Case No. 16-1871-EL-BGN

Icebreaker Windpower Inc.

Application-Part 5 of 13

Part 5 includes:

- Exhibit E. Mono Bucket Installation Video
- Exhibit F. Facility Substation Layout Plan
- Exhibit G. Great Lakes Wind Energy Feasibility Study

Date Filed: February 1, 2017

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Exhibit E

Mono Bucket Installation Video

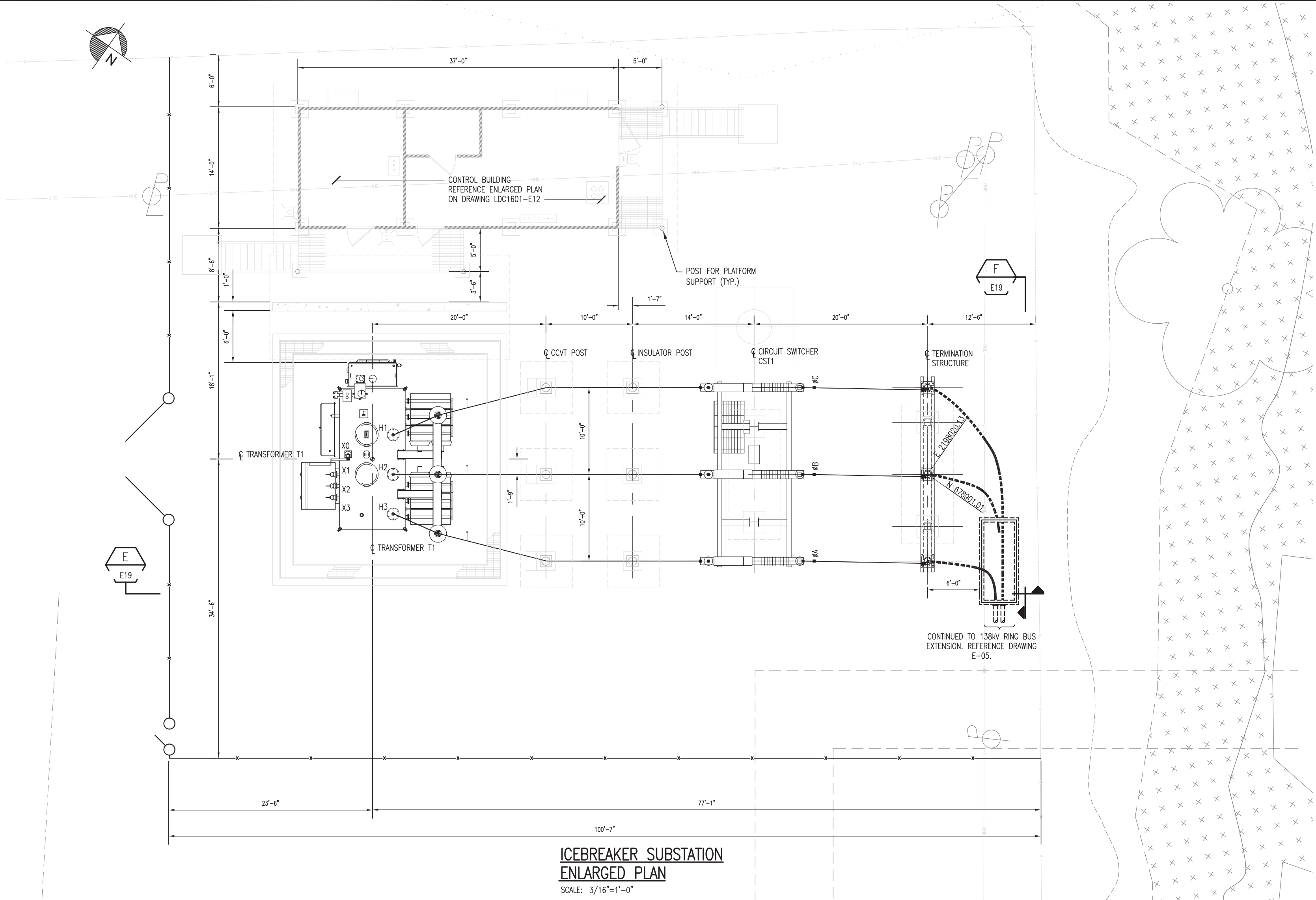
Exhibit E is displayed on a USB drive. Due to the fact that the Ohio Power Siting Board's Docketing Information System does not have the technical capability to receive the video, the Applicant has provided the USB copies of the video to the Board staff.

Case No. 16-1871-EL-BGN

Icebreaker Windpower Inc.

Application-Part 5 of 13

- Exhibit F. Facility Substation Layout Plan



ICEBREAKER SUBSTATION ENLARGED PLAN

SCALE: 3/16"=1'-0"

NOTES:

1. REFERENCE DRAWING #LDC1601-T01 FOR DRAWING INDEX AND GENERAL NOTES.
2. THE BASIS OF BEARINGS FOR THIS SURVEY IS OHIO STATE PLANE, NORTH ZONE NAD83(2011) GRID NORTH. WORK THIS DRAWING WITH LDC1601-C01.

MIDDOUGH PROJ. #: LDC1601

REVISION	DATE	DESCRIPTION	BY	APP'VD.
C	12/16/16	ISSUED FOR 90% REVIEW	SCS	TRH
B	11/11/16	ISSUED FOR 60% REVIEW	SCS	TRH
A	10/7/16	ISSUED FOR 30% REVIEW	SCS	TRH

REFERENCE DRAWINGS	NO.	DATE	DIST.

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icebreaker windwattswork

ICEBREAKER SUBSTATION
ICEBREAKER SUBSTATION ENLARGED PLAN

DRAWN BY SCS | CHECKED BY TRH | SCALE AS NOTED | DATE 9/12/16 | DRAWING NUMBER LDC1601-E17

Case No. 16-1871-EL-BGN

Icebreaker Windpower Inc.

Application-Part 5 of 13

- Exhibit G. Great Lakes Wind Energy Feasibility Study

Great Lakes Wind Energy Center

Feasibility Study

Final Feasibility Report

Submitted as part of the Great Lakes Wind Energy Center Feasibility Study to:

Cuyahoga County, Ohio

Great Lakes Energy Development Task Force

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Project Team

juwi

JWGL
JW Great Lakes Wind LLC

GL
OPERATING 24/7

BROWN
FLYNN

DLZ

BLACK & VEATCH
Building a world of difference.

Econnect

Curry & Kerlinger, LLC

Notice:

This report presents final feasibility results for the Great Lakes Wind Energy Center. The Great Lakes Wind Energy Center Feasibility Study is being conducted by juwi GmbH and its Ohio-based subsidiary JW Great Lakes Wind LLC, on behalf of the Cuyahoga County Great Lakes Energy Development Task Force. Please direct questions regarding the Great Lakes Wind Energy Center Feasibility Study to Ryan Miday at p4rm1@cuyahogacounty.us or (216) 299-9326.

Disclaimer:

This report was prepared by juwi GmbH and its subsidiary JW Great Lakes Wind LLC, with contributions from GLWEC Project Team members. Neither juwi GmbH, JW Great Lakes Wind LLC, nor Project Team members make any warranty of representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report. Neither JW Great Lakes Wind LLC, juwi GmbH, nor Project Team members assume any liability with respect to the use of, or damages resulting from the use of, any information disclosed in this report.

Table of Contents

NOTE TO THE READER:

With the exception of the Executive Summary, Introduction, Conclusions and Recommendations, and Suggestions for Next Steps, information in this report largely follows individual GLWEC Feasibility Study deliverables. At the start of each section, we indicate the deliverable(s) from which information is drawn. For original marked citations and appendices, and for the full text, readers are encouraged to refer to individual deliverables. Individual deliverables can be found on Cuyahoga County's Feasibility Study webpage: http://development.cuyahogacounty.us/en-US/Wind-Turbine-Feasibility-Study.aspx

1 Executive Summary

juwi GmbH was hired by Cuyahoga County to perform a feasibility study for the Great Lakes Wind Energy Center ("GLWEC"), which is envisioned to include a 5-20 MW pilot offshore wind energy project ("Pilot Project") in Lake Erie near downtown Cleveland and associated test, certification, and advanced research centers. juwi was the Project Manager with team members Germanischer Lloyd, BrownFlynn, Black and Veatch, Econnect, Curry and Kerlinger, and DLZ Ohio. This report presents final feasibility results across a variety of disciplines following an approximately one year study period.

The area investigated for the Pilot Project is generally three to five miles from shore, near downtown Cleveland. juwi has identified nine potential turbine configurations at different locations in the Project area. Based on established siting criteria, including water depth, geology, shipping lanes, underwater features, air navigation, radar, ecological concerns, wind resource, and others, juwi recommends an area east of the Cleveland water intake Crib, approximately three miles from shore. This location offers the highest iconic value for the Pilot Project while balancing other siting considerations and requirements. Final turbine locations will depend on regulatory consultation and approval.

Based on preliminary geological information, monopiles are suggested as the most economical foundation design alternative assuming sufficient depth for driving and load bearing strata. Wind and wave conditions can be considered moderate relative to other areas of Lake Erie, and certainly to other offshore wind energy sites in the world. A wind turbine fulfilling Germanischer Lloyd Class II requirements should be suitable for the Pilot Project.

Ice is expected to be the principal design driver for offshore wind turbines in Lake Erie. It is assumed that an ice cone will be integrated into foundation design to break up ice at the waterline, reduce loading on the structure and avoid or minimize ice induced vibrations. The cone should be designed as an inverted ice cone where upper diameter is greater than lower diameter. Final design of the ice cone may require ice modeling in a cold weather laboratory, however ice is not identified as a prohibiting factor for wind turbines in the Project area.

No "red flags" have been identified with respect to marine ecology and avian species, and especially due to its small scale the Pilot Project is expected to have minimal environmental impact. The largest impacts to marine ecology will be short term and limited to the construction phase of the Project. Short term impacts would include physical disturbance of the lake bottom by removing the substrate, loss of benthic fauna, and displacement of fish.

Long term, it is possible that the foundation structures will actually attract fish and otherwise provide marine habitat, similar to existing artificial reefs near the Project area.

The results of the Avian Risk Assessment indicate that only minimal impacts to avian species are likely. Potential impacts to avian species are characterized as habitat loss, displacement (barrier effect), and collision mortality.

Very few birds are expected to use the waters within the Project area during most of the year. During migration, many birds use the airspace over Lake Erie, with most songbirds, waterfowl, and shorebirds migrating at night. Radar and other studies in the U.S. indicate that nocturnal migration occurs mostly at altitudes above the height of wind turbines, with a small percentage of birds migrating at lower altitudes. An analysis of five years of NEXRAD data confirms that the majority of nocturnal migrants in the Project area fly above the height of turbines. Post-construction studies are recommended to validate pre-construction estimates, to inform future offshore wind development on Lake Erie, and ensure that the resource is harnessed responsibly and with minimal environmental impacts. It is recommended that post-construction study of avian interaction be done through an established Technical Advisory Committee (TAC), which would include members of USFWS, ODNR, Cuyahoga County Board of Commissioners, representatives from the wind development community, Great Lakes Energy Development Task Force and other relevant stakeholders.

It should be noted that, as defined by Audubon Ohio, the Cleveland Lakefront Important Bird Area extends about one mile (1.6 km) into the lake (although distances vary with respect to the shoreline) and does not include areas where the Pilot Project would be located.

While offshore wind energy development is more capital intensive than comparable projects onshore, the offshore wind resource is also typically greater than onshore. Lake Erie possesses the best wind resource in Ohio, and for sites considered for the Pilot Project, Crib anemometer measurements and long term correlation indicate that wind speed is approximately 7.5 m/s at 80 m height[1]. Although the wind regime offshore of Cleveland is better than regional onshore wind regimes, higher capital and operating costs, as well as the Pilot Project's subscale size lead to a higher levelized cost of energy (assuming no special subsidies or grants) than would be the case for onshore wind projects and larger, commercial-scale offshore wind projects in locations with higher wind speeds. However, investments associated with a Pilot Project will benefit the offshore wind industry—especially

[1] Initial LiDAR data collected at the Crib show a high degree of correlation (agreement) with Crib anemometers

in the Great Lakes—as supporting infrastructure, methods, and equipment are developed, refined, and leveraged. A Pilot Project will undoubtedly provide solutions to technical challenges (i.e. icing) and further reinforce the viability of large-scale offshore wind energy development on Lake Erie. Consequently, it is reasonable to assert that project economics should not be the only factor determining whether or not to proceed with a Pilot Project.

The difficulty in accessing offshore turbines, especially in icing environments, substantially increases costs associated with operations and maintenance and turbine downtime. A spare parts inventory and/or large service vessel would significantly improve offshore wind turbine availability on Lake Erie; however, high fixed costs make these uneconomical for a small-scale project like the proposed Pilot Project. The challenge of accessing offshore turbines presents research and development opportunities to investigate new access techniques and equipment.

It is assumed that Pilot Project installation will involve mobilization of jackup and other specialized vessels from North America, compliant with Jones Act provisions. It is also assumed that a helicopter and/or small service boat for personnel transport and routine service would be located in or near Cleveland harbor.

In total, eight potential Pilot Project scenarios are evaluated, representing a range in capital investment of $77.2 - $92.7 million ($2008), and average annual operations and maintenance costs of $2.7 - $4.6 million ($2010). Capital and operating costs are much higher than comparable wind projects onshore, primarily due to higher costs associated with offshore installation and maintenance, and the small scale of the Pilot Project. Designed to test and prove concepts, and promote technological and commercial development, the Pilot Project should not be expected to provide attractive economics as with a large-scale, commercial project. Therefore, the projected economics of the Pilot Project should not be considered to reflect the future economics of subsequent offshore wind projects in Lake Erie.

Given the likely costs of the Pilot Project, the energy production that might be realized, and assuming the Project were financed solely through private sector sources, it is likely that the power purchase agreement (PPA) pricing would need to be two to three-times current wholesale electricity market pricing in the region. PPA pricing estimates range between approximately $160 and $220 per megawatt hour, depending primarily on the ability to take advantage of the ITC grant through the 2009 Stimulus Act, or the traditional PTC, respectively. While PPA pricing estimates are higher than current wholesale regional electricity prices, impending carbon legislation through cap-and-trade and/or carbon tax might increase regional prices. Additionally, increases in fossil fuel prices—and especially natural gas—may also increase regional electricity prices near term. Because it offers a hedge against these impacts, offshore wind energy will become more economically attractive relative to other generating sources as electricity prices increase. For the Pilot Project, securing grants from the Department of Energy and other organizations would significantly improve project economics. Attracting a turbine manufacturer to participate in the Pilot Project in order to become a leader in the future wind market in the Great Lakes, by potentially providing turbines at reduced or no cost would also benefit the Project.

The Feasibility Study assumes that a PPA would be the major revenue stream associated with the Pilot Project. The Pilot Project would demonstrate the technical feasibility of offshore wind turbines in the Great Lakes and the eventual market feasibility of commercial projects. It is widely recognized that Pilot Projects of this type will have installed costs much higher than can be expected for commercial deployment. While no wind energy projects exist on the Great Lakes, several are in the feasibility or planning stages. Public and other support for the Pilot Project will advance knowledge of offshore wind and reduce risk for developers and private sector investors. As is the case with many new technologies, initial investments face technical and logistical challenges and are typically higher cost and risk. As markets mature, solutions to challenges emerge, and learning curves drive costs downward.

The results of market research indicate moderate demand from turbine and component manufacturers for the Test, Certification, and Advanced Research Centers proposed to be part of the GLWEC. Based on surveys of manufacturers, recommended areas for testing are prototype testing, condition monitoring systems, measurement of environmental conditions, calibration of test equipment, and site assessment. The areas where research should be undertaken are those not well covered by other research institutes. These areas are primarily wind energy integration, offshore deployment and operations and maintenance (O&M). Currently it is not mandatory to certify turbines or projects within the United States, however, as the industry grows investors and developers will push to standardize the quality of projects and components. With respect to each Center, it is recommended that Cuyahoga County partner with established research organizations, certification bodies, and/or academic institutions. Candidates include but are not limited to National Renewable Energy Laboratory and Case Western Reserve University for research and testing, and Germanischer Lloyd for certification. These partnerships will help to further identify viable opportunities for testing and research, potential facilities, and also create a framework for how different organizations could participate.

Public and community support for the Project, and for offshore wind energy on Lake Erie, are important to the future of the industry. Offshore wind energy can contribute significantly to Ohio’s renewable energy supply, to meet the Advanced Energy Portfolio Standard (AEPS) requirements of SB 221. Efforts have been taken during the Feasibility Study to communicate messages regarding the Project's purpose, and key findings. Continued and expanded community engagement and education is encouraged following the release of the Feasibility Study.

Altogether, the results of this report indicate that construction of the GLWEC is feasible, pending approval by regulatory agencies and solutions to make the project more economically viable. If the County decides to proceed, several steps are suggested to advance the Project post-feasibility stage. These include:

- Selection of a preferred site
- Continued consultation with regulatory agencies
- Additional technical studies prior to design, including but not limited to LiDAR[2], interconnection, and geotechnical studies
- Pursuit of funding opportunities and turbine manufacturer(s)
- Optimization of number and size of turbines relative to funding opportunities
- Partnership with established research and/or certification bodies
- Community and stakeholder engagement
- Policy incentives in Ohio that promote the emergence of the offshore wind industry

Elaborating on this last point, the development of the Great Lakes Wind Energy Center—and the future build-out of the offshore wind industry in Ohio—will require new policies to better incentivize offshore wind in Ohio. Offshore wind qualifies as a renewable energy resource under Ohio's AEPS, however additional incentives such as elevated Renewable Energy Credits or an offshore wind "carve out" in the AEPS would significantly promote the industry by enhancing the economics of offshore wind during its maturation. To remain a committed leader in the Great Lakes offshore wind industry, Ohio should adopt policies to make the initial build-out of the offshore wind industry economically attractive to private sector interests. Strong policies are critical to help ensure that significant development of the offshore wind industry in North America occurs in Ohio. While no wind energy projects exist in the Great Lakes, several are in the feasibility or planning stages. If elected office holders and administrations pursue offshore wind in Lake Erie in general and in Northeast Ohio in particular, the region will prevail in the contest with other regions.

[2] Cuyahoga County, City of Cleveland, and Case Western Reserve University have deployed LiDAR on the Crib. Since data collection was hampered by equipment failure in Winter 2009, further study is planned.

2 Introduction and Scope of Work

In August 2006, a group representing various private and public entities and named the Cuyahoga Regional Energy Development Task Force (now Great Lakes Energy Development Task Force) began exploring the legal, technical, environmental, and financial determinants of developing advanced energy technologies in the region of Cuyahoga County, Ohio. Due in part to the County's unique location on the shores of windy and shallow Lake Erie, and the great potential for leveraging the region's industrial manufacturing strengths, the group's initial efforts focused on the opportunity for economic development through offshore wind energy. In February 2007, the group published a report entitled "Building a New Energy Future", recommending that Cuyahoga County and other partners support efforts to accelerate development of offshore wind energy technologies, including a demonstration offshore wind turbine installation and a related research center. Through a subsequent national RFQ/RFP process, the Task Force awarded a contract to a team led by German developer juwi GmbH and their Ohio-based subsidiary JW Great Lakes Wind LLC to study the feasibility of a 5-20 MW Lake Erie pilot wind energy project and advanced research & development center, collectively called the Great Lakes Wind Energy Center (GLWEC).

Funders for the Feasibility Study include Cuyahoga County, The Cleveland Foundation, Case Western Reserve University, City of Cleveland, The Fund for our Economic Future via NorTech, Cleveland-Cuyahoga County Port Authority, and the Generation Foundation.

juwi has assembled a team of world-class businesses to conduct various feasibility analyses of the Great Lakes Wind Energy Center. Project team members are as follows:

- **juwi and its subsidiary JW Great Lakes Wind (Germany and Ohio)**
- **Germanischer Lloyd (Germany)**
- **DLZ Ohio, Inc.**
- **BrownFlynn (Ohio)**
- **Black & Veatch (Wind Division, Colorado)**
- **Curry and Kerlinger (Virginia)**
- **Econnect (UK)**

The Great Lakes Wind Energy Center (GLWEC) Feasibility Study began in March 2008. This report presents comprehensive feasibility results following individual deliverables on topics ranging from market demand to interconnection analysis. The scope of feasibility analysis is based on the following possible elements of the GLWEC:

1. A Pilot Project consisting of a 5-20 MW offshore wind energy project with 2-10 wind turbines installed in Lake Erie approximately three to five miles from shore.
2. A Test Center that would allow manufacturers to test new product designs.
3. A Certification Center where the technical acceptability of new wind-related equipment could be certified.
4. An Advanced Research Center for innovative wind energy research and technology development by public, private and/or academic institutions.

The Feasibility Study and contents of this report are divided into the following Tasks:

Task 1: Project Coordination and Management
Task 2: Pilot Project Site Evaluation and Data Collection
Task 3: Definition, Structure, and Economics of GLWEC and its Elements
Task 4: Desktop Studies and Cabling Determination
Task 5: Wind Assessment and Resource Report
Task 6: Visual Analysis
Task 7: Public Relations
Task 8: Final Feasibility Report

As a pioneer in offshore wind, the Cuyahoga County region would benefit greatly from economic growth associated with local research and manufacturing for utility-class wind turbines, especially for offshore utilization. The market for renewable energy is driven largely by the interest in clean, non-polluting sources of energy, and state-level renewable energy portfolio standards (RPS). Ohio’s RPS, signed by Governor Strickland in May 2008 as part of SB 221, requires at least 12.5% of the state’s electricity demand to be met by renewable sources by 2025. In the coming decades, Ohio’s RPS supports a market for thousands of megawatts of renewable energy, much of which is likely to be provided by new wind installations.

Offshore wind on Lake Erie is capable of factoring significantly in Ohio’s renewable energy supply, especially as onshore locations become increasingly developed or constrained due to limitations on the power grid. However, technical, regulatory, and economic questions face the development of offshore wind on the Great Lakes. For example, questions about icing and environmental impact are critical to ensuring the resource can be harnessed safely and efficiently. This feasibility report addresses such key questions for a Pilot Project. In turn, a completed Pilot Project will answer many questions related to larger-scale development of offshore wind in the Great Lakes.

There is significant and growing interest in harvesting offshore wind energy on the Great Lakes. In addition to Ohio, Michigan and Wisconsin are both currently exploring opportunities for offshore wind. In Canada, notable efforts are ongoing in Toronto and with Trillium Power Wind Corporation, a private developer proposing a several hundred MW project on Lake Ontario. As the market for offshore wind energy in the Great Lakes grows, it is the County's and Task Force's vision to establish Cuyahoga County as a primary hub for wind energy in North America, and a key hub for the offshore wind energy industry in the Great Lakes. This hub will capitalize on and expand the region's prominent position in the wind turbine supply chain (see Figure 2-1). Key opportunities include the expansion of local businesses into the international wind industry, job growth, and technological development through academic, private, and public sector research.

Figure 2-1: Ohio Wind Turbine Supply Chain

Cuyahoga County and the region have a unique opportunity to become a world leader in offshore wind energy by developing what could be the world's first freshwater pilot wind energy project. Experience, research, and information from the Pilot Project would be extremely valuable in demonstrating the longer-term technical and economic potential of offshore wind in the Great Lakes. In this sense, the Great Lakes Wind Energy Center would be much more than a generating plant for clean power: it would attract further investment in the regional wind energy industry while providing Cleveland with an iconic symbol of revitalization and forward-thinking.

3 Preliminary Site Selection

(Unless otherwise noted, all information in this section taken from GLWEC Preliminary Site Review Report, juwi and Germanischer Lloyd, October 2008).

Following the recommendations of the Great Lakes Energy Development Task Force's Site Evaluation Committee, submitted to the County Board of Commissioners in February 2007, the initial area of concentration for the Project is generally three to five miles off the Cuyahoga County shoreline, inside what has come to be known as the "Cleveland Bay". The "Cleveland Bay" refers to an area of Lake Erie formed by the natural southward depression in the Cuyahoga County shoreline relative to neighboring coastal counties (see Figure 3-1). While not formally a bay, it is useful to refer to this geographical feature as such in the context of possible sites for the Pilot Project.

Figure 3-1: "Cleveland Bay" and Crib location (3.5 miles from shore)

In addition to an area three to five miles from shore, juwi also evaluated potential turbine locations closer to the shoreline to enhance visibility of the Pilot Project from important vantage points in downtown Cleveland. Resulting is a range of possible siting options at distances greater and less than three miles from shore. Consistent with feasibility analysis, and because turbine type and Project size have yet to be firmed, a range of possible turbine configurations and locations are presented herein.

3.1 Siting Criteria

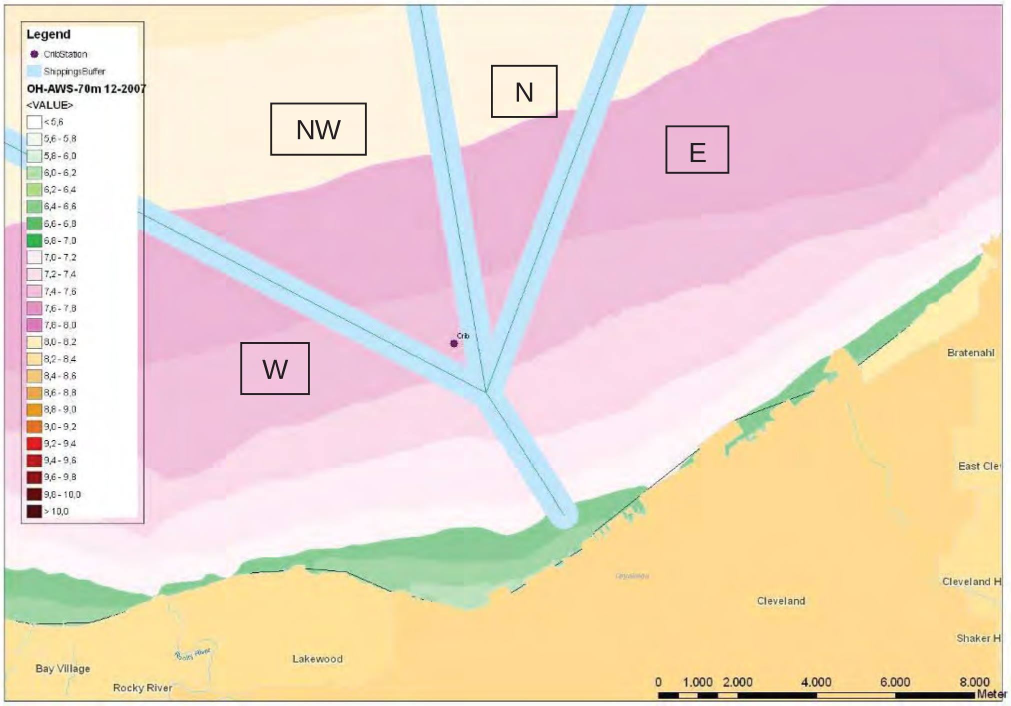
To narrow down potential locations for the GLWEC pilot wind project, important siting criteria are analyzed including shipping channels, water depth, distance to possible onshore interconnection locations, wind resource, the Cleveland Lakefront Audubon Ohio Important Bird Area, air navigation and radar, and the locations of lakebed factors such as dumping sites, artificial reefs and shoals, water intakes and sewer outfalls, shipwrecks, and the Cargill Salt Mine.

Siting criteria that vary between possible Pilot Project locations are addressed in more detail in the following sections. Other important siting criteria more general to the Project site—such as avian use, icing, wind resource, and other environmental conditions—are presented in later sections.

3.1.1 Shipping Channels

Established shipping channels to and from the Cuyahoga River are initial determinants of potential Pilot Project locations. The map below shows that shipping lanes divide the area into four sections: a large east section, a narrow north section, a wide northwest section that also includes the Crib, and a western section. To optimize the Project, minimize cabling distance, and enhance Project visibility, all turbines should be located within one section. Figure 3-2 shows the location of shipping channels within the Project focus area.

Figure 3-2: Shipping lanes showing division of area into four sections. Total buffer width shown in blue for each lane is 750 m (2,460 ft), or 375 m (1,230 ft) on each side.



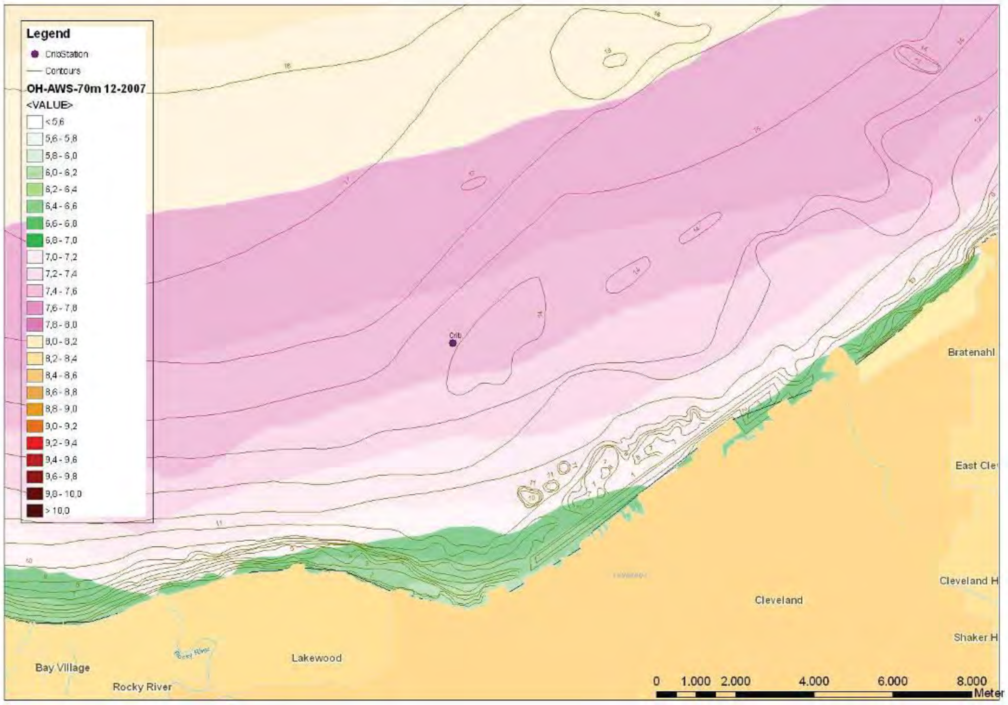
3.1.2 Water Depth

For all eight and three-turbine locations water depth varies between 13 m and 17 m (42 ft and 55 ft). While construction costs will likely be less in shallower water, water depth variation within the focus area is not a significant determinant of turbine location. It is likely that one turbine foundation (i.e. monopile) will be suitable for each of the turbine configurations presented herein.

Compared to European offshore projects, especially those in Germany, water depth within the project area can be considered moderate. In the North Sea and Baltic Sea water depths of future offshore wind farm locations reach up to 40 m (131 ft). Such water depth, combined with large turbines of 5 MW and the respective wind and wave conditions make it difficult to design monopile foundations of an economic and drivable size, and other foundation types have to be considered (e.g. jacket, tripod). But for the Pilot Project water depth does not seem to be a limiting factor for any particular foundation type.

The range of water depths within the eight proposed sites is ideal for wind turbine foundations of any type.

Figure 3-3: Water depth contours (m).



3.1.3 Air Navigation and Radar

Proposed structures over 200 ft all must undergo an Obstruction Evaluation by the Federal Aviation Administration (FAA) and be permitted through a form 7460-1 filing prior to construction. Wind turbines chosen for the Pilot Project are likely to be in the range of 380 to 500 ft from the base of the tower (lake level) to tip of blade, and therefore will require FAA approval.

Located on the Lake Erie shoreline just outside of downtown Cleveland, Burke Lakefront Airport will influence turbine locations for the Pilot Project. Figure 3-4 shows the FAA cone surrounding Burke, which in three dimensions extends upwards and outwards, reflecting the ascent and descent approaches for the two runways and navigational airspace. Depending on structure height, and on airport-specific flight patterns, it may be possible to site wind turbines within the horizontal extent of the cone. Permits from both the FAA and Ohio Department of Transportation Office of Aviation (OA) would be required in this case.

juwi contacted OA to discuss possible Pilot Project locations. Preliminary discussions with OA indicate no “red flags” for the four eight-turbine layouts. Of course, a formal determination and permit from the FAA is required to confirm these layouts as viable options for siting the Project with respect to airport safety. Filing a FAA form 7460-1 initiates the permitting and approval process, which currently takes approximately three to twelve months.

Regarding the three-turbine layouts closer to shore, OA advises siting turbines within the double-hatched area, and/or outside the FAA cone (outside yellow line), as depicted in Figure 3-5. The single-hatched area is a climb-descent zone for Burke Lakefront. As aircraft are climbing and descending within the single-hatched area, permitting for tall structures may be problematic. Again, that depends on structure locations / heights and airport specifics. The double-hatched area perpendicular to the runway in Figure 3-5 signifies where aircraft are to be level prior to descent or following ascent. At a certain distance from the runway and within the conical surface, structures up to 500 ft above ground level may be allowed. OA believes this may be the case for the three-turbine configuration depicted in Figure 3-5. Accordingly, this turbine configuration (Config 5 in Figure 3-15) could be the best option with respect to siting the Pilot Project as close as possible to downtown Cleveland while maintaining air navigation safety. Still, it should again be noted that for all turbine configurations FAA approval is required. If a hazard is determined for any turbine location, consultation with the FAA, Burke Lakefront Airport, and/or aviation consultants will be necessary to obtain a construction permit.

Figure 3-4: FAA cone surrounding Burke Lakefront Airport.

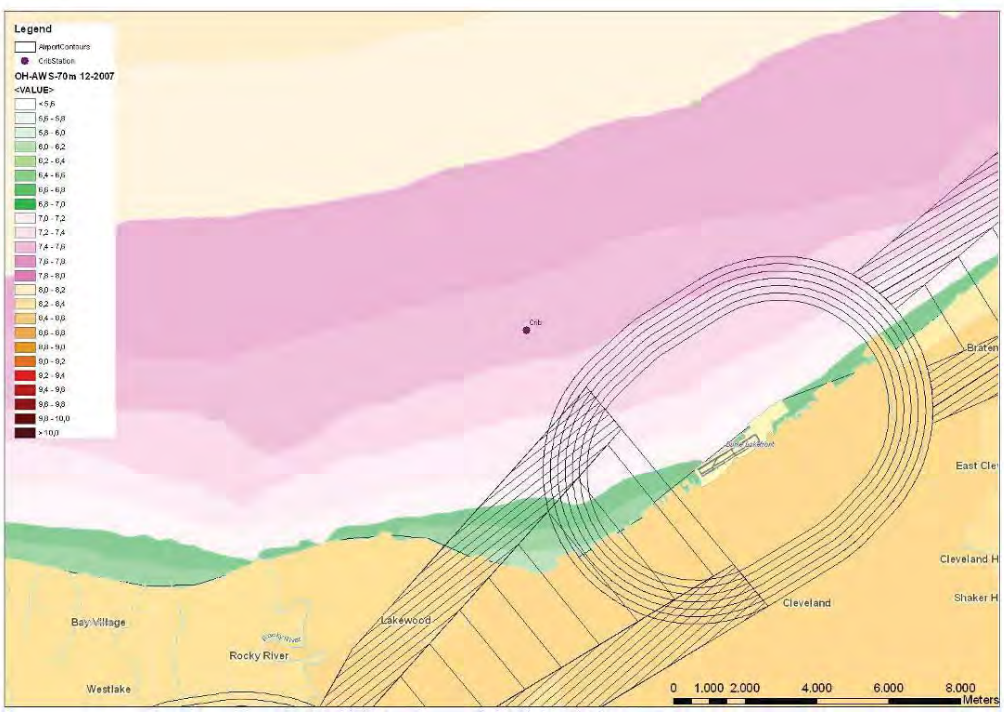
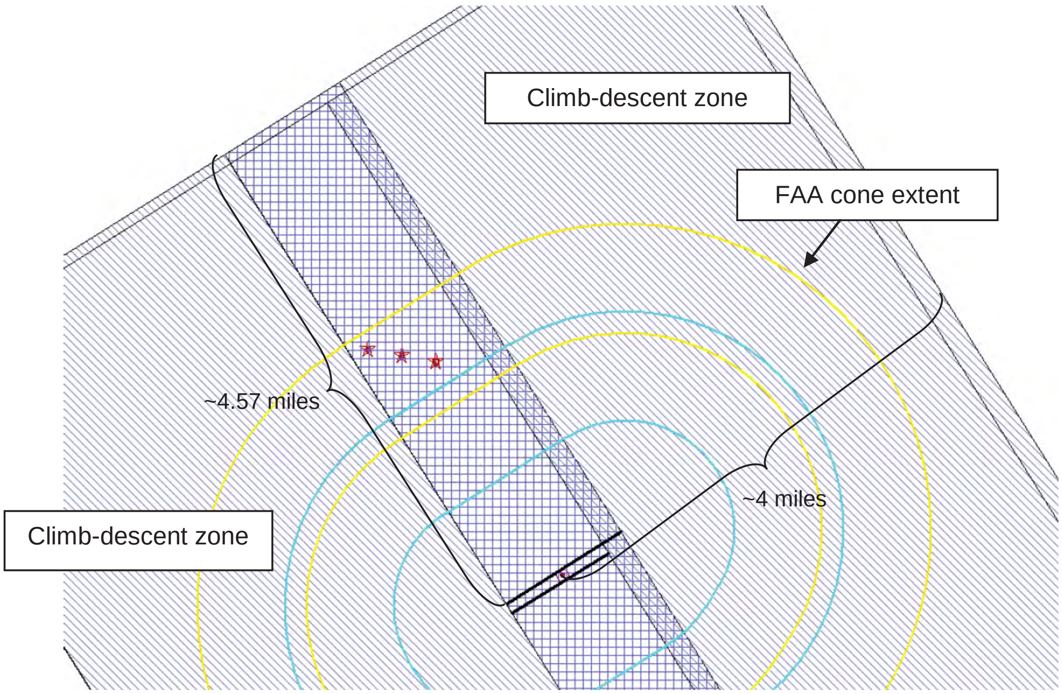


Figure 3-5: Terps® output for Burke Lakefront Airport. Hatched area is traffic pattern airspace. Single-hatched area reflects climb-descent zones; double-hatched area reflects where aircraft are leveled off. Stars are three-turbine configuration (Config 5 in Figure 3-15).



Two types of radar exist in the proximity of the Project area: NEXRAD (WSR-88D weather) radar and military radar. In some cases turbines can interfere through physical line of sight or electromagnetically with radar systems. The FAA provides an online screening tool for radar systems. Regarding NEXRAD, Figure 3-6 identifies the Project area in yellow, meaning the turbines will likely be in the radar's line of sight. This does not prohibit turbine placement in this area. The National Telecommunications and Information Administration now has a voluntary process to identify and mitigate potential impacts to NEXRAD. The NTIA has been consulted with respect to the Pilot Project. Information learned from the NTIA indicates that beyond 10 miles, impacts on NEXRAD are typically minimized. The closest NEXRAD station to the Project area is at Cleveland Hopkins International Airport, and Pilot Project turbines will very likely be 10+ miles away. Therefore Pilot Project turbines are not expected to significantly impact NEXRAD.

With respect to military radar, Figure 3-7 identifies the Project area in red, meaning impact to radar is highly likely. As is the case with structure height, an aeronautical study through the FAA will determine any potential impacts from Pilot Project turbines on military radar. At the time of this writing, turbine locations have been submitted to the FAA for review via the 7460-1 process. Depending on the outcome of their review, further consultation with the FAA and/or Department of Defense may be required to discuss potential impacts and mitigation techniques.

It should be noted that the FAA screening tool did not identify any potential impacts from Pilot Project turbine on military training routes or other operations.

Figure 3-6: NEXRAD Radar in Project Area

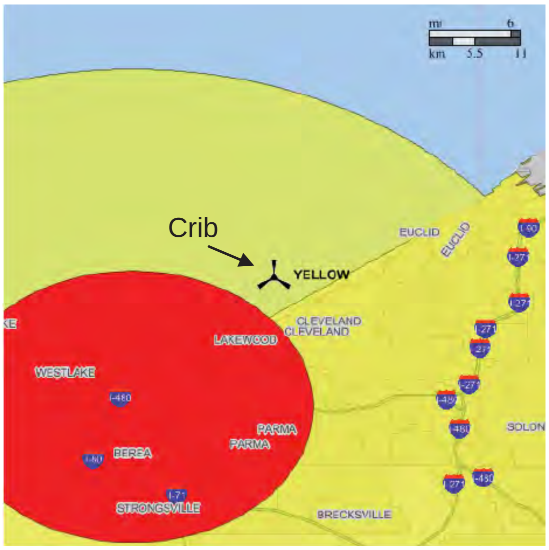
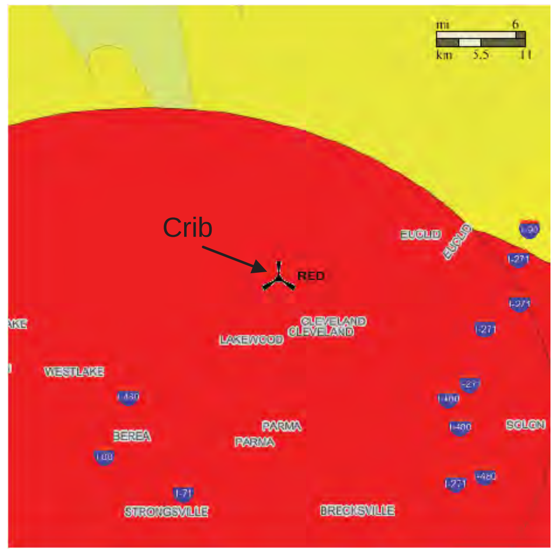


Figure 3-7: Military Radar in Project Area



3.1.4 Sailing Courses, Reefs, Dumping Grounds, and Salt Mine

Additional factors relevant to siting the GLWEC Pilot Project are artificial reefs and shoals that provide marine habitat, dumping grounds for dredged material, and sailing courses, as well as the Cargill Salt Mine. Figure 3-8 and Figure 3-9 show each of these criteria relative to the Cleveland / Cuyahoga lakefront. As can be seen, the reefs/shoals and dumping grounds will very likely not impact siting determination for the Pilot Project. Other factors, such as visibility and airport navigation restrict the influence these underwater features have on the Project. The mine's roof is approximately 1,700 ft below the lakebed and much of the water and airspace above the mine is impacted by shipping lanes and FAA restrictions, respectively, limiting the available area in which turbines could be sited above the mine. There are long-term plans to extend the mine north and/or west beneath Lake Erie, though salt deposits would not be mined any closer to the lakebed. Monopile foundations would penetrate the lakebed at maximum of 75-100 ft. At these depths, the mine is not anticipated to impact site selection or foundation choice. Discussions with Cargill staff and geologists have identified potential foundation subsidence as the primary concern. During final site selection, consultation with Cargill mine and geologists is suggested to ensure foundation subsidence will not occur due to mining activity.

With respect to sailing courses, it is likely that turbine locations west of downtown Cleveland, and within approximately 3.5 miles from shore, will conflict with existing buoys. Turbine locations east of downtown Cleveland will likely not impact existing sailing courses. Consultation with yachting organizations (i.e. Lakeside Yacht Club, Edgewater Yacht Club, Cleveland Yacht Racing Association) and other members of the Cleveland sailing and boating community is necessary to ensure minimal impact, and to address any potential concerns. It should also be noted that the Royal Yachting Association recommends a minimum distance between mean high water level and rotor tip of 22 m (72.2 ft).

