     

Economic and Technical Feasibility Study of Utility-Scale Wind Generation for the New York Buffalo River and South Buffalo Brownfield Opportunity Areas

Joseph Owen Roberts and Gail Mosey

Produced under direction of the U.S. Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-09-1750 and Task No. WFD3.1001.

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Technical Report
NREL/TP-5000-60440
April 2014

Contract No. DE-AC36-08GO28308

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Thanks go to Lura Matthews, Jessica Trice, and Shea Jones of EPA, as well as to everyone who participated in the site visit, shared the rich history of the Buffalo Reuse Authority area, and allowed NREL and EPA to assist in the potential reuse of the land.

Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land Initiative, selected the Buffalo Reuse Authority brownfield site for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) was contacted to provide technical assistance for this project. This report presents an assessment of the site for possible wind turbine installations and an estimate of the cost, performance, and site impacts of different wind energy options. In addition, this report recommends financing options that could assist in the implementation of a wind system at the site.

The feasibility of wind systems installed at this site is highly impacted by the available area for a project, wind resource, operating status, ground conditions and restrictions, distance to electrical infrastructure, future uses, and distance to major roads. The Buffalo site has some available area for several utility-scale wind turbines, and the wind resource is appropriate for development.

The site is approximately 2,500 acres in size with 180 acres appropriate for the installation of wind turbines. While this entire area does not need to be developed at one time due to the feasibility of staging installation as land or funding becomes available, calculations for this analysis reflect the wind potential if all 180 acres are used for wind energy production.

The economic feasibility of a potential wind farm on the site depends greatly on the purchase price of the electricity produced. An economic analysis of a potential project at this site indicates that a minimum power purchase agreement (PPA) price of $85/MWh is required for the project to be economically viable. In comparison, the current New York Independent System Operator (NYISO) wholesale electric rate is $57/MWh. However, prices for wind PPAs in the east and northeast regions in 2011[1] and 2012[2] have varied greatly, and longer-term wind prices in the NYISO service area may be closer to this project's potential PPA price. The analysis assumes that the production tax credit incentive would be captured for the system.

While it might not be the least expensive short-term option, wind energy can also help the EPA meet federal energy targets, such as those laid out in the Presidential Memorandum from December 5, 2013: Federal Leadership on Energy Management. President Obama called on all federal agencies to increase their use and purchases of renewable energy.

[1] Wiser, R.; Bollinger, M. *2011 Wind Technologies Market Report*. Washington, D.C.: Department of Energy, 2011; p. 53. Accessed January 6, 2014: http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf.

[2] Wiser, R.; Bollinger, M. *2012 Wind Technologies Market Report*. Washington, D.C.: Department of Energy, 2012; p. 53. Accessed January 6, 2014: http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf.

"By fiscal year 2020, to the extent economically feasible and technically practicable, 20 percent of the total amount of electric energy consumed by each agency during any fiscal year shall be renewable energy." [3] Section 1(d) of the Memorandum specifically states, "Agencies shall consider opportunities, to the extent economically feasible and technically practical, to install or contract for energy installed on current or formerly contaminated lands, landfills, and mine sites."

[3] Accessed March 24, 2014: http://www.whitehouse.gov/the-press-office/2013/12/05/presidential-memorandum-federal-leadership-energy-management.

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1 Project and Site Background

Under the RE-Powering America's Land Initiative, the U.S. Environmental Protection Agency (EPA) provided funding to the National Renewable Energy Laboratory (NREL) to support a feasibility study of wind renewable energy generation at the Buffalo Reuse Authority brownfield site (Buffalo site). Feasibility assessment team members from NREL, the Buffalo Reuse Authority, and EPA conducted a site assessment visit to gather information integral to this economic feasibility study. The team gathered and considered information about the wind resource, transmission availability, environmental considerations, radar, and ground conditions.

The Buffalo site is located in the southwest corner of Buffalo, New York, adjacent to the City of Lackawanna. The site was previously used for steel and chemical production, and the majority of the reclamation related to those activities has been carried out. The site is being developed as an industrial park that has several customers already occupying space in the brownfield area. The site has many possible development options, but many of these options will consume large amounts of electricity, which may facilitate a more cost-effective interconnection or possibly a behind-the-meter agreement with the local utility.

Adjacent to the Buffalo site is the Steel Winds wind farm, which also utilizes contaminated land reused for renewable energy production. The Buffalo site was a candidate for the Steel Winds project, but the developer indicated that the wind resource at the Steel Winds site was substantially greater, and at the time of the development, the land at the Steel Winds site was substantially less expensive than the Buffalo site.

2 Wind Energy

Uneven heating of the earth's surface creates motion in the atmosphere and thus kinetic energy in the form of wind. Variation in heating and factors, such as surface orientation, slope, rate of reflectivity, absorptivity, and transmissivity, also affect the wind resource. In addition, the wind resource can be affected (accelerated, decelerated, or made turbulent) by factors such as terrain, bodies of water, buildings, and vegetative cover.

Wind is air with kinetic energy that can be transformed into useful work via wind turbine blades and a generator. Overall, wind is a diffuse resource that can generate electricity cost effectively and competitively in regions with a good wind resource, high cost of electricity, or both.

2.1 Wind Characteristics

Winds vary with the season, time of day, and weather events. Analysis of wind data focuses on several critical aspects—average annual wind speed, frequency distribution of the wind at various speeds, turbulence, vertical wind shear, and maximum gusts. These parameters allow for estimation of available energy in the wind and the suitability of turbine technology for the site.

The wind speed at any given time determines the amount of power available in the wind. The power available in the wind is given by:

$$P = (A\ \rho V^3)/2$$

where

P = power of the wind [W]

A = windswept area of the rotor (blades) [m^2] = $\pi D^2/4 = \pi r^2$

ρ = density of the air [kg/m^3] (at sea level at 15°C)

V = velocity of the wind [m/s].

As shown, wind power is proportional to velocity cubed (V^3). This matters because, if wind velocity is doubled, wind power increases by a factor of eight ($2^3 = 8$). Consequently, a small difference (e.g., increase) in average speed causes significant differences (e.g., increases) in energy production. Examining ways to increase the wind velocity at a particular turbine location should be considered through modeling the terrain and micro-siting the turbines. Normally, the easiest way to accomplish this is to increase the height of the tower. The wind industry has been moving toward higher towers, and the industry norm has increased from 30 m to 80 m over the last 15–20 years.

Figure 1 is a map of the national wind resource. Wind maps can give a visual approximation of the wind resource in an area but do not provide enough data for estimating annual electricity output at a particular site. Onsite wind data are typically collected for 1–3 years and are necessary to accurately estimate future wind turbine performance.

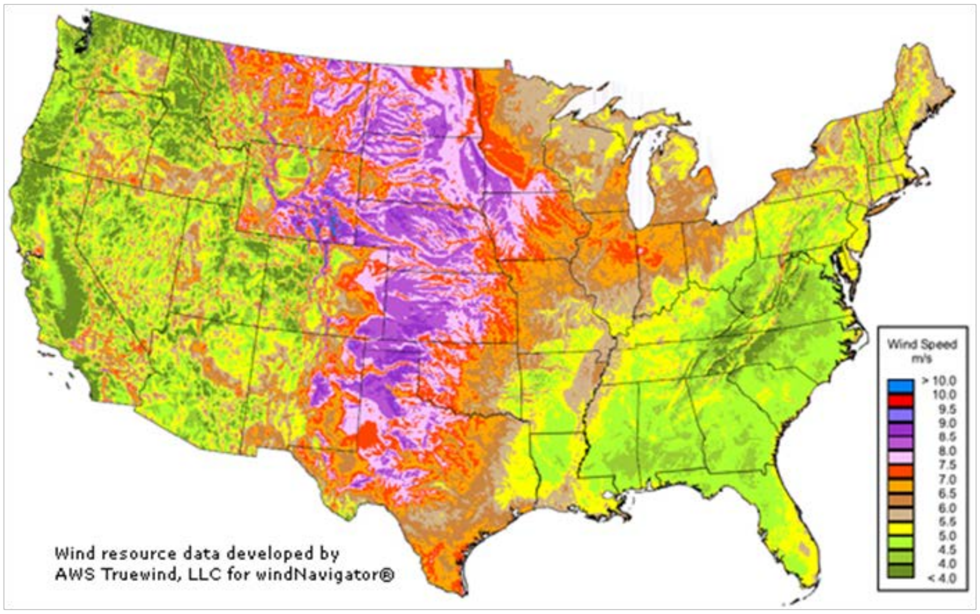

Figure 1. U.S. national wind resource map[4]

Figure 2 shows the New York state wind resource at 80 m above ground level. The Buffalo site is shown on the western edge of the state.

