Report to the Governor's Energy Office

Offshore Wind Supply Chain & Workforce Opportunity Assessment

Task 1 - Assessment of OSW Supply Chain Opportunity

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Revisions & Approvals

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1 INTRODUCTION

1.1 Overview

With an estimated project pipeline in excess of 28,000 MW in awarded lease areas and 14 projects, equating to over 9 GW in capacity, currently expected to be operational by 2026, the US Offshore Wind (OSW) market now represents a sizeable portion of the global OSW market.

Maine has set out a thoughtful and bold agenda for their ambitions to realize the economic opportunities of the emerging industry along the East Coast. With multiple projects estimated for deployment in the region before the end of the decade, OSW presents a significant opportunity to help the state meet its greenhouse gas (GHG) emission reduction mandates and goals, address the retirement of aging power plants, provide economic development opportunities for Maine businesses, and create thousands of jobs for Maine residents.

However, in order to realize this market potential, overcoming the hurdle of establishing a local and/or regional supply chain to support the industry needs to be achieved. Federal approval of the first project should, in theory, foster confidence that a sustainable and reliable pipeline of projects will come to fruition and, as such, investment in building the capabilities of the local supply chain will follow.

The current delivery model for the first commercial US OSW farm is built on the import of the main components from overseas. Components for early projects will be imported to local ports to be staged before being transported to the project site for installation. Some components will be taken directly to the wind farm project site, foregoing local staging. Even though the large majority of project infrastructure will be imported initially, these projects are still generating significant economic activity in the project development phases. The projects will require significant support and services from local business during their construction/installation.

However, it is recognized that this delivery model will become increasingly inefficient and detrimental to the development of a local industry. Therefore, Maine's Governors Energy Office (GEO) is supporting efforts to develop of a robust local supply chain in Maine that can fabricate, manufacture and produce components and associated equipment at a scale necessary to serve planned and anticipated OSW projects.

To support this ambition, GEO have contracted the support and insights from Xodus Group in order to learn more about supply chain needs and the specific supply chain capabilities that exist in Maine. The objective is to use these deeper supply chain insights to inform future strategic state-level investments, initiatives and policies that will enable companies throughout the supply chain to make more targeted and meaningful connections that lead to fruitful partnerships.

The economic benefit which Maine can realize from OSW will depend to a great extent on the success of the local supply chain in winning and delivering work on OSW projects. While the Maine market is expected to provide opportunities for the local supply chain, there will also be further economic benefit to Maine should local suppliers be successful in supporting projects along the entire US east coast and beyond.

In order to achieve this, a clear path must be found for Maine companies and workforce to develop further capabilities and facilities needed to be best in class, ensuring that those procuring products and services for projects in Maine, the US and overseas have good visibility of local companies and their offerings. This study aims to identify local supply chain companies that will be able to match their capabilities to the opportunities presented by this growing industry both in Maine and in export markets.

Due to the deep-water nature of the Gulf of Maine it is expected that floating OSW sites will be developed. Maine's strong wind resource, deep waters close to shore and marine industry heritage make it a logical place to develop a thriving floating OSW industry. Maine is soon to become home to the U.S.'s first floating OSW farm in the Aqua Ventus project. In addition, future development/leases along the East coast of the U.S. will shift to floating foundations as the areas suitable for fixed foundations become saturated and push development into deeper water further offshore.

Floating wind is a nascent industry, but one considered to have significant potential for growth. Planned installed capacity of fixed-based OSW currently far exceeds floating due in part to the wind technology evolution taking place in markets where shallow water sites with good wind resource were readily available. However, these site conditions are not the standard across the globe. Offshore areas with strong winds, close to human populations with high electricity demand, are more likely to be in deeper water locations. Floating OSW will therefore play an increasing role in the future to meet a growing global renewable energy demand. Thus, it presents a substantial opportunity to companies that are capable of supporting the sector.

1.2 Objective

The objective of this study is to identify and enhance Maine's OSW supply chain and workforce to maximize economic benefits to Maine from OSW development in the Gulf of Maine and along the U.S. eastern coast. This effort seeks to optimize Maine's supply chain and workforce to fully realize the economic opportunities of OSW.

Specifically, the objectives of this project are to:

- Deliver an assessment of the OSW supply chain opportunity for Maine to inform an action plan to enhance Maine's OSW supply chain position. [This report]
- Deliver an assessment of the OSW workforce opportunity for Maine to inform an action plan to strengthen Maine's workforce to serve the OSW industry [Performed by BW Research – report available separately]
- Develop strategies and plans to:
  - Support existing Maine OSW companies;
  - Attract existing OSW companies to Maine
  - Engage Maine companies not already engaged in OSW.
- Develop a strategy for partnership building between Maine companies and workforce and the OSW industry.
- Engage with Maine working groups and relevant public stakeholders and organizations.

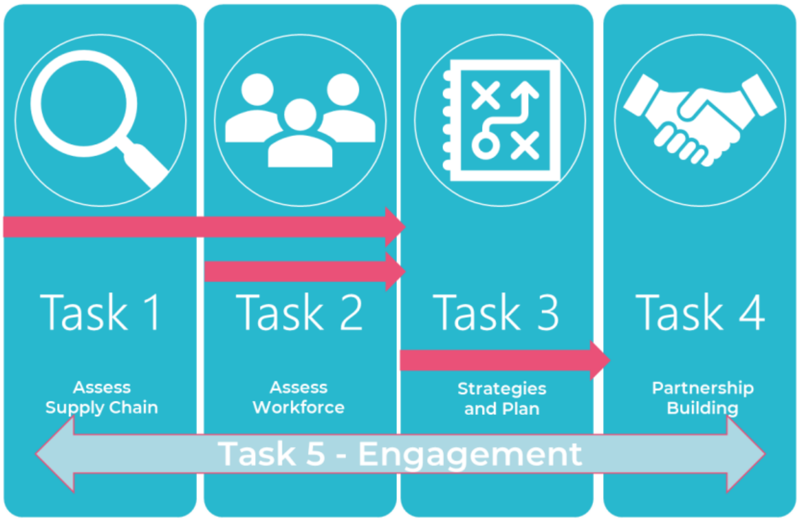


Figure 1.1 - Project Overview

1.3 Scope of Document

The focus of this report is the outcomes of Task 1 and is broken down accordingly:

- Section 2 – Review of comparable supply chain assessments from States engaged in OSW industry development
- Section 3 - Assessment of the Maine supply chain with additional focus on OSW vessels, data science and AI and Disadvantaged Business Enterprises.
- Section 4 – An opportunity analysis to identify supply chain sectors where Maine companies are well positioned to meet, or adapt to meet, the OSW industry's requirements
- Section 5 – SWOT analysis providing a high-level overview of the supply chain Strengths, weakness' Opportunities and Threats.
- Section 6 – Action Plan and Recommendations. Recommendations to show how various ideas could be developed to improve and bolster Maine's position within the OSW industry

1.4 Acronyms

Acronym	Definition
AI	Artificial Intelligence
AUV	Autonomous Underwater Vehicle
BNOW	Business Network for Offshore Wind
BOEM	Bureau of Ocean Energy Management
CA	California
CAPEX	Capital Expenditure
COD	Commercial Operations Date
CT	Connecticut
CTV	Crew Transfer Vessel
CVOW	Coastal Virginia Offshore Wind
DBE	Disadvantaged Business Enterprise
DMMaine	Virginia Department of Mines, Minerals and Energy
FERC	Federal Energy Regulatory Commission
GEO	Governor's Energy Office
GHG	Greenhouse Gas
GWO	Global Wind Organization
HLV	Heavy Lift Vessel
HSE	Health Safety and Environment
IoT	Internet of Things
LCOE	Levelized Cost of Energy
MA	Massachusetts
MassCEC	Massachusetts Clean Energy Center

MD	Maryland
Maine	Maine
ML	Machine Learning
MOU	Memorandum of Understanding
NAISC	North American Industry Classification System
NBMCT	New Bedford Marine Commerce Terminal
NC	North Carolina
NC TOWERS	North Carolina Taskforce for Offshore Wind Economic Resources
NH	New Hampshire
NJ	New Jersey
NJEDA	New Jersey Economic Development Authority
NOWRDC	National Offshore Wind Research and Development Consortium
NOWTC	National Offshore Wind Training Center
NREL	National Renewable Energy Laboratory
NY	New York
NYSERDA	New York State Energy Research and Development
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OR	Oregon
OSW	Offshore Wind
OWC	Offshore Wind Coalition
OWTI	Offshore Wind Training Institute
PMT	Portsmouth Marine Terminal
ProvPort	Port of Providence
R&D	Research and Development
RI	Rhode Island
ROV	Remotely Operated Vehicle
SBMT	South Brooklyn Marine Terminal
SMART- POWER	Southeast & Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources
SOV	Service Operation Vessel
UAV	Unmanned Aerial Vehicle
VA	Virginia
WEA	Wind Energy Area
WIND	Wind Innovation and New Development
WTG	Wind Turbine Generator
WTIV	Wind Turbine Installation Vessel

2 Review of Comparable Supply Chain Assessments

2.1 U.S. OSW Landscape

In response to the 32 GW of wind energy areas set for development in the US by 2035, States have been working towards strengthening their OSW supply chain to provide local benefits and capitalize on this opportunity. The states have seized local opportunities in different ways; by setting procurement targets, developing training programs, providing state funding, and building on their existing strengths to support the OSW industry, and more. It is important to analyze the OSW landscape in the US to better assess where there are gaps and where the greatest opportunities are for Maine's contributions to have the most impact. The OSW supply chain actions and assets for the states of New England, the Mid-Atlantic region, NY, NJ, and the West Coast have been examined, as summarized in Table 2.1.

Table 2.1 US OSW Supply Chain Landscape

FOCUS AREA	MA	ME	NH	CT	RI	NJ	NY	VA	NC	MD	CA	OR
Port infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
OEM & Tier 1				✓		✓	✓	✓				
Large manufacturing facilities		✓		✓				✓	✓	✓		
Shipyards	✓	✓						✓				
Pilot OSW project		✓			✓			✓				
Financial investment in Infrastructure	✓			✓	✓	✓	✓	✓		✓		
Procurement policy	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	
OSW task force	✓	✓	✓		✓	✓	✓	✓	✓		✓	
Supply chain registry	✓	✓			✓	✓	✓	✓	✓			
Supply chain assessment	✓	✓				✓	✓	✓	✓			
Workforce development program	✓				✓	✓	✓	✓	✓			
Financial investment in workforce program	✓				✓	✓	✓	✓		✓		
Regional collaboration								✓	✓	✓		
Signed offtake agreements	✓			✓	✓	✓	✓	✓	✓	✓		

New England Region

Maine has not yet established a project pipeline however is currently in the planning stages for the NE (New England) Aqua Ventus I demonstrator project, which will be the first floating OSW project in the US. In November 2020, the State of Maine is moving forward with a research array which will be one of the first pre-commercial scale (50-200MW) floating OSW projects and will highlight Maine's capability and potential. In 2008, Governor John Baldacci established Maine Ocean Energy Task Force to recommend a strategy to develop the renewable ocean energy resources in the Gulf of Maine. Maine has the deepest waters near its shores and could benefit from a early mover advantage to lead deep-water floating OSW development.

New Hampshire has not yet established an OSW project pipeline. Legislation is under consideration during the current 2021 session, calling for the development of up to 800MW of clean energy, 600MW which would be allocated for OSW. Clean Energy NH has been established to promote NH as a prime conduit for OSW supply chain development and actively involved in various efforts to advance OSW.

Massachusetts is leading the New England region in supply chain development, with strong public endorsement via early state procurement policy of 5.6 GW by 2035 along with public funding towards OSW workforce development and port infrastructure renovations. MA has announced a proposed $750M in An Act to Power Massachusetts' Clean Energy Economy, and if approved, will be directed towards innovation, R&D and workforce development for the clean energy sector. Driven by the first commercial scale OSW project in the US, Vineyard Wind I Project, New Bedford and the Commonwealth of Massachusetts completed a 2-year construction of the Marine Commerce Terminal in the Port of New Bedford in 2015. Furthermore, Vineyard Wind recently announced a partnership with Crowley Maritime to a establish Salem Harbor as the state's second OSW port. The terminal represents a 29-acre facility built specifically for the construction, assembly, and deployment of OSW turbines. In MA, the Vineyard Wind I project has collaborated with New Bedford Ocean Cluster and MassCEC to develop the Act Local program, which is committed to a "look local first" approach policy and have planned "Meet the Buyer/Employer" matchmaking events.

Rhode Island completed the Block Island Wind Farm, the first operational OSW array in the US in November 2016 and has the 400MW Revolution Wind project in the pipeline for 2024. The Port of Providence (ProvPort) in RI recently announced plans to build a facility to fabricate and assemble wind turbine generator (WTG) foundations in support of projects planned in CT and NY. Sponsored by Ørsted and its partner Eversource, the plant is to be used as a regional hub to supply projects they are developing in the Northeast. While RI is the smallest US state in terms of geography, it is using its early mover advantage in building the first OSW farm in the US to benefit from other states' agreements to purchase OSW power. Additionally, the facility is planned to be built using union labour exclusively following a labour pact with the Rhode Island Building and Construction Trades Council and Dimeo Construction, the project's lead contractor. Rhode Island has invested in over $4M to support higher-education, workforce development, and supply chain development needs for OSW.

Connecticut has committed to 2.0 GW of OSW by year 2035 and holds two attractive ports for OSW activities, as well as a cable manufacturing facility proposed by Marmon Utility. The Port of Bridgeport, which will act as the staging port for the Park City Wind project being developed by Vineyard Wind and the Port of New London, CT, which has entered into a partnership with the OSW developer Ørsted and Eversource for a $157M joint public-private investment for port improvements needed for the Revolution Wind project. The State Pier is planned to be upgraded to accommodate OSW turbine assembly and installation staging, as well as a broader range of cargo businesses.

New York and New Jersey

New York and New Jersey may be considered part of the Mid-Atlantic region but have been broken out here due to the relatively high level of OSW activity that is planned in the near-term. NY and NJ are investing significantly into ports infrastructure opportunities. Both states are vying to become the hub of O&M for OSW on the East Coast. Both states are well-prepared with strategic plans mapped out and are independently leading the OSW supply chain development on the East Coast.

