and earns entry-level wages throughout the apprenticeship period. Typically, union apprenticeships also require several hundred hours of classroom instructions. Most programs are completed after four years of full-time commitment.

In Europe, many OSW apprenticeships are industry-subsidized, i.e., apprentices are incumbent employees of the company who must complete training to improve skills, with the cost of the apprentice program covered by their employer.[59] Additionally, some formal apprenticeship programs are located at facilities funded by members of a regional industry group. Apprenticeships provide students with training in real industrial facilities without the location hazards associated with the OSW industry. Since the Massachusetts OSW industry is in its very early stages, the Commonwealth has an opportunity to adopt, adapt, and benefit from these models by developing a broader workforce development strategy to support the emerging OSW industry.

American labor unions already play a significant role in the training of new trade workers and the upskilling of incumbent professionals. For instance, the International Association of Bridge, Structural, Ornamental, and Reinforcing Ironworkers of America sponsors several technical training programs within their national network of regional training centers and aggressively promotes the use of apprenticeship models for training new workers in the welding occupations. [60] The organization also sponsors refresher courses for incumbent union members. The Ironworkers union supports a network of 150 training academies across the United States and Canada, with training facilities in Boston and Worcester in Massachusetts, as well as nearby in East Providence, Rhode Island.

In addition, the Massachusetts Building Trade Council actively promotes and supports technical and safety training for its members, and apprenticeship programs for workers seeking to become new members. Comprising several local union chapters in the different trades, the Building Trade Council provides potential workers with access to training and apprenticeships. Another example is the New England Laborer's Training Trust Fund. Created in 1969, the Trust supports a combination of classroom and simulated hands-on training in a variety of trade occupations. It also sponsors an active apprenticeship program in middle-skilled trade occupations, often leading to the acquisition of licenses and other industry-recognized credentials.

Founded in 1900, the Boston Chapter 104 of the International Brotherhood of Electrical Workers (IBEW) is part of a national labor organization and focuses on producing a well-trained and productive workforce for the electric utility sector.[61] The national IBEW is part of the Electrical Training Alliance, which oversees apprenticeship and workplace safety training programs and provides standard educational materials.[62] The IBEW supports a center for member development and training in Barrington, New Hampshire. Its goal is to create a safer working environment for electric utility workers by providing its members with technical and safety training.

Yet another important element of the workforce pipeline is the Utility Workers Union of America (UWUA). The UWUA created the "Power for America" Trust fund to provide its members and new apprentices with a multi-faceted combination of skill training and upgrades to specialized technology awareness, electricity, and basic safety, including working at heights, working in confined spaces, and emergency rescue.[63] The UWUA/Power for America team is developing a Memorandum of Agreement with Bristol Community College and other potential parties to develop an OSW training center in New Bedford. UWUA has similar agreements in place with community colleges in Midwestern states and a program in place with Bunker Hill Community College to train utility workers. They also have a recruitment campaign targeting veterans who are transitioning out of active duty. Finally, the U.S. Department of Labor certified Power for America as a designated "Apprenticeship" program.

There is an opportunity for organized labor to play a key role in the Massachusetts workforce development pipeline to support the emerging OSW industry due to the heavy presence of trade labor in the OSW workforce. The development of the Power for America Trust demonstrates that labor unions are prepared to take a role in expanding the skills of members to fill the needs of new industries. Employing best practices from Europe to expand existing training systems will provide Massachusetts with an advantage in creating and improving the local workforce for the OSW industry as it develops, helping to minimize the need to import workers from neighboring states. Effective and integrated partnerships between industry organizations, trade unions, and the community college and vocational school systems can help to create a pipeline of new workers with the skills needed to work in the OSW industry.

7.3 OPERATION AND MAINTENANCE TECHNICIANS

O&M technicians account for the bulk of the O&M workforce. They conduct both routine and emergency maintenance on towers, foundations, blades, and all equipment inside the nacelle (after receiving proprietary training from the turbine manufacturer). Becoming an O&M technician requires a high school diploma and some post-secondary education as well as training for working safely at heights and in confined spaces, sea safety, and crew transfer. Trade workers and construction laborers who worked on the construction of the wind farm are often well qualified to transition into this role. As noted in Section 6 above, Massachusetts has an unfavorable location quotient in occupations with skills similar to those required of O&M technicians, and currently, the state has no measurable workforce in any form of wind turbine maintenance technicians.

O&M technicians must have a core skill set that includes understanding electricity transmission, mechanics, and hydraulics. Workers can acquire these generic skills at vocational/technical schools and at community colleges. These foundational skill sets are augmented with technology-specific training and health and safety training. The standard model in U.S. land-based wind and throughout Europe is for the turbine manufacturers to train employees on their equipment and according to their proprietary standards, which typically align with industry-accepted credentials. There are a limited number of secondary and higher education institutions that offer a program of studies leading to certificates and degrees in O&M occupations. In Massachusetts, Bristol Community College is the only institution that offers both a certificate and an associate's degree program for aspiring OSW technicians.

7.4 GWO TECHNICAL AND SAFETY TRAINING FOR TRADEWORKERS AND O&M TECHNICIANS

GWO provides oversight to a global network of "GWO certified" training providers, setting technical performance and competency standards for basic technical training and basic safety training. To receive certification by GWO, training providers are audited by an independent third party to confirm that they are capable of delivering courses and training programs that comply with GWO standards for each specific training activity.

In 2016, GWO established a standard credential for wind turbine technicians called the Basic Technical Training (BTT) standard. According to GWO, "The Standard has been developed in response to the demand for recognizable Basic Technical Training in the industry, and has been prepared in co-operation between the members of GWO based on risk assessments and factual incident and accident statistics pertaining to the installation, service, and maintenance of wind turbine generators and wind power plants."[64] The standard covers basic hydraulic, mechanical, and electrical skills and will become effective on March 31, 2018. Major wind turbine manufacturers have signaled their intent to require their installation and O&M workers to have completed GWO BTT.

In addition to the Basic Safety Standard discussed in Section 7, the GWO also has rigorous certification standards for refresher courses in basic safety. Developers and OSW turbine manufacturers have expressed interest in having access to a local "one stop shop" that would offer GWO Basic Safety and Basic Technical Training as well as provide access to classroom space for company-specific proprietary trainings. Thus, it is anticipated that there will be a demand for these training resources in Massachusetts.

7.5 PRIVATE U.S. TRAINING PROVIDERS WITH CREDENTIALS

The U.S. is home to a very limited number of private OSW training providers with credentials from one of the recognized organizations. Notably, no private OSW training providers are located in Massachusetts, or even in New England, which speaks to the investment being made elsewhere in the country to train workers for jobs in the land-based wind industry.

7.6 HIGHER EDUCATION TRAINING INSTITUTIONS

While there are not yet private OSW training providers in Massachusetts, the project team identified several higher education institutions with existing training programs. These programs range from wind energy to renewable energy programs, and training programs related to the wind industry, but not necessarily to OSW. In order to evaluate existing training programs in the state, the project team created a multi-tiered ranking system that classifies each Massachusetts higher education training provider by the following set of criteria:

1. Certified by credentialing organizations that certify OSW Training Programs, such as BZEE or GWO.

2. Infrastructure/Labs needed to cover the five GWO Basic Safety Modules.

3. Offshore Wind Curriculum and/or Wind Certificate/Degree.

4. Curriculum and/or degree in a related area such as Clean Energy or Land-Based Wind.

5. Located at an accredited school.

6. Have a physical location to provide training.

The Tiered System provides a framework to evaluate a training provider or program by assigning a specific rating based on the institution's offering of training or educational programs anticipated to be in demand by companies in OSW. This Tiered System is designed to assist both companies and incumbent and new workers in identifying training providers and needed curriculum with industry-recognized credentials that lead to careers in OSW.