[4] DOE. "Utility-Scale Land-Based 80-Meter Wind Maps. Accessed November 20, 2013: http://www.windpoweringamerica.gov/wind_maps.asp.

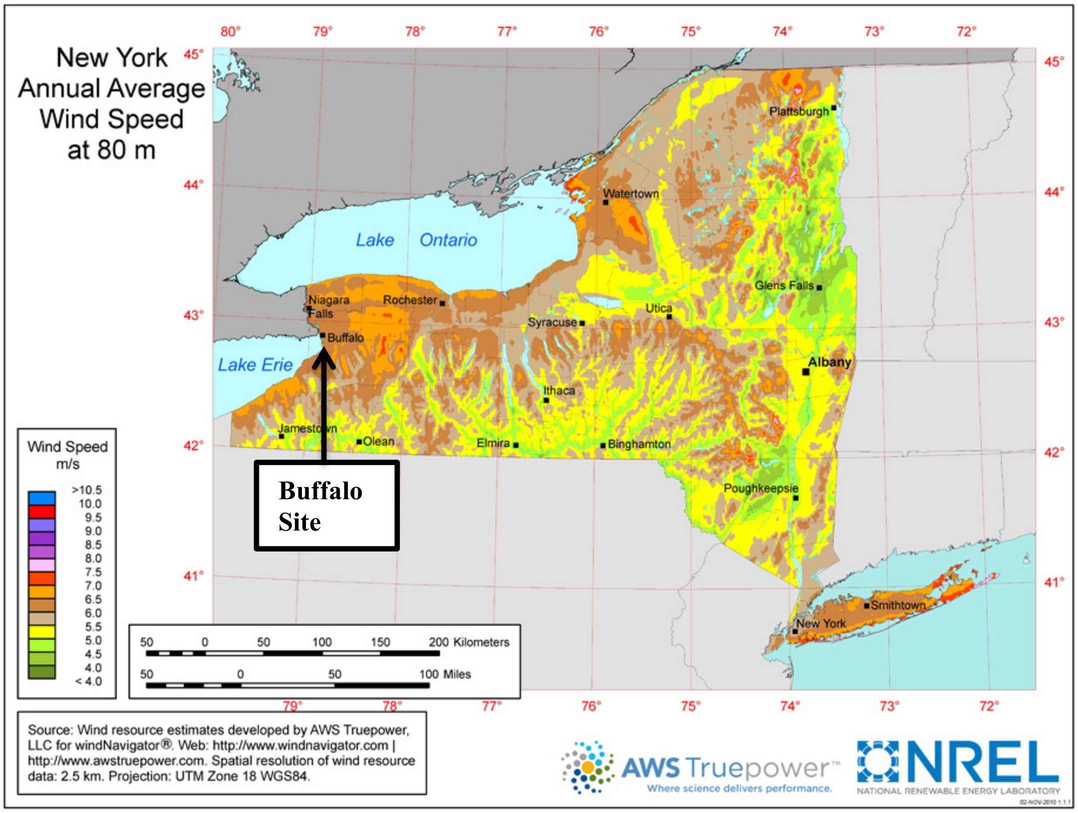

Figure 2. New York 80-m annual average wind speed map[5]

2.2 Wind Turbines

Wind turbines consist of rotating blades that convert the kinetic energy of the wind into mechanical energy that is then converted into electrical energy. They have a number of moving parts that require regularly scheduled and unscheduled maintenance. Manufacturer warranties cover the first 2–10 years. Professional wind turbine maintenance contractors are recommended after the warranty period. Figure 3 shows large wind turbines that are of the scale and general size that might be considered at the Buffalo site.

[5] "New York 80-Meter Wind Map and Wind Resource Potential." U.S. Department of Energy, 2013. Accessed 2013: http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=ny.

Figure 3. Modern utility-scale wind turbines. ***Photo by Joseph Owen Roberts***

Wind farms are typically cost effective where the average wind speed is high, where the competing energy costs are high, or where both conditions exist. Large wind farms of 100–500 MW are commonly deployed instead of wind farms with only 1 or 2 turbines because of lower installed costs largely due to economies of scale. In the United States, about 60,000 MW of wind power have been installed.[6] Turbines as small as 250 W and as large as 5 MW are available. For the size of the wind plants considered here, large turbines in the range of 1,000–3,000 kW per turbine would be appropriate due to the advantage of economies of scale that larger turbines present. Small turbines may only be able to achieve levelized cycle costs of energy of approximately $200/MWh, whereas large wind turbines in large wind farms can have a levlized cost of energy (LCOE) of roughly $70/MWH.[7]

Wind power became a commercial-scale industry more than 30 years ago. Over that time, wind power has moved from the fringes of the electric power sector to a mainstream resource responsible for 35% of new U.S. power capacity from 2007 through 2011; it is

[6] Wiser, R.; Bollinger, M. *2012 Wind Technologies Market Report*. Washington, D.C.: Department of Energy, 2012. Accessed January 6, 2014: http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf.

[7] Lantz, E.: Wiser, R.: Hand, M. "IEA Wind Task 26: The Past and Future Cost of Wind Energy, Work Package 2." p. 16.

second in new capacity additions only to new natural gas power.[8] In the best resource areas or localities with exceptionally high electricity costs, wind power can be cost effective even in the absence of direct financial incentives or subsidies. Recent technological improvements[9] are expected to significantly lower the life cycle cost of wind energy. Initial investment costs for wind power are high compared with such costs for natural gas or other forms of generation[10]; however, with zero fuel costs and relatively modest fixed annual operations expenditures, wind-generated electricity is often an economical generation resource over the long term.

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[8] Williams, E.; Hensley, J. *AWEA U.S. Wind Industry Annual Market Report 2012.* 2013.
[9] Wiser, R.; Lantz, E.; Bolinger, M.; Hand, M. *Recent Developments in the Levelized Cost of Energy from U.S. Wind Power Projects*, February 2012. Accessed January 6, 2014: http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf.
[10] U.S. EIA. *Updated Capital Cost Estimates for Utility Scale Electricity Generation Plants,* April 2013. Accessed November 20, 2013: http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf.

3 Potential Turbine Locations

3.1 Area Available for Turbines

The Buffalo site has more than 180 acres of land within the brownfield areas potentially suitable for the placement of wind turbines. Figure 4 shows the site extent in light red, landfill sites in dark red, the Tifft Nature Preserve in blue, and potential turbine locations as blue markers. Some of these areas will be excluded for potential bird interactions, as well as for business development and infrastructure, but the exact bird migratory paths and redevelopment plan are currently unknown. The blue-shaded area shows the extent of the Tifft Nature Preserve.[11] Further investigation into the population, species, and migration paths should be done. Contacting the organizers of the nature preserve is highly recommended if the development of a wind project is pursued.