New York has the largest OSW pipeline in the US with five projects under contract, totalling over 4.3GW, and a target of 9GW of OSW by 2035. NY has announced a tower and transition piece fabrication at the Port of Albany, as well as a foundations facility at the Port of Coeymans, announced by Ørsted and Eversource. This has been made possible through public and private investments. Equinor will match public funding almost 3-to-1 for a combined investment of $644 million in port upgrades to the South Brooklyn Marine Terminal (SBMT) and the Port of Albany. The funding is intended to help transform the ports into facilities for tower manufacture, staging and O&M. NY has announced $200 million in port investment funding. NYSERDA, New York State Department of Transportation, and Empire State Development are leading a competitive solicitation process to allocate the funds.

NYSERDA conducted 20 studies to create the Offshore Wind Master Plan, a comprehensive roadmap to determine the most responsible and cost-effective pathway for developing OSW energy. NY is collaborating with industry to develop a regional OSW training infrastructure to support the workforce needed to support the OSW industry. A total of $30M has been invested toward the development of the New York Offshore Wind Training Institute (OWTI), the National Offshore Wind Training Center (NOWTC) as Suffolk Community College, and the Center of Excellence for Offshore Energy at SUNY Maritime College.

New Jersey has established an ambitious state procurement policy of 7.5 GW of OSW by 2035. NJ is geographically well positioned for regional connectivity; Northern NJ ports can support the development of projects in NJ, NY, and New England while Southern NJ ports can support the development of NJ projects as well as those in states further south such as DE, MD, and VA. In 2019 Ørsted and EEW announced plans to establish foundation manufacturing capabilities in Paulsboro, NJ with a $250M joint private-public investment. After NJ announced a $200M investment in the NJ Wind port, GE and Vestas are anticipated to locate a US Nacelle assembly facility there.

In 2019 NJ legislation was passed to create the Wind Innovation and New Development (WIND) Institute, which will provide workforce training, apprenticeship, and recruitment programs, including developing a Global Wind Organisation (GWO) certification program. The WIND Institute will become a centre for education, research, innovation and workforce training for OSW energy development in NJ and act as a centralised hub for OSW workforce development.

Mid-Atlantic Region

In 2020, MD, VA and NC formed the Southeast and Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources (SMART-POWER) to collaboratively advance the region's OSW sector and its supply chain. The framework seeks to "increase regulatory certainty, encourage manufacturing of component parts, reduce project costs through supply chain development, share information and best practices, and promote synergy between industry and the signatory jurisdictions."

Maryland has committed to at least 1.2 GW of OSW capacity by 2030. The former Sparrows Point steel mill will receive $20M of federal investment in upgrades, including port upgrades at Baltimore's Tradepoint Atlantic. Furthermore, Ørsted is funding $13.2 million in upgrades at the Sparrows Point site, which will allow for the transportation of heavy wind turbine components, such as blades, foundations, nacelles and towers for the Skipjack Wind Farm and future projects. Ørsted's agreement with Crystal Steel Fabricators in Federalsburg will establish the state's first OSW steel fabrication center. To support the increased workforce in the region, Maryland has developed the Arcon Training Center, which provides high quality, certified Onshore/Offshore Wind (OSW) and Safety GWO training.

Virginia is advancing their supply chain development on all fronts, by leveraging on their strategic geographic location, existing assets, and port infrastructure to support the development of an OSW supply chain. The state has committed 5.2 GW by 2034 and is home to the first installed OSW project in federal waters, Dominion Energy's CVOW 12MW pilot project developed jointly by Ørsted and Dominion Energy. VA is home to a heavy concentration of shipbuilding and ship repair activities and will house the first Jones Act compliant wind installation vessel. The Portsmouth Marine Terminal (PMT) has received $40M of the State's 2021 budget for upgrades and a $200M private investment by Siemens in a blade finishing facility at PMT. The Port of Virginia is the deepest water harbor on the U.S. East Coast and second largest in tonnage on the East Coast and third largest in container volume. Virginia's 50-foot channels and unobstructed terminal access have allowed the size of the vessels at the Port of Virginia to increase significantly.

The Commonwealth of Virginia's Mid-Atlantic Wind Training Alliance was formed by a partnership between The New College Institute, Mid-Atlantic Maritime Academy and Centura College, and includes courses certified by the GWO. The state has recently announced the Virginia Offshore Wind Landing, a collaborative space where companies in Hampton Roads can become part of the region's maritime network and growing OSW industry, providing a platform for companies to work, connect and access resources.

North Carolina ranks 1st among East Coast states in the value of its manufacturing sector's GDP and is aiming to leverage on their existing manufacturing capabilities to support the OSW industry. In 2021, Governor cooper issues an executive order which establishes OSW development goals of 2.8 gigawatts off the North Carolina coast by 2030 and 8.0 GW by 2040. The executive order also directs the North Carolina Department of Commerce to establish the NC Taskforce for Offshore Wind Economic Resource Strategies (NC TOWERS), to provide expert advice for advancing North Carolina OSW energy projects, economic development, and job creation. On May 11th BOEM held an auction for two offshore wind sites off the coast of North Carolina. The two sites (54,937 acres and 55,154 acres) will support fixed bottom wind projects and sold for a combined value of $315M.

West Coast

Despite the large resource potential off the Pacific Coast, the region has progressed more slowly than the East Coast and there are currently no contracts or leases for OSW in CA or Oregon (OR). There are two renewable energy efforts underway offshore California. Morro Bay in central California and Humboldt in northern California are currently both subject to environmental assessment by BOEM.

Currently, none of the west coast states have set a capacity target specifically for OSW development. Legislators in both CA and OR have however recently introduced bills that would establish state-level goals if signed into law. CA's bill, introduced in February 2021, would target 3GW by 2030 and 4GW by 2040. In March 2021, an OR representative introduced a bill targeting 3GW of commercial scale floating OSW by 2030.

While OR has not developed a state body to represent OSW efforts, CA has developed the Offshore Wind California (OWC), a coalition of industry partners who promote policies and build public support for responsible development of OSW power off the coast of California.

US Supply Chain Heatmap

To visualize the efforts made across the US described above, a heatmap has been created to gauge the strengths of each state, displayed in Table 2.3. Five categories were considered and evaluated between 1-4, with one being the lowest and four being the highest score. The scoring was determined based on the criteria described in Table 2.2.

Table 2.2 - Scoring Criteria

Category	1	2	3	4
Supporting Assets/ Infrastructure	Limited infrastructure identified to meet the requirements of OSW (No more than 1)	May have a key port, a lay-down/ marshalling area and sector support services i.e. shipbuilding capabilities or cable manufacturing facilities.	At least one port identified for OSW use and large manufacturing facility to be used regionally	Two or more manufacturing facilities have been announced and large deep-water ports with sufficient space for OSW installation & commissioning activities
Infrastructure investments	Public and private combined support of less than $100M	Public and private combined investment between $100M-$300M	Public and private combined investment between $300M-$600M	Public and private combined investment above $700M
Legislation – procurement authority	State procurement policy of 1,600 MW or less	State procurement policy btwn. 1,600 - 3,000 MW	State procurement policy btwn. 3,000 - 6,000 MW	State procurement above 6,000 MW
Supporting programs and supply chain work	Not involved in collaborative groups and have not assessed their supply chain opportunity.	Centralized state groups have been created, limited to no investments in workforce development or supply chain	Centralized state groups created, large investments made to support workforce and supply chain development.	Conducted supply chain studies, are participating in regional groups, have large investments towards regional workforce/training programs and supply chain development
Project Pipeline	No signed offtake agreements	< 2000 MW	2000 MW - 4000 MW	> 4000 MW

Table 2.3 - Supply Chain Heat Map

State	Supporting Physical Assets/ Infrastructure	Infrastructure Investments	Legislative – Procurement Authority	Supporting programs & workforce development	Project Pipeline
New Hampshire	1	1	1	1	1
Massachusetts	2	4	3	4	4
Rhode Island	2	1	1	3	2
Connecticut	3	2	2	1	2
New York	4	4	4	4	4
New Jersey	4	3	4	4	4
Maryland	3	2	1	2	2
Virginia	4	4	3	4	3
North Carolina	1	1	4	2	3
California	1	1	2	2	1
Oregon	1	1	1	1	1

New York, New Jersey and Virginia are leading the supply chain efforts along the east coast, followed by Massachusetts. What these states have in common are a centralized state body that is driving OSW development, e.g., creating workforce training programs, conducting supply chain studies, stakeholder engagement, and matchmaking/ supply chain registries. NYSERDA, NJEDA, MassCEC, and the Virginia Department of Mines, Minerals and Energy (DMMaine) are examples of effective and collaborative state bodies advancing OSW development.

The OSW environment is driven by both legislative policies set and project pipeline. These two factors foster confidence in developers and private investors to invest in infrastructure which will result in a future supply chain growth clustered around the infrastructure.

The following scoring logic has been applied to Maine with the outcome detailed in Table 2.4 below and discussed accordingly.

Table 2.4 - Maine - Comparable Supply Chain Score

State	Supporting Physical Assets/ Infrastructure	Infrastructure Investments	Legislative – Procurement Authority	Supporting programs & workforce development	Project Pipeline
Maine	2	1	1	2	1

Supporting Physical Assets and Infrastructure: Searsport has been recently studied to determine the suitability and required upgrades to support OSW. Although other ports have self-identified as having capability or desire to support OSW it is understood infrastructure improvement will be concentrated around Searsport. Cianbro and Bath Iron works both represent relatively large scale manufacturing capabilities in Maine.

Infrastructure Assessments: No investment (private or public) has been made in infrastructure (ports, transmission, facilities etc) to date in Maine.

Legislative – Procurement Authority: Although BOEM announced an expected OSW lease auction in 2025 the state has yet to commit to any future OSW procurements (beyond the research array procurement of up to 144 MW), a key driver seen in other states to support the development of a robust OSW project pipeline and subsequent supporting supply chain.

Supporting Programs and Workforce Development: Maine is developing an OSW roadmap to support the development of the OSW industry in the state. Multiple working groups have been established that report back to an advisory committee and are focussed on driving forward a broad range of studies and initiatives, including this report. As the state moves into operationalizing the outcomes of the establishment of the roadmap it is likely the score will move from a score of 2 to 3.

Project Pipeline: No project offtakes have been signed to date.

This analysis has provided Maine with an overview of the 'State of the States' with regards to development of OSW and supporting development of the supply chain, infrastructure, legislation and workforce development programs.

Having this overview will allow Maine to establish which 'focus areas' should be elevated to the benefit of the advancement of the OSW industry in Maine and demonstrating there are significant economic/jobs opportunities. This will ensure that unnecessary replication or allocation of 'effort' of focus areas which may not be required or considered a priority. Initial prioritization of recommendations can be found in Section 6.

2.2 State Supply Chain Assessments

2.2.1 Overview

A review of the supply chain assessments along the East Coast has been conducted to provide points of comparison and contrast for strategic planning for Maine to participate in the OSW industry. The following States with supply chain assessments that have been reviewed are Massachusetts, New York, New Jersey, Virginia, North Carolina, and Maryland. The recommendations from the various supply chain studies follow a common theme, as shown in Table 2.5 where most states share the following similar recommendations:

- Attract OEM and Tier 1 suppliers
- Invest in Port development
- Develop a workforce training program
- Create matchmaking between OEMs and local suppliers
- Promote industry and regional collaboration.

Table 2.5 Supply Chain Assessment Recommendations

Recommendation	MA	NY	NJ	VA	NC	MD
Develop a workforce training program	✓	✓	✓	✓	✓	
Attract OEM & Tier 1s	✓	✓	✓	✓	✓	✓
Matchmaking events / supply chain registry	✓	✓	✓	✓	✓	
Regional collaboration	✓			✓	✓	✓
Port development investment	✓	✓	✓	✓		✓
Manufacturing infrastructure investments	✓	✓	✓		✓	✓
Financial incentives to attract business	✓		✓	✓	✓	
Promote industry collaboration (R&D, universities, nonprofit, adjacent industries)	✓	✓	✓	✓	✓	✓
Support existing heavy manufacturing capabilities					✓	✓
Increase OSW capacity targets					✓	
Accelerate leasing of WEA					✓	

2.2.2 Discussion

Momentum and confidence - A key driver to growing the States' supply chain is to attract OEM and Tier 1 suppliers to the region, through investments in port development and by offering financial incentives to attract businesses. This will inevitably drive growth to Tier 2 and Tier 3 suppliers. A high visibility transformation project attracts the attention from the industry and gives developers confidence in making investments, this will be explored further in Task 3. The state of New Jersey announced a $200M investment in the New Jersey Wind Port, which later attracted GE and Vestas to commit to a US Nacelle assembly facility. Other successful implementations include the public investments made by the state of VA in the Hampton roads region, and more notably, NYSERDA's $730M investment in the Port of Coeymans, South Brooklyn Marine Terminal, Port of Albany, Port Jefferson Harbor, and Montauk Harbor.

Supply chain registries – Various states have developed bespoke supply chain registries dedicated to highlighting companies within the state that have capabilities to support OSW. A good example of a bespoke state focused registry is the MassCEC OSW directory. Others have chosen to align with the Business Network for Offshore Wind (BNOW) registry, which Maine are currently utilizing. In either case an effective supply chain registry is one which is comprehensive in breadth and depth of company information, designed and presented around the needs of the end users, and regularly maintained to keep data up to date. Should Maine look to enhance its own OSW focussed registry our recommendation would be for close alignment and linkage with the BNOW database to create a consistent and comparable accessible online dataset of Maine companies with capability to support OSW projects.

Regional and industry collaboration – The nascent renewable energy industry has the potential to provide generational economic opportunities as the industry itself is only in the early stages of development. The SMART-POWER MoU is in development between VA, NC, MD and similar recommendations have been made for Massachusetts. To develop a Maine renewable energy cluster quickly and efficiently, the creation of a regional approach to renewable energy development is essential. The New England states, by joining together, will encourage developers, OEMs and tier 1 suppliers to look at investment levels greater than those for individual state projects. A regional approach will result in workforce growth, investment growth and a faster path to achieving regional renewable energy goals. The individual states can capitalize on their strengths and share resources across state lines to encourage supply chain growth, economic development and workforce development. It is recognized that implementation (and even leadership) of such an initiative has significant challenges and it is recommended that Maine develop a strategic plan and understanding of what 'regional collaboration' would mean in the context of the development of the Maine OSW industry to allow the State to engage meaningfully with neighboring states while ensuring the interests of Maine are brought to the table as early as possible.

