New York State Great Lakes Wind Energy Feasibility Study: Infrastructure Assessment

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Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

New York State Great Lakes Wind Energy Feasibility Study: Infrastructure Assessment

Final Report

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Abstract

The Great Lakes Wind Feasibility Study investigates the feasibility of adding wind generated renewable energy projects to the New York State waters of Lake Erie and Lake Ontario. The study examines myriad issues, including environmental, maritime, economic, and social implications of wind energy areas in these bodies of freshwater and the potential contributions of these projects to the State's renewable energy portfolio and decarbonization goals under the New York State Climate Act.

The study, which was prepared in response to the New York Public Service Commission Order Case 15-E-0302, presents research conducted over an 18-month period. Twelve technical reports were produced in describing the key investigations while the overall feasibility study presents a summary and synthesis of all twelve relevant topics. This technical report offers the data modeling and scientific research collected to support and ascertain Great Lakes Wind feasibility to New York State.

To further inform the study in 2021, NYSERDA conducted four public webinars and a dedicated public feedback session via webinar, to collect verbal and written comments. Continuous communication with stakeholders was available through greatlakeswind@nyserda.ny.gov NYSERDA's dedicated study email address. Additionally, NYSERDA and circulated print advertisements in the counties adjacent to both Lake Erie and Lake Ontario as to collect and incorporate stakeholder input to the various topics covered by the feasibility study.

Keywords

Great Lakes, offshore wind, ports, wind turbine installation vessels

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Acronyms and Abbreviations

CTV	crew transfer vessel
DTU	Technical University of Denmark
FFI	floating foundation installer
GBF	gravity-base foundation
IEC	International Electrotechnical Commission
MT	metric ton (tonne)
MW	megawatts
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
OSV	offshore supply vessel
RNA	rotor nacelle assembly
TLP	tension-leg platform
U.S.	United States
WTIV	wind turbine installation vessel

Executive Summary

This report provides an assessment of available infrastructure and wind plant technologies that could be used to deploy wind energy in the Great Lakes. It examines possible deployment scenarios and upgrades that could support potential Great Lakes wind energy development. The inability of standard wind turbine installation vessels to navigate the locks and canals of the St. Lawrence Seaway is one of the most limiting factors of infrastructure for wind energy development on the Great Lakes. The optimal wind turbine substructure type would likely be some adaptation of an existing substructure that meets the ice, geotechnical, and logistical requirements for the region. In terms of infrastructure, all the ports considered would need upgrades to be able to accommodate wind energy development on the Great Lakes, including additional high capacity (lifting height and weight) cranes, expanded quayside length, expanded laydown area for component staging, and dredging of the channels and cargo ports to be able to accommodate the large vessels required to transport, assemble, and install wind turbines in the Great Lakes.

1 Introduction

This study comprehensively assesses the existing ports and infrastructure in the Great Lakes that could support the development of wind energy for the New York State, including the eastern portion of Lake Erie and the United States portion of Lake Ontario. Conventional offshore wind infrastructure systems and facilities primarily include manufacturing facilities for components, transportation of those components to port, assembly of the components either at port or on site, and installation of the assembled systems. These conventional processes are evaluated for their feasibility in the Great Lakes. Gaps and constraints are identified where improvements and upgrades would be required to support Great Lakes Wind.

Due to relatively shallow water depths, wind projects in Lake Erie will likely use fixed-bottom substructures, whereas projects in the relatively deeper water depths of Lake Ontario will likely need to use floating substructures. Each type of technology requires a different set of procedures and various equipment to assemble and install. For fixed-bottom projects in Lake Erie, the general development procedure follows the manufacturing of components, transportation of those components to port, loading components on a capable installation vessel at port, transiting the vessel to site, and assembly and installation of the system. These installation vessels typically require heavy-lift cranes to assemble and install the substructure and turbine components on site. For floating projects in Lake Ontario, the general development procedure follows the manufacturing of components, transportation of those components to port, assembly of the substructure and turbine at port, transiting of the assembled substructure and turbine from port to site, and connecting the floating system to a pre-installed mooring system. Most floating systems will require sizable quayside space and heavy-lift cranes at port for assembly.

This study begins with a discussion of the required vessels for Great Lakes Wind development and how the dimensions of the St. Lawrence Seaway limit the availability of capable vessels. Following the vessel evaluation, a range of turbine and substructure component sizes are identified as feasible for the Great Lakes. Using the vessel, turbine, and substructure information, an analysis of the ports on Lake Erie and Lake Ontario is given, in which the feasibility of each port is evaluated for wind energy development. In general, the feasibility assessment in this study assumes the use of typical offshore wind installation processes. In the future, there may be opportunities to customize port and infrastructure solutions that would be more feasible and cost-effective for wind energy projects in the Great Lakes.

2 Vessels

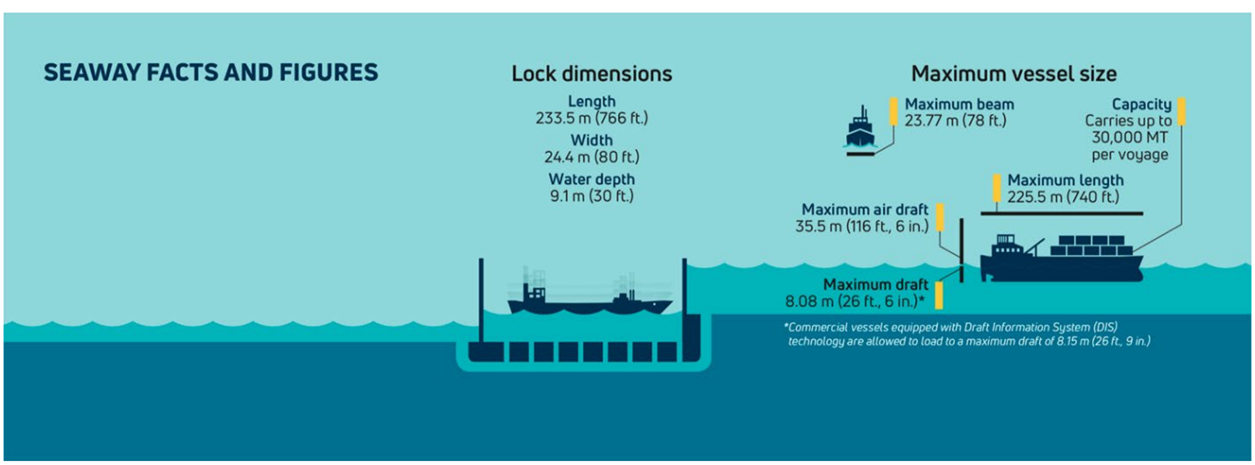
Offshore wind developers use various specialized vessels to support the transportation and installation of wind turbines, substructures, substations, and submarine cables. Different vessels are needed for fixed-bottom versus floating wind projects and the types and capacities of available vessels in the Great Lakes will significantly determine requirements for other port and infrastructure systems. For fixed-bottom projects, wind turbine installation vessels (WTIVs) are typically used to install the turbine and substructure at the site where the turbine will operate. For floating projects, either submergible barge-vessels are used to carry an assembled substructure and turbine to site, or towing vessels, such as tugboats, are used to tow the floating structure. To support wind energy development in the Great Lakes, these vessels would either need to (1) transit the locks and canals of the St. Lawrence Seaways, (2) already exist in the Great Lakes, or (3) need to be built specifically for Great Lakes Wind. The availability of these vessels is one of the most limiting factors of infrastructure for wind energy development on the Great Lakes.

2.1 St. Lawrence Seaway

The most limiting physical constraint on the types of vessels available in the Great Lakes is the dimensions of the St. Lawrence Seaway. Most conventional vessels used for offshore wind development are too large to transit the series of locks and canals. There are seven locks (two are American and five are Canadian) among four canals between Montreal and Lake Ontario and there are eight locks in the Welland Canal that connect Lake Ontario to Lake Erie.[1]

Figure 1. St. Lawrence Seaway System of Locks and Canals

Source: Great Lakes St. Lawrence Seaway Development Corporation n.d.



The standard lock size for the entire St. Lawrence Seaway is 233.5 meters in length, 24.4 meters wide and 9.1 meters in draft, and the maximum vessel size that can navigate the locks is 225.5 meters long, 23.77 meters wide and 8.08 meters in draft (Figure 1). The maximum height for overhead clearance, or air draft, is 35.5 meters. The maximum capacity of these vessels is 30,000 metric tonnes (MT).[2]

2.2 Jones Act

The Jones Act creates another limitation on the vessels that can be used to install wind turbines on the Great Lakes. This act states that any vessel transporting goods from one U.S. port to another must be built, registered, owned, and crewed by U.S. citizens. Individual wind turbine locations in U.S. waters are treated as U.S. ports under the Jones Act. This means that foreign-flagged ships cannot load wind turbine components from a U.S. port on shore and unload them to a wind turbine installation site. Offshore wind projects in Rhode Island and Virginia were able to use foreign-flagged installation vessels stationed at a turbine site in combination with smaller U.S.-flagged feeder vessels that brought turbine components out to the installation vessel[3]. Transportation of components between Canadian ports and U.S. wind farm sites does not fall under the Jones Act and could be feasible, but we did not include a full assessment of Canadian port capabilities since this study is primarily interested in the potential effects on the New York State economy.