TABLE 24
TIERS FOR EVALUATING WIND TRAINING AND EDUCATIONAL PROGRAMS AT MASSACHUSETTS HIGHER EDUCATION INSTITUTIONS

Tier 1:	
• Certified by the listed global credentialing organizations such as GWO or BZEE, • Infrastructure/labs needed (five basic safety protocols/ tower) • OSW curriculum and/or wind certificate/degree, accreditation • Physical location	Providers in this tier will have met all relevant criteria.
Tier 2:	
• Infrastructure/labs needed (five GWO Basic Safety Modules • OSW curriculum and/or wind certificate/degree, accreditation • Physical location	Providers in this tier are without a recognized industry certification.
Tier 3:	
• OSW curriculum and/or wind certificate/degree, accreditation • Physical location	Providers in this tier are without the needed infrastructure and industry certification.
Tier 4:	
• Related certificate/degree programs (not specifically wind) • Accreditation • Physical location	Providers in this tier are without infrastructure, industry certification, and have a related certificate/degree but not specifically OSW.
Tier 5:	
• Accreditation • Physical location	Providers in this tier are without related certificate/degree programs, infrastructure, and industry certification.
Tier 6:	
• Offshore wind curriculum and/or wind certificate/degree	Providers in this tier are without infrastructure, industry certification, accreditation, and a physical location.

An institution must meet all criteria to be classified as a Tier 1 institution, which includes academic accreditation by its jurisdictional accrediting body, a specific training location, certification from one of the three industry-recognized OSW credentialing organizations, the necessary training infrastructure (labs, classrooms, tower, facilities for Basic Safety training, etc.), and the presence of a specific OSW curriculum and/or a certificate or degree in OSW. Table 24 above summarizes the Tiered System's ratings for each tier by specifying the offerings of educational and training programs in OSW.

Each of these seven institutions listed in Table 25 meets at least one of the six tiers based on the criteria described in Table 24. Viewed through the lens of the tiered system, there are no "Tier 1" OSW higher education training institutions in Massachusetts. None of the state's educational organizations has the necessary training and credentialing components recognized by the global accrediting organizations as described above. Consequently, both the Commonwealth and the nation will need to develop a network of accredited education and training providers with the appropriate facilities to achieve a comprehensive and certified U.S. workforce.

In Massachusetts, there are currently five institutions that the project team characterize as "Tier 2" institutions, meaning they lack only certification. These institutions have training facilities/labs curriculum, offer a certificate or degree in wind, are accredited, and have a physical location.

Accordingly, these five Tier 2 organizations—Bristol Community College, Cape Cod Community College, Massachusetts Maritime Academy, University of Massachusetts Amherst, University of Massachusetts Lowell—are uniquely positioned to train and educate candidates for a new and nascent industry, except for the required certification from an internationally recognized body.

Other institutions meet a limited number of the required criteria such as a physical location, an accredited school, and degrees and certifications that would be acceptable in the wind industry; however, the degree does not focus specifically on OSW. These "Tier 4" institutions—Greenfield Community College and New England Institute of Technology—provide opportunities for pathways into wind energy and other sectors, for example, engineering, renewable and green technology.

TABLE 25
MASSACHUSETTS HIGHER EDUCATION INSTITUTIONS WITH PROGRAMS RELEVANT TO OSW

Institution	Tier	Program(s)
Bristol Community College	2	Fundamentals of Wind Energy Certificate
Cape Cod Community College	2	Environmental Technology Certificate: Small Wind Technology
Massachusetts Maritime Academy	2	Energy System Engineering
University of Massachusetts Amherst	2	Marine Safety/Environmental Protection
University of Massachusetts Lowell	2	Offshore Wind Energy Systems Engineering Graduate Certificate
	4	Graduate Program in Energy Engineering
Greenfield Community College	4	Certificate in Renewable Energy/Energy Efficiency Program Renewable Energy Management Advanced Certificate
	4	Bachelor of Science in Renewable Energy Engineering
New England Institute of Technology	4	Associate of Science in Electrical Technology with Renewable Energy

7.7 BASIC TECHNICAL AND HEALTH & SAFETY TRAINING NEEDS AND OPPORTUNITIES

The credentialing of training providers is critical to establishing an effective workforce development strategy in the U.S.[65] OSW work can be very dangerous and the equipment is very expensive, therefore, developers and turbine manufacturers highly value workers with both the required technical competencies and industry-recognized credentials for health and safety training. It is therefore very important for OSW companies and economic and workforce development practitioners to develop clear career pathways to access those credentials.

Based on a review of OSW worker health and safety regulations and industry standards, there is significant opportunity for Massachusetts to build upon existing worker training capacity by strategically investing in the development of local health and safety training curriculum, courses, and infrastructure resources.

In particular, It is anticipated that there will be local demand for both GWO Basic Safety Training and Basic Technical Training. A number of educational institutions, including the Massachusetts Maritime Academy (MMA) and Bristol Community College, have already expressed interest in providing these trainings. Through a 2016 grant from MassCEC, MMA is actively developing a crew transfer training facility as a part the installation of a wave attenuator dock system. With the completion of the crew transfer training facility and the installation of a training tower for the Working at Heights module, MMA will be well positioned to offer all five Basic Safety Training modules.

Prior to offering GWO training, training providers must go through an audit process performed by a certification body. The purpose of this process is to verify that the training provider can consistently deliver training to the relevant GWO Standards. Additional information, including the certification criteria and process is available on the GWO website.[66]

8 Conclusions And Recommendations

Massachusetts is at the forefront of the emerging offshore wind industry in the United States. As documented in this report, the construction of 1,600 MW of offshore wind in the Commonwealth will create between 2,279 and 3,171 direct job-years in Massachusetts and between 6,878 and 9,812 total job-years, including indirect and induced impacts. An additional 140 to 256 direct permanent jobs will support the operation and maintenance of the 1,600 MW of installed OSW capacity. In total, O&M activities will support between 917 and 1,748 total FTE jobs annually, including indirect and induced impacts. Notably, while construction activities will primarily occur over two-year periods, O&M activities will occur throughout the lifecycle of the wind farms, which is typically about 25 years.

As noted in Section 6, Massachusetts—for most occupations—is well prepared to support the OSW industry and has a workforce that aligns well with projected job creation. However, there are several "high priority" occupations for which the Commonwealth will need to produce or attract new talent. These occupations make up a large percentage of the total anticipated OSW workforce and are in relatively short supply. The identified high priority occupations include water transportation workers, trade workers, and O&M technicians. Consistent with previous studies, the greatest potential for long-term employment is associated with offshore wind farm O&M.

Recommendation: Workforce development efforts should be targeted at the high priority occupations of water transportation workers, trade workers, and O&M technicians.

Typically, developers and turbine manufacturers provide turbine-specific technical training, but prior to employment, O&M technicians must obtain foundational technical knowledge through a certified provider that has the appropriate facilities. As documented in Section 8, there are not yet workforce or educational programs in Massachusetts ready to fill these positions, but several Massachusetts organizations can achieve full accreditation with strategic investments in key courses and physical facilities.