Port and infrastructure investment – Approximately two billion USD has now been committed to the development, upgrades and establishment of OSW ready port infrastructure and manufacturing facilities along the East coast. This in turn has been seen to drive the growth of Tier 2 and 3 suppliers, economic activity, and job creation as the infrastructure/facilities will serve as a major hub of supply chain development. In order to support this further, Maine should work with neighboring states, mainly MA, to understand the potential support/services that could be provided from the region. Consideration should be given to the potential for support or incentive packages for public-private partnerships in the support of port development.

Ensure timely WEA leasing – Development of WEAs in the Gulf of Maine is currently at the end of the BOEM leasing pathway with the greatest uncertainty around timing. As visibility and certainty of an OSW project pipeline is essential to the development of a robust supply chain it will be important for Maine to consider how it can support timely establishment of local WEAs. Any WEA leasing must be done via a measured approach that ensures appropriate stakeholders (social, political and environmental) are considered. A balanced approach to this type of recommendation may be useful for Maine to consider given supply chain development is typically linked to a visible project pipeline but Maine must be sure not overshadow the value and importance of the research led (pilot array) approach. This balance will ensure that all the data and lessons gained through the development and implementation of the research array are carried forward when seeking to ensure WEA leasing occurs as early as possible.

Workforce – Workforce programs have been initiated along the east coast and are typically focussed on building the connections between workforce training and employment, internships and pre-apprenticeships and expanding opportunities through a Diversity, Equity and Inclusion lens. Maine should strive for consistency in training and credentialing across multiple states to drive regional workforce collaboration.

2.3 Floating Wind Project Case Study

Figure 2.1 provides and overview of the supply chain that contributed to the establishment of the floating OSW pilot array (Hywind Scotland) off the East Coast of Scotland.

The figure illustrates the requirement for a global mobile supply chain to deliver a floating wind project and further demonstrates that project developers will bring the strengths of relevant suppliers, regardless of location, to ensure successful deployment.

It should be noted that the Hywind project was deployed as the worlds first floating wind research array, as such, there was no dedicated supply chain. The project therefore drew heavily on existing fixed wind and oil and gas supply chains. Future commercial scale (+1 GW) projects will require more localized supply chains as the project pipeline grows and suppliers (OEMs and Tier 1s) have confidence in the market to justify the establishment of local manufacturing facilities.

Figure 2.1 - Hywind Supply Chain Map

3 Assessment of the Supply Chain

3.1 Existing Maine Supply Chain

The OSW supply chain can be classified in a way that is closely aligned with typical contracting structures for an OSW project. While the requirements of fixed-based and floating OSW projects differ in the supply and installation of the turbine foundations, the approach to project contracting remains similar. The taxonomy encompassing element for both fixed and floating OSW projects is given in Table 3.1.

Table 3.1 - Offshore Wind Supply Chain Taxonomy

Supply Chain Area	Supply Element
Project development	Development and permitting
	Surveys
	Engineering & design
	Project management
Wind turbine supply	Nacelle
	Rotor
	Tower
Balance of plant supply	Foundations
	Export and array cables
	Anchors and moorings
	Offshore substation
	Onshore infrastructure
Installation and commissioning	Turbine installation
	Foundation installation
	Subsea cable installation
	Anchors and mooring installation
	Onshore construction
	Ports and logistics
Operations and maintenance	Operations
	Turbine inspection and maintenance
	BoP inspection and maintenance
Sector support	Training provider
	R&D and academia
	Other professional services

This approach comprises multiple supply elements that describe the broad requirements for products and services that enable the development, construction and operation of an OSW project. The elements within the categories of project development, wind turbine supply, balance of plant supply, and installation and commissioning generally represent Tier 1 and Tier 2 packages, or package areas, where supply is commonly fulfilled by a distinct provider or group of providers. At this stage there are typically 2-10 main contracts issued for the development, supply, installation and commissioning of an OSW project.

Due to the length of operational lifetime (+20 years) and range of services required (both onshore and offshore), the operations phase of an OSW project typically comprises of hundreds of individual supply contracts. These services can be grouped into broad elements to enable analysis of supply chain capability. Similarly, the range of services required for wind farm decommissioning are varied but have been grouped for simplicity of analysis.

Sector support functions are not typically considered part of the OSW supply chain. However, this category and the constituent elements have been included for analysis as they are representative of the quality of the supply chain environment. Presence of good sector support organizations will be necessary for the growth and development of supply chain capability.

An understanding of the Maine OSW supply chain landscape was developed through an assessment of several database sources containing information on Maine supply chain companies, which were:

- Maine Supply Chain Database;
- Maine International Trade Center member directory;
- New England Aqua Ventus supplier interest list;
- Business Network for Offshore Wind supply chain connect directory;
- 4C Offshore stakeholder database.

While several Maine companies were listed in multiple data sources each source also provided companies that were not found in any of the other datasets. Companies which appeared to no longer be trading or did not have a presence in Maine were excluded from the assessment.

Figure 3.1 shows the number of Maine supply chain companies relevant to OSW present across the databases categorized by the supply chain elements outlined in Table 3.1. The Maine supply chain shows apparent strength in project development services, secondary steelwork fabrication, and other professional services not directly required on an OSW project. An opportunity analysis assessing the strengths and gaps of Maine supply chain capability within these areas is provided in Section 4.

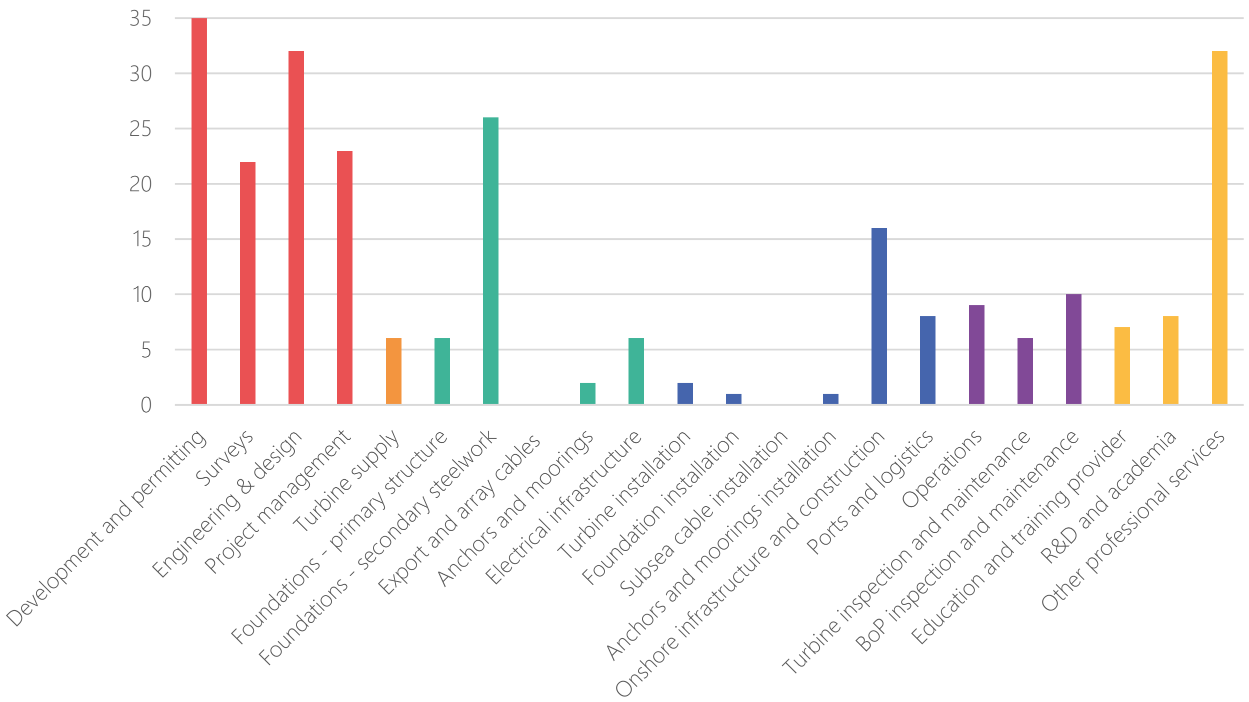


Figure 3.1 - Maine OSW Supply Chain Companies Categorized by Contracting Area

As expected, due to the nascency of the US OSW sector very few Maine companies have direct experience of supplying to OSW projects. The categorization of companies is therefore based on their potential to at least part-supply products or services in accordance with the requirements within each supply element.

The volume of potential capability across various elements of the project development phase is related to the overlap in requirements with delivering infrastructure projects in other industries. There are a range of Maine companies able to support with permitting; environmental surveying, consulting and assessment; structural and electrical engineering; and project management including legal and financial services. While much of this capability relates to project work in the onshore environment several suppliers have experience in the offshore space.

The potential capability in turbine component supply is predominantly comprised of Maine companies with expertise in composites manufacturing. While composite materials are required in the supply of the turbine nacelle and rotor it is unlikely these companies will supply components at the required scale or volume for an OSW project. Some Maine companies appear to have supplied turbine components in the onshore wind sector.

The vast majority of potential Maine capability in supplying balance of plant is in the number of small and medium-sized machining, fabrication and welding suppliers who may have capability to support in secondary steelwork. The opportunity for manufacturing steel or concrete primary substructures in Maine will depend on the requirements of an OSW project. There is a lack of native companies in the supply of subsea cables or their ancillary components, but capability exists in moorings and small electrical systems.

Despite Maine's strong maritime heritage there is an absence of companies supporting offshore construction in the state. A higher number of industrial construction companies experienced onshore is typical where civil and structural contractors apply their skillset across multiple industries with similar requirements. Similarly, companies providing port services and logistics support supply multiple sectors.

While few Maine companies have experience in the operations and maintenance services in the OSW sector there are several who may have capability to transition into this space. Software developers may support wind farm operations while mechanical and electrical inspection, maintenance and certification companies may be able to apply existing capabilities to an offshore environment.

A Maine OSW industry would appear to be able to benefit from a number of training, education and R&D institutions. There are also a high number of environment and energy related consultancies and associations that, although not direct suppliers to OSW projects, demonstrate a broad range of related capabilities in state.

3.2 Offshore Wind Vessel Assessment

3.2.1 Overview of Vessels Required

The construction and maintenance of OSW projects calls for a combination of expertise that is comparatively new to the U.S. market and requires a variety of specialist support vessels. The Jones Act requires any vessel transporting equipment between U.S. ports to be built, crewed and flagged in the U.S. A fixed wind turbine foundation is considered a U.S. 'coastwise point' and therefore considered a port.

To use a foreign, non-Jones Act installation vessel, components from a U.S. port must be transported by a U.S. built feeder vessel/barge. The feeder vessel/barge is brought to the OSW site, where the foreign Wind Turbine Installation Vessel (WTIV) may lift the components off the feeder vessel onto the foundation without moving. Other wind support vessels such as a Service Operation Vessel (SOV), floating heavy-lift vessel, and Crew Transfer Vessels (CTV) operating in U.S. OSW farms are required to comply with the Jones Act.

Table 3.2 - Overview of Vessels Required for Offshore Wind

ACTIVITY	DESCRITPION	EXAMPLE
Foundation Installation	A typical specification for a heavy lift vessel is: • Length: 260m, beam: 50m, draft: 12m • Crew berths: 150 • Crane: 2,000 tonnes • Dynamic positioning system.	
Turbine Installation	An example of specification for these vessels is: • Length: 130m, Beam 40m, Draft 5m • Crew: 100 • Crane: 2,200tonnes • Jack-up depth: 65m • Jack up speed: 1m/min,	
Transportation/Feeder	The feeder barge, used to transport components to a non jones act compliant WTIV, should have sufficient deck space and strength to transport the wind turbines and their components. The barge may be equipped with dynamic position, stabilization, and/or heave compensation systems	
Cable Laying (Inter Array and Export)	Cable-laying vessels are characterised as follows: • Length: 140m, Beam: 30m • Crew: 90. • Carousels capacity: 10,000t. • Personnel transfer gangway • ROV & Trenching Equip	
O&M	CTVs transport personnel to the wind farm on a daily basis. Wind farm operators typically use aluminium catamarans up to 30m long with capacity for 12 to 16 technicians. Vessel speeds can be up to 30kn and are designed to transfer maintenance and service team members in comfort and safety	

ACTIVITY	DESCRITPION	EXAMPLE
	to the wind farm ready to start work. SOVs offer accommodation, mess and welfare facilities for wind farm technicians, as well as workshop and spares storage. SOVs will stay at the wind farm for up to four weeks at a time, at which point they will return to port to restock & change crews.	
Other	Other vessels include: • Guard Vessels • Rock dumping vessels • Cable burial vessel • Dive Support Vessel • Survey Vessel • Walk to work vessel • General Construction Vessel (Moorings and Anchors) • Anchor Handling Tug (Floating Platform Tow out)	

3.2.2 Market Demand

Demand for wind farm support vessels is expected to increase to support planned construction projects for both fixed and floating OSW farms in U.S. waters.

In order to develop the demand for vessels to support the current U.S. OSW build out scenario Xodus analyzed publicly available data to determine the projected capacity build out on a year by year basis. The following was assumed:

- Project construction durations were determined on nameplate capacities:
  - < 400 MW can be built across 2 calendar years
  - > 400 MW and < 1600 MW can be built across 3 calendar years
  - > 1600 MW can be built across 4 calendar years.
- Turbine installation is assumed to be the final year of construction (blue band in Figure 3.2), construction years preceding are assumed to be Balance of Plant installation (purple in Figure 3.2).
- No analysis on vessel capabilities (jack-up capacity or crane capacity/height) has been performed.
- Projects call areas in North Carolina, Maine, Central Atlantic or Gulf of Mexico have not been included at this time.