2.3 Vessel Types

Vessels for potential Great Lakes development would either (1) come from outside the Great Lakes through the St. Lawrence Seaway, (2) already exist in the Great Lakes, or (3) be custom built for the Great Lakes. Most vessels used for offshore wind development are too large to transit the locks and canals of the St. Lawrence Seaway and would not be able to access the Lakes. Table 1 lists the types of vessels required for the installation of offshore wind farms in the ocean and their maximum and minimum dimensions[4] with a depiction of the size of a conventional WTIV shown in Figure 2. The dimensions of each vessel in Table 1 are compared to the maximum allowable dimensions of the St. Lawrence Seaway locks. The green shaded squares indicate that the vessel can fit through the locks and the red shaded squares indicate vessel dimensions that exceed the limit.

Table 1. Types of Vessels Used to Install Offshore Wind Plants and Minimum and Maximum Dimensions of the Current Fleet

Source: Douglas-Westwood, 2013

Vessels	Min length	Max length	Min width	Max width	Min draft	Max draft
*WTIV	75 m	160 m	30 m	50 m	3.4 m	10.9 m
Jack-ups	40 m	100 m	20 m	40 m	2.4 m	8.3 m
Heavy lift	100 m	180 m	25 m	70 m	3.6 m	13.5 m
Cable lay	25 m	150 m	10 m	30 m	2 m	9.1 m
**OSV	45 m	110 m	10 m	25 m	3.8 m	6.7 m
***CTV	20 m	70 m	5 m	15 m	0.9 m	3.6 m
Tugs	20 m	50 m	5 m	15 m	3.2 m	6.3 m
Barges	25 m	100 m	10 m	25 m	2.5 m	3.6 m
Survey	15 m	160 m	5 m	30 m	1.2 m	8 m
Max vessel dimensions for lock		225.5 m		23.77 m		8.08 m

* WTIV–Wind Turbine Installation Vessel

** OSV–Offshore Supply Vessel

*** CTV–Crew Transfer Vessel

Figure 2. Example Installation Vessel Used for Offshore Wind Development

Source: Photo by Lyfted Media for Dominion Energy

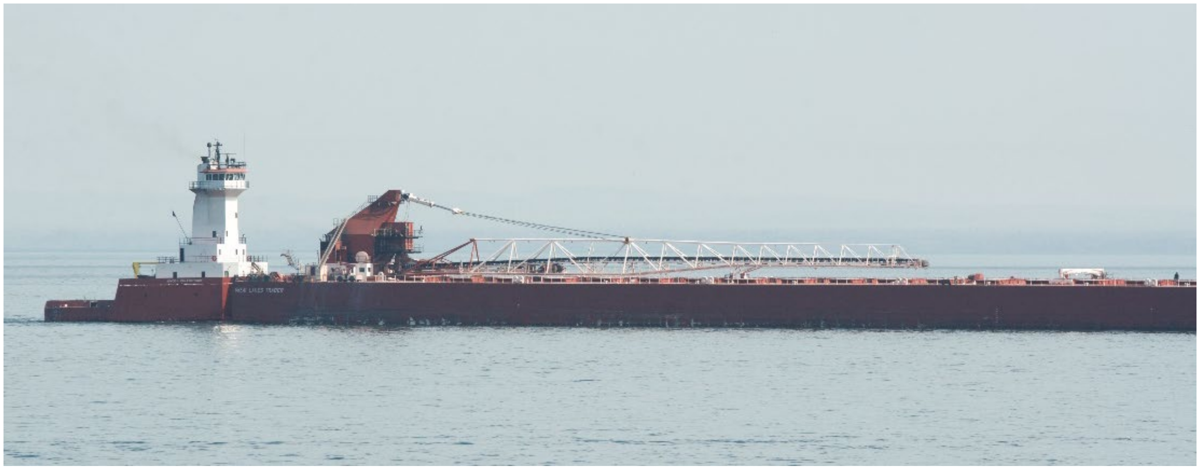
WTIVs, jack-ups, and heavy lift vessels are the larger vessels typically used to transport, lift, or assemble offshore wind turbines and substructures. The remaining vessels are used for various aspects of offshore wind development, operation, and maintenance. Most vessel types are restricted from navigating the St. Lawrence Seaway due to beam width, while several are also restricted due to the vessel's draft. Based on Table 1, the minimum and maximum sizes of WTIVs and heavy lift vessels used in industry today are too big to fit through the locks on the St. Lawrence Seaway.[5] The smaller sizes of jack-ups, cable lay, offshore supply vessels (OSV), barges, and survey vessels are able to transit the St. Lawrence Seaway, as well as any typical crew transfer vessel (CTV) or tugboat.

Given that WTIVs and heavy-lift vessels are too large to transit the locks, smaller jack-ups and towing vessels are the primary options of potential vessels to navigate the locks for fixed-bottom and floating turbine and substructure installation, respectively. Smaller jack-ups are technically feasible to navigate the St. Lawrence Seaway but would not be an ideal candidate vessel type for fixed-bottom installations. One example of a feasible jack-up vessel, with a maximum crane load of 680 tonnes at a 43-meter crane height, can transport and install wind turbines with rated capacities of up to 4–5 megawatts (MW).[6] Tugboats do not impose limits on the size of floating turbines and substructures. For typical installations using only tugboats, any floating turbine and substructure size must be fully assembled in port and able to maintain stability during towing.

There are few, if any, vessels capable of supporting Great Lakes wind farm development already in the Great Lakes. Current ships that navigate the Great Lakes primarily consist of large bulk cargo vessels that transport goods to ports in the Great Lakes via the St. Lawrence Seaway. Other than that, the remaining types of vessels on the Great Lakes are various oil or chemical tankers, tugboats and barges, or passenger boats and ferries.[7] Figure 3 shows an example of a tugboat and barge that are used to transport bulk cargo in the Great Lakes.

Figure 3. Example Great Lakes Tug and Barge

Source: Photo by Peter J Markham



One of the most common vessels on the Great Lakes are large lake. Most of these freighters are designed to transport free-flowing bulk cargoes such as coal or grain; however, some vessels can carry large items, including wind turbine blades. Oil or chemical tankers are designed for specific types of liquid cargoes and are unlikely to play a role in the development of wind energy on the Great Lakes. The only ships that currently exist on the Great Lakes that could be used to install wind turbines are tugboats and barges. As described previously, tugboats can tow floating turbines and substructures into position for mooring connection.[8] It would be possible to install fixed-bottom turbines on Lake Erie using barges by, for example, combining multiple smaller barges in conjunction with a land-based crane. Barges can also be used for floating projects to support a fully assembled substructure as it is transferred from the quayside at port to the water.

Vessels transiting the St. Lawrence Seaway or vessels currently existing in the Great Lakes are not the only two options. Vessels could also be constructed or retrofitted specifically for Great Lakes Wind development. A purpose-built vessel for wind turbine installation on the Great Lakes could be designed with the capability to handle larger turbines and substructures, including the 12–15 MW sizes that are planned to be deployed on the Atlantic coast. To install turbines of that size, a vessel would likely be too large to transit the locks of the St. Lawrence Seaway, so the vessel would have to permanently reside in the Great Lakes (excluding Lake Ontario, which is separated from Lake Erie by the Welland Canal). The economic feasibility of constructing such a vessel would depend on achieving a large enough pipeline of wind energy development throughout the Great Lakes.

2.4 Vessel Requirements

The vessels needed for fixed-bottom projects, required in Lake Erie, differ from the vessels needed for floating projects, such as those required in Lake Ontario. The following discusses the necessary vessel solutions for fixed-bottom projects in Lake Erie and floating projects in Lake Ontario.

2.4.1 Lake Erie

Fixed-bottom offshore wind development typically involves a WTIV to transport the substructure and turbine components from port to site and then install the system on site, as well as other procedures that require the use of the other types of vessels listed in Table 1. The smaller auxiliary vessels are able to transit the locks of the St. Lawrence Seaway, but the larger vessels needed for component installation are too large to access the Great Lakes. Smaller jack-ups would potentially be able to transit the locks and install turbines but only to a maximum turbine capacity of 4–5 MW.

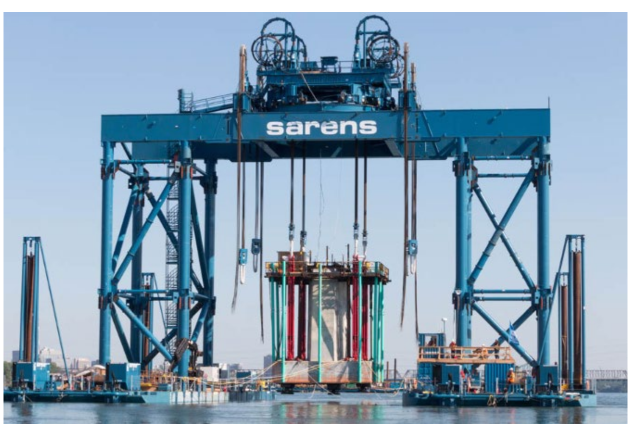
Non-conventional, innovative installation vessel solutions have potential in Lake Erie, such as an altered barge with a land-based crane. An example of this solution was used during the construction of Windpark Fryslân on Lake Ijsselmeer in the Netherlands. The project consists of 89 4.3 MW wind turbines on monopiles in 3–6 meters of water. Access to the lake is via locks that are too small for traditional WTIVs. To install the monopiles and turbines, a large, shallow installation barge called the Sarens Soccer Pitch was assembled from many smaller barges on the lake (Figure 4). It consists of a heavy-lift crane, 88 modular barges, and a twin barge, with beams installed on top of the barges to distribute the load from the main crane across the barges. The Sarens barge was equipped with four legs that can be grounded into the seabed for stability.[9] The system used feeder vessels to deliver substructure components to the main barge for installation.