Figure 3-8: Locations of artificial reefs, dumping grounds, and sailing courses within Project area.

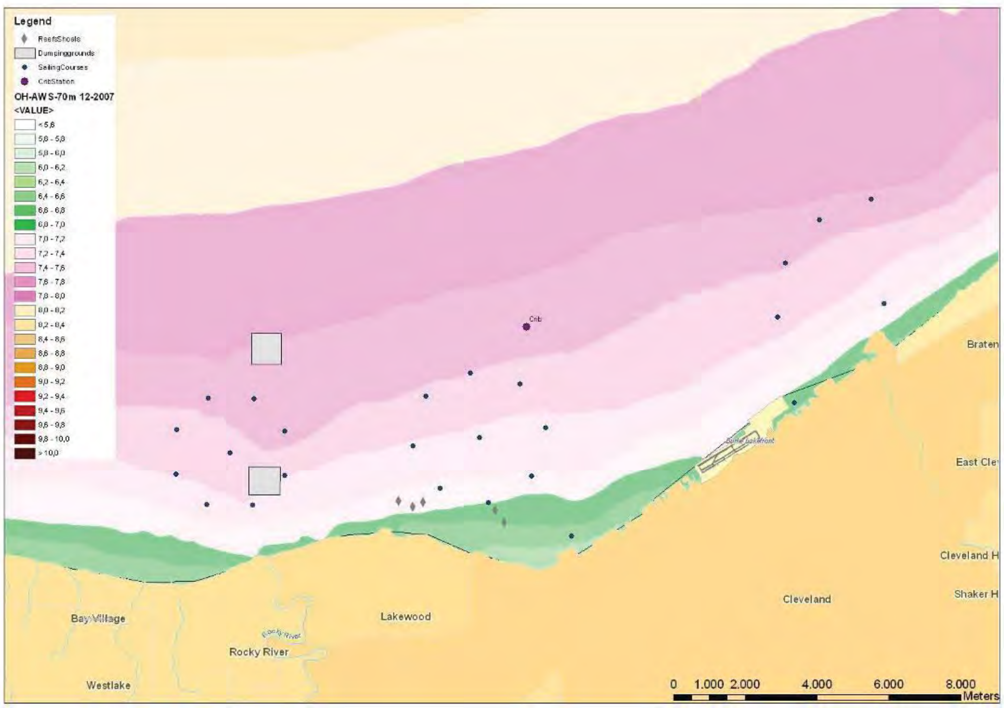
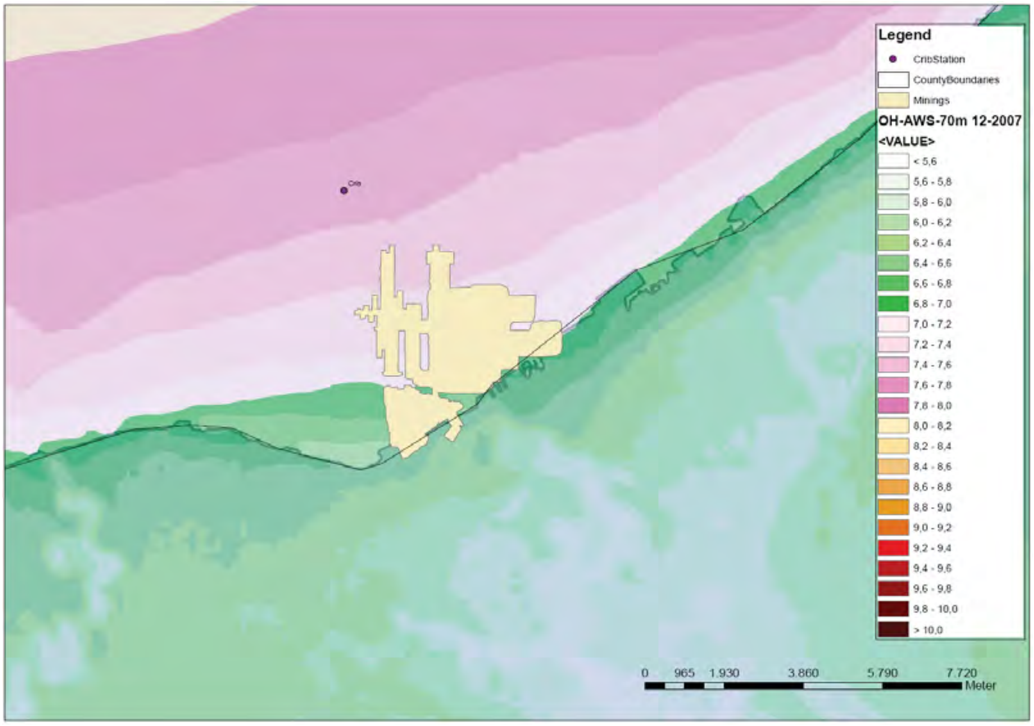


Figure 3-9: Extent of Cargill Salt Mine beneath Lake Erie.



3.1.5 Wind Resource

With prevailing winds from the southwest, wind speed increases in the Cleveland Bay with increasing distance from shore. Therefore, an appropriate balance between wind resource and visibility should be considered in a final siting determination

Figure 3-10 is the energy rose from two years of Crib wind data and is representative of the entire Cleveland Bay. The energy rose indicates that kinetic energy is greatest in wind originating from the west and west-southwest. In order to maximize the power output of any given wind turbine configuration, and to reduce stress (turbulence) on turbine components, siting should take into consideration the dominant wind direction. The best solution is to orient turbines to the cross wind direction NNW to SSE. A second option is to increase spacing between the turbines to minimize wake effect of the neighboring machine. The only disadvantage to increasing turbine spacing is the additional cabling required between turbines.

The nine Project locations (Figure 3-14 and Figure 3-15) are linked to annual average wind speeds, and the resulting turbine classes are shown in Table 3-1.

Figure 3-10: Energy rose from Crib wind data showing dominant winds from the WSW and W directions.

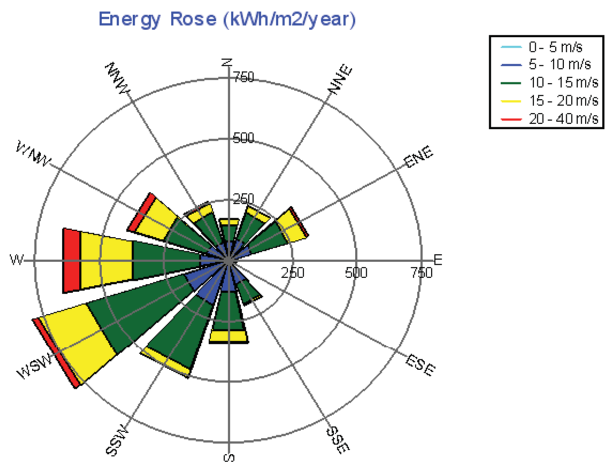


Table 3-1: Annual average wind speed at 70 m hub height and resulting turbine classes

Pilot Project Location	Mean Wind Speed	Turbine Class
Configuration 1:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 2:	7.6 m/s to 8.2 m/s	GL turbine class II
Configuration 3:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 4:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 5:	6.6 m/s to 7.0 m/s	GL turbine class III
Configuration 6:	6.6 m/s to 7.0 m/s	GL turbine class III
Configuration 6A:	6.8 m/s to 7.2 m/s	GL turbine class III
Configuration 7:	6.4 m/s to 6.6 m/s	GL turbine class III
Configuration 8:	6.8 m/s to 7.2 m/s	GL turbine class III

3.1.6 Distance to Interconnection Locations

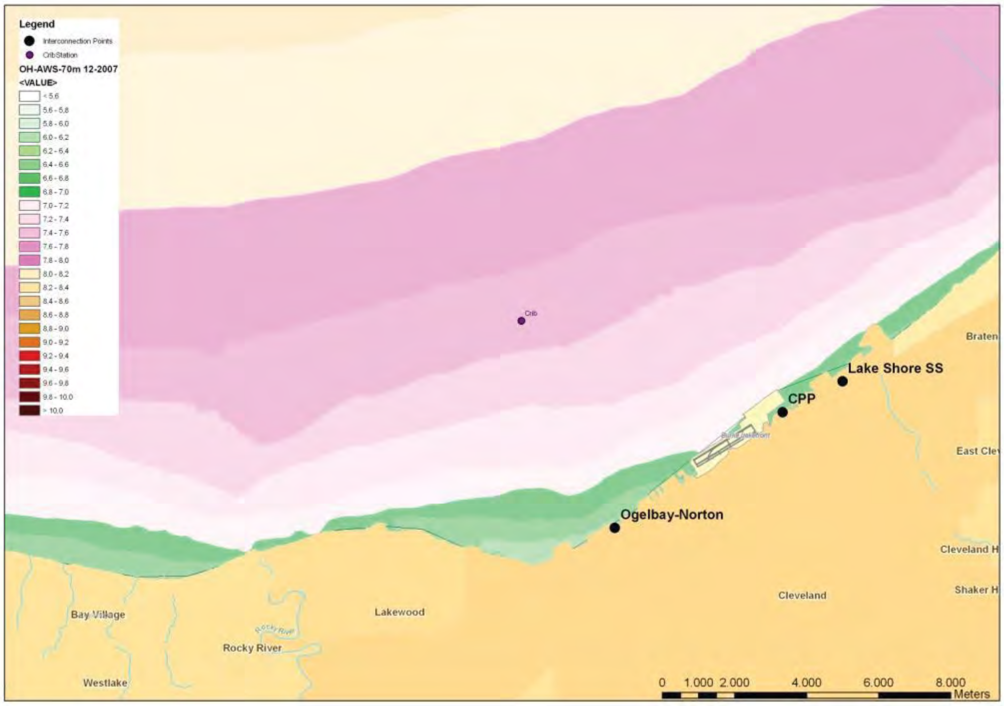
Offshore cabling is an important cost factor for the Pilot Project, and cable distances are dependent on the Project location relative to the onshore interconnection location through which electricity accesses the utility grid. Through the course of their onshore interconnection analysis, Black & Veatch has narrowed down two most feasible interconnection options within Cleveland Electric Illuminating's system. These include the Lakeshore Substation via 35 kV – 11 kV transformer, and a direct tap into an existing 36 kV transmission line at Oglebay-Norton, near Wendy Park. Additionally, Black & Veatch has determined the most feasible interconnection option within Cleveland Public Power's system as the Lake Road Substation via 35 kV – 69 kV transformer. The CEI locations would require an onshore cabling component to reach existing infrastructure, whereas the CPP substation is located directly adjacent to the water. These interconnection options are addressed in more detail in the interconnection and cabling reports, separate deliverables within the GLWEC feasibility study. Distances from turbine configurations to the possible CEI and CPP interconnection locations are provided in Table 3-2, and the onshore interconnection locations are shown in Figure 3-11.

Table 3-2: Approximate offshore cabling distances from closest turbine in configuration to possible onshore interconnection locations.

Turbine configuration	Distance to CEI Lakeshore Substation	Distance to CEI Oglebay-Norton Tap	Distance to CPP Lake Road Substation
Config 1 (8 turbines)	3.5 miles	5.5 miles	3.9 miles
Config 2 (8 turbines)	5.8 miles	6.3 miles	6.2 miles
Config 3 (8 turbines)	6.4 miles	4.6 miles	6.8 miles
Config 4 (8 turbines)	9.0 miles	5.9 miles	9.4 miles
Config 5 (3 turbines)	3.8 miles	4.1 miles	4.1 miles
Config 6 (3 turbines)	5.9 miles	3.2 miles	6.3 miles
Config 6A (3 turbines)	6.4 miles	2.7 miles	6.7 miles
Config 7 (3 turbines)	4.1 miles	4.0 miles	4.5 miles
Config 8 (3 turbines)	5.8 miles	3.1 miles	6.2 miles

**Note: Distances assume path around breakwalls, and include onshore components of 0.3 miles for CEI Lakeshore, and 0.2 miles for CEI Oglebay-Norton*

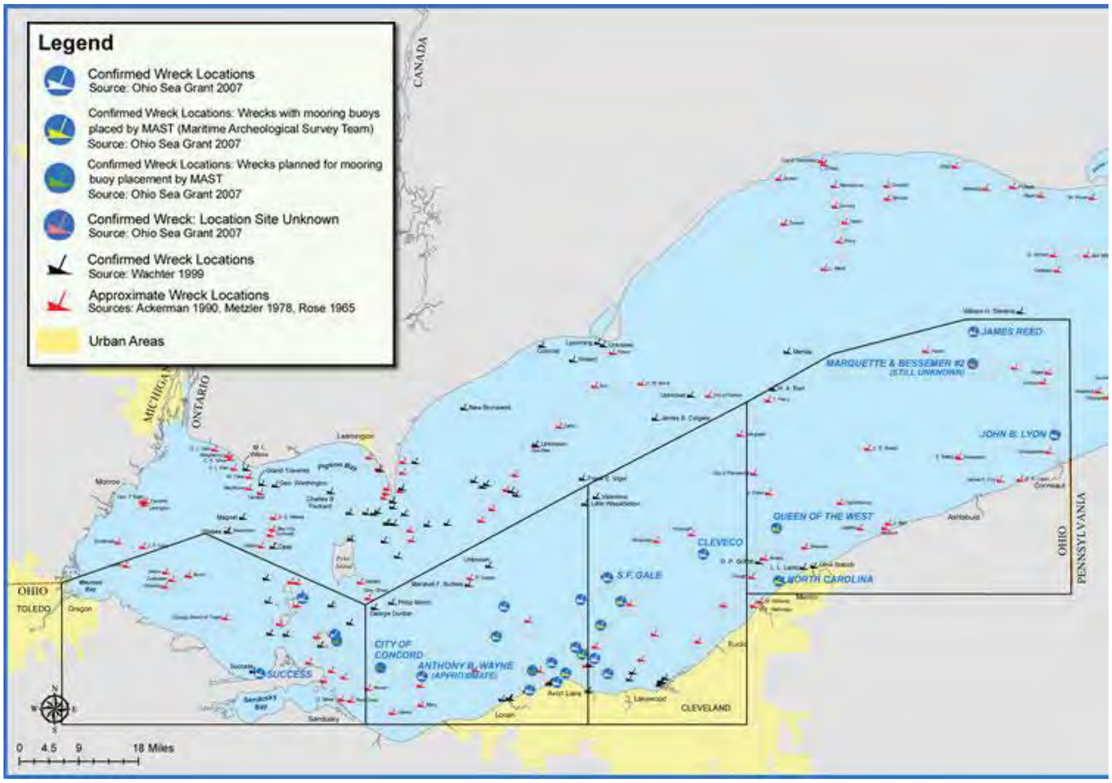
Figure 3-11: Three most feasible interconnection options for Pilot Project: CEI's Lakeshore Substation and Oglebay-Norton tap, and CPP's Lake Road Substation.



3.1.7 Shipwrecks

A number of documented and undocumented shipwrecks exist in Lake Erie and within the Project area. Sources for shipwreck locations include the National Oceanic and Atmospheric Administration's Automated Wreck and Obstruction Information System, other public and research bodies such as Ohio Department of Natural Resources and Ohio Sea Grant, and private / recreational divers. Figure 3-12 illustrates documented shipwrecks in Lake Erie and the Project area. If turbines or cables will be located in the vicinity of known shipwrecks, an underwater survey via side-scan SONAR or underwater dive may be necessary to map and avoid obstacles, and preserve any wrecks designated as having historical value. Consultation with the ODNR's Office of Coastal Management and other stakeholders will be necessary to mitigate impact and obtain historical or salvage permits, if any are required. Following the results of surveys or other methods to determine wreck locations, it is likely that micro-siting with respect to cable and turbine locations will also help avoid significant impact from the Project on shipwrecks.

Figure 3-12: Documented shipwreck locations in Lake Erie and Project area.

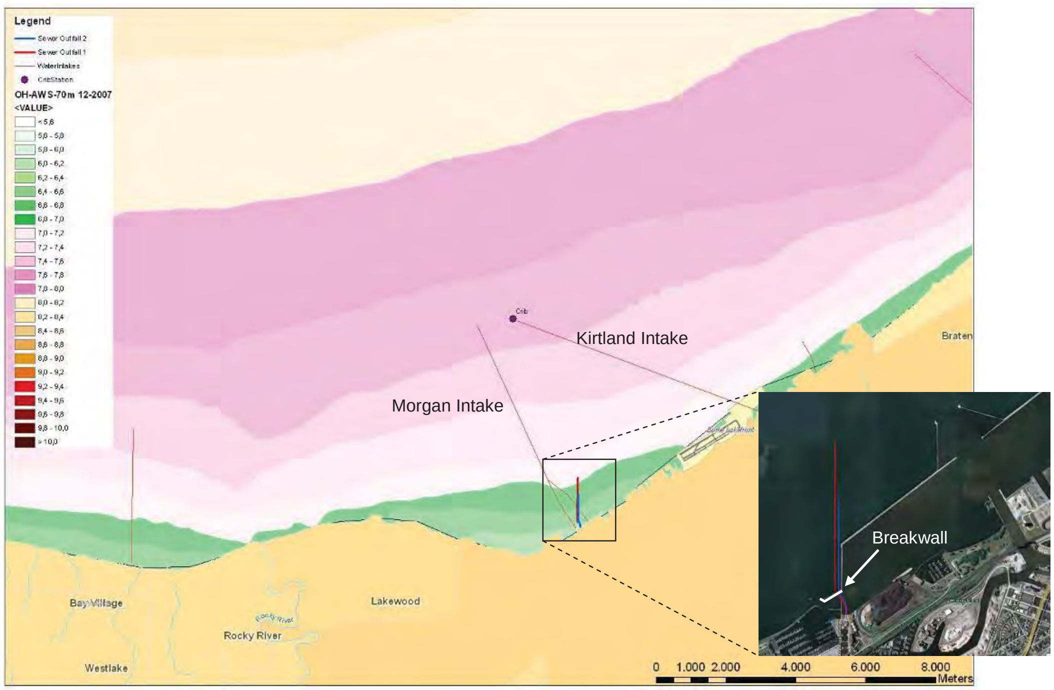


3.1.8 Water Intake and Sewer Outfall Pipes

Water intake and sewer outfall pipes exist within the Project area, as shown in Figure 3-13. The locations and burial depths of these structures need to be considered in determining turbine locations and potential cable routes. The Kirtland and Morgan water intakes, which connect onshore to the Kirtland Pumping Station and the Morgan Water Treatment Plant, respectively, are buried beneath the lakebed within the Project area. Both structures are owned and maintained by the City of Cleveland Water Department. Discussions with City staff indicate that both intakes vary between approximately 50 and 60 feet below the lakebed. Close to shore, the Morgan intake splits and two pipes bring water from the Lake. The western most pipe might approach approximately 35 ft below the lakebed in one section, but is closer to 50 ft below the lakebed in most parts. At these depths, the two intakes will impact turbine location and need to be considered during construction to avoid damage. However, as cables are typically installed at depths of ~1.5 m (~5 ft), the intakes will likely not pose a concern for cable routes or installation.

Two sewer outfall structures extend beneath Lake Erie from the Westerly Wastewater Treatment Plant, operated by the Northeast Ohio Regional Sewer District (NEORSD). While the outfall locations are within one mile from shore and not likely to affect turbine placement, their shallow depths must be considered for potential cable routes, especially to the Oglebay-Norton option. Outfall 1 (shown in red in Figure 3-13) varies from 0 ft below lakebed at its northern extent to approximately 13 – 23 ft below lakebed near shore. Outfall 2 (shown in blue) is <5 ft below lakebed for much of its length, and approximately 8 – 13 ft below lakebed near shore. Therefore, it is likely that any potential cable crossing will need to occur near shore south of the breakwall depicted in the inset photo of Figure 3-13. Appropriate installation methods and consultation with NEORSD will also be required to ensure no damage to the outfall pipes.

Figure 3-13: Water intake and sewer outfall structures in Project area, and aerial photo showing closer view of sewer outfalls.



3.1.9 Audubon Ohio Important Bird Area

Audubon Ohio lists a number of Important Bird Areas (IBA) throughout the State. Audubon Ohio defines IBAs as areas that “provide essential habitat for one or more species of birds and include sites that birds use during their nesting season, during the winter and/or while they are migrating. Usually these sites stand out as special from the surrounding landscape”.

The Cleveland Lakefront IBA is defined as approximately one mile into the Lake, and potential turbine locations will very likely be outside the IBA. Audubon Ohio stated in an August 20 2008 phone conversation that the IBA boundary is somewhat conservative and "plastic". Audubon agrees with GLWEC Feasibility Study avian consultants Curry & Kerlinger that bird use—and potential avian impacts from the Pilot Project—will be greater over shallower water closer to shore (see Section 6.1). At a distance from shore of two miles and in water depths of approximately 40 ft, sunlight penetration and lakebed vegetation will not support large fish populations. In turn, birds are not likely to feed in large numbers and waterbird use is expected to be minimal. Further consultation with Audubon Ohio and regulatory agencies is advised to confirm the siting of turbines with respect to the IBA.

Though the IBA boundary is described to be somewhat conservative and plastic, ecological concerns should be considered very seriously. In Europe, and especially for German offshore wind projects, strong opposition from environmental organizations and the public arises if environmental concerns are perceived not to be taken seriously. For this reason, locating turbines outside the IBA may help streamline permitting and Project approval among the public.

3.1.10 Geology

For further discussion on Geology, also refer to Section 6.3.

Soil properties are of high importance for the determination of the sub structure, the load calculation and the support structure design. For a conceptual design, it is possible to use existing soil data from a nearby location if it is evident that the soil types correspond to those at the turbine locations. For the final design of the individual turbines, geotechnical data from each turbine location will be necessary.

For the 1974 Burke Airport Feasibility Study, a number of borings, vibracores and seismic survey were conducted. The Airport Feasibility Study contains soil profiles derived from vibracores and deep borings. Two sections (S/N and E/W) are derived from the borings and vibracores. These sections show some regularity in the makeup of the soil layers:

- The top layer (roughly 5 to 10 meters) is soft clay that would probably not support any foundation. For design purposes this layer might be regarded as non-existent. The thickness of this layer increases from west to east but no significant change from south to north is indicated.
- The lower strata consist of stiff and very stiff silt and silty clay that could be used to support the foundation.
- At one area in the western part of the study area that resembles a buried glacial valley, the soft layer is thicker and bedrock was encountered 10 m below the upper boundary of the stiff soil. The exact position of the section could not be determined

but it seems to be located north of the proposed sites. In the other areas, bedrock is located much deeper; “a few hundred feet” was stated in the Airport Feasibility Study.

The GLWEC Geological and Geotechnical Desktop Study (see Section 6.3) provides generalized geological cross sections that are related more closely to the possible Project locations. An extrapolation of the bedrock horizons to the proposed locations gives the following estimates:

Table 3-3: Conservative estimation of the thickness of the soil strata available for load bearing at the different locations.

Site no.	Lake Bed (Desktop study) [ft]	Bedrock horizon (Desktop study) [ft]	Thickness of glacial deposits [ft]	Thickness of soft clay, estimations taken from Airport Feasibility Study [ft][3]	Available pile length for load bearing, est. [ft]
1	510	400	110	20	90
2	525	380	145	20	125
3	510	430	80	20	60
4	500	450	50	20	30
5	510	400	110	20	90
6	500	410	90	20	70
6A	480	420	80	20	60
7	510	400	110	20	90
8	490	460	3	20	10

After evaluating these estimates, the proposed sites 1, 2, 5, and 7 would be more preferable from a geological perspective due to estimated depth of load bearing strata and drivability. It is assumed that a piled foundation would be suitable. Piles cannot always be drilled into bedrock because of high costs.

3.1.11 Pilot Project Locations

With a maximum capacity of 20 MW, different turbine configurations are possible depending on turbine type. Assuming that the Pilot Project consists of turbines from a single

[3] Numbers are rough estimates based on the results of the Airport Feasibility Study borings. From the results of the boring it seems, as a mean value, that the upper 20 ft (7 m) of the soil profile should be estimated as soft to very soft clay.

manufacturer, the following technical designs are possible for a 20 MW project using commercially available offshore wind turbines:

- Four 5.0 MW turbines (REpower, Multibrid or BARD)
- Six 3.0 MW turbines (Vestas)
- Eight 2.5 MW turbines (Clipper or others)
- Eight 2.3 MW turbines (Siemens)
- Five 3.6 MW turbines (Siemens or GE)

To ensure that the suggested locations are valid for any number of turbines necessary to reach the maximum capacity of 20 MW, juwi based possible turbine configurations on a maximum scenario of eight Clipper 2.5 MW machines with a 96 m rotor. Maps showing various eight-turbine configurations are provided in Figure 3-14. From a planning perspective, the constraints influencing wind farm design are more complex with more turbines, and thus initial planning accounts for a maximum number of turbines. Visualization of a smaller project or fewer turbines can be inferred from the general placement of an eight-turbine layout.

The distance between turbines in the eight-turbine layouts is equal to four times the rotor diameter, or 384 m (1,260 ft). Based on the wind resource and prevailing wind direction, the recommended angle of each row is 330° to 150° to maximize park efficiency and minimize losses between turbines.

With the request to evaluate potential locations within the three-mile boundary from the County shoreline, the Task Force also requested a configuration based on three turbines. For the three-turbine layouts, the distance between turbines is five to ten times the rotor diameter, depending on the orientation of the turbines to the prevailing wind direction. Balancing the importance of visibility and turbine performance, different orientations of 280° to 100° and 250° to 70° are offered. As turbine orientation changes relative to the prevailing wind direction, turbine spacing increases to reduce turbulence and stress on the machines and wake effect losses. This explains the difference in turbine spacing for the three-turbine layouts compared to the eight-turbine layouts. At this preliminary stage, five layouts with three turbines each are provided in Figure 3-15 to maintain a range of possible siting options.

Figure 3-14: Possible layouts for 20 MW GLWEC pilot project consisting of eight turbines. Distance between turbines is 384 m (1,260 ft). Orientation of turbine rows 330° to 150°.

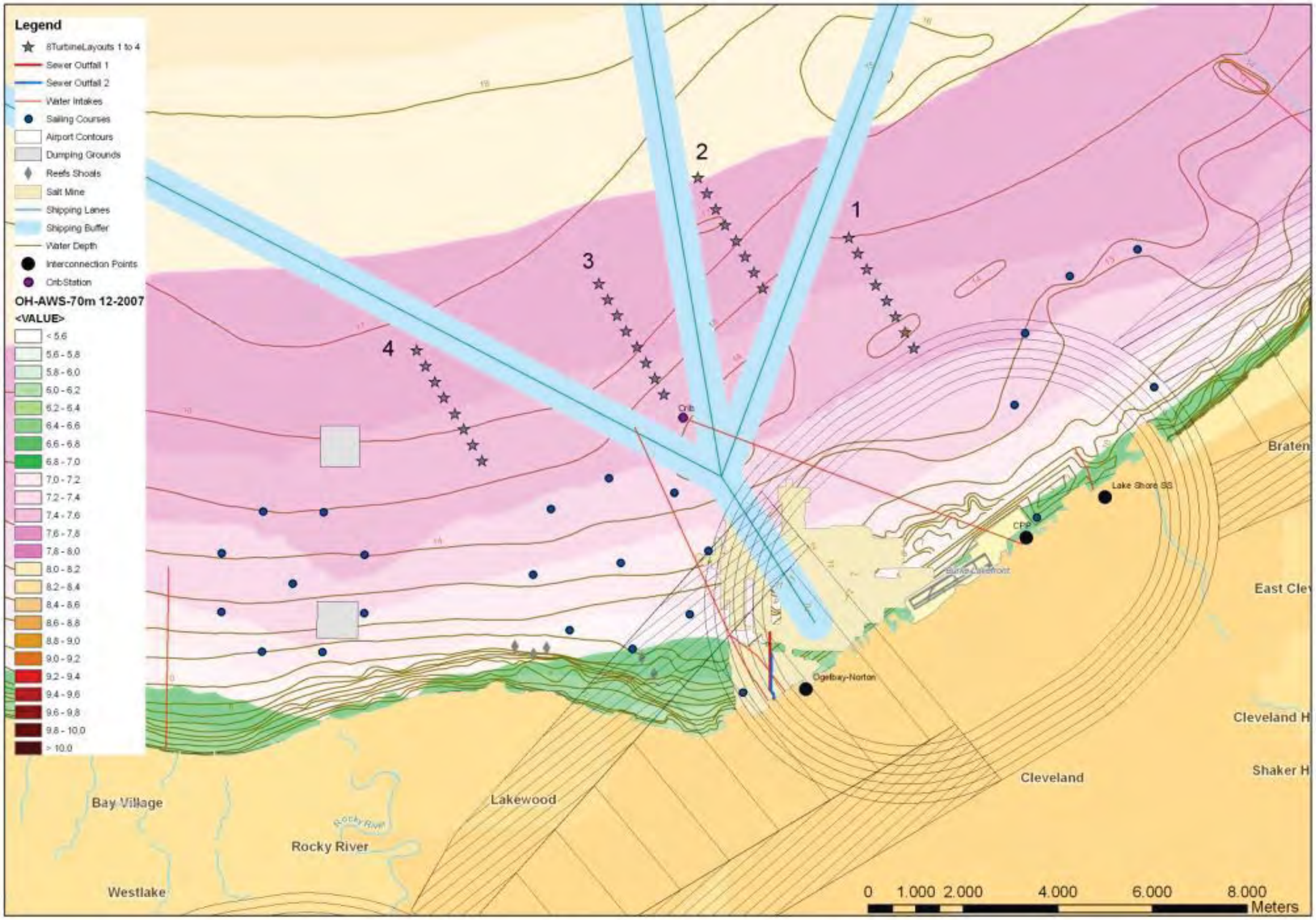
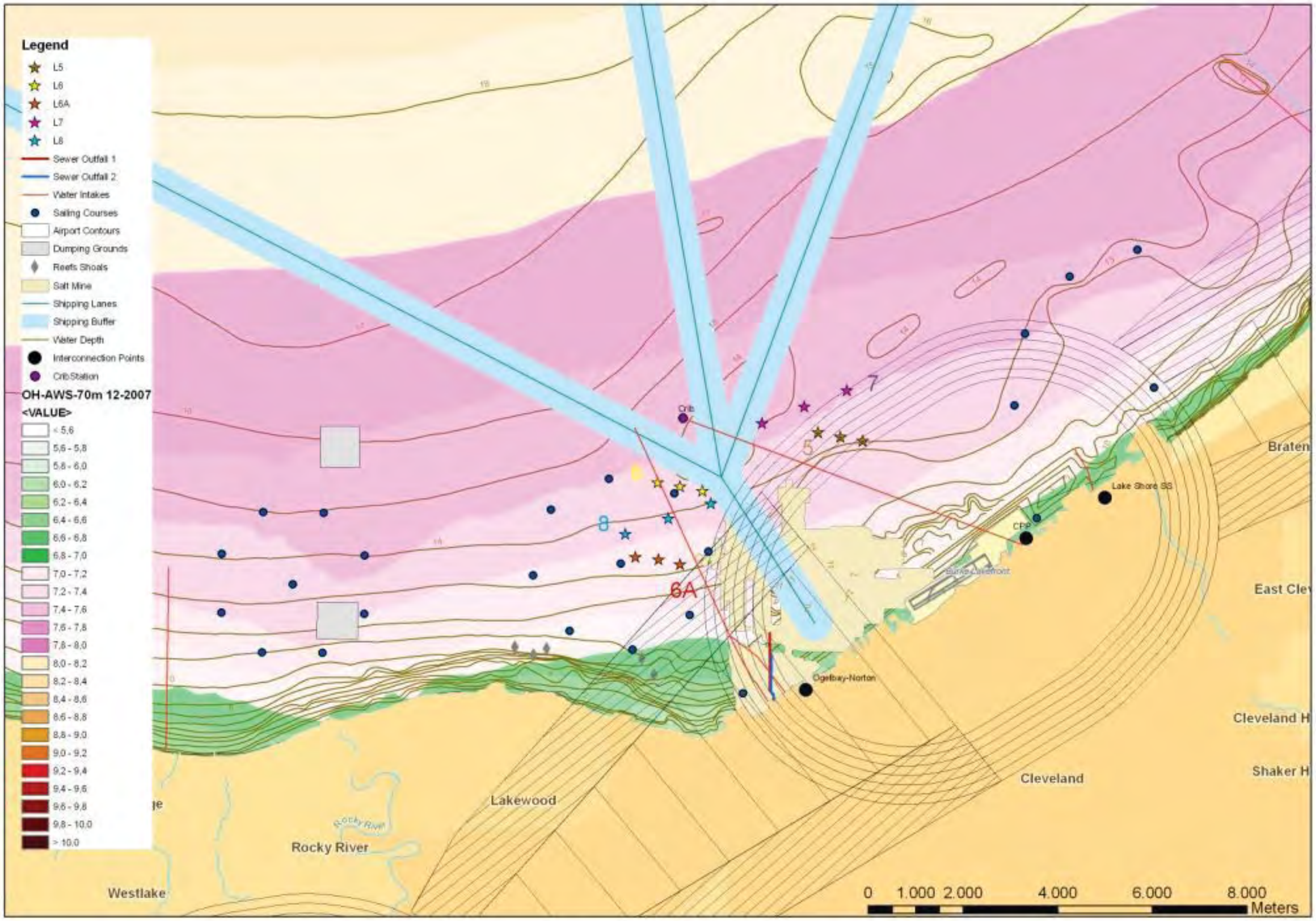


Figure 3-15: Possible layouts for three-turbine GLWEC pilot project. Distance between turbines in Configurations 5, 6, and 6A is 480 m (1,575 ft), orientation of turbine rows 280° to 100°. Distance between turbines in Configurations 7 and 8 is 960 m (3,149 ft), orientation of turbine rows is 250° to 70°.



3.2 Photosimulations

To gain a better sense of how Pilot Project turbines will appear from shore, Black & Veatch performed a number of photosimulations. Configurations 6A and 7 were chosen as example Pilot Project locations, and vantage points include Gordon Park, the downtown Mall, Voinovich Park, Wendy Park, Edgewater Park, Lakewood Park, and Key Tower. Additionally, both Clipper 2.5 MW and REpower 5.0 MW turbines were chosen. For the complete set of photosimulations, refer to the GLWEC photosimulations (Black & Veatch, October 2008). Example photosimulations of possible Pilot Project configurations are provided in the following figures.

Figure 3-16: Layout 7 from Gordon Park (REpower turbines)

Figure 3-17: Layout 7 from downtown Mall (REpower turbines). Note turbine blade above Science Center

Figure 3-18: Layout 7 from Voinovich Park (REpower turbines)

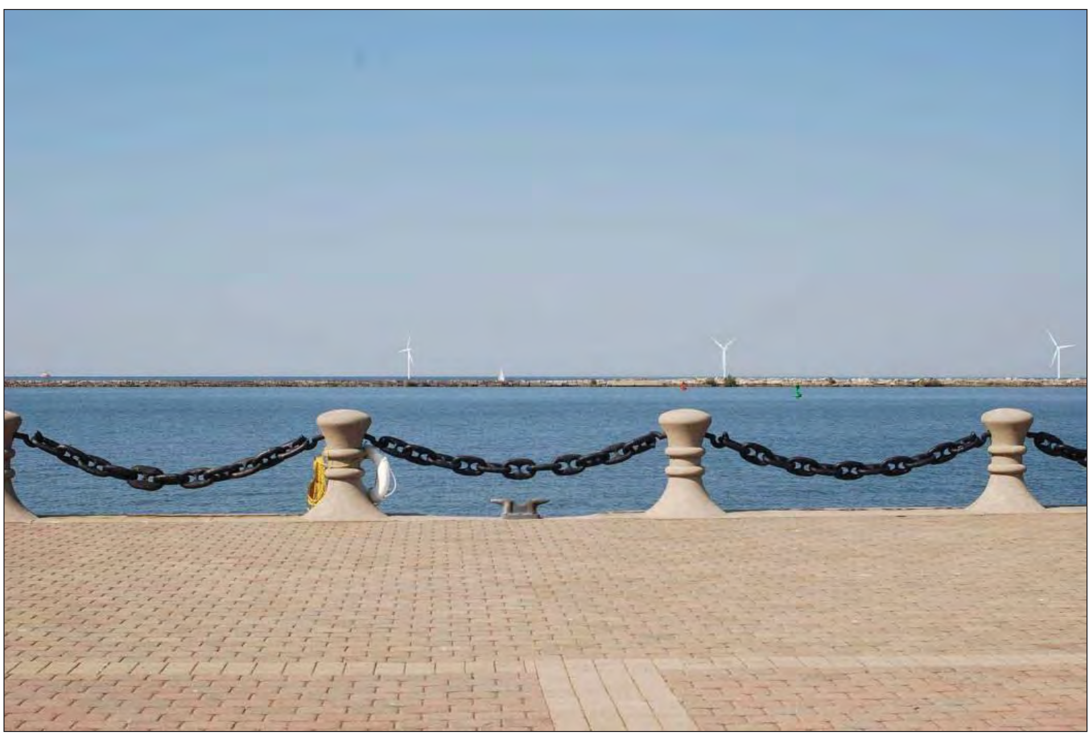


Figure 3-19: Layout 7 from Wendy Park (REpower turbines)

Figure 3-20: Layout 6A from Wendy Park (REpower turbines)

Figure 3-21: Layout 6A from Key Tower (REpower turbines)

Figure 3-22: Layout 7 from Key Tower (REpower turbines)

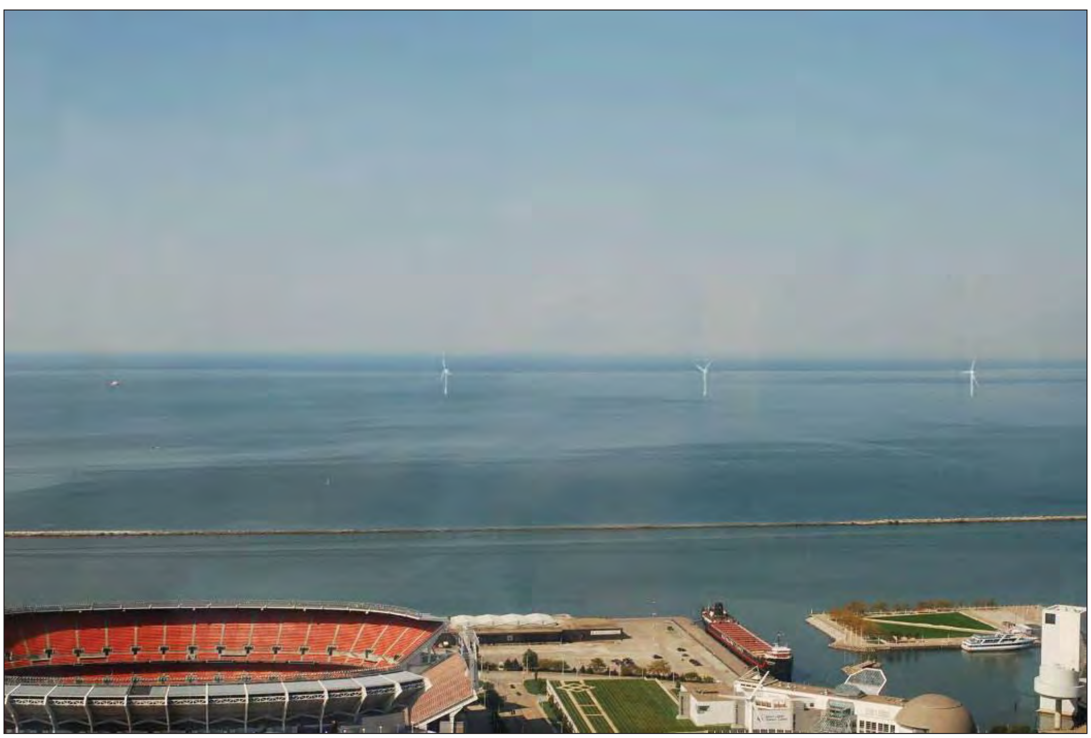


Figure 3-23: Layout 7 from Lakewood Park (Repower turbines)

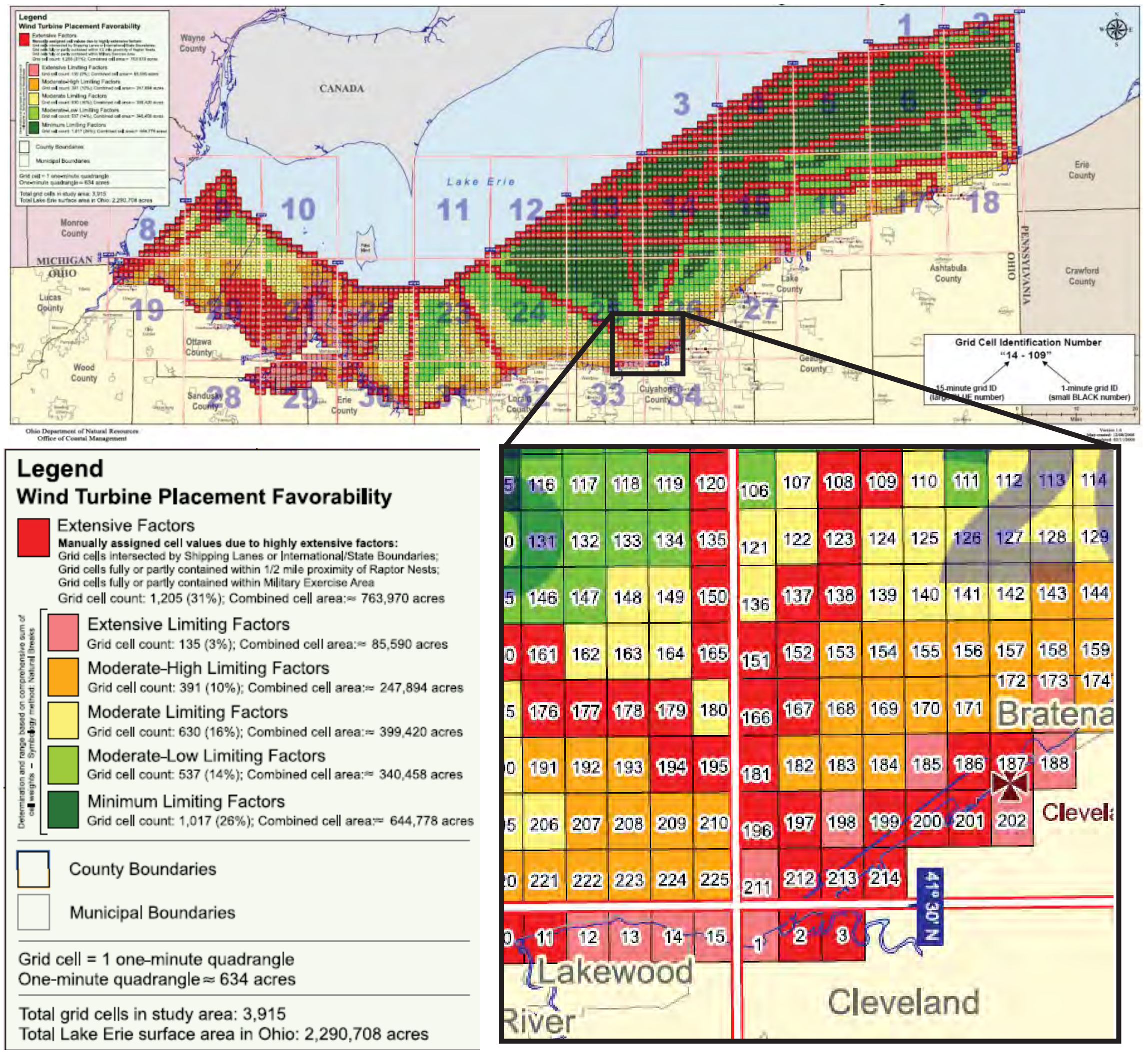
Figure 3-24: Layout 6A from Lakewood Park (Repower turbines)

3.3 ODNR Favorability Map

With increased interest in offshore wind energy development, The Ohio Department of Natural Resources, Office of Coastal Management has issued the map below (Figure 3-25) to help guide responsible development on Lake Erie. The Lake is divided into grid cells and color-coded to illustrate favorability for turbine placement based on relative weighting of a set of criteria, including shipping lanes, lakebed substrates, fish communities, distance from shore, and other factors. Grid cells provide the basis for applications to ODNR for submerged land leases. While the map accounts for important siting criteria on Lake Erie, ODNR has provided the map to help guide responsible development only, not to proscribe “go or no-go” areas necessarily. Additionally, grid cells in the map are the basis for submerged land lease applications administered by the ODNR Office of Coastal Management.