Two closed landfills on site present increased elevation and exposure to the predominant wind direction. These areas are shaded in dark red in Figure 4. Multiple turbines have been constructed atop older landfills and uncontrolled fill and demonstrate that such projects can be feasible, including Hull, Massachusetts; Falmouth, Massachusetts; Buffalo Mountain wind farm near Oak Ridge, Tennessee; and Stony Creek wind farm in Somerset County, Pennsylvania. These sites use monopile or "can" type foundations rather than gravity/ballast systems, such as "spreadfoot foundations." The monopile or "can" foundations use skin friction and large surface areas to provide sufficient support to a turbine in poor soil conditions, such as a landfill or mine spoil soils. Typical spreadfoot foundations are not feasible due to possible differential settlement of the soil in uncontrolled fill areas. Potential turbines in the landfill areas of the Buffalo site would therefore be expected to be monopile or "can" type foundations.

[11] "About Tifft." Buffalo Museum of Science, 2013. Accessed December 2013: http://www.sciencebuff.org/tifft-nature-preserve/about-tifft/.

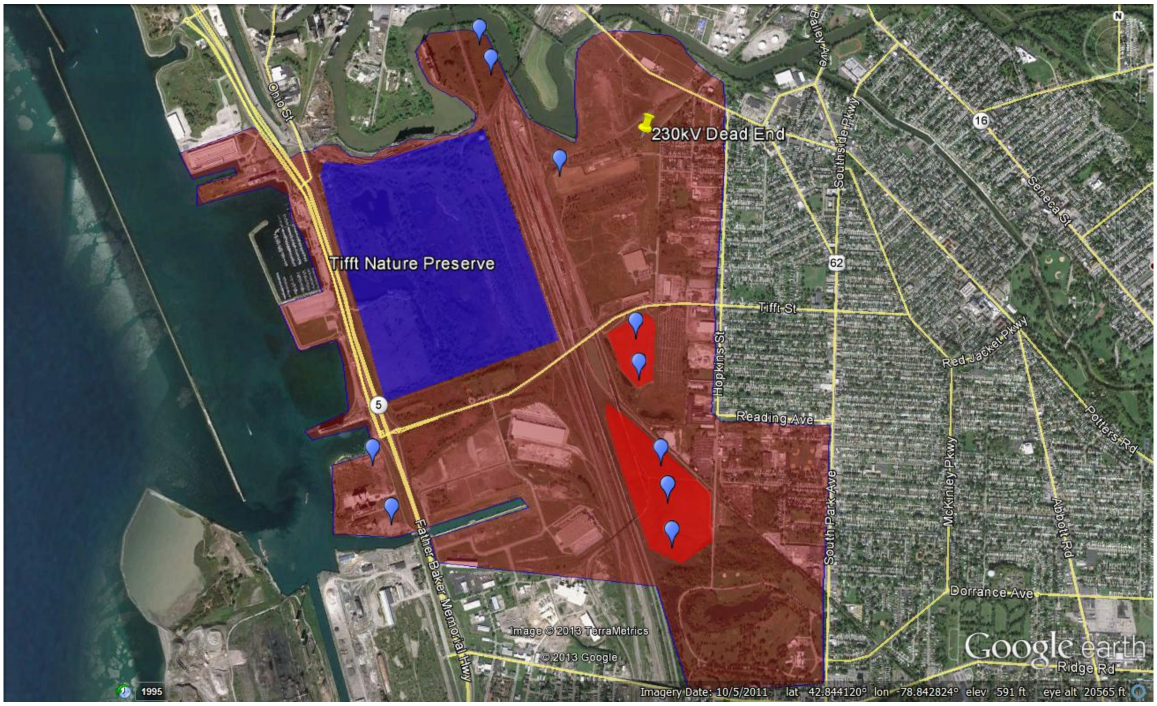

Figure 4. Site extent map

Image generated in Google Earth

3.2 Site-Specific Considerations

As shown in Figure 4, the site has sufficient space to allow for the installation of several utility-scale turbines and depending on the actual wind direction distribution, turbine manufacturer specifications, and actual suitable turbine sites. An onsite 230-kV transmission tower is designed to serve as the end of transmission line (a dead-end structure), as seen in Figure 5. The tower would need a substation added for interconnection and could be cost prohibitive as only several turbine sites appear suitable for installation and the distance between the interconnection point ant the developable areas is too great. Smaller distribution voltage lines could be considered for interconnecting at a lower voltage or existing substation at a significantly lower cost than a 230-kV substation. Further investigation into the cost of a substation and the possibility of connecting turbines to distribution voltage power lines is recommended. There is also a large amount of distribution level voltage infrastructure in the area that could allow interconnection of 10–15 MW of turbines, depending on the size of the conductor and distance to the nearest substation. Further investigation into the local distribution voltage level infrastructure is recommended.

Figure 5. 230-kV dead-end structure. ***Photo by Joseph Owen Roberts, NREL***

3.3 Permitting and Setbacks

One of the largest constraints to permitting large wind turbines can be the avoidance of interference with air traffic, weather radar, and military operations. The Buffalo site is not within any direct flight paths that would automatically preclude it from the possibility of installing a utility-scale turbine, and the nearest FAA-regulated airspace is for the Heussler Hamburg Heliport, which is approximately 3.5 miles from the nearest developable turbine location. The Steel Winds project's nearest wind turbine is within 1 mile of this same heliport.

Local ordinances might also apply, and they should be investigated further, as some local governments have regulations that constrain the overall height of structures for viewshed reasons. If the installation of utility-scale turbines is pursued, investigation of all local ordinances for structure heights and viewshed considerations is recommended.

Long-range radar can also be affected by the movement of the turbines' blades, and it can cause interference for air traffic control if not mitigated. Figure 6 is a screen shot from a Department of Defense Preliminary Screening Tool and shows that there is a high likelihood of interference with long-range radar at the site; contacting the FAA should be one of the first steps in the siting process. The red area in Figure 6 represents a potentially severe impact on local radar and as one can see the entire area is red. Many turbines have been installed in potential impact zones, and mitigation measures can vary from ignoring the interference to upgrading the software of the radar to filter this interference. The Steel Winds turbines are also located within this area of potential impact, but this does not guarantee that the proposed turbines for the Buffalo site will not severely impact the radar.

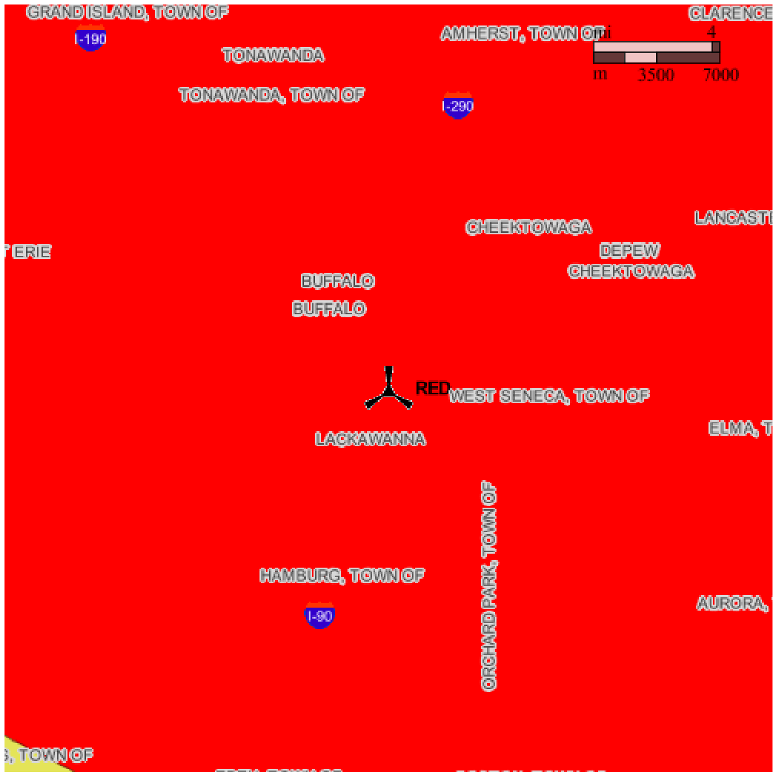

Figure 6. Screen shot of long-range radar impact potential[12]

[12] "DoD Preliminary Screening Tool." Federal Aviation Administration, 2013. Accessed December 2013: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm.