Figure 4. Sarens Soccer Pitch, Consisting of an Assembly of Smaller Barges and Outfitted with a Heavy-Lift Crane for Monopile and Wind Turbine Installation

Source: Sarens 2021

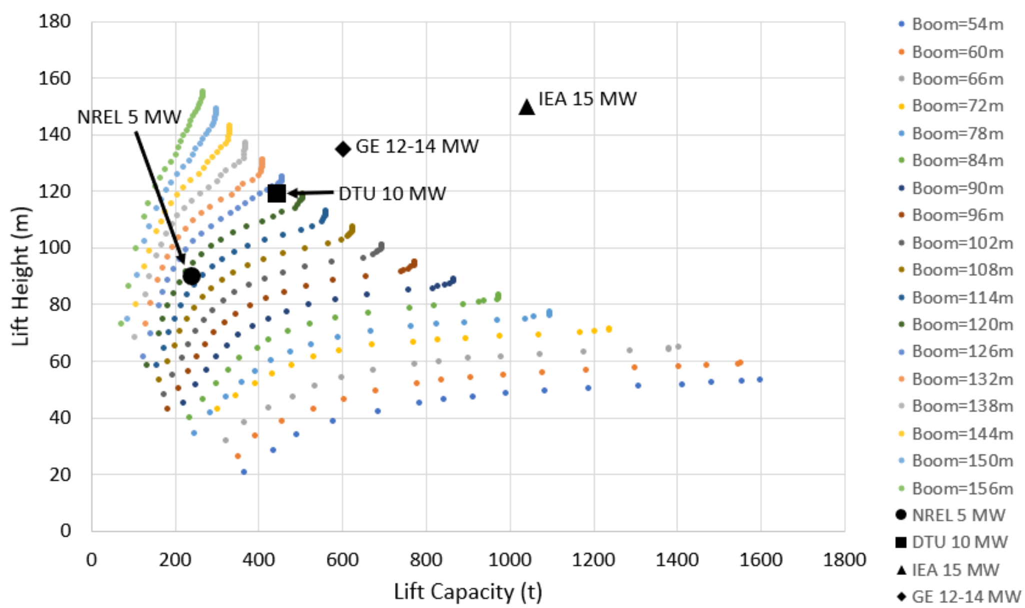
Another applicable example for Lake Erie is the Floating Foundation Installer (FFI), also designed by Sarens, that was used to perform footing installations for the New Champlain Bridge in Montreal, Canada, which crosses the St. Lawrence River (Figure 5). The FFI is a floating catamaran with a gantry crane that can lift, transport, and install bridge foundations on the bottom of the river. It consists of two barges primarily connected by two towers and the gantry beam, and the crane can lift up to 1,000 tonnes. It is self-propelled, outfitted with eight thrusters, and can operate and maneuver in strong currents.[10] While it has a large lifting capacity, it has a limited lifting height, which would make it difficult to support wind turbine installations, but could be feasible for substructure installations.

Figure 5. Sarens Floating Foundation Installer (FFI) Used to Lift, Transport, and Install Bridge Foundations in the St. Lawrence River



Wind energy development in Lake Erie could use similar creative approaches for fixed-bottom installations. There are dozens of barges on the Great Lakes[11] that can operate in Lake Erie and could potentially be outfitted with heavy lifting equipment, such as land-based cranes. One of the world's largest land-based crawler cranes, the DEMAG CC 8800-1, is one example of a crane that could be feasible to put on a barge for fixed-bottom installation projects in Lake Erie. It has a maximum capacity of 1,600 tonnes and a maximum hook height of 231 meters. To estimate its capacity to potentially lift and install a nacelle on top of a wind turbine tower, this crane can lift 860 tonnes at a height of 90 meters, 550 tonnes at a height of 114 meters, 496 tonnes at a height of 120 meters, and 268 tonnes at a height of 156 meters.[12] For reference, the NREL 5 MW reference turbine has a nacelle mass of 240 tonnes and a hub height of 90 meters and the DTU (Technical University of Denmark [Danmarks Tekniske Universitet]) 10 MW reference turbine has a nacelle mass of 446 tonnes and a hub height of 119 meters. A detailed figure of this crane's lift capacity and height limits is shown in Figure 6. Each different color represents a different boom length of the crane and each dot along those lines represents a different hook radius, with dsmaller radii forming the top of the curves at the higher lift heights.

Figure 6. DEMAG CC 8800-1 Crane Lift Capacity and Height Limits as Related to Turbine Installations



A crane of this size mounted on an assembly of barges, like the Sarens Soccer Pitch, could theoretically be used to transport and install turbines and substructures on the order of 5–10 MW. The barge assembly would have to be engineered properly to support the weights and moments of the crane.

These kinds of customized, innovative installation solutions are likely to be the most technically and economically feasible for fixed-bottom projects in Lake Erie. Similar solutions can also be developed to support other non-installation procedures, like maintenance and repair. A custom-built installation vessel that could permanently reside in the Great Lakes is another possible solution, but none exist today. These fixed-bottom solutions may become more attractive if regional development of Great Lakes Wind, with Lake Erie in particular, expands beyond the New York State.

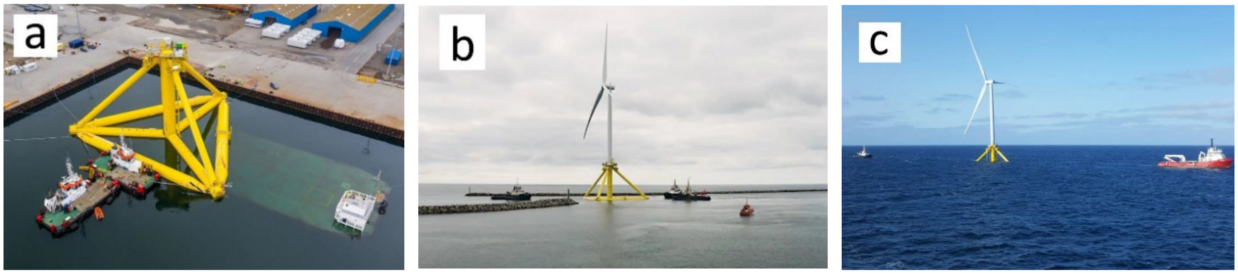
2.4.2 Lake Ontario

Floating offshore wind development typically involves the assembly and commissioning of the substructure and turbine at port, and then transportation of the fully assembled system to site either by a heavy-lift vessel or by tugboats for connection to the mooring system. Conventional heavy-lift transport vessels are too large to transit the locks of the St. Lawrence Seaway, which leaves tugboats or submergible barges as the primary options for transporting the assembled floating system out to site. Installation of the mooring system would also be handled by anchor handling tug supply vessels, which would be able to navigate the locks of the St. Lawrence Seaway.

One example of a recent floating wind project that represents a possible installation strategy in Lake Ontario is the TetraSpar Demonstration Project, which successfully installed a 3.6 MW Siemens Gamesa Renewable Energy wind turbine on a TetraSpar substructure off the coast of Norway in July 2021.[13] Turbine and substructure components were manufactured in Denmark and transported by road to the Port of Grenaa, Denmark. The substructure was assembled at quayside using only cranes and no other specialized equipment, and then transferred to a submergible barge at port (Figure 6a) using self-propelled modular transporters. The turbine was then installed on the assembled substructure in the water using a land-based crane, with the rotor nacelle assembly (RNA) installed as one piece. The completely assembled turbine and substructure was towed from the Port of Grenaa (Figure 6b) using tugboats to the METCentre test site in Norway and then connected to the mooring system and subsea cable (Figure 6c) using small, but appropriate installation vessels.

Figure 7. Lake Ontario Representative Installation and Vessel Solution

Source: "The TetraSpar full-scale demonstration project" n.d.



A similar procedure would be feasible for floating projects in Lake Ontario. The rated capacity of wind turbines in Lake Ontario is not limited by vessel availability as tugboats would be able to transport a turbine of any size. There are many tugboats and barges that currently exist in the Great Lakes that could be used to transport floating systems of any size from port to site. It would be up to the developer to determine what size barges or how many tugboats are required for a desired level of turbine or plant capacity. Other novel floating project installation solutions that have not been developed yet could be equally feasible in the Great Lakes. As floating wind is still in a nascent stage of development, the most likely optimal solution for the Great Lakes, and Lake Ontario in particular, will be an adaptation of the methods used for ocean projects customized for the unique vessel constraints of the Great Lakes.

3 Turbines and Substructures

3.1 Turbines

Wind turbine size is a key parameter that affects all aspects of a project, from its cost and installation logistics to power output and visual impacts. For ocean-based offshore wind, these factors have tended to promote increasing turbine size, with manufacturers beginning to produce wind turbines with capacities of 14–15 MW.[14] Larger turbines allow for significant reductions in per-MW costs of installation, operation, and maintenance because there are fewer units to install and maintain for a given power output. Larger turbines also reduce substructure unit costs because less material is needed per megawatt. Reducing the number of turbines and associated cables can lower cable costs and lessen environmental impacts due to cable burial. Subjectively, fewer, larger turbines can potentially reduce visual impacts.

However, larger turbines would require larger installation vessels for fixed-bottom turbines in Lake Erie and increased port infrastructure capacity to handle them. For fixed-bottom projects, the dimensions of the locks on the St. Lawrence Seaway prevent conventional, ocean-based wind turbine installation vessels from operating in the Great Lakes, so only smaller turbines that can be installed by existing lake vessels such as barge-mounted cranes or smaller jack-up vessels are considered.

