New York State Great Lakes Wind Energy Feasibility Study: Physical Siting Analysis

Final Report | Report Number 22-12b | December 2022

NYSERDA's Promise to New Yorkers:

NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Our Vision:

New York is a global climate leader building a healthier future with thriving communities; homes and businesses powered by clean energy; and economic opportunities accessible to all New Yorkers.

Our Mission:

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: Physical Siting Analysis

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Prepared by:

National Renewable Energy Laboratory (NREL)

Golden, CO

NYSERDA Report 22-12b NYSERDA Contract 123452 December 2022

Notice

Preferred Citation

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

Abstract

The Great Lakes Wind Energy 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, energy generation potential

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

GCF	gross capacity factor
GLAHF	Great Lakes Aquatic Habitat Framework
GW	gigawatts
MW	megawatts
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority

Executive Summary

This report assesses the technical potential generating capacity of wind energy in the Great Lakes in New York State. Based on detailed physical siting analysis, the generating potential was estimated to be up to 2 GW on Lake Erie and up to 18 GW on Lake Ontario. When areas with more challenging site conditions (such as steep lakebed slopes) are removed, the remaining area was estimated to be able to support 1.6 GW on Lake Erie and 14.5 GW on Lake Ontario. Daily generation profiles based on 21-years of high fidelity modeled wind data show that average diurnal wind variations align with New York electricity loads in the winter.

1 Physical Siting Analysis

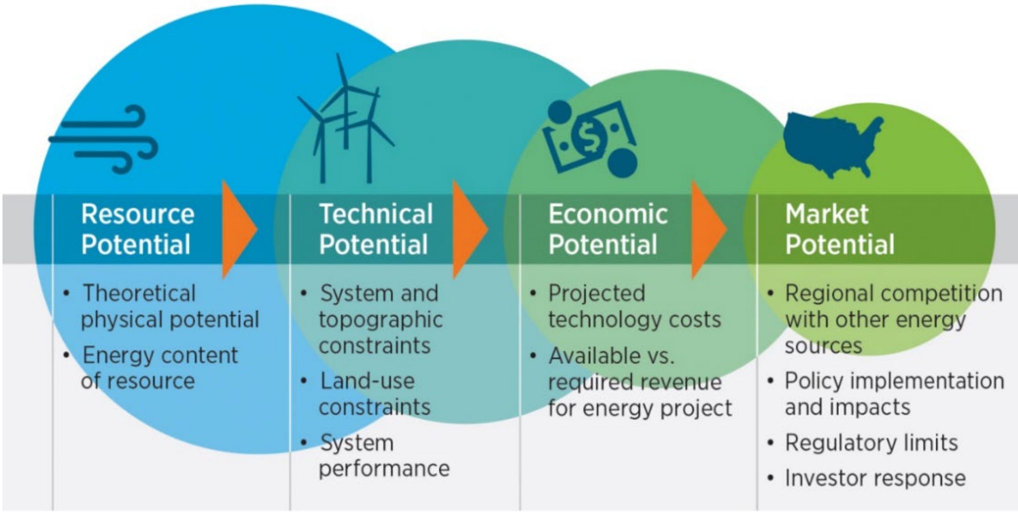
The technical wind resource area of New York State waters in Lake Erie and Lake Ontario was assessed to help determine the potential capacity for wind energy generation. The assessment includes (1) identifying locations with physical characteristics that may be poorly suited to current and near-term wind energy technology, based on the available data, and (2) estimating the amount of generation capacity that could be installed in the remaining areas at distances greater than 4 miles from the lakeshore. Daily and seasonal generation patterns are compared with typical electricity demand across the State.

1.1 Analysis Methodology

The wind energy generating potential of a region can be assessed on several different levels, as illustrated in Figure 1. The broadest measure is the resource potential, which describes the energy available from the wind based on measurements and modeling of wind speeds throughout the region. The technical potential is obtained by applying technical constraints to the theoretical resource. Constraints include the performance characteristics of the available wind turbines, characteristics of the terrain or environment that limit the ability to site wind turbines in specific locations, and social constraints that affect where turbines would interfere with other users of the space. The economic potential is a subset of the technical potential that also considers the cost of developing wind energy generation relative to the expected revenue. Finally, the market potential includes policy and regulatory factors that affect wind energy deployment as well as effect competition from other energy sources within regional markets. In some cases, the market potential may exceed the economic potential if policies provide subsidies to offset higher costs. In this section, we focus on the technical potential for wind energy deployment in New York State's Great Lakes; costs are addressed in New York State Great Lakes Wind Energy Feasibility Study: Cost Analysis. (NYSERDA 22-12g).

Figure 1. Layers of Assessment for Wind Energy Potential (Brown et al., 2016)

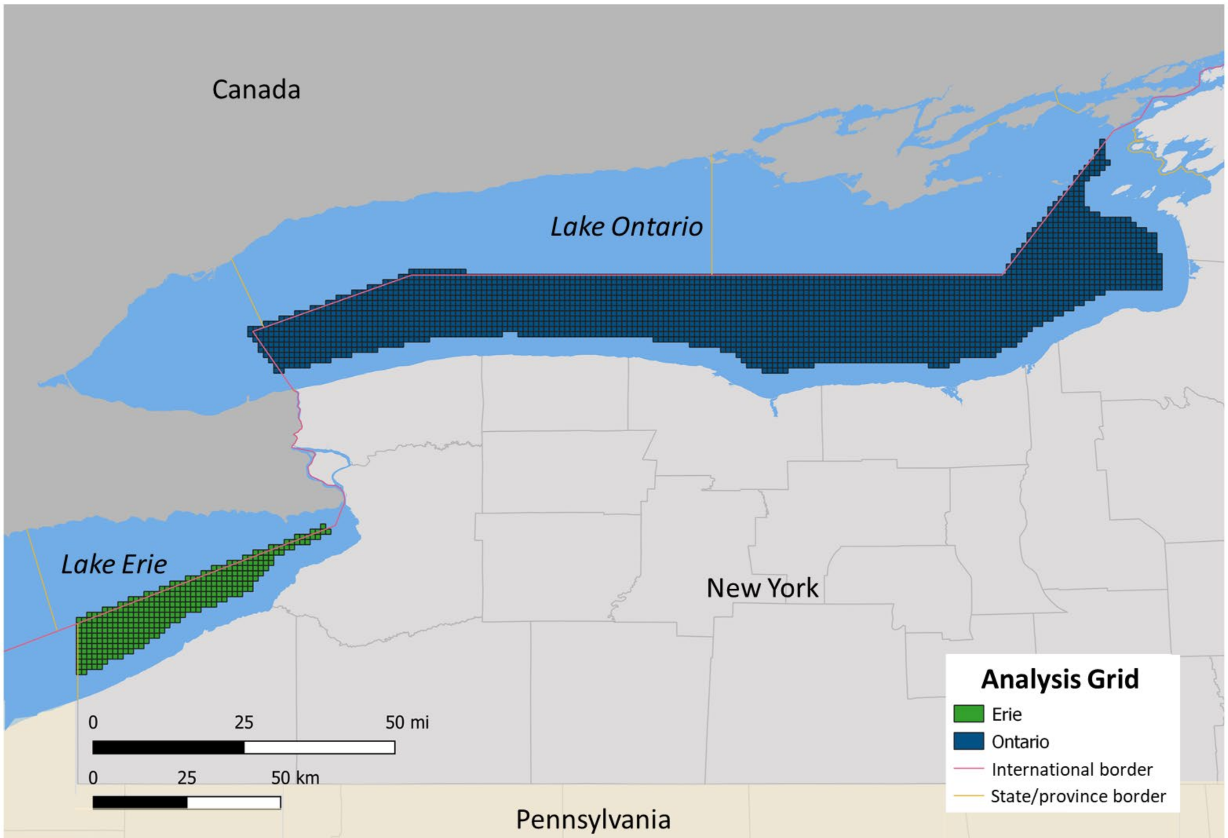
This study focuses on the technical potential for wind energy in the Great Lakes.