Figure 7 shows that the site has a high probability of interference with local NEXRAD radar, as the centrally located black wind turbine symbol coincides with some of the semi-circular areas that represent local weather radar. The existing Steel Winds turbines are in a very similar location, which suggests that interference might not be an issue, but further discussion with the FAA is recommended.

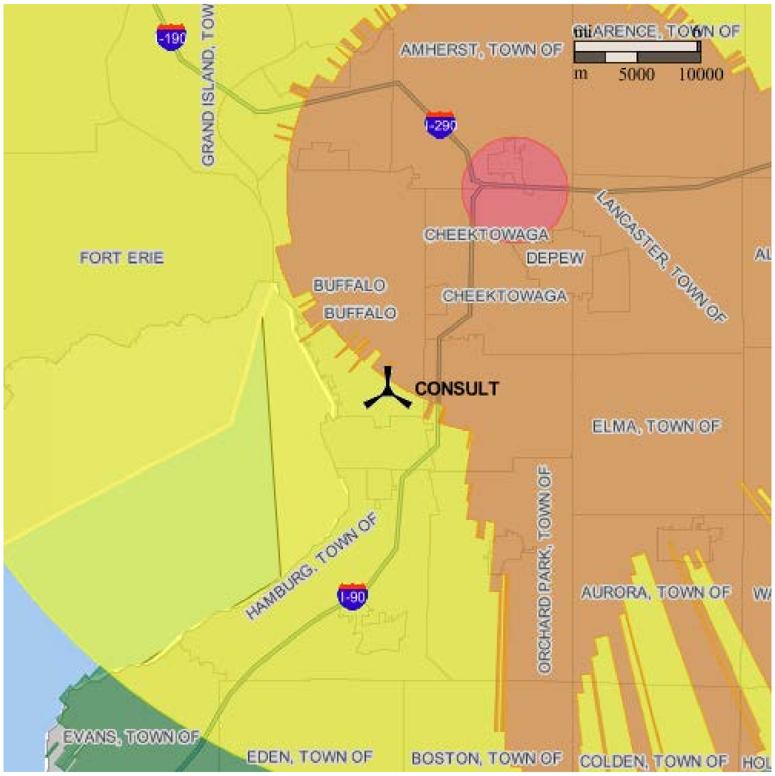

Figure 7. NEXRAD radar impact potential[13]

3.4 Environmental Siting Considerations

The Buffalo site has the potential for significant bird presence due to the site's proximity to the Tifft Nature Preserve.[14] Wind turbines have been shown to kill birds in their operation, and this should be considered when placing turbines in an area that has a bird population. Currently, the U.S. Fish and Wildlife Service (USFWS) is making recommendations to specific projects, such as wind farms, but these are not yet stipulated for specific technologies, species, or other factors. Each site is specific to each species, wind regime, and turbine height and model.

The USFWS has developed voluntary guidelines[15] that provide a tiered approach in which each tier can provide a developer with information that can then be used to make

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[13] "Notice Criteria Tool." Federal Aviation Administration, 2013. Accessed December 2013: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm.
[14] Buffalo Museum of Science. "Tifft Nature Preserve." Accessed January 6, 2014: http://www.sciencebuff.org/tifft-nature-preserve/.
[15] National Wind Coordinating Collaborative. "Comprehensive Guide to Studying Wind Energy/Wildlife Interactions." Accessed November 20, 2013: http://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildl

decisions on how to proceed with a wind project at a particular site. Potential developers can consults with the USFWS, which will provide non-binding recommendations, and it is up to the developer to choose to follow the recommendation. Tier 1 is a preliminary site evaluation typically conducted as a desktop study. The developer should use all available information for this initial screening, but no site visit is needed. Tier 2 is frequently referred to as "boots on the ground," for which a site visit is needed, and a site characterization can be done. Tier 3 is typically where pre-construction site assessments are conducted and are focused on species or habitat considerations that were identified during Tier 2. Tier 4 focuses on post-construction monitoring to coincide with whatever species of importance were identified and assessed during Tier 3. Finally, if the site has a major species issue but the developer is still interested in going forward with the project, more complex studies or research would be conducted under Tier 5. The need for Tier 5 research is likely to be determined during Tier 3, so these two activities should align.

Given the proximity of the Tifft Nature Preserve, it is assumed that at least Tier 1 and Tier 2 studies would be recommended by USFWS for the Buffalo site, with those findings determining whether further study will be recommended.

The National Wind Coordinating Collaborative published the "Comprehensive Guide to Studying Wind Energy/Wildlife Interactions" in 2011.[16] This document is a resource describing methods and metrics for conducting wildlife studies at wind facilities and is referenced in the USFWS guidelines.

Research on land-based wind-wildlife interactions has been conducted beginning with the first wind facilities in California. As wind development has moved across the country, various species- and habitat-specific issues have been raised. Research is now being conducted or supported by a wide range of sectors and stakeholders, including the federal government (e.g., DOE, U.S. Department of the Interior), states including the Association of Fish and Wildlife Agencies (AFWA), trade industry, academia, non-governmental organizations (e.g., The Nature Conservancy, Union of Concerned Scientists, Audubon Society, Defenders of Wildlife), individual wind developers, and virtually all other sectors and stakeholders.

The species currently of most interest include eagles, Greater Sage-Grouse, Greater and Lesser Prairie Chickens, bat species, Whooping Cranes, condors, and Marbled Murrelet. Habitat fragmentation and disturbance are also issues—it is not just about collision with a wind turbine but also how the species could be affected by the presence of the wind turbines and the effects on the landscape due to the construction of the facility. Other species, such as federally threatened and endangered bird and bat species, candidate species, state species of concern, and various other raptor species, including several hawk and owl species, for example, should also to be considered.

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ife_Interactions_2011_Updated.pdfhttp://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdf.

[16] National Wind Coordinating Collaborative. "Comprehensive Guide to Studying Wind Energy/Wildlife Interactions." Accessed November 20, 2013: http://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdfhttp://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdf.

Although the USFWS guidelines are voluntary, a discussion of adherence in the guidelines says, "Adherence to the Guidelines is voluntary and does not relieve any individual, company, or agency of the responsibility to comply with laws and regulations. However, if a violation occurs the Service will consider a developer's documented efforts to communicate with the Service and adhere to the Guidelines" (p. vii).

3.5 Local Wind Resource Characteristics

This study assumed the use of utility-scale wind turbines with 80 m or greater hub heights. Modern turbine technology and improvements in modeling wind resources in North America have changed which wind resources are cost effective to develop for utility-scale wind energy. NREL and AWS Truepower previously partnered to determine the potential for wind development in all U.S. states.[17] These potential state-installed capacities were developed assuming older turbine technologies that now underestimate the total potential for installed capacity.

Advancements in modern, commercially available turbine technologies have drastically increased turbine energy yields, especially for lower wind speed sites. The industry trend for utility-scale wind turbines is larger rotor diameters (referred to below as current technology in Figure 8) and smaller electrical nameplate capacities for lower wind speed regimes. This has been shown to be cost effective, especially for lower wind speed sites, as shown in Figure 8.

As no onsite wind monitoring was performed for this study, typical meteorological year data from AWS Truepower were used to estimate the energy production of various turbines at the site. These data are created from numerical weather models and are adjusted using surface observations, such as airport weather stations. The data are then compiled to create a typical year of hourly data that should be representative of an average year at the site.