Wind Farm	Region	Offshore Construction Starts	Full Commissioning	Capacity MW (Max)
Vineyard Wind 1	MA	2022	2024	804
South Fork	RI/MA	2022	2023	132
US Wind Maryland (MarWin)	MD	2023	2024	268
CVOW Commercial - phase one	VA	2024	2026	880
Ocean Wind	NJ	2024	2026	1100
Revolution Wind	RI/MA	2024	2026	880
Empire Wind 1	NY	2024	2026	816
Sunrise Wind	RI/MA	2024	2026	925
Atlantic Shores 1	NJ	2025	2027	1510
CVOW Commercial - phase two	VA	2025	2027	880
Kitty Hawk Wind - phase 1	NC	2025	2027	800
Park City Wind	MA	2025	2027	804
Lease Area 522	MA	2025	2028	2500
Skipjack	DE	2025	2026	120
Skipjack 2+	DE	2025	2027	760
Empire Wind 2	NY	2025	2027	1260
Beacon Wind 1	MA	2026	2028	1230
CVOW Commercial - phase three	VA	2026	2028	880
Mayflower Wind	MA	2026	2028	804
Sunrise Wind 2	RI/MA	2026	2028	1000
Mayflower Wind+	MA	2026	2028	796
Bay State Wind	MA	2027	2030	2000
Kitty Hawk Wind - phase 2	NC	2027	2029	800
Commonwealth Wind	MA	2027	2029	1200
Kitty Hawk Wind - phase 3	NC	2028	2030	800
Ocean Wind 2	NJ	2028	2030	1148
CVOW Commercial - phase four+	VA	2028	2031	2600
Atlantic Shores 2	NJ	2029	2031	1425
Atlantic Shores 3+	NJ	2029	2032	2000
Beacon Wind 2	MA	2029	2031	1170
Central Bight (OCS-A 0537)	NY	2030	2032	946
Garden State Offshore Energy	DE	2030	2032	1000
Hudson North (OCS-A 0544)	NY	2031	2033	481
Hudson South A (OCS-A 0543)	NY	2031	2033	958
Hudson South B (OCS-A 0538)	NY	2031	2033	942
Hudson South C (OCS-A 0539)	NY	2031	2033	894
Hudson South D (OCS-A 0540)	NY	2032	2034	851
Hudson South E (OCS-A 0541)	NY	2032	2034	946
Hudson South F (OCS-A 0542)	NY	2032	2034	982

Figure 3.2 - US Offshore Wind - Year by Year Build Out (Purple indicates Balance of Plant Installation, Blue indicates WTG installation)

Table 3.3 below details the overlap of projects on a year by year basis.

Table 3.3 - Year by Year Project Overlap by Installation Activity

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Balance of Plant Installation Vessels	2	2	5	13	12	9	6	7	6	7	7	3	0
Wind Turbine Installation Vessels	0	1	2	0	6	6	6	2	3	3	3	4	3

The market demand analysis shows that in 2025 and 2026 there are at least 12 projects that will be installing balance of plant concurrently. This could include foundations, inter array and export cable installation. Each project could be utilizing 2-3 'core' vessels (excluding CTVs and support vessels) in the field during at any one time. Therefore, during the peak of 2025 and 2026, it could be anticipated that 25-40 vessels could be operating off the coast off the US East Coast installing OSW equipment.

WTIVs (excluding CTVs and support vessels) will reach a peak requirement of 6 across 2026, 2027 and 2028. A recent study by Tufts University identified that there are only 7 vessels in the world (including Dominion Energy's WTIV) that have the ability to install a 15MW turbine in +50m water depth. Given that the U.S. will also be competing with the established European market and rapidly growing Asian market to secure these vessels, the supply vs. demand equation for US OSW construction does not currently balance.

The results of our modelling exercise indicate that the projected demand for various vessel types associated with the construction and maintenance of OSW installations cannot be met and poses a significant threat to the build out of the U.S. OSW industry. Our model suggests that the US turbine installation vessel fleet would have to grow aggressively to achieve the installed capacity foreseen in the market demand analysis scenario. Notwithstanding, even the most aggressive expansion of US OSW will require multiple (3-5) specialized vessels (HLVs, WTIV, SOVs, CTVs, etc.) be constructed per year. To the extent these will be newbuild units constructed in the US, the opportunity to secure the economic benefits will likely be concentrated around Gulf Coast shipyards. However, supply chain benefits related to smaller vessel builds, vessel fit-out, local services and O&M support represents a significant opportunity for Maine.

3.2.3 Case Study – Moray East

In order to illustrate the vessels involved in the construction of an OSW farm Xodus have analyzed real-world data of the vessels deployed in the construction of the Moray East OSW farm in Scotland. Moray East is being developed by Ocean Winds (a joint venture between EDPR and ENGIE) and has been undergoing the installation of 100 x 9.5 MW turbines over the course of the last 3 years.

Xodus have mapped the vessels involved port of origin and transit to the wind farm and detailed the duration they spent in port as part of the construction campaign. This analysis does not include guard vessels (of which there were at least 5 deployed during construction) and CTVs of which there were multiple. Note the analysis only covers 2019 and 2020. Wind turbines have been installed over the course of 2021 however this data is not available for analysis.

Figure 3.3 illustrates for 2019 and 2002 the vessels deployed to Moray East, their track lines, port of origin and time spent at various locations (including port).

Figure 3.4 illustrate individual vessel activity as part of the Moray East wind farm construction.

It was determined that over the course of 2019 and 2020 vessels spent approximately 220 days combined in the construction port (Cromarty Firth) in support of the project. Furthermore, an additional 142 days combined were spent at surrounding ports in support of the project.

Figure 3.3 Moray East - 2019 & 2020 Vessel Activity

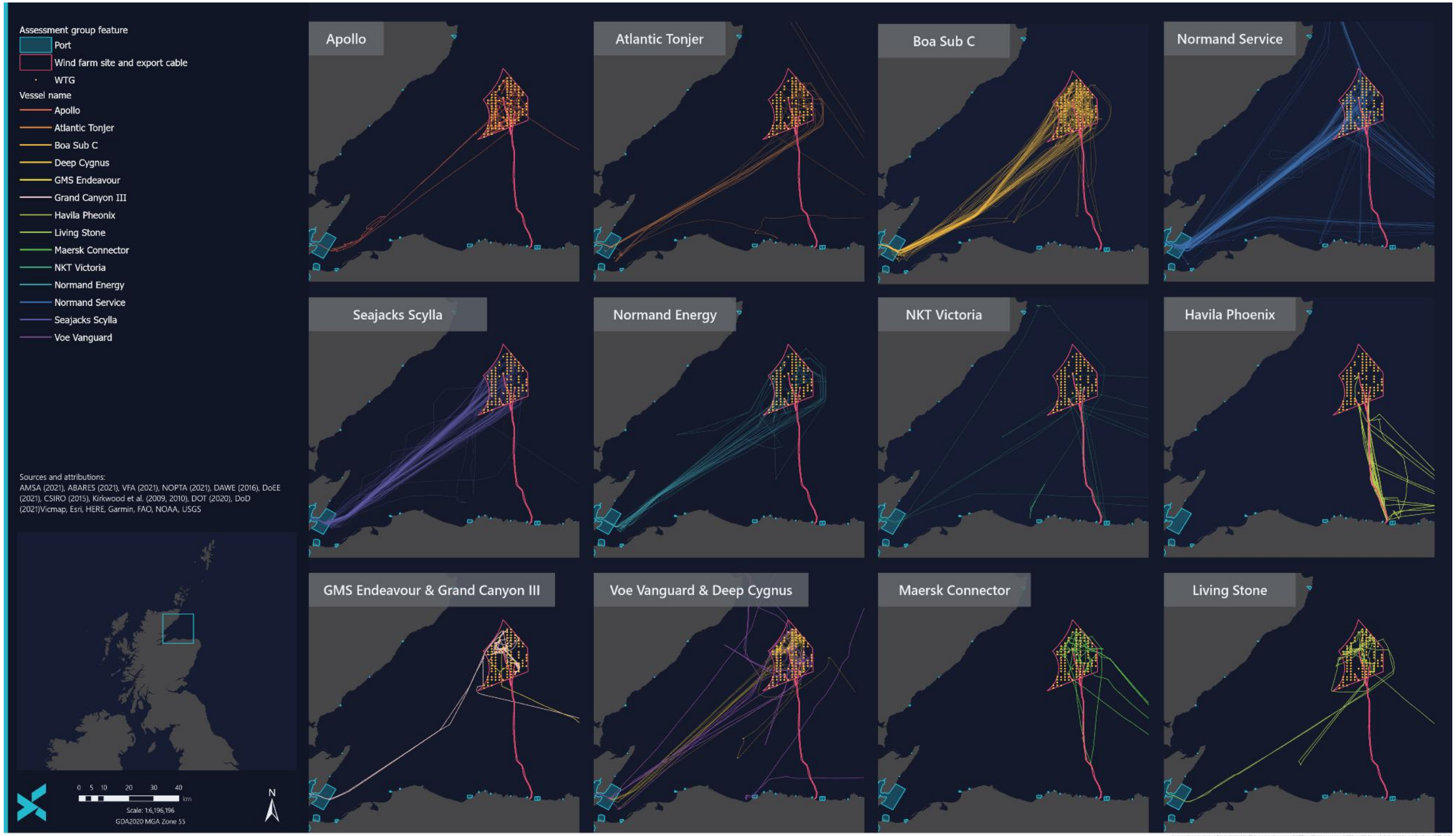


Figure 3.4 Moray East - Vessel Activity Breakdown

3.2.4 Discussion

The OSW vessel market presents multiple opportunities for the State of Maine. While vessel building present an (albeit narrow) opportunity the adjacent services/sectors also present a significant opportunity.

- Wind Turbine Installation Vessel building - Maine shipyards are aware of the potential that lies in OSW vessel building. Bath Irons Works, one of the largest employers in Maine with significant yard capabilities have tracked the industry for years. However, they have no experience in building purpose-built turbine installation vessels. In all likelihood, this yard would be capable of constructing such a vessel, should the need arise, but they can only do so at the expense of long-term defense contracts. Deviating away from building Navy Destroyers to build a WTIV would require a change in workforce skillsets, re-engagement with supply chain on material specifications and significant reconfiguration of equipment to support the build.

  It is also unlikely that new shipyard would be built-in Maine purely for the construction of turbine installation vessels. While the demand has been established the total volume, requirement is not sufficient to support the business case for the establishment of a new shipyard. However, a substantial amount of vessel fit-out can be accomplished at the quayside and, therefore, while hull fabrication will likely be limited to established shipyards, the value of final assembly may be captured locally in Maine.

- Crew Transfer Vessel building – Building of CTVs presents a significant opportunity for Maine, with companies such as Lyman-Morse boatbuilding expressing a desire to be involved and actively pursuing opportunities. Multiple CTVs will need to be built over the coming decade to support offshore installation and O&M and while CTVs will be able to support multiple project it is estimated by Xodus that an additional 30-40 will be needed over the coming decade to support the East Coast build out. Lyman-Morse have suitable facilities to support the build of a CTV and have an extensive track record in supporting the maritime industry. Passenger comfort is key, and it is a priority for technicians to arrive at the OSW site feeling well and ready to transfer/work, as such, vessel fit-out is typically very high specification and will not be challenge for companies well versed in delivery high end pleasure boats. A forward-thinking attitude to next generation CTVs (autonomous, hybrid, all-electric and alternative fuels) will enable companies in Maine to convert opportunities into contracts.

- Vessel Mobilization, Interim Mobilization and Demobilization - As described above the opportunity for Maine ports to act as construction ports or support ports for OSW is significant. As a result, there is an opportunity for multiple adjacent services to benefit from the time these vessels spend in port. This includes
  - Fuel and fresh water bunkering;
  - Food stores replenishment;
  - Stevedoring;
  - Sea-fasting supply and welding;
  - General vessel servicing and repair;
  - Longshore services;
  - Haulage;
  - Adjacent service (hotels, personnel transport etc.).

- Major equipment supply used on installation vessels includes engines, cranes, navigation, heave compensation, jacking systems and dynamic positioning systems. While it is unlikely that major equipment suppliers would establish a facility in Maine purely for this purpose, the deep maritime and defense background does present a significant opportunity for the state to leverage. A linkage to an OSW project could be a reason to choose Maine as an investment destination. Making leading suppliers aware of investment support for Maine could attract inward investment in this area.

- Repurposing and upgrading – An alternative option to new vessel building, that may present a more attractive opportunity to Maine shipbuilding and marine companies, is to repurpose existing Jones Act-compliant and non-compliant vessels for OSW farm installation. Repurposing existing US vessels may prove significantly more affordable than constructing new sophisticated purpose-built vessels. Upgrades could include jack up leg extensions and crane capacity upgrades.

- Maritime logistics and construction management covers a wide range of services including contract management, health and safety and marine coordination. However, it is evident Maine has a wealth of maritime experience it could be exporting around Maine and down the East Coast. For example, Bath Iron Works, has a wealth of understanding regarding the raw material supply chain, naval and maritime engineering, potential secondary steel fabricators and the logistics/management required to execute billion-dollar projects. A strategy should be developed how best to utilize skillsets and put them to work for the advancement of OSW.

3.3 Data Science, Artificial Intelligence and Robotics

3.3.1 Data Science and Robotics in Offshore Wind

Digitization of the OSW industry and robotic applications are becoming increasingly important due to the opportunity for cost reduction, improved safety, and operational efficiency. Digital solutions can drive improvements in decision making from the project development phase through the O&M phase of the project lifecycle. The OSW industry is a data-rich environment and requires skillsets in general data science which includes preparation, filtering, and analysis of complex data to provide insight and illuminate decision making. The use of artificial intelligence (AI) and machine learning will have the greatest impact in revolutionizing the OSW industry, particularly when combined with robotics and autonomous systems.

The most significant opportunity for data science, AI, and the role of robotics in OSW appears in the O&M activities, which account for between 35% and 50% of the lifetime cost of an OSW farm. The cost-reduction opportunity for AI and robotic applications is to reduce the levelized cost of energy (LCOE) by up to 3.5%. As the OSW industry continues to evolve, AI and robotics will play a powerful role in growing the industry by mitigating risks, operating more efficiently and providing significant cost-saving solutions.

Project Development

Throughout the lifecycle of an OSW project, large volumes of data are collected and used to drive decisions and improve the engineering & design of projects. Opportunities for data science in the project development phase are predominantly related to optimizing the engineering design. For example, Optioneer software, is a powerful tool used to map cable routing for subsea cables. It combines several data inputs AI and optimization algorithms to select the optimum route for subsea cables. The cost of subsea cables contributes to a significant proportion of the capital cost of a large-scale OSW project and through using this tool, the LCOE is reduced, and risks are mitigated. The cable routing tool provides visualization for large amounts of data, improves accuracy, and reduces the time to complete the task.