We established a geospatial grid over the study area for analysis of the physical site characteristics, using the methodology established by LEEDCo's Icebreaker project on Lake Erie (U.S. DOE, 2018). The method uses an analysis grid, shown in Figure 2, made up of rectangular grid elements that are each 1 minute in latitude by 1 minute in longitude. Despite having the same angular measurements, the grid elements are not square because lines of constant longitude become closer together as they approach the poles, whereas the lines of constant latitude are always spaced 1 nautical mile[1] apart. At the latitude of Lake Erie and Lake Ontario, approximately 43 degrees, each grid element is 1.9 km (1.15 miles) north to south by approximately 1.4 km (0.8 miles) east to west, encompassing an area of about 2.5 km^2 (0.99 square miles or 630 acres). Considering only the technical resource area that is at least 4 miles (6.4 km) from the lakeshore, there are a total of 338 grid elements in New York State's Lake Erie waters and 2,553 in Lake Ontario. Elements that partially overlap Canadian waters[2] are included in the analysis of physical characteristics but excluded from the calculation of total generating potential. Physical characteristics that are relevant to wind energy feasibility were assessed at each grid element to provide a broad view of development potential in the region. However, the selection of any individual site for wind energy development would require more extensive, site-specific studies to determine suitability.

Figure 2. Analysis Grid on Lakes Erie and Ontario

Consists of 1-minute grid squares located at least 4 miles from shore.



To estimate the gross energy generation capacity of the study area, we use a constant nameplate capacity density of 3 megawatts (MW) per square kilometer (MW/km^2). This metric is a typical value used as a rule of thumb until the actual array densities are known. It is strongly influenced by turbine spacing, which in turn is affected by considerations of wake effects, lakebed terrain, siting regulations, and other uses of the site (fishing, navigation, etc.). Because these factors can be different for each site, actual as-built capacity densities vary widely across installed wind plants (Harrison-Atlas et al., 2021). Offshore wind farms in Europe have capacity densities between 3–18 MW/km,[2] with average values in the range of 5.5–6.0 MW/km^2 (Deutsche WindGuard, 2018). We consider the value of 3 MW/km^2 to be a conservative estimate of potential generating capacity because historically, many offshore wind developers have used projects with higher power densities. However, this default value allows for the likelihood that some areas which appear suitable for development may face unforeseen technical, environmental, or social challenges that could limit the developable area. These challenges may include necessary easements, underwater hazards, visual impacts, conflicts with other users, or unforeseen geotechnical obstacles.

Physical characteristics of potential sites for wind energy development in New York State's Great Lakes were discussed in detail in appendices 1 and 2. The physical characteristics included in this analysis are:

- **Wind speed**. Mean wind speeds at 100 meters (m) above the lake surface were obtained from a new analysis of 21 years of data (NREL, 2021b). Values in the study region range from 8.3 to 9.0 meters/second (m/s). Sites with higher mean wind speeds typically have higher annual energy production.
- **Distance from shore**. The minimum distance to shore in any direction was calculated for each grid element. Sites farther from shore tend to have deeper water and to be farther from ports and points of interconnection, all of which increase the costs to install and maintain a wind plant. On the other hand, wind turbines in these locations are less visible from the shore, may have fewer conflicts with the environment, and may encounter less surface ice cover.
- **Water depth**. Average water depths in each grid element were calculated from National Oceanic and Atmospheric Administration NOAA bathymetric data (National Geophysical Data Center, 1999a, 1999b). Water depth affects the choice of wind turbine substructure as well as the cost of installation. Fixed-bottom substructures have been used for wind turbines in depths of up to 60 m, while floating substructures are designed for deeper water.
- **Lakebed slope**. The lakebed slope was derived from the same bathymetric data used for water depth. Slopes in Lake Erie are generally below 4%, while Lake Ontario contains some areas of steeper slopes. Each grid element is characterized by its steepest slope. Installation of foundations and mooring systems is simplest in flat areas and steeper slopes can be unstable when disturbed (Tajalli Bakhsh et al., 2020).
- **Ice cover**. Annual ice cover durations during the period 2005–2014 were drawn from the Great Lakes Aquatic Habitat Framework (GLAHF, n.d.), which summarizes annual ice durations from daily assessments of ice cover percentages based on remotely sensed imagery. Wind turbines in the Great Lakes are assumed to experience surface ice cover in winter which will require ice cones or other mitigation measures built into the design and system cost.
- **Soil type**. Soils on the lakebed surface were classified into four types, from largest to smallest grain size: gravel, sand, clay, and silt (NYSERDA 2022c). The soil type affects the choice of foundation or anchor system.
- **Sediment depth**. Shallow bedrock can potentially prevent installation of some wind turbine foundations and anchors. The depth to bedrock was determined in The New York State Great Lakes Wind Energy Feasibility Study: Geophysical and Geohazards Characterization (NYSERDA 2022c) based on data from Morgan, Todd, and Lewis (2020) for Lake Erie and the National Geophysical Data Center (1999b) and Hutchinson, Lewis, and Hund (1993) for Lake Ontario. Sediment depths are reported in increments of 25 ft. (7.6 m) in Lake Erie and 20 ft. (6.1 m) in Lake Ontario.
- **Distance to port**. The ports considered for this analysis are the ports of Buffalo and Erie (PA) on Lake Erie and Oswego and Rochester on Lake Ontario. Shorter distances to port reduce the amount of time vessels spend traveling to and from a wind power plant, which can lower vessel traffic and associated environmental impacts, as well as reducing costs for installation, operations, and maintenance. The average distance to port for grid elements in this analysis is 40 km (25 mi), with maximum distances of approximately 60 km (37 mi) on Lake Erie[3] and 135 km (84 mi) on Lake Ontario.

- **Distance to point of interconnection**. Several locations were identified as potential points of interconnection, where power from a wind plant enters the electricity grid (NYSERDA 2022f) The average interconnection distance among locations considered in this study is 19 km (12 mi) on Lake Erie and 32 km (20 mi) on Lake Ontario. Longer distances to the grid require longer cables, which cost more to procure and install, and require longer cable burial trenches that have a proportionately greater impact on the benthos and water column during installation. Electrical losses also increase with cable length.