Recommendation: Strategic investment in key courses and physical facilities are needed to provide O&M and installation technicians with the appropriate industry-recognized technical training.

Other types of employment in OSW include numerous professional, scientific, and technical occupations, such as engineering, marine science, legal, and finance occupations. Massachusetts' history as a leading maritime state and a center for research and innovation is in part due to the presence of a robust pipeline for creating new scientific and engineering professionals. While it is expected that initially these positions will be filled, in part, by imported labor with experience in the industry, over the long term the Massachusetts workforce possesses the capacity to expand into these fields and meet emergent needs as more wind farms are planned and developed.

Health and safety training programs often require capital equipment designed to simulate the real-world conditions of an offshore wind farm. Existing Massachusetts training or educational institutions do not currently offer the health and safety training programs with the appropriate industry-recognized credentials from organizations such as GWO and BZEE. However, with strategic investments in key courses and physical facilities, several Massachusetts organizations can achieve full accreditation by the appropriate credentialing bodies.

Recommendation: The Commonwealth, in partnership with academic and labor organizations, should consider capital investments to leverage and match private sector investments in OSW health and safety programs designed to comply with the requirements of national and international credentialing bodies.

Construction activities are estimated to generate and support between $1.2 billion and $1.8 billion in additional economic activity in Massachusetts, including indirect and induced impacts. In addition, it is estimated that O&M will result in between $3.7 million to $6.7 million in direct annual output for each 400 MW project once each is producing power, or $14.8 million to $26.7 million for all four projects. In total, O&M activities are estimated to create a total of between $190.7 million to $364.3 million annually in direct, indirect, and induced impacts. These impacts vary over time, but extend for the full life of the wind farm. If a supply chain is developed to produce the replacement parts for O&M, it is expected that these impacts will increase significantly.

While the economic impacts documented in this report are substantial, they pale in comparison to those that would be associated in the event a local supply chain serving the domestic OSW industry emerges in Massachusetts. For example, we estimate manufacturing 50 percent of towers in Massachusetts would increase the number of job-years associated with the 1,600 MW build out by over a third. In addition, a domestic supply chain would reduce transportation costs and by extension the cost of OSW development and the prices of the electricity generated by OSW farms. While during the build out of 1,600 MW, it is likely that much of the supply chain inputs will be sourced from European manufacturers, this can be expected to change as the pipeline of domestic OSW developments grows to scale. Large industrial sites with waterfront access are key to attracting offshore wind manufacturers. A recent assessment of Massachusetts OSW ports and infrastructure found that Massachusetts is home to 18 waterfront sites that have the potential to accommodate these developments.[67]

Recommendation: Massachusetts should continue to prepare its port infrastructure and development-ready sites to position the Commonwealth to be at the epicenter of supply chain activities in the United States.

As documented in this report, the emerging offshore wind industry presents a significant opportunity for Massachusetts workers and suppliers. The Commonwealth is well-positioned to capture much of the economic activity that the development of offshore wind will generate, but to take full-advantage of these opportunities, Massachusetts' workers need to have the necessary skills and credentials and the Commonwealth will need the programs and the infrastructure required to meet the needs of OSW developers in the near term, and supply chain firms in the longer term.

The findings presented in this report provide evidence to support several near-term actions designed to help ensure that Massachusetts workers and businesses are fully prepared to seize the opportunities presented by the nascent OSW industry. Ultimately, the degree to which the Commonwealth is able to reap the full economic benefits of OSW, including a Massachusetts-based supply chain, will depend greatly on the extent to which the state, industry, and academia can develop the workforce, provide the infrastructure, and work with educational and labor leaders to meet the workforce and infrastructure needs of the emerging OSW industry .

APPENDIX A: METHODOLOGICAL OVERVIEW

This research is grounded in site visits and interviews with key informants representing the full array of primary OSW activities, both in the United States and abroad. The key informants include all three leaseholders in the Massachusetts WEA and the Rhode Island/Massachusetts WEA, offshore wind turbine manufacturers, European OSW project O&M managers, education and training providers, and representatives of several industry associations, among others. In addition, the project team conducted an extensive literature review of all the relevant studies published to date that could be identified.

In order to understand the full scope of workforce needs from project development to operations and maintenance, the project team developed a profile of each occupation involved in the development of an OSW farm, including any educational and training needs. This was done by first identifying the occupations and skills required for each phase through a literature review and interviews with OSW industry representatives, including developers in Massachusetts and key informants in the European OSW industry.

Skill, training, and education requirements for each occupation were then defined using a "crosswalk" analysis of the current occupational profile of European developments and manually matching those to comparable occupations in the U.S. The crosswalk matched European occupational requirements (primarily from the U.K.) to those for land-based wind occupations outlined in the Department of Energy (DoE) "Wind Career Map," and those for related occupations in the Bureau of Labor Statistics (BLS) and O*Net's occupational databases.[68] This process involved converting U.K. experience levels (National Vocational Quotients and Regulated Qualification Frameworks: NVQs and RQFs) into recognizable U.S. equivalents, primarily based on O*Net's Job Zone system, and reviewing and cataloging other skill requirements. Key informant interviews with developers and other individuals involved in workforce training and hiring for the OSW industry in the U.K. further informed the skill and credential crosswalk.

For some OSW occupations, the "crosswalking" is straightforward. Electrical Engineers, for instance, require the same level of education (typically, a master's degree) to work in OSW as they would in a related existing industry in Massachusetts, such as power generation and transmission. The only difference is that the engineer working in OSW has received some training in turbine design and functionality.

Occupations like O&M Technicians, that do not yet exist in Massachusetts in sufficient quantities to be captured in official occupation data, involved a more complex crosswalking process to match the skillset, education, and vocational training to related occupations from which workers could transition. For these occupations, the existing U.K. OSW industry acted as a template for occupational requirements. These requirements were mapped to related positions identified by the DoE, O*Net's wind energy occupational descriptions, and the BLS Occupational Outlook Handbook.

To quantify the potential job creation and economic development impacts associated with the development of the first 1,600 MW of offshore wind, the project team used NREL's Jobs and Economic Development Impact (JEDI) model. Using the lifecycle timeline and information gathered in key informant interviews, and informed by an extensive literature review, the project team developed custom inputs to the JEDI model in order to estimate the number of workers needed during each project phase. JEDI phase totals were then apportioned to the occupations identified through the crosswalk process based on typical workforce distributions in existing OSW planning, construction, and operations phases.

In order to identify gaps and areas of economic opportunity for the existing workforce, the project team evaluated the expected OSW workforce needs against a detailed profile of the skills base of the Massachusetts workforce. The project team determined the Commonwealth's workforce capacity for each OSW job using a location quotient (LQ)[69] approach and insights gained from key informant interviews, and informed by the European experience. An occupation with a high LQ (> 1.0) indicates that the state has a greater share of its workforce concentrated in that occupation relative to the national workforce, and it can be inferred that education and training systems exist to support the production of workers for these occupations. Low LQs (< 1.0) imply the opposite, and were used to identify low specialization in Massachusetts.

The project team designated occupations that demonstrated a high demand for workers and had a low LQ "High Priority Occupations." Through this process, comparisons are made between job-years and employment estimates for each occupation and related occupations, and it should be noted that although IMPLAN does not explicitly distinguish between full- and part-time jobs, JEDI converts to FTE using supplementary conversion data provided by IMPLAN. Most industry sectors, including the construction and energy sectors, have high FTE per employment ratios (>96%), thus it is likely that the number of job-years is close to the actual number of employees working on a project.