The ability to assess and characterize the wind resource is a crucial factor in the development, siting, and operations of a wind farm. Managing large sets of time-series wind data requires a skillset in the general data science field. A wind farm can be designed to maximize the cost-benefit of the project based on power predictions made from historical wind data. Energy yield can also be maximized by using wind data during the operational phase of a project. Google and DeepMind AI have used AI to produce more accurate wind predictions for bidding into day-ahead markets, which has increased the value of their projects.

Autonomous underwater vehicles (AUVs) are unmanned submersibles that can be pre-programmed to navigate in three dimensions under water and occasionally used to perform bathymetric surveys in the project development phase, which provide substantial reductions in operational time, and therefore cost.

Manufacturing and Fabrication of Large (Scale and Volume) OSW Components

- Robotics, AI and machine learning technologies play a significant role in industrial automation, which will lower facility operating costs and increase productivity and quality of the OSW components produced. Innovations in AI are already being integrated into manufacturing to work with robots (automated welding for example) and process large sets of data. While manufacturing of wind turbine components will be in high demand in the United States, there is an opportunity for Maine to contribute to the industrial production automation of OSW components as OEMS and Tier 1s establish their locations on the East Coast.
- Virtual commissioning enables building a virtual factory and run entire manufacturing lines before ever having to bring expensive materials on site. This will be of particular interest as OEMS and Tier 1s establish new facilities and prepare for starting up a new facility with a new workforce.

Operations and Maintenance

As the OSW industry expands into more remote locations with deeper waters and harsher environments, the adaption of robotic solutions will be critical for the inspection, repair, and maintenance of projects. The operational cost of a windfarm includes the turbine downtime, where no power is generated due to ongoing maintenance or waiting for suitable conditions for repairs to be completed. There is an opportunity for innovations in robotics to minimize turbine downtime and reduce lost revenue. Current and future trends of robotics in the OSW industry include aerial devices, subsea vehicles, and crawler devices that are either remotely operated or demonstrate semi or full autonomy.

Remotely operated vehicles (ROVs) are used to carry out most tasks in place of a human dive team including underwater visual inspection of boat landings, turbines foundations, scour protection and subsea cables.

The challenge with conventional methods of inspecting OSW turbines are the risks exposed to workers climbing at heights above sea level, the labor intensity of the tasks and the limited data capture capability due to inaccessible areas. Unmanned aerial vehicles (UAVs) are drones equipped with high-resolution cameras to inspect OSW turbine platforms with automated flight and data capture. Machine learning is implemented and used to rapidly process data and enable better analytics and predictive models for comparative analysis when reviewing historical captured data. UAVs result in high resolution images of all key inspection areas, provide 99% accuracy, and perform the task in 1.5 hours per turbine foundation compared to 6 hours for conventional inspection methods.

Innovations such as BladeBUG, a crawler robot designed to inspect hard to access wind turbine blades, have recently been introduced into the market to assist technicians in the inspection and repair of turbine blades without the need for rope access, preventing associated costs and risks with the use of a traditional rope access team. The maintenance of OSWfarms relies heavily on sending people to carry out inspections via CTV, SOV, or in some cases helicopter. The transition to robotic O&M will mitigate environmental impacts associated with the large number of vessels required to carry personnel offshore.

High costs associated with the operations and maintenance for OSW farms are related mainly to high labor costs, logistics, and constrains in accessing OSW farms. There is a clear opportunity to decrease LCOE by reducing O&M costs through digital solutions. Condition monitoring involves observing the components of a wind turbine to identify changes in operation that can be a sign of a developing fault.

Digital twins are a physics-based model and serve as a virtual representation of the physical asset. The physical asset is equipped with sensors which send real-time data to a cloud-based host known as internet of things (IoT). It is a digital mirror of the physical windfarm that allows users to see what's happening while operating at a remote location. A set of machine learning techniques are applied to historical data to derive a framework able to predict the failure of a component. Using digital twins and machine learning techniques, engineers are able to analyze and identify problems remotely – only dispatching humans when necessary – and alerting key personnel, up to 6-12 months in advance depending on the failure mechanism and location.

Machine learning techniques have been applied to identify protected species and minimize impact on wildlife. For example, IdentiFlight's cameras detect birds near turbines; if its artificial intelligence software determines any are eagles at risk of collision, it sends operators a shutdown signal to stop the turbine blades from spinning and mitigate risks to birds.

3.3.2 Supply Chain in Maine

Universities and R&D

Several universities in Maine have been identified as having the curriculum and research areas to support the technological needs of the OSW industry. Educational and research programs offered in Maine, specifically geared towards robotics, data science and AI have been identified and summarized in Table 3.4.

The University of Maine (UMaine) has several research groups, curriculum, and grant funding directly applicable to the OSW industry needs. There is an opportunity to support a wide-range of activities geared towards physics-based numerical modelling, AI, robotics, machine learning, and statistics offered by the research groups at UMaine, including MOOR, MaineSAIL, and MARINE. The greatest opportunity for AI and data science support is at the UMaine Software Agents/AI Laboratory (MaineSAIL). Ongoing work at MaineSAIL includes intelligent, high-level control of autonomous or semi-autonomous agents including AUV and land robots, and sea bird recognition programs through deep learning techniques.

A grant awarded by the UMAINE AI Initiative focuses on context-dependent deep learning for sea bird recognition in drone survey imagery. An additional $350,000 grant from the National Science Foundation was received to fund the acquisition of high-performance computing instrument to support deep learning, modelling/simulation, and visualization for STEM at UMaine.

UMaine Marine Aligned Research, Innovation and Nationally-Recognized Education (MARINE) is a collaborative effort between university, industry, government and community leaders focused on marine research, education and outreach. Projects in adjacent industry include aquaculture research projects and tidal energy projects.

The Roux Institute, at Northeastern University in Portland, is a postsecondary institution that offers curriculum and research projects targeted towards emerging, tech-forward industries. With a strong focus on data science and more specifically artificial intelligence, Roux University is well suited to support a wide range of services in the OSW industry. Ongoing research work includes advancing technology in autonomous drones, designing algorithms using AI paired with machine learning to identify IoT devices, and developing robotic solutions for the seafood processing industry. The research work is supported by partnerships across the country between industry, academia, and government. While projects are not specific to the OSW industry, the core skills and knowledge are transferrable.

More notably, the Roux Institute encourages entrepreneurship through two different programs. The immersion program is designed for students and recent graduates interested in creating a tech-related start-up, focused in Maine. The program offers professional experience with successful tech start-ups. This presents an opportunity to introduce the OSW industry through the lens of AI and data science, while making the transition from academia to industry. The Founder Residency program promotes start-ups in tech-forward industries, supporting early-stage entrepreneurs through providing living stipends, mentorship, research opportunities and a network of experts.

Furthermore, it is understood that the Roux Institute is considering a regional advanced manufacturing cluster program that could be leveraged as a the catalyst for wider regional collaboration in the OSW industry.

The Colby College Davis Institute for Artificial Intelligence, established in 2021 following $30 million investment, was developed to provide students and academics a pathway to research and create and apply AI and machine learning across multiple disciplines, including the environment and ocean. The model deployed encourages students to consider AI and ML concepts as early as possible in their education to ensure this way of thinking becomes second nature.

Community Programs

Maine Mathematics and Science Alliance works towards encouraging youth involvement in Science Technology Engineering and Math (STEM) projects and offers support via staff and funding. The following programs and events that support early engagement (K-12) of STEM fields, applicable to the needs of the OSW and Marine industry are:

- Oceans Wide Training;
- USM Robotics;
- Destination imagination;
- Maine State Science Fair.

The outreach programs host projects related to the marine environment, ROVs, robotics, data science and innovation. USM's STEM Outreach program provides Maine youth and teachers with mentored activities on robotics for science. A strong community for the development of learning and training for robotics in Maine. USM involvement with robotics camp for elementary and high school students to get involved.-Table 3.4 - Overview of Areas of Research

UNIVERSITY / INSTITUTE	AREAS OF RESEARCH
University of Maine	• Marine Aligned Research, Innovation, and Nationally recognized Education (MARINE) • Marine Ocean and Offshore Research (MOOR) • Artificial Intelligence • Cooperating Robots, Creating Intelligent Robots, Intelligent Undersea Vehicles • Green supercomputing • Spatial computing • MaineSAIL
University of Southern Maine	• Maine robotics, computer science
Colby College	• Davis Institute for Artificial Intelligence- The Environment and the Oceans

UNIVERSITY / INSTITUTE	AREAS OF RESEARCH
Gulf of Maine Research Institute	• New England Marine Monitoring • Ocean Observation in the Northeast
Roux Institute	• Experiential AI, data visualization • Materials and manufacturing • Robotics/Autonomy • IoT
University of New England	• Data Science • AI & Machine learning graduate certificate

3.3.3 Discussion

As the industry matures, we will continue to see a growth in data science applications throughout the project life cycle to improve efficiency of project delivery. Robotics and autonomous systems paired with advanced ML and AI will be critical in growing the OSW industry by lowering OPEX and CAPEX costs (by saving time to execute tasks and reducing personnel required) and mitigation of HSE risks and environmental impacts.

Companies – There are a lack of companies in Maine working in the OSW space to support the general digitalization and automatization of the OSW industry. Opportunity for companies in adjacent industries to transition skillset, especially in the forestry and aquaculture industries where robotics and automation is occurring presents an opportunity for Maine. A roadmap to support company formation from ideas generated in academia and R&D is required.

Community programs -There is an opportunity to provide a program for youth to picture themselves in a clean energy career with AI and data science at the core of such a program. This leads to an opportunity to incorporate OSW specific projects into youth engagements, especially in the USM robotic and Oceans Wide Training program.

UMaine - Demonstrates a strong capability to support the needs of data science and AI in the OSW field. While programs and projects are non-industry specific, it would be beneficial to host an OSW specific training program hosted at Maine based academic institute and in collaboration with other universities.

Roux Institute – Provides strong technical program in data science and AI. Roux Institute is well connected across the country with industries, but it will be important to connect with OSW industry and include OSW specific research projects. The entrepreneur programs will aid in filling the gap in data science and robotic companies working in OSW.

3.4 Assessment of Opportunities for Minority and Women Owned Small Business Enterprises

The Disadvantaged Business Enterprises (DBE) Directory was assessed to identify the opportunity for certified diverse companies in Maine to participate in the OSW industry. Due to the nascency of the US OSW sector there is currently a need to rely on established European supply chains to enable delivery of projects. As the OSW sector continues to grow it is expected that investment will take place that establishes greater US supply chain capability and allows for projects to be technically and economically feasible with higher levels of local supply chain content.

The DBE Directory categorizes certified diverse companies by product codes and NAISC description to enable study and search of contents. The Directory was first assessed for the potential relevance of product codes against the supply requirements of an OSW project to better understand the potential overlap between the presence of certified diverse companies in Maine and the needs of the OSW industry. The product codes were assessed as having either: potential applicability (e.g. engineers, steel fabrication, maintenance); limited or niche applicability (e.g. chemicals, apparel, aircraft contracting, accounting, office supplies, IT services or related services); or little or no applicability (e.g. telemarketing, sporting goods).

Assessing the DBE Directory by the number of companies present according to the relevance of their product code suggested a fairly low potential for certified diverse suppliers in Maine to have an opportunity for involvement in the OSW supply chain. As shown in Figure 3.5, over half of the 60 Maine based DBE companies in the Directory are categorized as having little or no relevance in OSW with only 12 companies with potential to service the OSW industry. However, the DBE Directory remains a generalized resource for listing and categorizing certified diverse suppliers rather than a tool curated for the purposes of any specific industry. Thus, the Directory may not be fully representative of the potential for diverse suppliers in the OSW industry through both lack of technically suitable companies currently listed able to meet specialized OSW requirements and the possibility that diverse companies in Maine with capability have not yet been captured in this database.

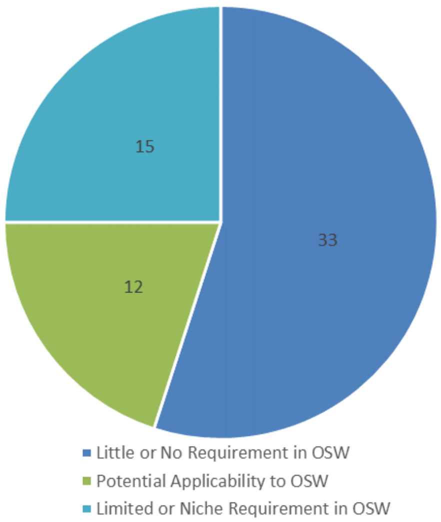


Figure 3.5 Potential relevance to OSW of DBE Directory companies by given product code category or description

The development phase of an OSW project is likely to provide a range of contracting opportunities for Maine based companies. While there is capability across certified diverse companies to provide OSW project permitting, engineering and design, and surveying services, the experience and focus of companies given in the database is almost exclusively related to onshore aspects of project development.

Sub-contracting opportunities in onshore construction scopes are likely to be delivered by local suppliers where they are available. The DBE Directory several companies under a relevant onshore construction supply chain element who may be used to support the construction of an onshore substation, onshore cable route or O&M base (if required) for an OSW project.

The operations phase of an OSW project typically provides good opportunity for local content where the cost and timing of mobilization provides strong logic for the local supply of O&M services. Despite the high opportunity for local supply there is a currently an absence of companies in the DBE Directory with a focus on offshore O&M. The significant majority is focussed on the inspection, maintenance and repair of fire protection, plumbing, and heating, ventilation and air conditioning systems for residential and commercial properties. While these capabilities have some applicability to an OSW setting there is currently low opportunity for certified diverse companies to provide O&M services for turbines or offshore structures.

Assessment of the current capability of certified diverse suppliers in Maine suggests that there may be limited sub-contracting opportunities as part of any upcoming OSW project. The most immediate opportunities for diverse suppliers will be in the project development phase likely to support onshore design, environmental assessment and construction planning. There are also a high number of generic project and company support services that could be contracted through certified diverse companies.