Other site-specific factors that were not assessed in this analysis include archaeological sites, shipwrecks, pipelines, and cables (other than those associated with a wind energy project). No pipelines or cables were identified within the offshore study area; however, in the event that a new wind project and its export cable(s) were to be located in close proximity to a pipeline or cable, a crossing agreement would need to be negotiated between the owners of the respective infrastructure. The legal status of shipwrecks and other cultural heritage is discussed in the New York State Great Lakes Wind Energy Feasibility Study: Relative Riske, Minimization/Mitigation, and Benefits (NYSERDA 2022i).

1.2 Analysis of Physical Characteristics

In this section we summarize the distribution of physical characteristics among grid elements in Lake Erie and Lake Ontario. Physical characteristics within each lake are grouped by distance from shore using the bands shown in Figure 3. Because there is no regulatory requirement establishing a minimum distance to shore for wind turbines in the Great Lakes, we chose to provide information at 2-mile increments covering a range of possible siting scenarios. The analysis focuses on the grid elements that are beyond 4 miles (6.4 km) from shore to avoid anticipated nearshore environmental and visual impacts that are analyzed in detail in New York State Great Lakes Wind Energy Feasibility Study: Visual Impacts (NYSERDA 2022j).

1.2.1 Lake Erie

In Lake Erie our analysis encompasses a total of 338 grid elements (867 km^2 or 214,000 acres). The distribution of physical characteristics for grid elements in Lake Erie beyond 4 miles from the shoreline is shown in Figure 4 and Tables 1–3. Mean water depths in this region most often fall between 20–40 m (66–131 ft.). The maximum lakebed slope is less than 2% across more than 98% of the grid elements, and the surficial soils are predominantly either clay or silt. Mean wind speeds range from 8.6 m/s–9.0 m/s (19 to 20 mph) in this area. The mean ice cover duration between 2005 and 2014 was 6–10 weeks for most sites within the Lake Erie study area. Figure 4 shows that the duration of ice cover decreases with increasing distance to shore.

Figure 3. Minimum Distance to Shore for Each Grid Element in 2-mile Increments

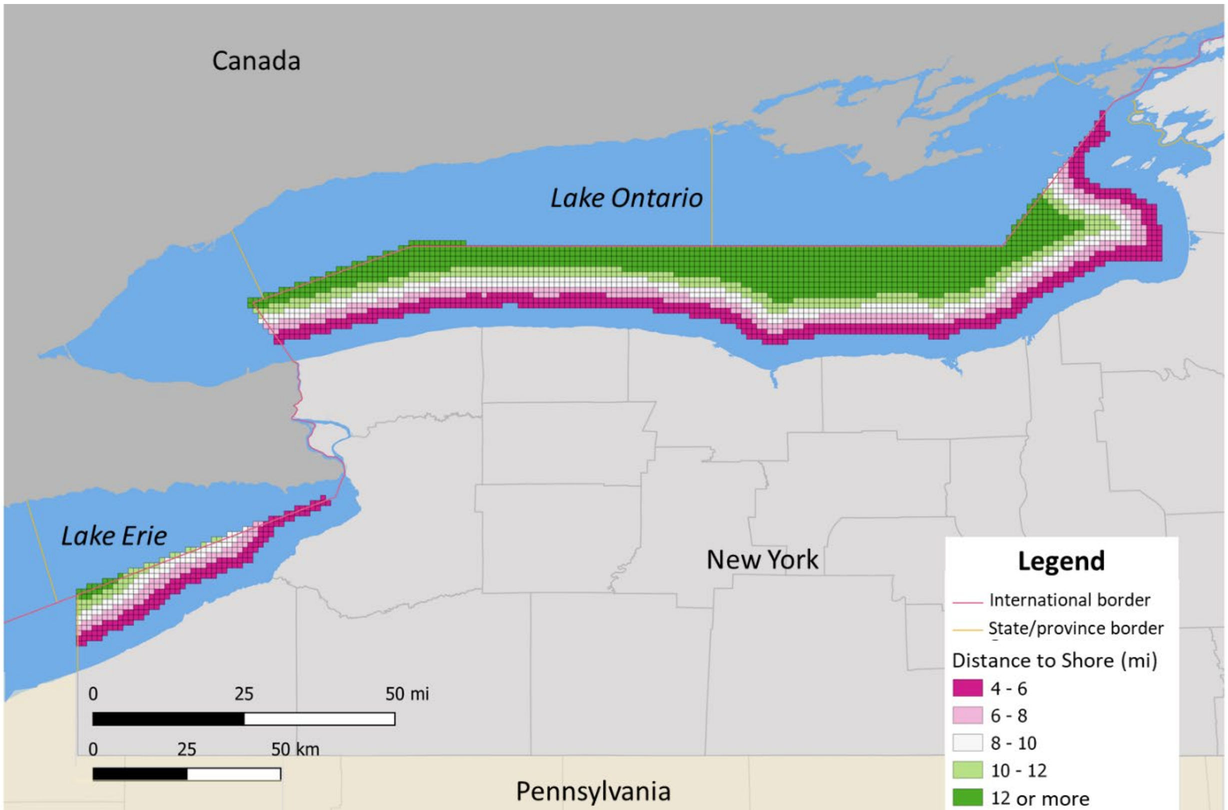


Figure 4. Distribution of Physical Characteristics among 1-minute Grid Elements on Lake Erie Located More than 4 Miles from the Shoreline