The inset figure below illustrates that the majority of the Project site has moderate to extensive limiting factors. Shipping lanes are the primary extensive limiting factor, and any cell intersected by a shipping lane is colored red. Possible Pilot Project locations presented in Figure 3-14 and Figure 3-15 account for a 1,230 feet buffer from the center of shipping lanes. If the Project moves toward the design stage, an appropriate buffer should be established through consult with the Cleveland-Cuyahoga Port Authority, Lake Carriers Association, and/or other relevant organization(s). Final turbine placement for the Pilot Project will also require collaboration with ODNR and other agencies.

Figure 3-25: ODNR Wind Turbine Placement Favorability Analysis Map

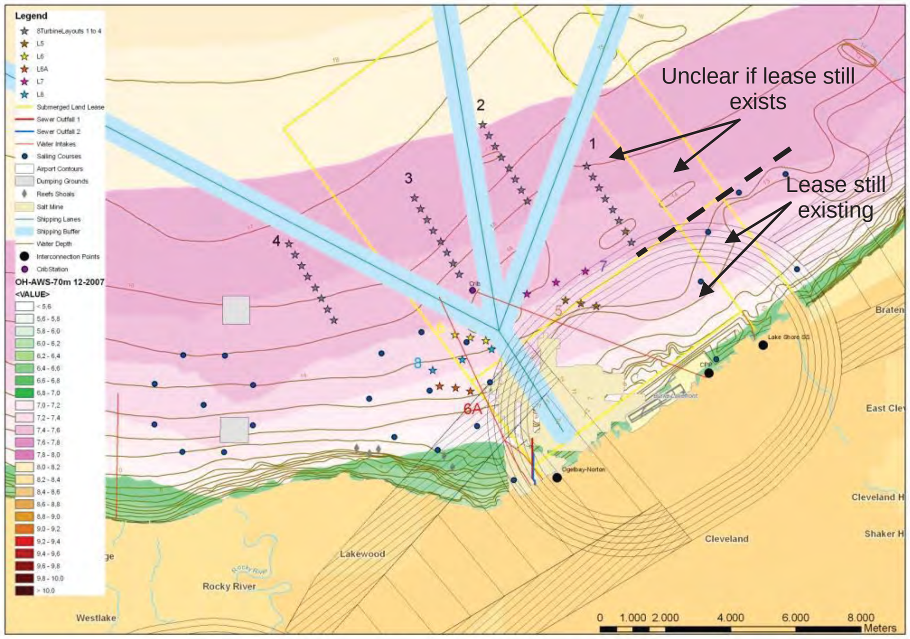


Source: ODNR, Office of Coastal Management, http://www.ohiodnr.com/LakeErie/WindEnergyRules/tabid/21234/Default.aspx

3.4 Port Authority Submerged Land Lease

The Cleveland-Cuyahoga Port Authority has an existing lease for submerged land offshore from Cleveland. The lease is dated in 1972 and is related to efforts to locate an airport in Lake Erie. Figure 3-26 illustrates (in yellow) the extent of the Port's lease originally mapped by the Cuyahoga County Planning/GIS department. At the time of this writing, it is unclear based on ODNR and Port Authority records whether the northern sections of the lease is still valid. Nevertheless, under Ohio law assignment of any existing submerged land lease for the new purpose of harvesting offshore wind energy will require ODNR approval and a process similar to making an application for a new submerged land lease (see previous section).

Figure 3-26: Pilot Project Locations in Relation to Port Submerged Land Lease



3.5 Conclusions: Determination of Pilot Project Sites

Section 3 provides a summary of preliminary information relevant to possible locations for the GLWEC Pilot Project. The turbine locations presented herein are based on key siting factors including wind resource, distance to interconnection locations, air navigation and radar, water depth, shipping channels, Cargill Salt Mine, visibility, and the location of underwater features. While these factors determine the turbine configurations presented herein, final turbine locations will require consultation and approval from the FAA, ODNR, USACE, USFWS, OEPA, and other agencies.

All turbines for the Pilot Project must obtain permits from the FAA prior to construction to ensure that there is no impact on aircraft navigation. At the time of this writing potential turbine locations have been submitted to the FAA for review. Based on available information from the Ohio Office of Aviation, it is likely that the four eight-turbine configurations, despite being partially or wholly within traffic pattern airspace, are an acceptable distance from Burke Lakefront Airport. Being closer to shore, and entirely within traffic pattern airspace, the three-turbine configurations may be more difficult to obtain permits for. Discussions with the Ohio Office of Aviation suggest that the area outside the climb-descent zone may be the best location for siting the Project closer to shore within traffic pattern airspace. Configuration 5 is the only three-turbine layout that is currently outside the climb-descent zone.

Pilot Project turbines are not expected to impact NEXRAD radar. FAA review will identify any potential impacts to military radar. If impacts are identified, consultation with the FAA and/or Department of Defense may be required to discuss mitigation techniques.

Project visibility is primarily a result of distance from shore and location relative to well-trafficked vantage points in downtown Cleveland (i.e. Voinovich Park, Rock n' Roll Hall of Fame, Browns Stadium, Key Tower). On a clear day, and assuming structure heights in the range of 115 – 150 m (380 - 500 ft), all turbine locations presented herein will be visible from the Cleveland shore. The Cleveland water intake Crib – which stands approximately 15 m (50 ft) tall and is 3.5 miles from downtown Cleveland – is visible on a clear day from shore and provides a reference for turbine visibility. Naturally, turbines closer to shore will appear more prominently in the viewshed.

The wind resource is expected to be similar for all the turbine configurations, with the possible exception of Configuration 2, where the narrow angle of the shipping lanes forces the layout further north into an area of presumably higher wind speeds. Generally, turbines should be oriented roughly perpendicular to the prevailing wind direction to minimize turbulence and wake effect. If a different orientation is preferred, increasing turbine spacing is the second-best method to reduce turbulence and wake effect.

As a result of the preliminary analysis of the wind conditions, no major issues ("no go" criteria) are identified. The resulting design conditions at the sites are all in the range of turbine class II. Thus, the design of common wind turbine types can be used at the site. Nevertheless, this preliminary analysis is not a substitute for more detailed analyses required for design.

The Lake Erie site shows wind conditions that appear gentle with respect to the structural integrity of the turbines. Because no significant difference in wind conditions is assumed between possible layouts, optimizing energy yield is considered the major factor for site decision with respect to wind conditions.

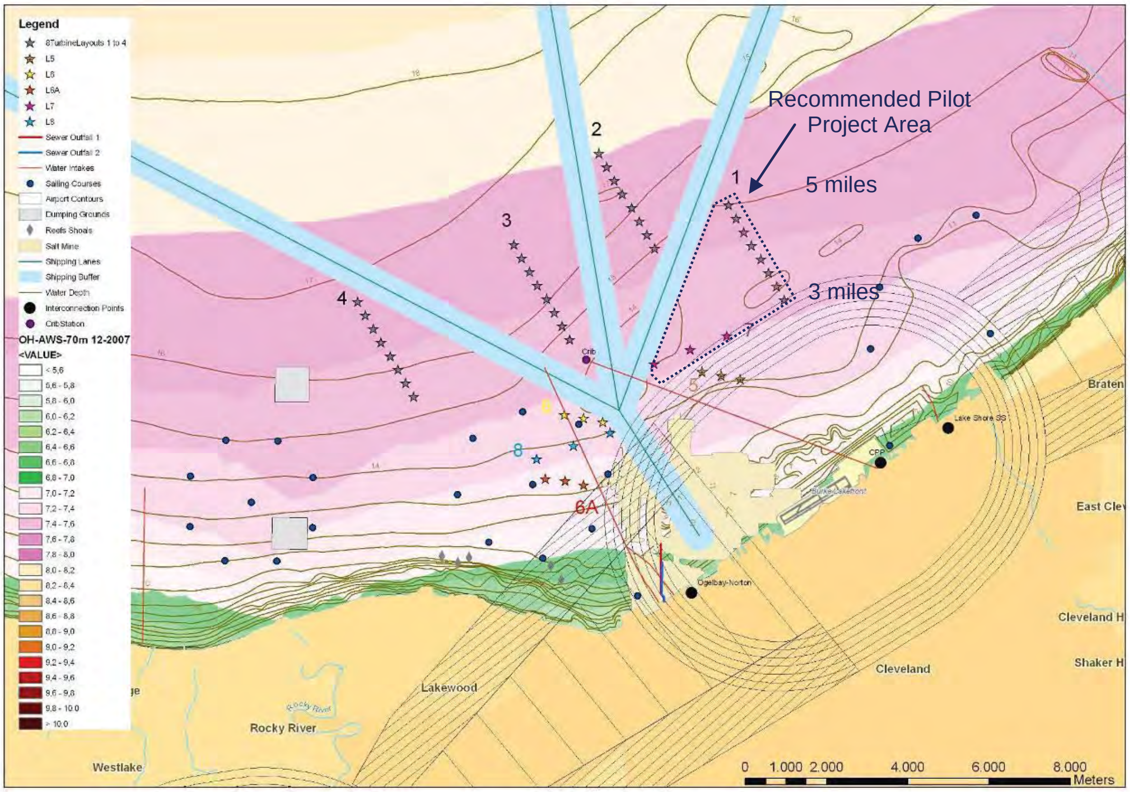
Evaluating soil estimates, Configurations 1, 2, 5 and 7 would be more preferable compared to the other sites. The assumptions made here is that a piled foundation (monopile, tripod or jacket) would be chosen. The piles are not ideal for drilling into the bedrock because of high costs. Furthermore, assuming comparably low water depths, ice and wave loads, a standard foundation type such as a monopile could be chosen for cost reasons. Suction buckets would be a possible alternative if the soil strata thickness of a location is not sufficient for a piled foundation. It should be noted that know-how of suction buckets and other "cutting-edge" designs is not as in-depth as other standard designs.

Based on established siting criteria and information collected throughout the course of the Feasibility Study, juwi recommends an area east of the Cleveland water intake Crib, generally between potential turbine configurations 1 and 7 (see Figure 3-27). Primary reasoning for this site includes:

- Sufficient wind resource for Pilot Project – estimated to be ~7.5 m/s annual average at 80 m hub height, based on Crib anemometer measurements
- Safe distance from Burke Lakefront Airport / outside FAA cone (pending FAA review and approval)
- Close proximity to proposed most feasible interconnection locations at CPP or CEI, reducing cabling distances and associated costs
- Presumed geological conditions supporting drivability of monopile foundations and load bearing strata
- No conflict with artificial reefs or shoals, dumping grounds, known / documented shipwrecks, or other underwater features
- No presumed conflict with established sailboat race courses
- Turbines are outside Audubon Ohio Important Bird Area; avian impact is expected to be minimal
- Site should allow sufficient buffer from shipping lanes to mitigate risk of collision
- High iconic value, while preserving the above

Other potential sites in the Project area share attributes listed above, and final site determination should involve consultation with regulatory agencies and other stakeholders (i.e. Lake Carriers Association, Burke Lakefront Airport, FAA).

Figure 3-27: Recommended Pilot Project Site



4 Wind Resource

(Unless otherwise indicated, information in this section is from the GLWEC Final Wind Report, juwi, December 2008).

This section addresses the available wind resource on Lake Erie in the near-shore area adjacent to downtown Cleveland. Assessment is based on two years of measured wind data—between October 1, 2005 and September 30, 2007—collected from a meteorological tower on the Cleveland Water Intake Crib, and provided to juwi by Cuyahoga County. The assessment also includes virtual met tower data from two heights above sea level at the Crib location. These data are provided by AWS Truewind, a wind energy consulting firm that specializes in wind resource assessment.

The Crib meteorological tower was installed by Green Energy Ohio, The Renaissance Group, and volunteers in 2005. The project was a result of interest among several organizations interested in harnessing the winds of Lake Erie for electricity production, including Green Energy Ohio, The Cleveland Foundation, the Steffee Foundation, the City of Cleveland, the George Gund Foundation, Cuyahoga County, and the Great Lakes Energy Development Task Force. These and other organizations and individuals have contributed the necessary resources to install wind monitoring equipment on the Crib, and collect and analyze wind resource data. To date, wind data from the Crib are the only consistent data above buoy height on Lake Erie, and the only data acquired for the relatively windier months of October-May for any year. Thus, the value of Crib data in assessing the potential of offshore wind energy on Lake Erie (and regionally on the Great Lakes) is significant.

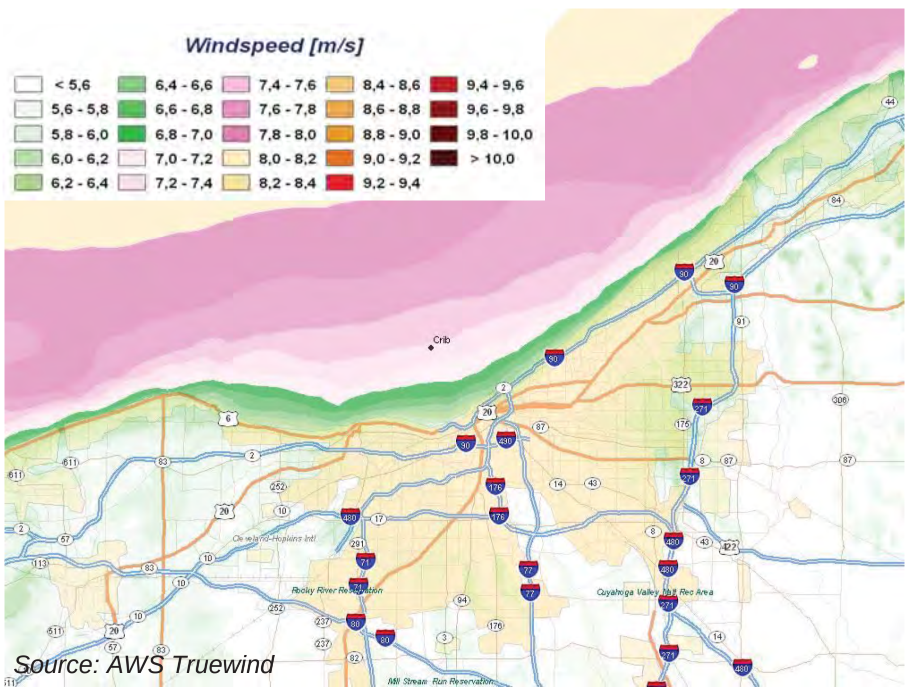
A long term correlation is performed to validate the two-year period of measurement against long term trends. The primary purpose of this report is to characterize the long term wind resource on Lake Erie in the general vicinity of the Crib, and provide the basis for energy production estimates for the Pilot Project.

4.1 Crib Structure and Site

The Cleveland Water Intake Crib is a solid, robust structure built in 1904 and located in Lake Erie approximately 3.5 miles northwest from the closest point on the shore of Cuyahoga County and downtown Cleveland. On August 29th, 2005 a 125 ft (38 m) tower was installed on the Cleveland Water Intake Crib. Data collection started on September 20th.

The Crib is the only existing structure on Lake Erie on which placement of a met tower is feasible because the structure is anchored to the lakebed and does not move, even during heavy winter storms. While the existence of the Crib structure is highly advantageous for offshore wind measurement, its location in the Cleveland bay is a disadvantage with respect to wind speeds. Measured wind speeds at the Crib station may not reflect the available wind resource on Lake Erie. This is due to the Crib's location in a somewhat sheltered bay formed by a natural depression in the Lake Erie / Cuyahoga County shoreline (Figure 4-1). From the prevailing southwest direction, winds flow over land with higher roughness—which increases turbulence and decreases speed—and have only a few miles of flow over Lake Erie before being measured at the Crib. Despite this, the ongoing wind measurement is highly important, producing the only wind data on the Great Lakes at significant height above the water surface.[4]

Figure 4-1: 50 m wind speed map and Crib location



[4] Other wind speed data are available on Lake Erie from NOAA buoys. Being close to lake level, these data have limited applicability for offshore wind energy potential, and no buoy data are available for the winter months, when wind speeds are greatest.

Figure 4-2: Picture of the Crib station prior to the met tower installation

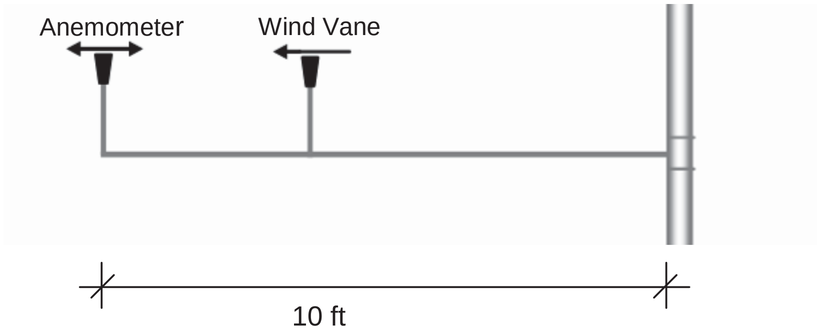
4.2 Analysis of Wind Data

4.2.1 Wind Measurement System

A special 125 ft (38 m) tower was custom engineered for application on the Crib. Total tower height is 166 ft (50 m) above lake level. The tower and measurement system was developed by GEO, in consultation with AWS Truewind and following guidelines for wind monitoring set forth in the National Renewable Energy Laboratory's Wind Resource Assessment Handbook (1997).

The tower has six booms that are each 10 ft long; two booms at each height of 98 ft, 131 ft and 164 ft (30 m, 40 m, 50 m). Three booms are oriented northwest (315°) and three are oriented south (180°) to minimize the effect of wind speed shadowing from the tower. Each boom has an NRG-40 anemometer and an NRG-200P wind vane as shown in Figure 4-3.

Figure 4-3: Setup of sensors on each boom

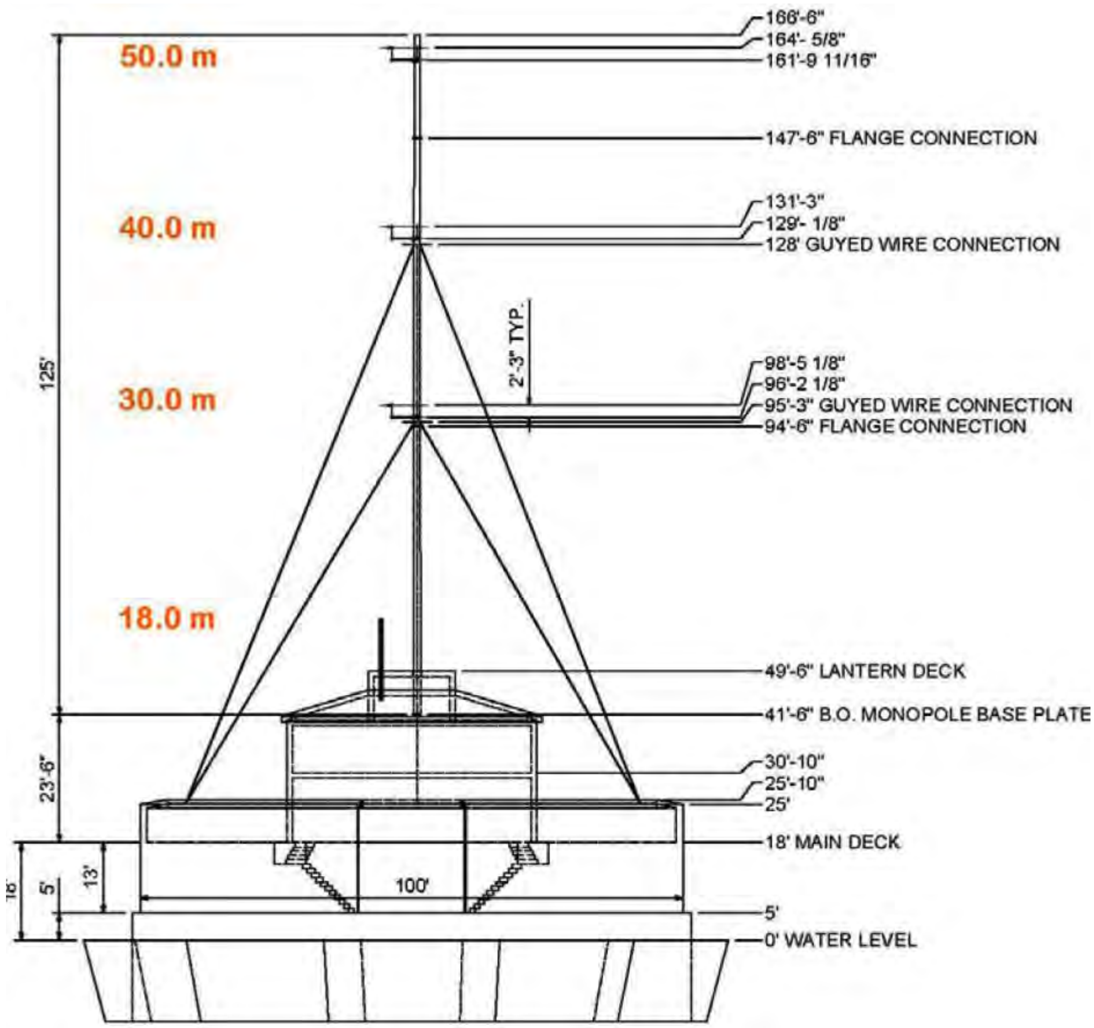


Data are recorded every 4 seconds (at 0.25 Hz) and then averaged to 10-minute periods and stored by a Campbell Scientific CR23X Micrologger. Speed, direction and temperature are recorded, and the logger calculates, transmits, and stores standard deviations for each sensor on a 10-minute interval basis. Minimum and maximum values for each sensor are also stored, as well as precipitation (rain), humidity, barometric pressure, and solar radiation. Table 4-1 lists the geographical coordinates in WGS84, elevation, height and other met tower characteristics. A detailed drawing of the tower is shown in Figure 4-4.

Table 4-1: Crib met tower details

Crib Met Tower Details	
Name	Lake Erie Crib
Lat/Long (WGS84)	N 41° 32' 54" W 81° 45 1"
Lake Erie Elevation (AMSL)	571 ft
Tower height	125 ft
Crib main deck (above lake level)	18 ft
Crib Building (above lake level)	23 ft
Total tower height (above lake level)	166 ft
Logger	Campbell Scientific CR23X
Resolution	10-min intervals
Anemometers	NRG Maximum #40
Wind Vanes	NRG 200P
Temperature Sensors	NRG 110S

Figure 4-4: View of the met tower on the Crib



Source: A Wind Resource Assessment for Near-Shore Lake Erie: Cleveland Water Crib Monitoring Site Two-Year Report. Green Energy Ohio, January 10, 2008

4.2.2 Wind Data

4.2.2.1 Wind Speed

The Crib wind data show a high data availability rate which helps limit uncertainties related to wind energy forecasting. After verifying the measured data the time series of the 10-minute average values are classified according to wind direction (12 sectors of 30°) and wind speed (bin width 0.1 m/s). Mean wind speed over the entire twenty-four month measuring period is 7.37 m/s (16.5 mph) at 50 m height for the A5 anemometer and 7.34 m/s (16.4 mph) at 50 m height for the A6 anemometer. Table 4-2 lists all anemometer heights with corresponding wind speed averages for each height.

Table 4-2: Mean wind speed for each anemometer

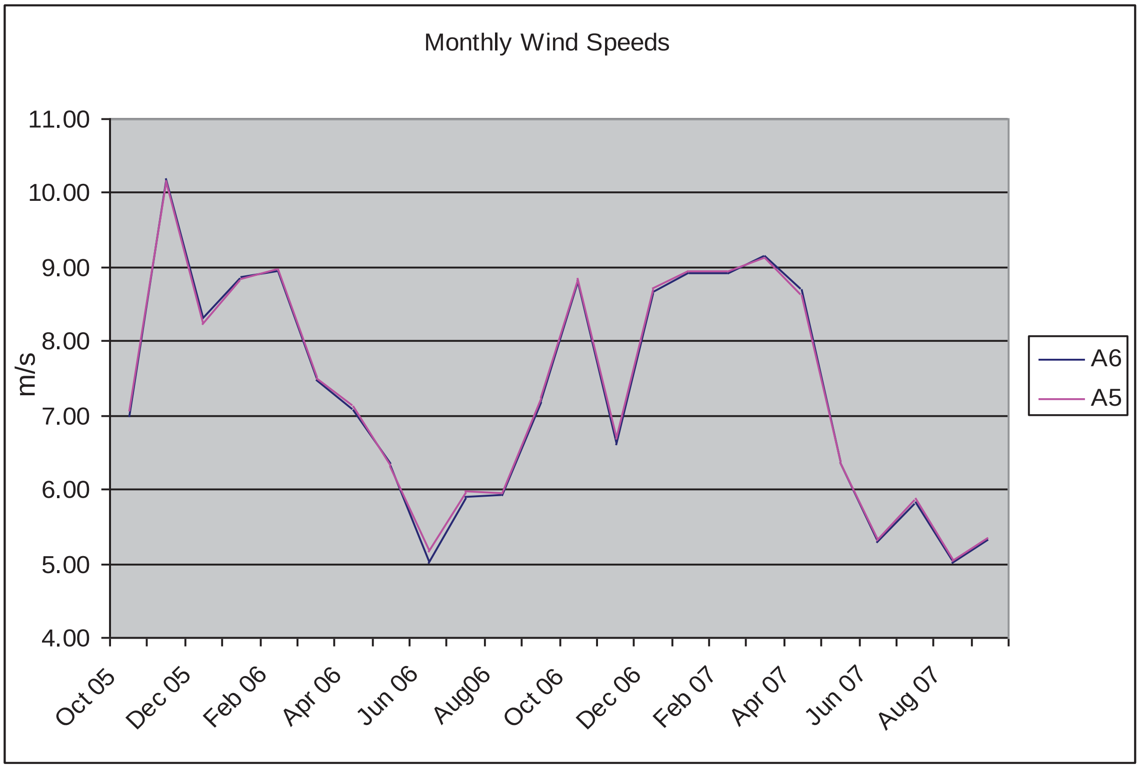
Met mast	Height	Mean wind speed (m/s)
Crib	A6 50 m	7.347
	A5 50 m	7.371
	A4 40 m	7.272
	A3 40 m*	7.567
	A2 30 m	7.219
	A1 30 m	7.198

**Anemometer A3 only operated for the first 10 months before permanent failure.*

Figure 4-5 below shows two very consistent curves for the top anemometers over the entire measuring period, an indication of high quality and reliability of the data. The different direction the sensors face seems not to have any significant effect on the data, as the average wind speeds between anemometers A5 and A6 only differ by ~1%.

Usually wind speeds increase with height above ground. It would be most accurate to measure wind speeds at hub height. However, this is not normally possible with a met tower as costs and technical hurdles are prohibitive, especially with regard to the unique situation at the Crib. For production calculations the most important wind data are those from the top anemometer, but all other data are necessary for comparison to each other (reliability check) and for further calculations.

Figure 4-5: Monthly average wind speeds for 50 m anemometers A5 and A6*



4.2.2.2 Wind Shear

The shear factor describes the relation between wind speeds at different heights above ground level. With the wind shear the measured wind speed can be recalculated to a final turbine hub height.

Periods of low wind speeds tend to yield higher shear factors as slower winds tend to blow with less consistency and greater turbulence. For example, it is possible that during a summer month a single 10-minute wind speed value at 50 m might be zero and the 30 m value might be e.g. 0.5 m/s. This example would yield a shear factor of -7.2 for this 10-minute period (as wind speeds typically increase with height above ground, shear factors are most commonly positive).

Because low wind speeds are characterized by high turbulence and shear values that are not representative of normal wind conditions, wind speeds below 4 m/s are excluded from analysis. 4 m/s is a typical cut-in wind speed where utility scale wind turbines begin rotating and producing electricity. As wind speeds vary seasonally over the course of a year, shear values show similar variability. This trend can be seen in Figure 4-6 where the monthly average wind shear values between the 50 m and 30 m anemometers are shown. Usually the increase of wind speed with height is highly affected by the roughness of the surrounding terrain. Trees and other obstacles reduce wind speed near the surface and to a lesser extent at higher altitudes. Due to the very low roughness of the water surface the expected wind shear exponent for offshore locations is in the range of 0.10 - 0.11. The calculated wind shear factors for the Crib data are significantly lower. Between the A5 and A1 and A6 and A2 sensors (50 m – 30 m) a shear factor of 0.067 and 0.04 are calculated, respectively. The effect of different shear factors on projected wind speeds at heights of 70 m and 80 m is also shown in Table 4-3.

Figure 4-6: Monthly average shear across 50 m and 30 m anemometers (A5-A1; A6-A2)

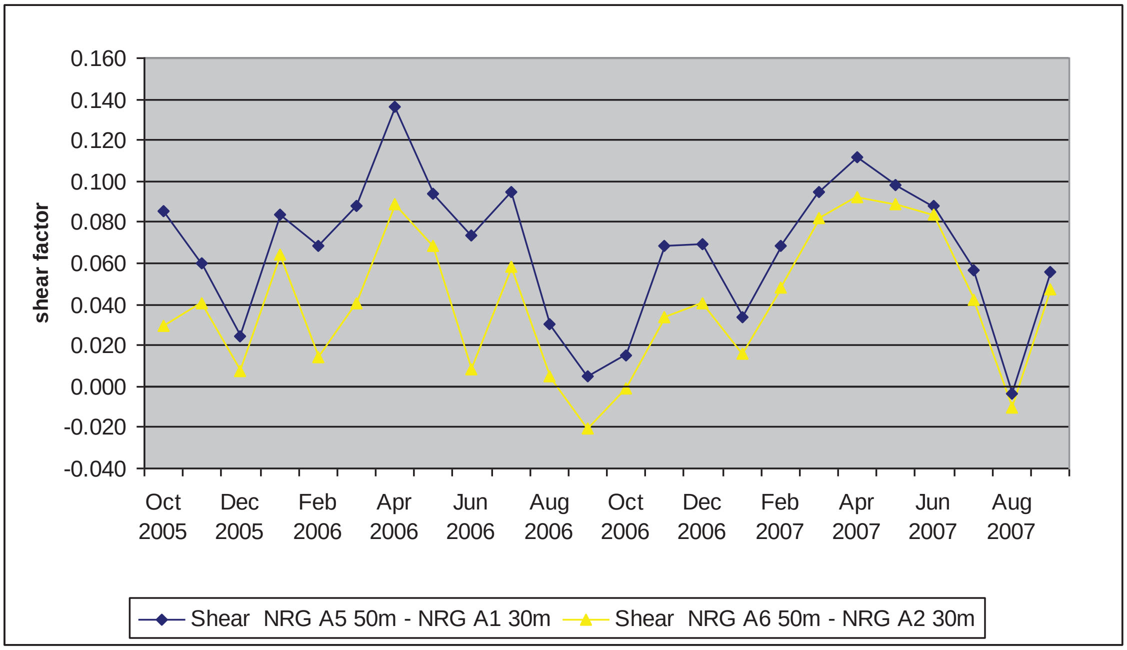


Table 4-3: Example shear factors and effect on projected long term adjusted wind speed of 7.24 m/s at 50 m

Shear factor	Projected annual average wind speed at 70 m (m/s)	Projected annual average wind speed at 80 m (m/s)
.01	7.26	7.27
.02	7.29	7.31
.03	7.31	7.34
.04*	7.34	7.37
.05	7.36	7.41
.06	7.39	7.44
.067*	7.41	7.47
.07	7.41	7.48
.08	7.44	7.52

.09	7.46	7.55
.1	7.49	7.58

**Indicates the range of shear factors calculated for the Crib data*

There is a clear difference between the two curves in Figure 4-6 although the final average wind speeds for the 50 m sensors match very well. This suggests that the difference between the two shear curves is driven by the 30 m wind data. A recalibration of all sensors—especially the non-calibrated anemometers A1, A2, A3, A4—is highly recommended after final decommissioning of the equipment to better compare the operational quality of the anemometers across consistent wind conditions in a wind tunnel.

juwi also calculated average wind shear for the other sensors and heights. Unfortunately the A3 anemometer failed in July 2006 which reduces the amount of available data for a quality check. Generally the shear factors between the two booms at each level do not correlate well. This is problematic especially since the measured shear values are low, and quality checking adds confidence. The wind shear is critical in estimating wind speed at final hub height. Normally the projection from measuring height to hub height leads to an increased average wind speed. With the current wind shear in the range of 0.04 to 0.067 there is no significant increase in wind speed from 50 m to 70 m or 80 m.

Whereas juwi does not believe it is impossible that shear values at the Crib are in reality as low as calculations indicate, there is also reason to believe the real wind shear differs from what we calculate from the existing data. For reference, at the German FINO1 offshore measuring platform the average wind shear is 0.1 – 0.11. FINO1 is located in the German North Sea approximately 38 miles north of the German mainland.

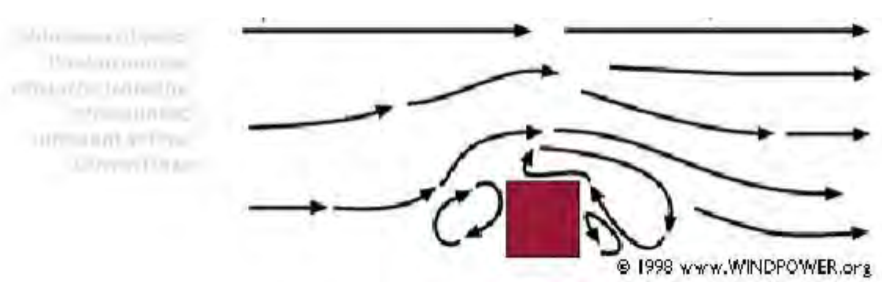
Both the relatively unexpected low wind shear plus inconsistency between the different boom levels suggest that the Crib structure itself may have an influence on the wind readings. Especially in this case, with the rather large structure of the Crib surrounded by a vast area of very low roughness it seems likely that the measured data do not reflect the real wind shear conditions on Lake Erie surrounding the Crib.

Table 4-4 shows a comparison of the shear factors between the different heights of the south oriented sensors. It is notable that the different values are not consistent with normal expectations. Usually shear between the 30 m and 50 m sensors would be highest due to the greater distance between sensors and hence more increase in wind speed. Also, as the influence of the land or lake surface decreases with height the shear from 40 m to 50 m should be lower than the shear between 30 m and 40 m. This is not the case. Unfortunately, for reliability purposes the same comparison cannot be made with the northwest sensors as it is not clear how long the A3 anemometer recorded faulty data before it permanently failed in July 2006.

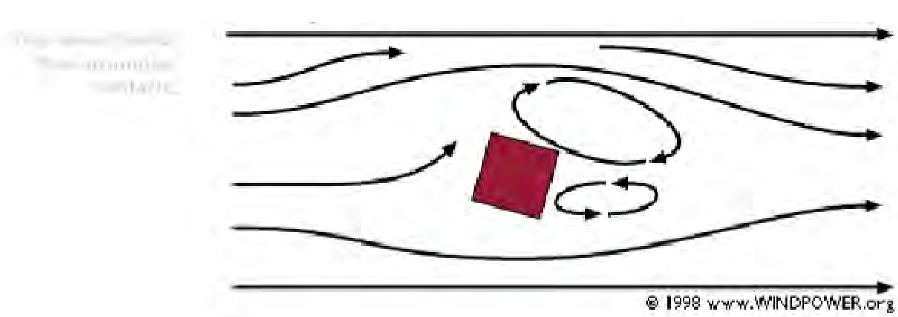
Table 4-4: Shear factors at the south oriented sensors

Sensor	Heights	Shear Factor
A6 - A2	50 m - 30 m	0.04
A6 – A4	50 m - 40 m	0.051
A4 – A2	40 m - 30 m	0.033

Standing 41 ft above the lake surface, the Crib structure very likely affects wind measurements on the monitoring tower. The height of the tower was limited due to technical and loading considerations. But it is still worth noting that the Crib tower design is significantly different than a state of the art 50 m met tower designed for onshore use, which would have no structure at its base to impede or interfere with wind flow. The two drawings below demonstrate how an obstacle such as the Crib can influence wind flow and wind speed.



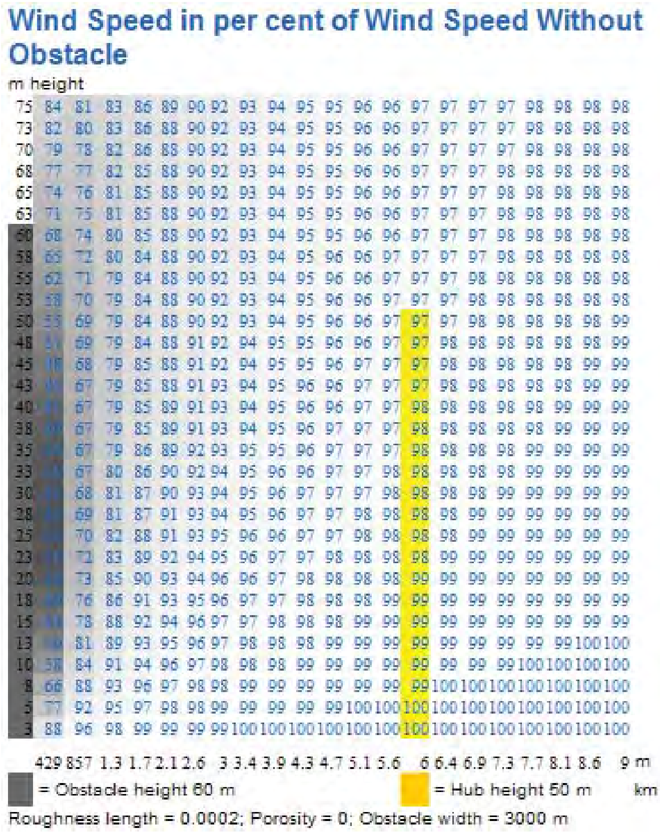
The side view picture above indicates that wind can accelerate as it flows up and over a structure. Accordingly, if the 30 m sensors experience accelerated wind speed due to wind flow up and over the Crib structure, the measured difference between the 30 m and 50 m sensors will be reduced. This is a possible explanation for the low shear values at the Crib.



The top view picture above shows that wind flow is affected as it moves horizontally around an obstacle. This is a possible explanation why the shear factor differs between the south and the northwest booms.

Finally, another explanation why the measured wind shear factors might be inaccurate is the influence the Cleveland cityscape could have. With just ~3.5 miles distance between downtown Cleveland and the Crib station, this is likely to influence southerly winds even at the Crib station. The phenomenon of wind shade is depicted in Figure 4-7. While this wind shade calculator cannot be used to determine any reduction in wind speed caused by onshore roughness, we offer this graph to illustrate the likelihood that the City of Cleveland has a negative effect on the wind speeds measured at the Crib. Figure 4-7 also offers an explanation for low shear. The reduction of wind speed in percent is greater at the 50 m level than at 30 m. It is possible that the lower anemometers experience accelerated winds that flow up and over the Crib while the higher anemometers experience reduced wind speed due to Cleveland's skyline.

Figure 4-7: Wind shade example



m height	429	857	1.3	1.7	2.1	2.6	3	3.4	3.9	4.3	4.7	5.1	5.6	6	6.4	6.9	7.3	7.7	8.1	8.6	9
75	84	81	83	86	89	90	92	93	94	95	95	96	96	97	97	97	97	98	98	98	98
73	82	80	83	86	88	90	92	93	94	95	95	96	96	97	97	97	97	98	98	98	98
70	79	78	82	86	88	90	92	93	94	95	95	96	96	97	97	97	97	98	98	98	98
68	77	77	82	85	88	90	92	93	94	95	95	96	96	97	97	97	98	98	98	98	98
65	74	76	81	85	88	90	92	93	94	95	95	96	96	97	97	97	98	98	98	98	98
63	71	75	81	85	88	90	92	93	94	95	95	96	96	97	97	97	98	98	98	98	98
60	68	74	80	85	88	90	92	93	94	95	95	96	96	97	97	97	98	98	98	98	98
58	65	72	80	84	88	90	92	93	94	95	96	96	97	97	97	97	98	98	98	98	98
55	62	71	79	84	88	90	92	93	94	95	96	96	97	97	97	98	98	98	98	98	98
53	58	70	79	84	88	90	92	93	94	95	96	96	97	97	97	98	98	98	98	98	98
50	55	69	79	84	88	90	92	93	94	95	96	96	97	97	97	98	98	98	98	98	99
48	[illegible]	69	79	84	88	91	92	94	95	95	96	96	97	97	98	98	98	98	98	98	99
45	[illegible]	68	79	85	88	91	92	94	95	95	96	97	97	97	98	98	98	98	98	99	99
43	[illegible]	67	79	85	88	91	93	94	95	96	96	97	97	97	98	98	98	98	98	99	99
40	[illegible]	67	79	85	89	91	93	94	95	96	96	97	97	98	98	98	98	98	99	99	99
38	[illegible]	67	79	85	89	91	93	94	95	96	97	97	97	98	98	98	98	98	99	99	99
35	[illegible]	67	79	86	89	92	93	95	95	96	97	97	97	98	98	98	98	99	99	99	99
33	[illegible]	67	80	86	90	92	94	95	96	96	97	97	98	98	98	98	98	99	99	99	99
30	[illegible]	68	81	87	90	93	94	95	96	97	97	97	98	98	98	98	99	99	99	99	99
28	[illegible]	69	81	87	91	93	94	95	96	97	97	98	98	98	98	99	99	99	99	99	99
25	[illegible]	70	82	88	91	93	95	96	96	97	97	98	98	98	98	99	99	99	99	99	99
23	[illegible]	72	83	89	92	94	95	96	97	97	98	98	98	98	99	99	99	99	99	99	99
20	[illegible]	73	85	90	93	94	96	96	97	98	98	98	98	99	99	99	99	99	99	99	99
18	[illegible]	76	86	91	93	95	96	97	97	98	98	98	99	99	99	99	99	99	99	99	99
15	[illegible]	78	88	92	94	96	97	97	98	98	98	99	99	99	99	99	99	99	99	99	99
13	[illegible]	81	89	93	95	96	97	98	98	98	99	99	99	99	99	99	99	99	99	100	100
10	58	84	91	94	96	97	98	98	98	99	99	99	99	99	99	99	99	100	100	100	100
8	66	88	93	96	97	98	98	99	99	99	99	99	99	99	100	100	100	100	100	100	100
5	77	92	95	97	98	98	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100
3	88	96	98	99	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: www.windpower.org

Figure 4-8: View from the Crib station to the City of Cleveland (looking south)

Source: Green Energy Ohio

4.2.2.3 Wind Direction

The wind direction is most important in determining the magnitude of blockage or wake effect that occurs between turbines, and to enable the most efficient wind park design. It is also important to know the prevailing wind direction and how variable wind direction is over the course of a year.