The maximum size of jack-up vessel that could enter the Great Lakes via the St. Lawrence Seaway can support wind turbines on the order of 4–5 MW and the largest available crane for an altered-barge installation solution can potentially support turbines on the order of 5–10 MW. However, using findings from other parts of this study, such as port constraints and viewshed considerations, the range of potential turbine capacities for Lake Erie was conservatively set at 4–7 MW. Floating projects in Lake Ontario are not limited by the size of installation vessels and would only be limited by the sizes and capacities of cranes at port. For the purposes of this analysis, it is assumed that both lakes would have the same 4–7 MW turbine capacity range, but turbine upscaling may be easier on Lake Ontario. This range is consistent with emerging markets for larger land-based wind turbines. The use of land-based turbine models would enable Great Lakes Wind to leverage a domestic supply chain that already exists to serve land-based wind installations in the Great Plains, western New York State and Pennsylvania, and other U.S regions. Table 2 lists key characteristics for wind turbines with rated capacities between 4–7 MW. These turbines represent the size range of turbines that may be feasible with existing technology on the Great Lakes.

Table 2. Characteristics of Commercially Available 4-7 MW Wind Turbines and NREL 5 MW Reference Turbine

Source: Manufacturers' websites and NREL analysis

Manufacturer/ Source	Model	Location	Rated Power (MW)	Specific Power (W/m^2)	Rotor Diameter (m)	Tip height* (m)
GE	Haliade 150-6MW	offshore	6.0	340	150	175
GE	Cypress 6.0-164	land	6.0	284	164	189
Nordex	N149/5.X	land	5.0 – 5.5	315	149	174
SGRE	SWT-6.0-154	offshore	6.0	322	154	179
SGRE	SG 5.0-145	land	4.0 – 5.0	303	145	170
Vestas	EnVentus V150-6.0	land	6.0	340	150	175
Vestas	V136-4.2	land	4.2	289	136	161
NREL	5MW Reference	offshore	5.0	401	126	151

* Tip height = rotor diameter + 25 m clearance from mean lake height, regardless of currently available hub heights.

Rotor diameters for 4–7 MW wind turbines are between 120 meters (m) and 170 m. Manufacturers typically offer a range of hub heights that can be customized for specific site conditions; the minimum hub height must provide sufficient clearance between the rotor and the ground or waterline. Tip heights in Table 2 are assumed to be the full rotor diameter plus an additional 25 m clearance. Nacelle masses and other weights were not included in Table 2 because in most cases they are not published on manufacturers' websites; however, some estimates can be made. The most demanding lift, due to the height and component weights, is the RNA. Examples of RNA masses for wind turbines in the 4–7 MW size range include the NREL 5 MW reference turbine with a nacelle mass of 240 tonnes and an RNA mass of 350 tonnes, and the General Electric (GE) Haliade 6 MW turbines with an RNA mass of 400 tonnes.[15]

The GE Cypress 6.0–164 was selected from Table 2 as one example of a turbine that would be feasible for Great Lakes Wind. This turbine is representative of a machine designed for the IEC Class II wind resource that is characteristic of Lakes Erie and Ontario. The turbine's larger rotor diameter improves its power production in lower wind speeds. The large rotor diameter also provides a conservative (worst case) scenario for evaluating the viewshed. In addition, GE's presence in the New York State region can potentially have secondary benefits for the local economy.

The detailed dimensions and weights of the GE Cypress 6.0-164 are not publicly available, but the RNA mass is assumed to be on the order of 350 tonne, with an estimated nacelle mass between 200 and 220 tonne, based on weights of similar turbines. This weight would be feasible for heavy-lift cranes that can be outfitted to a barge as a potential installation solution for fixed-bottom turbines in Lake Erie. Lake Ontario can potentially support much larger turbines, since ports could have multiple heavy-lift cranes at quayside to assemble turbines, on the order of 15 MW. However, the size of the GE Cypress 6.0–164 is still used as a primary turbine example for all aspects of this study, fixed and floating.

3.2 Substructures

Fixed-bottom and floating projects use the same turbines; however, the substructures for each will vary depending on the seabed and other physical conditions. The substructure options for fixed and floating turbines are discussed in detail in the Great Lakes Wind Energy Substructure Study,[16] but their approximate dimensions and weights for a 4–7 MW turbine are discussed here and will be used as a basis for following port requirements. These dimensions and weights will vary depending on the specific site conditions and even the infrastructure constraints but are representative of substructures that can support 4–7 MW turbines in the Great Lakes.

Based on the analysis in part I of the substructure Study[17], feasible fixed-bottom substructures for wind turbines in the Great Lakes may include gravity-base foundations (GBFs), piled tripods or those that use suction bucket foundations, and monobuckets. Concrete GBFs historically have been used in shallow waters (e.g., 20–30 m) although the only limit to deeper installations is cost. They have base diameters between 20–35 meters, and weigh about 3,000–4,000 tonnes. GBFs can be constructed at port or in dry-dock, and then floated out to site. Tripods can be used at any depth in Lake Erie, which would require a maximum component length of about 50 meters, and they can weigh up to 1,500 tonnes. For piled tripods, substructure installation vessels would be needed. In comparison with pile driving, the installation of the suction bucket tripod would be relatively simple given the suction bucket installation equipment is self-contained on the tripod legs. Monobuckets would use the same installation technology as the suction buckets of a tripod, are feasible at any depth in Lake Erie (e.g., 15-55 meters), and would weigh no more than a tripod. Refer to part I of the substructure study[18] for more information on fixed-bottom substructures.

Based on the analysis in part II of the substructure study[19], feasible floating substructures for the Great Lakes are tension-leg platforms (TLPs) and hybrid substructures (e.g., the TetraSpar). The TetraSpar consists of components that are no greater than 30–40 meters in length, and the entire floater, including ballast, is upwards of 1,300 tonnes.[20] The dimensions and weights of TLPs are less certain because they have not yet been demonstrated for offshore wind, but some studies suggest that a TLP substructure could weigh up to 1,320 tonne for a 6 MW turbine[21] or 950 tonne for a 6 MW turbine with 25 m steel structural components.[22] Another study investigated various TLP component configurations and found optimal substructure weights between 800 and 1,300 tonne, with 28–35 m component lengths for a 5 MW turbine.[23] However, they are likely to be similar to the TetraSpar. Refer to part II of the substructure study[24] for more information.

4 Ports

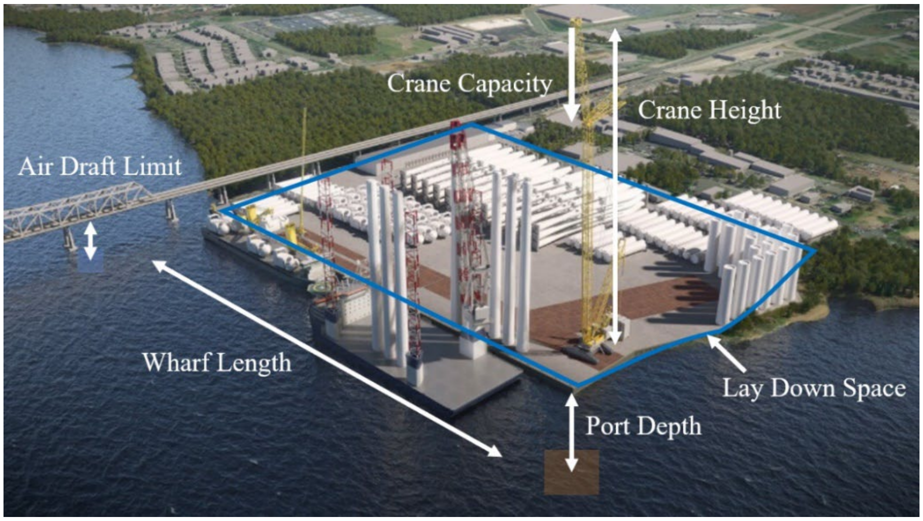
4.1 Port Requirements

As a primary factor in the overall infrastructure of the Great Lakes, the ports on the lakes need to be able to support the expected level of wind farm development. Ports for wind farm development require a certain capacity to assemble, load, and install wind turbines and substructures. In general, there are three main types of ports: manufacturing ports, operations and maintenance (O&M) ports, and marshalling ports. Manufacturing ports contain the manufacturing facilities and processes in port, where the turbine and substructure components can be directly assembled and transferred to installation vessels. O&M ports are the base for all operational and maintenance activities for a wind project's lifetime and are typically as close to the wind farm as possible. Marshalling ports are typically smaller ports with less equipment and facilities and assist with the transfer of manufactured components to installation vessels near the wind farm site to minimize the time and cost of an installation vessel on site.[25]

Great Lakes ports likely do not have the proper manufacturing facilities at port for Great Lakes Wind projects but will still be able to assemble turbines and substructures and transfer them to installation vessels or the lake for fixed-bottom and floating projects, respectively. Until manufacturing ports are in operation on the Great Lakes, turbine and substructure components will have to be transported from outside manufacturing facilities to a Great Lakes port by either water, rail, or highway, and offloaded to either a quayside area at port, a floating barge staging area, or the installation vessel itself. From there, depending on the handling capacities at port, the components can be assembled, transported to site, and installed on site. A general port layout for wind farm development is shown in Figure 7 and the following list defines a set of requirements for ports to support wind energy development in the Great Lakes.