To determine what types of OSW workforce training and education programs currently exist or are needed, the project team researched and mapped existing educational and training organizations to identify providers who have the capacity or the potential to provide the required workforce training programs and apprenticeships for the sector. Lastly, the project team identified and investigated strategies that training organizations, higher education programs, high school vocational programs, and other workforce organizations not currently involved in the OSW industry can use to develop training and/or curriculum to better meet the needs of the OSW industry. Toward this end, the project team created a multi-tiered ranking system that classifies each training provider using a set of the basic criteria used by the OSW industry to credential its workforce. The tiered system begins to identify gaps in the current workforce pipeline and offers both companies and incumbent and new workers the ability to identify training providers and needed curriculum with industry-recognized credentials that lead to careers in OSW.

APPENDIX B: SUMMARY OF EUROPEAN BEST PRACTICES/THEMES AND LESSONS LEARNED

Standardized Credentials

The offshore wind (OSW) industry in the United Kingdom (UK) increasingly depends upon the National Vocational Qualifications (NVQs) system developed in England, Wales, and Northern Ireland to classify the knowledge, skills, and abilities (KSAs) required for successful worker performance in jobs in the industrial sectors. In 2015, the British federal government replaced this regulatory framework with a Regulated Qualifications Framework (RQF) system.

Skill competencies based on recognized occupational standards, work-based, and/or simulated work-based assessment enable education and training organizations to certify a student's occupational competence. Student competencies develop through assessment and training wherein successful students demonstrate their ability and competence to carry out jobs to the standard required by the NVQ/RGF framework.

The UK's Commission for Employment and Skills has developed a system for defining national occupational standards that describes the "competencies" expected in any given occupation across a wide range of industry sectors. NVQ's are competence-based qualifications. There are five levels of NVQ competencies ranging from Level 1, which focuses on basic work activities, to Level 5 for senior management. The five levels of NVQ have the following competencies.[70]

NVQ Competency Levels

Level 1 – Competence, which involves the application of knowledge and skills in the performance of a range of varied work activities most of which may be routine and predictable.

Level 2 – Competence, which involves the application of knowledge and skills in a significant range of varied work activities, performed in a variety of contexts. Some of the activities are complex or non-routine, and there is some individual responsibility or autonomy. Collaboration with others, perhaps through membership of a work group or team, may often be a requirement.

Level 3 – Competence, which involves the application of knowledge and skills in a broad range of varied work activities performed in a wide variety of contexts and most of which are complex and non-routine. There is considerable responsibility and autonomy, and control or guidance of others is often required.

Level 4 – Competence, which involves the application of knowledge and skills in a broad range of complex, technical, or professional work activities performed in a wide variety of contexts and with a substantial degree of personal responsibility and autonomy. Responsibility for the work of others and the allocation of resources is often present.

Level 5 – Competence, which involves the application of skills and a significant range of fundamental principles and complex techniques across a wide and often unpredictable variety of contexts. Very substantial personal autonomy and often a significant responsibility for the work of others and for the allocation of substantial resources feature strongly, as do personal accountabilities for analysis and diagnosis, design, planning, execution and evaluation.

The U.S. lacks an integrated qualification system like the NVQ. However, the Department of Labor does have two classification systems of job credentials. The O*Net Job Zones system groups occupations by similar educational requirements, related experience, and on-the-job training. There are five Job Zones, with Zone One being jobs that are suitable for people just entering the workforce, Zone Two requiring a high school diploma or GED, Zone Three requiring a vocational education, related experience, or an associate's degree, Zone Four requiring a bachelor's degree and considerable work experience, and Zone Five requiring graduate-level education and specialized skills. Additionally, the Bureau of Labor Statistics' Occupational Outlook Handbook provides detailed descriptions of how to enter occupations including the educational pathway starting with high school and relevant professional licenses, certifications, and registrations.

The table below reflects the process developed to convert U.K. education and training credentials, standardized at the national level, to comparable education and workforce experience classifications used in the United States. These conversions allowed the project team to match the education and experience required for a given established occupation in Massachusetts to an equivalent occupational category identified in the analysis of the U.K. OSW experience.

O*Net Job Zones, developed to group occupations that are similar in education requirements, expected experience, and on-the-job training, map fairly well to the U.K.'s NVQ levels, which similarly describe the competence standards expected for workers in a given field and occupation. Unlike the Job Zones, the NVQs are a standardized certification system managed by professional organizations and the central government to test workers on current practices and the main responsibilities of an occupation. This system allows new techniques to be adapted into the workforce training system across the country as they are developed.[71]

Company Provided Occupational and Safety Training

In the overwhelming majority of cases, recruitment of the existing OSW workforce in the United Kingdom and Europe is either from the oil and gas industry or the military. Expenses associated with the specialized occupational training received by production level workers are largely covered by the individual OSW development companies and their turbine manufacturers in most cases. These new workers in the OSW sector typically come with a foundational skill set in electronics/electricity, mechanics, and hydraulics acquired from previous employment, military service, or formal education.

Each turbine manufacturers or OSW development company provides those new workers with comprehensive technical and safety training aligned with their specific product group and the occupational/safety standards set by global credentialing organizations such as the Global Wind Organization, BZEE, or WindEurope.

Company-sponsored training is provided either on-site at the Developer/OEM's manufacturing, construction, or deployment facilities; or by a network of private, for-profit training organizations and training academies such as 3Suns Group, Applied Industrial Solutions, and Maersk; or membership-supported training centers such as the CATCH Center in the Humber region of the U.K.

For port workers, training programs align worker skill competencies with the U.K.'s NVQs, which is described elsewhere in this report. In addition to technical training in areas such as crane operations, hosting, material handling, and heavy equipment operations, supplemental health and safety training is provided to instill in workers an understanding of the monetary values of OSW components so that expensive OSW components can be safely and securely moved at the quayside and transported on the deck of OSW deployment vessels.

Apprenticeship Programs

Overall, apprenticeship programs in the UK are strong and more widely utilized in comparison to the U.S. A typical student in an apprenticeship program is often hired directly out of secondary school (16 years old). Interview subjects reported that some training facilities have been enrolling older students more recently.

Through apprenticeship experiences, OSW technicians learn to work in real world conditions. Length varies, but some are up to three years or longer. Many of the U.K. apprenticeships are industry-subsidized; i.e., apprentices are incumbent employees of the company sent to training to improve skills. Apprenticeships provide students with training in real industrial facilities without the risks associated with the OSW industry.

Related to the apprenticeship model, labor union organizations provide a wide range of training. Most labor unions have a network of technical training centers to provide basic and advanced occupational training, particularly in occupations such as welding, electricity, iron works, and other construction trades.

These observations about apprenticeship and union-sponsored workforce development are particularly relevant to the emerging Massachusetts and U.S. offshore wind industry. There already exists in New England an extensive network of union-sponsored training centers that are well positioned to help prepare the workforce required by the BOEM leaseholders and their respective turbine manufacturers.

Training/Cross-Training

Manufacturers and partner organizations typically have in-house training facilities or partnerships with training institutions to train employees according to their own corporate standards of competence. In addition, incumbent workers regularly (annually/biennially) participate in refresher courses in topics such as industry safety, equipment repairs, working in confined spaces, sea survival and first aid.