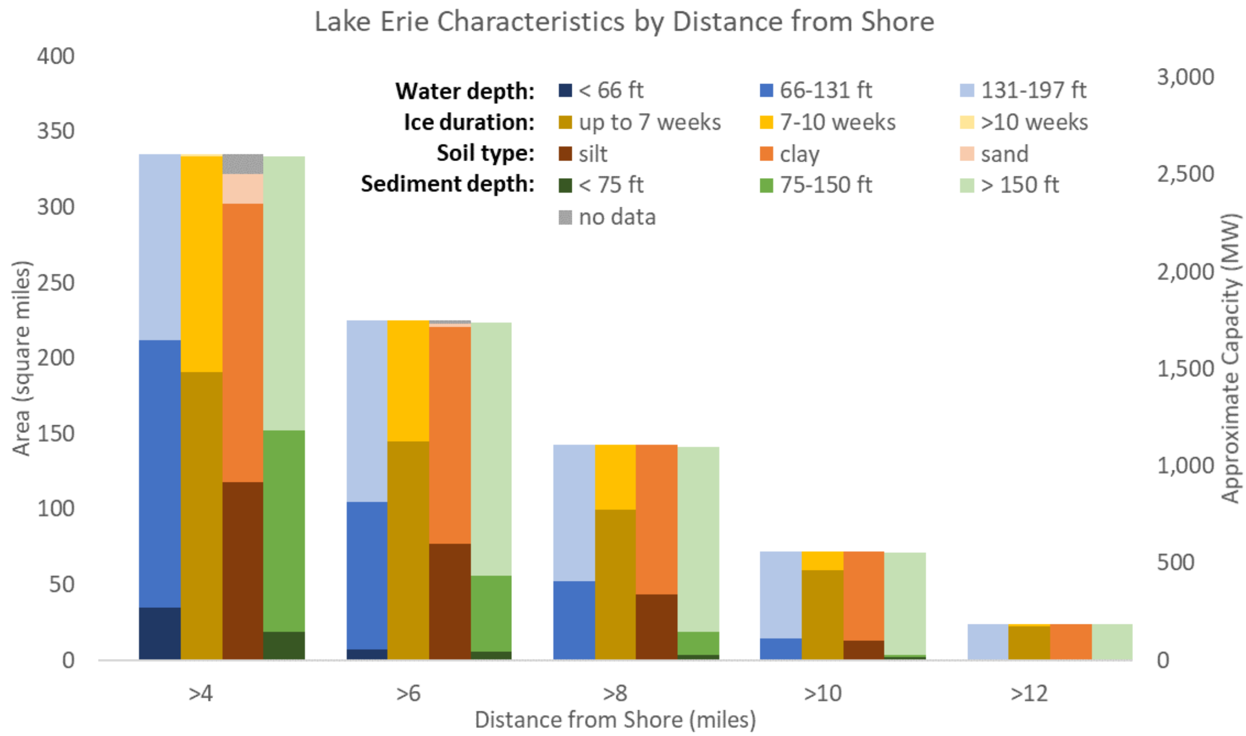


Table 1. Area (square miles) in Lake Erie with Specified Mean Water Depth and Maximum Lakebed Slope, Binned by Distance to Shore

Distance from Shore	Mean Water Depth			Max. Lakebed Slope			
	< 66 ft	66-131 ft	131-197 ft	<2%	2-4%	> 4%	% NY Lake Area
< 4 mi	201	51	0	174	65	12	**43%**
4-6 mi	28	79	3	109	1	0	**19%**
6-8 mi	7	46	30	82	0	0	**14%**
8-10 mi	0	38	33	70	0	0	**12%**
10-12 mi	0	15	34	47	2	0	**8%**
> 12 mi	0	0	24	21	3	0	**4%**
% of Area > 4 mi	**10%**	**53%**	**37%**	**98%**	**2%**	**0%**	**100%**

Table 2. Area (square miles) in Lake Erie at Varying Distances to Shore with Specified Soil Type and Thickness

Estimated by the depth to bedrock from the lakebed.

Distance from Shore	Sediment Thickness			Predominant Soil Type				
	< 75 ft	75-150 ft	> 150 ft	Sand	Clay	Silt	No Data	% NY Lake Area
< 4 mi	141	86	11	83	89	30	50	**43%**
4-6 mi	13	84	13	18	41	41	11	**19%**
6-8 mi	2	35	46	2	45	34	2	**14%**
8-10 mi	2	13	55	0	40	31	0	**12%**
10-12 mi	2	2	44	0	36	13	0	**8%**
> 12 mi	0	0	24	0	24	0	0	**4%**
% of Area > 4 mi	**6%**	**40%**	**54%**	**6%**	**55%**	**35%**	**4%**	**100%**

Table 3. Area (square miles) in Lake Erie with Specified Annual Mean Ice Cover Durations, Binned by Distance to Shore

Distance from Shore	Ice Cover Duration			Mean Wind Speed			
	6-7 weeks	7-10 weeks	> 10 weeks	8.5-8.75 m/s	8.75-9.0 m/s	>9 m/s	% NY Lake Area
< 4 mi	20	212	20	119	133	0	43%
4-6 mi	47	62	1	33	77	0	19%
6-8 mi	45	38	0	5	77	0	14%
8-10 mi	41	30	0	0	70	0	12%
10-12 mi	37	12	0	0	43	6	8%
> 12 mi	23	1	0	0	0	24	4%
% of Area > 4 mi	57%	43%	0%	27%	68%	5%	100%

1.2.2 Lake Ontario

In Lake Ontario, there are a total of 2,553 grid elements corresponding to an area of 6,550 km^2 (1.6 million acres) farther than 4 miles from shore. Physical characteristics of these grid elements are summarized in Figure 5 and Tables 4–6. Only 7% of grid elements beyond 4 miles from shore have mean water depths less than 60 m. The majority of grid elements at these distances have water depths between 150–200 m reaffirming that floating technology will be the primary focus. Maximum lakebed slopes are less than 4% in most grid elements. Typical ice cover durations are one week or less, with an average ice duration of 4 days across the technical resource area. The maximum ice cover duration of up to 12 weeks occurs in the northeastern portion of the lake. The predominant soil type in the technical resource area is clay, followed by silt and sand, and the majority of sediment thicknesses above the bedrock fall between 60–120 ft. (18–37 m). Mean wind speeds on Lake Ontario range from 8.4 m/s to 8.9 m/s (19 to 20 mph), with more sites experiencing wind speeds near the upper end of the range. Typical ice cover durations are significantly shorter on Lake Ontario than on Lake Erie, but regardless of which lake is considered, the shores freeze earlier, resulting in a pattern of decreasing ice duration with distance of shore. A total of 759 grid elements in Lake Ontario beyond 4 miles from shore, representing nearly 1,950 km^2 (480,000 acres) of surface area, experience less than one day of ice cover in an average year (Table 6).

Figure 5. Distribution of Physical Characteristics among 1-Minute Grid Elements on Lake Ontario Located More than 4 Miles from the Shoreline