The opportunity for certified diverse companies to provide support during project installation is currently anticipated to be significantly higher for any onshore scopes than in support to offshore work due to the contrast in similar supply requirements with adjacent industries. While there is strong logic for local suppliers to be contracted to support the operations phase of an OSW project, similarly to offshore installation services, there does not appear to be an adjacent supply chain of certified diverse companies to draw from and thus the current opportunity for diverse Maine companies is low.

The assessment of the Maine supply opportunity is based on the companies listed in the DBE Directory, where this may not be fully representative of the actual opportunity for diverse suppliers at the time of project contracting. Supplier databases are unlikely to capture the complete supply chain landscape where qualifying companies are either not aware or not interested in being listed. The DBE Directory is also not an OSW specific resource tool for identifying potential suppliers and so relevant companies may currently exist in Maine without their capabilities being categorized in way that is accessible and understandable to their potential future clients. Notably there are gaps in supply areas that could be supported by Maine companies but where no certified diverse suppliers appear to be able to meet the requirements. This is particularly true in the installation and operations phases where there is good logic for local supply.

Assessment of the opportunity for diverse suppliers is also limited by available information on listed companies. Many of the listed suppliers lack a working website where typically company capabilities would be described. Of the suppliers assessed as having potential opportunity to support an OSW project who did have accessible company information few refer to an interest in renewables or have an offshore focus. Further information lacking, such as the size of a company, is necessary to gauge whether a supplier is likely to have the capability to supply to a commercial scale OSW project.

The economic impact that could be felt among certified diverse suppliers is proportional to the contract value placed in support of an OSW project. Although there are a range of potential sub-contracting opportunities available for Maine-based companies few appear to be able to be delivered by companies listed in the DBE Directory.

For OSW project developers and their Tier 1 suppliers turning potential suppliers into contracts requires building one-to-one relationships. While the DBE Directory is a useful resource for listing potential suppliers, as a database it provides limited value as a means to establish strong supply chain relationships. Developers and Tier 1 suppliers will need to use the information in the DBE Directory in conjunction with local partner organizations who are well placed to identify and introduce diverse businesses.

4 Opportunity Analysis

4.1 Approach

The outputs of the supply chain assessment were mapped against the Xodus supply chain taxonomy and analyzed to identify supply chain sectors where Maine companies are well positioned to meet, or adapt to meet, the OSW industry's requirements. Companies identified through the earlier assessment that are not currently in the Supply Chain Directory were also considered. The analysis was carried out using a consistent set of criteria applied to each supply chain element:

- Experience in OSW: The number of companies in-state who have supplied to the OSW sector, either in the US or elsewhere in the world;
- Experience in adjacent industries: The strength and applicability of supply chain expertise in state supplying relevant adjacent industries, such as the marine and energy sectors;
- Market volume resilience: How much the success of supply chain companies will depend on the volume of installed OSW project capacity;
- Advantage for local supply: The nature of any competitive advantage for supply from in-state, considering possible logistics benefit or existing supply chain strength;
- Opportunity for export supply: The potential for in-state companies to supply projects down the US east coast or beyond, should capability be established;
- Relative project spend on supply area: Proportion of total lifetime project spend typically attributable to the supply chain category; and
- Investment case: Level of investment and market confidence needed to develop supply chain capability.

A scoring system was applied to each criterion as described in Table 4.1.

Table 4.1 Scoring system for opportunity analysis

CRITERION	SCORE 1	SCORE 2	SCORE 3	SCORE 4
Experience in OSW	No local companies with experience in OSW.	Local companies have no OSW experience but are known to be actively pursuing opportunities.	Up to two local companies with OSW experience.	More than two local companies with OSW experience.
Experience in adjacent industries	No known local companies with relevant experience in an adjacent industry.	Local companies with some relevant experience but are unlikely to offer a competitive solution in OSW.	Local companies with some relevant experience that may need some change in strategy or additional investment to support supply to OSW projects.	Local companies with some relevant experience and are likely to supply in OSW with minimal change in strategy or additional investment.
Market volume resilience	Local companies' success is likely to depend almost entirely on orders from the OSW sector.	Local companies' success is likely to depend on >50% of order book from the OSW sector.	Local companies' success is likely to depend on <50% of order book from the OSW sector.	Local companies' success can be independent of orders from the OSW sector.
Advantage for local supply	No competitive advantage to local	Minor competitive advantage to local	Competitive advantage to local suppliers, either	Competitive advantage to local suppliers from

CRITERION	SCORE 1	SCORE 2	SCORE 3	SCORE 4
	suppliers from either existing local supply capability or logistics benefit.	suppliers, either from existing local supply capability or logistics benefit.	from strong local supply capability or significant logistics benefit.	both strong local company experience and significant logistics benefit.
Opportunity for export supply	Significant logistics barrier to non-local supply or established competing supply harms export opportunity.	Some logistics benefit to local supply or established competing supply limits export opportunity.	No particular logistics benefit to supply or lack of established competing supply means non-local suppliers are not disadvantaged.	No particular logistics benefit to supply and lack of established competing supply means non-local suppliers will be required on nearby export projects.
Relative project spend on supply area	Average spend in elements is <1% of project lifetime expenditure.	Average spend in elements is between 1% and 1.5% of project lifetime expenditure.	Average spend in elements is between 1.5% and 5% of project lifetime expenditure.	Average spend in elements is >5% of project lifetime expenditure.
Investment case	Investment required to supply is significant enough to need public support and requires long-term confidence in OSW market.	Investment required to enable supply triggered by long-term confidence in OSW market.	Investment required to enable supply can be triggered by single OSW contract.	Little or no further investment needed to enable supply.

4.2 Opportunity Assessment

4.2.1 Project Development

Figure 4.1 - Assessment of Maine project development opportunity

Scope of supply

Project development includes the work undertaken by the wind farm developer and the services contracted prior to the developer reaching final investment decision on the project. This includes project design, planning and permitting services; offshore and onshore surveys and studies required to inform wind farm project and component design, as well as to obtain necessary construction permits; environmental impact assessment; front-end engineering and design (FEED) studies to advance the wind farm and component concepts ahead of procurement, contracting and construction; and a wide range of other project management consultancy and supporting services including legal, financial, procurement and recruitment support.

Unique floating wind requirement

Project development and permitting is similar to fixed OSW. The greater spread of mooring patterns and more items in the water column (semi-buoyant cables and mooring lines) will lead to more complex permitting discussions.

Surveying is similar to fixed OSW. Site investigations will be required at deeper water depths, particularly sea bed surveys and wind resource assessment. More boreholes and side-scan sonar surveys will be required due to the mooring lines and anchoring locations, plus potentially longer inter-array cable routes due to avoiding mooring lines. The depth of surveys will be less as the piles generally are shallower for moorings than fixed jacket foundations. Avoiding the necessity for heavy jack-up vessels required for the construction of fixed OSW eliminates the need for seabed surveys for the jack-up spudcan locations.

Relevant design standards for floating hulls, mooring and anchoring systems have been developed from the adjacent oil and gas and shipbuilding sectors. While those industries are well developed there is a need to ensure strong due diligence is followed through as the consequences of loss of water-tight integrity or mooring failure are new to the wind industry, having not previously been relevant to fixed wind.

Project management in floating OSW is largely the same as in fixed OSW. Differences in scope and an increased number of sub-contractors and relationships means interface management becomes critical.

Maine experience in OSW

Maine-based SGC Engineering undertook OSW farm site and export cable route geophysical and hydrographic surveys on the Bay State Wind and Ocean Wind projects.

Several Maine based organisations and companies have supported the planning, environmental assessment and permitting of the New England Aqua Ventus project including Maine Maritime Academy, Gulf of Maine Research Institute, HDR and Kleinschmidt.

Tetra Tech, who have presence in Maine, supported permitting and construction of the CVOW demonstrator project among others.

Several other key organizations with presence in Maine have significant experience in OSW projected development, including, Stantec, Normandeau, VHB, Ramboll, SGC Engineering, and Wood.

The VolturnUS floating concrete hull was designed by the University of Maine's Advanced Structures and Composites Center.

Maine experience in adjacent industries

The capability to support OSW developers in the development phase of the project comes from a deep-rooted experience in supporting large civil infrastructure and energy infrastructure projects onshore. Over 70 companies were found in the Maine OSW supply chain assessment with some capability to support project development.

Market volume resilience

The companies supporting development, design, permitting and management of OSW projects were largely established prior to the emergence of the US OSW industry and will support industries beyond OSW, although permitting for offshore infrastructure is not commonplace. While surveying is required in other industries, OSW presents significant opportunity for offshore surveying services.

Advantage for local supply

Permitting services can be delivered from multiple locations with the only advantage of delivering locally being the ability to engage with local stakeholders, state authorities and non-governmental organizations. Local firms may have some advantage due to their track record in supporting project development and permitting.

Local understanding of the environment and marine logistics can be a key differentiator for survey services. Local vessels are often used to undertake environmental surveys where available.

For support to engineering and design, competitive advantage is not defined by supplier location. Similarly, most project management services can be delivered independent of location. In both cases competitive advantage is based on capability and track record.

Opportunity for export supply

Support for project development and permitting can be provided by non-local suppliers with negligible logistical barriers. However, other states have or will be developing native capability.

The logic of export supply is strong for the main site survey investigation work, as this is further offshore and less reliant on local knowledge of the environment. Onshore and nearshore site investigation and environmental surveys benefit from local expertise and understanding and therefore there will be limited opportunity for exporting these services if there are capable local suppliers in competition.

Maine based suppliers of engineering and design and project management services will be able to access multiple US projects.

Relative project spend on supply area

Each element of the project development phase spend typically accounts for less than 1% of total OSW project costs.

Investment case

There are several Maine companies already fully capable of providing permitting support in other sectors so no additional investment to supply OSW is necessary.

Companies operating in the survey (onshore or offshore) market will need to make investment to be able to support the OSW industry. The industry has seen large mutli-national survey companies enter the US OSW market in the very early stages and dominate the large site investigation scopes. Where local survey firms will see success is in smaller nearshore and environmental focused scopes.

The expertise and equipment required for most engineering and design and project management services are used across several sectors and so no additional investment is required to support the OSW sector.

Discussion

Project development services emerge as a potential area of opportunity for the Maine supply chain. Although some Maine companies have successfully supplied OSW projects in other states this opportunity is typically best developed through companies gaining experience on local projects. Where Maine companies may find an advantage in the future is in having experience and track record in the development of floating OSW projects over competitors in other states. Where these services do not require local presence (such as in engineering and design) there will be an opportunity to export knowledge and experience to emerging floating OSW markets both in the US and globally.

4.2.2 Wind Turbine Supply

Figure 4.2 - Assessment of Maine turbine supply opportunity

Scope of supply

The wind turbine supply category includes general components of the turbine supply contract. The assembly of the turbine is carried out by the turbine OEM, with the rotor, nacelle, and tower elements being broad terms encompassing several Tier 2 and below supply packages. Supply chains for rotor and nacelle components tend to consist of one or two suppliers for each or all turbine OEMs due the high specification and need for high reliability.

Wind turbines require sub-supply of a range of components prior to assembly including: bedplate, gearbox, driveshafts, generators, power take-offs, pitch and yaw bearings, main bearings, nacelle and hub casing, pitch and yaw drive systems, control cabinets, cooling systems, lighting and anemometry. Blade manufacture requires supply of resins, glass and carbon raw materials and preformed items, coatings, lightning protection systems, blade bolts and sensors.

Tower supply includes steel rolling and coating to provide the main structure as well as sub-supply of internal components including access systems (ladders, elevators, platforms), health and safety equipment, lighting and electrical control panels.

Unique floating wind requirement

Turbine components are largely similar to fixed OSW, but motions of the floating turbine increase the fatigue of the tower, hence some small increase to tower stiffness through increased diameter or wall thickness is likely.

Maine experience in OSW

There are no companies in Maine with experience supplying components in commercial scale OSW turbines.

Maine experience in adjacent industries

Maine companies' experience in supplying wind turbine components is limited to hubs and shafts of smaller scale onshore wind turbines. The in-state capability to provide advanced composite fabrication has some applicability in the production of nacelle and rotor hub covers, although there are currently no native nacelle assembly facilities in the US.

Market volume resilience

A US nacelle assembly facility or blade manufacturing facility will be entirely dependent on the size of the OSW market. The same skills and tools (though at different scale) are also required in onshore wind.

Offshore wind towers are bespoke to the OSW turbines and are significantly larger than onshore wind turbine towers. The long-term success of an OSW towers facility would be entirely reliant on the OSW project pipeline.

Advantage for local supply

Local supply of nacelles, blades and towers can reduce logistical challenges associated with marshalling.

Opportunity for export supply

A nacelle assembly facility or blade manufacturing facility would serve the whole US geographical market. Given the volume of projects in the US pipeline there will be appetite from the turbine OEMs to eventually establish US facilities with the ability to export to the entire US industry, though there is little likelihood of these being located in Maine.

Relative project spend on supply area

This portion of the project spend on the total turbine package typically accounts for around 15% of total project costs.

Investment case

A high level of investment and long-term confidence in obtaining suitable market share of the future project pipeline would be required to establish nacelle, blade or tower fabrication facilities.

Discussion

It is unlikely that a turbine OEM will locate in Maine. As the requirements for sub-suppliers are strict to achieve (turbine OEMs tightly control subcontracting opportunities and parts are generally standardized limiting opportunities for new suppliers) there is likely only limited supporting supply chain opportunity. Nacelle components such as control and communication systems, HVAC, lighting, cabling, and secondary steel and machined parts such as brackets, plating, handrails, flooring and ladders could be supplied by Maine companies.

4.2.3 Balance of Plant Supply

Figure 4.3 - Assessment of Maine balance of plant supply opportunity

Scope of supply

Supply of monopile foundations includes manufacture of relatively simple, but large, cylindrical steel structures. Supply of steel transition piece structures between the monopile foundation and the turbine requires sub-supply of secondary steelwork such as work platforms, boat landing systems, ladders, guardrails, cranes and j-tubes for cables. Jacket foundations require the supply and assembly of steel lattice, struts and nodes as well as sub-supply of components for an integrated transition piece. Jacket foundations also require sub-supply of steel pin piles of suction caissons to secure the structure to the seabed. Floating foundation designs can vary significantly from large semi-submersible hulls comprised of columns and trusses to monopile-like spars to tubular semi-spars. Floating foundations can be manufactured from primarily steel or concrete and require a similar set of secondary steelwork. All foundation types require sub-supply of coatings and other forms of corrosion protection.