CONVERTING U.K. NATIONAL EDUCATION AND TRAINING CREDENTIAL TO U.S. EQUIVALENTS

Stages of employment and education	U.K.			U.S. Equivalent	
	NVQ Levels	RQF Levels	Certificates/Degrees	Education and Experience	O*Net Job Zones
Postgraduate education, Professional employment in trades	5	8	Doctoral Degree, Level 8 Certificate for senior management in a trade	Doctoral Degree	5
Graduate school, Advanced training for leadership in the trades		7	Master's Degree, Level 7 Certificate for management and leadership in a trade	Master's Degree	
Continuation in higher education, Advanced/specialized training in trades		6	Bachelor's Degree, Degree Apprenticeship	Bachelor's Degree, Professional vocation credentials	4
	4	5	Diploma of Higher Education, Higher National Diploma	2 full-time years in college or Associate's Degree, Vocational apprenticeship or license	3
Entry to higher education, Specialized training in trades		4	Certificate of Higher Education, Higher National Certificate	1 full-time year in college, Vocational apprenticeship	
Continuation of secondary education, or Vocational training	33		A-Level	AP-Level high school courses or SATs, Vocational certificate	2
Continuation of secondary education, Skilled employment training	22		GCSE score 4 or higher	High school diploma	
Secondary education, Workforce entry	11		General Certificate of Secondary Ed score below 4	Age 16 Grade 10	1
	n/a	Entry	Entry Level CertificateA	ge 14-16 Grades 8-10	

Wind turbine technicians typically receive proprietary training aligned with standards set by turbine manufacturers. For most production associates and turbine technicians, the core skills are knowledge of electricity, mechanics, and hydraulics augmented with courses such as working at heights, and the health and safety courses set by the Global Wind Organization for workplace safety.

High-level engineers sometimes need to work on the turbines during pre-commission phase and receive refresher-training courses to upgrade and sharpen worker KSAs associated with production and O&M occupations.

Design of Training Programs

Regional employers and members of supply chain organizations drive demand for training and education programs offered in OSW. This also extends to non-apprenticeship training as well. For example, workers periodically attend a refresher class to shore up their skills or to meet new or revised industry regulations, particularly with regard to safety.

Many schools and training providers take a collaborative approach with members of supply-chain organizations to provide authentic training in the workplace and at training centers. Private companies provide the financial support for these training activities. Recently, federal governments and the European Union (EU) directed additional funding to support public/private training developed in conjunction with leadership representing key industry organizations.

Technology in offshore wind is constantly changing, so training facilities need to be "future proofed." For example, at one emergency simulator in the U.K., the facilities can be customized to match the real-life context of various OSW operations.

University/Quasi-Public Involvement

Following the example of Denmark, universities in the U.K. are increasingly working with the OSW industry to find areas where expertise and facilities can be of help. A number of fora for collaboration between industry, government, and academia have emerged across the U.K. National and regional education and training institutions regularly engage in mapping career pathways for students to improve access to jobs through education. The universities have also played an important role in identifying areas for cost reduction and innovation in delivery of training programs for OSW.

Vocational Training

The vocational education system has an important role in the emerging OSW market in the United States, since many of the occupations involve the skilled trades. England is currently experimenting with a technical training system for students ages 14

APPENDIX C: BIENNIAL NEW JOB-YEARS BY OCCUPATION: LOW AND HIGH SCENARIOS

LOW SCENARIO:
BIENNIAL NEW JOB-YEARS BY OCCUPATION, 2017-2030

Occupations	2017-18	2019-20	2021-22	2023-24	2025-26	2027-28	2029-30	Total Job-Years
Planning & Development	**87**	**149**	**133**	**109**	**50**	**24**		**553**
Engineering	31	31	31	31				123
Surveying and Scientific Monitoring	10	21	21	21	10			82
Finance	10	10						20
Permitting		21	21					41
Legal	4	4						8
PR and Marketing	5	10	5					20
Machine Maintenance and Port Services	10	21						31
Site Managers			24	25	24	24		98
Water Transportation Workers	6	11	11	11	5			44
Other	11	22	22	22	11			86
Construction			**415**	**454**	**443**	**416**		**1727**
Project Engineers			14	15	15	14		57
Construction Managers			34	37	37	34		143
Machine Maintenance and Port Services			10	21	10	10		51
Water Transportation Workers			101	102	102	100		405
Trade Workers			245	267	266	246		1023
Longshoremen/Stevedores			34	37	37	34		142
Structural Iron & Steel Workers			68	74	74	69		286
Electricians			45	50	49	46		190
Material Moving Machine Operators			34	37	37	34		143
Other Installation Technicians			23	25	25	23		95
Laborers			40	43	43	40		167
Other			12	12	12	12		48
Operations & Maintenance				**35**	**35**	**35**	**35**	**140**
Site/Plant Managers				6	6	6	6	24
Project Engineers				5	5	5	5	18
Water Transportation Workers				5	5	5	5	18
O&M Technicians				18	18	18	18	71
Other				2	2	2	2	9
Total Annual Job-Years	**87**	**149**	**548**	**598**	**528**	**475**	**35**	**2420**

through 19. This innovative approach in the U.K. provides students an educational experience that is equivalent to the education provided to U.S. students from middle school through community college. This new network of University Technical Colleges (UTC) operate with an extended academic day (8 AM – 5 PM) and links students at an early age with OSW supply chain companies through various experiential learning opportunities.

O&M Specific Workforce Training

O&M technicians working offshore will need to receive a variety of training to maneuver safely in their work environment. In the Humber region, two facilities have adapted existing workforce training techniques from the oil and natural gas extraction and chemical industries, (which have a heavy presence in the region) to OSW.

First, the CATCH facility offers a number of services to OSW and other industries. Of great importance to the developing wind industry are training courses that simulate working at heights, on scaffolding, and working in the confined spaces of the turbine nacelle, and rope training. CATCH designs its courses in partnership with member organizations, who have access to the CATCH facilities to train their workers, and access to academic courses and apprenticeships for new hires in engineering and mechanical skills like welding and machining.

Second, the Humber Offshore Training Association (HOTA) training facility adapted its helicopter and sea safety training courses used to train workers in the oil, natural gas, and shipping industries to meet the needs of the OSW industry. This facility has a 10-meter-deep pool and a helicopter simulator used to simulate a helicopter crash at sea. In addition, HOTA utilizes the pool for sea survival and crew transfer training. OSW workers have to renew their training certification in these skills every four years.

HIGH SCENARIO:
BIENNIAL NEW JOB-YEARS BY OCCUPATION, 2017-2030

Occupations	2017-18	2019-20	2021-22	2023-24	2025-26	2027-28	2029-30	Total Job-Years
Planning & Development	104	178	159	130	60	29		661
Engineering	37	37	37	37				147
Surveying and Scientific Monitoring	12	25	25	25	12			98
Finance	13	11						24
Permitting		25	25					49
Legal	5	5						10
PR and Marketing	6	13	6					24
Machine Maintenance and Port Services	12	25						37
Site Managers			29	30	29	29		117
Water Transportation Workers	7	13	13	13	6			52
Other	13	26	26	26	13			103
Construction			603	659	645	604		2511
Project Engineers			21	23	23	21		88
Construction Managers			53	58	58	53		221
Machine Maintenance and Port Services			121	123	122	120		486
Water Transportation Workers			12	25	12	12		61
Trade Workers			378	412	411	380		1581
Longshoremen/Stevedores			53	58	58	53		221
Structural Iron & Steel Workers			105	115	115	106		441
Electricians			70	77	76	71		294
Material Moving Machine Operators			53	58	58	53		221
Other Installation Technicians			35	39	39	35		147
Laborers			62	67	67	62		257
Other			18	19	19	18		74
Operations & Maintenance				64	64	64	64	256
Site/Plant Managers				11	11	11	11	44
Project Engineers				8	8	8	8	33
Water Transportation Workers				8	8	8	8	33
O&M Technicians				33	33	33	33	130
Other				4	4	4	4	16
Total Annual Job-Years	104	178	762	853	769	697	64	3428

APPENDIX D: SUPPLY CHAIN INVESTMENT

The project team developed Low, Medium, and High supply chain scenarios that anticipate the state's supply chain developing and maturing as projects move from the planning and development to construction phases, as additional OSW projects enter the pipeline in other states, as suppliers expand and adapt products, and as new suppliers relocate or start businesses in the region.[72] A key step in this process was to determine which activities must occur at the port, which could possibly take place locally, and which will likely rely on foreign expertise, production, and manufacturing capacity.