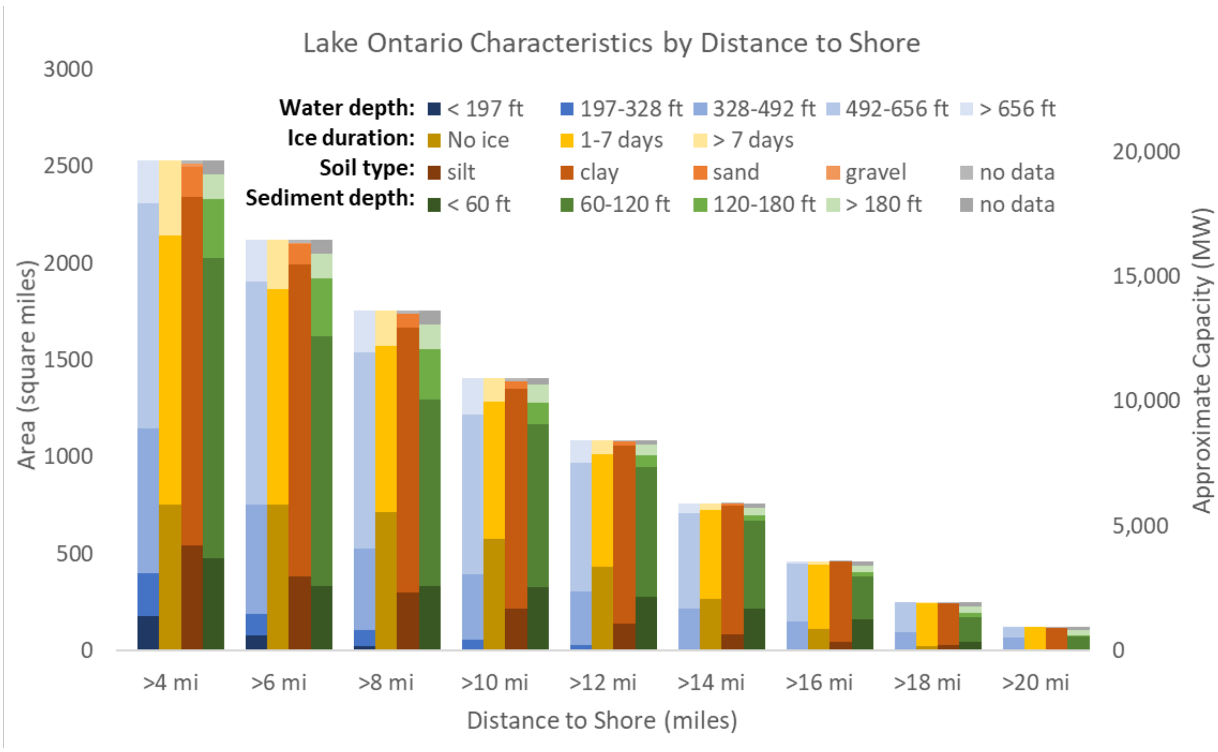


Table 4. Area (square miles) in Lake Ontario at Varying Distances to Shore with Specified Mean Water Depth and Maximum Lakebed Slope

Distance from Shore	Mean Water Depth					Max. Lakebed Slope				
	< 197 ft	197-328 ft	328-492 ft	492-656 ft	>656 ft	< 2%	2-4%	4-8%	> 8%	% NY Lake Area
< 4 mi	832	135	10	0	0	259	505	178	35	**28%**
4-6 mi	101	114	179	14	0	101	190	105	12	**12%**
6-8 mi	52	30	147	137	2	141	147	77	2	**10%**
8-10 mi	23	25	83	186	34	169	114	60	7	**10%**
10-12 mi	3	28	60	158	70	156	107	40	17	**9%**
> 12 mi	0	28	275	669	113	527	345	155	58	**31%**
% of Area > 4 mi	**7%**	**9%**	**29%**	**46%**	**9%**	**43%**	**36%**	**17%**	**4%**	**100%**

Table 5. Area (square miles) in Lake Ontario at Varying Distances to Shore with Specified Soil Type and Thickness

Estimated by the depth to bedrock from the lakebed.

Distance from Shore	Sediment Thickness					Predominant Soil Type				
	< 60 ft	60-120 ft	120-180 ft	> 180 ft	No Data	Gravel	Sand	Clay	Silt	% NY Lake area
< 4 mi	147	483	161	16	169	115	221	247	348	**28%**
4-6 mi	142	261	6	0	0	8	53	186	160	**12%**
6-8 mi	0	329	38	0	0	8	31	244	84	**10%**
8-10 mi	6	123	146	38	39	2	31	232	84	**10%**
10-12 mi	53	166	54	37	9	0	20	214	78	**9%**
> 12 mi	277	671	60	53	23	0	20	921	138	**31%**
% of Area > 4 mi	**19%**	**61%**	**12%**	**5%**	**3%**	**1%**	**6%**	**71%**	**22%**	**100%**

Table 6. Area (square miles) in Lake Ontario at Varying Distances to Shore with Specified Annual Mean Ice Cover Durations

Distance from Shore	Mean Annual Ice Cover Duration			Mean Wind Speed			
	< 1 day	1-7 days	> 7 days	8.25-8.5 m/s	8.5-8.75 m/s	8.75-9.0 m/s	% NY Lake Area
< 4 mi	37	110	830	472	409	96	**28%**
4-6 mi	0	277	131	33	192	183	**12%**
6-8 mi	40	252	75	10	159	197	**10%**
8-10 mi	137	152	62	12	112	227	**10%**
10-12 mi	142	132	46	13	83	223	**9%**
> 12 mi	434	578	73	46	256	784	**31%**
% of Area > 4 mi	**30%**	**55%**	**15%**	**17%**	**35%**	**49%**	**100%**

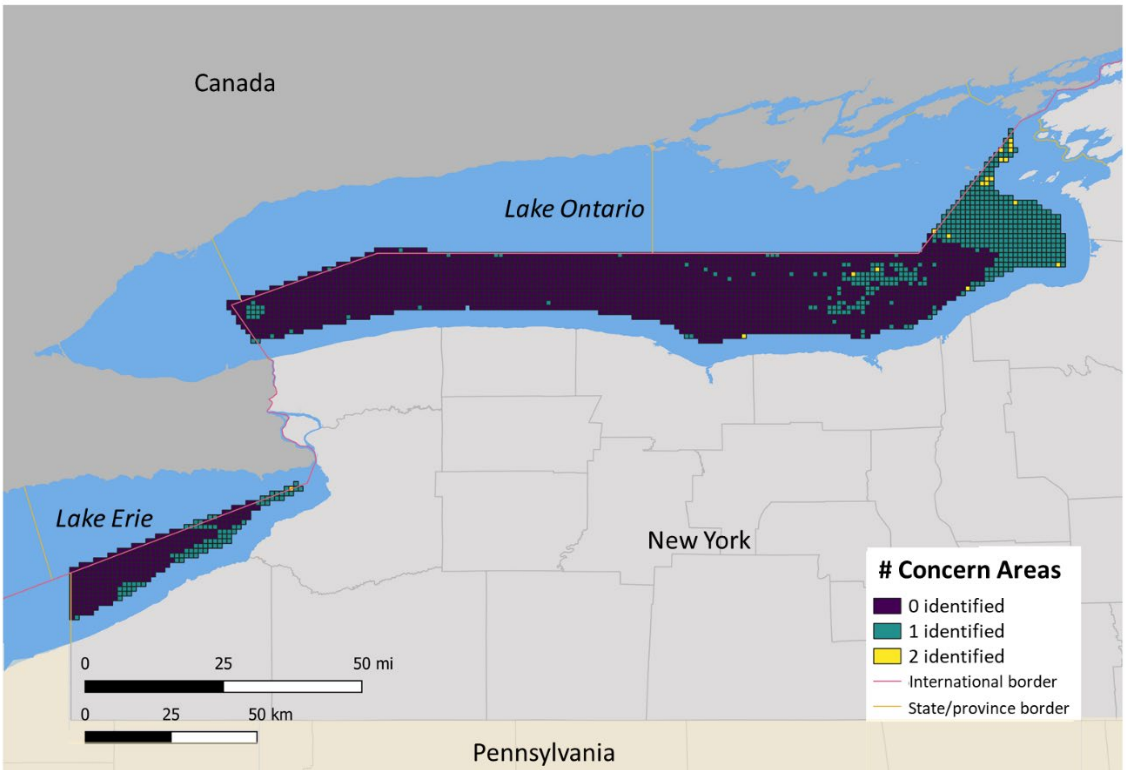
1.3 Energy Generation Potential

All of the physical characteristics described in the previous section are likely to affect the technology selection and cost of wind energy development in the Great Lakes. Conditions in some locations are relatively favorable for wind turbines, while other locations present challenges. Although the literature and data reviewed for the study do not provide the level of detail that would be required to fully assess a proposed site, it is possible to identify locations that are less suitable for development based on their physical characteristics. Fixed-bottom foundations that rely on piles driven into the lakebed for stability require a minimum penetration depth that varies depending on the soil type. A preliminary analysis described in New York State Great Lakes Wind Energy Feasibility Study: Substructure Recommendations (NYSERDA 2022e) identified likely pile depths of up to 27 m in firm clay and 48 m in softer soils. The report also indicates that anchors for floating wind turbines may require up to 10 m of soil for embedment. Hard rock and exposed bedrock present barriers to anchor embedment or pile driving. Uneven terrain and steep slopes—defined here as gradients of 8%—are also unsuitable for piles, anchors, or gravity-based foundations. The effects of ice on fixed and floating substructures are discussed in detail in New York State Great Lakes Wind Energy Feasibility Study: Substructure Recommendations (NYSERDA 2022e); in this analysis we highlight the areas with the longest ice cover durations on each lake. The following criteria were applied to identify areas that are less suitable for wind energy development on the analysis grid:

- Sediment depth is less than 27 m in clay or 48 m in silt, sand, or no data (in Lake Erie)
- Sediment depth is less than 10 m (in Lake Ontario)
- Majority soil type is rock or no data
- Maximum lakebed slope is greater than 8%
- Ice cover duration is greater than 1 week (on Lake Ontario) or 10 weeks (on Lake Erie)

Grid elements that have one or more of these criteria are highlighted in Figure 6. There are 78 grid elements (23% of the total beyond 4 miles) that meet the above criteria in Lake Erie and 512 (20%) in Lake Ontario. Note that the concern areas in Figure 6 are not meant to exclude those areas but should serve as a caution for possible Great Lakes wind developers and state energy regulators and planners. We recommend more thorough analysis before determining site suitability.

Figure 6. Map Showing Quantity of Undesirable Attributes in Each Grid Element



The energy generation potential of New York State's Great Lakes is summarized in Table 7. Based on a capacity density of 3 MW/km,[2] Lake Erie waters beyond 4 miles from shore could support up to 2 GW of wind energy generation, while New York State's Lake Ontario waters beyond 4 miles from shore could support up to 18 gigawatts (GW). If the grid elements with one or more concerns shown in Figure 6 are excluded, the remaining elements provide enough area to support 1.6 GW on Lake Erie and 14.5 GW on Lake Ontario.[4] The generation potential is highly dependent on the assumed capacity density. Increasing the capacity density to 6 MW/km^2 results in a doubling of the estimated potential, while decreasing the density to 1.5 MW/km^2 cuts the generation potential in half. The assumption of uniform density, while useful for estimating the resource potential, is not representative of actual observed wind energy development on land or offshore.

Table 7. Energy Generation Potential in Gigawatts

	Lake Erie–All Elements	Lake Erie–Excluding Concern Areas	Lake Ontario –All Elements	Lake Ontario – Excluding Concern Areas
> 4 mi. from shore	2.0	1.6	18	15
> 6 mi. from shore	1.3	1.3	15	12
> 8 mi. from shore	0.75	0.72	12	10
> 10 mi. from shore	0.28	0.28	9.6	8.0
> 12 mi. from shore	0.06	0.06	7.1	6.1

1.3.1 Diurnal and Seasonal Variation

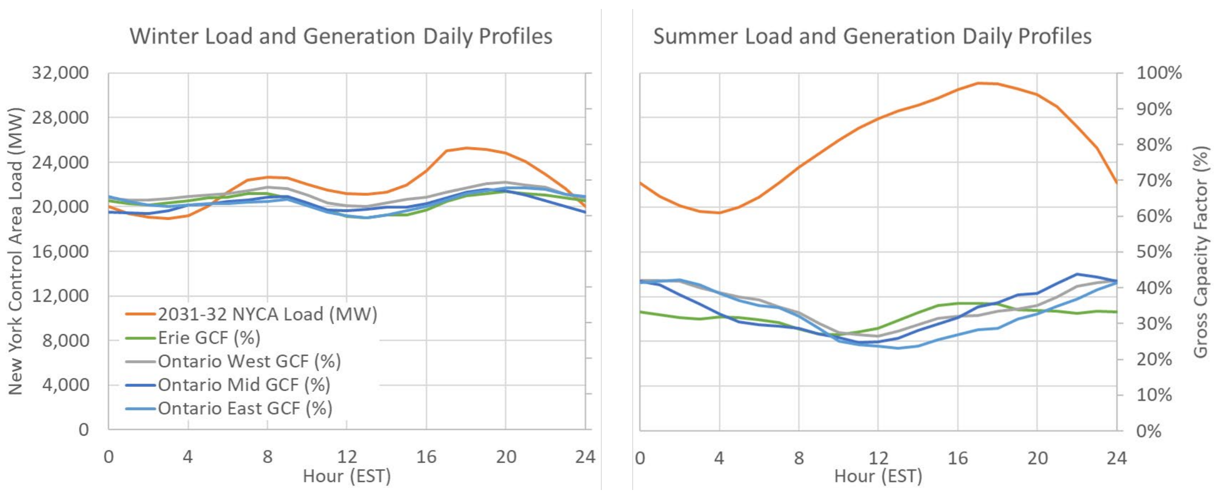
The wind resource over the Great Lakes varies over time and some daily and seasonal patterns can be observed. Wind speeds tend to be highest in the winter months and lower during the summer, with peak wind speeds typically occurring in the evening and minimum wind speeds in the early afternoon. Electricity demand also varies over time, with peak loads in the evening and lower loads in the early morning. Figure 7 compares how electricity demand and potential Great Lakes wind power generation change during the day in the summer and winter months. Electricity demand is based on the New York Independent System Operator's (NYISO's) projected load in the New York Control Area covering all of New York State in 2031–2032 (NYISO, 2021). The potential wind power output for the corresponding seasons is represented by the gross capacity factor calculated from the average 100-m wind speed at hourly intervals over a 21-year modeling period for four hypothetical reference locations: a central site in New York State's Lake Erie waters and three sites between 10 and 11 miles from the shoreline of Lake Ontario, spaced equidistantly east-to-west. Physical parameters of the example locations are provided in Table 8. A power curve for a 6-MW turbine (NREL, 2021a) was used to assess the potential wind generation at each wind speed. The potential power output does not account for any of the losses that would occur in a real system, such as wake effects, transmission losses, or maintenance downtime. Capacity factors are also affected by characteristics of the turbines selected for a particular site; for example, a turbine with a higher hub height or larger rotor diameter for a given power rating could achieve a higher capacity factor.

Table 8. Physical Characteristics of Locations Used for Diurnal Generation Profile Analysis

Example Locations	Erie	Ontario West	Ontario Center	Ontario East
Distance from Shore	9 miles (14 km)	11 miles (17 km)	10 miles (17 km)	11 miles (18 km)
Mean Wind Speed at 100 m	20 mph (8.8 m/s)	19 mph (8.7 m/s)	20 mph (8.9 m/s)	20 mph (8.8 m/s)
Water Depth	78 ft (24 m)	533 ft (162 m)	513 ft (156 m)	615 ft (187 m)

Figure 7. Projected Electricity Loads in the New York Control Area (NYCA) for Winter 2031–2032 and Summer 2031 Compared with Daily Generation Profiles

Gross capacity factor (GCF) produced from 21-year average hourly wind speeds for selected locations on Lakes Erie and Ontario.