While in most areas in the United States there exist several sources of historical wind direction data, it is important to measure wind direction directly at the proposed site in order to determine site-specific wind conditions. The Crib wind direction data more or less confirm what is already known through NCEP/NCAR or ASOS weather station data. Still, more precise analysis for the Crib location is made possible by the on-site directional data.

The prevailing wind direction during the measuring period is west southwest which is to be expected for the area. The data indicate that more than 13% of the time winds are from the west southwest and ~12% of the time winds are from the south southwest. With the west and south sectors at 10% each a total of more than 45% of the time wind is coming from the 120° sector between south and west. Figure 4-9 shows the frequency of wind speeds in each direction at the Crib met tower location. The colors signify average wind speeds for each 30° sector.

Figure 4-9: Frequency Rose for Crib data

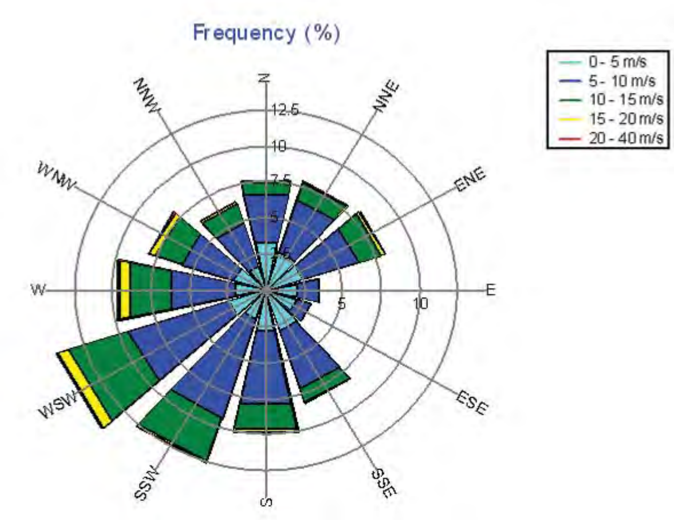
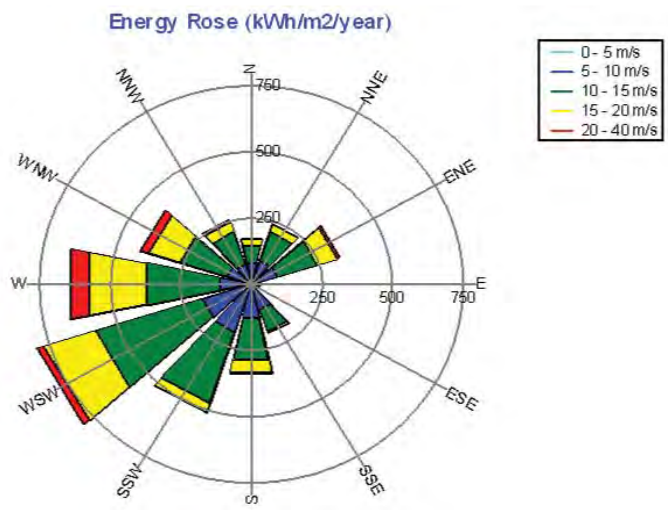


Figure 4-10 is an energy rose for the data collected at the Crib met tower. The energy rose incorporates wind speed and wind direction into a diagram predicting energy output by direction. The energy rose is used to determine the orientation of wind turbines if multiple are planned. In the case of the Crib station most of the energy in the wind is coming from the west and southwest and therefore the orientation of any row of turbines should be on a north-south (0°-180°) or northwest-southeast axis (315° - 135°) in order to avoid shading (or wake) effects between turbines.

Figure 4-10: Energy Rose for Crib data

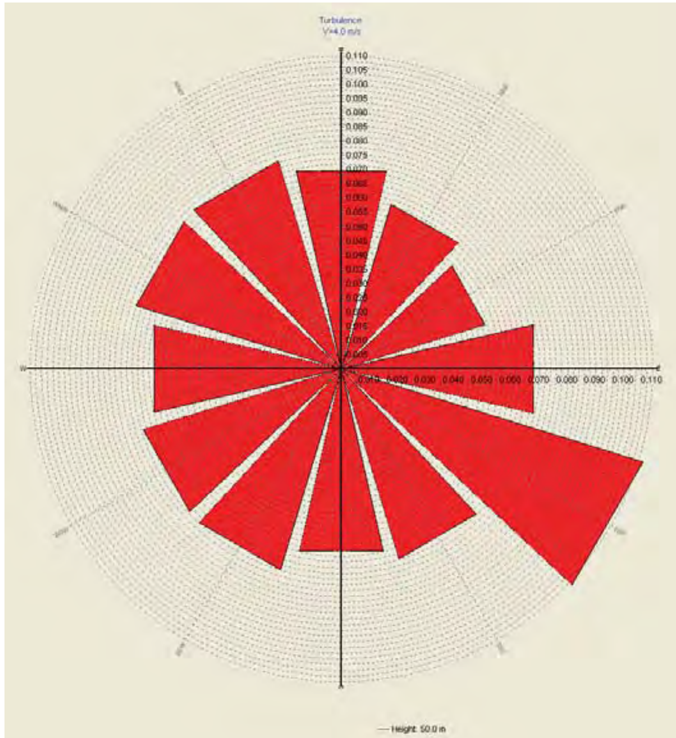


4.2.2.4 Turbulence

The turbulence of the wind can be calculated from the measured wind data. Turbulence is a measure of the consistency or steadiness of wind flow. The turbulence intensity at the Crib station ranges from approximately 5 to 11% for wind speeds higher than 4 m/s (typical cut-in speed for a utility-scale wind turbine).

In general the turbulence intensity at the offshore sites is much lower than at comparably windy onshore sites because of less surface roughness and consequent mixing of air. Figure 4-11 shows that turbulence intensity is highest (~11%) for wind speeds coming from east southeast. This is to be expected, as turbulence is usually greater at lower wind speeds, and Figure 4-9 and Figure 4-10 demonstrate the relative infrequency of winds from the east southeast. For the other wind direction sectors the turbulence intensity is rather consistent in the range of 5 to 8%. These numbers can be considered as low compared to wind industry standards at onshore sites. This low turbulence intensity suggests stresses on turbine blades—which in turn lead to technical problems in the turbine—will be relatively low.

Figure 4-11: Turbulence Rose for Crib data



4.2.3 AWS Virtual Met Tower Data

To supplement on-site data collected at the Crib, juwi obtained virtual met tower data from AWS Truewind for both 50 m and 80 m height levels for the exact location of the Crib. Virtual met tower data include an annual hourly time series of simulated wind speed, wind direction and other meteorological parameters.

AWS uses its MesoMap system to estimate and create wind maps and virtual met towers. MesoMap combines a state-of-the-art numerical weather model for simulating regional (mesoscale) weather patterns and a wind flow model for calculating local (microscale) terrain and surface conditions. The main inputs for the computer model are reanalysis data, particularly the historical data set produced by the US National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR). The virtual met towers rely on data from a 15-year period to simulate the weather conditions over 366 days. Days are chosen through stratified random sampling so that each month and season is represented equally in the sample. Thus, virtual met tower data are automatically adjusted for long term weather patterns. Key results from the virtual met towers are presented in Table 4-5.

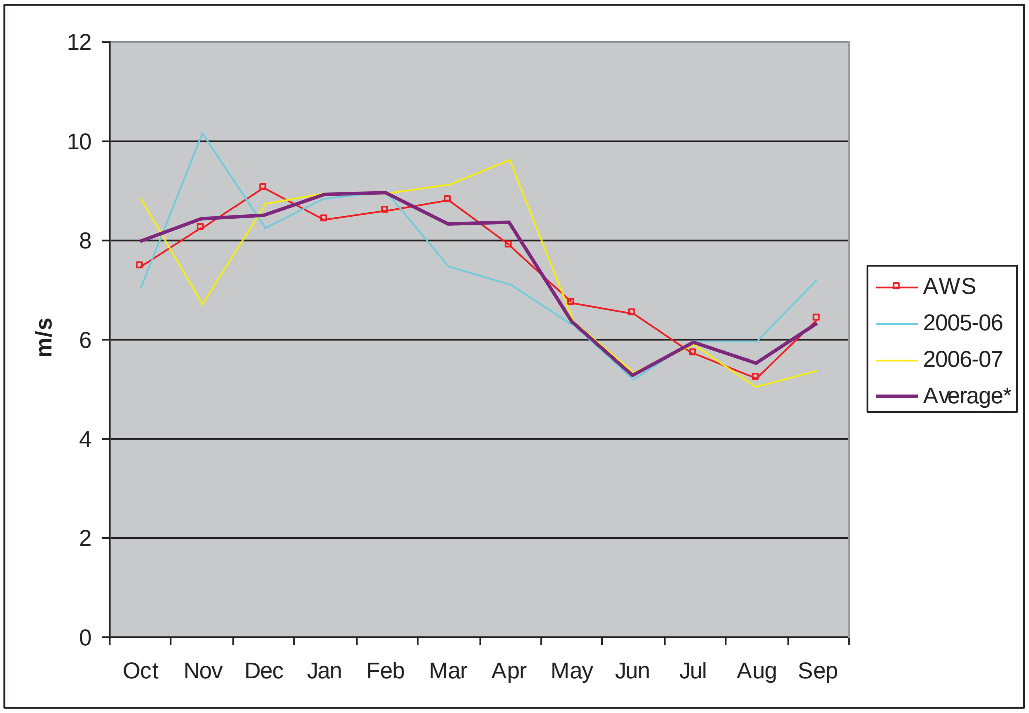
Table 4-5: Key Virtual Met Tower results

VMT coordinates (Crib)	Average wind speed at 50 m	Average wind speed at 80 m	Main wind direction
41.548° N 81.750° W	7.42 m/s	7.85 m/s	SW

Figure 4-12 compares the monthly means of the A5 50 m anemometer with the results of the 50 m virtual met tower. The two year measuring period (average line) matches well with the estimated monthly means provided by AWS, which are adjusted for long term trends. The agreement between the Crib and virtual met tower data is an important indication that—at least at 50 m height—the AWS wind map of Ohio and Lake Erie is an accurate predictor of actual average wind speeds.

The increase in wind speed from 50 m to 80 m results in a shear factor of 0.12, which is above what is measured at the Crib but in line with common shear factors to be expected for offshore or near shore sites.

Figure 4-12: Monthly average wind speeds for 50 m anemometer A5 and 50 m virtual met tower



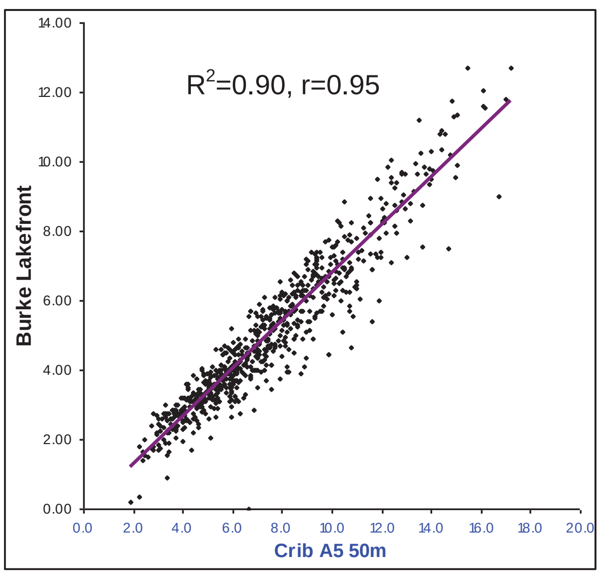
**Average Crib data for the two periods 2005-06 and 2006-07.*

4.2.4 Correlation

It is common practice to check the reliability of wind data by correlating the measured data with any nearby wind data sources. Gusts measured at the met tower should also be verified by data from weather stations nearby. For this analysis the ASOS (Automated Surface Observing Systems) weather station at Burke Lakefront Airport is used for a reliability check. The weather station is suitable for correlation as it is just 3.5 miles southeast of the Crib station. It should be noted that although the weather station is the best available source for long term data near the Crib its wind data will be highly affected by the Cleveland area. Therefore, as an additional source of long term data and for added reliability, we have performed a correlation with two NCEP/NCAR nodes.

The Burke weather station data from 10 meters height above ground show very high correlation with R^2=0.90, corresponding to a correlation r-value of 95% (Figure 4-13). This correlation value justifies using the weather station for long term adjustment of the data measured at the Crib site as further described in Section 4.2.5. This process removes short-term biases inherent in a data collection period of two years or less.

Figure 4-13: Correlation between Burke Lakefront Airport and Crib

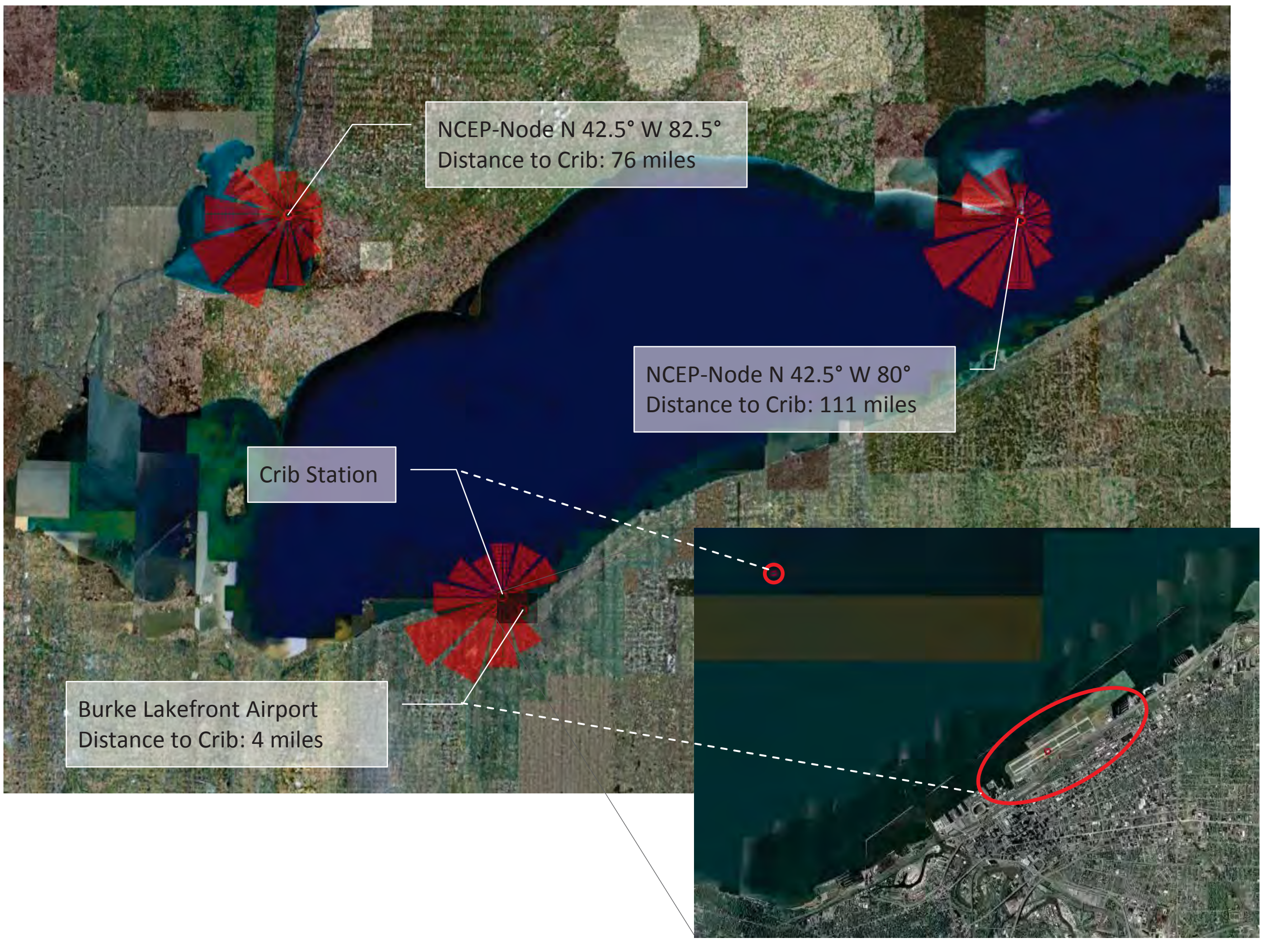


4.2.5 Long-term Correlation

Wind conditions and consequently the energy yield of any given wind turbine may vary considerably from one year to another. Therefore it is absolutely necessary to assess the long term wind conditions at any measurement site to get a reasonable basis for wind energy planning considerations. Since all project related wind measurement is usually time-limited an adjustment with respect to long term weather and wind patterns is required. Although the Crib analysis in this report covers twenty-four months, long term adjustment is necessary.

Figure 4-14 shows the wind rose of the Crib measurement, the wind rose from the ASOS weather station, and the wind roses of the two NCEP/NCAR reference points.

Figure 4-14: Long term references and met tower location



Due to the high correlation the first long term adjustment of wind speeds is performed with the Burke Lakefront Airport ASOS weather station. For the adjustment the years 1999 to 2007 are used. Using linear regression for analysis, wind speed averages during the two year measuring period seems to be slightly higher than the long term trend. The resulting long term adjusted wind speed is 7.22 m/s.

Table 4-6 shows the monthly means from the Burke station and the long term adjusted monthly means for the Crib station, including the resulting long term adjusted annual average wind speed. As it is plausible that wind flow at the Crib station is affected by the City of Cleveland's cityscape, it is also highly likely that the Burke weather station underestimates the real wind conditions, and hence the long term adjustment applied herein can be considered conservative.

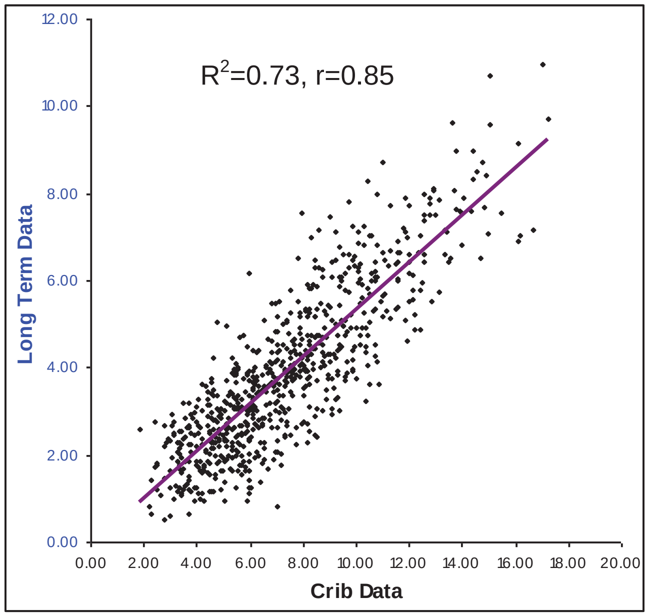
Table 4-6: Monthly average Burke weather station and long term means of Crib data

[m / s]	Burke Lakefront Airport 10 m AGL												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1998			6.3	4.74	3.71	4.07	3.89	3.49	4.29	4.87	6.08	5.95	
1999	6.21	5.72	5.5	5.05	4.52	4.02	4.07	4.07	4.29	5.36	6.17	5.68	5.1
2000	6.3	5.14	5.05	4.34	4.56	4.38	3.44	3.76	4.74	4.16	5.77	6.12	4.8
2001	5.3	5.9	5.5	4.9	4.0	3.4	3.7	3.7	4.6	6.0	5.1	5.7	4.8
2002	6.0	6.4	5.8	4.8	4.6	3.7	3.7	4.0	4.1	4.7	6.5	6.0	5.0
2003	6.3	5.6	4.6	5.4	4.6	3.0	3.8	3.5	4.6	5.0	5.8	6.4	4.9
2004	6.4	5.0	5.3	5.4	4.3	3.8	3.8	3.8	4.0	4.7	5.1	6.6	4.9
2005	5.3	4.3	4.7	5.3	3.7	3.5	3.2	3.8	3.7	4.6	6.8	5.9	4.6
2006	5.9	6.4	5.3	4.7	4.1	3.4	3.9	3.8	4.6	6.0	4.4	5.9	4.9
2007	6.4	6.4	5.7	5.6	3.9	3.6	4.1	3.6	4.1	4.9	5.8	5.5	5.0
Long Term Averages	6.01	5.64	5.27	5.06	4.26	3.65	3.74	3.78	4.29	5.04	5.72	5.97	4.87
Percentage relative to standard year	123.37%	115.88%	108.23%	103.85%	87.44%	75.07%	76.83%	77.58%	88.15%	103.44%	117.57%	122.59%	

Crip A5 50	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Long Term Mean by Linear Regression	8.91	8.37	7.82	7.50	6.32	5.42	5.55	5.60	6.37	7.47	8.49	8.86	7.22
NCEP-Node N42,5° W82.5° weighting factors	98.07%	102.25%	97.49%	98.82%	101.39%	97.04%	100.45%	101.30%	101.45%	100.48%	98.08%	100.21%	99.75%
weighted average windspeeds	9.09	8.19	8.02	7.59	6.23	5.59	5.52	5.53	6.28	7.44	8.66	8.84	7.24

Long term adjustment also includes correlation of Crib data with NCEP/NCAR data. Figure 4-15 shows a correlation of R^2=0.73 (corresponding to a correlation r-value of 0.85) which still can be viewed as high with respect to wind industry standards. As the Burke Lakefront weather station shows a higher correlation we choose Burke data as the bases for long term adjustment, but in order to minimize the negative effect that the station experiences due to its proximity to the City of Cleveland we have weighted the long term adjustment with Burke by including the NCEP/NCAR data as well.

Figure 4-15: Correlation between NCEP Node N 42.5° W 82.5° and Crib met tower data



While both NCEP/NCAR grid nodes show a good correlation with the Crib data we decided to use only grid node N 42.5° W 82.5° for the long term adjustment of wind speeds at the Crib site. A time period from 1977-2007 was chosen for the long term correction. Comparison between the 24 month measuring period with the NCEP data indicates the measuring period is slightly above the 30 year average (100.21%). This is consistent with the same comparison with Burke Lakefront Airport. To minimize the influence of Burke Lakefront data on the long term adjustment we weighted the Burke data with the long term trend from the 30 years of NCEP/NCAR data. Table 4-7 shows long term adjusted annually average of the Crib weighted with the NCEP/NCAR data.

Table 4-7: Long term adjusted wind speed

Met mast	Height	Measured mean wind speed	Long term corrected mean wind speed
Crib	50 m	7.35 m/s	7.24 m/s

According to the US Standard Wind Class Definitions (Table 4-8) the Crib location is a Class 4 site with 7.24 m/s at 50 m height.

Table 4-8: US standard wind class definitions (National Renewable Energy Laboratory)

Class	30 m height		50 m height	
	Wind speed m/s	Wind power W/m^2	Wind speed m/s	Wind power W/m^2
1	0-5.1	0-160	0-5.6	0-200
2	5.1-5.9	160-240	5.6-6.4	200-300
3	5.9-6.5	240-320	6.4-7.0	300-400
4	6.5-7.0	320-400	7.0-7.5	400-500
5	7.0-7.4	400-480	7.5-8.0	500-600
6	7.4-8.2	480-640	8.0-8.8	600-800
7	8.2-11.0	640-1600	8.8-11.9	800-2000

Table 4-9 compares the long term adjusted average wind speeds between AWS Truewind maps and Crib data at three different heights. Whereas the wind speed estimates match at the 50 m level, the difference between the numbers increases with height. The increasing difference with height is most likely explained by different shear factors used in the estimation of wind speeds. The shear factor AWS uses for their wind maps is 0.15, which is a standard assumption for flat, relatively open terrain.

Table 4-9: Wind speed comparison between AWS Truewind maps and Crib data

Height	Average wind speed AWS Truewind map	Average wind speed Crib measurements
50 m	7.2 – 7.4 m/s	7.24 m/s
70 m	7.6 – 7.8 m/s	7.34 – 7.41 m/s*
100 m	8.0 – 8.2 m/s	7.44 – 7.58 m/s*

**Range is due to varying calculated shear factors between 0.04 and 0.067*

4.3 Conclusion: Wind Resource for the Pilot Project

Crib data were provided to juwi by Cuyahoga County for analysis. Data collection at the Crib is ongoing, and a LiDAR unit was deployed in Winter 2009 to conduct further investigation of wind shear and wind speeds at higher heights above Lake Erie. Although equipment failure led to limited data retention, initial results indicate a high degree of correlation (agreement) with Crib anemometers. At the time of this report, plans exist to collect further data in the coming months. A more robust LiDAR data set will confirm shear and other estimates based on Crib anemometer measurements.

Compared to onshore sites in Ohio the measured wind speed at 50 m height from the Crib indicates an excellent resource. The annual long term corrected average wind speed at 50 m is 7.24 m/s, which is greater than at most onshore locations in Ohio at 80 m hub height. Nevertheless the wind measurement from the Crib resulted in a relatively low shear factor in the range of 0.04 – 0.067. While it is typical for offshore sites to have lower shear than comparably windy onshore sites, it is possible that measured values are distorted due to influence from the Crib structure and/or Cleveland cityscape. Using the measured shear factors, wind speeds are not projected to increase significantly at turbine hub heights; long term average wind speed estimates at 70 m and 80 m are 7.34 – 7.41 m/s and 7.37 – 7.47 m/s, respectively. This can be considered relatively low for an offshore site.

Generally offshore sites, due to their higher installation and maintenance costs, require a significantly better wind resource than onshore sites. Calculating the wind speed with the typical offshore shear value of 0.1 the average wind speed at 80m hub height is still at moderate 7.58 m/s.

There is a chance that not only the Crib structure influences the wind readings negatively with regard to the wind shear, there is also the theory that the Crib itself is still highly influenced by the skyline of the City of Cleveland. While the Crib is currently the only possible location for wind measurement, there is a possibility the wind readings do not reflect the real wind conditions on Lake Erie. This refers to the measured shear factor as well as to the measured average wind speed.

LiDAR can measure wind speeds up to 200 m which presents a significant advantage compared to the maximum measuring height of the met tower at 50 m. With wind data from hub height and even higher negative influence from the Crib structure will be reduced. The LiDAR should help minimize uncertainties with regard to the increase in wind speed with height. With a better understanding of the average wind speed at greater heights above the lake, calculations for offshore wind energy potential on Lake Erie will be refined.

5 Availability Assessment and Energy Production Estimates

5.1 Availability Assessment

(Unless otherwise indicated, information in this section taken from the GLWEC Availability Assessment, Germanischer Lloyd, March 2009).

5.1.1 Introduction

The aim of the Great Lakes Wind Energy Center – Availability Assessment is to analyze the theoretical availability of the offshore wind energy Pilot Project with regard to environmental restrictions during the winter and spring seasons in Lake Erie, with a particular focus on ice conditions. This assessment examines two turbine types with nameplate capacities of 2.5 MW and 5.0 MW. Furthermore, Germanischer Lloyd (GL) is identifying and assessing the corresponding down-time and production losses for these turbine types while assuming various ice coverage concentrations and two access strategies. To provide context for potential revenue losses context a preliminary revenue estimation is done based on typical offshore turbine data.

5.1.2 Definition of Availability

Availability describes the degree to which a technical system is operable with respect to a defined period. Mathematically, availability is simply defined in 1 minus unavailability. Another expression is given using the utilization ratio between the times in which the system is in operation to the whole period of time which is considered. The ratio shows how efficient the theoretical operation time is used and is therefore defined as effective availability:

$$A_e = \frac{uptime}{uptime + downtime}$$

Equation 1

With respect to wind turbines availability is only considered for the time in which the wind conditions are favorable for electricity generation. Hence, only the range between the cut-in and cut-out wind speeds is considered. There are in addition different means of expressing availability, for instance operational and technical availability.

5.1.2.1 Technical Availability

Technical availability is determined by the reliability of the system and the corresponding maintainability, namely the amount of time a maintenance activity requires. Both are strongly influenced by the manufacturer as the latter is responsible for the reliability and the repair work effort. Reliability can be expressed by the mean time between failures (MTBF) which indicates after how many hours of operation the next failure is to be expected:

$$MTBF = \frac{\sum uptime}{\sum failures}$$ **Equation 2**

A large MTBF value means high reliability, i.e. low failure rate, and is defined by the ratio of up-time sum to the failure sum.

Further, it is critical to know how long the mean time to repair (MTTR) is, which mainly depends on the system design. The MTTR is defined as the ratio between the amount of time spent on O&M activities to the amount of failures:

$$MTTR = \frac{\sum repair-time}{\sum failures}$$ **Equation 3**

Taking these two parameters into account, the technical availability can be determined by:

$$A_t = \frac{MTBF}{MTBF + MTTR}$$ **Equation 4**

5.1.2.2 Operational Availability

The operational availability represents the ratio of uptime hours to total hours including O&M activities as well as waiting hours. Waiting time is defined in this case as down-time caused by lead times for spares, personnel and equipment. Waiting time however carries a high improvement potential which may be achieved via remote monitoring, short reaction times in case of failures as well as reasonable strategies for spare part procurement and storage.

$$A_o = \frac{uptime}{uptime + waiting\_time + repair\_time}$$ **Equation 5**

5.1.3 Availability Assessment

The calculation of availability is based on the down-time arising from scheduled preventive maintenance and randomly necessary corrective maintenance. Preventive maintenance consists of a fixed set of maintenance operations which are required periodically for all components of the offshore wind farm. These maintenance operations can be planned and scheduled in advance and therefore lead and waiting times are not relevant. For corrective maintenance, random occurrence (i.e. time of year) of failures is assumed and failure frequencies for 42 relevant components of the wind turbine, the foundation and the interconnection are included in the calculation. The down-time resulting from component failure is a function of lead times for the equipment, waiting times caused by adverse weather conditions and operation times including travel and repair time. Failure frequencies are based on a database of the Institut für Solare Energieversorgungstechnik [Institute for Solar Energy Supply Technique] (ISET) and on research conducted by the Energy Research Centre of the Netherlands (ECN) on operational offshore wind turbines. The cumulated failure frequencies for all components translate into an overall rate of 4.46 failures per year and turbine. Additionally, the 42 components are divided into six different maintenance categories representing different levels of damage and the required equipment for their maintenance. The failure frequencies of the components are broken down to the maintenance category level. Due to the random occurrence of the failures, lead time for equipment and waiting time due to inclement weather must be taken into account in the calculation of down-time. For each component and the relevant maintenance categories, material, labour and equipment costs as well as the lead, waiting and maintenance times are calculated. Multiplying the costs and time for the various maintenance operations by the corresponding failure frequencies gives the annual O&M costs and time required to maintain the turbine.

The overall down-time for the availability assessment is obtained by adding the preventive maintenance down-time and the corrective maintenance down-time.

According to the above-defined definition the availability assessment deals with the analysis of the technical and operational availability. Technical availability expresses the theoretical turbine performance without external influences such as lead and waiting times. In a parallel calculation, the operational availability assessment puts the technical performance data into context by considering environmental conditions restricting access to turbines and lead times in the maintenance activities. In this report, the operational availability assessment is based on two different scenarios, the first assuming no icing during the winter period and the second taking into account icing conditions.

The underlying data for this assessment are wind measurements provided by juwi and wave data from a buoy (No. 45005) of the National Oceanic and Atmospheric Administration (NOAA). The period for the used data is from the 2006-01-01 to 2006-12-31 and given in hourly values. For the icing data long-term average values are used based on NOAA measurements.

5.1.3.1 Technical Availability

The technical availability describes the ratio between three values of turbine performance (see Equations 3, 4 and 5): (i) the uptime which represents the time of the turbine in operation (excluding unsuitable wind conditions and downtimes), (ii) the failure rates over the year based on a generic turbine type and (iii) the resulting repair time for the maintenance. This ratio is calculated for a single turbine. Equation 6 shows again the derivation of the technical availability and the relevant parameters:

$$A_t = \frac{\frac{\sum uptime}{\sum failure}}{\left(\frac{\sum uptime}{\sum failure}\right) + \left(\frac{\sum repair\_time}{\sum failure}\right)} = \frac{uptime}{uptime + repair\_time}$$

Equation 6

The uptime is obtained by taking the total number of hours in a year (8760) and subtracting the sum of (i) the number of hours of wind speeds outside the operating range of the turbine and (ii) the total down-time. Unsuitable wind conditions for production are defined as the hours with wind speeds below cut-in (including calms) and above cut-out. For both investigated turbine types generic cut-in and cut-out values were used (see Table 5-1). The down-time represents the hours required for lead time of the spare parts, waiting time for the equipment, travel and maintenance time for O&M activities. The failure types cover all relevant critical components of the rotor system, nacelle, tower, foundation and cables and are attributed a corresponding failure frequency. The failure frequencies are based on performance data from 2.5 MW turbines. GL assumed lower failure frequencies for the 5.0 MW turbine class than for the 2.5 MW class due to advanced turbine technology and the gain in operating experience implemented in the newest turbine types. In the current availability assessment, the same failure frequencies are used for the investigated turbines classes and considered to be conservative. The failure rate gives the cumulated probability of the failure types. Repair time is directly correlated with the failure frequencies and represents the sum of the required hours for maintenance excluding lead and waiting time for spare parts and equipment. Table 5-1 shows all relevant parameters for the assessment of technical availability.

Table 5-1: Results of Technical Availability Assessment

		2.5 MW Class	5.0 MW Class
Failures per year		4.46	4.46
Repair Time	[hrs]	31.85	31.85
Down-time (including lead, waiting, travel and repair time)	[hrs]	701.64	701.64
Unsuitable wind conditions	[hrs]	1026.00 cut-in wind speed: 4 m/s cut-out wind speed: 25 m/s	798.00 cut-in wind speed: 3.5 m/s cut-out wind speed: 30 m/s
Uptime	[hrs]	7032.36	7260.36
Mean Time Between Failure (MTBF)	[h]	1576.76	1627.88
Mean Time To Repair (MTTR)	[h]	7.14	7.14
Technical Availability (A_t)	**[%]**	**99.5**	**99.5**

The mean time between failures (MTBF) indicates an average period of 65.7 days between any failure types for the 2.5 MW turbine type and 67.82 days for the 5.0 MW turbine type. The difference in MTBF values between the two turbine classes can be explained by the different cut-in and cut-out wind speeds of the generic wind turbines. Table 5-2 provides a detailed break-down of the failure types under different maintenance categories. Maintenance categories 1, 2 and 3 cover mainly internal and external repair and inspection of the turbine including maintenance and replenishing of consumables, whereas maintenance categories 4, 5 and 6 correspond to the replacement of larger components. Moreover, analysis has shown that for the 2.5 MW turbine type a Category 1, 2 or 3 failure occurs an average of every 132.33 days and a Category 4, 5, or 6 failure every 130.47 days. A similar portrait can be drawn for the 5.0 MW turbine types where every 136.62 days a failure of categories 1-3 and every 134.70 days one of categories 4-6 occurs. The mean time to repair (MTTR) amounts to 7.14 hrs per failure for both turbine types. The MTBF and the MTTR result I n the technical availability of the turbine which has been calculated to be 99.5% for both MW classes.

Table 5-2: Maintenance Categories and associated parameters

No.	Category	Fault type	Crew size	Repair time [hrs]
1	Repair and inspection interior	1	2	4
2	Repair and inspection exterior	2	2	4
3	Maintenance and renew of consumables	3	2	4
4	Small part replacement (internal crane, weight <3 t)	4	2	4
		5	2	8
		6	2	8
		7	2	16
5	Large part replacement (internal + external crane, weight 1-50 t)	8	2	8
		9	2	16
		10	4	16
		11	4	16
		12	4	24
		13	4	24
6	Major part replacement (large external crane, weight 50-350 t)	14	4	24
		15	4	24
		16	4	40

This technical availability is largely in line with the availability data for commercially available turbine types. These values mostly correspond to the technical performance of the turbines provided that frequent preventive maintenance is performed; turbines are designed by the manufacturers to demonstrate such availability for the duration of their typical lifetime. In the case of insufficient preventive maintenance or unsuitable site conditions for the turbine type, the technical availability cannot be attained as designed.

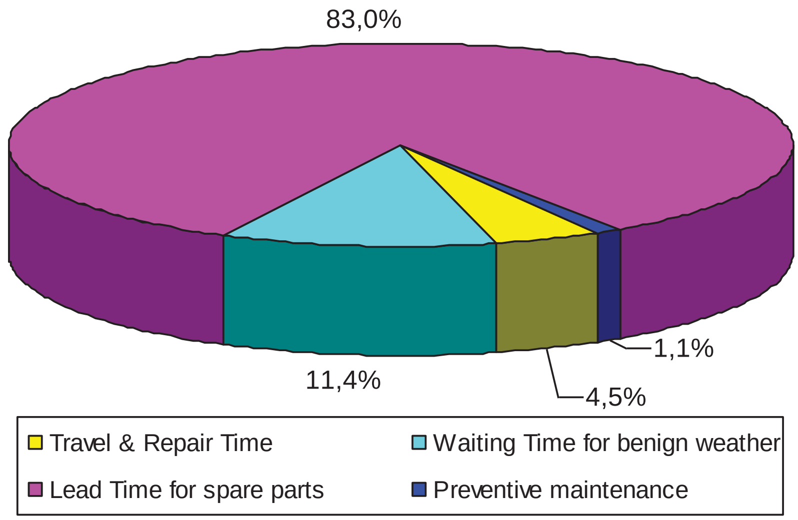
5.1.3.2 Operational Availability

Scenario 1: Availability Assessment without Ice Influence

As a baseline scenario the availability assessment was conducted without any consideration of ice influence. In this assessment it is assumed that the maintenance vessels can operate in Lake Erie during the entire year only restricted by wave and wind limitations of the operation vessels. As an example, due to these wave and wind limitations inter array cable installation activities are unfeasible with a wave height of 1.0m and the installation or repair of the nacelle with a jack-up barge can only be executed with wind and wave parameters under 1.5m wave height and 16 m/s wind speed. The combination of the wave and wind limitations of the different vessel types with the historical weather data at the site gives the possible weather windows for the maintenance operations and therefore waiting time for benign weather. Another assumption had to be made regarding wave conditions during the winter and spring season. Wave data recorded by the National Oceanic and Atmospheric Administration (NOAA) end prior to the ice season and resume thereafter. For the said period wave conditions were assumed to be nil and only the examination of wind conditions restricting the operation of vessels was performed.

Section 5.1.2.2 presents the equation for the calculation of the operational availability and defines the relevant parameters such as the turbine uptime and down-time including lead, waiting, travel and repair time. As discussed in Section 5.1.3.1, the uptime is obtained by taking the total number of hours in a year (8760) and subtracting the sum of (i) the number of hours of wind speeds outside the operating range of the turbine and (ii) the total down-time. The uptime for the generic 2.5 MW turbine type is 7032.36 hrs and for the 5.0 MW type, 7260.36 hrs.

Figure 5-1: Distribution of Down Time



The total down-time comprises travel and repair time, waiting time for equipment and lead time for spare parts. The total down-time is 701.64 hours for both turbine types due to the approach of assuming the same failure frequencies (see Section 5.1.3.1).

As shown in Figure 5-1, the overwhelming majority of down-time (83%) is due to lead times for spare parts, whereas waiting time for benign weather makes up 11.4 % and travel and repair time, 4.5%. Preventive maintenance, with just 1% of total down-time, requires the least effort in this context. The high share of lead time in the total down-time is a reflection of the tight market situation for wind turbines and their spare parts. Though it is expected that this situation will improve somewhat in the near- to mid-terms, it is assumed that small operators will still experience some difficulties in promptly acquiring spare parts. The time frames assumed for the acquisition of various spare parts take into consideration a moderate development of the tense market situation. In the case of larger wind farms or an association of wind farm operators, a spare parts inventory could be implemented to reduce lead times, but this would create additional costs for stocking. Depending on the strategy of the spare parts inventory and the wind farm size all major spare parts and lubricants with an appropriate sized ware house are necessary. Within the spare parts inventory additional work incurs by maintaining the spare parts, e.g. the gearboxes must run the whole storage time to avoid corrosion.

These data result in an operational availability of 90.9% for the 2.5 MW class and 91.2% for the 5.0 MW class.

Table 5-3: Results of the Operational Availability Assessment without Icing

		2.5 MW Class	**5.0 MW Class**
Down-time (including lead, waiting, travel and repair time)	[hrs]	701.64	701.64
Uptime	[hrs]	7032.36	7260.36
Operational Availability (A_o)	**[%]**	**90.9**	**91.2**
Loss of production	[kWh]	684,095.83	1,368,191.67
Revenue losses	[US$]	68,409.58	136,819.17
Energy production	[kWh]	7,718,868.84	14,545,347.17
Total maintenance cost	[US$/kWh]	0.0784	0.0629
Revenues	**[US$]**	**166,970.44**	**540,276.03**

All results for a single turbine over a one-year period.

Considering a value of 0.10 US$/kWh , this operational availability would lead to annual revenue losses of US$ 68,409.58 for the 2.5 MW class and US$ 136,819.17 for the 5.0 MW class. With annual energy yields of 7.71 MWh for the 2.5 MW class and 14.54 MWh for the 5.0 MW class, specific O&M costs amount to 0.0784 US$/kWh and 0.0629 US$/kWh, respectively.

Accordingly, total annual revenue would be US$ 166,970.44 for one 2.5 MW turbine and US$ 540,276.03 for one 5.0 MW turbine.

Scenario 2: Availability Assessment Including Ice Influence

Scenario 2 of this availability assessment investigates the influence of ice on Lake Erie during the winter and spring season on the operational availability of both turbine types. Ice conditions on Lake Erie fluctuate yearly depending on water depth, position within the lake and seasonal weather variations. According to measurements taken by the National Oceanic and Atmospheric Administration (NOAA) over the past 30 years the ice season – defined as an ice cover concentration ≥10% – can begin as early as mid-December and last until mid-April. The average duration of the ice season over the past 30 years is 60.5 days, i.e. from 10th January to 10th March (ice cover concentration ≥ 10% for a water depth range of 0-20 m). Shipping activities are possible for this degree of ice cover. Higher degrees of ice cover

(≥90%) are observed on average for a duration of 48.2 days, corresponding to the period from 16th January to 04th March.

In terms of accessibility of offshore wind turbines by service vessels, restrictions must be expected within this period due to the fact that the ice formation will start in shallow waters and around static constructions. Even minimal ice coverage around the foundation and access system can restrict the efficient access by service vessels. Therefore within an average period of 60.5 days during the winter boat access to the wind turbine cannot be guaranteed. Figure 5-2 shows a typical boat access system for an offshore wind turbine foundation.

Generally, in the early and late parts of the icing season, ice-breakers keep the main shipping lanes ice-free up to a certain ice thickness and coverage. Beyond a certain thickness and extent of ice coverage, shipping routes in Lake Erie are closed. Special ice-breaking vessels would be required to access offshore turbines by water; however, due to lacking equipment, economic reasons and the damage risk to the turbine, ice breaking in close proximity to turbines is not advisable. Therefore it is assumed ice cover concentration ≥10% prevents boat access to the turbines. This includes personnel transport boats as well as jack-up barges and crane-vessels for replacement of larger components.