The uncertainty in this modeled dataset varies by location. For the Buffalo site, the uncertainty appears low as the model predicts the existing Steel Winds wind farm to have a long-term adjusted annual capacity factor for the Clipper C96 turbines of 31.2%,[18] and the actual long-term capacity factor is roughly 29.9%.[19] Also, the fact that the Steel Winds turbines were known to have major periods of inoperation for blade and gearbox repairs shows that there is a high uncertainty in this comparison. The other large source of uncertainty is the actual surface roughness characteristics of the upwind areas as the native resolution of the AWS dataset is much too coarse for a site-specific turbine production estimate. It is highly recommended that on-site measurements be used or that validated model data is used in conjunction with high topographic and surface roughness data (to more accurately estimate the energy production of turbines at the site).

[17] DOE. "Wind Resource Maps and Anemometer Loan Program Data." Accessed November 20, 2013: http://www.windpoweringamerica.gov/windmaps/.

[18] Estimates are based on 200-m resolution data comparing both sites generated in conjunction with the typical meteorological year dataset.

[19] Emera. "Power Plant Profile." Accessed January 6, 2014: http://www.snl.com/irweblinkx/PowerPlantProfile.aspx?iid=4072693&PlantID=9027&Graph=3.

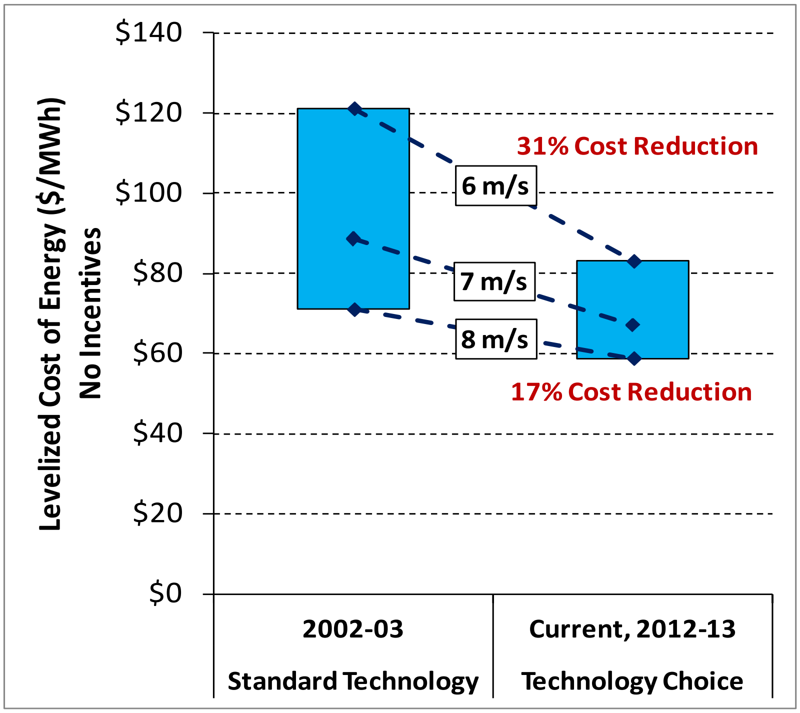

Figure 8. Levelized cost of energy comparison of modern turbines with historical performance[20,21]

These data show that turbines being produced and installed in North America, especially for lower wind speed sites, such as at the Buffalo site, now have a much better chance of producing cost-effective electricity. It appears that the industry is continuing in this direction, and the next generation of turbines already being tested and installed could have a similar impact on the cost of energy as their rotors are even larger. It is yet to be seen where turbine pricing for these new machines will fall, but recent industry trends indicate that prices will continue to decrease over the long term.[22] It is worth noting that modern International Electrotechnical Commission (IEC) Class III turbines with larger rotor to nameplate electrical capacity typically reduce the volatility of annual variations in the wind resource. As the datasets used are focused on temporally longer periods, turbulence intensity is not included as part of either dataset. For this reason, standard industry practice or discussions with a financier or turbine manufacturer that has confidence in the wind resource in the area are recommended to any developer.

[20] Wiser, R.; Lantz, E.; Bolinger, M.; Hand, M. *Recent Developments in the Levelized Cost of Energy from U.S. Wind Power Projects,* February 2012. Accessed January 6, 2014: http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf.

[21] This model assumes current turbine and installation pricing, reduced operation and maintenance (O&M) costs, production tax credits (PTC) and modified accelerated cost-recovery system (MACRS) tax incentives, increased turbine availability, and the comparative capacity factors for the current and previous generation turbine technologies.

[22] Wiser, R.; Lantz, E.; Bolinger, M.; Hand, M. *Recent Developments in the Levelized Cost of Energy from U.S. Wind Power Projects,* February 2012. Accessed January 6, 2014: http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf.

These modeled data provide significant additional insights regarding the wind resource at the site. Figure 9 shows the wind rose, indicating the directionality of the wind resource. The blue area of the figure plots the total wind energy from a given direction.

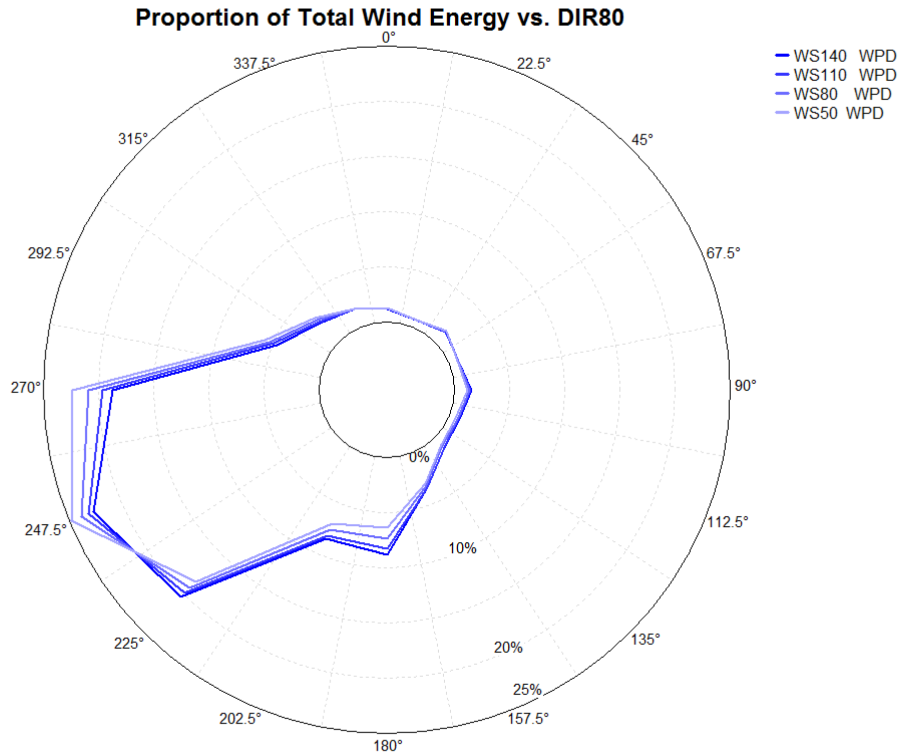

Figure 9. Wind rose at the Buffalo site

Figure 10 illustrates the frequency of different wind speeds at the site, which is critical to turbine selection and energy production. This histogram shows the frequency of occurrence on the y-axis and the wind speed on the x-axis. The Weibull parameters K and c are 2.13 and 6.87, respectively.