Figure 8. General Port Layout to Support Wind Farm Development

Source: Atlantic Offshore Terminal



Great Lakes Wind port requirements:

- **Crane capacity**: the largest amount of weight that a crane can lift. Crane capacities vary with parameters such as the boom length, the hook radius, or the counterweight. Note crane lifting capacity decreases as the height of the lift increases.
- **Crane height**: the furthest extension of the boom to lift components to the top of a turbine tower.
- **Laydown space:** the area required for turbine and substructure components to rest, typically quayside.
- **Port depth:** the water depth where vessels may dock at port or where substructures will be assembled including the channel onto the lake.
- **Wharf length:** The total length of the wharf where a vessel may dock at port.
- **Air draft:** the height of a structure above the waterline. Examples of air draft limits are bridges or powerlines.

The following subsections discuss the limits of these requirements as they apply to potential fixed-bottom and floating projects at Great Lakes ports that can support the transfer of components, assembly of components, and installation of turbines and substructures. The assumption that only fixed-bottom projects will be feasible in Lake Erie and only floating projects will be feasible in Lake Ontario is applied.

4.1.1 Lake Erie

In general, for fixed-bottom projects in Lake Erie, the substructure and turbine can be transported out to site and then assembled and installed using an installation vessel. This installation method typically involves the use of WTIVs and other ocean-based installation vessels, which are not able to access the Great Lakes. Because of this, vessels like altered barges that are outfitted with land-based cranes will likely be used for fixed-bottom installations. Another possible solution to avoid the need for an installation vessel would be to use a substructure that can be assembled in a dry dock and then floated out to the installation site and sunk. However, a vessel that is large enough to support a land-based crane would still be needed to install the turbine. An example layout of the Port of Bremerhaven and the loading of fully assembled fixed-bottom substructures onto vessels is shown in Figure 8a. An example of how tripod substructures loaded onto a barge could be towed out to site using tugboats is shown in Figure 8b, and an example of how those tripods might be installed on site using a crane-mounted vessel is shown in Figure 8c.

Figure 9. Example of Offshore Wind Port to Show the Scaling of Various Components for a Project that Uses Fixed-Bottom Substructures

Source: "New Bedford Delegation Visits EUROGATE Container Terminal Bremerhaven, Germany" 2013

Figure 10. Example of a Potential Installation Vessel Solution where Assembled Tripods are Loaded onto a Barge

Source: Manzano-Agugliaro et al. 2020

Figure 11. Installed on Site by a Barge-Crane Used for the Alpha Ventus Windfarm

Source: Manzano-Agugliaro et al. 2020

Referencing the example 6 MW turbine and any of the feasible fixed-bottom substructures, the port requirements for fixed-bottom turbine and substructure development are as follows: The RNA of the candidate turbine would likely weigh on the order of 350 tonne and would need to be lifted to a maximum hub height of about 115 m for the 4–7 MW class turbines. This RNA assembly process would likely be performed by a crane on the installation vessel and would be completed as the whole rotor-nacelle assembly to save installation time. At port, a crane is required to assemble individual turbine and substructure components and then transfer the turbine and substructure to an installation vessel. If a GBF substructure is desired, it would likely either need to be assembled at port and lifted onto a submergible barge, or assembled on the barge, and finally submerged at port to be towed to site. Tripods and monobuckets would likely be assembled at port and then transferred to an installation vessel, possibly by the crane already on the installation vessel or by other cranes at port. Therefore, ignoring the crane requirements for the installation vessel, the required port crane capacity would need to potentially lift fully assembled tripods that can weigh up to 1,500 tonne, but only at a height of up to 50 m. If there are to be other solutions to transfer a fully assembled substructure to an installation vessel or have the installation vessel's crane assemble the substructure on site. The required port crane capacity would then decrease to the heaviest individual substructure or turbine component.

The required laydown space would vary based on the substructure type, the processes needed to handle the substructure's components, the project size, and the installation vessel type. Based on other ports that have supported offshore wind and the space they required, the minimum laydown space required is assumed to be 25 acres.[26] The required port depth would need to be deep enough to support a fully loaded installation vessel (i.e., a barge), which will depend on the installation vessel type, or the port would need to be deep enough to support a fully loaded semi-submersible barge used for substructures like a GBF. Using the Sarens Soccer Pitch[27] as a representative installation vessel solution in Lake Erie, the modular barges used to assemble the floating platform have a draft of 1.85 m[28]. Fully loaded and assembled, the complete altered barge would not be expected to have a large draft, which means the required port depth would be relatively low. The required wharf length would also depend on the size of the installation vessel but again, referencing the size of the Sarens Soccer Pitch, the length of a representative installation vessel would likely be on the order of 100–150 m, which would set the required wharf length. Ideally, the wharf length would be able to support the length of the installation vessel plus the length of any other substructure components in queue for general efficiency and component maneuverability at port. The last port requirement is the air draft limit, to ensure that the height of the turbine and substructure components at port or on the installation vessel would not interfere with any existing structure, such as powerlines or bridges, respectively. These will need to be considered before assembly and installation procedures start.

It should be noted that these conventional assembly and installation methods for fixed-bottom wind projects are what are being used for ocean-based applications today. It is not to say that this is the only way to assemble and install fixed-bottom systems. More customized approaches and methods that are tailored for the Great Lakes are likely to be more efficient.

4.1.2 Lake Ontario

In general, for floating projects on Lake Ontario, each floating wind turbine unit can be assembled in port and floated out to the installation site. This type of installation requires a large crane at port but alleviates the need for large installation vessels on the lake. It would also open the possibility of using multiple heavy-lift cranes to support larger capacity turbines. Figure 9 shows an example of the port (a) and installation method (b, c, d) used for installing the TetraSpar, which is considered a “hybrid” substructure, and would be feasible in Lake Ontario.

Figure 12. The Port in Denmark and Quayside Space Used for Installation

Source: “The TetraSpar full-scale demonstration project” n.d.

Figure 13. The Size of the Substructure Components Relative to the Required Cranes at Port

Source: “The TetraSpar full-scale demonstration project” n.d.

Figure 14. How the Assembled Substructure Was Initially Floated

Source: "The TetraSpar full-scale demonstration project" n.d.

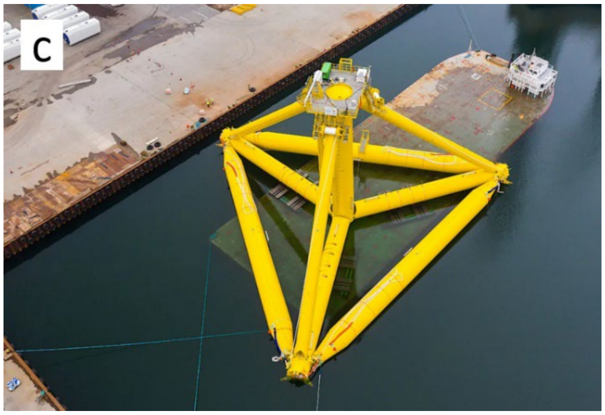
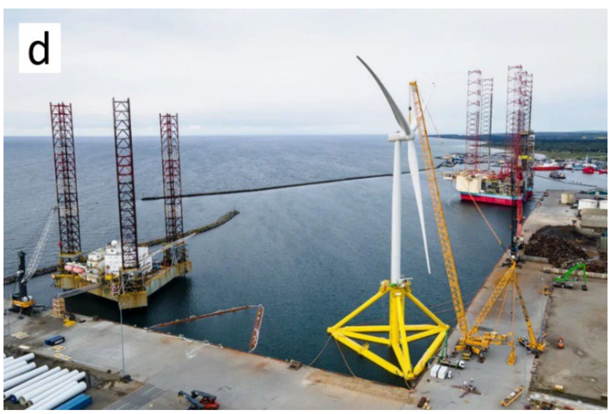


Figure 15. How the Turbine Was Installed at Port

Source: "The TetraSpar full-scale demonstration project" n.d.