Cable suppliers manufacture subsea cables from conductive cable cores, insulation and protective armouring. Sub-supply of components includes fibre-optics, accessories for electrical termination and mechanical support, such as interface plugs and hang-off clamps, and cable protection systems. Termination, jointing and testing services are required on complete cable lengths and any joints applied during manufacture.

A mooring system for station keeping of a floating platform is made up of mooring lines, anchors, and connectors. Mooring lines in floating OSW are expected to be either all chain or a combination of chain and fibre rope. Anchors are typically steel structures that range in design and fabrication complexity including gravity-based, piled, drag-embedded and suction caissons. Mooring system ancillaries include turrets, chain stoppers, tensioners, transition joints and buoyancy modules.

Offshore substations require supply of a foundation structure (typically a steel jacket similar to turbine jacket foundations but larger in scale) and a topside structure containing the electrical equipment, a helipad and auxiliary facilities. The electrical systems include supply of high voltage switchgear, transformers, reactive power compensation, control and monitoring systems, as well as small electrical components. Sub-supply of auxiliary facility systems includes communications, fire and blast protection, control rooms and equipment, HVAC (heating, ventilation and air conditioning), refuge rooms, water systems, low-voltage power suppliers, cranes, navigational aids and lighting, and health and safety systems. Onshore substations require supply of similar electrical systems as those required in offshore substations as well as supply of a building to house them.

Unique floating wind requirement

Floating wind substructures are entirely different to those used in fixed OSW and are predominantly adapted designs from the oil and gas industry. Substructure manufacturing in oil and gas occurs at much lower production volume than will be required in floating wind. An alternative approach to design and manufacturing culture that focusses on lower cost serialised production will be necessary for the industry to succeed.

Subsea cables are significantly more complex for floating wind projects. Dynamic array cables (medium voltage), and ancillaries (dry or wet connectors, buoyancy modules, bend restrictors, various clamps and anchoring points) are required. Dynamic high voltage cables for export to shore have not yet been brought to market.

Anchors and mooring lines are a unique element not used in fixed OSW but already in use in oil and gas and shipping industries where only minor adjustments in design are considered necessary, however higher volumes are required. The most suitable mooring configuration for a floating project is subject to the substructure type and a function of the water depth and wave height.

Maine experience in OSW

Cianbro are the EPC contractor on the New England Aqua Ventus project and built the Volturn US 1:8 floating OSW prototype platform with support from Bath Iron Works.

DeepWater Buoyancy have designed a distributed buoyancy product for moorings and cables used in floating wind applications.

Maine experience in adjacent industries

Around 30 companies were identified as part of the supply chain assessment with some capability to support the production of steel components, although many may not be able to meet the specification and volume requirements of an OSW project.

There is no clear experience in adjacent industries for the supply of subsea cables.

While only two companies in Maine were identified as suppliers of mooring rope and subsea buoyancy products in the oceanographic, offshore oil & gas and maritime sectors these companies are well placed to supply a future floating OSW industry.

There appears to be limited experience in the supply of onshore electrical infrastructure in-state. However, those that do supply onshore grid transmission projects should be well positioned to support the OSW industry.

Market volume resilience

Offshore wind foundations, whether fixed or floating, are bespoke to the offshore environment and synergies and support are normally sought from oversees or the oil and gas industry.

There is limited demand for high voltage submarine cables in local adjacent industries. Company success in this sector would be entirely reliant on the size of the US OSW industry.

Many anchor types projected to be utilized in floating OSW projects could be manufactured at non-specialist fabrication yards that support other industries. Mooring lines are required in the marine sector although the type and volume required in OSW will be different.

Companies manufacturing electrical infrastructure would look to supply other industries in addition to OSW.

Advantage for local supply

Local supply of balance of plant components such as foundations, subsea cables and mooring systems significantly reduces logistical challenges associated with marshalling of components.

Supply of offshore substation electrical infrastructure is likely in part to still come from Europe so local capability would reduce logistics costs. For offshore substation foundations there is less competitive advantage for a local supplier when structures can be produced in fabrication yards around the Gulf of Mexico.

Opportunity for export supply

A facility with the capability to manufacture foundations, subsea cables or mooring lines for OSW projects would be likely to serve at least the US East Coast market. Electrical infrastructure manufacturing capability would serve a wide geographical market. There is less logic for export of substation foundations and anchors where these can be supplied from other US fabrication yards such as those around the Gulf of Mexico.

Relative project spend on supply area

Foundations on a fixed OSW project typically account for around 6-8% of total project costs. Depending on the technology choice, floating foundations may account for around 15-20% of the total cost of a commercial scale floating project.

The electrical infrastructure (export cables, array cables and substations) account for around 8% of total project costs.

Mooring systems for floating projects vary with technology choice and water depth but estimations for typical upcoming projects anticipate 5-10% of total project costs.

Investment case

A high level of investment and market confidence in OSW would be required to locate and establish any facility to manufacture foundations, subsea cables, mooring systems or complex electrical infrastructure for offshore substations.

Discussion

Maine does not currently have a Tier 1 supplier capable of suppling a commercial scale OSW project. These types of suppliers typically act as anchors for the Tier 2 and below supply chain. Where these suppliers are considering investment in new facilities to supply the U.S. market, they may be more likely to be incentivized to locate in states with a significant project pipeline. However, suitable land adjacent to quayside without air draft restriction is at a premium and will likely require significant refurbishment. There may be opportunity in Maine to attract or support the development of a native Tier 1 manufacturer in the future.

Supply of secondary components to a primary fabrication facility could present an opportunity for Maine based companies. Supply of steel sub-components could include machined and fabricated items such as railings, barriers, platform, J-tubes, boat interface steelwork, brackets, plating, handrails, flooring and ladders.

4.2.4 Installation and Commissioning

Figure 4.4 - Assessment of Maine installation support opportunity

Scope of supply

Installation and commissioning includes the services contracted to construct an OSW project. These elements can be Tier 1 or Tier 2 packages, with the exception of ports contracts, which are typically Tier 2 or Tier 3.

In addition to the usual systems required to construct and operate large foundation and turbine installation vessels (such as jack-up, heavy lift and sheerleg vessels), there is a requirement for handling and installation equipment including cranes, lifting tools, frames for upending and positioning, piling hammers and noise mitigation equipment. Bespoke equipment may be required to fit a vessel for a specific project or installed almost permanently on a vessel that is designed to be flexible to support a range of different project needs. Sea fastenings are also required for the transportation of foundations and WTG components.

Subsea cable installation requires a vessel supplied with cable handling equipment such as a carousel and tensioner, ROV support, and cable burial tools including cable plough, vertical injector and jetting sled. Termination and testing services are required on the installed cable.

Installation of anchors and moorings will take place with an anchor handling vessel capable of transporting and launching the anchors and performing a pull-in using the mooring line, where applicable.

Following installation, commissioning services are required to energise systems and assess safe working performance of components.

Construction, staging and marshalling ports and associated port services are contracted in support of project installation where components are not installed directly from the manufacturing facility. Support services for OSW project installation includes marine coordination, weather forecasting and supply of guard vessels, feeder barges, crew transfer vessels (CTVs) and accommodation vessels.

Unique floating wind requirement

Installation procedures for anchors, moorings, dynamic subsea cables and floating substructures are not required for fixed OSW projects. Methods and equipment for these elements are relatively well-established from the oil and gas sector. The construction schedule can avoid the requirement for heavy lift vessels, is less weather sensitive and has greater time planning flexibility. Installation procedures will differ depending on the substructure and it is likely that turbine installation for floating projects will take place at quayside using large cranes.

WTG integration for floating wind projects is likely to occur at the quayside rather than offshore. This requires significant quayside length and laydown areas to be available. In addition, the port will require a large crane (ring-crane likely) to install these turbines. This level of crane capability will likely not currently exist in Maine.

Floating projects will utilise many of the same vessel types that are currently employed in the construction and operation of fixed OSW projects. There is an additional requirement for tugs and anchor-handling vessels for the installation of the anchors, moorings and substructures unique to floating wind. There is much greater use and opportunity for ROVs and AUVs for subsea installation and inspection.

Much of the requirement for ports and logistics infrastructure is similar to fixed OSW. Key differences are brought about by the choice of floating substructure. Floating OSW ports supporting substructure and turbine installation are likely to require additional quayside draft and significant wet or dry storage areas as a minimum. Installation of anchors and moorings may be supported by smaller ports than those previously used to install OSW projects.

Maine experience in OSW

Cianbro launched the DeepCWind prototype platform from its Eastern Manufacturing Facility.

Maine experience in adjacent industries

Although Maine has a long maritime history and a range of yards experienced in shipbuilding there is an absence of companies supplying offshore transport and installation services for OSW specifically.

Onshore civil infrastructure construction firms based in Massachusetts should be well positioned to support the onshore construction requirements of an OSW farm.

Maine has several ports and multiple companies in the adjacent marine industry supply chain that have capability to support the OSW industry.

Market volume resilience

While offshore heavy lift vessels supporting the installation of turbines and foundations in the fixed foundation OSW market can support offshore and quayside lifting operations in other sectors, the requirement from the OSW sector is likely to be the primary driver for the construction of any new Jones Act compliant vessel.

There is need for installation of submarine cables in other sectors, but the requirement in OSW is likely to be significant.

Anchor handling tugs are also used in the oil and gas sector but the demand is relatively small.

Companies supporting onshore construction for an OSW project will support a wide range of other infrastructure projects.

Expanded port infrastructure could be used to support other industries but few have the same requirement as commercial scale OSW projects.

Advantage for local supply

Major transport and installation companies are multi-national and support project around the globe. Locality can be advantage to partnering with local barge suppliers or marshalling yards.

There is no strong logistical benefit to local supply of cable installation. Due the costs associated with cable handling it is typically the case that subsea cables are installed directly from the manufacturing facility.

Local civil construction companies are likely to be contracted for onshore works.

Local supply provides increased logistical benefit due to shorter transiting times to the OSW project location. However, some components may be installed directly from manufacturing facilities.

Opportunity for export supply

Transport and installation vessels can support projects globally.

Installation and staging ports with strong capability can be used to support projects across a wide geographical area, although there will be logistical benefit to local supply where available.

Relative project spend on supply area

For fixed OSW projects installation and commissioning can account for 8-10% of the total project costs. For floating OSW projects the absence of requirement for heavy lift vessels means installation costs can be significantly lower.

Investment case

Long-term confidence in the US OSW market would be required for a Maine based company to commission any Jones Act compliant installation vessel.

Project developers have typically been willing to provide some investment and share risk in developing installation ports.

Discussion

The predominant opportunity in Maine to support the installation of OSW projects appears to be in the use of port facilities for staging and marshalling of components. Utilizing Maine ports in support of fixed OSW projects will depend on the development of the US East Coast market and actions taken in other states to develop overflow port laydown areas.

In addition to the Maine port infrastructure to support OSW projects, there may come significant opportunity for local companies to provide port and logistics services including security, utilities, fuel bunkering, stevedoring, cranes, handling, forklifts, SPMTs, trailers, vessel maintenance, ships agent, towage, and waste removal. Provision of these services is not limited to the project installation phase, where smaller ports in Maine may aid in these logistical services to support the development surveys and wind farm O&M stages.

Maine's unique capability in deep water port infrastructure may provide a competitive advantage in the installation of floating OSW projects where this cannot currently be provided at other locations on the US East Coast. It should be noted however that floating foundation technologies are being developed that can be installed using shallow quaysides. Should that technology mature quickly or Maine's port infrastructure not be suitably developed in time to support commercial floating OSW projects on the East Coast there is a risk that the opportunity to use Maine ports is diminished.

4.2.5 Operations and Maintenance

Figure 4.5 - Assessment of Maine O&M support opportunity

Scope of supply

Wind farm operations require supply of services that support the management and optimization of the project including control room equipment and software to deliver asset performance, health and safety, and environmental monitoring. A range of services and software are required to support marine coordination and planning such as communications and weather forecasting. The wealth of operational data generated by OSW projects is also likely to create opportunities for supply of data and digitalization services.

Regular inspection and certification of safety-critical systems is required throughout the project lifecycle; this includes crew access systems, cranes, firefighting and fire prevention equipment, and navigational aids and lighting. Whether turbine maintenance is carried out by the project operator using in-house capability or supplied by a third-party provider, services are required for the training and certification of O&M technicians.

Specialist inspection and repair services are contracted for components such as blades, foundations, subsea cables and electrical infrastructure. Increasingly the use of unmanned, autonomous or remotely operated vehicles are being used where safe and reliable for wind farm inspections.

Unique floating wind requirement

Routine operations, inspection and servicing will be similar to fixed OSW. The substructure, mooring and dynamic cable inspection will be unique to floating wind projects with a reduced focus on scour issues and cable protection. Depending on the substructure choice, floating OSW projects may also adopt a tow-to-port strategy for major repairs to occur at quayside.

Maine experience in OSW

There are no apparent companies in Maine with experience providing inspection, maintenance and repair services in OSW.

Maine experience in adjacent industries

Maine has several organizations with capability in maritime training as well as companies involved in software development that may be well placed to support the OSW industry. Those potential suppliers looking to expand capability to offer bespoke OSW training or software services will need to understand specific sector needs.

Engineering and inspection companies may see provision of turbine technicians and inspection and repair services as an opportunity for diversification, where investment in training and certification will be required. Companies with turbine inspection capability to serve the onshore wind sector can also transition to working offshore with appropriate training and certification.

Market volume resilience

There is overlap in the services provided to project operators with the marine operations and onshore wind sectors. Companies moving to support OSW O&M will anticipate being able to provide services long-term.

Advantage for local supply

For provision of operations software tools there is no competitive advantage to locality, but operations typically occur at a local base where locality of support services is advantageous.

There is a significant logistics benefit to local supply where mobilization costs can be minimized and the ability to attend to repairs quickly reduces generation downtime.

Opportunity for export supply

Provision of software and digital services to support wind farm operations are not tied to location, and local training of technicians can be of benefit to non-local projects.

Specialist O&M provision can be mobilized from further afield.

Relative project spend on supply area

O&M represents a long-term opportunity for supply chain. This portion of the project spend typically accounts for around 35-50% of total project costs.