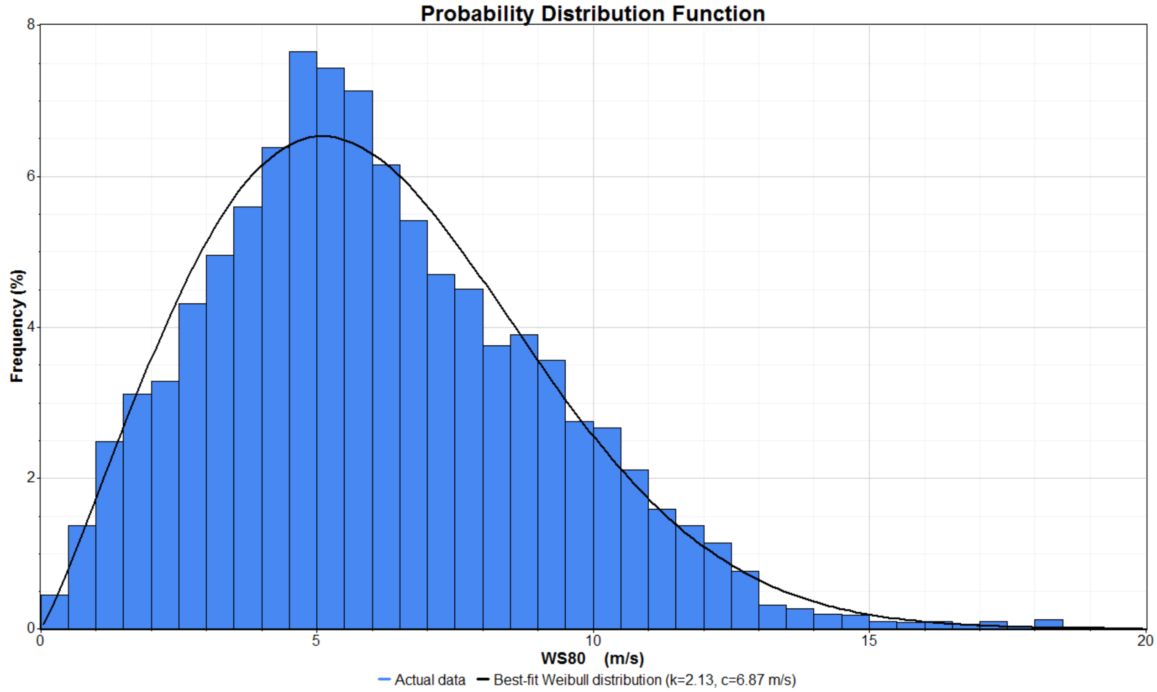

Figure 10. Frequency of wind speeds at the Buffalo site

Figure 11 indicates that the strongest winds occur in the winter at this site. Such variability is not expected to have a significant impact on the economic viability of wind power on the local utility.

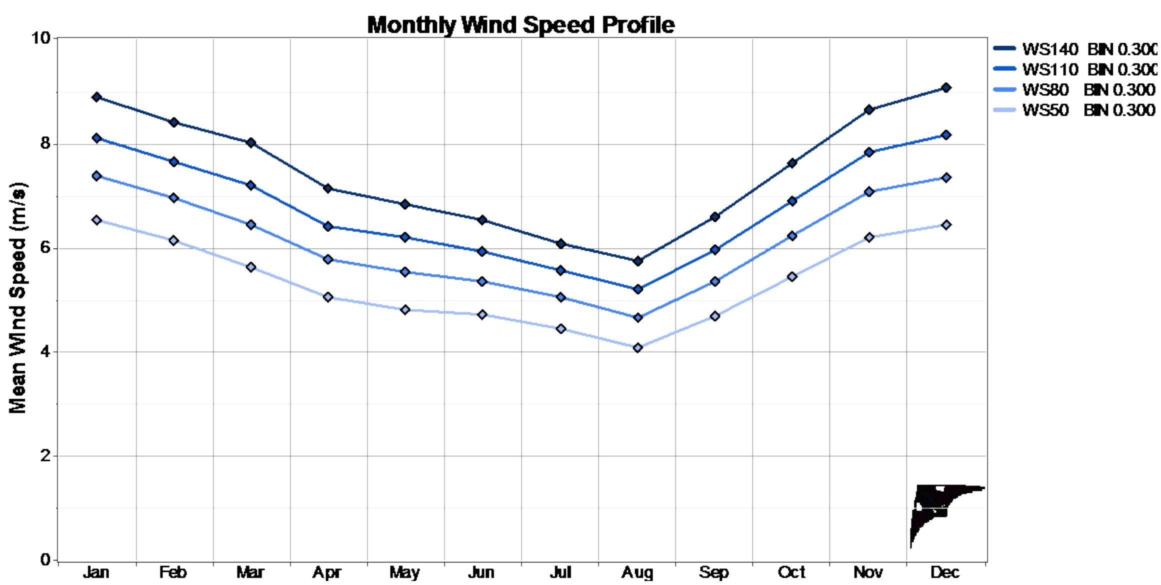

Figure 11. Monthly long-term wind speed averages

Figure 12 indicates that the strongest winds occur during the night; the x-axis indicates hours with the beginning of the day starting at 0 Coordinated Universal Time—not local time.

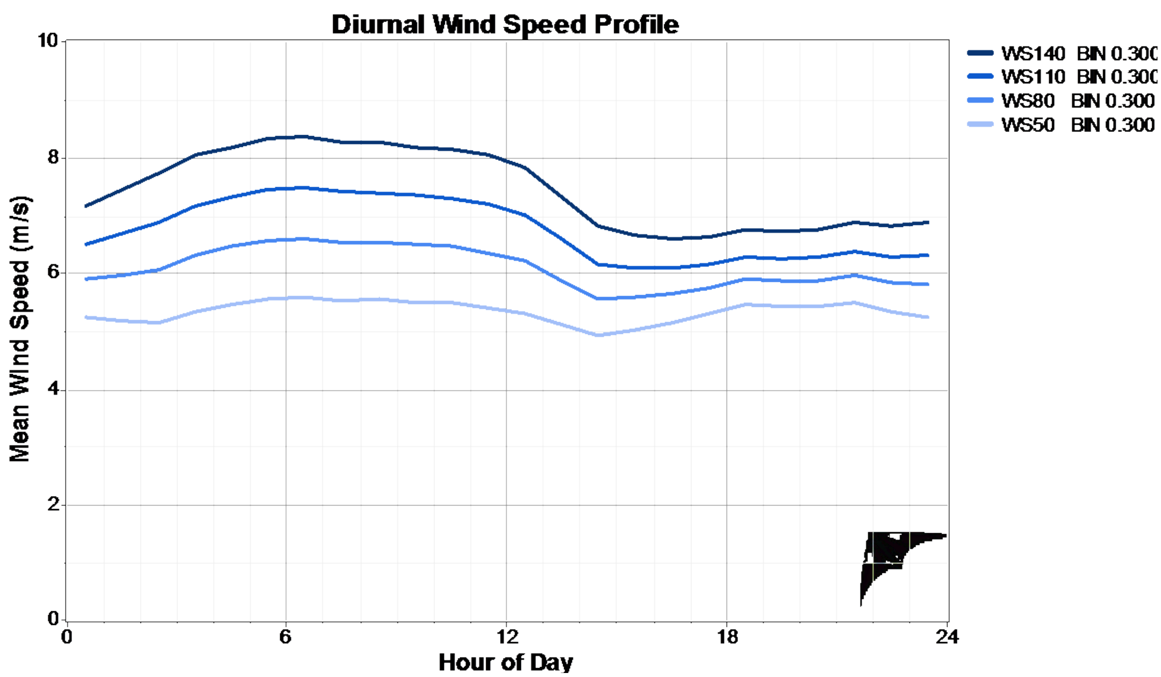

Figure 12. Diurnal wind speed profile (x-axis in Coordinated Universal Time)

Figure 13 shows the site average wind shear, where wind shear is defined as how the average wind speed changes as the height above the ground increases. The shear is high enough (i.e., the wind speed greatly increases as elevation above the ground increases) that taller turbines could increase their energy production enough for taller turbines to be cost effective.