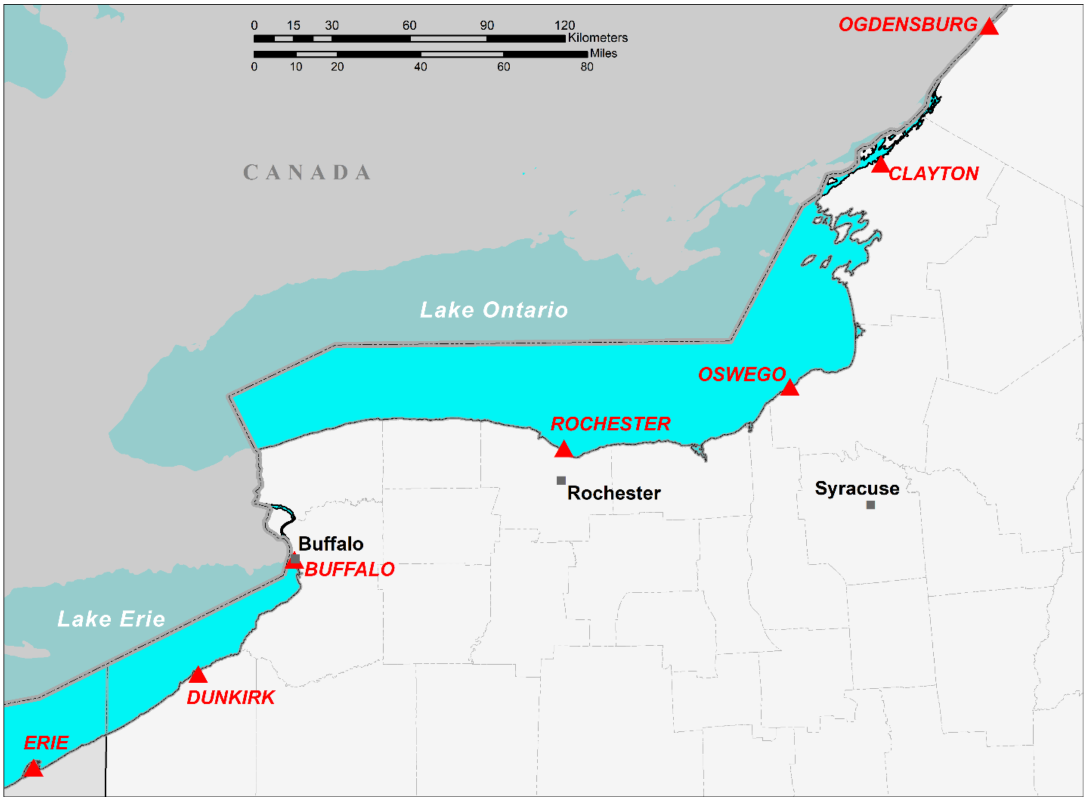
Referencing the example 6 MW turbine and the feasible floating substructures, the port requirements for floating turbine and substructure development are as follows. The crane(s) at port would need to lift the candidate nacelle of approximately 210 tonne up to a maximum hub height of about 115 m for the 4F7 MW class turbines. It would not need to lift the complete RNA, since the installation of each RNA component can all be done at port. They would also need to assemble the required substructure components for a TLP or a hybrid substructure (i.e., the TetraSpar) at port, which would require lifts of a couple hundred tonnes up to a height of 50 m, depending on the individual substructure component lengths and weights. The fully assembled substructure can then be loaded onto a submergible barge to allow for turbine assembly in the water. The TetraSpar used a quayside space of about 20 acres[29] for assembly, which can likely be expected for similar TLP assembly processes. The port depth will need to be deep enough to support the draft of the fully assembled substructure and turbine, or the draft of a submergible barge, which will depend on the specific substructure dimensions and weights. The wharf length must be longer than the substructure's dimensions in the water, which is not expected to exceed 50 m for these substructures. Additional quayside space, port depth, and wharf length above the minimum values could enable a port to handle multiple components simultaneously. The last port requirement is the air draft limit, to ensure that the height of the turbine and substructure components at port would not interfere with any existing structure, such as powerlines or bridges. Blade tip heights up to 200 m (Table 2) far exceed vertical clearances in Great Lakes ports with air draft restrictions; therefore, floating wind turbines must be transported from ports that do not have these limits.

It should be noted that these conventional assembly and installation methods for floating wind projects are what are being used for ocean-based applications today, although there may be other methods to assemble and install floating systems that have not yet been conceived. More customized approaches and methods that are tailored for the Great Lakes are likely to be more efficient.

4.2 Port Descriptions

The ports considered in this analysis are all located on the U.S. shore of either Lake Ontario or Lake Erie. The ports on Lake Ontario are the Port of Ogdensburg, Port of Clayton, Port of Oswego, and the Port of Rochester. The ports on Lake Erie are the Port of Buffalo, Port of Dunkirk, and Port of Erie (PA). See Figure 10 for each port location on the Lakes. Ogdensburg, Oswego, Buffalo, and Erie all have previous experience handling and distributing wind turbine components for land-based wind projects.[30] Each port considered has unique benefits, but all ports would require significant upgrades to support Great Lakes wind energy development.

Figure 16. United States Ports Assessed for Supporting Wind Energy Development on the Great Lakes



In general, larger ports are better equipped to support the transfer of components, assembly, and installation of wind energy projects in the Great Lakes. The most promising ports for supporting wind energy development in the Great Lakes are the Port of Oswego, the Port of Buffalo, and the Port of Erie. On Lake Ontario, the Port of Ogdensburg has an air draft limit of an international bridge that presents a constraint. The Port of Clayton is relatively small with the inability to expand, and Rochester is highly urbanized and would also not be able to easily expand. Oswego is currently the most suitable port on Lake Ontario to support wind energy development. On Lake Erie, the Port of Buffalo has the potential to be a viable option if air draft limits can be avoided or removed. Dunkirk is relatively small with minimal space to expand, and the Port of Erie is a suitable port to support Great Lakes Wind. The ports that would struggle to support all aspects of Great Lakes Wind still have the potential to be used as supporting marshalling ports.

4.2.1 Lake Erie

The Port of Buffalo is located on the east end of Lake Erie near Niagara Falls. Its pier is over 900 m (3,000 ft) long and can accommodate several vessels simultaneously with a water depth of 8.2 m.[31] The Port of Buffalo is equipped to do large vessel repairs and there is tug assist available.[32] The two cranes available at the port are a 50-tonne LeTourneau gantry crane that can lift up to 12 meters (40 ft) in the air, and a 230-tonne crawler crane, both of which can be used to unload bulk cargo onto 200 acres of available laydown space.[33] The Port of Buffalo has overhead power cables at various locations throughout the port,[34] but if these power cables would cause an air draft limitation for Great Lakes Wind operations, they can likely be buried. This port has access to rail, highway, and inland river transportation.[35]

The Port of Dunkirk is located on the south shore of Lake Erie. It is the southernmost port within New York State's Lake Erie waters. Until 2005, this harbor was a commercially active harbor that received coal for a waterfront powerplant from self-unloading vessels. The City of Dunkirk and Chautauqua County are considering options for redevelopment—including power offtake from wind turbines in Lake Erie—following the closure of the coal plant.[36] It has a 230 m long steel pier[37] and approximately 76 acres of laydown space. Dunkirk Harbor supports 24 charter fishing boats. There are also large breakwaters that protect the harbor.[38] The port of Dunkirk is dredged every three years to maintain its depths of 5.2 meters in the outer channel, 4.9 meters in the inner channel and 2.4 meters in the access channel, which would likely be deep enough to support most fixed-bottom project operations, but should be analyzed further for any large, heavy substructure operations. There are currently no cranes available, no air draft limits, and the port is accessible to rail and highways.

The westernmost port considered in this study is the Port of Erie. The Port of Erie is located on the north coast of Pennsylvania. The port has 460 meters (1,500 feet) of dock frontage with water depths that range from 7.0 to 7.9 meters (23 to 26 feet).[39] The port has one fixed heavy lift crane with a 272 MT capacity, as well as two Manitowoc 4100W cranes each with a 170 MT capacity.[40] There are wharves for loading and unloading to the two to seven acres of laydown space,[41] as well as a large drydock with dimensions of 1,250 feet (ft) in length, 120 ft in breadth, and 22 ft in depth, for shipbuilding and repairs.[42] The shipyard that uses the drydock is located on 44 acres and has more than 4.5 acres of production area.[43] There are no air draft restrictions, and the port is accessible to rail and highway.

The capabilities of each Lake Erie port are summarized in Table 3. Note that crane heights were not included in this port capability assessment since the crane specifications for each port were not readily accessible.

Table 3. Current Infrastructure, Equipment, and Means of Transportation for Lake Erie Ports

Sources: Sea Ports of United States US, n.d., WCSC (2021); Great Lakes Wind Collaborative (2010)

Port	Buffalo	Dunkirk	Erie (PA)
Crane Type and Capacity	Fixed and Mobile 50 tonnes, 230 tonnes	none	Fixed and Mobile 272 MT, 170 MT (2)
Laydown Space	200 acres	76 acres	2 – 7 acres
Port Depth	8.2 m	4.9 – 5.2 m	7.0 – 7.9 m
Channel Depth	7.1 – 9.1 m	2.4 m	7.1 – 9.1 m
Wharf Length	900 m	230 m	460 m
Air Draft	power cables	none	none
Rail Accessible	yes	yes	Yes
Highway Accessible	yes	yes	yes
Inland Water Accessible	yes	no	no

4.2.2 Lake Ontario

The Port of Ogdensburg is located on the St. Lawrence River just above the mouth of Lake Ontario. This port has a dock loading zone that is 381 meters long.[44] The port depth and channel depth are 8.2 meters (27 feet), which is the standard St. Lawrence Seaway depth. There are 5–10 heavy lift cranes located off site that are rated from 50–220 tonnes. There are over 70 acres of laydown space with additional acreage nearby and over 2.8 acres (125,000 square feet) of warehouse storage. The Thousand Islands Bridge, located between the Port of Ogdensburg and Lake Ontario, creates an air draft limit of 46 meters of clearance underneath it, which would prevent fully assembled turbines from traveling from port to site[45] There is access to a class I rail line and two main highways from the port,[46] which would enable the port to serve as a manufacturing or preassembly port.

The Port of Clayton is located near the merging of the St. Lawrence River and Lake Ontario. It is a small harbor that can fit vessels up to 152 meters in length. There are loading and unloading zones. The channel and cargo pier have water depths ranging from 6.4–7.6 meters, and there are fixed cranes on site that can lift up to 100 tonnes.[47] There is no dedicated quayside space for material handling, there are no air draft limits, the port is only accessible by highway, and the port has had no previous experience with handling wind turbine components.