The parameters of each scenario were informed by interviews with industry leaders, the experience in the United Kingdom, and a systematic consideration of the factors affecting the share of local content and labor that will be used to develop and operate 1,600 MW of OSW in Massachusetts. The Low scenario assumes that the supply chain will not develop to a high degree primarily due to a lack of a sufficient pipeline of projects along the Eastern seaboard, although it does assume some local content. The High scenario assumes that the supply chain will develop more quickly and the procurement of some materials and equipment from Massachusetts-based firms and institutions.

The following summarizes information from key informant interviews and an extensive literature review regarding the jobs most likely to be sourced locally. These insights were the basis for the development of the assumptions underlying each of the supply chain scenarios.

Manufacturing of Components: The major turbine equipment (e.g. nacelles, blades, towers, foundations, cables, etc.) account for approximately 40 percent of total capital expenditures for a wind farm project. However, since the scope of this study does not extend to manufacturing occupations, apart from the analysis described in the "Scale of Opportunity" section of this report, our economic impact estimates assume that none of the primary components will be sourced in Massachusetts during the first 1,600 MW buildout in the Low scenario and only a small amount of secondary foundation parts will be locally sourced in the High scenario. Capital expenditures that are more likely to be spent in Massachusetts include cables, substations, and labor installation costs related to foundations, substructures, tower erection, grid interconnection, and development services (e.g., engineering, legal, public relations, ports and staging, marine transportation, etc.).

All three developers in the lease areas report the importance of a balance between experienced labor from Europe and local suppliers and workforce. According to one developer, the first project could be completed using only European companies, if price were the only factor, but since there are more projects to come, it makes economic sense to invest locally from the start to encourage and nurture the local supply chain. However, in the eyes of foreign companies, "local" may mean the United States more broadly, and not necessarily simply Massachusetts.

Given the high cost to import some of the larger components, like towers and foundations, it is likely that some manufacturing capacity will eventually be developed in the United States. However, as noted previously, there will need to be a large pipeline of future projects for companies to justify the capital investment to establish local manufacturing occurs, and any new production facilities may take several years to site and build. In the meantime, fabrication and installation of secondary steel can be supplied locally, including internal tower components such as electronics, elevators, and other internal components. In addition, spare parts will be needed throughout the 25-year O&M phase.

The manufacturing of vessels is another potential area of domestic economic opportunity for U.S. and Massachusetts firms. Large installation vessels will be brought over from Europe for the foreseeable future since they are costly to build and the U.S. pipeline has not developed sufficiently to warrant the construction of a U.S. flagged vessel. While the recent 83C bids indicated that the developers are looking to support the construction of a U.S. flagged vessel, it remains far from certain if and when this will occur. Given the region's expertise in shipbuilding and the requirements of the Jones Act, there is the possibility that installation ships could be built in the U.S., although Massachusetts is not well positioned to benefit from these opportunities given the substantial shipbuilding capacity located in the Gulf states that are home to the offshore oil and natural gas industry. There are, however, boat builders in Massachusetts that are certified to build Crew Transfer Vessels (CTVs) for the O&M phase, and there will be meaningful opportunities for local firms that lease barges and other vessels during the Construction phase.

Planning and Development: While the employment impacts of development and permitting are more modest and specialized compared to the other phases, and therefore not the focus of this report, this phase involves well paying jobs and supply chain opportunities for the region's research-oriented organizations, particularly those with expertise in oceanographic and fisheries research.[73] Massachusetts has a strategic advantage in the marine technology cluster, including at the Woods Hole Oceanographic Institute, the largest oceanographic research center in the country, and UMass Dartmouth's School for Marine Science and Technology among others.

To some extent, developers will rely upon foreign expertise and research vessels, but there have already been some visible local employment impacts in engineering, legal, and permitting related services, and fisheries research. For example, all three leaseholders have contracted with onshore and offshore survey scientists. In the case of Block Island Wind Farm, onshore survey scientists were local, geophysical surveyors were local and imported, geotechnical surveyors were from the Gulf states, and engineering, cable survey, and permitting employees were all drawn from the local and regional labor market.

Construction: The installation of the OSW turbines will rely heavily on foreign installation vessels, which will be accompanied by experienced installation teams. However, there are still many early phase construction opportunities, including secondary steel manufacturing (e.g., tower internals), logistics support, heavy equipment supply (e.g., cranes, self-propelled modular transporters), and staging grounds for local workers and marine and onshore construction firms.

Port Activities: According to key informant interviews, the project team expects local employment in port activities associated with each 400 MW installation. These jobs are included in the JEDI model as "other construction services." Employees in this category include members of the Port Authority, security providers, stevedores, cargo handlers, truck drivers, site managers, transport managers, crane drivers, the health and safety coordinator, quality inspectors, and others. While some jobs (particularly the higher-level supervisory roles) will likely rely upon foreign expertise, the majority will be sourced locally.

Pre-Assembly: About half the jobs in pre-assembly are expected to be filled locally. We expect the workers to be mostly Massachusetts residents, since the New Bedford Marine Commerce Terminal will be the primary location for pre-assembly activities. Positions in pre-assembly include site manager, foremen, mechanical and electrical technicians, Quality Assurance/Quality Control, and environmental health service workers. As with other phases of development, most of the supervisory positions will be filled, at least during the initial phase of development, by international experts. Many of the jobs in this phase will continue into subsequent phases. For example, the pre-assembly electrical technicians will likely be redeployed during commissioning.

Installation: Turbine installation is expected to require mechanical technicians (such as structural welders), who will be hired locally, and foremen, such as installation managers and supervisors. Again, the supervisory roles will likely be filled by overseas experts during the initial 1,600 MW of development. Original equipment manufacturers will seek local workers with significant experience in steel manufacturing during installation. This includes material handlers, steel fabricators, fitters, painters, welders, and assemblers. For these types of jobs, training support from the community college system, vocational schools, and, to a lesser extent at the University level, will be needed.

Commissioning: Locally sourced electrical technicians will be needed during the commissioning process. Other positions are supervisory in nature and will most likely be filled by experienced foreign professionals, including the commissioning manager and deputy manager, the monitoring and evaluation supervisor, and a high voltage control expert. Interview subjects report that some firms use commissioning as an opportunity for their experienced foreign workers and experts to train the local workers who will subsequently take over the O&M duties. Developers and turbine manufacturers, therefore, have a strong incentive to hire local electrical workers, since O&M staff must live in immediate proximity of the O&M facility site.