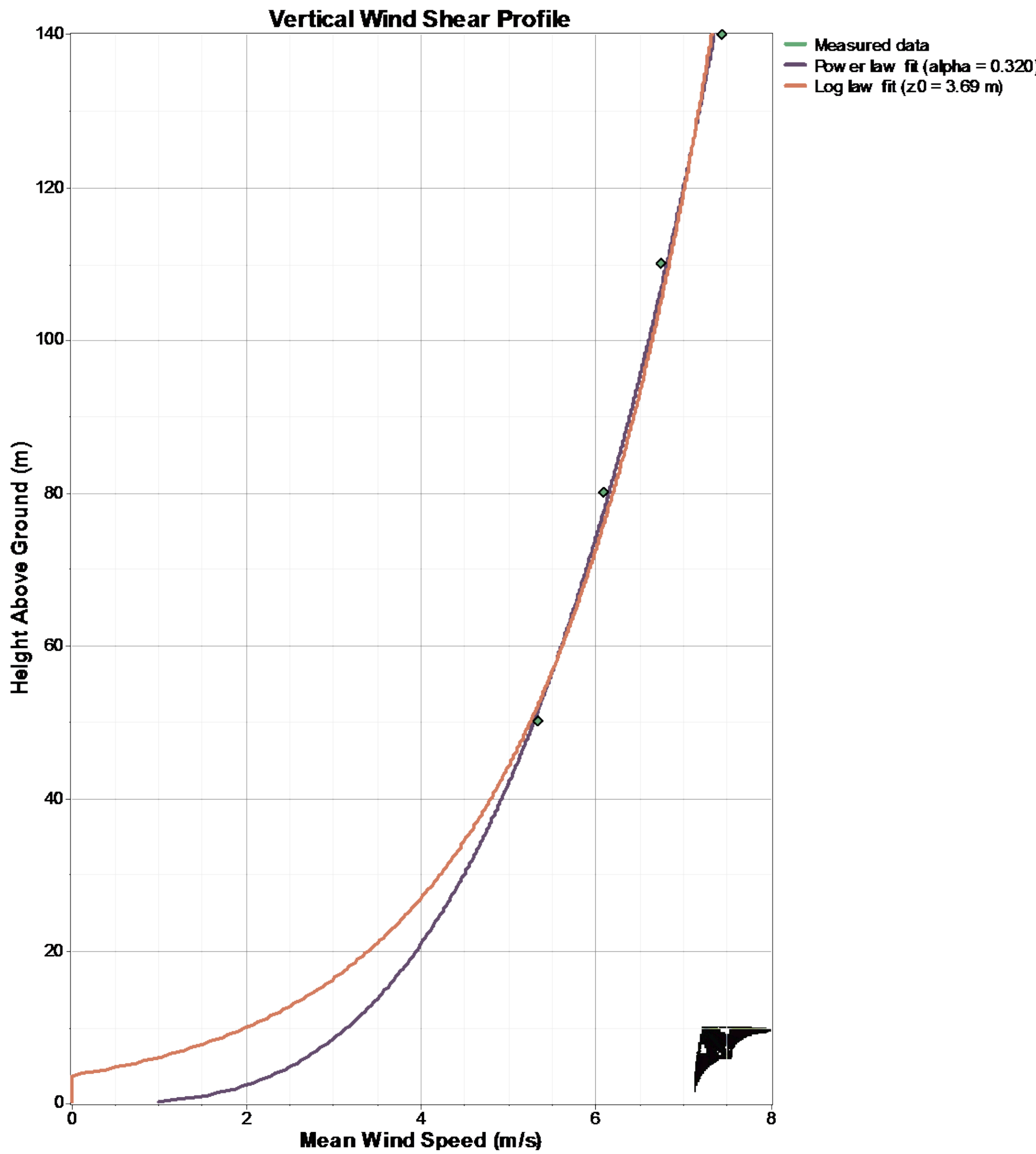

Figure 13. Average wind shear

The average annual wind shear at the Buffalo site is characterized by a power law equation exponent of 0.320 when using all four heights provided by the AWS dataset (50–140 m). The shear is very high but consistent with very high surface roughness areas. As shear values increase, it becomes more cost effective to install taller towers because the taller hub heights can reach faster average wind speeds. However, the construction, material, and labor costs also increase, and this balance will require estimates of site-specific energy production to understand whether taller towers are cost effective.

3.6 Estimated Power Production and Cost of Energy from a Potential Wind Facility at the Buffalo Site

Four key elements are necessary to estimate power production from a wind facility:

1. Wind resource potential
2. Project size or capacity (in MW)
3. The respective wind turbine power curve, a function that demonstrates the energy produced at a given wind speed
4. Estimated losses likely associated with a given project.

Table 1 shows the estimated capacity factors for various IEC class III wind turbines. As discussed earlier, there is uncertainty in these capacity factor estimates due to the complex terrain and interaction of the wind with this transition between water and high surface roughness land. Further analysis utilizing modeled wind data that are adjusted from a local source, such as the Steel Winds nacelle anemometers or the met tower from the initial investigation of the Steel Winds site, can be used along with much higher resolution topographic and surface roughness data to more accurately predict the turbine energy productions at the site. It is worth noting that these modern turbines have significantly higher capacity factors than turbines from 5–10 years ago, such as the turbines at the Steel Winds site. The Buffalo site was not as desirable as the Steel Winds site due to the fact that the annual average wind speeds are significantly lower the farther inland from Lake Erie. However, the cost-per-unit energy for modern machines is significantly lower than for turbine technology 5–10 years ago, so a wind project at the Buffalo site could be economically viable.

Table 1. Estimated Capacity Factors

Turbine	Hub Height Average Wind Speed (m/s)	Net Capacity Factor (15% Losses) (%)
GE 1.6-100 (80 m)	6.09	32.4
Nordex N117/2400 (80 m)	6.09	30.7
Siemens SWT-2.3-113 (80 m)	6.09	32.7
Vestas V100 - 1.8 MW 60 Hz (80 m)	6.09	29.1
Vestas V110 - 2.0 MW 60 Hz (80 m)	6.09	31.6

Note: Estimates shown here do not account for terrain, roughness, wake losses, or localized differences in wind resource. The number of turbines in each case was determined by local topography and turbine spacing of roughly three rotor diameters between turbines. Capacity factor is a means of illustrating the average energy production of a turbine or plant as a share of its theoretical potential over the course of a year. Capacity factors shown here are a function of the wind resource and the expected performance of the turbine models listed here.

The potential project size at the Buffalo site is highly constrained by industry standard setbacks from adjacent landowners, bat habitat and buffer, and future use areas for the industrial park development. Figure 14 shows a possible turbine layout that meets industry standard setbacks from homes, roadways, rail lines, and occupied buildings. Of the 10 possible turbine sites, the 2 closest to Lake Erie will have significantly higher annual energy output, but these sites might not be cost effective, depending on the cost to interconnect them to either the existing grid or a substation.

Figure 14. Possible turbine layout (turbines are blue symbols)

Image generated in Google Earth

Modern utility-scale turbines, especially turbines designed for the lower wind resource areas, are reducing the cost differential between lesser wind resource sites and sites where the wind resource is greater. This trend is illustrated in Figure 8. Energy production estimates are based on inputs of wind resource potential derived from the AWS-modeled data, turbine-specific power curves extracted from manufacturer data by NREL, and estimated losses. Energy production estimates were then used to estimate the net capacity factor for the respective turbine models noted in Table 1.