The Port of Oswego is located on the southeastern shore of Lake Ontario. This port has two terminals, an East Terminal, and a West Terminal. The East Terminal is the larger of the two and has 579.1 meters of dock space with 8.1 meters draft.[48] Available equipment at the East Terminal includes forklifts, cranes, and front-end loaders. There is a 360 tonne Liebherr crane on site, but the port also has access through an outside contractor to ten, larger, heavy-lift cranes that can lift up to 600 tonnes. There are 20 acres of storage area available,[49] with 9,300 square meters (100,000 square feet, 2.3 acres) of warehouse storage immediately available adjacent to the dock.[50] The West Terminal has 335.3 meters of dock space with a draft of 7 meters and an additional 427 meters of dock space with a draft of 4.25 meters. The channel depth and port depth of each terminal both range from 6.4 to 7.6 meters. There is a 5,100 square meter (55,000 square feet, 1.3 acres) asphalt pad available for bulk cargo storage.[51] The Port of Oswego has highway, rail, and inland river access for transportation of goods. Oswego has previously transferred 28,500 tonnes of wind turbine components from vessels to trucks to be transported to installation sites.[52] The port has the ability to expand its laydown space to 50 acres with potential to expand further, as well as the ability to deepen the channel depth as needed.[53]

The southernmost port on Lake Ontario is the Port of Rochester. This port is a small harbor that can host vessels up to 152 meters. There are wharves for loading and unloading. There are also floating cranes that can lift up to 50 tonnes. The water depth at this port ranges from 4.9–6.1 meters.[54] The air draft limit for the Port of Rochester is downriver of the port where a bridge gives a 13.7-meter (45 foot) clearance, which would only affect transportation through the river and not be a concern for wind energy development on Lake Ontario. There is no dedicated quayside space for material handling, the port is accessible by highway and inland waterway (with an air draft restriction).

The capabilities of each Lake Ontario port are summarized in Table 4. Note that crane heights were not included in this port capability assessment since the crane specifications for each port were not readily accessible.

Table 4. Current Infrastructure, Equipment, and Means of Transportation for Lake Ontario Ports

Sources: Sea Ports of United States US, n.d., WCSC (2021); Great Lakes Wind Collaborative (2010)

Port	Ogdensburg	Clayton	Oswego	Rochester
Crane Type and Capacity	Mobile 50-220 tonnes	Fixed 100 tonnes	Mobile 600 tonnes	Floating 50 tonnes
Laydown Space	70 acres	none	20 acres	none
Port Depth	7.1 - 9.1 m	6.4 – 7.6 m	6.4 – 7.6 m	4.9 – 6.1 m
Channel Depth	4.9 – 6.1 m	6.4 – 7.6 m	6.4 – 7.6 m	4.9 – 6.1 m
Wharf Length	381 m	152 m	Up to 579 m	152 m
Air Draft	46 m	none	none	13.7 m upriver
Rail Accessible	yes	no	yes	no
Highway Accessible	yes	yes	yes	yes
Inland Water Accessible	no	no	yes	yes

4.3 Port Feasibility

Based on the above information, all the ports studied here would require some level of upgrade to support assembly and installation of wind turbines on the Great Lakes. Possible solutions include adding additional cranes; dredging; adding more quayside storage or assembly space; removing overhead barriers; and—for smaller ports—focusing on support of operations and maintenance and marshalling duties rather than installation.

Ports that support the assembly and installation of wind turbines on the Great Lakes will need channels deep enough for the types of installation vessels and substructures that will be used on Lake Erie and Lake Ontario. Ports on Lake Ontario and potentially Lake Erie (depending on the substructure installation method) will also need channels large enough to float out the substructure. Most of the ports on both lakes have channel and cargo port depths of 4–9 meters. To achieve the required channel depth for various installation vessels or semi-submerged substructures, the channels would need to be dredged, otherwise other vessel, substructure, or port innovations would be required. Dredging removes sediment from the bottom of a body of water. The cost of dredging depends on the (1) amount of material removed, (2) dredge method, (3) type of material removed, (4) disposal location, (5) contamination of the material, and (6) frequency of the dredging. In conjunction with the channel depth, the channel width also needs to meet certain width requirements which are typically a function of the channel depth and the width of the vessels of interest. Based on maps of all seven ports, the channels that a large vessel would maneuver through in each port are all over 30 m (100 ft) in width, which is more than three times the standard St. Lawrence Seaway depth of 8.2 m (26.9 ft), a common depth among most ports.

All ports will require sufficient heavy-lift crane capacity. There are multiple types of substructures that will be installed on the two different lakes, fixed or floating, with each substructure type requiring a different installation process. For both cases, there will need to be a land-based crane large enough to lift individual turbine parts. The heaviest component on the turbine is the nacelle, with an approximate weight of 210 t. For floating turbines on Lake Ontario, assembly of the turbine can most likely be done at port. In that case, one or more large land-based cranes will be required to assemble the turbine components on the floating substructure at port. For fixed-bottom turbines on Lake Erie, a heavy-lift crane could be required to transfer the turbine and substructure components to the installation vessel or barge, and then another heavy-lift crane will be needed for installation on site, if that installation vessel is a solution like an altered barge. A related consideration to heavy-lift crane capacity is the quayside load bearing capacity, which must be adequate to support a heavy-lift crane and its load. Each Great Lakes port will likely need to be upgraded to increase load bearing capacity. Upgrades to the bearing capacity for a given port should be evaluated when the installation strategy and required crane size have been determined.

All ports will require enough quayside space to store or assemble the turbines and substructures. This space is more important for floating turbines as they will be fully assembled at port. For fixed-bottom turbines, much less space is required because the individual components will be brought to the installation site for assembly. To assemble five floating offshore wind turbines in port for the Hywind Scotland Pilot Park, 8,000 sq meters (2 acres) of quayside space was required.[55] The Ports of Ogdensburg, Oswego, Buffalo, and Dunkirk may have sufficient quayside storage that could be used to assemble the turbines, whereas the rest of the ports would likely need to expand their quayside space.

Smaller ports that are not large enough to support the transportation, assembly, and installation of wind turbines, such as the Port of Clayton and the Port of Rochester, could potentially become marshalling ports to assist with component transfer and handling or help support regular maintenance of the turbines.

Table 7. Assessment of Port Readiness

Sources: Sea Ports of United States US, n.d.

Port	Ogdensburg	Clayton	Oswego	Rochester	Buffalo	Dunkirk	Erie
Lake	Ontario	Ontario	Ontario	Ontario	Erie	Erie	Erie
Channel Depth							
Cranes							
Quayside Space							
Air Draft							

Table 7, above, applies the four previously discussed limitations to each port considered (channel depth, crane availability, quayside space, and presence of air drafts). A red box signifies that it may not be feasible to upgrade the port to the specified criteria. A yellow box indicates that it may be feasible to upgrade the port to the specified criteria. Lastly, a green box indicates that the port is already able to accommodate the given criteria. The ports with no red squares are assumed to be viable choices for Great Lakes Wind Energy development.

No port considered in this study currently has a channel deep enough to support Great Lakes Wind. Therefore, each port was assigned a yellow box for this criterion, meaning accommodation is possible with an expected amount of work.

The only port that has access to cranes large enough to support Great Lakes wind is the Port of Oswego. The remaining ports will have to buy or rent cranes that are large enough to support wind development.

Each port also needs enough quayside space to support the assembly of the wind turbines. The ports that have yellow squares have potential to expand their quayside space, but currently lack sufficient space. The ports that have red squares do not have enough space and are unable to make expansions. The ports with green squares have enough quayside space currently to support wind energy development.

The Port of Ogdensburg was assigned a red square for air draft as it has an air draft that would be difficult to work around (i.e., the Thousand Islands Bridge). The Ports of Rochester, Buffalo, and Dunkirk were assigned yellow squares for air draft as they all have overhead power cables, which theoretically can be buried. The Ports of Clayton, Oswego, and Erie do not have air draft restrictions, so they were assigned green squares.

In conclusion, all the ports considered need upgrades to be able to accommodate wind energy development on the Great Lakes. There are ports that are more suitable than others but they each need significant upgrades. Most of the ports would require additional cranes to move the bigger, heavier components of the turbines, and most of the ports would also require expanded quayside space along with dredging of the channels and cargo ports to be able to accommodate the large vessels required to transport, assemble, and install wind turbines in the Great Lakes.

5 References

Bachynski, Erin E., and Torgeir Moan. 2012. "Design Considerations for Tension Leg Platform Wind Turbines." Marine Structures 29 (1): 89-114. https://doi.org/10.1016/j.marstruc.2012.09.001

Bocklet, Charles, Christian Herbosa, Greg Loweth, Matthew Griswold, Lauren Quickel, Roan Gideon, Jay Borkland, Rocky Weitz, Barbara Kates-Garnick, and Eric Hines. 2021. "Wind Turbine Installation Vessels: Global Supply Chain Impacts on the U.S. Offshore Wind Market." OSPRE-2021-02. Tufts University.

Borg, Michael, Morten Walkusch Jensen, Scott Urquhart, Morten Thøtt Andersen, Jonas Bjerg Thomsen, and Henrik Stiesdal. 2020. "Technical Definition of the TetraSpar Demonstrator Floating Wind Turbine Foundation." Energies 13 (18): 4911. https://doi.org/10.3390/en13184911

Casale, C., E. Lembo, L. Serri, and S. Viani. 2010. "Preliminary Design of a Floating Wind Turbine Support Structure and Relevant System Cost Assessment." Wind Engineering 34 (1): 29-50. https://doi.org/10.1260/0309-524X.34.1.29

"Current Great Lakes Fleet." 2020. Shipwatcher News Great Lakes Ships (blog). May 19, 2020. https://greatlakesships.wordpress.com/current-great-lakes-fleet/

"DEMAG CC 8800-1 Specification Chart." n.d. Tadano Group.