In general crane access to turbines during the ice season is not possible by water or by transport over the ice crust due to the weight of the crane. Personnel transport by car or sled over the ice crust is theoretically possible but limited due to ice floes and cracks. Assuming 100% ice coverage, a flat surface area would ensure fast and easy access to turbines. However, an aggravating factor is the surface area relief of the ice: the ice surface of Lake Erie is assumed to be rather rough as a result of the slow freeze-up process which allows ice floes to build up. However, the possibility of building ice roads might warrant further investigation. At this stage of the project the best solution for an access system for personnel transfer during the ice season seems to be by helicopter. This access strategy would ensure a high accessibility for nearly 50% of failure types.

Figure 5-2: Offshore Wind Access Boat for Personnel Transport

For the Scenario 2 availability assessment (including ice conditions), two O&M strategies for failure categories 1, 2 and 3, which do not require a jack-up barge or crane vessel, are chosen. The first one uses the boat access strategy as a standard solution and the helicopter access strategy during the ice season. The boat access strategy is commonly used for offshore wind farms but due to limited access during the icing season this strategy has to be combined with the helicopter access strategy. The advantage of the boat access strategy is the generally lower costs of hiring boats compared to helicopters, but considering waiting time due to inclement weather and corresponding revenue losses, the helicopter strategy might be in a similar cost range. Therefore the second access strategy adopts the helicopter strategy as a standard solution for the entire year. Given the small number of turbines in the demonstration project, under both access strategies the service boat and the helicopter are mobilised on an as-needed basis. The repair of main components falling into failure categories 4, 5 and 6 is not possible during the ice season. Should such a failure occur, the turbine would need to be shut down and repaired at the next possible operation time window for a jack-up barge or crane vessel.

Table 5-4 presents the results for the 2.5 MW class as a function of ice coverage concentration and access strategy.

Table 5-4: Results of Operational Availability Assessment with Lake Ice Coverage ≥ 10%

		2.5 MW Class	2.5 MW Class
O&M Strategy Failure Category 1-3		Boat & Helicopter	Helicopter only
Down-time (including lead, waiting, travel and repair time)	[hrs]	999.90	983.48
Uptime	[hrs]	6,734.10	6,750.52
Operational Availability (A_o)	**[%]**	**87.1**	**87.3**
Loss of production	[kWh]	974,904.90	958,896.43
Revenue losses	[US$]	97,490.49	95,889.64
Energy production	[kWh]	7,391,486.16	7,409,507.94
Total maintenance cost	[US$/kWh]	0,0818	0,0816
Revenues	**[US$]**	**134,492.95**	**136,247.23**

All results refer to a single turbine over a one-year period.

During ice coverage concentration of ≥10%, operational availability drops from 90.9% to 87.1% or 87.3%, depending on the access strategy. This is mainly a result of longer turbine down-times caused by the probability of turbine shut down due to restricted access during the winter and spring. Corresponding revenue losses are more than doubled: US$ 130,002.87 to 132,577.88 vs. US$ 68,409.58 in the baseline scenario. Total O&M costs remain unchanged but given the lower energy yields, slightly higher specific maintenance costs of US$ 7.99 / kWh are foreseen. Due to lower energy production the calculated revenues drop significantly from US$ 166,970.44 without icing to US$ 134,492.95 to 136,247.23 with ice coverage concentration ≥ 10%.

The influence of icing on Lake Erie on the operational availability of the 5.0 MW class is similar to the 2.5 MW class. Due to the higher uptime, the decline in the operational availability is marginally smaller for the 5.0 MW turbine type. With an ice coverage concentration of ≥ 10%, the difference from the baseline scenario is 3.5-3.7%, i.e. an operational availability of 87.4 to 87.6%. The higher down-time leads to higher revenue losses of US$ 191,779.29 to 194,980.98 which reduce the theoretical annual revenues by approximately 11%.

Table 5-5: Results of Operational Availability Assessment with Lake Ice Coverage ≥10%

		5.0 MW Class	**5.0 MW Class**
O&M Strategy Failure Category 1-3		Boat & Helicopter	Helicopter only
Down-time (including lead, waiting, travel and repair time)	[hrs]	999.90	983.48
Uptime	[hrs]	6962.10	6978.52
Operational Availability (A_o)	**[%]**	**87.4**	**87.6**
Loss of production	[kWh]	1,949,809.81	1,917,792.86
Revenue losses	[US$]	194,980.98	191,779.29
Energy production	[kWh]	13,947,804.29	13,980,697.87
Total maintenance cost	[US$/kWh]	0.0655	0.0654
Revenues	**[US$]**	**480,782.52**	**480,023.97**

All results refer to a single turbine over a one-year period.

Of course, assuming accessibility of the turbines to a higher degree of ice cover the restricted access period becomes shorter. For example, if turbines were accessible up to 90% ice cover, the restricted period is reduced to an average of 48.2 days. With a shorter restricted period, the influence on operational availability is less, resulting in greater operational availability. The results show a decrease in the operational availability by 2.1-2.4% for the 2.5 MW turbine and 2.1-2.3% for the 5.0 MW turbine compared to the baseline scenario (i.e. an increase in operational availability of approximately 1.5 % compared to the results in Table 5-4 and Table 5-5). To ensure accessibility for this shorter period of 48.2 days new access systems are necessary. The standard access systems available at today's market do not take high degrees of ice cover into account.

For both turbine types the influence of the "helicopter only" access strategy for failure types of categories 1-3 on annual revenues is marginal. The cost break-down of the service boat vs. helicopter gives a significantly higher hourly rate for the helicopter (US$2,000 to US$3,500 depending on the size of the helicopter). Due to longer lead times of 12 hrs for the service boat for each operation, longer travel time caused by a slower speed (18 knots for a personnel transfer boat) and plus additional waiting time due to the service boat's higher sensibility to bad weather, the service boat leads to a lower operational availability creating higher revenue losses. In the sum the service boat strategy actually proves to be more costly. Overall, the difference between these two strategies is less than US$ 2000 for the 2.5 MW turbine type and around US$ 3000 for the 5.0 MW turbine type. But considering financial investment issues for the maintenance equipment it may be advantageous to use a single access system rather than two.

5.1.4 Availability Reduction through Blade Icing

In addition to the availability reduction due to ice coverage on Lake Erie, further production losses due to blade icing must be taken into consideration in cold climate regions. The reason for icing of rotor blades is the combination of a certain degree of humidity and cold temperatures. The source of this icing is referred to as atmospheric icing and is caused by the humidity in the atmosphere. Atmospheric icing can stem from in-cloud-icing or precipitation icing. In-cloud-icing means that water droplets within the clouds which are too small for condensation come into contact with the freezing surface of the wind turbine and generate ice. Precipitation icing refers to freezing rainfall and wet snowfall. In general icing at wind turbines occurs at temperatures in the range of -20°C to 0°C combined with a relative humidity greater than 95%. Icing due to wet snowfall can even occur at temperatures of up to 3°C.

Though the icing of turbine surfaces has a major influence on the loads, the turbine can continue to operate safely, though with reduced energy production. When excessive levels of icing are measured by the turbine's detection device, the turbine will automatically be shut down.

Table 5-6: Major Impacts of Icing at Wind Turbines

Impact	**Consequence**
Additional mass	Higher static load at the turbine
Unbalance	Asymmetric ice formation causes mass and aerodynamic unbalances which can damage the drive train, pitch control system and tower structure.
Oscillatory pulse	Additional ice formation on main wind turbine components can modify the vibration behaviour through eigenfrequencies. This could result in resonance vibration at the rotor blades and additional vibrations at the tower.
Aerodynamic influences	Ice formation modifies the geometry of the rotor blades and therefore their aerodynamics. Even minimal ice formation increases the surface area of the blades. Through the ice-foundation the lifting forces at the blades can be reduced by up to 35%. Simultaneously, drag increases, which reduce rotation speed and thus energy production.
Noise emissions	Ice formation at the rotor blade creates turbulent airflow resulting in higher noise emissions.
Freezing of measuring instruments	The freezing of measuring instruments can lead to erroneous data and affect the save operation management. Frozen anemometers can cause failures for the pitch control which lead to overspeeding, output loss, vibrations etc. A frozen wind vane influences the yaw control, resulting in a tilted inflow at the blades and higher loads at the turbine.
Repairing & maintenance	Higher loads cause higher material fatigue.

In this study, the examination of theoretical blade icing only covers in-cloud-icing. Analysis of precipitation icing would require additional on-site measurements to quantify rainfall / snowfall. For the in-cloud-icing analysis, humidity, temperature, air pressure and wind speed data for the site are required. The calculation was performed with wind speed and temperature data from the Crib station at Lake Erie, with a calculated mean annual value for air density from the Crib station (using Windpro®) and with relative humidity data from the Burke Lakefront Airport. Given the offshore character of the proposed demonstration project, the calculation of blade icing using relative humidity data from an onshore site can be only considered to be preliminary and should be verified at a later stage with humidity data recorded at the proposed site or at the Crib station.

The data basis used for this report covers 10-minute intervals of 2006.

The analysis of the blade icing stemming from in-cloud-icing detected two ice-formations within the investigated period with a cumulated duration of 55.67 hrs. The main driving factors in the blade icing assessment are humidity and temperature. For the period December through March, the average probability of temperatures below 0°C is 39.5%, with extreme values in February (65.6%) and March (45.5%). The limiting factor for the blade icing is relative humidity, which exceeds the 95% criterion only 1.5% of the days in the period from December to March (2.4% in February). Due to this low probability of sufficiently high relative humidity, the risk of blade icing resulting from in-cloud-icing is considered to be very limited. Other regions in North America demonstrate similar experiences with low icing issues at wind turbines due to low humidity, though it should be noted that these experiences are based on onshore wind farms in Minnesota. Therefore it is recommended to verify the relative humidity data from the Burke Lakefront Airport with appropriate data gathered offshore. Given the high frequency of temperatures under 0°C, a change in relative humidity to above 95% would lead to higher blade icing occurrences and durations. Additionally, it is recommended to measure rainfall and snowfall amounts at the Crib station to investigate the risk of precipitation icing. Any occurrence of rain or wet snow can lead to ice formation at the turbines at temperatures below 0°C.

The influence of the calculated down-times due to blade icing on overall turbine availability and corresponding revenue losses, etc. can be seen in Table 5-7 for the 2.5 MW turbine type and in Table 5-8 for the 5.0 MW turbine type. Availability figures are reduced by 0.7 to 0.8 percentage points while revenues drop by 4.6 to 4.7% for the 2.5 MW turbine type and 1.5 to 2.4% for the 5.0 MW turbine type.

Table 5-7: Results of Operational Availability Assessment – 2.5 MW Turbine including Blade Icing

		2.5 MW Class	Ice coverage conc. ≥10% - Boat & Heli Strategy	Ice coverage conc. ≥10% - Helicopter Strategy
Down-time (including lead, waiting, travel and repair time)	[hrs]	759.30	1,057.57	1,041.15
Uptime	[hrs]	6,974.7	6,676.43	6,692.85
Operational Availability (A_o)	**[%]**	**90.2**	**86.3**	**86.5**
Revenue losses	[US$]	74,032.08	103,112.99	101.512,14
Total maintenance cost	[US$/kWh]	0.0790	0.0825	0.0823
Revenues	**[US$]**	**160,640.83**	**128,163.34**	**129,917.61**

All results refer to a single turbine over a one-year period.

Table 5-8: Results of Operational Availability Assessment – 5.0 MW Turbine including Blade Icing

		5.0 MW Class	Ice coverage conc. ≥10% - Boat & Heli Strategy	Ice coverage conc. ≥10% - Helicopter Strategy
Down-time (including lead, waiting, travel and repair time)	[hrs]	759.30	1,057.57	1,041.15
Uptime	[hrs]	7,202.36	6,904.43	6,920.85
Operational Availability (A_o)	**[%]**	**90.5**	**86.7**	**86.9**
Revenue losses	[US$]	148,064.17	206,225.98	203,024.29
Total maintenance cost	[US$/kWh]	0,0634	0,0661	0,0659
Revenues	**[US$]**	**528,723.14**	**469,229.63**	**472,471.09**

All results refer to a single turbine over a one-year period.

5.1.5 Conclusion of the Availability Assessment

This report provides an assessment of the technical and operational availability of a 2.5 MW and a 5.0 MW turbine type for the Pilot offshore wind Project in Lake Erie. The Pilot Project will be located in waters approximately 15 m deep and roughly 5 km off the shores of Cleveland, Ohio.

Both turbine types show technical availabilities of 99.5% with uptime of 7032.36 hrs for the 2.5 MW turbine type and 7260.36 hrs for the 5.0 MW type. These figures are representative of commercially available turbine types and can be attained by choosing suitable site conditions and ensuring appropriate preventive maintenance.

Not considering ice influence, the site conditions at Lake Erie reduce the value of the technical availability to 90.9% for the 2.5 MW and 91.2% for the 5.0 MW turbine class and represent the operational availability. Availability values are mainly influenced by the lead times for spare parts (83% of total down-time for the no-icing case) whereas the actual travel and repair time contributes only about 5% and waiting time due to inclement weather 11% to the total down-time.

Ice conditions prevalent during the winter and spring seasons at Lake Erie reduce these operational availability values further. Depending on possible access under different ice coverage concentrations, operational availability is reduced to 87.1% as a minimum and to 88.8% as a maximum. The resulting revenue losses are 40-43% higher than in the ice-free baseline scenario when assuming 100% access restriction for ice coverage concentration of ≥10%. This ice coverage concentration prevents the access of lifting vessels to the offshore wind turbine for a period of 60.5 days per year.

The 5.0 MW class shows a similar picture to the 2.5 MW turbine class. Due to the ice influence the operational availability decreases by 2.1-3.7%, resulting in 87.4 to 87.6% for ice coverage concentration of ≥10%.

These operational availability values could be improved by 1-2% if accessibility to the turbines is ensured by a higher degree of ice cover (up to 90%). The state-of-the-art access technology for wind turbines does not provide offshore wind turbine access systems for extreme ice conditions.

Further reduction of the availability values must be taken into consideration in colder climate regions due to icing, mainly of the rotor blades. The analysis of in-cloud-icing for the demonstration project estimated an additional 55.67 days of down-time. Due to the low probability at the site for relative humidity above 95%, in-cloud-icing cannot form even if the probability of temperatures under 0°C is relatively high (39.5%). The source of the humidity data is the Burke Lakefront Airport and therefore it is recommended to validate these data with measured data from the Crib station to avoid erroneous results.

Additionally, further analysis of precipitation icing is recommended to quantify the amount of rainfall and snowfall at the Crib station. With the mentioned high probability of temperatures below 0°C in the winter season, additional icing of blades could be possible due to freezing rain and snow on site.

Table 5-9 shows the final results of the availability values with the corresponding revenues losses and specific maintenance costs. The availability figures are reduced by 0.7 to 0.8 percentage points; consequently, a reduction in revenues by 4.64 to 4.7% for the 2.5 MW turbine type and 1.58 to 2.4% for the 5.0 MW turbine type is observed.

Table 5-9: Results of Operational Availability Assessment including Blade Icing

		Scenario 1	Scenario 2	
		No ice coverage	Lake Ice coverage ≥10% - Boat & Heli Strategy	Lake Ice coverage ≥10% -Helicopter Strategy
Down-time (including lead, waiting, travel and repair time)	[hrs]	759.30	1057.57	1041.15
Turbine Class		2.5 MW	2.5 MW	2.5 MW
Uptime	[hrs]	6974.7	6676.43	6692.85
Operational Availability (A_o)	**[%]**	**90.2**	**86.3**	**86.5**
Revenue losses	[US$]	74,032.08	103,112.99	101.512,14
Total maintenance cost	[US$/kWh]	0.0790	0.0825	0.0823
Revenues	**[US$]**	**160,640.83**	**128,163.34**	**129,917.61**
Turbine Class		5.0 MW	5.0 MW	5.0 MW
Uptime	[hrs]	7202.36	6904.43	6920.85
Operational Availability (A_o)	**[%]**	**90.5**	**86.7**	**86.9**
Revenue losses	[US$]	148,064.17	206,225.98	203,024.29
Total maintenance cost	[US$/kWh]	0.0634	0.0661	0.0659
Revenues	**[US$]**	**528,723.14**	**469,229.63**	**472,471.09**

All results refer to a single turbine over a one-year period.

In general the ice coverage of Lake Erie has a significant influence on the availability of the turbines designed for the pilot offshore wind energy project. Even with a high technical availability of today's commercially available turbine types, the remaining failure occurrences lead to high average losses over the lifetime of the project. Frequent and accurate preventive maintenance could reduce the risk of failure occurrence during the ice season.

5.2 Energy Production Estimates

(Unless otherwise indicated, information in this section from GLWEC Final Wind Report, December 2008).

Long term adjustment of Crib data (see Section 4.2.5) allows for an accurate forecast of electricity production based on historically average wind conditions. WindPro®, an industry standard software package, incorporates site-specific wind data to calculate energy production for commercially-available turbines. Turbine specifications including generator size, rotor diameter, and power curve are built into the software.

As final turbine type has not been selected for the GLWEC Pilot Project, energy production estimates are provided for a range of commercially-available turbines that are generally suitable for offshore installations. At this stage of feasibility analysis, we consider machines that are designed solely for offshore use, such as REpower 5M and Multibrid M5000. We also consider turbines that are primarily used for onshore installations, but are suitable for offshore deployment in freshwater, such as Siemens SWT 93/2.3 and Vestas V90 3.0 MW.

Table 5-10 lists key assumptions, turbine specifications, and gross and net production estimates for seven turbine types. The Crib location and a constant 80 m hub height are assumed for all turbines to illustrate relative performance. Production losses that explain the difference between gross and net figures are due to availability (turbine down-time, time required / ability to service, etc.) and electrical losses. Availability accounts for a significant reduction in turbine production. Availability of 86.6% is assumed for all estimates, representing an average of figures provided by Germanischer Lloyd in their Availability Assessment (Section 5.1). This number assumes that vessels capable of transporting service personnel and equipment will not be able to access the offshore turbines with lake ice coverage ≥10%, leaving helicopters as the only option during this time. Typically, turbine availability for onshore projects in the US is ~95%. The relatively low number estimated for the GLWEC Pilot Project reflects the greater difficulty of servicing and maintaining offshore wind turbines, especially in icing environments. Average ice coverage ≥10% over the past 30 years lasts 60.5 days from about January 10th to March 10th. As even small ice coverage around the turbine foundation and platform can restrict access by a service vessel, maintenance requiring vessel transport (i.e. for large components) cannot be guaranteed during the icing period. While in some years turbines may experience high availability, energy production estimates must account for an average availability over total turbine lifetime. For further explanation of availability assumptions, please refer to the GLWEC Availability Assessment report. Because Table 5-10 provides single-turbine values only, wake effect losses (park efficiency) are not included.

Table 5-10: Single-Turbine Production Estimates at Crib Location

	Siemens SWT-2.3	Clipper Liberty	Vestas V90	GE 3.6s	Siemens SWT-3.6	Multibrid M5000	REpower 5M
Nominal Capacity [**MW**]	2.3	2.5	3.0	3.6	3.6	5.0	5.0
Rotor Diameter [**m**]	93	96	90	104	107	116	126
Hub height [**m**]	80	80	80	80	80	80	80
Average wind speed at hub height* [**m/s**]	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Gross production [**MWh**]	7,905	8,456	8,632	11,124	11,338	15,165	15,905
Gross capacity factor [**%**]	38.2	37.5	31.8	36.6	35.8	33.4	35.1
Availability** [**%**]	86.6	86.6	86.6	86.6	86.6	86.6	86.6
Electrical losses*** [**%**]	2	2	2	2	2	2	2
Net production [**MWh**]	6,709	7,176	7,326	9,441	9,622	12,870	13,498
Net capacity factor [**%**]	33.30	32.77	27.88	29.94	30.51	29.38	30.82

*Calculated by WindPro® using long term adjusted Crib wind data
**Availability losses reflect an average of estimates provided by Germanischer Lloyd in the GLWEC Availability Assessment of December 2008
***Reflects an industry standard assumption for electrical losses

Table 5-10 illustrates that turbines with a larger rotor diameter relative to generator size (i.e. Siemens 2.3 MW) yield higher capacity factors. These turbines typically perform well in moderate wind sites (such as the Crib), as the larger rotor captures more kinetic energy from the wind to turn the relatively smaller generator. Of course, the disadvantage of a smaller generator is that more turbines are required to reach a desired project size, or if fewer turbines are used total production may be reduced. This is illustrated by comparing the Clipper and Vestas machines in Table 5-10. Although performance is less with respect to capacity factor for the Vestas vs. Clipper turbine, total production per turbine is greater for Vestas due to its larger generator. Therefore, a balance between turbine performance and construction / turbine / maintenance costs should be considered for final turbine selection. At this stage, all turbines included herein are deemed suitable with respect to predicted performance.

The GLWEC Pilot Project will likely consist of more than a single turbine, and therefore production estimates must account for turbine layout. With multiple turbines, added losses due to wake effect between turbines are introduced. Experience from European offshore wind energy projects—and primarily research on the Horns Rev and Nysted projects in Denmark (see Figure 5-3), where wake effects are greater than predicted—underscores the importance of wind park design to minimize wake effect. With only 2-10 turbines in the Pilot Project, turbines should be oriented in a single row to minimize wake effect.

Figure 5-3: Example of Wake Effect Between Offshore Wind Turbines

Preliminary turbine configurations are shown in Figure 3-14 and Figure 3-15. Four eight-turbine configurations with 2.5 MW units and five three-turbine configurations with 5.0 MW units are presented. Of the nine total configurations, four are chosen for energy production estimates: configurations 7, 5, 6A, and 1. These four configurations are chosen as representative of the other five. Specifically, Config 1 is representative of 2-4, Config 7 is representative of 8, and Config 5 is representative of 6. Config 6A is closest to shore, and is included to demonstrate the effect of less wind resource. Production estimates for the turbine configurations are provided in Table 5-11.

Table 5-11: Energy Production Estimates for Different Pilot Project Configurations

	Turbine Configuration			
	Config 7	Config 5	Config 6A	Config 1
Project size	15 MW	15 MW	15 MW	20 MW
Turbines	3 x 5.0 MW (REpower)	3 x 5.0 MW (REpower)	3 x 5 MW (REpower)	8 x 2.5 MW (Clipper)
Turbine orientation	250° to 70°	280° to 100°	280° to 100°	330° to 150°
Distance between turbines	960 m (3,149 ft)	480 m (1,575 ft)	480 m (1,575 ft)	384 m (1,260 ft)
Hub height	80 m	80 m	80 m	80 m
Availability	86.6%	86.6%	86.6%	86.6%
Electrical losses	2%	2%	2%	2%
Park efficiency	98.4%	97.8%	97.7%	96.5%
Net production	39,595 MWh	38,907 MWh	37,560 MWh	55,254 MWh
Net capacity factor	30.13%	29.60%	28.60%	31.53%

At 20 MW, Config 1 yields the highest production of all configurations. Because of the Clipper Liberty's relatively large rotor diameter / generator ratio the capacity factor is also highest (31.53%). Despite optimal orientation with respect to wind direction, park efficiency is least for Config 1 (96.5%) due to the higher number of turbines and closer spacing (made possible by orientation). Of the three-turbine configurations, park efficiency and capacity factor are greatest for Config 7 (98.4%, 30.13%, respectively), primarily because of the large spacing between turbines (960 m, or 7.6 x rotor diameter). Being closest to shore, Config 6A has the least wind resource of the four configurations and a net capacity factor of 1% less than Config 5, which has the same turbines and turbine orientation. For all configurations, park efficiency can be improved either by changing turbine orientation or increasing turbine spacing. The primary tradeoff for improving park efficiency with these methods is increased cabling.

6 Environmental Conditions

6.1 Avian Risk Assessment

(Unless otherwise indicated, all information in this section from GLWEC Avian Risk Assessment, Curry & Kerlinger, November 2008).

The study on avian risk assessment is based on published literature, local/regional data sources on avian use, and internet-accessible databases. The report describes the Project site and avian habitats, profiling the birdlife expected to occur at the Project site during the breeding, spring and fall migration, and wintering seasons.

Nocturnal migration is given special attention through a separate study (Appendix A to ARA 2008) commissioned for the report by Curry & Kerlinger. This study examined the most recent five years of archived data from the nearby KCLE weather surveillance radar (WSR-88D, also known as “NEXRAD” [Next Generation Radar]). The NEXRAD study demonstrated that night migration over the Project site is broad-front and without major concentrations or migration pathways. Density patterns of birds flying over this portion of Lake Erie were similar to those found in other locations in the Midwestern and northeastern states.

The avian risk assessment summarizes European literature on avian interactions with offshore wind-energy development, adding appropriate research findings from onshore projects. By relating the avian profile at the Project site with the literature findings on avian effects, Curry and Kerlinger establish an avian risk assessment for the Project and make recommendations for minimizing avian impacts.

6.1.1 Avian Profile at Project Site

Table 6-1: Avian Groups Likely to Use Airspace at Project Site

Avian Group	Likely Occurrence at Project Site
Songbird migrants (nocturnal)	Large to very large numbers over Lake Erie
Waterbird migrants (mainly nocturnal)	Large numbers over Lake Erie
Raptor migrants (diurnal)	Very small numbers over Lake Erie

Table 6-2: Species Likely to Use Waters at Project Site[1]

Species	Likely Occurrence at Project Site
Common Merganser	Small to moderate numbers in migration
Red-breasted Merganser	Potentially large numbers, particularly in fall migration
Common Loon	Small numbers in migration
Horned Grebe	Small numbers in migration
Double-crested Cormorant	Small numbers in summer, larger numbers in migration
Bonaparte's Gull	Potentially large numbers, particularly in fall migration
Ring-billed Gull	Small to moderate numbers, except in winter
Herring Gull	Small to moderate numbers, except in winter
Great Black-backed Gull	Small numbers, except in winter
Caspian Tern	Small numbers in migration
Common Tern (OH-E)	**Small numbers mainly in fall migration**

[1] Ohio-listed species indicated in boldface. E = Endangered.

Except in winter, when waterbirds concentrate at warm-water outlets that remain ice-free, and in fall migration, when large numbers of Red-breasted Mergansers and Bonaparte’s Gulls stage on Lake Erie, waterbird diversity and abundance along the highly developed Cleveland lakefront is dominated by a few common species. Studies indicate that this diversity and abundance decreases with distance from the lakefront as water becomes deeper offshore. Few waterbirds (limited to fish-eaters, surface-scavengers, and surface-gleaners) are able to forage farther from the lakeshore.

At two to five miles (3.2 to 8.0 km) offshore, and with water depths exceeding 33 feet (10 m), very few birds are expected to use the waters within the Project area during most of the year. In summer, the most frequently occurring species will be Ring-billed Gull, Herring Gull, and Double-crested Cormorant, but their numbers will be much less than closer to shore. Red-breasted Merganser and Bonaparte’s Gull will be two of the most common migrants using Lake Erie waters, particularly in fall migration, with occasionally large numbers offshore. Common Loon appears to occur more often in migration offshore than inshore, but its abundance on Lake Erie is relatively low. When icebound in winter, the Project site will lack waterbirds, but when ice-free, some species, mainly gulls, may forage at the Project site on occasion. Some may attempt to perch on the docking portions of the turbines.

In migration, many birds use the airspace over Lake Erie, with most songbirds, waterfowl, and shorebirds migrating at night. Radar and other studies in the U.S. indicate that nocturnal migration occurs mostly at altitudes above the height of wind turbines, but a small percentage of birds migrate at lower altitudes. The density of nocturnal migration at

Cleveland will be similar to other sites studied at similar latitudes. An analysis of archived NEXRAD radar data from the Project site has confirmed this.

Those concentrations of migrating hawks that occur around Lake Erie are generally close to the shoreline. However, a few hawk species are adapted to crossing large water bodies during migration. The likeliest species to cross the lake include Peregrine Falcon (Ohio threatened), Osprey (Ohio endangered), and Northern Harrier (Ohio endangered), none of which come from Ohio nesting populations. The incidence of migrating hawks at the Project site is expected to be nil.

Among Ohio-listed and other special-status species, Common Tern (Ohio endangered) may occur infrequently at the Project site during fall migration. There is no reason to believe that it would be attracted to the waters of the Project site. As noted above, it is unlikely that Osprey (Ohio endangered), Northern Harrier (Ohio endangered), and Peregrine Falcon (Ohio threatened) that nest in Ohio would migrate over or through the Project site. Most of the common Ohio-listed species that migrate nocturnally over Lake Erie are from northern populations that are reasonably secure. Most of the common migrants among *WatchList* species are near the northern limits of their ranges in Ohio; therefore, the numbers of those species crossing Lake Erie will be minimal. The federally listed Piping Plover and Kirtland's Warbler are accidental in the Cleveland region, implying that they are rare in migration across this portion of Lake Erie.

6.1.2 Important Bird Areas and Sensitive Habitats in Project Vicinity

It is important to note that Audubon Ohio has designated the Cleveland lakefront as an Important Bird Area (IBA) for its gull congregations in winter (in the 1990's, daily averages of 15,000 Bonaparte's Gulls, 50,000 Ring-billed Gulls, and 15,000 Herring Gulls, mainly at warm-water outflows), waterfowl congregations in spring (in the 1990s, maximum daily counts of 7,000 scaup and 1,500 Canvasback), and Red-breasted Merganser congregations in fall migration (daily maximum of 250,000 birds in the 1990s). As defined by Audubon Ohio, this IBA extends about one mile (1.6 km) into the lake (although distances vary with respect to the shoreline) and does not include areas where turbines would be located.

6.1.3 NEXRAD Study

In the NEXRAD study, levels of reflectivity in radar pulse volumes (pixels) were collected at an area between 11 and 31 km (6.9 and 19.4 miles) from the KCLE radar between the azimuths of 0° and 50°.

Data for spring migration were analyzed for the period April 1 to May 31, 2004-2008, while fall migration data were analyzed for August 15 to November 15, 2003-2007. On each night, data were analyzed from 5:00 PM to 5:00 AM. Data are reported in birds/km3.

In spring migration, the sum of nightly peak densities in the sample area (0.5° radar beam) ranged from 376 in 2006 to 525 in 2004. The maximum nightly density was 184, recorded May 10, 2005. In the general area (1.5° radar beam), the sum of nightly peak densities ranged from 770 in 2006 to 1,227 in 2008. The maximum nightly density was 327, recorded on May 13, 2008.

During fall migration, the sum of nightly peak densities in the sample area ranged from 260 in 2007 to 960 in 2004. The maximum nightly density of 184 was recorded on September 28, 2006. In the general area, the sum of nightly peak densities ranged from 705 in 2007 and 1,399 in 2006. A maximum nightly density of 327 was recorded twice on the same night, October 5, 2005 and 2006.

In both seasons, there was more migration at higher altitudes (general area versus sample area).

The NEXRAD study showed that spring migration began to build in late April and peaked in mid May. Fall migration began to build in early September and peaked in early October. By November, very little migratory movement was noted. Spring and fall migrations typically started about 30-45 minutes after sunset. Spring migration peaked most evenings at between 11:00 PM and 3:00 AM. In fall, the peak was somewhat earlier, at between 10:00 PM and 12:00 AM. Migration direction in spring was north-northeast (between 11° and 35°). In fall, it was southeast to south-southwest (between 164° and 190°).

The NEXRAD study also analyzed the number of nights when the altitude of migration might be lower because of meteorological factors, such as ceilings below 1,000 feet (305 m) and precipitation ranging from fog to heavy rain. During the spring season, 26 of 305 total nights (8.5%) had those meteorological conditions, while 28 of 465 total nights in fall (6.0%) had those conditions. Nonetheless, none of those nights had birds movements of 25 birds/km3 or greater. In other words, on nights when weather conditions might have forced birds to fly at lower altitudes, migration density was always low.

In conclusion, the NEXRAD study indicates that the density and rate of nocturnal migration above the Project site is similar to those determined by NEXRAD and marine surveillance radar studies at many other eastern U.S. sites. The NEXRAD study also demonstrates that migration density increases with altitude, reinforcing a conclusion drawn from marine surveillance radar studies that most birds fly above the height of wind turbine rotors, with a relatively small percentage flying at rotor height.

6.1.4 Literature Review of Risk to Birds at Offshore Wind Energy Sites

Offshore wind-energy development is still largely a European phenomenon. The world's first offshore wind farm (a project of 11 turbines totaling nearly 5 MW) went on line in 1991 at Vindeby in Denmark. Presently, 24 of the world's 25 offshore wind farms are located in Europe, with 1,037 MW of installed capacity. Looking ahead, European countries have approved or are planning nearly 100 more projects, totaling nearly 50,000 MW. More than one-half of this capacity would be installed in German waters. The only project on a freshwater lake is at Lake IJsselmeer in the Netherlands, but this lake is coastal, separated from the Wadden Sea by a dike.

The effects of offshore wind on birds have been well studied in Europe, where final reports on multi-year, post-construction studies have been published for three Danish and two Swedish wind farms. Baseline conditions at these wind-farm sites were also established through pre-construction studies. Recently, these and other studies have been reviewed for the German Environment Ministry. This review, the studies themselves, and other research out of Europe provide significant information on how offshore wind development has affected birds.

Following the German review, the findings of the European studies may be summarized as follows:

Habitat Loss

Six species (Black Scoter, Red-throated Loon, Arctic Loon, Northern Gannet, Common Murre, and Razorbill) have been found to strongly avoid offshore wind farms. One species (Long-tailed Duck) showed much lower numbers in wind farm areas after construction than before. Seven species (Common Eider, Red-breasted Merganser, Great Cormorant, Parasitic Jaeger, Black-legged Kittiwake, Common Tern, and Arctic Tern) did not show any obvious effects. Three gull species (Little, Lesser Black-backed, and Great Black-backed) increased in numbers. For most other species, research to date allows no conclusions as to how wind farms affect their habitat use, mostly because these species were not common enough at offshore wind-power facilities to study or analyze.

Habitat loss for species that avoid wind farms has been found to be greater than the wind farm's actual footprint, due to the displacement distances from turbines. The loss of bottom habitat to turbine foundations and scour protectors appears to be of minor importance, because the area lost is small. The addition of reef-like habitat has not yet been demonstrated to attract seabirds, but other human and natural structures do attract birds in marine and freshwater environments, often years after they have been constructed.

It has been posited, but never demonstrated, that indirect mortality may result among seabird species that avoid offshore wind farms, particularly if habitat loss and avoidance increase bird densities in replacement habitats and lead to lower energy-intake rates. This could potentially have a carry-over effect with regard to the reproductive rate, if birds arrive at their breeding grounds in poor condition.

Barrier effect

Most of the information about flight reactions of seabirds is limited to migrating birds, which may behave differently to local or staging birds on flights between foraging and roosting sites. Eight species (White-winged Scoter, Black Scoter, Red-throated Loon, Artic Loon, Northern Gannet, Common Murre, Razorbill, and Black Guillemot) have been found to commonly fly detours around, rather than cross, offshore wind farms. Detours were noted for another four species (Greater Scaup, Common Eider, Northern Fulmar, and Great Cormorant), but it is not clear whether they do so regularly. Fifteen species (mostly gulls and terns, but also staging Long-tailed Ducks and Red-breasted Mergansers) have been found to fly through wind farms commonly. For other European seabirds, no information is available on which to base conclusions. Long-term habituation among these species has not been studied.

Regularly flown detours could increase the energy consumption of seabirds if detours were significant. It has even been suggested, without empirical support, that offshore wind farms may act as barriers that fragment habitat, leading to abandonment of certain sea areas or to changes in migration routes. A recent review suggests, however, that none of the barrier effects identified so far have had significant impacts on populations, but it seconds the concern that population-level effects could result from wind farms that block regularly used flight paths between nesting and foraging areas, or that lead to detours of many tens or hundreds of kilometers, thereby increasing energy costs. Because migration distance varies so much with weather and other topographic features, the small detours that might result from turbines acting as barriers would likely not add significantly to the energy costs of migration.

Collision Mortality

Despite the fact that only one seabird collision has been witnessed at sea, given that the different types of seabirds have been recorded in mortality studies at coastal wind farms, seabirds must be regarded as vulnerable to collision. Collision rates and additive mortality remain uncertain, given the difficulties of recording collisions at sea. However, large-scale mortality of seabirds resulting from collisions with offshore turbines has not been documented in Europe.

Table 6-3: Summary of Effects of Offshore Wind Farms on Seabirds (Dierschke and Garthe 2006)

Name[1]	**Habitat Loss**[2]	**Barrier Effect**[3]	**Fatal Collisions**[4]
Greater Scaup	?	0*	?
Common Eider	+	0*	00
White-winged Scoter	?	00	?
Black Scoter	00	00	?
Long-tailed Duck	0	+	?
Red-breasted Merganser	+	+	?
Red-throated Loon	00	00*	0
Arctic Loon	00	00	?
Horned Grebe	?	?	?
Red-necked Grebe	?	+	?
Northern Fulmar	?	0	0
Northern Gannet	00	00	?
Great Cormorant	+	0*	0
Parasitic Jaeger	+	+	?
Little Gull	++	+	?
Black-headed Gull	?	+*	0
Mew Gull	?	+*	0
Herring Gull	++	+*	0
Lesser Black-backed Gull	?	+*	0
Great Black-backed Gull	++	+*	0
Black-legged Kittiwake	+	+	0
Caspian Tern	?	?	?
Sandwich Tern	?	+*	?
Common Tern (OH-E)	+	+*	0
Arctic Tern	+	+	?
Black Tern (OH-E)	?	+*	0
Common Murre	00	00	0
Razorbill	00	00	?
Black Guillemot	?	00	?

[1] Names and taxonomic order follow American Ornithologists' Union (see www.aou.org/checklist/index.php3). Boldface indicates seasonally common species in Cleveland region or homologue of seasonally common species (i.e., Great Cormorant for Double-crested Cormorant, Black-headed Gull for Bonaparte's Gull, and Mew Gull for Ring-billed Gull). Ohio endangered species are noted as OH-E.

[2] Habitat Loss: 00 strong avoidance, 0 reduced numbers, + occurring with no or only few effects, ++ increased numbers, ? Little or no data to draw conclusion.

[3] Barrier Effect: 00 strong avoidance, 0 detours occurring, + commonly flying through wind farms, * includes information from coastal wind farms, ? Little or no data to draw conclusion.

[4] Fatal Collisions: 00 casualties recorded at offshore and coastal wind farms, 0 casualties recorded at coastal wind farms, ? Little or no data to draw conclusion.

6.1.5 Literature Review of Risk to Birds at Onshore Wind Energy Sites

Post-construction studies have demonstrated that collision mortality is relatively infrequent at onshore U.S. wind farms. In a recent literature review, mortality estimates were similar among projects, averaging 2.51 birds per turbine per year and 3.19 birds per MW per year. Rates have been slightly greater in the Eastern U.S. (maximum about 5-8 per turbine per year) than in the West, presumably because of denser nocturnal migration of songbirds in eastern North America. No federally listed endangered or threatened species have been recorded in any of the studies undertaken, and only occasional raptor, waterfowl, or shorebird fatalities have been documented. In general, the documented level of fatalities has not been large in comparison with the source populations, nor have the fatalities been suggestive of biologically significant impacts.

Except for waterbirds, these conclusions should hold for the Project. Fatality numbers and species impacted at the Project site are likely to be similar, on a per turbine per year basis, to those found at Eastern and Midwestern U. S. projects that have been studied. These fatalities, when distributed among many species, are not likely to be biologically significant. When compared with the Altamont Pass Wind Resource Area, the sum of collision risk factors for raptors is minimal or nil. Collision risk to day-migrating, nesting, and wintering songbirds is likely to be negligible. Collisions of night-migrating songbirds are likely to be similar to other sites examined, because the altitude of migration is generally above the sweep of the wind turbine rotors. However, the potentially greater height of turbines, combined with the fact that turbines in excess of 500 feet (152 m) may have L-810 steady-burning red lights, suggests a greater fatality rate among night migrants at this Project. The fact that the Project will consist of few turbines further suggests that, even with elevated fatality rates, the likelihood that such rates would be biologically significant is low.

6.1.6 Conclusion: Avian Risk Assessment

Habitat Loss

Based on the results of European studies for the same species and homologues (i.e., species that fill the same ecological niche, such as Bonaparte’s Gull and Black-headed Gull), *habitat loss* is only questionably indicated for Common Loon, but it is not indicated or uncertain in other species likely to occur at the site (including Red-breasted Merganser, Double-crested Cormorant, Bonaparte’s Gull, Ring-billed Gull, and the Ohio endangered Common Tern). Two common gulls (Herring and Great Black-backed) were found to increase in numbers at offshore wind farms. In other words, the wind farms and activities at them (particularly increased boat traffic) have had an apparent effect of increasing habitat for some gulls. Nonetheless, boat and helicopter traffic to service the wind farm may cause temporary habitat loss in some species (e.g., Red-breasted Merganser). The fact that the amount of habitat that potentially could be lost as a result of the Project is such a small percentage of the available habitat in Lake Erie, biologically significant impacts to these species are highly unlikely.

Regarding Common Loon, it would not be surprising if studies at the Project site proved inconclusive about habitat loss, simply because so few loons use the open waters of Lake Erie and statistical inference based on small samples is difficult if not impossible. Unlike Red-throated Loon, which breeds on remote ponds in coastal tundra habitat, Common Loon mainly breeds on lakes surrounded by forest. Therefore, many individuals have habituated to tall structures (i.e., trees) in their environment. Furthermore, many Common Loons are used to interacting with humans, boats, and even ocean-going ships on breeding lakes and in coastal waters where they stage and winter. This suggests that Common Loon may not exhibit the high avoidance to wind farms and boats noted in Europe for Red-throated Loon.

Barrier Effect

Barrier effect is not indicated for Red-breasted Merganser, gulls, and Common Tern (Ohio endangered), which were found to commonly fly through European wind farms. It may be indicated for Common Loon, because strong avoidance was recorded for Red-throated and Arctic Loons. Double-crested Cormorant may detour around the Project's turbines, because its congener, the Great Cormorant, was recorded doing so in Europe.

It is highly unlikely that the Project will pose a significant barrier to bird migration or local flight paths on Lake Erie. In a worst-case scenario, if turbines were arrayed in a string perpendicular to prevailing bird movements, the Project would stretch approximately 5 km (3.1 miles). European studies indicate that migrating waterfowl approaching the Project will make course adjustments many kilometers before they reach the Project in both day and night. Such course changes would add perhaps a few of kilometers to their migration, resulting in a minimal additional expenditure of energy. For most species, this would increase their entire migration distance by perhaps 0.05% (assuming a 1,500-mile migration and a 1-mile detour. This increase would not result in a significant increase in migration time, distance, or energy expended. In any event, waterfowl are accustomed to flying longer distances than the straight-line distance between migration stops.

Regarding local bird movements, the Project is unlikely to be situated between a feeding a roosting area. The closest feeding and roosting area is inshore of the Project, at the Cleveland Lakefront IBA. This IBA is judged to extend about one mile (1.6 km) into the lake. Based on the Project description provided to us, the Project would not be situated closer than two miles (3.2 km) from the lakefront. Therefore, any birds flying from the east or west to feed or roost in the IBA would not likely intersect the wind farm. Instead, their flight paths would take them inshore of the turbines.