In the winter, Figure 7 shows that the timing of morning and evening peaks in wind speeds are relatively closely aligned with peaks in the electricity demand. On average, the potential generation decreases overnight and at midday, while the load decreases more significantly overnight and to a lesser degree at midday. In the summer, loads tend to be higher than in the winter months with the peak load typically occurring in late July. In contrast, wind speeds over the Great Lakes are lower during the summer, reaching their lowest point around midday on Lake Ontario and mid-morning on Lake Erie. Although the daily profile of the summer wind resource does not match well with the total electricity demand, it may complement other resources such as solar power, which has higher output during summer days and peaks at mid-day. Over the next two decades, increasing electrification due to increased electric space heating and electric vehicles, as well as broader adoption of behind-the-meter solar power, may shift the peak load in New York State from summer to winter (NYISO, 2021). The daily and seasonal trends in wind speeds suggest that Great Lakes wind energy could have greater value in a winter peaking system, depending on the overall mix of generation sources.

1.4 Conclusions

The technical potential for wind energy sited at least 4 miles offshore in New York State's Great Lakes is estimated to be approximately 2 GW on Lake Erie and 18 GW on Lake Ontario. Our estimate of technical potential is based on a uniform capacity density of 3 MW/km.^{2} Approximately 20% of the area within each lake was identified as having physical conditions that may present challenges for wind energy development, reducing the estimated potential generation to 1.6 GW and 15 GW, respectively, although detailed site assessments would need to be carried out in any potential wind energy area to determine its suitability for development.

Daily generation profiles based on 21-year average wind speeds show a relatively good alignment with New York State electricity loads in the winter. Wind speeds over the lakes are slower during the summer and tend to peak late in the evening, after the typical peak in electricity demand. The value of winter generation may increase if, as projected by NYISO, the peak electric load shifts from summer to winter by the 2040s.

2 References

Deutsche WindGuard GmbH. (2018). Capacity Densities of European Offshore Wind Farms (SP18004A1). Bundesamt fur Seeschifffahrt und Hydrographie. https://vasab.org/wp-content/uploads/2018/06/BalticLINes_CapacityDensityStudy_June2018-1.pdf

GLAHF. (n.d.). Data | Great Lakes Aquatic Habitat Framework. Retrieved April 28, 2021, from https://www.glahf.org/data/

Harrison-Atlas, D., Maclaurin, G., & Lantz, E. (2021). Spatially Explicit Prediction of Capacity Density Advances Geographic Characterization of Wind Power Technical Potential. Energies, 14(12), 3609. https://doi.org/10.3390/en14123609

Hutchinson, D., C. F. Lewis, and G. Hund. (1993). "Regional Stratigraphic Framework of Surficial Sediments and Bedrock Beneath Lake Ontario." Géographie Physique et Quaternaire 47 (3): 337–52. https://doi.org/10.7202/032962ar

Morgan, N A, B J Todd, and C F M Lewis. (2020). Interpreted Seismic Reflection Profiles, Sediment Thickness and Bedrock Topography in Lake Erie, Ontario, Canada and Michigan, Ohio, Pennsylvania and New York, U.S.A. Geological Survey of Canada Open File 8733. https://doi.org/10.4095/326715

National Geophysical Data Center. (1999a). Bathymetry of Lake Erie and Lake Saint Clair [Data set]. National Geophysical Data Center, NOAA. https://doi.org/10.7289/V5KS6PHK

National Geophysical Data Center. (1999b). Bathymetry of Lake Ontario [Data set]. National Geophysical Data Center, NOAA. https://doi.org/10.7289/V56H4FBH

NREL. (2021a). "2016CACost_NREL_Reference_6MW" in NREL Wind Turbine Power Curve Archive. https://github.com/NREL/turbine-models

NREL. (2021b). US Offshore Wind Resource data for 2000-2019 [data set]. Retrieved from https://dx.doi.org/10.25984/1821404

NYISO. (2021) 2021 Load & Capacity Data Report. https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64

New York State Energy Research and Development Authority (NYSERDA). 2022. "New York State Great Lakes Wind Energy Feasibility Study: Geophysical and Geohazards Characterization," NYSERDA Report Number 22-12c. Prepared by the Worley Group, Inc., (dba Advisian), Reading, PA. nyserda.ny.gov/publications

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, Golden, CO. nyserda.ny.gov/publications

New York State Energy Research and Development Authority (NYSERDA). 2022. "New York State Great Lakes Wind Energy Feasibility Study: Interconnection," NYSERDA Report 22-12f. Prepared by Pterra Consulting Albany, NY, and The Brattle Group, Boston, MA. nyserda.ny.gov/publications

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

New York State Energy Research and Development Authority (NYSERDA). 2022. "New York State Great Lakes Wind Energy Feasibility Study: Relative Risks, Minimization/Mitigation, and Benefits," NYSERDA Report Number 22-12i. Prepared by, Worley Group, Inc. (dba Advisian), Reading, PA. nyserda.ny.gov/publications

New York State Energy Research and Development Authority (NYSERDA). 20212. "New York State Great Lakes Wind Energy Feasibility Study: Visual Impacts," NYSERDA Report Number 22-12j. Prepared by, Worley Group, Inc. (dba Advisian), Reading, PA. nyserda.ny.gov/publications

Tajalli Bakhsh, T., Monim, M., Simpson, K., Lapierre, T., Dahl, J., Rowe, J., & Spaulding, M. (2020). Potential Earthquake, Landslide, Tsunami, and Geo-Hazards for the U.S. Offshore Pacific Wind Farms (OCS Study BOEM 2020-040). US Department of the Interior, Bureau of Ocean Energy Management.

U.S. Department of Energy, U.S. Coast Guard, & U.S. Army Corps of Engineers. (2018). Final Environmental Assessment LEEDCo Project Icebreaker (EA-2045). Appendix C: Favorability Analysis Map. https://www.energy.gov/nepa/downloads/ea-2045-final-environmental-assessment

Appendix A. Supplemental Information

A.1 Additional Figures

Figure A-1. Analysis Sites for Wind Energy Generation Estimates

Analysis sites in Lake Ontario are each 10 miles from the shoreline with equal spacing east to west. The site in Lake Erie is located 8 miles from shore, centered east to west within New York State's waters.