Balance-of-Plant: The foundations, substation, cables, and the remainder of the balance-of-plant are already in place before the turbine manufacturers arrives to install the wind turbine. This infrastructure is the responsibility of the OSW developer. At the time this report was prepared, very limited information on developer plans was available, due to the ongoing competitive bidding process. Depending on the type of foundation the successful bidder(s) use, there may be a sizeable need for local and experienced welders. Other parts of the construction phase, such as cable laying, are expected to require fewer employees, and these are likely to be contracted out to the same company that leases the cable installation vessel. The process for manufacture, assembly, and installation the offshore substation is unclear, although it is possible that some of the electronic components could be sourced locally.

Operations and Maintenance: The experience of the U.K. and our interview subjects makes it clear that the majority of employment in O&M will be sourced locally. This is particularly true for the OSW technicians, logistical support workers, and vessel crew that will operate and maintain the installed OSW turbines. Technicians work long days and are often on call on weekends. Therefore, there is little alternative to hiring locally. At one U.K.-based O&M facility that the project team visited, the employment contract requires OSW technicians to move to the region if they do not already live there.

For a single 400 MW project, we estimate there will be a need for technicians, managers, vessel operators (often subcontracted), engineers, and office staff. Office staff includes site managers, a warehouse manager, administrative support, and an occupational health and safety officer. The number of O&M employees will be higher if the monitoring is done on-site, but quite often, this is done from a central location for all of the turbines and is managed by a single developer or turbine manufacturers. Consequently, there may not be meaningful local employment impacts from the monitoring activities due to the remote control centers.

There are additional O&M employment opportunities for subcontractors, which are considered indirect impacts in this report. Developers typically use 15 to 20 subcontractors during O&M. Subcontractors have specialized skills that are required on an as-needed basis, such as for blade maintenance, and for specific aspects of the turbine system, such as cranes and elevators. In the U.K., subcontractors come from both within and outside of the region, including from Denmark.

Endnotes

[1] Note that this does not include manufacturing of the primary components. For more information on the JEDI model, see http://www.nrel.gov/analysis/jedi/.

[2] FTE job-years refers to the years of full-time equivalent (FTE) employment created by the wind farm project, including wage and salary employees and self-employed persons. One FTE is the equivalent of one person working full time for one year (2,080 hours), thus, two half-time employees would equal one FTE.

[3] Induced impacts are driven by reinvestment and spending of earnings by direct and indirect beneficiaries and are often associated with increased business at local restaurants, hotels, and retail establishments.

[4] The Medium scenario is presented here for a clear presentation. Occupation tables for the Low and High scenarios can be found in Appendix B.

[5] Due to rounding and redistributing Water Transportation job-years to different phases, the totals in this table may differ slightly from the JEDI model's original output. Also, note that the JEDI model reports only full-year job-years, meaning it combines any fractional job-years that would extend throughout the entire calendar year.

[6] A more in-depth analysis of the health and safety training requirements is included in Section 7.

[7] Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs, 2015 Massachusetts Ocean Management Plan, Volume 1 Management and Administration (2015), p. 1-1.

[8] A joint venture of Ørsted (formerly DONG Energy) and Eversource Energy.

[9] Deepwater Wind is owned by DE Shaw.

[10] Formerly known as OffshoreMW and a joint venture of Copenhagen Infrastructure Partners and Avangird Renewables.

[11] For BOEM's tracking of activities at the state level see: https://www.boem.gov/Renewable-Energy-State-Activities/.

[12] For a list of possible locations see: Apex Companies, Ramboll, Tufts University, and Urban Harbors Institute. (2017). Massachusetts Offshore Wind Ports & Infrastructure Assessment. Massachusetts Clean Energy Center: Boston, MA. Retrieved from: http://www.masscec.com/ports.

[13] Based on the national wage for onshore O&M technicians and adjusted with a differential for offshore work informed by studies of European OSW farms.

[15] Tegen, Susan and D; Keyser, F. Flores-Espino. J. Miles and D. Zammit, D. Loomis. (2015). Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios. National Renewable Energy Laboratory. Golden, CO.

[16] The actual deployment and construction timetable can extend beyond that date.

[17] The last two assumptions are based on interviews with developers, Renewable UK, Greenport UK, the construction schedule for the Deepwater Wind (Block Island) project, and other primary resources. While some key informants suggested that a 400 MW development could be constructed in a single season, the project team took a conservative approach and based its estimates on an 18-month to two-year construction window.

[18] In terms of economic impacts, the difference in the number of jobs created by deploying 8 MW turbines versus 10 MW turbines is relatively small, primarily since the turbines are not likely to be manufactured in the U.S. in the near term. For example, JEDI (using the model's default values) estimates that the difference in total job impacts of a 400 MW project utilizing 8 MW or 10 MW turbines is about six percent.

[19] Floating foundations are just nearing commercial availability.

[20] Ho, Andrew and Ariola Mbistrova. 2017. The European Offshore Wind Industry. Ney Trends and Statistics 2016. Wind Europe. Brussels, Belgium.

[21] Supply chain impacts from Massachusetts OSW will also likely accrue to other states, particularly New England states. However, a multi-state analysis is not part of the scope of this project.

[22] International Renewable Energy Agency. (2016). Innovation Outlook: Offshore Wind. International Renewable Energy Agency. Abu Dhabi.

[23] Bloomberg New Energy Finance. "H2 2016 LCOE: Giant Fall in Generating Costs from Offshore Wind." Press Release. November 1, 2016.

[24] Kempton, Willett; Stephanie McClellan and Deniz Ozkan. (2016). Massachusetts Offshore Wind Future Cost Study. University of Delaware Special Initiative on Offshore Wind: Newark, DE.

[25] Costs for some European OSW developments have actually risen in recent years, although these increases are primarily driven by the fact that the wind farms are located in deeper waters. Comparatively, the Massachusetts lease areas are relatively shallow.

[26] Kempton, Willett; Stephanie McClellan and Deniz Ozkan. (2016). Massachusetts Offshore Wind Future Cost Study. University of Delaware Special Initiative on Offshore Wind: Newark, DE.

[27] The model includes transmission costs and proposes three tranches: 400 MW commercial operation date in 2023, 800 MW commercial operation date in 2026, and a 400 MW commercial operation date in 2029.

[28] Beck et al. 2016. National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States. U.S. Department of Energy and U.S. Department of the Interior. Washington, DC.

[29] The cost reduction model considers investments made to technology innovation to reduce cost over time, including, but not limited to, wind turbine drivetrains, rotors, and control systems; balance-of-plant (substructure, tower); electrical infrastructure; construction; decom-

missioning; and innovative solutions for operation and maintenance. These cost reduction scenarios represent the average physical conditions of the current U.S. offshore wind lease areas. To address U.S.-specific market needs, the cost reduction model was modified to include electrical infrastructure and floating wind turbines.

[30] BVG Associates. 2017. U.S. Job Creation in Offshore Wind. A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind. Clean Energy State Alliance.

[31] Note that the actual parts and supplies to construct the wind farm are included as Turbine and Supply Chain impacts.

[32] Although IMPLAN does not explicitly distinguish between full- and part-time jobs, JEDI converts to FTE using supplementary conversion data provided by IMPLAN. Most industry sectors, including the construction and energy sectors, have high FTE per employment ratios (>96%), thus it is likely that the number of job-years reported by JEDI is close to the actual number of employees working on the project.