Collision Mortality

Regarding waterbirds, a review of bird mortality at coastal wind farms in Europe has demonstrated that all groups of waterbirds occurring on the Great Lakes are potentially vulnerable to turbine collisions offshore. But, collision frequency at these coastal wind farms was directly related to abundance and propensity to fly at rotor height, with common species of gulls (particularly Herring Gull) recorded most frequently. It should be noted that many of these coastal wind farms were located adjacent to nesting colonies and on flight routes between nesting sites and foraging areas. Therefore, collision risk was greater than at other sites.

Given that the Project will be constructed more than two miles (3.2 km) offshore, bird abundance will be significantly less than along the Cleveland lakefront. The only common colonial nester in Cleveland is Ring-billed Gull, which nests on large rooftops, but the Project would not be located between its nesting sites and prime foraging areas.

In Europe, where wind farms have been constructed on heavily used waterfowl migration routes, flocks usually detour around the wind farms. The small number of flocks that fly through the wind farms, including at night, generally do so beneath the rotor-swept area. These and other behavioral adjustments have been found to markedly decrease collision risk.

The Project site does not appear to be on a heavily used migration route for waterfowl or other waterbirds. Large numbers of Red-breasted Merganser and Bonaparte's Gulls stage on Lake Erie in fall migration, but they are more likely to fly inshore of the Project site to roost or forage in the Cleveland Lakefront IBA. Should migratory or local movements take waterbirds in the vicinity of the Project, it is expected that birds would detour around the turbines, or cross the wind farm below the rotor-swept area. Therefore, in all cases, collision risk to waterbirds is judged to be low and unlikely to rise to the level of biological significance.

6.1.7 Recommended Studies and Construction Guidelines

Recommended Studies

All in all, the results of this avian risk assessment do not indicate the need for further pre-construction research, as it would not improve precision or confidence levels regarding prediction of risk to birds at the Project.

However, given that this Project will be a first for the Great Lakes, it would be valuable to conduct pre and post-construction studies to gauge how waterbirds react to the Project in terms of habitat loss, barrier effect, habituation, reef effect, and other factors. Such information on a species-specific level would help future offshore wind-energy projects in the Great Lakes to evaluate potential avian effects. Another important consideration is collision mortality, but it remains to be seen if a cost-effective remote method or carcass searches for quantifying collision mortality can be deployed. (ARA p.6-7) However, collision rates at offshore wind farms may be obtained by remote methods, two of which are being developed. These methods should be evaluated for deployment post-construction if larger facilities are planned in the Great Lakes. In addition, if large facilities are planned for the Great Lakes, it may be worth experimenting at those sites with drift nets to collect carcasses below turbines at the Project site.

Once the Great Lakes Wind Energy Center is constructed, other studies of avian interactions with the turbines besides the collision mortality study should provide valuable information to help assess avian risk from the much larger wind farms that are likely to be constructed in the Great Lakes in the coming decades. Stakeholder participation in the post-construction study of the Project is recommended. To this end, a Technical Advisory Committee (TAC) should be established as a means of reviewing the scope of work for each of the following recommendations, as well as reports that result from such studies. Members of the TAC should include the USFWS, ODNR, Cuyahoga County Board of Commissioners, a representative from the wind development community (i.e. juwi), the Great Lakes Energy Development Task Force, and other relevant stakeholders. This approach to post-construction studies has been used at more than a dozen wind-power projects across the United States.

Based on these considerations, Curry & Kerlinger see the Project as a possibility to carry out the following studies to help further advance knowledge about avian impact from offshore wind turbines:

- Carcass searches should be investigated as a means of determining the number and type of birds that collide with turbines. The potential for netting deployed on buoys should be tested as a means of finding and gathering carcasses of birds that have collided with turbines.
- At least two remote methods for quantifying turbine collisions have been developed (e.g., TADS and WT-Bird), although they have not been shown to be useful. Each should be evaluated for potential use, with particular attention paid to the number of units that would need to be deployed to generate a statistically valid sample.
- A study of waterbird reactions to the Project would provide valuable information to evaluate avian risk at future offshore wind farms in the Great Lakes. Sampling techniques to consider include direct visual and, possibly, radar observations from the

Cleveland Crib, as well as boat and aerial surveys. This study would look at habitat loss, barrier effect, habituation, reef effect, and other factors.

- Results of the fatality study should be compared with cradle-to-grave (life cycle) impacts to birds from other types of power generation now supplying electricity in Ohio. This comparison would facilitate long-term planning with respect to electrical generation and wildlife impacts. The study should seek information from USFWS and ODNR on existing energy-generation impacts to wildlife. If information is not available, as our preliminary review appears to reveal, these agencies should consider providing financial support for such studies.

Recommended Construction Guidelines

Observing the following guidelines will help minimize the impact from the construction and operation of wind turbines on avian species in an offshore environment.

- Disturbance of bottom habitat, and ship and helicopter traffic to and from the site should be minimized.
- The onshore installation of any new above-ground electrical lines should follow Avian Power Line Interaction Committee (APLIC) guidelines for insulation and spacing.
- Lighting of turbines and other infrastructure should be minimal to reduce the potential for attraction of night migrating songbirds and similar species. Federal Aviation Administration (FAA) night obstruction lighting should be only flashing beacons (L-864 red or white strobe [or LED], or red flashing L-810) with the longest permissible off cycle. Steady burning (L-810) red FAA lights should not be used, although if turbines exceed 152 m (500 feet), the FAA may recommend them. Sodium vapor lamps and spotlights should not be used at any facility (e.g., lay-down areas or substations) at night except when emergency maintenance is needed. If steady burning lights are needed for maintenance purposes, the use of green or blue lights should be investigated as a means of minimizing bird attraction. Navigation lights (steady red and green, located near the water level) will likely be required, but these have not been demonstrated to attract migrating birds.

These recommendations are made with the knowledge that they may not be economically feasible for a small, pilot project. If these studies are to be done, funding from state and federal agencies, as well as the non-profit environmental community, should be sought. Such funding would be a significant and proactive step in the development of clean-energy solutions.

6.2 Initial Marine Ecological Assessment

(*Unless otherwise indicated, information in this section taken from GLWEC Initial Ecological Assessment, DLZ Ohio, September 2008).*

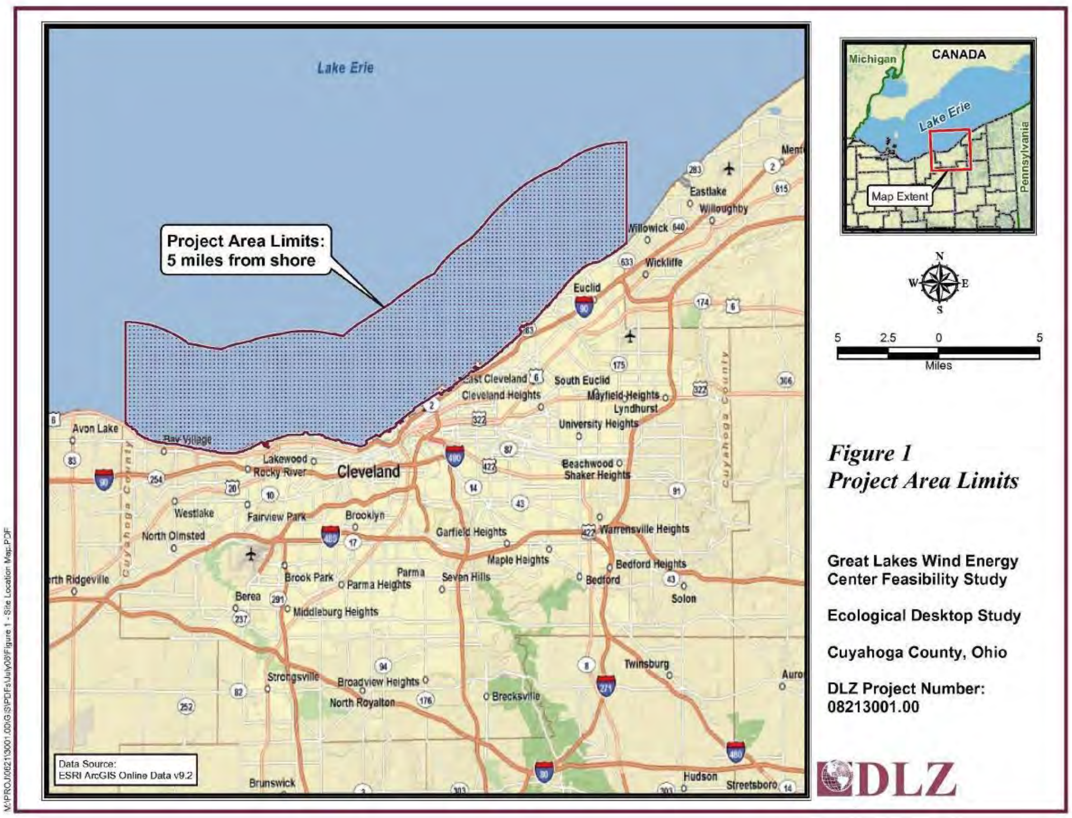
The purpose of the GLWEC Initial Ecological Assessment is to provide preliminary background information on the ecological resources in the Pilot Project Site and, based on this information, to identify and evaluate potential impacts of the Pilot Project on these resources.

In support of the GLWEC Feasibility Study, this desktop study report presents the on-shore, near-shore, and off-shore ecological resources of Lake Erie in Cuyahoga County, Ohio based on a review of existing literature, ecological references, resource agency interviews and other relevant information. Topics covered include water quality, fisheries, benthic ecology, terrestrial resources, threatened and endangered species, and exotic/invasive species.

6.2.1 Description of Study Area

The Pilot Project would be located off-shore from the City of Cleveland (Cuyahoga County) within the central basin of Lake Erie. The project focus area for this study is a band that extends from the east-west county lines out three to five miles off-shore (Figure 6-1).

Figure 6-1: Project Area Limits



6.2.1.1 Generalized Offshore Environmental Conditions

The long term mean surface elevation of Lake Erie, based on data from 1860 to present, is approximately 571 feet above sea level. Over this same period, the average lake level has generally fluctuated between elevations of 568 and 574 feet. Bathymetric data collected in 1974 suggests that over most of the study area the water depth is between 40 and 70 feet deep. The information also indicates that the bathymetric contours are roughly parallel to the shore. The water depths surveyed at three to five miles off-shore varied from about 40 feet to a little more than 50 feet. This data is generally consistent with more recently compiled bathymetric contour mapping available from the National Oceanographic and Atmospheric Administration (NOAA). A detailed bathymetric map of the Cuyahoga County shoreline can be found in the Geological and Geotechnical Desktop Study for the Great Lakes Wind Energy Center Feasibility Study.

6.2.2 Natural Resources of Lake Erie

The Lake Erie watershed includes portions of Ohio, Indiana, Michigan, New York Pennsylvania and Ontario, Canada. The portion of the watershed within Ohio covers 7.45

million acres and drains portions of 35 counties with a total population of 4.65 million people. Land use in the watershed is more than 72 percent agriculture or open space, 20 percent wooded, approximately 2 percent is wetland, 4 percent is developed and urban and the remaining 1 percent is open water (lakes and rivers).

The average depth of the lake is only about 62 feet, although the area of the lake is about 10,000 square miles. Lake Erie's water levels fluctuate throughout the year, with the lowest levels in January and February, and the highest in June or July. The average yearly levels also vary depending on long-term precipitation variations, with levels falling during droughts and rising during periods of extended above-average precipitation. Lake Erie has a lake retention time of 2.6 years, which is the shortest of all the Great Lakes.

Lake Erie is comprised of three basins based on shape and depth. Each has very different geophysical, chemical and hydraulic properties and, as a result, the aquatic resources within each basin are presented with diverse environmental conditions.

6.2.2.1 Natural Resources of Central Basin of Lake Erie

The Western, Central, and Eastern Lake Erie basins are deeper from west to east. The Western Erie Basin extends to 36-foot depths, the Central Erie Basin extends to 79-82 foot depth, and the Eastern Erie Basin extends to depths exceeding 130 feet and reaches a maximum depth of about 207 feet. The Central basin of Lake Erie is the area between Sandusky and Erie. The near-shore zone all around the lake is characterized by irregular topography which deepens abruptly within the first 0.5 to 2 miles of the shore, then flattens farther offshore. This steeper topography near the shore extends to depths ranging from 9 to 49 feet, such depths having the appearance of being proportional to the amount of wave energy concentrated on different areas of the shoreline. In most areas the high-energy zone is one of mostly active erosion with only sand-sized sediments remaining in the zone and being moved via longshore drift.

Away from the shore the three basins are broadly bowl-shaped, with depths extending smoothly from near-shore down to the greater depths. The bowl shape suggests postglacial deposition and sediment-smoothing in response to a gyre of water circulation in each basin, or progressive shoreline modifications in the zone of Holocene rising lake levels. This sediment-smoothing has diminished or eliminated surface relief left in place by the last glaciations, as is evident in the Central basin where the bottom is very flat with little variation in topography. Only in the Eastern Erie Basin, at depths exceeding 115 feet, does the topography have a remnant glacial character.

6.2.2.2 Natural Resources of Study Area

As of the 2000 Census, the city proper had a total population of 478,403, and is estimated to be the 40th largest city in the nation and the second largest city in Ohio. The city has a total area of 82.4 square miles, of which 77.6 square miles is land and 4.8 square miles is water. The total area is 5.87% water. The urban environment surrounding the study area limits the type of resources that will be found along the shoreline and near-shore areas.

The shore of Lake Erie is 569 feet above sea level; however, the city lies on a series of irregular bluffs lying roughly parallel to the lake. In Cleveland these bluffs are cut principally by the Cuyahoga River, Big Creek, and Euclid Creek. The land rises quickly from the lakeshore. Less than a mile inland, Public Square sits at an elevation of 650 feet, and Hopkins Airport, only five miles inland from the lake, is at an elevation of 791 feet.

The Cuyahoga River begins in Hambden, Ohio prior to emptying into Lake Erie 100 miles downstream. The Cuyahoga River and its tributaries drain 813 square miles of land in portions of six counties. The depth of the river, except where it has been modified, ranges from 3 to 6 feet. The current mouth is man-made, which allows shipping traffic to flow freely between the river and the lake. Additionally, the U.S. Army Corps of Engineers periodically dredges the navigation channel of the otherwise shallow river to a depth of 27 feet along the river's lower 5 miles. The Corps of Engineers has also straightened river banks and widened turning basins in the Federal Navigation Channel on the lower Cuyahoga River to facilitate maritime operations.

The other inlets to Lake Erie within the study area include Rocky River, Euclid Creek, Porter Creek and Cahoon Creek The Rocky River is a relatively short river which forms the western boundaries of the cities of Cleveland and Lakewood, Ohio. The river itself is formed at the confluence of two tributaries at a point known as Cedar Point just west of Cleveland-Hopkins International Airport. The Rocky River flows through a heavily forested V-shaped valley and is part of the Cleveland Metroparks system. Euclid Creek is located 10 miles east of downtown Cleveland. It drains 24 square miles and has 43 miles of stream segments. Both Porter Creek and Cahoon Creek enter Lake Erie near Bay Village.

6.2.3 Water Quality

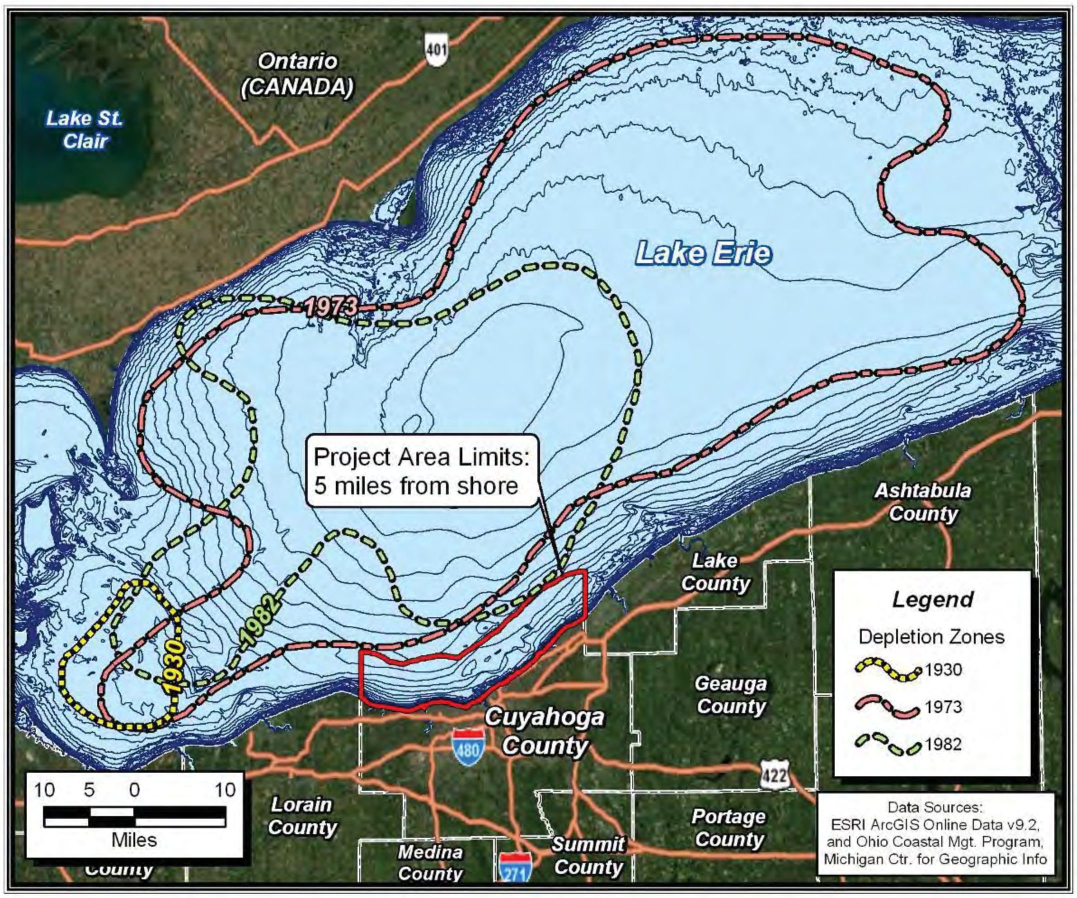
Ninety-five percent of the water entering Lake Erie comes from the upstream Great Lakes (Superior, Michigan, and Huron), as well as all of the rivers and streams that flow into these lakes. The remaining 5% comes from rain and snow in the Lake Erie drainage basin, which includes the various streams and rivers that flow into Lake Erie.

Since the 1970s, water quality conditions in Lake Erie have vastly improved. Lake Erie was at that time considered dead, suffering greatly from water pollution from both point and non-point sources from the watershed and contributing rivers and streams. This pollution did not get much attention until the great Cuyahoga River Fire in June 1969. Pollution from Cleveland and other Ohio cities had so contaminated this tributary with petrochemicals that it actually caught on fire. The fire prompted the United States Congress to pass the Clean Water Act in 1972, leading to significant improvement in water quality throughout the country. The cleanup effort for Lake Erie was centered on limiting point source discharges by constructing facilities that treat both domestic and industrial wastewater. Non-point pollutants have been reduced by the adoption of conservation tillage practices in farming. However, increasing development pressures have added to the problems of Combined Sewer Overflows (CSOs) and non-point source pollution from agriculture and development contribute to the nutrient enrichment and continue to jeopardize water quality in Lake Erie. Lake Erie has higher nutrient levels among the Great Lakes primarily because of shallower depths and nutrient circulation in the well-mixed waters. Since virtually all of the Great Black Swamp and coastal wetlands have been cleared and drained, there is no ability to prevent pollutants and sediments from entering the lake.

6.2.3.1 Generalized Water Quality Issues in Study Area

The Central Basin stratifies into three distinct layers in the summer, a warm top layer (epilimnion) and a cooler bottom layer (hypolimnion), with area thin layer of rapid temperature change in between (thermocline). The separation of water into three layers may occur in off-shore waters deeper than 49 to 60 feet to the bottom of the lake. Density variations in these layers prevent them from mixing with one another, essentially creating layers with very different chemical and physical characteristics. The hypolimnion of the Central basin is susceptible to becoming anoxic in late summer. Due to the strong thermal stratification of the layers, there is no way to replenish the dissolved oxygen until the thermocline erodes in the fall as the lake cools. This condition is termed the “Dead Zone” and occurred historically and has returned in the last several years. Generally it has been located in areas with 40-foot water depths or greater (Figure 6-2). Too many nutrient inputs (i.e., nitrogen and phosphorus) and the shape of the basin create the conditions for this to occur. It also appears that exotic species, like both the zebra mussel (Dreissena polymorpha) and quagga mussel (D. rostriformis bugensis) are enhancing the problem by changing the way nutrients are cycled and the timing of nutrients being made available to other organisms. Additionally, climate changes may play a factor in the shrinking hypolimnion.

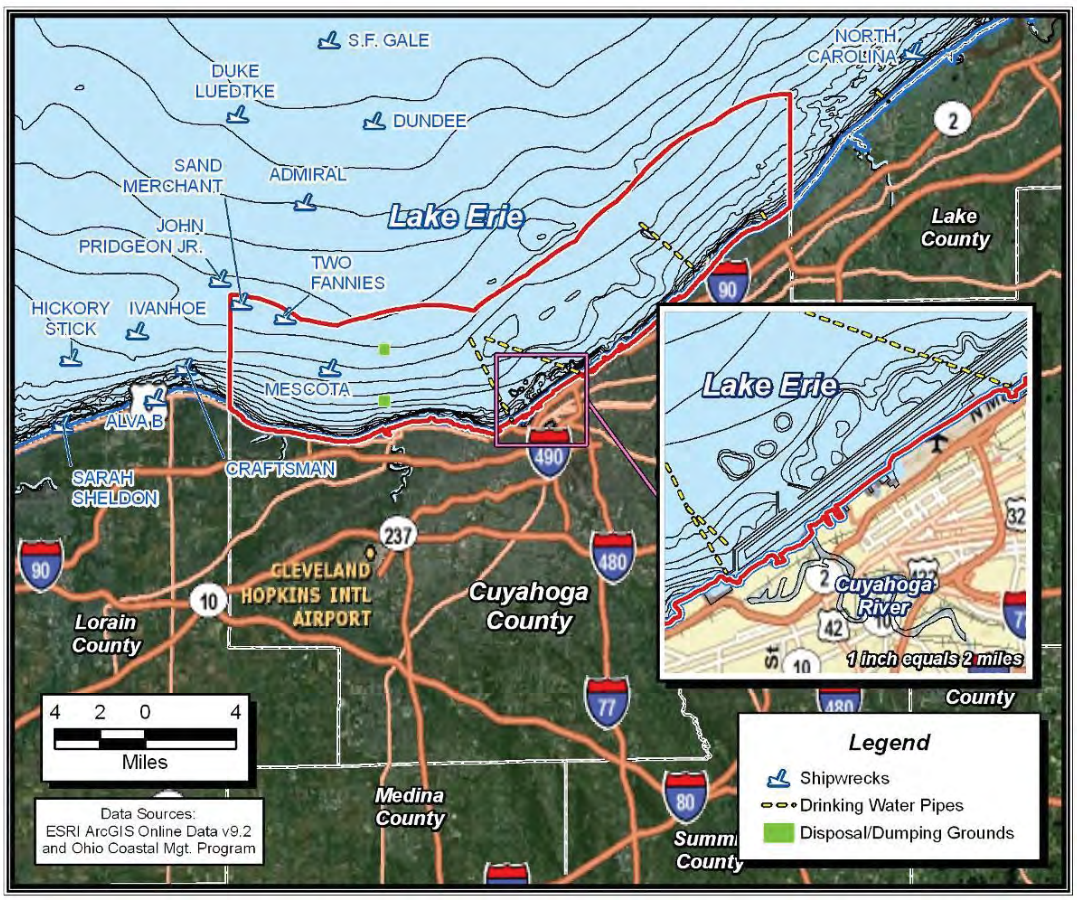
Figure 6-2: Historical "Dead Zones" in Lake Erie Central Basin



As in most urban areas across the nation, Greater Cleveland's earliest sewers (primarily within the City and its inner ring suburbs) are Combined Sewers. Built around the turn of the 19th century, these sewers carry sewage, industrial waste and storm water in a single pipe. Heavy rain events often exceed the capacity of wastewater treatment plants, causing an emergency discharge of CSO water directly into surface waters. The Northeast Ohio Regional Sewer District (NEORSD) owns, operates and maintains three wastewater treatment plants with a combined average daily flow of about 235 million gallons (MG), and a combined wet-weather peak capacity of 1.5 billion gallons per day (BGD). The NEORSD is also responsible for the interceptor sewers, which are large diameter conveyance sewers, and CSO regulating structures.

The Cleveland Division of Water (CWD) uses surface water drawn from four intakes in Lake Erie as their source of drinking water. The intake systems are located a considerable distance off-shore (built in the early 1900s and again in the '40s and '50s) (Figure 6-3). From there, four filtration plants (Garret A. Morgan, Baldwin, Nottingham and Crown Water Works) receive, treat and distribute the water. Raw water is supplied to the Baldwin Water Works Plant by the Kirtland Pumping Station. The Kirtland Pumping Station Water Intake Crib houses one of the main intakes for Cleveland's municipal water supply and is located approximately 3.5 miles out into Lake Erie and 5 miles from the pumping station. Completed in 1904, the 100-foot diameter steel and cement Crib sits in approximately 53 feet of water.

Figure 6-3: Underwater Features Within Project Area



6.2.4 Fishery Resources

While a variety of fish species exist in Lake Erie, two species, yellow perch (Perca flavescens) and walleye (Sander vitreus vitreus), far exceed all others in terms of their recreational and commercial value to fisheries lakewide. These two fisheries are assessed and managed on a lakewide basis through the efforts of the Lake Erie Committee (as facilitated by the Great Lakes Fishery Commission), consisting of fisheries professionals from the four surrounding states (MI, NY, OH and PA) and the Canadian Province of Ontario with statutory jurisdiction over all Lake Erie waters. The Committee is charged with generating an annual Total Allowable Catch (TAC) by evaluating the population sizes and health of these fisheries and addressing both sustainability and viability of these resources. Annual TACs for walleye and yellow perch stocks are allocated according to water surface area in each jurisdiction.

6.2.4.1 Generalized Lake Erie Fishery and Habitat

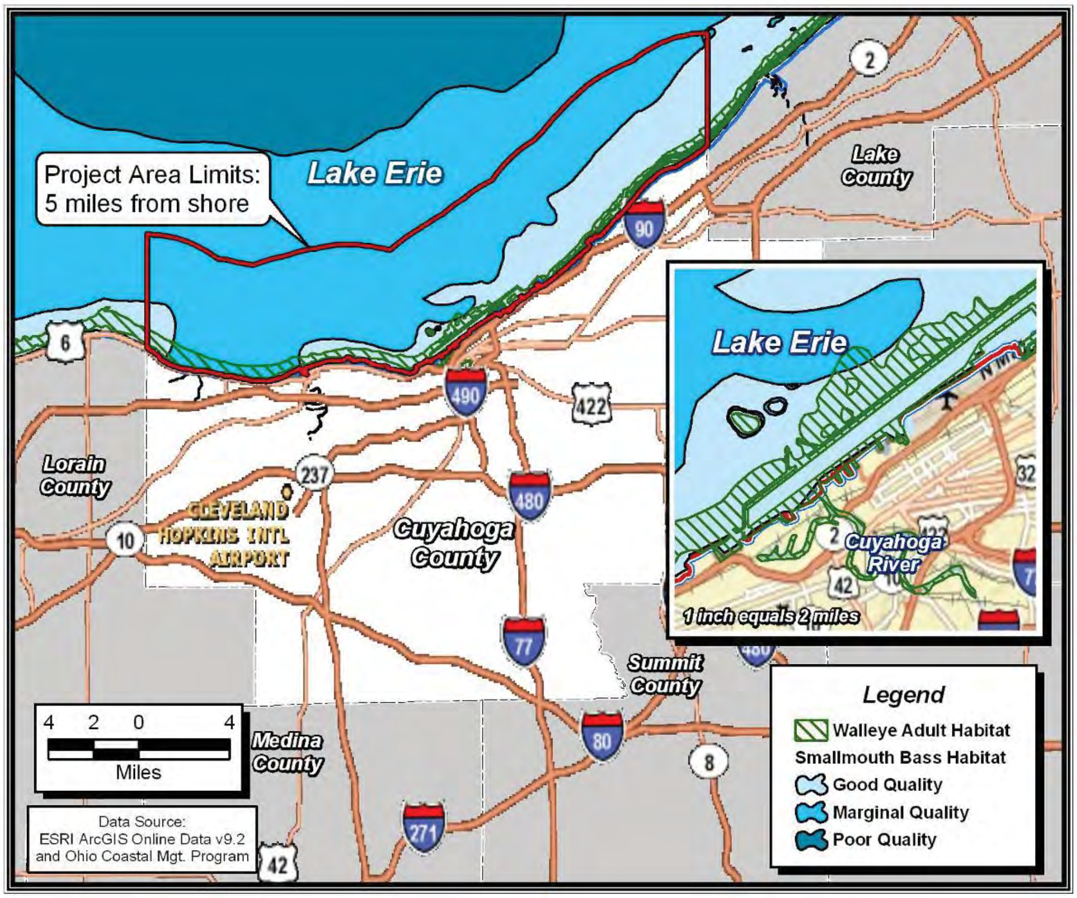
Habitat conditions at three spatial scales influence fish-habitat interactions in Lake Erie. The first scale includes local-scale in-stream habitat/stream flows which influence spawning habitat and outwelling zones. In Lake Erie, tributary flows extend into the lake and may influence near-shore and open-lake water quality, circulation, and water-mass characteristics. Another scale is the meso-scale habitat, which in Lake Erie is generally linked to tributaries and their associated plumes or outwelling zones. Lastly is the broad-scale off-shore water masses defined by gyres, open-lake hydrodynamics, and large scale inflows. The Central basin appears to be structured by two dominant gyres east to west. The western gyre typically circulates counter-clockwise, while the eastern gyre generally circulates in a clockwise direction.

The Cuyahoga River, located within the project area, has been identified for protection/restoration efforts for walleye. Because concentrations of dissolved oxygen are unfavorable in the lower reaches of the river, resident fish in these habitats are dominated by tolerant species (GLFC 2005). Lake sturgeon (Acipenser fulvescens), state listed as endangered, have been reported in catches and dead carcasses have been observed washing up on shore in the area. Historically present in the Cuyahoga River, no formal studies are being conducted to determine their occurrence presently.

Coastal areas provide habitat for larval and young-of-year fishes. Many forage fish such as gizzard shad (Dorosoma cepedianum), emerald shiner (Notropis atherinoides) and rainbow smelt (Osmerus mordax mordax) spawn throughout the lake and can use this near-shore habitat as well. Many adult species, including walleye, use the coastal waters while migrating to and from spawning areas in the western basin. A narrow fringe (up to several miles wide) of optimal adult walleye habitat is located along the coastline of Cleveland (see Figure 6-4). Quality habitat is generally related to depth, most walleye are caught in 60-feet or less depths, and water clarity. Walleye spawning and nursery grounds are primarily located in the western basin.

Some species use near-shore reefs for spawning, including smallmouth bass (Micropterus dolomieui). Moderate to high quality smallmouth bass habitat is located in the near shore areas off Cleveland (see Figure 6-4). High quality habitat constitutes boulder- to gravel-sized substrate in areas with maximum water depths between 13 and 33 feet.

Figure 6-4: Adult Walleye and Smallmouth Bass Habitat



6.2.4.2 Recreational Fishery

Recreational fishing is popular along the Lake Erie coastline. In 2006, over 1.25 million licenses were sold in Ohio; close to one-third of the fishing licenses sold in Ohio were sold in the counties that border the lakeshore. Over $1 billion in retail sales were recorded in Ohio in 2006; close to half was from fishing in Lake Erie. Diverse habitats, ranging from major tributaries to shallow rocky reefs, shoals, rocky island shores and deep-water flats provide diversity and abundance to the sport fishery. Walleye is the most popular sport fish in Lake Erie; however, yellow perch, smallmouth bass, white bass (Morone chrysops) and steelhead trout are also sought. Steelhead (Oncorhynchus mykiss) move into the Central basin streams in the fall and provide recreational fishing opportunities for wading anglers from fall through spring. Anglers also catch additional species, such as catfish (Ictalurus sp.), white perch (Morone americana), freshwater drum (Aplodinotus grunniens), crappie (Pomoxis sp.), largemouth bass (Micropterus salmoides), rock bass (Ambloplites rupestris) and sunfish (Lepomis sp.), especially along the shoreline in the bays and harbors. Several boat access sites are located in the study area, allowing the public to launch or dock a vessel. There are also a large number of charter boats catering to fishing on Lake Erie.

6.2.4.3 Commercial Fishery

Lake Erie is home to one of the world's largest freshwater commercial fisheries. Once a basis of communities around the lake, commercial fishing is now predominantly based in communities from Canada, with a much smaller fishery restricted to yellow perch in Ohio. The Ohio Lake Erie Fishing Regulatory Reform Task Force was created in 2007 to evaluate topics of catch quota allocations, game fish size limitations, existing vessel monitoring system (VMS) and electronic data reporting devices (EDR), commercial fishing license transfers, and fisheries resource management practices. The Task Force focused on yellow perch because walleye are not legally available for commercial harvest in Ohio. A report of its findings was completed December 31, 2007. All commercial fishing vessels must be equipped with a VMS which allows for tracking of commercial fishing vessels to ensure compliance with regulations that dictate area of fishing and allow for fine-scale recording of net locations. EDR eliminates paper forms, improves data accuracy, provides real-time assessment of quota balances, and improves compliance.

There are legal size limits on commercial fish and all undersized fish and species that cannot be commercially taken must be released immediately. It is unlawful to set a net within ¼ mile of the mainland bordering Lake Erie from June 15 through September 15. Trap nets are not to be set within four miles of navigational lights located around Cleveland Harbor from May 15 through October 15, but can be set within the 4-mile zone outside of those dates. Twenty trap nets are allowed, which are usually connected in gangs of 4-8 nets in a single “string” to maximize efficiency. Gill nets have been outlawed in Ohio since 1983 but are still used in Canada. Seines are exclusively used in Sandusky Bay and Western Lake Erie.

6.2.4.4 Exotic / Invasive Fish Species

A number of exotic (non-endemic) fish, plankton, and plant species not native to the Great Lakes have been identified as being present in Lake Erie. At least 185 different exotic species have entered the Great Lakes via man-made locks and canals around natural obstacles to migration (i.e. Niagara Falls) or in the ballast waters of ocean-going vessels from Eurasia. Several fish species (salmon, trout, etc.) were purposely introduced to the Great Lakes by man to enhance fishing opportunities. Common fish species, such as rainbow smelt, alewife (Alosa pseudoharengus), white perch and common carp (Cyprinus carpio), have all been introduced from outside the Great Lakes. While the impact of some fish species is negligible, the impact to the ecology of the lake and the economic cost is significant in some cases.

Sea lampreys (Petromyzon marinus), a jawless, parasitic fish native to the Atlantic Ocean, was first discovered in Lake Erie in 1921, only two years following completion of the Welland Canal. Sea lampreys devastated the Great Lakes fishery and are thought to be a primary cause for the extinction of three native species of cisco (Coregonus sp.). Sexually mature adults swim up Central basin tributaries in the spring to spawn. The larvae live 4 to 6 years as filter feeders in the tributaries. After transforming into free-swimming juveniles, the lamprey move downstream into Lake Erie. As adults, the lamprey attach to fish with their sharp teeth and sucking disk-like mouth to feed on body fluids. During the 12 to 20 months of its life, an adult lamprey can kill 40 or more pounds of fish. The impact of the sea lamprey in Lake Erie and other Great Lakes has been dramatically reduced only because of significant efforts to reduce their population.

The round goby (Neogobius melanostomus) was first discovered in the Great Lakes Region in 1990 and first found in Lake Erie in 1993. Populations of round goby are estimated to be over 10 billion (2002 data) in the western basin alone. Round gobies are aggressive and fecund, which aids in being able to out-compete native species for food and spawning habitat. Round gobies prefer rocky, shallow areas, but are found in a variety of habitat types. Round gobies are a nuisance to fisherman, as they are often too small to catch but aggressively attack natural baits. The numbers of native fish species have declined in areas where round gobies have become abundant. They have been found to prey on darters, other small fish, and lake trout eggs and fry in laboratory experiments. They also may feed on eggs and fry of sculpins, darters and logperch and compete with rainbow darters (Etheostoma caeruleum), logperch (Percina caprodes) and northern madtoms (Noturus stigmosus) for small macroinvertebrates (amphipods, dipterans and ephemeroperan nymphs). The invasion of round gobies into Lake Erie has had very real environmental and economic impacts. The State of Ohio has closed for possession the smallmouth bass fishery in Lake Erie during the months of May and June, as high predation rates by round gobies on nests are affecting smallmouth recruitment. Under normal circumstances male smallmouth bass guard nests and are effective in keeping round gobies away. When males are removed by sportfishermen, round gobies immediately invade and have been shown to eat up to 4,000 eggs within 15 minutes. The months of May and June normally account for 50 percent of the total smallmouth catch in Lake Erie so there is a considerable loss in funds normally generated by recreational fishers.

6.2.5 Lake Bottom Habitats and Benthic Ecology

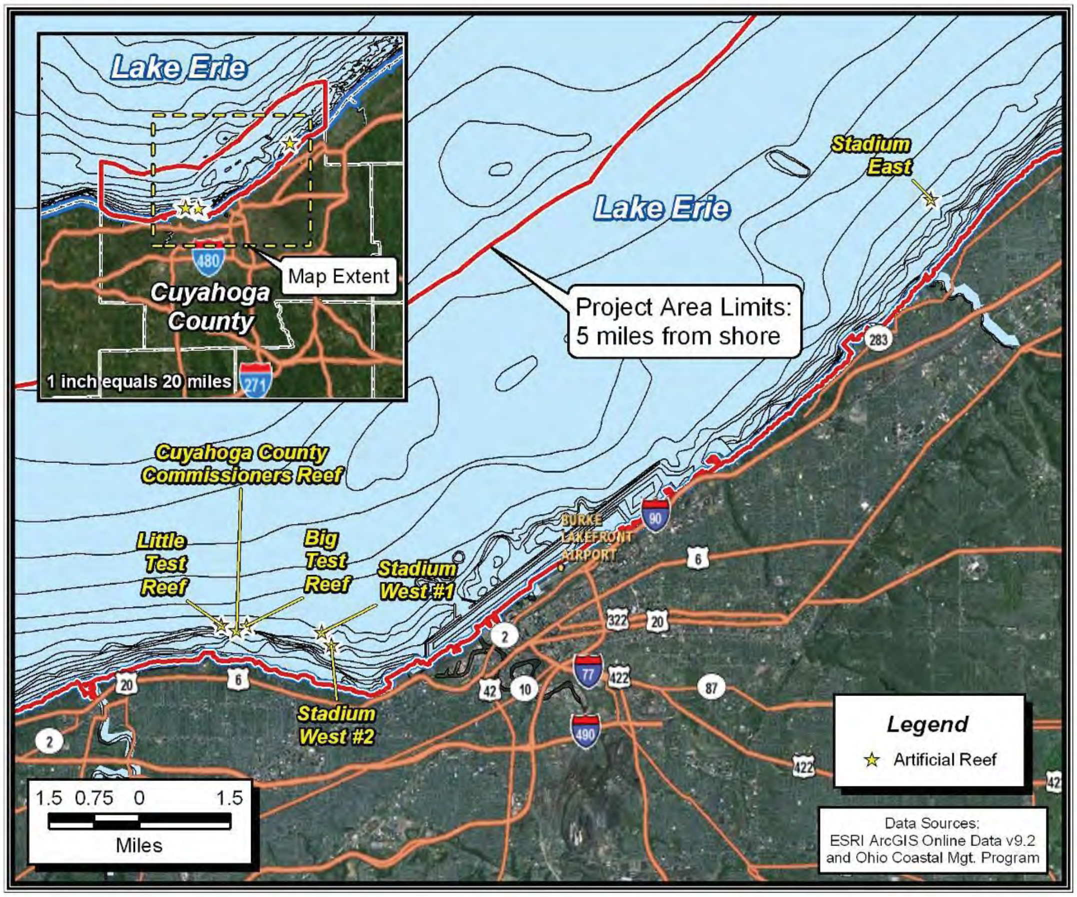
6.2.5.1 Near-Shore and Offshore Habitats

The Ohio EPA uses a habitat evaluation method known as the Qualitative Habitat Evaluation Index (QHEI). The Lake Erie shoreline and freshwater estuary habitats are evaluated based on their substrate quality, suitable cover for fish, shoreline morphology, nearby land use and aquatic vegetation. The shoreline along Cuyahoga County scored a 45, which puts the shoreline quality in the Fair category. The low quality of shoreline habitat is primarily due to the high degree of human induced disturbance in the area as there is little remaining natural physical environment. Having the lines connect to a power source within the city, avoiding parks and undisturbed habitat, would not create any additional disturbance.

Several artificial reefs are present within the proposed project site boundaries including, Big Test Reef, Little Test Reef, Cuyahoga County Commissioner's Reef and the Cleveland Stadium Artificial Reefs, which were made in 1998 of clean stadium concrete rubble (see Figure 6-5). The Stadium reefs are the two reefs located northwest of the Edgewater Ramp and Marina (Stadium West #1 and #2), and the one located northeast of the Euclid/Wildwood State Park Ramp and Marina (Stadium East). They are part of an artificial reef program started and supported by the Ohio Sea Grant since 1984. All reefs are located within 3 miles to the shoreline. Artificial reefs have been created as part of an Ohio Sea Grant program to construct near-shore, complex, reef habitat in areas of featureless substrate to create suitable and stable habitat for fish that congregate around structure. Reefs can provide refuge and food to aquatic organisms, including macroinvertebrates and larval fish, as well as spawning areas for fish such as walleye and lake trout (Salvelinus namaycush). Fish like smallmouth bass and yellow perch have been observed in a "halo" orientation around the reefs.

Other features that are present located in the bottom waters within the project area boundaries include previously mentioned water intake pipes, several shipwrecks and two disposal ground areas (see Figure 6-5). These features would have to be avoided when siting the turbines.