Investment case

Investment required to develop capability in operations services is relatively low. Companies investing in own capability to provide O&M will take confidence from the long-term opportunity.

Discussion

With little installed OSW capacity in the US and operations stage contracting typically not occurring until late in the project development process there have been few opportunities to date for Maine companies to engage with the sector and demonstrate capability. As projects become operational (particularly local projects) it can be anticipated that a greater number of suppliers will be identified to support OSW farm O&M.

A key challenge for Maine companies in supporting wind farm O&M is the logistical benefit to local supply in inspection, repair and maintenance services where the ability to mobilize quickly at low cost is advantageous. An opportunity for Maine companies may be in specialized services related to the O&M of floating OSW projects where the requirements to inspect and maintain moorings, dynamic cables and floating hulls is distinct from fixed OSW projects.

4.3 Summary Matrix

The table below provides a tabulated summary of the numerical scoring (as per table 4.1) of the opportunity analysis detailed in Section 4.2.

Supply Element	Experience in OSW	Adjacent experience	Market volume resilience	Advantage for local supply	Opportunity for export	Relative project spend	Investment case
Development and permitting	4	4	4	2	3	1	4
Surveys	3	3	3	2	2	1	4
Engineering & design	3	3	4	2	3	1	4
Project management	3	4	4	2	3	1	4
Nacelle	1	2	1	1	4	4	1
Rotor	1	1	1	1	4	3	2
Tower	1	1	1	1	3	3	2
Foundations	3	3	1	2	4	4	1
Export and array cables	1	1	1	2	4	3	1
Anchors and moorings	3	4	2	2	4	3	2
Offshore substation	2	2	2	2	3	2	2
Onshore infrastructure	2	3	4	3	2	2	3
Turbine installation	1	1	2	1	4	2	2
Foundation installation	1	1	2	1	4	3	2
Subsea cable installation	1	1	2	1	4	3	2
Anchors and mooring installation	1	1	2	1	4	2	2
Onshore construction	2	4	4	4	1	2	4
Ports and logistics	3	3	3	4	3	1	3
Operations	2	3	3	3	3	4	3
Turbine inspection and maintenance	1	3	3	4	2	4	3
BoP inspection and maintenance	1	3	3	4	2	4	2

5 Maine Supply Chain SWOT Analysis

Strengths

- Good experience in some project development categories that can be utilized on future projects.
- Aqua Ventus project leading the way in the US floating wind arena
- Good focus on developing Maine ports to support commercial scale OSW projects
- Strong higher education system producing high value lead technical and engineering workers with a strong focus on innovation and data science
- Leading shipbuilding know-how and marine logistics capabilities.
- Academia, R&D and youth engagement/ training

Weaknesses

- Current absence of significant manufacturing capability for high capital expenditure items.
- Historically heavy steel fabrication capability has not been located in state.
- No clear experience in adjacent industries being untapped.
- Workforce labor gap still to be addressed (requirement for manual skills such as construction, manufacturing and fabrication) including to attain better representation for historically disadvantaged communities.
- Lack of companies involved in robotics, AI, data science relevant to OSW despite strength in R&D.

Opportunities

- The export supply opportunity remains high while the US supply chain is still to be firmly established, allowing for the possibility for an Maine company to capture a significant US market share should manufacturing capability be established in state.
- Opportunity to support fixed projects and build track record in developing commercial scale project in advance of a Maine leasing round and commercial scale floating wind projects.
- Opportunity for companies to spin off from academia and research work
- Boston is seen as the birthplace for AI and has a huge influence in the academic and business communities, this presents a regional collaboration opportunity.

Threats

- Dependency on US market volume to enable investment in facilities.
- Strength of competing supply chain from established OSW markets.
- Strong project pipelines in other states could result in companies being incentivized to locate in other states.
- Development of floating foundation technology not requiring deep water ports for installation.
-

6 Action Plan/Recommendations

6.1 Approach

Based on the information, assessment, and results of the completed project phases, and informed by virtual workshop sessions between members of Xodus Group and Maine GEO, a set of 14 recommendations have been developed.

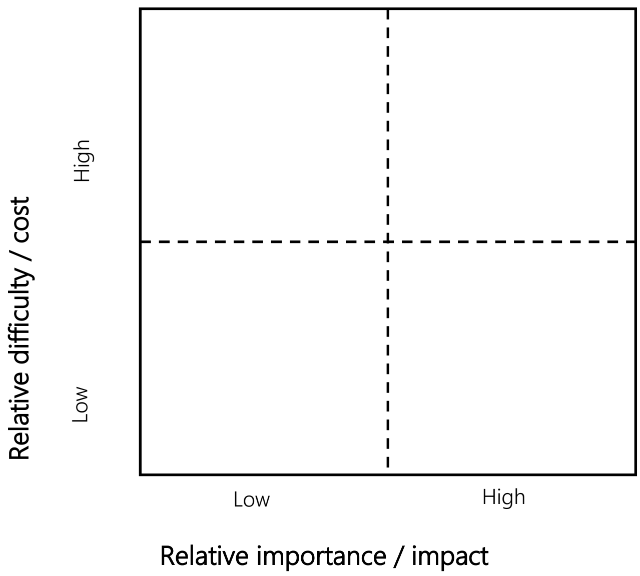
In these sessions, several thematic areas for recommendations were introduced:

- Market development
- Investment
- Innovation
- Policy

Recommendations were formulated, discussed, and categorized according to thematic area to show how various ideas could be developed to improve and bolster Maine's position within the OSW industry.

The recommendations for each thematic area were then transposed onto a matrix used to discern the associated relative difficultly and/or cost in addition to the relative importance and/or impact that implementing the recommendations would have. Considering in which quadrant recommendations fell on the impact-difficulty matrix enabled further characterization of their type according to four broad designations:

1. Lower difficulty/Lower Impact - Relatively straightforward to execute but somewhat limited consequence/outcomes. This group of recommendations is not urgent to implement but could be advanced opportunistically.
2. Higher difficulty/Lower impact - Complex/difficult to execute but somewhat limited consequence/outcomes. Recommendations in this group would benefit from further evaluation to assess cost/benefits.
3. Lower difficulty/Higher impact - Relatively straightforward to execute; should result in important consequence/outcomes. This group should be considered as higher priority.
4. Higher difficulty/Higher impact - Recommendations in this group are complex and/or challenging to execute; these should result in important consequence/outcomes. Recommendations in this group will benefit from strategic planning, coordination, and cost-sharing.



6.2 Recommendations

6.2.1 Market Recommendations

Market 1 – Further develop a bespoke supply chain registry dedicated to highlighting companies within the state that have capabilities to support OSW. This will enable OSW developers, OEMS and Tier 1s to access with greater ease the available Maine supply chain.

Market 2 – There is a unique opportunity for Maine to establish a position as a leader in the floating OSW sector. Several Maine based organizations have supported the project development of the New England Aqua Ventus project. As Maine gains experience in floating OSW, there will be an opportunity to export knowledge and experience to emerging floating OSW markets in the US, specifically the West Coast. The New England Aqua Ventus project and proposed research array gives Maine an early mover advantage to supply floating wind specific balance of plant components such as mooring ropes, cables and buoyancy products.

Market 3 – Leverage Maine's physical assets to support fixed projects and gain experience and prepare for floating projects in the Gulf of Maine and beyond. Focus should be paid to the ongoing efforts at Searsport to ensure robust business case is developed that identifies potential market share (fixed and floating) that the port could capture.

Market 4 – Through the analysis of Maine's supply chain databases, shipbuilding and maritime companies were identified such as Bath Iron Works and Lyman-Morse. Maine's experience in shipbuilding and marine logistics presents an opportunity to support CTV building, maritime logistics, and ports for service and maintenance. This knowledge can be exported along the East coast. A strategy should be developed to identify key partnerships that could be established on a regional or global basis to support the exporting of these services.

Market 5 – Matchmaking events to connect Maine companies to upcoming OSW project opportunities. Engage with key stakeholders i.e., project developers, OEM and Tier 1s to collaborate on matchmaking events which will encourage local content and alleviate the complexity of the OSW tendering process for small to medium-sized enterprises. This will be explored further in later phases of this project to ensure a roadmap for this recommendation is developed. It will be important to connect relevant 'OSW ready' companies based in Maine to projects in other states in order to gain relevant experience and position them to subsequently support the floating wind industry.

6.2.2 Policy Recommendations

Policy 1 – Create state OSW procurement policy to demonstrate ambition to industry. With other US states having developed and delivered strong OSW procurement targets there is a risk that project and supply chain development advances in other areas to a point where the opportunity for Maine companies to support becomes greatly limited.

Policy 2 – Support to ensure timely WEA leasing through BOEM will enable visibility and certainty of a nearby project pipeline in the Gulf of Maine. The current BOEM leasing pathway has the Gulf of Maine behind other regions for OSW development, including others suited to floating OSW projects.

Policy 3 – Regional and industry collaboration will be necessary to develop a Maine renewable energy cluster quickly and efficiently. A regional approach is essential which allows states to capitalize on their strengths and share resources across state lines to encourage supply chain growth. Further in-depth analysis should be performed to identify key opportunities for regional collaboration that are both beneficial for Maine and the industry as a whole. The study should define the geographical limitation of regional collaboration, the key objectives Maine would hope to achieve and an assessment of how the Maine OSW supply chain compares against various neighbouring states and, potentially, Canada.

6.2.3 Investment Recommendations

Investment 1 – A high visibility investment project (such as the establishment of a Maine OSW port) will attract OEM and Tier 1s to Maine which attracts attention from the industry and gives developers confidence in making investments. Investment in a Maine port for OSW activites will result in future supply chain growth clustered around the infrastructure. Maine's port facilities and maritime experience can contribute to the staging and marshalling of components and their port logistics. These services can be used in the project development phase for surveys, installation phase and throughout operations and maintenance.

Investment 2 – Consideration should be given to financial incentives to support state supply chain involvement in OSW and to attract organizations from outside the state (nationally and internationally) to set-up entities in Maine. Task 3 report details areas of supply chain to focus on in terms of investment following engagement with local organizations.

Investment 3 – Vessel Major Equipment Supply. Equipment used on installation vessels includes engines, cranes, navigation, heave compensation, jacking systems and dynamic positioning systems. Maine's deep maritime and defense background presents a significant opportunity for the state to leverage. A linkage to an OSW project could be a reason to choose Maine as an investment destination. Making leading suppliers aware of investment support for Maine could attract inward investment in this area; this model could be replicated for other identified needs within the supply chain as well.

6.2.4 Innovation Recommendations

Innovation 1 – Expand on the entrepreneurship and incubator programs at Roux University to attract entrepreneurs/start-ups in the field of data science and robotics and connect them to the OSW industry, academic and research institutions, and other technology development assets. Distinct from the efforts of NREL and NOWRDC, the purpose of this concept is to nurture ideas specific to AI, data science and robotics technologies and processes to build on Maine's leadership in innovation. This state-wide program would serve as 'hub' for technology screening and enable the acceleration of commercialization of innovative solutions. A strong focused should be placed on robotic technologies that contribute to the O&M phases of the project lifecycle, as that is where there is greatest opportunity for cost-saving.

Innovation 2 – Leverage Maine's academic and R&D capabilities, particularly in floating OSW. Current and future lessons learned from Maine's pilot array approach will be highly valuable to the OSW industry. Facilitating enhanced relationships and knowledge transfer partnerships with European innovation hubs may be beneficial to keep Maine's academic R&D institutions at forefront of the sector. ORE Catapult (UK) has established the Floating Offshore Wind Centre of Excellence (FOW CoE) in 2019 to accelerate the commercialization of floating OSW for the UK's benefit. A formal relationship with an organization such as this and could be an avenue for sharing best practices and lessons learnt.

Innovation 3 – Several universities in Maine have identified to have the core competencies and tools to support the role of AI, Data Science and Robotics in OSW. However, OSW specific research projects need to be encouraged. Develop research areas within the universities specifically targeted for data science and robotics in the OSW. By creating partnerships with companies internationally, Maine will develop relationships while advancing technology in OSW. Maine could pull these resources together into an industry advisory group (IAG) that will establish the link between AI/Data Science/Robotics and the OSW industry. This IAG could be a source of central funding to support ideas and initiatives in this area specific to OSW.

6.3 Summary

The tables below represent a summary of the recommendations identified during the workshops broken down in terms of the four broad designations as described in Section 6.1. These have been further prioritized to enable GEO to understand, relatively, the recommendations to action first.

Where applicable, it has been noted (*) if a recommendation could be broadened to support the broader clean energy sector in Maine.

6.3.1 Lower Difficulty/Higher Impact

RECOMMENDATION REF.	DESCRIPTION	RELATIVE PRIORITY
Market 3	Leverage Maine physical assets to support fixed projects	High
Market 2	Leverage first-mover advantage and establish as leaders in floating OSW (experience and supply)	High
Investment 3	Leverage Maine maritime capabilities to support vessel major equipment supply & attract investment for Maine	Low

6.3.2 Higher Difficulty/Higher Impact

RECOMMENDATION REF.	DESCRIPTION	RELATIVE PRIORITY
Policy 1	Create OSW procurement policy	High
Policy 2	Ensure timely WEA leasing through BOEM	High
Investment 1	High visibility investment in a port	High
Policy 3 *	Regional & industrial collaboration to develop a Maine renewable energy cluster	Medium
Market 4	Leverage Maines experience in shipbuilding to support CTV building	Low

6.3.3 Lower Difficulty/Lower Impact

RECOMMENDATION REF.	DESCRIPTION	RELATIVE PRIORITY
Market 5 *	Matchmaking events to connect Maine to OSW project opportunities	Medium
Innovation 2	Leverage R&D - lessons learned from pilot array	Medium
Innovation 3 *	Develop OSW specific research projects & research areas targeted for data science & robotics	Medium
Innovation 1 *	Expand on incubator programs at Roux to attract start-ups in data science & robotics	Low
Market 1 *	Further develop bespoke supply chain registry	Low

6.3.4 Higher Difficulty/Lower Impacts

RECOMMENDATION REF.	DESCRIPTION	RELATIVE PRIORITY
Investment 2	Financial incentives to support supply chain in OSW (state-wide, nationally & internationally)	Medium

APPENDIX A RECOMMENDATION WORKSHOP SESSION