[33] The JEDI model's estimate of direct O&M jobs was lower than the numbers provided to the project team by acting OSW developers and O&M managers. Consequently, the direct O&M jobs presented here are based on actual employment levels provided by OSW developers and O&M managers.

[34] The O&M phase for each OSW farm is considered to be 25 years, after which Decommissioning occurs.

[35] O&M job estimates for the 25-year period are constant and do not reflect additional cost savings or occupational decisions that may affect the actual number of O&M employees. For example, an operator may decide to shift some of its functions to a central location or vice versa.

[36] The impact analysis presented in the previous section does include some local capital expenditures for equipment such as cables and substations.

[37] For this analysis, it was anticipated that the entire 1,600 MWs will be up and running by the end of 2028.

[38] Running the impact directly in IMPLAN rather than JEDI estimates that about 72 percent of the total jobs will be located at the plant, with the remainder of the jobs attributed to businesses that supply the plant.

[39] Running the impact directly in IMPLAN rather than JEDI estimates that about 74 percent of the total jobs will be located at the factory, with the remainder of the jobs attributed to businesses that supply the factory.

[40] Running the impact directly in IMPLAN rather than JEDI estimates that about 77 percent of the total jobs will be located at the factory, with the remainder of the jobs attributed to businesses that supply the factory.

[41] Section 3 outlines the crosswalk process.

[42] Presenting the new job-years in two-year periods preserves the original JEDI output without making arbitrary divisions of the job-year totals for each phase.

[43] Although IMPLAN does not explicitly distinguish between full- and part-time jobs, JEDI converts to job-years using supplementary conversion data provided by IMPLAN. Most industry sectors, including the construction and energy sectors, have high job-years per employment ratios (>96%), thus it is likely that the number of job-years per phase is close to the actual number of employees working on the project.

[44] Due to rounding and redistributing Water Transportation job-years to different phases, the totals in this table may differ slightly from the JEDI model's original output. Tables for the JEDI model's Low and High scenarios can be found in Appendix B.

[45] An LQ is calculated by dividing the share of a particular job in a region's total workforce by the share of the same job in the U.S. workforce, and the result shows the level of specialization in the region relative to the nation. A result greater than 1.00 means that the region of interest is more specialized in an occupation than the nation and a result less than 1.00 means the opposite. Understanding which occupations have high and low LQs allows us to understand the capacity of the workforce currently residing in Massachusetts.

[46] Advanced Manufacturing Regional Partnership Academy (AMRPA).

Retrieved from https://amrpa.wordpress.com/research/regional-needs-assessment/

[47] Notably, these estimates are based on peak demand for four sequential 400 MW projects, when in fact, there may be some construction overlap simply due to the logistics of each project, requiring additional workers. To arrive at this estimate, certain simplifying assumption were made, as they have been throughout this report, and therefore the estimates presented here are most likely conservative.

[48] Notably, these estimates are based on peak demand for four sequential 400 MW projects, when in fact, there may be some construction overlap simply due to the logistics of each project, requiring additional workers. To arrive at this estimate, certain simplifying assumption were made, as they have been throughout this report, and therefore the estimates presented here are most likely conservative.

[49] Although the project team is aware of Wind Turbine Service Technicians working on land-based turbines in Massachusetts, the low total counts means that the number of workers is suppressed in employment data for privacy reasons.

[50] A discussion of the particular workplace hazards and safety issues facing OSW workers is beyond the scope of this study. The Transportation Research Board at the National Academies has prepared an extensive review of these issues, which is available here: http://onlinepubs.trb.org/onlinepubs/sr/sr310.pdf.

[51] 30 C.F.R §585.810 (2014). Retrieved from: https://www.boem.gov/uploadedFiles/30_CFR_585.pdf.

[52] LaBelle, R.P. & Zukunft, P. (2011). "Memorandum of Agreement Between the Bureau of Ocean Energy Management, Regulation and Enforcement – U.S. Department of the Interior and the U.S. Coast Guard – U.S. Department of Homeland Security" BOEMRE/USCG MOA: OCS-06. Retrieved from: https://www.boem.gov/MOA-USCG-BOEMRE/.

[53] Refer to https://tethys.pnnl.gov/sites/default/files/publications/USCG-2007.pdf.

[54] Refer to https://media.defense.gov/2017/Mar/15/2001716995/-1/-1/0/CI_16003_2A.PDF.

[55] Ibid.

[56] Under this statutory regime, USCG has the discretion to promulgate regulations regarding offshore worker safety and health if (a) no such regulations exist and (b) it deems such regulations necessary. DOI also has broad authority to promulgate renewable safety regulations under OCSLA Section 8(p)(4)(A). If neither USCG nor DOI promulgate regulations (and the activities are therefore "unregulated"), the task would default to OSHA.

[57] http://www.globalwindsafety.org/download/2927/2017-05-04-btt_final_v3_final_junepdf.

[58] https://awea.ebiz.uapps.net/PersonifyEbusiness/Default.aspx?TabID=251&productId=2625614

[59] CATCH, which grew out of a training center founded by the Humber's regional chemical and chemistry industry in England, is good example of such a program. See: http://www.catchuk.org/about-hcf-catch/

[60] http://www.ironworkers.org/training/regional-training-centers

[61] For more information about IBEW training see: http://ibew104.org/

[62] The Alliance's programs and mission can be found at: http://electricaltrainingalliance.org/

[63] See: https://power4america.org/

[64] http://www.globalwindsafety.org/download/2927/2017-05-04-btt_final_v3_final_junepdf.

[65] Some of this work is based on the experience of U.K. and European training providers, which have developed skill competencies, based on recognized occupational standards, work-based, and/or simulated work-based assessment. More about best practices in the U.K. and Europe can be found in Appendix A.

[66] http://www.globalwindsafety.org/gwo/training_providers/become_a_gwo_training_provider.html

[67] Apex Companies, Ramboll, Tufts University, and Urban Harbors Institute. (2017). Massachusetts Offshore Wind Ports & Infrastructure Assessment. Massachusetts Clean Energy Center: Boston, MA.

[68] DoE Wind Career Map, retrieved from: https://energy.gov/eere/wind/wind-career-map-text-version; O*Net Online, retrieved from: https://www.onetonline.org/find/quick?s=wind+energy; Bureau of Labor Statistics Occupational Outlook Handbook, retrieved from: https://www.bls.gov/ooh/.

[69] An LQ is calculated by dividing the share of a particular job in a region's total workforce by the share of the same job in the U.S. workforce, and the result shows the level of specialization in the region relative to the nation. A result greater than 1.0 means that the region of interest is more specialized in an occupation than the nation and a result less than 1.0 means the opposite. Understanding which occupations have high and low LQs allows us to understand the strengths and weaknesses of the Massachusetts economy from a workforce perspective.

[70] Vocational Qualifications". Department for Business, Innovation and Skills. 23 March 2016.

[71] City & Guilds. (2017). "National and Scottish Vocational Qualifications." Retrieved from: http://www.cityandguilds.com/qualifications-and-apprenticeships/qualifications-explained/nvqs-svqs-keyskills-vocational-skillsforlife

[72] Supply chain impacts from Massachusetts OSW will also accrue to other states, particularly New England states. However, a multistate analysis is not part of the scope of this project.

[73] For example, see http://www.southcoasttoday.com/news/20160920/more-offshore-wind-action-deepwater-wind-opening-new-bedford-office-offshoremw-survey-boat-arriving; http://www.southcoasttoday.com/news/20170517/energy-companies-laying-groundwork-in-waters-off-marthas-vineyard.