"Donjon Shipbuilding & Repair." n.d. Accessed April 26, 2022. https://donjonshipbuilding.com/#facility

Douglas-Westwood LLC. 2013. "Assessment of Vessel Requirements for the U.S. Offshore Wind Sector." DOE-DWL-05370. https://www.osti.gov/biblio/1095807-assessment-vessel-requirements-offshore-wind-sector

Great Lakes St. Lawrence Seaway Development Corporation. n.d. "The Seaway - Great Lakes St. Lawrence Seaway System." Accessed June 16, 2021. https://greatlakes-seaway.com/en/the-seaway/

Great Lakes Wind Collaborative. 2010. "The Role of the Great Lakes-St. Lawrence Seaway Ports in the Advancement of the Wind Energy Industry." Great Lakes Commission. https://www.glc.org/wp-content/uploads/2016/10/2010-role-ports-wind-energy.pdf

"Information and Characteristics about Buffalo Port United States." n.d. SeaRates. Accessed June 16, 2021. https://www.searates.com/port/buffalo_us.htm

"Information and Characteristics about Clayton Port United States." n.d. SeaRates. Accessed June 16, 2021. https://www.searates.com/port/clayton_us.htm

"Information and Characteristics about Rochester Port United States." n.d. SeaRates. Accessed June 16, 2021. https://www.searates.com/port/rochester_us.htm

"Jacket Hardware for Deepest Fixed-Bottom Wind Farm Starts Arriving in Scotland." 2021. August 11, 2021. https://www.offshorewind.biz/2021/08/11/jacket-hardware-for-deepest-fixed-bottom-wind-farm-starts-arriving-in-scotland/

Manzano-Agugliaro, Francisco, Sánchez-Calero, Alfredo Alcayde, Carlos San-Antonio-Gómez, Perea-Moreno, and Salmeron-Manzano. 2020. "Wind Turbines Offshore Foundations and Connections to Grid." Inventions 5: 8. https://doi.org/10.3390/inventions5010008

Musial, Walt, Paul Spitsen, Philipp Beiter, Patrick Duffy, Melinda Marquis, Aubryn Cooperman, Rob Hammond, and Matt Shields. 2021. "Offshore Wind Market Report: 2021 Edition." https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf

"New Bedford Delegation Visits EUROGATE Container Terminal Bremerhaven, Germany." 2013. Offshore Wind. April 24, 2013. https://www.offshorewind.biz/2013/04/24/new-bedford-delegation-visits-eurogate-container-terminal-bremerhaven-germany/

New York State Energy Research and Development Authority (NYSERDA). 2022. "New York State Great Lakes Wind Energy Feasibility Study: Substructure Recommendations," NYSERDA Report Number 22-12e. Prepared by the National Renewable Energy Laboratory, Boulder, CO. nyserda.ny.gov/publications

"NorSea Stordbase." n.d. NorSea Group. Accessed June 16, 2021. https://norseagroup.com/bases/norsea-stordbase

"NRG Power Plant Feasibility Study and Alternatives Analysis." 2021. Bergmann. https://planningchautauqua.com/wp-content/uploads/2021/06/FINAL_NRG-Alternatives-Report_.pdf

"Ogdensburg Bridge & Port Authority." n.d. Ogdensburg Bridge & Port Authority. Accessed June 16, 2021. http://www.ogdensport.com/index.html

"Port of Buffalo." n.d. New Enterprise Stone & Lime Co., Inc. Accessed April 18, 2022. https://www.nesl.com/products/port-of-buffalo/

"Port of Buffalo – Buffalo, New York | World Shipping, Inc." n.d. Accessed June 16, 2021. https://www.worldshipping.com/portfolio/port-of-buffalo-buffalo-new-york/

"Port of Oswego." n.d. Accessed June 16, 2021. https://portoswego.com/port-capabilities

Raimondo, Gina, M., Richard Spinrad W., and Nicole R. LeBoeuf. 2022. "United States Coast Pilot 6 Great Lakes: Lakes Ontario, Erie, Huron, Michigan, Superior and St. Lawrence River." National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA).

Ryan, Leo. 2021. "Wind Powers Robust Project Cargo Shipping." Chamber of Marine Commerce. https://www.marinedelivers.com/2021/04/wind-powers-robust-project-cargo-shipping/

Sarens. 2016. "The Champlain Bridge Project." https://www.sarens.com/about/projects/the-champlain-bridge-project.htm

Sarens. 2021. "Sarens Soccer Pitch Installs 89 Monopiles at the Wind Farm Fryslân." https://www.sarens.com/about/news/sarens-soccer-pitch-installs-89-monopiles-at-the-wind-farm-frysl-n.htm

Scriber, William. 2021. Director of the Port of Oswego Authority. Private communication.

“Seaway Map.” n.d. Great Lakes St. Lawrence Seaway System. Accessed April 15, 2022. https://greatlakes-seaway.com/en/navigating-the-seaway/seaway-map/

“Supply Chain, Port Infrastructure and Logistics Study.” 2016. For Offshore Wind Farm Development in Gujarat and Tamil Nadu. Global Wind Energy Council (GWEC).

“The Seaway.” n.d. Great Lakes St. Lawrence Seaway System. Accessed April 15, 2022. https://greatlakes-seaway.com/en/the-seaway/

“The TetraSpar full-scale demonstration project.” n.d. Stiesdal. Accessed June 22, 2021. https://www.stiesdal.com/offshore-technologies/the-tetraspar-full-scale-demonstration-project/

“Thousand Islands Bridge Authority.” 2008. May 15, 2008. https://web.archive.org/web/20080515071852/http://www.tibridge.com/facts.htm

US Army Corps of Engineers. 2020. “Dunkirk Harbor, NY.” https://www.lrb.usace.army.mil/Portals/45/docs/ProjFact/New%20York%2023/NY23NAVDunkirkHarbor.pdf

US Army Corps of Engineers, Buffalo District. 2021 “USACE Announces Contract Solicitation for Ogdensburg Harbor Deepening Project.” https://www.lrb.usace.army.mil/Media/News-Releases/Article/2581738/usace-announces-contract-solicitation-for-ogdensburg-harbor-deepening-project/

Uzunoglu, Emre, and C. Guedes Soares. 2020. “Hydrodynamic Design of a Free-Float Capable Tension Leg Platform for a 10 MW Wind Turbine.” Ocean Engineering 197 (February): 106888. https://doi.org/10.1016/j.oceaneng.2019.106888

“WCSC Waterborne Commerce Statistics Center.” n.d. Accessed July 21, 2021. https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center-2/

Endnotes

[1] “The Seaway” n.d.

[2] Great Lakes St. Lawrence Seaway Development Corporation n.d.

[3] NREL 2021

[4] Douglas-Westwood LLC 2013

[5] Douglas-Westwood LLC 2013

[6] Douglas-Westwood LLC 2013

[7] “Current Great Lakes Fleet” 2020

[8] NREL 2021

[9] Sarens 2021

[10] Sarens 2016

[11] “Seaway Map” n.d.

[12] “DEMAG CC 8800-1 Specification Chart,” n.d.

[13] “The TetraSpar Full-Scale Demonstration Project” n.d.

[14] NREL 2021

[15] Bocklet 2021

[16] NYSERDA, 22-12e, 2022

[17] NYSERDA, 22-12e, 2022

[18] NYSERDA, 22-12e, 2022

[19] NYSERDA, 22-12e, 2022

[20] Borg et al. 2020

[21] Uzunoglu and Guedes Soares 2020

[22] Casale et fal. 2010

[23] Bachynski and Moan 2012

[24] NYSERDA, 22-12e, 2022

[25] “Supply Chain, Port Infrastructure and Logistics Study” 2016

[26] Douglas-Westwood LLC 2013

[27] Sarens 2021

[28] Sarens 2021

[29] “The TetraSpar Full-Scale Demonstration Project” n.d.

[30] Great Lakes Wind Collaborative 2010; Ryan 2021

[31] Port of Buffalo n.d.)

[32] “Information and Characteristics about Buffalo Port United States” n.d.

[33] “Port of Buffalo–Buffalo, New York | World Shipping, Inc.” n.d.

[34] Raimondo, Spinrad, and LeBoeuf 2022

[35] Great Lakes Wind Collaborative 2010

[36] “NRG Power Plant Feasibility Study and Alternatives Analysis” 2021

[37] “WCSC Waterborne Commerce Statistics Center” n.d.

[38] U.S. Army Corps of Engineers 2020

[39] “WCSC Waterborne Commerce Statistics Center” n.d.

40 Great Lakes Wind Collaborative 2010

41 Great Lakes Wind Collaborative 2010

42 "Donjon Shipbuilding & Repair" n.d.

43 "Donjon Shipbuilding & Repair" n.d.

44 "Ogdensburg Bridge & Port Authority" n.d.

45 "Thousand Islands Bridge Authority" 2008.

46 "Ogdensburg Bridge & Port Authority" n.d.

47 "Information and Characteristics about Clayton Port United States" n.d.

48 "Port of Oswego" n.d.

49 Great Lakes Wind Collaborative 2010

50 "Port of Oswego" n.d.

51 "Port of Oswego" n.d.

52 Great Lakes Wind Collaborative 2010

53 Scriber 2021

54 "Information and Characteristics about Rochester Port United States" n.d.

55 "NorSea Stordbase" n.d.

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