Figure 6-5: Artificial Reefs Within Project Area

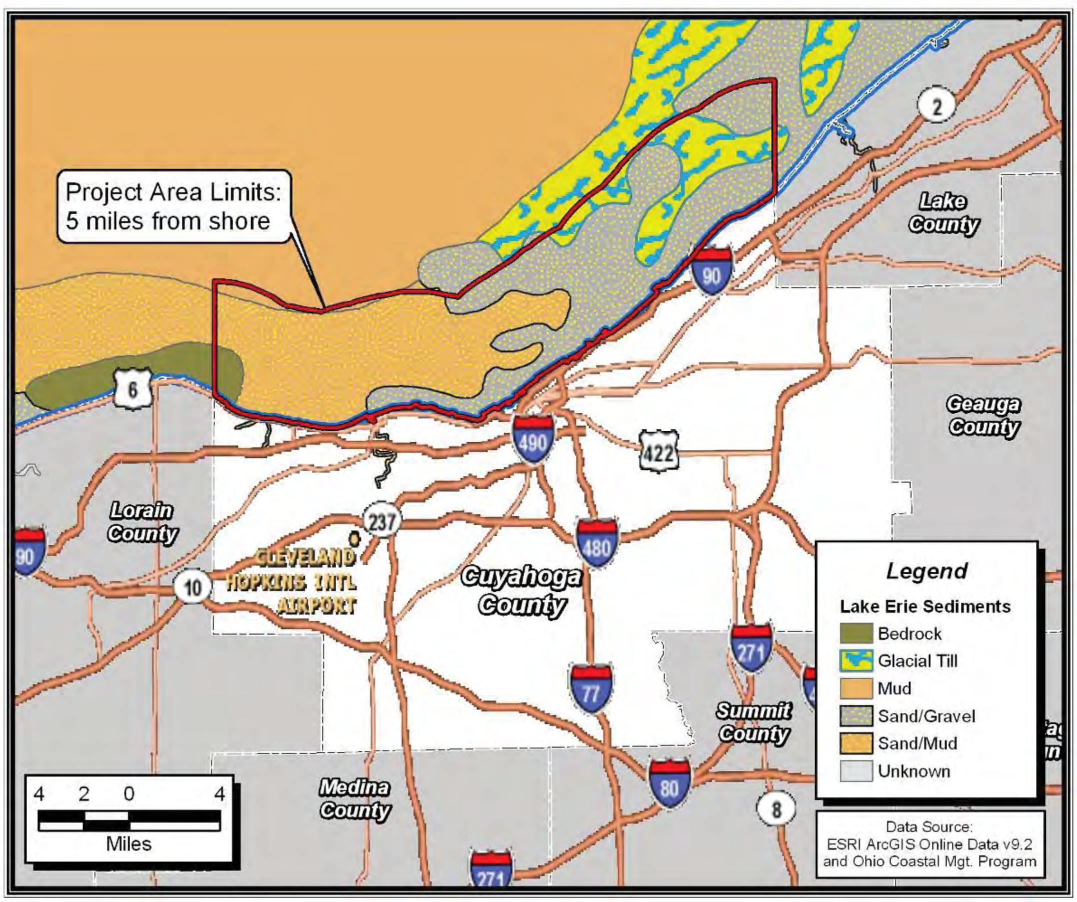


6.2.5.2 Lake Sediments

Sediments were deposited during the postglacial period following the Pleistocene, which is also referred to as the Holocene Epoch, approximately 10,000 years ago. These more recent sediments include soils derived from the weathering process of existing rock and sediments into finer particles. These sediments on land are typically the near surface soils derived from the breakdown of the parent rock and soil into finer material though physical and chemical weathering processes. These soils can also be the result of soil deposition by movement (colluviums) and deposition by flowing water (alluvium). Soils vary from clays to large boulders depending on the environment. Coarse grained sediments are found in the Rocky River Valley, east of Cleveland, where deeply incised stream channels result in the cleaving of larger rocks from the steeper side walls while the less energetic, nearly level, till plains around Cleveland are covered with finer grained soils developed in the tills and beach sands.

Lake sediments have been laid down over the older material from the previous epoch. These sediments also vary in consistency from very fine mud, organic muck and clays to sands and gravels associated with the beach environments. Rivers, streams and sewers flowing to the lake also contribute sediment to the lake bottom. In general, the higher the energy, the coarser the sediments encountered. Typically this translates into coarser sediments being found in shallow water with higher wave action and finer grained materials in deeper water with low water movement. Generally, boulders are not found in recent age sediments; however, rafting of near-shore materials by ice is also a possibility. Due to the temperate nature of the climate in this epoch, the movement of large boulders by ice rafting is not likely. A generalized map of the near-shore substrates is presented in Figure 6-6 below. A more detailed presentation of the sediments off the Cuyahoga County shore can be obtained in the Geological and Geotechnical Desktop Study for the Great Lakes Wind Energy Center Feasibility Study, or Section 6.3 of this document.

Figure 6-6: Near Shore Substrates of Lake Erie in Cuyahoga County



6.2.5.3 Benthic Community

A wide variety of fish, macroinvertebrates, and small invertebrates are included in the benthic (bottom) zone of Lake Erie. Benthic invertebrate communities are well suited for use as biomonitoring tools, because the various benthic organisms have differing sensitivities to environmental stressors or responses to conditions. By measuring the diversity of the benthic community and the specific species present, some insight into the level of human impacts on the water quality of an aquatic system can be inferred. A good example would include burrowing mayflies of the genus Hexagenia. Mayflies and other macroinvertebrates are an important food source for fish and are very sensitive to oxygen levels in the water. The presence of mayflies can infer that an area is not experiencing extended periods of oxygen depletion. A number of exotic species now dominate the benthic community and are discussed in the next section.

The small, shrimp-like organism Diporeia is normally the dominant benthic invertebrate in most off-shore areas of the Great Lakes, historically comprising over 70 percent of the biomass in healthy off-shore lake bottoms. Diporeia is also very sensitive to the environment, requiring clean, cold, highly-oxygenated water to survive. While historically present there, Diporeia is not currently found in Lake Erie, a fact that is thought to be a major contributor to the decrease in the populations of rainbow smelt and lake trout. The decline in Diporeia is related to the introduction and expansion of zebra and quagga mussels in Lake Erie, as they out compete Diporeia for available food.

The only data available from the OEPA is from a mid-1990s macroinvertebrate survey along the Lake Erie shoreline. Samples collected at 2 stations within the vicinity of Rocky River were dominated by side swimmers (Gammarus fasciatus), oligochaetes and chironomids (midge larvae). Samples collected just east of the mouth of the Cuyahoga River were dominated by zebra mussels, side swimmers and chironomids (see Appendix A of GLWEC Initial Ecological Assessment). In 2010, the USEPA will be performing a National Coastal Assessment Survey along 50 randomly selected sites along the Lake Erie coast.

6.2.5.4 Exotic / Invasive Benthic Organisms

Zebra mussels and quagga mussels are mollusks native to the Caspian Sea region of Asia. The zebra mussel was discovered in Lake Erie in 1988 and the quagga mussel was first sighted near Lake Erie in 1989. Both mussels are expected to be present within the boundaries of the project area. Quagga mussels have the ability to be more of a nuisance than zebra mussels because they appear to be able to tolerate a wider range of temperature and water depth and are able to thrive directly on sandy or muddy substrates. Like zebra mussels, they are capable of filtering large amounts of phytoplankton and suspended sediments from the water column, which reduces the food resources for zooplankton and bottom-dwelling organisms. This reduction in food for native benthic organisms can result in an undesirable effect on the entire food web. Also, both species accumulate contaminants within their tissue, which increases the exposure to other species like fish and ducks that consume them.

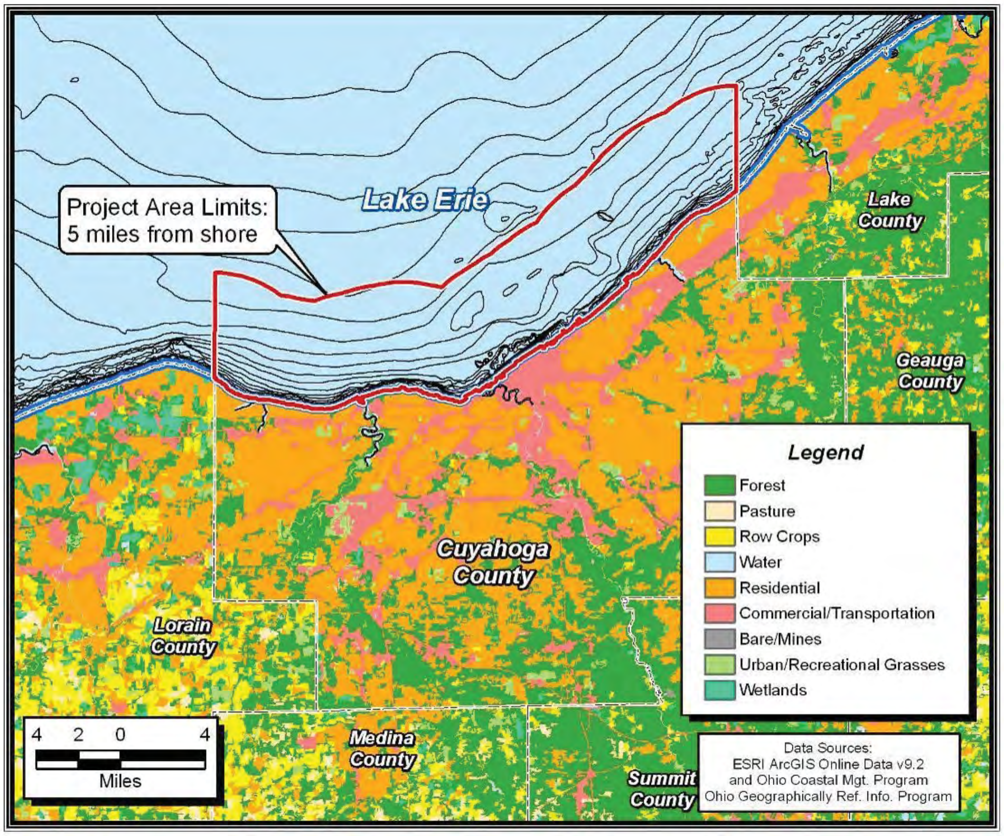
The New Zealand mudsnail (Potamopyrgus antipodarum) was found mid-lake north of Vermillion, OH in Lorain County in 2005 and is considered established. In the Great Lakes the snail can reach very high densities and can be found at depths of 4 to 45 meters on silt and sand substrates, but prefers silt and organic matter substrates in the littoral zones in lakes. The snail is a grazer that may potentially out-compete other native grazers and inhibit colonization by other macroinvertebrates.

6.2.6 Onshore Habitat and Terrestrial Communities

The on-shore habitat concerns would be concentrated at the point where the cable connecting the wind farm would connect to the existing grid system or new facilities housing electrical-conducting equipment such as transformers. The location of the interconnection remains to be determined, however it will most likely be somewhere within the urbanized Cleveland city limits.

The coastal habitat is located within the Erie Lake Plain eco-region. This eco-region is a nearly level strip of lacustrine deposits interspersed with beach ridges and swales. The annual growing season is several weeks longer than inland areas because of the lake-modified climate. Much of the coast in the project area is developed as an urban-industrial use with their associated impervious surfaces. Thus, land cover is primarily high and low intensity developed with some grassland areas (see Figure 6-7).

Figure 6-7: Land Use in Cuyahoga County



There are several “Protected Lands” within the project area. The one ODNR Protected Land is the Cleveland Lakefront State Park. The Non-ODNR Protected Lands are lands protected for conservation purposes and include several Cleveland Metroparks, Confined Disposal Facility (CDF) 12 and CDF 14 or “Dike 14”.

Territory from nine counties in Ohio is included in the state's designated Coastal Management Area. Those counties include, from west to east, Lucas, Wood, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, Lake and Ashtabula. Under Ohio Revised Code Section 1506.01 (A), the designated Coastal Area includes the waters of Lake Erie, the islands in the lake, and the lands under and adjacent to the lake, including transitional areas, wetlands, and beaches. The designated Coastal Area extends in Lake Erie to the international boundary line between the United States and Canada and landward only to the extent necessary to include shorelands, the uses of which have a direct and significant impact on coastal waters as determined by the director of natural resources. Within Cuyahoga County, the coastal management boundary extends inland on average from about one-eighth mile to one-quarter mile, but continues to incorporate lake-influenced tributaries, embayments, wetlands and estuarine areas. In urban areas, the coastal boundary is generally less than one-half mile from the shore.

Terrestrial wildlife will vary considerably depending on the land use. In urban areas, there will not be many concerns regarding wildlife impacts. Most organisms are mobile and would be able to relocate away from construction activities and are expected to re-colonize the area post-construction. Potential vegetation impacts are avoidable because plants can be identified in advance and either avoided or relocated.

6.2.7 Threatened and Endangered Species

Federally-listed species in Cuyahoga County include the Indiana bat (Myotis sodalis; endangered) and piping plover (Charadrius melodus; endangered). The bald eagle (Haliaeetus leucocephalus), present in the county, was just recently delisted by The Department of Interior. The Service will work with ODNR to monitor eagles for at least five years, as required by the Endangered Species Act. Avian concerns are addressed in Section 6.1 of this document.

Of the state-listed plant species located in Cuyahoga County, there are 23 wetland plants that could potentially be present within the project limits (see Appendix B, GLWEC Initial Ecological Assessment). Only four plant species have been recorded within the project area (see Appendix C GLWEC Initial Ecological Assessment). It is unlikely that these plant species will be present at the probable location of interconnection given the urban nature of the landscape. Of the state-listed animal species, the Canada darner (Aeshna Canadensis), a state endangered dragonfly, is the only one likely to be located within the study area. Due to the mobility of this species, this project will not likely impact this species (see letter response in Appendix C, GLWEC Initial Ecological Assessment). Four fish species that have state status are listed as having been located within the project area (most being last observed over 30 years ago).

6.2.8 Conclusion: Potential Impacts of Turbines on Marine Ecology

Given the small footprint of this Pilot Project (i.e., a 5-20MW facility with 2-10 turbines), the potential impacts to the water quality, benthic community and fishery will be minimized. At this time, there are no ecological concerns that would limit construction and operation of the Pilot Project. The highest potential for possible ecological impacts would be during construction. A summary of the potential ecological effects of off-shore wind farm development on existing habitats and species is summarized in Hiscock et al. (2002). Although the report was generated for facilities located in marine habitats, many of the potential concerns are analogous for freshwater habitats. Development of the wind farm involves pre-installation exploration, construction, operation and decommissioning, all of which can affect certain environmental factors and, consequently, impose potential ecological effects. The potential for impacts is greatest for construction and operation activities, therefore those impacts are described below in more detail.

6.2.8.1 Construction

Construction activities, such as building the foundation, disposal of excavated material and cable installation, will generate potential short-term impacts to the biota. Large reef structures could present a problem for siting the turbine foundations, however the artificial reefs discussed earlier are all within very shallow waters (less than 40 feet deep), are relatively small in area, and will likely not be in the area of proposed development. It could be argued that placing the turbines in the vicinity of the artificial reef would be best since the addition of another stable structure would only add to the artificial habitat and would already be in an established area easily avoided by commercial fisherman. However, it could also be argued that when siting the turbines an appropriate buffer around the reefs should be established so that fishing and diving activities are not impacted by the placement of the turbines in nearby waters. Short-term impacts would include physical disturbance of the lake bottom by removing the substrate and loss of benthic fauna and displacement of fish.

Impacts caused by the excavation of spoil can include smothering of benthic organisms, suspension of sediments, increases in turbidity, and changes to lakebed height and sediment dynamics. Of these, the increases in sediment suspension and turbidity would be considered short-term impacts and any impacts to the benthic community would be temporary and limited in spatial importance. The remaining impacts are considered longer term, however, given the small size of this project both of these impacts would be localized and neither would be expected to have effects on the dynamics of water currents, sedimentation or wave action outside the wind farm.

Cable installation effects include the potential electromagnetic disruption of larval and adult fish feeding and migration behavior. The concern of electromagnetic fields is usually minimized by using three-phase cables and burying the cable underground. No conclusive studies have been performed that demonstrate an electromagnetic effect (including no effects) on fish. On-shore disturbances from burying cable would potentially have short-term impacts to vegetation and animals present at the site. Surveys would be performed prior to this work to ensure that no rare plants or animals were being disturbed, though given the urbanized location, no impacts are expected.

6.2.8.2 Operation

The potential ecological effects of the wind farm are going to be predominantly from the physical presence of the turbines in the sediment and water column and above the water surface. Environmental factors that may be affected by the operation include noise and vibration, water flow, and the addition of artificial habitats.

Turbine noise and vibration are transmitted down the tower into the foundations and transmitted as vibration into the water column and sediments. Depending on the intensity, turbine noise may disturb fish. This project proposes to build only 2-10 turbines and should not be at a scale that would keep fish from moving around the structures to migrate and feed. The base of the tower and foundations will alter the local water flow across the sediment, resulting in scour and deposition changes. These impacts can be minimized by the spacing of the turbines. Concerns have been raised by ODNR about the disruption of water currents and the potential to affect feeding behavior of fish like yellow perch, migratory behavior of fish such as walleye, and possible deleterious effects to larval and young-of-year fishes. Changes in behavior of yellow perch could have some consequences on the commercial fishery. Unfortunately, not much is known about the effects of small-scale disturbances on water current and the potential impact to migrating fish. Because of the scale of this project, only localized disruptions of currents should result. It is not expected to have a significant impact on the overall current generated by the prevailing west-to-east winds and the near shore current flow to the east.

Increased surface area under water, by way of the addition of new substrate, would contribute to increased density of exotic organisms, including both zebra and quagga mussels, and likely the New Zealand mudsnail. Depending on the depth of the foundations, either mussel would be expected to colonize fairly quickly. There is also the potential for creating additional habitat for round gobies when building the foundations for the turbines. At the same time the foundations will likely provide additional habitat for some beneficial fishes for possibly food, shelter from predation, nursery areas and spawning. It has been documented that lake trout will spawn on artificial reefs within a few months of construction and, as was mentioned previously, yellow perch and smallmouth bass were observed using the artificial reefs located within the study area. This would provide additional recreational fishing opportunities by congregating the fish in one area. Additionally, a potential increase in the species richness, abundance or biomass of the benthic community may result from the introduction of a hard surface that was not present prior.

Another potential long-term impact that might become an issue is not being able to access the area if the wind farm becomes a restricted area. The ODNR is concerned about the

Department of Homeland Security (DHS) possibly establishing restricted or off-limits zones which would prevent recreational fishing and boating access off of Cleveland.

6.3 Geology

(*Unless otherwise indicated, information in this section from the GLWEC Geological Desktop Study, DLZ Ohio, August 2008).*

6.3.1 Introduction

A desktop study was carried out by DLZ Ohio to provide preliminary subsurface information for the Pilot Project site and, based on this information, to identify and evaluate potential foundation types suitable for supporting the Pilot Project.

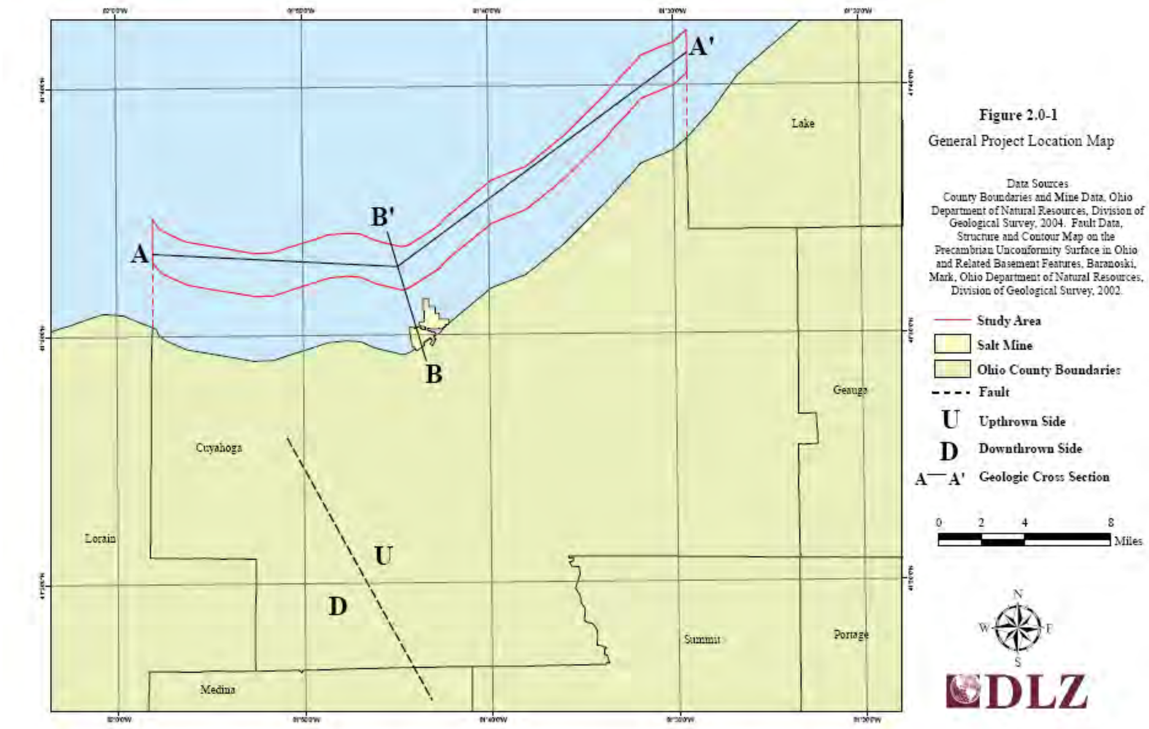
The results of this desktop study are contained in this section and present the geologic history and generalized subsurface conditions of the lakefront and offshore areas along the shore of Lake Erie in Cuyahoga County, Ohio. The findings are based on a review of existing literature, geologic references and other relevant information. In addition to the documented geologic, stratigraphic and lakebed conditions, this section also provides descriptions and preliminary recommendations and opinions regarding potential foundation alternatives for supporting wind turbines in Lake Erie up to approximately five miles off the Cuyahoga County shoreline.

Information in this section is not intended for use in final design. Additional geotechnical studies will be needed if the Project proceeds to design and construction.

6.3.2 Geological Conditions

The study area for the Pilot Project (Figure 6-8) lies in the Central Basin of Lake Erie and can generally be described as a band three to five miles (five to eight kilometers) off the Cuyahoga County shore. Geologic information within the Central Basin of Lake Erie has not been well documented by the Geologic Surveys of the United States, Canada, the State of Ohio or the Province of Ontario. While some limited information is available in the publications reviewed, much of the information was inferred from information collected from onshore data.

Figure 6-8: General Project Location Map



6.3.2.1 Physiographic Setting

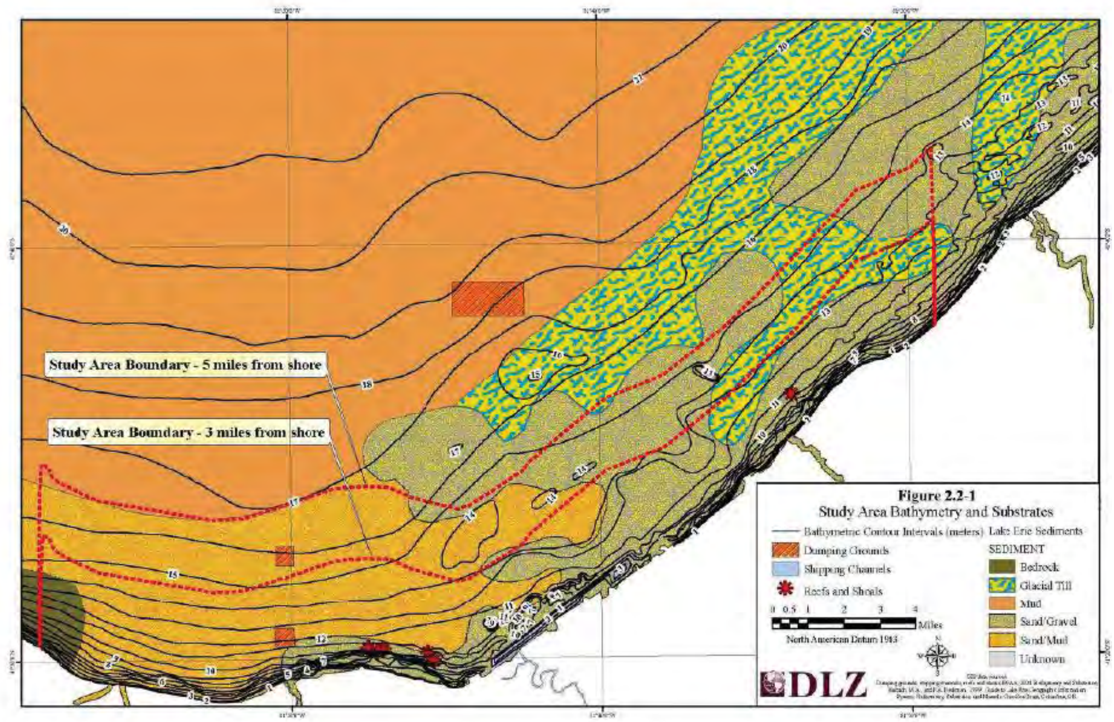
Cuyahoga County lies on the boundary between the Central Lowland and Appalachian Plateaus Physiographic Provinces. The shoreline and northern and western portions of the county fall within the Huron-Erie Lake Plane Section of the Central Lowland Province. The northern portion lies in the Erie Lake Plane Region of the section. This Region is characterized by the low relief features that were within or along the margins of Pleistocene Age lakes, which were the precursors of Lake Erie.

6.3.2.2 Lake Elevation and Bathymetry

The long term mean surface elevation of Lake Erie, based on data from 1860 to present, is approximately 571 feet above sea level. Over this same period, the average lake level has generally fluctuated between elevations 568 and 574 feet.

Bathymetric data collected for the mid-lake airport feasibility study suggest that, over most of the study area, the water depth is between 40 and 70 feet (12 and 21 meters) deep. The information also indicated that the bathymetric contours are roughly parallel to the shore. The water depths observed in the area three to five miles offshore for the airport feasibility study varied from about 40 feet (12 meters) to a little more than 50 feet (15 meters). These data are generally consistent with more recently compiled bathymetric contour mapping available from NOAA. Bathymetric contours off the Cuyahoga County shoreline are presented in Figure 6-9.

Figure 6-9: Study Area Bathymmetry and Substrates



6.3.2.3 Recent Sediments

Sediments were deposited during the postglacial period following Pleistocene, which is also referred to as the Holocene Epoch, approximately 10,000 years ago to present. These more recent sediments include soils derived from the weathering process of existing rock and sediments into finer particles. These sediments on land are typically the near surface soils derived from the breakdown of the parent rock and soil into finer material though physical and chemical weathering processes. These soils can also be the result of soil deposition by movement, colluvium, and deposition by flowing water, alluvium. The soils vary from clays to large boulders depending on the environment. Coarse grained sediments are found in the Rocky River Valley, east of Cleveland, where deeply incised stream channels result in the cleaving of larger rocks from the steeper side walls while the less energetic, nearly level, till plains around Cleveland are covered with finer grained soils developed in the tills and beach sands.

Lake sediments have been laid down over the older material from the previous epoch. These sediments also vary in consistency from very fine mud, organic muck and clays to sands and gravels associated with the beach environments. Rivers, streams and sewers flowing to the lake also contribute sediment to the lake bottom. In general, the higher the energy, the coarser the sediments encountered. Typically this translates into coarser sediments being found in shallow water with higher wave action and finer grained materials in deeper water with low water movement. Generally, boulders are not found in recent age sediments; however, rafting of near shore materials by ice is also a possibility. Due to the temperate nature of the climate in this epoch, the movement of large boulders by ice rafting is not likely. A detailed presentation of the postglacial sediments off the Cuyahoga County shore is shown in Figure 6-9 above.

6.3.2.4 Glacial Sediments

Near surface geological conditions of the area have been influenced by numerous factors over the ages. The most recent, regional reshaping of the area was the result of glaciation occurring during the Pleistocene. The Pleistocene, also referred to as the Ice Age, occurred between approximately 1.8 million to 10,000 years ago. During that period, the continental ice sheet moved across Ohio at least four times. Often, the later phases of glaciation remove or cover the features created by the earlier glacial activity. It is widely believed that, during this epoch, the basin, which contains Lake Erie, was gouged from an existing ancient river (Erigan River) valley by the movement of the ice sheet. Evidence of the glacial process in the lake is visible in the Glacial Grooves State Park on Kelley's Island where the limestone outcrop has been deeply incised by the ice movement (Figure 6-10).

Figure 6-10: Grooves in Limestone, Glacial Grooves State Park

Unconsolidated sediments that resulted during the Pleistocene can be classified into four general groups on the basis of the environment in which they were deposited. These types are tills, outwash, glacio-lacustrine (lakebed deposits) and glacial beach sediments. Tills are typically a mixture of fine and coarse-grained sediments laid down beneath the ice and in end moraines of glaciers. Outwash deposits are typically coarse sediments consisting of sands and gravels that are derived from flowing water and typically contain fewer fine-grained sediments. Outwash deposits can be large or can also be interspersed as layers or lenses within the tills. As the glaciers retreated out of the current basin in which Lake Erie is contained, lakes formed against the retreating ice margin and ice and sediment formed dams impounding the glacial melt water and precipitation in the basin. Sediments derived from these processes include the lacustrine sediments on the ancient lake bottom. These ancient lakes formed beaches along their shores at levels generally higher than the present lake level. West of Cleveland in Lakewood, prominent beach ridges are set back from one-half to three miles (0.8 to 5 kilometers) from and approximately parallel to the present day shoreline. Beach ridges have also been mapped east of Cleveland but are now concealed by dense urban cover. Depending on the energy of the beach environment in the area, sand and/or gravel beach deposits were formed along the ancient lake margins. In some cases, these deposits can be quite extensive. Generalized geologic profiles of the glacial sediments in the study area, both parallel and perpendicular to the shoreline, are presented in Figure 6-11 and Figure 6-12. The approximate alignments of the profiles are shown in Figure 6-8.

Figure 6-11: Generalized Geologic Cross Section (A-A')

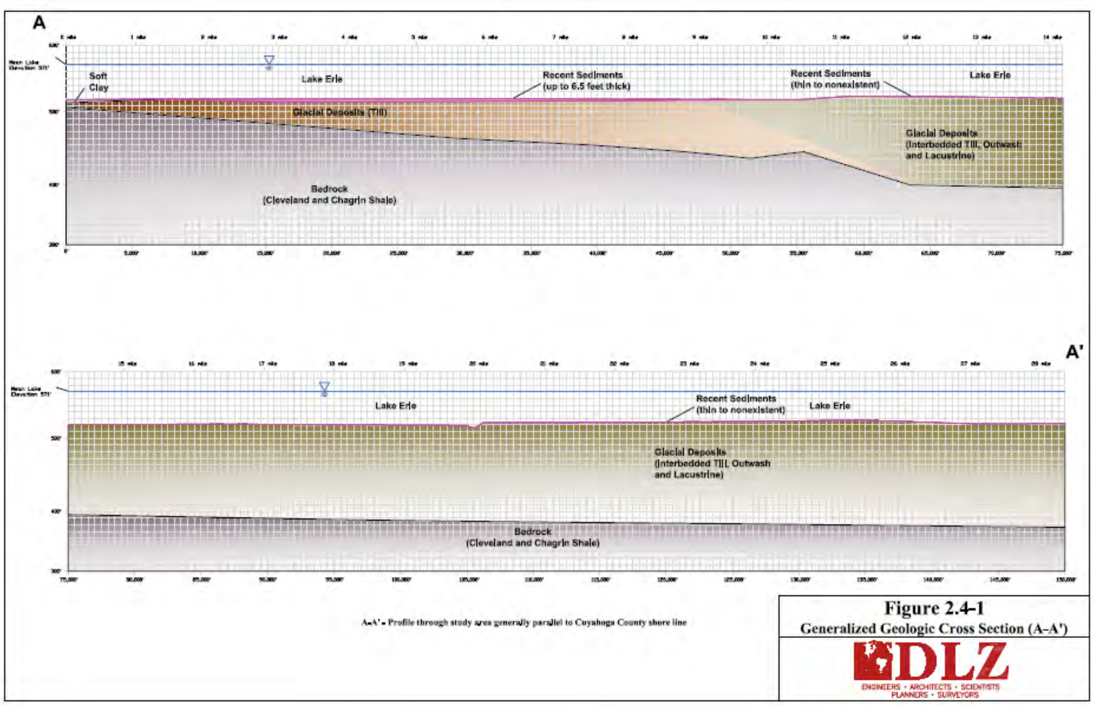
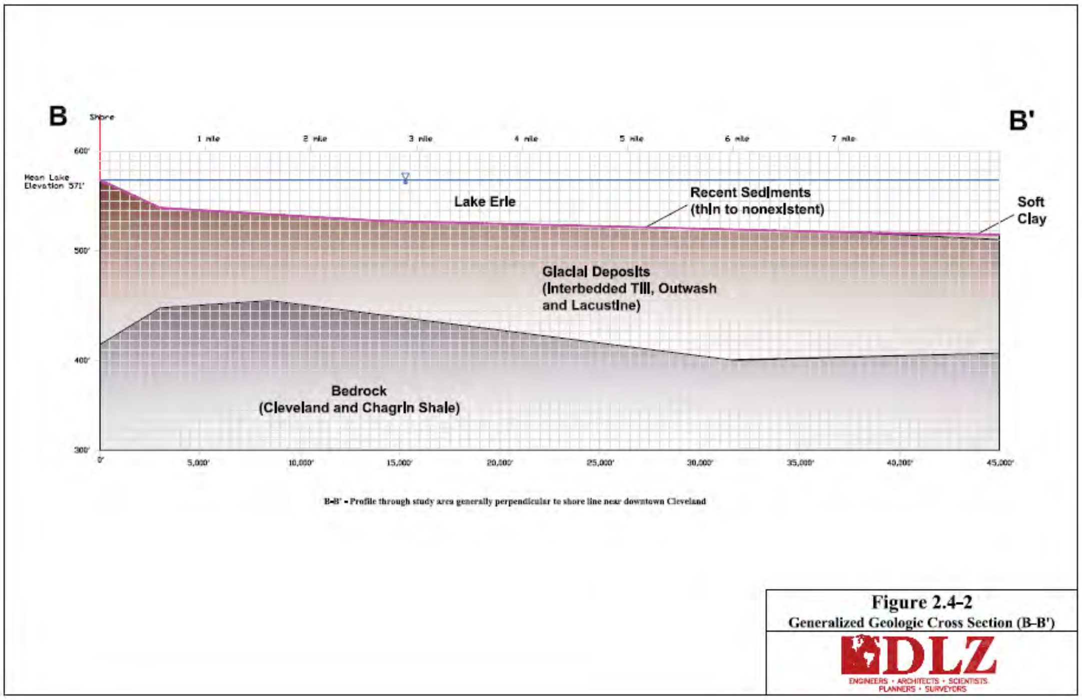


Figure 6-12: Generalized Geologic Cross Section (B-B')



The occurrence of boulders and cobbles in both tills and lacustrine sediments is also common. Individual large boulders, called glacial erratics, can be released from the ice in moraines or beneath the glacier. Boulders and cobbles can also be deposited as a somewhat discrete layer within the till as well. Cobbles to large boulders can also be encountered in lacustrine deposits. These are typically the result of sediments that are entrained in the ice and released as the ice melts. These large coarse sediments could also have been rafted into the lake by icebergs, which then released the sediments as they melted some distance away from the retreating ice sheet. Glacial erratic cobbles and boulders ranging in diameter from several inches to more than six feet (0.1 to more than 2 meters) are widely scattered at the surface in Cuyahoga County.

6.3.2.5 Bedrock

Due to depositional and erosion processes, the youngest bedrock encountered in northern Cuyahoga County and within the bounds of the County within the lake is Devonian in age, approximately 360 million years before present. The uppermost Devonian bedrock units off the Cuyahoga County shoreline include the Cleveland, Chagrin and Huron Members of the Ohio Shale formation. In the study area, the surface of these units typically ranges from elevations of 400 to 500 feet (122 to 152 meters) above mean sea level with their lower contact with the Hamilton Group bedrock more than 350 feet (107 meters) below mean sea level near the shore. However, due to the tilted bedding of the bedrock, the elevation of the bottom of the shale units may be around 300 feet (91 meters) above mean sea level near the Canadian border. The approximate top of bedrock profile within the study area is presented above in Figure 6-11 and Figure 6-12.

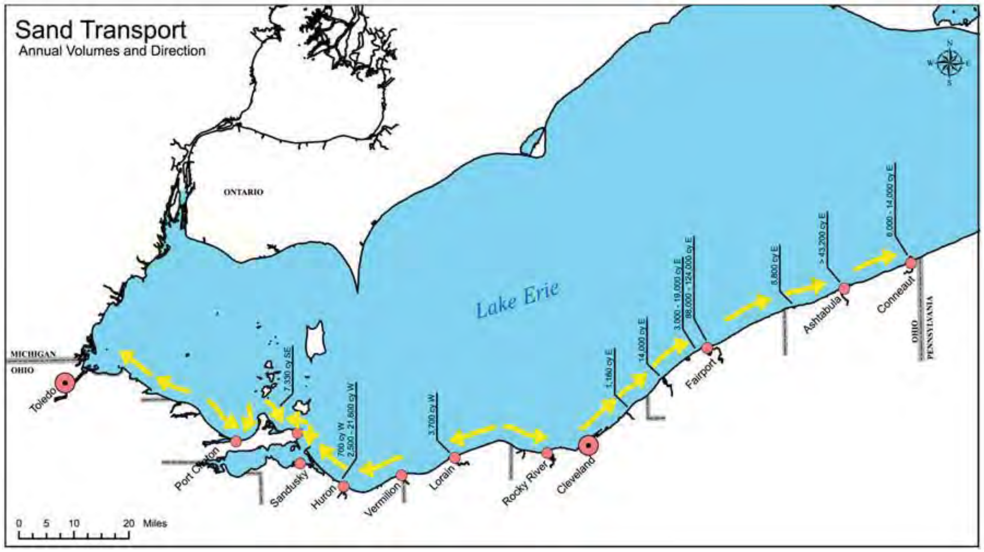
The underlying Hamilton Group includes the Olentangy Shale as its basal unit. Ohio Department of Natural Resources (ODNR) structure maps of the area indicate that the contact between the Olentangy formation and the underlying Onondaga limestone is between 300 and 480 feet (91 and 146 meters) below sea level from the northwest corner to southeast corner of the study area, respectively. The bedrock below these formations includes, in descending order, the Devonian Delaware group, Dundee Formation and the Silurian units Bass Island Formation and seven sub units of the Salina Formation, units A though G. The base of the Salina in the Cleveland area lies at an elevation of in excess of 2,000 feet (610 meters) below the ground surface.

In the Cuyahoga river valley of downtown Cleveland and the coastal area north of Cleveland, salt resources of the F unit of the Salina have historically been mined from a depth of approximately 1700 feet (518 meters) below the ground surface. The Cleveland salt mine extends from downtown Cleveland approximately 2.3 miles north beneath Lake Erie. The mine is operated from the Whiskey Island Peninsula just west of the Cuyahoga River. A majority of the mined area is located beneath the lake as depicted on Figure 6-8. Maps of the Cleveland mine indicate that it is a room and pillar configuration with columns remaining to support the overlying rock. The mine reportedly exploits the upper halite (rock salt) deposits of the Salina Formation. The mining activities, based on the reported depth and location of the mine, are not anticipated to affect the site selection or foundations for the Pilot Project.

6.3.2.6 Coastal Processes

The term coastal processes refer to the normal evolution of the near shore environment due to natural and manmade influences. The driving force in the coastal process is water action in the near shore environment. This includes wave action and near shore currents. These activities account for the breakdown of rock and sediment and the transport of the sediment in the near shore environment. As depicted in Figure 6-13 below, the littoral currents (near shore currents) move sediments along the shoreline. In the Cleveland area this movement is from west to east.

Figure 6-13: Sand Transport Map

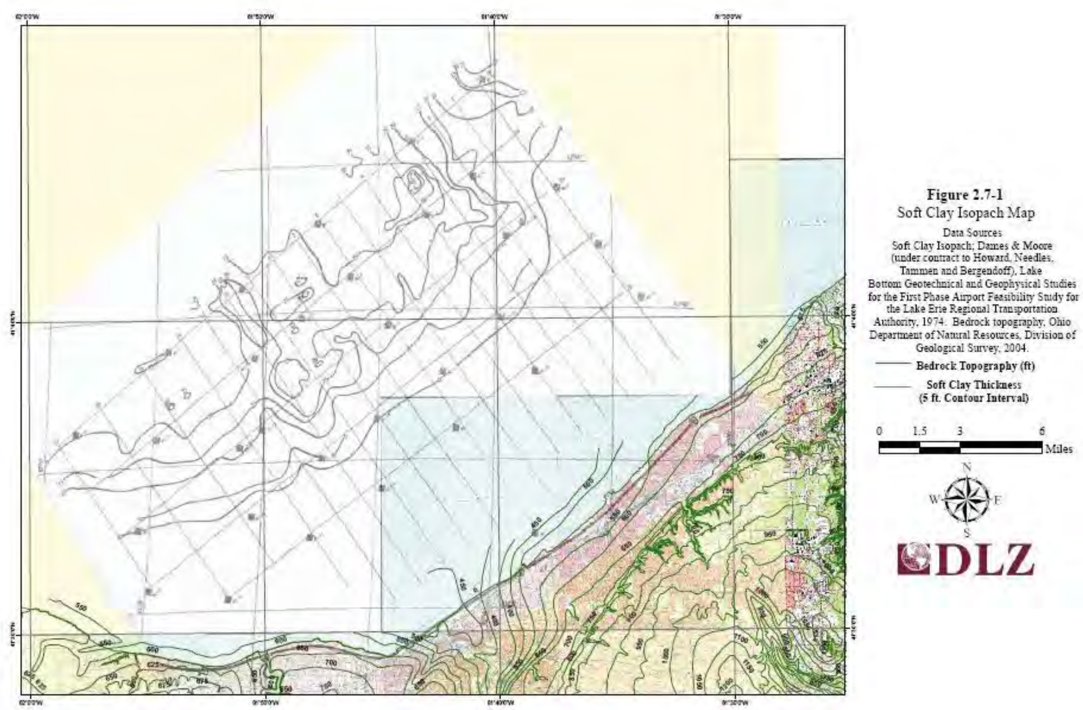


The movement is a natural process, which transports sediments from one location to another, resulting in erosion in some areas and deposition in other areas. The natural erosional processes have also been altered by man through the installation of near shore current obstacles including marinas, jetties, breakwaters, and groins or altering the lake floor by dredging. Changes to the littoral currents by these manmade alterations have larger impacts away from the structures. Installation of groins and jetties result in sediment accretion on the up current side while sediment erosion occurs on the down current side.

Lake floor conditions have been documented in the area of the proposed Pilot Project by several other investigations. These have included a mid-lake airport feasibility study, offshore sand resource studies and a wider ranging seismic reflection and vibracore study of the regional geology of the southern Lake Erie bottom off the Ohio shore. Probably some of the best available subsurface information in Lake Erie near Cleveland is presented in the 1974 geotechnical report prepared by Dames & Moore for the Airport Feasibility Study.

The Dames & Moore study included geophysical surveys, vibracores and soil borings. The vibracores extended as deep as 40 feet (12 meters) while the soil borings ranged from 70 to nearly 100 feet (20 to 30 meters) below the lake bottom. The study area for the airport feasibility exploration can be generally described as a rectangular area approximately 10 miles wide by 20 miles long (16 by 32 kilometers), beginning 3 to 5 miles (5 to 8 kilometers) from shore and generally parallel to the Cuyahoga County shoreline. Vibracore studies conducted in this area indicated that soft clay deposits covered the northernmost portion of the floor of the lake within the study area. The extent of the soft clays is illustrated in Figure 6-14.