3.7 Buffalo Site Energy Use

The Buffalo site could have some large electrical loads from industrial customers in the future. However, the electrical loads are currently small, and this study focuses on the possibility of a utility-scale wind farm. It is highly unlikely that any state policy, renewable portfolio standard (RPS), or other legislation would allow connection of a utility-scale project behind the meter at this scale. New York has an RPS that escalates in

2015, which requires 29% renewable energy, but additional investigation is warranted. If the RPS is met though other projects, there will be less incentive for a project such as this. New York also has a net-metering policy, but the capacity for any net-metered facility is capped at 2 MW for commercial facilities.[23] For this reason, a conventional third-party ownership model may be the most likely scenario for a utility-scale project at the Buffalo site, but individual turbines could be placed behind the meter if individual industrial customers are interested. If a third-party PPA is to be pursued, the first step would be to finalize which areas of the site can be set aside for wind development. Integral to this land allocation is a final recommendation by USFWS, which should be in place to ensure that bird habitat is protected. The site also needs an electrical interconnection capable of handling the capacity of the wind farm. As previously noted, the current electrical interconnection onsite is inadequate for the size of project in this report, but it appears that industrial customers will require a larger electrical service on the site regardless of the wind developments discussed here. After these critical steps are taken, a request for proposal can be generated and be made public to gauge interest by third-party developers and owners to own and operate a wind farm on the site.

3.7.1 Ownership Options

In the case where a third party would own and operate a wind farm on the Buffalo site, the owner would lease land and the rights to install turbines and electrical components from the industrial park. The magnitude of these annual lease payments could be on the order of $5,000–$10,000 per turbine as per typical industry practice.

[23] "New York: Incentives/Policies for Renewables and Efficiency." Database of State Incentives for Renewables & Efficiency, 2013. Accessed 2013: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY05R&re=0&ee=0.

4 Project Financial Performance

The NREL System Advisor Model (SAM)[24] was used to model the financial performance of one possible project scenario at the Buffalo site. Assuming conventional third-party ownership, as well as use of the production tax credit (PTC), this project might be financially viable in the New York Independent System Operator (NYISO) territory, given the assumptions in Table 2. However, as detailed in Figure 15, the average PPA price in the Northeast in 2011–2012 was approximately $57/MWh. For a target internal rate of return of 10%, the PPA is required to be $85.3/MWh for a project at the Buffalo site. The assumptions use turbine prices and installed costs from 2012, and they do not reflect any advantages or disadvantages of economies of scale, existing or planned substations, or current construction costs and turbine prices. This financial model is not meant to be representative of an actual project cost but to estimate what a project could cost in this terrain, region, and general state of the industry.

Table 2. Buffalo Wind Farm Financial Assumptions

Annual energy	45,951,000 kWh
Turbine capacity	1.62 MW
Wind farm capacity	16.20 MW
Capacity factor	32.4%
Losses	15.0%
Installed cost	$2,150/kW
Land lease cost (annually)	$100,000
Project life	20 years
PPA price	$85.3/MWh
Calculated PPA escalation	2%
Debt fraction	0%
Internal rate of return	10%
Federal income tax rate	35%
State income tax rate	3.90%
Inflation rate	2.50%
Nominal discount rate	9%
Production tax credit value (non-escalating)	$0.023/kWh
Accelerated depreciation	5 years

[24] SAM. National Renewable Energy Laboratory, 2013. Accessed June 5, 2013: https://sam.nrel.gov/.

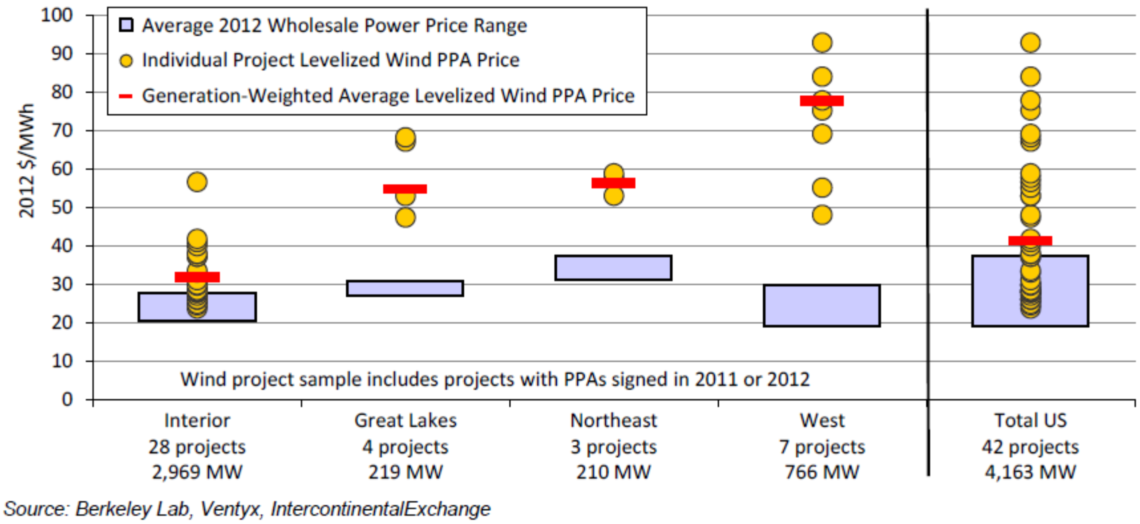

Figure 15. Levelized PPA power prices by U.S. region: 2011–2012 projects[25]

The economic feasibility of a potential wind farm on the site depends greatly on the purchase price of the electricity produced. An economic analysis of a potential project at this site indicates that a minimum PPA price of $85.3/MWh is required for the project to be economically viable. Prices for wind PPAs in the east and northeast regions in 2011[26]and 2012[27] vary greatly, and the sample size in recent years is much smaller than previous years, which suggests longer-term wind prices in the NYISO service area may be closer to this project's potential PPA price. The analysis assumes that the PTC incentive would be captured for the system.

[25] Wiser, R.; Bollinger, M. *2012 Wind Technologies Market Report*. Washington, DC: Department of Energy, 2012. Accessed December 2013: http://emp.lbl.gov/sites/all/files/lbnl-6356e.pdf.
[26] Wiser, R.; Bollinger, M. *2011 Wind Technologies Market Report*. Washington, D.C.: Department of Energy, 2011; p. 53. Accessed December 2013: http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf.
[27] Wiser, R.; Bollinger, M. *2012 Wind Technologies Market Report*. Washington, D.C.: Department of Energy, 2012; p. 53. Accessed December 2013: http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf.

5 Conclusions and Recommendations

The site locations considered for a wind system in this report are suitable areas in which to implement wind systems. Using land that cannot be used for other purposes would minimize the environmental impact of a wind generation plant. The Buffalo site also has the following attributes, which greatly increase the viability of a potential wind project at the Buffalo site:

- Adequate wind resource
- Low potential for public opposition due to land use
- Access to multiple transmission lines (although interconnection oversized)
- Potential for wind to co-exist with future uses of site
- Constructible site, but landfills will increase foundation costs.

Multiple customers onsite may be interested in paying for portions of the wind energy, which is an example of consumers paying for local energy. Further development of ownership and investment options should be explored.

It is recommended that the Buffalo Reuse Authority further pursue opportunities for a wind system installation on the Buffalo site. Some of the first steps the Reuse Authority could undertake that could make the project more attractive to potential wind developers are investigation of the Tifft nature preserve species and local support or opposition for environmental concern and investigation as to a local substation that could be interconnected at a lesser cost than building a new 230-kV substation on site, as well as potential radar interference and local government opposition. It is recommended that a public request for intent to bid be issued to gauge interest from developers in the location and site. For multiple reasons—a combination of acceptable resource, potential developable area, utilization of contaminated lands, onsite loads, onsite electrical infrastructure, and low impact to surrounding neighbors—this assessment finds that a wind system is a reasonable use for the site. A third-party ownership PPA is the most feasible way for a system to be financed and installed on this site, as ownership of the wind farm would require substantial financing and transaction costs for the PTC.