Figure A-2. Diurnal Profiles by Month-Erie

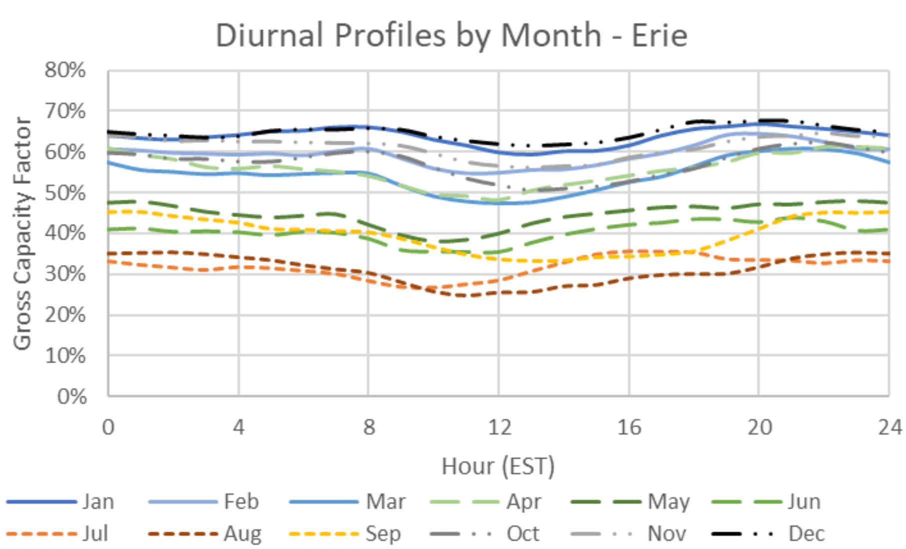


Figure A-3. Diurnal Profiles by Month- Ontario West

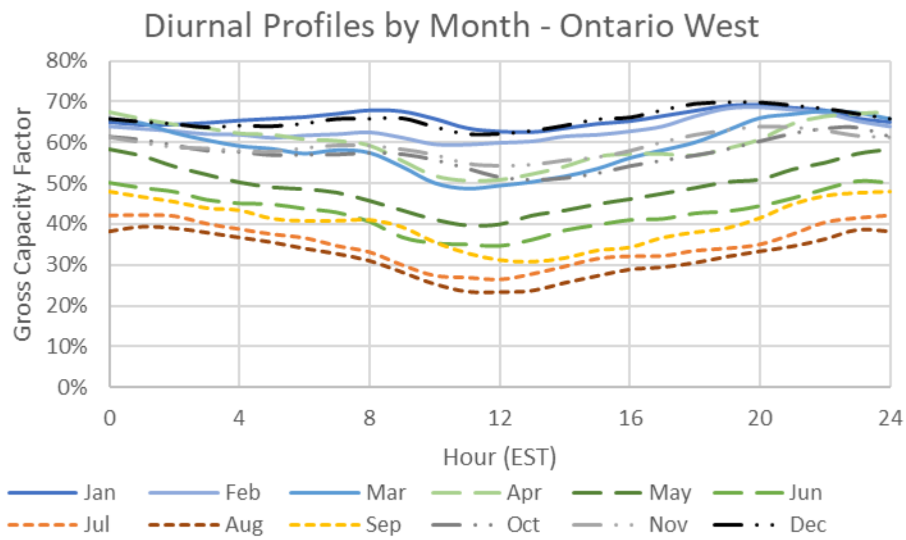


Figure A-4. Diurnal Profiles by Month- Ontario Mid

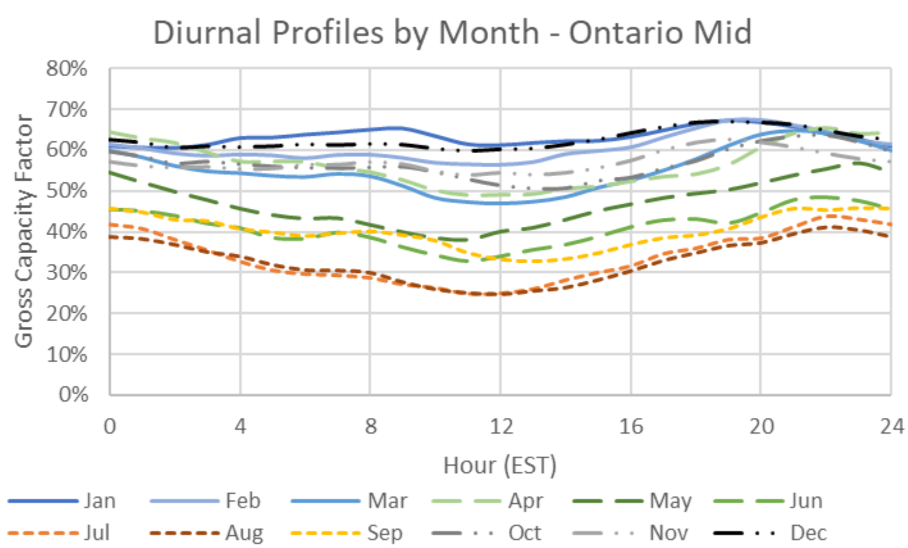
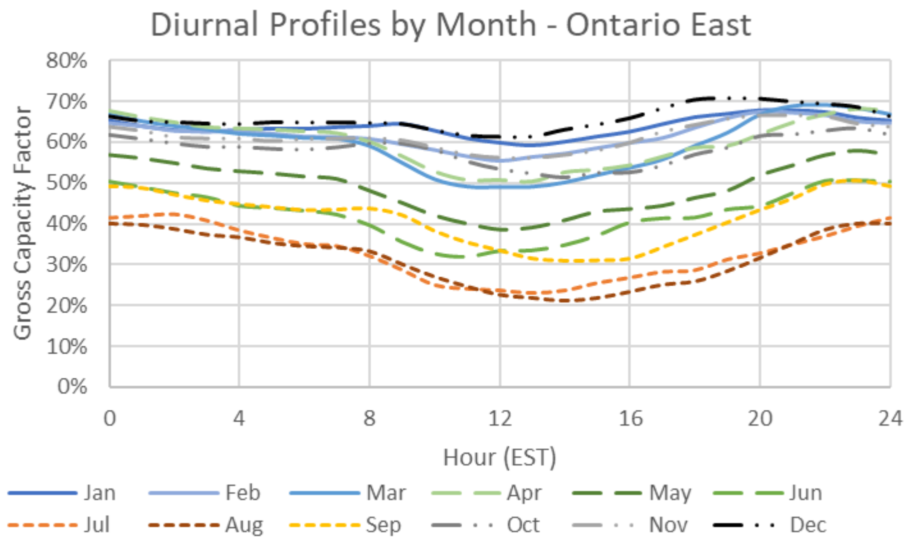


Figure A-5. Diurnal Profiles by Month-Ontario East



Endnotes

[1] One nautical mile is equal to 1.1508 statute miles which are commonly used to measure distance on land. Henceforth miles will be expressed as statute miles unless otherwise stated.

[2] The boundary between the United States and Canada is drawn through international agreements at approximately the point equally distant from the two countries.

[3] Note that a port upgraded for offshore wind on Lake Erie could serve offshore wind commerce in at least four states (NY, PA, OH, and MI). Ports tend to become magnets for other supply chain activities.

[4] Grid elements that overlap the U.S.–Canadian border are shown in Figure 5 for information only; they are not included in the calculated generation potential.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

New York State
Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

State of New York
Kathy Hochul, Governor

New York State Energy Research and Development Authority
Richard L. Kauffman, Chair | Doreen M. Harris, President and CEO