Figure 6-14: Soft Clay Isopach Map



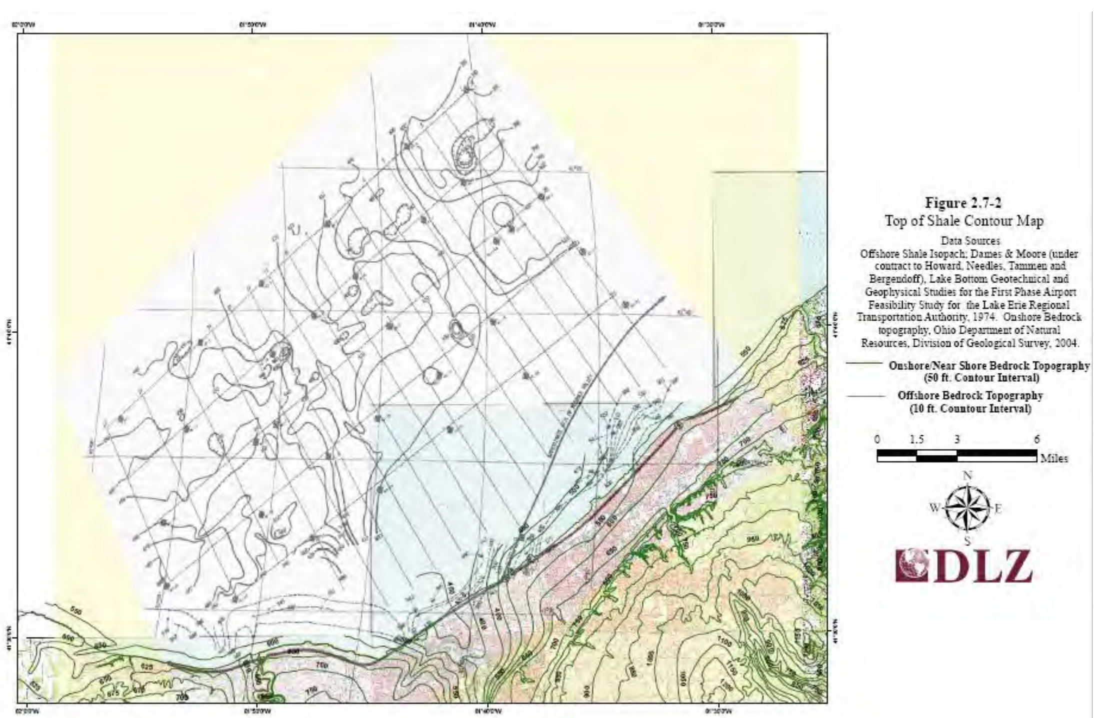
A majority of the study area was covered with stiff to very stiff silty clay. Analysis of the cores from this study suggested that the soft clays would not be adequate to support the high fill that was proposed for the airport. A medium stiff silty clay layer typically lies beneath the soft clays and appears to be a transition layer between the stiff to very stiff silty clay with small gravels (glacial till) that lies below. Both materials were assessed for the airport study, which found that, while the intermediate material was relatively compressible, the underlying silty clay with sand and small gravel had good shear strength at depth. In addition, consolidation tests conducted on these deeper soils indicated that they are preconsolidated and have moderate compressibility. The airport study also indicated that sand, gravel and silt are interspersed in the area and was reported to generally occur in thin layers.

Sand resource studies in the same area indicate similar findings; however, the depth of these investigations was only between 10 and 20 feet (3 and 6 meters) below the lake floor. The sand survey also indicated the presence of soft to medium stiff silty clays. One boring in the study area encountered hard silty clay with minor gravel at a depth of 10 feet (3 meters) below the lake floor.

A geophysical and vibracore study was performed in the Ohio waters of Lake Erie from Marblehead to Conneaut in 1977 and 1978 under direction of the Department of the Army, Coastal Engineering Research Center. This study found that postglacial sediments, about three miles offshore from Cleveland west to Lorain, ranged from 0 to 6.5 feet (0 to 2 meters) in thickness and consisted mainly of soft mud. From Cleveland, east to the Grand River in Lake County, the study indicated the lake floor consisted of glacial till and generally lacked appreciable postglacial sediment. East of the Grand River to Conneaut, postglacial sediment thickness five to six miles offshore ranged from approximately 30 to 50 feet (9 to 15 meters), consisting of "muddy sand" and "sandy mud".

Results of seismic surveys and exploratory borings conducted for other studies indicate that bedrock (shale) is generally encountered at elevations of between 400 and 500 feet (122 and 152 meters) above sea level within the study area. The bedrock topography in the study area, compiled from various sources, is presented in Figure 6-15.

Figure 6-15: Top of Shale Contour Map



Based on the investigations conducted previously, conditions on the lake floor can vary considerably over relatively small intervals of depth and horizontal distance.

6.3.3 Natural Hazards

6.3.3.1 Natural Gases

In Cuyahoga County, the Cleveland and Chagrin Shales are known to contain pockets of gas. Encounters with natural gas have been recorded in several exploratory borings for tunnel projects at locations scattered around the greater Cleveland area. The gases are typically encountered in borings extending 150 to 300 feet (45 to 90 meters) in depth and penetrating 50 feet (15 meters) or more into the rock formations. Natural gas has also been observed within porous, granular horizons in the glacio-lacustrine sediments and glacial tills overlying the Chagrin Shale.

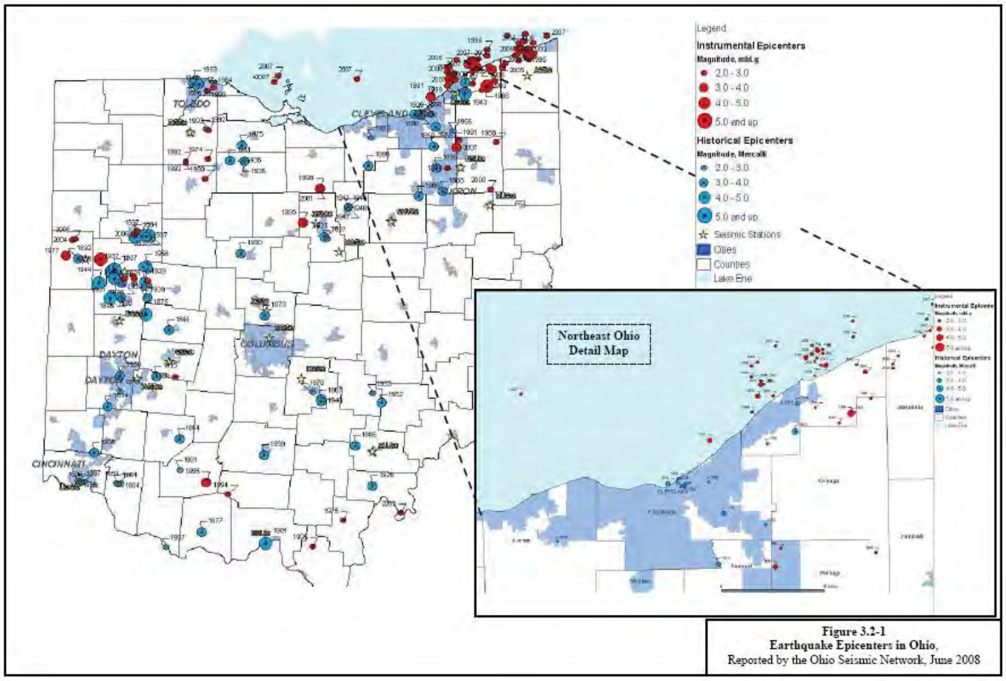
Gas concentrations during exploratory drilling are typically monitored by measuring the Lower Explosive Limit (% LEL). The LEL measurements respond to several types of combustible gases including methane (CH4), which is believed to be a major constituent of the natural gases encountered. Hydrogen sulfide (H2S) and carbon monoxide (CO) gases have also been detected.

Often, the quantity/concentration of gas is low enough that exploratory drilling operations are unaffected. However, in some cases drilling operations were suspended from a few hours to a few weeks to allow the gas to dissipate. In a few extreme cases, gas and drilling fluids were expelled to heights of 30 to 40 feet (9 to 12 meters) above the ground surface.

6.3.3.2 Seismicity and Faults

Compared to seismically active areas of the United States (California or Alaska), Ohio has relatively few earthquakes. The most frequent and damaging earthquakes in the state have originated in the vicinity of western Ohio at Anna in Shelby County. During the last 100 years, this area has experienced more than 30 earthquakes. The decade of the 1930s was the most active period. During this time, 23 events were recorded, including the most severe shock ever recorded in Ohio. Figure 6-16 shows the earthquake epicenters in Ohio including the Anna area. Other areas of earthquake activity include northeastern, southeastern, and other western areas of Ohio. Most of these have been of minor intensity, causing little or no damage.

Figure 6-16: Earthquake Epicenters in Ohio



Within the past three years, the Ohio Seismic Network has reported approximately 27 small quakes in Lake Erie. Generally these quakes are about magnitude 2.0-3.8. These quakes are typically shallow and centered about 3 to 6 miles (5 to 10 kilometers) below the ground surface. The epicenters of the seismic activity appear to be located outside of the Cuyahoga County borders in the lake. Like most quakes reported in Ohio, these are considered to be minor and often result in little to no damage. According to the Ohio Seismic Network reports, these quakes are detected by seismic stations but are typically not felt by humans.

Historic quakes have been reported in close proximity to the study area. These were all identified along the Cuyahoga River Valley by the National Center for Earthquake Engineering Research. Five quakes dating from 1836 to 1924 were estimated to have had magnitudes of between 2.9 and 3.3.

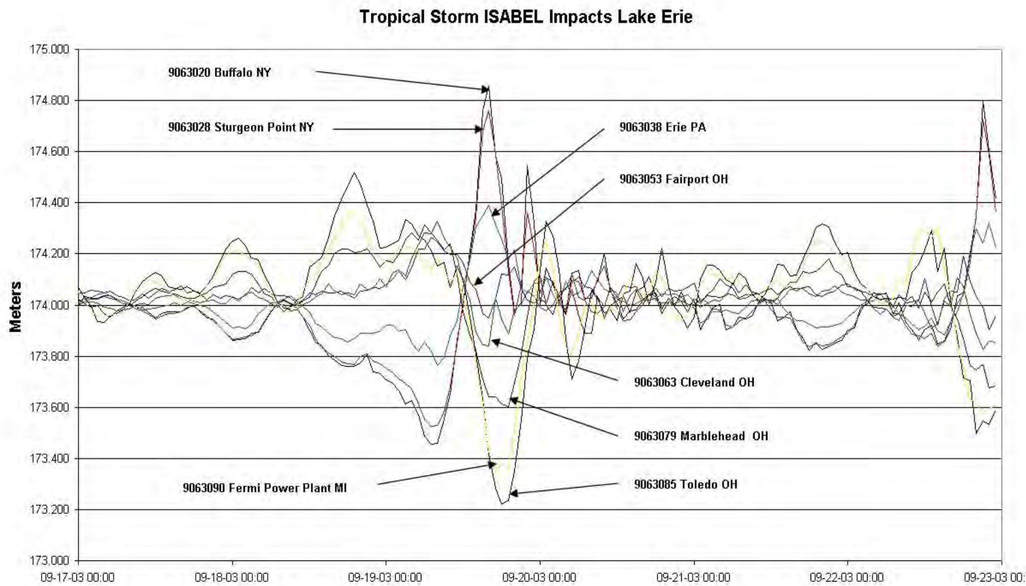
Although seismically active areas and faulting are known to exist in some portions of Ohio, faults are generally not mapped in this area of the State. An exception to this is the Middleburg fault. The Middleburg fault is located in western Cuyahoga County and extends from just south of the Medina County line north-northeast to a point approximately 3 miles inland from the Lake Erie shore. The mapped location is provided on Figure 6-8. The fault originates in the Precambrian unconformity in excess of 4,500 feet (1,370 meters) below mean sea level. The Middleburg fault is a normal fault with the up thrown block on the eastern side of the fault. The fault was reported and named in a 1982 paper by John Gray et-al identifying Devonian-age gas shales. Information reviewed from the Ohio Seismic Network indicates that no documented earthquakes have originated in the area of this fault.

6.3.3.3 Waves and Seiche

Although tidal influences do affect the lake, more significant variations in lake level are caused by wind driven waves. The long axis of Lake Erie is roughly aligned with the predominant east-west wind direction. The presence of higher wind velocities across the lake causes an increase in wave amplitude. Wave conditions reported by the NOAA National Data Buoy Center observations at Station 45005 - W ERIE, 28 nautical miles Northwest of Cleveland, Ohio (41.68 N 82.40 W) (41°40'36" N 82°23'54" W) reported swells of as much as 12.8 feet (3.9 meters) between the wave peak and trough (see also Section 6.4.4.7 for further information).

While wave amplitude is a localized interaction of the wind action and barometric pressure on the water, a regional phenomenon known as seiche is also associated with the wind action on the shallow lake. Seiche is the result of the water mass of the lake being mounded on the one end of the lake by wind action and/or barometric pressure differential and then oscillating back to the other end of the lake. The phenomenon is most easily demonstrated with a long shallow pan filled with water being tipped slightly to one end and then leveled to induce a wave. The water in the pan oscillates from end to end until the energy is dissipated. Seiche within the lake has been recorded and an example of seiche as recorded by NOAA stations along the lake is presented below. Seiche combined with wind driven waves have been reported to raise the water level as much as 22 feet (6.7 meters) in Buffalo, New York. NOAA reports that the typical period of the seiche oscillation is approximately fourteen hours in Lake Erie. Conditions reported by the Cleveland NOAA observation station 9063063, shown below in Figure 6-17, show significantly less dramatic affects of seiche due to its location a near the mid point of the lake.

Figure 6-17: Oscillation and Storm Surge on Lake Erie, 17-22 September 2003

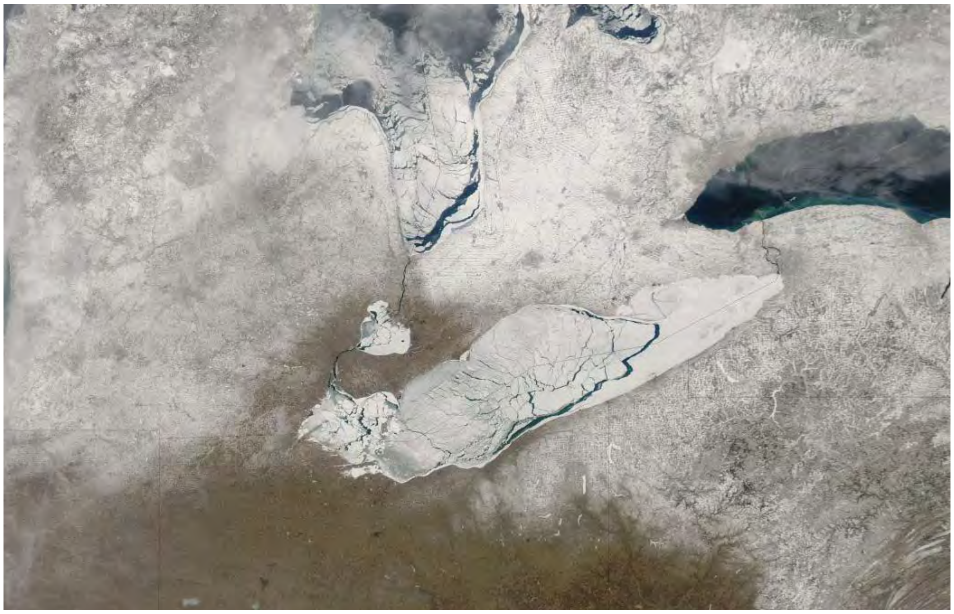


Rogue waves, also known as freak waves, are unique waves that are distinguished by an instant, singular and unexpected wave profile with an extraordinarily large and steep crest or trough. Rogue waves are rare phenomena that have been reported in Lake Erie. NOAA is engaged in research of rogue waves in the Great Lakes; however, at this time, limited research has been completed and published. The ODNR has indicated the following: “There are several recorded instances of so-called "rogue" waves that have suddenly swamped a comparatively small area of Lake Erie shoreline. None of these events have been associated with earthquakes and all have been confined to a local area of shoreline.”

6.3.3.4 Generalized Ice Conditions

Lake Erie lies in the northern part of the temperate zone of North America and is subject to the seasonal temperature variations associated with the climate. During the late fall and winter months, sub freezing temperatures are common to the region. Of the Great Lakes, Lake Erie is the shallowest and has the greatest surface area to depth ratio. Therefore, Lake Erie has the least thermal mass and is subject to freezing earlier and more completely than the other Great Lakes. Historically the lake has had 100 percent ice cover as shown in the following NOAA satellite image.

Figure 6-18: Satellite Image of Lake Erie with near 100% Ice Coverage (9 March 2007)



Lake ice is also subject to the same wind driven forces as the water. The predominant west to east wind flow drives ice into the eastern basin and the Niagara River. To combat the affects of ice on the easternmost shoreline of the lake and the mouth of the Niagara River, a joint Canadian-United States project using an ice boom constructed of steel pontoons has successfully been used to suppress ice movement into the bay. In addition, the predominant west to east ice flows, wave action, near shore currents and wind also move lake ice in other directions impacting the physical features of the lake bottom and coastline. Ice thickness on the lake varies with air temperature, lake temperature and precipitation; however, the affects of ice, even less that a few feet thick, can be dramatically compounded by the formation of ice ridges. Ontario Hydropower documented ice ridge formation in an investigation in February 1982. Video images of ice less than three feet (one meter) in thickness formed a ridge approximately 33 feet (10 meters) high. During formation of the ice ridge, wind driven lake ice was forced under the leading edge of the ridge and driven into the lake bottom, at a reported depth of nearly 65 feet (20 meters), before breaking off the ice sheet and adding to the ridge from beneath. Figure 6-19 illustrates an ice ridge in Lake Erie.

Figure 6-19: Near Shore Ice Ridge

A geophysical survey conducted in the area of the documented ice ridge indicated extensive lake floor disturbance had occurred. The survey, conducted in the spring of 1982, indicated that an area measuring 1.5 miles (2.5 kilometers) long by 100 feet (30 meters) wide and up to five feet (1.5 meters) deep had been gouged into the lake floor during the formation of the ice ridge. Water depth in the area was found to be between 52 and 62 feet (16 and 19 meters).

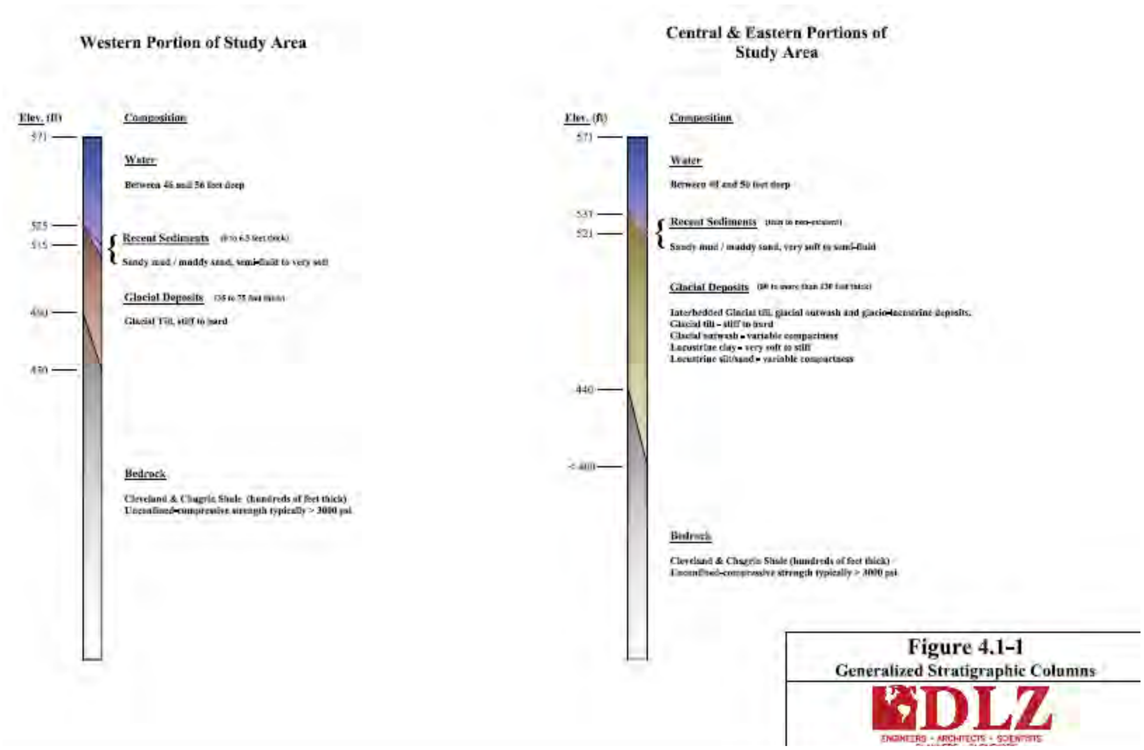
6.3.4 Preliminary Geotechnical Assessment

Selection of a suitable foundation for supporting offshore wind turbines depends upon a variety of factors including subsurface conditions, water depth, loading conditions, environmental considerations and cost. This section is focused on identifying feasible foundation alternatives for the site conditions anticipated based upon the geologic and geotechnical information and data presented in the preceding sections and the following paragraphs.

6.3.4.1 General Stratigraphy

The area under consideration for potentially siting wind turbines is generally three to five miles (five to eight kilometers) off the Cuyahoga County shore. The water depth in this area ranges from approximately 40 to 55 feet (12 to 17 meters). Generalized geologic references report the stratigraphy in the area to consist of recent lake sediments overlying a complex system of interbedded glacial till, glacial outwash and glacio-lacustrine silts/clays associated with the advancing and retreating ice margins during the Pleistocene glaciation, as well as beach deposits of sand and gravel from various ancient lake stages. Shale bedrock is present beneath the glacial deposits. Generalized stratigraphic columns are presented on Figure 6-20, one for the area generally west of the boundary between the Cities of Cleveland and Lakewood and one from that point east representing the central and eastern portions of the study area. The stratigraphy is characterized in more detail in the following paragraphs.

Figure 6-20: Generalized Stratigraphical Column



Recent Sediments

As discussed previously herein, recent sediments are those materials deposited following the last glaciation (i.e. within about the last 10,000 years). The texture of the recent sediments at a given location is essentially a function of the energy of the environment in which they are laid down. Coarser grained materials are found in the lake, for example, in shallow waters with high wave action or near the mouths of fast flowing streams. In the low energy, deeper water environment a few miles (several kilometers) offshore, the sediments are correspondingly finer grained. Generalized geologic references and studies characterize these recent sediments as “sandy mud” and “muddy sand.” They are usually very soft or even semi-fluid and essentially incapable of supporting load. West of Cleveland within the study area, these materials are reportedly up to 6.5 feet (2 meters) thick while to the east, they are very thin or nonexistent.

Glacial Deposits

The four types of glacial or glacial related deposits are tills, glacio-lacustrine (lakebed deposits), outwash and glacial beach sediments. Large glacial erratic boulders are also commonly present in glacial till deposits and lacustrine sediments of glacial origin. Beaches and dune ridges formed on the shores of ancient lakes when water levels were significantly higher than at present. Consequently, these deposits are located at higher elevation on the Lake Plain south of the present day Lake Erie shore. Generalized descriptions and characteristics of the other types of glacial deposits are presented in the following paragraphs.

Glacial Till

Glacial till is an unsorted, unstratified mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by the ice. Characteristics of individual tills tend to remain relatively constant over limited areas.

Glacial tills in the Cuyahoga County area are generally over-consolidated, stiff to hard in consistency and have low compressibility. They are often capable of providing allowable bearing capacities of several thousand pounds per square foot (200 to 500 kilopascals) with relatively small post-construction settlement.

Glacio-Lacustrine

Glacio-lacustrine deposits generally consist of stratified deposits of fine-grained sand, silt and clay that were laid down in lakes which formed against the retreating ice margin. Where encountered, these deposits usually overlie glacial till but may also lie directly on bedrock. Lacustrine clays are generally of moderate to high plasticity and are often laminated.

Lacustrine clays are not usually as strong as glacial tills, typically ranging from very soft to stiff consistency, have higher moisture content and are more compressible. Lacustrine silts and fine sands are often of very loose to loose compactness. Lacustrine deposits can also be stiffer or more compact; particularly where they are interbedded with tills due to re-advances of the ice sheets. Compared to tills, lacustrine deposits generally provide lower bearing capacity and allowable loading is likely to be governed by the settlement tolerance of the proposed structure.

Glacial Outwash

Outwash materials are typically laid down by flowing water from glacial melt water and precipitation within the basin as the glacier retreats. As such, these deposits are coarser, consisting primarily of sand and gravel, and contain a lesser fraction of fine-grained sediment. Outwash deposits can be extensive or interbedded as layers or lenses within tills.

These coarse sediments generally possess excellent frictional characteristics and provide good bearing support for foundations when confined. Settlement of foundations supported on these relatively "clean" granular deposits can be expected to occur rapidly upon application of load, essentially during construction for dead loads, and is a function of the in-situ compactness of the deposit.

Bedrock

Beneath the recent sediments and/or glacial deposits, the underlying bedrock consists of the Devonian age Cleveland, Chagrin and Huron Shales of the Ohio Formation. Old preglacial valleys are present offshore of downtown Cleveland and to the east within the study area. In these old buried valleys, the shale is generally more than 100 feet (30 meters) below the lakebed and unlikely to significantly affect foundation selection. However, the offshore bedrock surface rises in elevation towards the west. This trend is in evidence onshore where shale cliffs line the shore in the western part of Cleveland. Offshore of the westernmost part of Cleveland and continuing westward to the Cuyahoga County line, shale is documented in the study area (3 to 5 miles/5 to 8 kilometers out) as little as 40 feet (12 meters) below the lakebed and could be shallower in places.

The upper part of the Ohio Formation, the Cleveland Shale and Chagrin Shale, is the only bedrock strata likely to be encountered by any potential wind turbine foundation. The strike of these members in Cuyahoga County generally trends northeast to southwest. Beds and laminations are typically planar and dip to the southeast less than five degrees below horizontal.

The Cleveland Shale generally ranges from 20 to 60 feet (6 to 18 meters) in thickness. It is typically dark gray to black, thin bedded and weathers to a brown, laminated, fissile material. The Cleveland Shale contains pyrite concretions and scattered siltstone and sandstone interbeds that are typically less than one inch (25 millimeters) thick. Joints in the Cleveland Shale are occasionally clay coated. The contact between the Cleveland and Chagrin Shales is characterized by a ½- to 1-inch (12 to 25 millimeter) thick pyritized fossil bed together with changes in color and material.

The Chagrin Shale is more than 400 feet (120 meters) thick and, when unweathered, consists of blue-gray clay shale in medium to thick beds. It is generally less brittle and fissile than the Cleveland Shale. The Chagrin weathers to yellowish-gray, very soft, clayey shale when exposed. Concretions and sandstone/siltstone interbeds are scattered randomly throughout the formation. Joints in the Chagrin Shale are often clay coated.

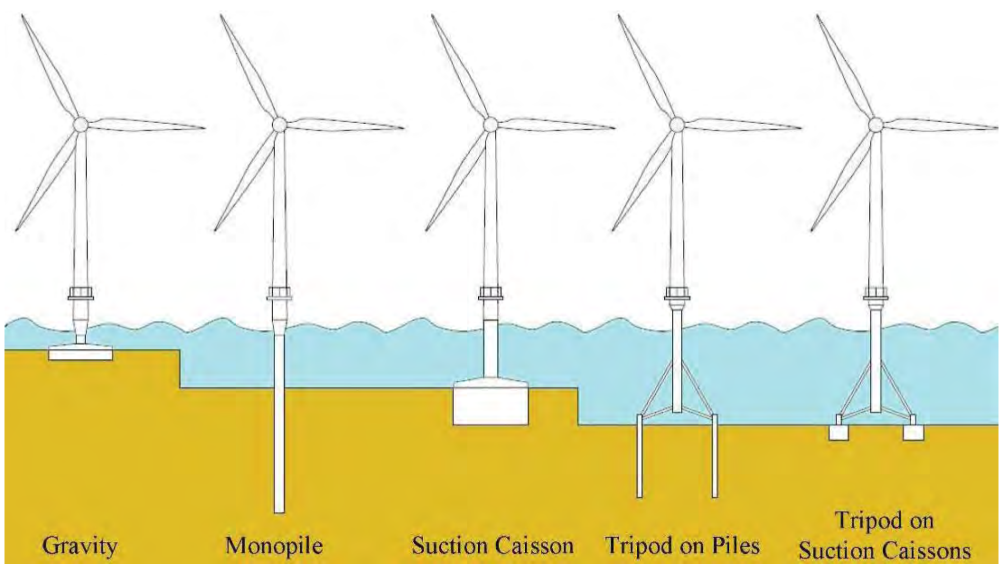
The unconfined compressive strength of intact cores of the shale typically ranges from 3,000 to 12,000 pounds per square inch (20 to 85 megapascals). However, weathered specimens may have compressive strength as low as a few hundred pounds per square inch (2 to 5 megapascals).

6.3.5 Foundation Types

The most common foundation types currently used for support of offshore wind turbines are monopile and gravity base foundations. Over the past several years, the Civil Engineering Research Group at Oxford University has performed considerable research relative to the design and installation of suction caissons for support of offshore wind turbines. In 2002, a full-scale prototype suction caisson was installed at the Aalborg University offshore test facility in Frederikshavn, Denmark to support an offshore wind turbine.

Piles, gravity and suction caisson foundations may also be used to support multi-legged or lattice structures in deeper water applications (greater than about 65 to 80 feet/18 to 24 meters) where monopiles or gravity/suction based monopods are typically inadequate. However, the slender structural members comprising the tower support frame are susceptible to damage from ice loads. These foundation types are illustrated schematically in Figure 6-21.

Figure 6-21: Schematic of Offshore Turbine Foundation Types



Research and development is also ongoing for floating/moored structures for support of single and multiple turbines in very deep water applications, greater than about 120 feet (35 meters) up to hundreds or even thousands of feet. Jacket foundations (lattice) are also employed especially in deep water applications.

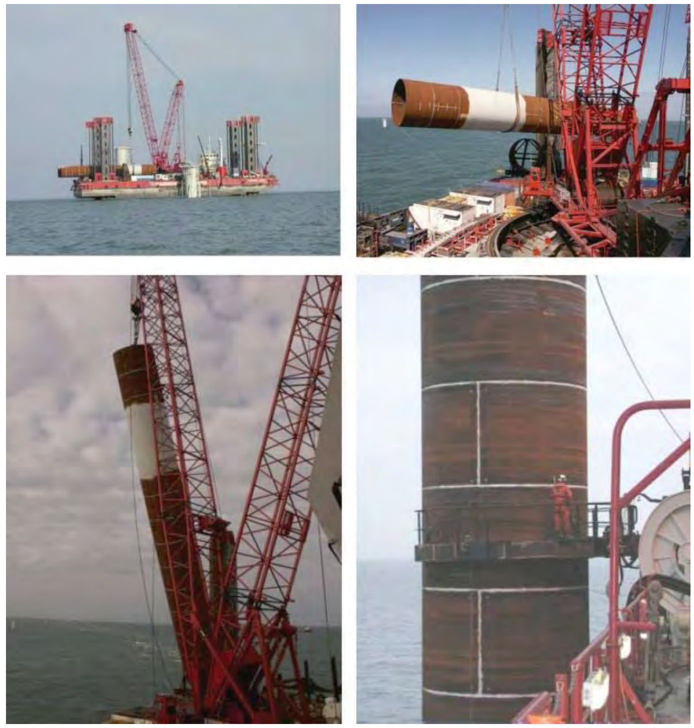
The Lake Erie waters three to five miles (five to eight kilometers) off the Cuyahoga County shoreline are generally no deeper than 55 feet (17 meters). For offshore wind turbines sited in this area, the commonly used monopile and gravity foundations as well as the currently developing suction caisson foundations are potentially applicable. More detailed descriptions of these foundation types, their applicability and some advantages and disadvantages of each are presented in the following paragraphs. A discussion of foundations for the Pilot Project can also be found in Sections 6.4.5 and 7.6.

6.3.5.1 Monopile

Most existing offshore wind turbines are supported on monopiles. The monopile foundation is a relatively simple design consisting of a large diameter (typically 10 to 16 feet/3 to 5 meters) steel pile. The piles are commonly transported on barges but can also be capped and floated to the installation site. The monopile is advanced into the lakebed by drilling, driving or a combination of both. The required penetration depth varies depending on the design loads, water depth and subsurface conditions but is typically in the range of 3.5 to 4.5 times the pile diameter in stiff clay and 7 to 8 times the diameter in softer soil.

Monopiles are generally suitable for use in waters up to 65 to 80 feet (20 to 25 meters) deep; however, the offshore wind industry is pushing these limits to support larger turbines in deeper waters than previously thought possible. In 2003, monopiles as large as nearly 17 feet (5.1 meters) in diameter and weighing more than 300 tons were used in water up to 85 feet (26 meters) deep to support seven GE Wind 3.6 MW turbines at Arklow Bank, Ireland. Some of the piles were driven more than 100 feet (30 meters) into the seabed.

Figure 6-22: Monopile Installation at Arklow Bank, Ireland



Thirty Vestas V90 3.0 MW turbines are supported on monopiles at the Barrow Offshore Wind Farm in the East Irish Sea. The piles at Barrow are 15.6 feet (4.8 meters) in diameter, up to 200 feet (60 meters) long, weigh nearly 500 tons and, in 2006, were installed in water up to 75 feet (23 meters) deep. Nine of the piles encountered refusal before reaching their design penetration depth. The soil and weak sedimentary rock within the piles was drilled out and the holes advanced below the bottoms of the piles allowing them to subsequently be driven to final depth. The drilling was accomplished with a BAUER BFD 5500 Flydrill; a drilling system especially developed by the German company BAUER Maschinen GmbH for installation of offshore monopiles in difficult conditions (see Figure 6-23). During drilling operations, the more than 80-ton Flydrill unit is supported directly on the partially driven pile. The drilling bucket is extended to the seabed within the pile by means of a telescoping kelly bar.

Figure 6-23: BAUER Flydrill

Monopiles are an attractive option in that they are relatively simple to fabricate, require little or no preparation of the lakebed and can be installed quickly. Conversely, specialized, heavy-duty equipment is required to install monopiles. Deep soft soil deposits may require excessive penetration depths and monopiles are not well suited to soils containing boulders. Finally, monopiles would be difficult to remove, should it ever be required for future decommissioning activities. It is more likely that they would be cut off at or slightly below the lakebed since complete extraction would be practically impossible due to the overwhelming resisting forces.

In the Great Lakes region, Tower Tech Systems, Inc. currently has the capability to fabricate monopiles at their Manitowoc, Wisconsin facility. From their location on the Manitowoc River, Tower Tech has access to Lake Michigan and, thus, all of the Great Lakes and, via the St. Lawrence, the Atlantic Ocean for shipping their products.

6.3.5.2 Gravity Caisson

Gravity foundations for offshore wind turbines generally consist of a large reinforced concrete base with a relatively slender stem extending above the water surface. The bases typically range from 40 to 60 feet (12 to 18 meters) in diameter or base width. For cold weather applications, a cone is typically incorporated in the design of the stem to reduce ice loads. As the name suggests, gravity foundations resist overturning due to their weight together with soil support on the downwind (compression) side of the foundation. Gravity foundations have been used predominantly in shallow water applications, typically less than 35 feet (10 meters). At greater water depths, monopiles generally become more economically attractive.

Two examples of gravity foundation supported wind farms are those at Middelgrunden and Nysted, Denmark. At Middelgrunden, the foundations are between 55 and 60 feet (16.5 and 18.5 meters) in diameter, range in total height from 26 to 37 feet (8 to 12 meters) and weigh nearly 2,000 tons each. Water depths at the Middelgrunden site vary from approximately 13 to 26 feet (4 to 8 meters).

Figure 6-24: Middlegrunden Gravity Caisson construction in Dry Dock

At Nysted, gravity foundations support 72 Bonus (Siemens) 2.3 MW turbines in 20 to more than 30 feet (6 to 9 meters) of water. The design of these foundations differed from those at Middelgrunden. Rather than a solid circular concrete base, the Nysted foundations were designed and constructed with open cell hexagonal bases and filled with ballast after positioning on the seafloor. The up to approximately 56-foot (17-meter) wide Nysted foundations weighed more than 1,400 tons before ballasting and approximately 2,000 tons after ballasting the base and hollow shaft with olivine, rock and sand. The bases are founded on stiff clay till generally 25 to 40 feet (7.5 to 12 meters) below the water surface.

Figure 6-25: Gravity Foundations Being Installed at Nysted, Denmark

Gravity base foundations can be founded on a wide range of materials but; due to bearing capacity and settlement considerations, are best suited for use where soil conditions are relatively uniform. They can also be placed on soil deposits containing boulders where the use of monopiles might be impractical or impossible. Gravity foundations have the further advantage of being constructed onshore using conventional means. Since they are founded only a few feet below the sea/lakebed level, gravity bases can also be completely removed upon decommissioning of the wind turbine.

Although having the advantage of onshore construction, gravity foundations require specialized, heavy lifting equipment for transport to the installation site. Another disadvantage of gravity bases is the significant sea/lakebed preparations necessary prior to placement. These include, but are not limited to, dredging of soft sediments and careful placement and leveling of a gravel pad upon which to place the foundation. These operations are generally expensive and become more so as water depth increases. Gravity base foundations are also more sensitive to scour from ocean currents than other foundation types; however, scour may be of less concern in the Lake Erie setting.

6.3.5.3 Suction Caisson

Suction based foundations for supporting offshore wind turbines have been adapted from concepts previously used in the offshore oil and gas industry for anchoring floating platforms. The geometry of suction caissons resembles that of most gravity foundations, consisting generally of a large diameter base (up to 50 feet/15meters or larger) supporting a smaller diameter column upon which the turbine tower is mounted. However, the suction caisson base consists of a steel cylinder, open at the bottom, and resembles an upside-down bucket. Once installed, the suction caisson functions similar to a gravity foundation, relying on the weight of the soil enclosed in the bucket and suction for stability.

The unusual installation method of the suction caisson sets it apart from other foundation types. The rim of the bucket, or skirt, cuts into the sea/lakebed a short distance under its own weight and achieves a seal. The water trapped in the bucket is then pumped out through the top producing differential pressure (suction) and advancing the bucket deeper into the sea/lakebed. In cohesive soils, the suction advances the caisson to its final depth by overcoming the bearing capacity beneath the rim and adhesion/skin friction on the inner and outer surfaces of the bucket. In more permeable sand soils, water flows upward into the caisson due to the suction. The upward flow reduces the effective stress, nearly causing the granular soil to boil. This phenomenon greatly reduces the bearing capacity beneath the rim and the frictional resistance on the inside of the bucket facilitating penetration into the sand. Installation can be problematic in layered soils, particularly where clay overlies sand, since the clay layer prevents upward water flow through the sand. Also, if the unbalanced pressure is too great across a relatively thin clay layer, it could rupture or heave within the suction caisson.

A prototype suction caisson was installed in 2002 at the Aalborg University offshore test facility in Frederikshavn, Denmark to support a Vestas V90 3MW wind turbine. The prototype was approximately 40 feet (12 meters) in diameter with an approximately 20-foot (6-meter) skirt or bucket and weighed approximately 150 tons. The installation period at this near-shore location was approximately twelve hours with the actual soil penetration accomplished in six hours. Research indicates this foundation type to be feasible, given favorable subsurface conditions, in water depths up to 130 feet (40 meters).

Figure 6-26: Prototype Suction Casisson

Development of the suction caisson concept for supporting offshore wind turbines has been slowed by an incident during installation of a second prototype in Wilhelmshaven, Germany in the spring of 2005. This second prototype was more than 50 feet (15 meters) in diameter with a 50-foot (15-meter) skirt and weighed nearly 450 tons. It was intended to support a 4.5 MW Enercon E-112 turbine. The skirt failed during installation most likely due to collision with a crane barge that compromised the structural integrity of the skirt.

Like gravity foundations, suction caissons are well suited for uniform soil conditions where differential settlements will be small, particularly sands and softer clays. Because they are light compared to gravity foundations, suction caissons do not require specialized heavy lifting equipment and can be floated to the installation site. Neither do they require specialized driving equipment like monopiles. Perhaps the greatest advantage of suction caissons is the simplified installation method. Once positioned on the sea/lakebed, installation is essentially accomplished with a pump of suitable capacity to withdraw the water trapped within the bucket. Suction caissons can also be completely removed at the end of their design life relatively easily by reversing the installation process and pumping water back into caisson forcing it out of the sea/lakebed.

Since suction caissons are relatively new to the offshore wind industry, they have yet to establish a successful track record and thus far have been proven useful over a limited range of conditions. Like gravity foundations, they are also susceptible to scour in marine environments.

6.3.6 Conclusions: Geological Conditions and Foundation Types

The information from generalized geologic references together with the available site-specific data indicates that a wide range of lakebed conditions can be anticipated off the Cuyahoga County shore. While these varying conditions might make one foundation type preferable to another in a particular location, they do not preclude the siting of wind turbines anywhere within the study area. Except for a surficial layer of soft recent sediment, the area west of downtown Cleveland contains glacial till over relatively shallow bedrock is anticipated. East of downtown Cleveland, the study area lies over an ancient buried river valley where bedrock is 100 feet (30 meters) or more below the lakebed. The old valley is filled with interbedded glacial related deposits of till, outwash and lacustrine sand, silt and clay of varying consistency and compactness.

Given the broad range of subsurface conditions that could possibly be encountered at the eventually selected turbine sites, none of the three foundation alternatives presented stands out as an obvious choice over the others based on soil conditions alone. However, with water depths generally 40 feet (12 meters) or deeper 3 to 5 miles (5 to 8 kilometers) offshore, monopiles are an attractive option for a wide range of potential soil/bedrock conditions. In addition, facilities for the fabrication and supply of monopile foundations currently exist within the Great Lakes Basin (Tower Tech Systems, Inc. on the Manitowoc River/Lake Michigan in Manitowoc, Wisconsin).

Monopiles would be well suited for use in stiff glacial till or in areas offshore of the western part of the County where they might be socketed into shale bedrock. Monopiles might also be preferred in this area to penetrate through deposits of soft or semifluid recent lake sediments that would require more significant lakebed preparation for a gravity foundation alternative. Some risk of obstruction by large glacial erratic boulders exists for the monopile option; however, this risk could be substantially mitigated by exploratory drilling at each monopile location. Offshore of the central and eastern parts of the County, piles longer than typically required could be necessary should deep deposits of soft lacustrine clay be encountered in the old buried bedrock valley.

Gravity foundations appear to be feasible for nearly all the potentially anticipated lakebed conditions. However, wind, wave and ice loads combined with water depths of typically 40 feet (12 meters) or greater will likely result in the need for very large, heavy gravity bases. If placed on thick deposits of soft clay, gravity base foundations could undergo significant post construction settlement. Gravity foundations also have the disadvantage of requiring significant lakebed preparation efforts prior to installation. This issue could be of particular concern for turbines located in the offshore area west of Cleveland where soft sediments up to 6.5 feet (2 meters) thick are reported. Furthermore, very large, specialized equipment is required for transport and installation of gravity bases. Such equipment would either need to be custom fabricated locally or existing equipment likely disassembled for mobilization into the Great Lakes Basin at great expense and effort.

Suction caissons are also a viable, albeit developing, alternative for support of offshore wind turbines. Successful installation has thus far, however, only been proven in sands and soft clays so their application may be limited. Achieving adequate penetration with suction caissons may be difficult or impossible if located in areas of hard till deposits or if boulders are encountered. Given the complex geologic history of the site, layered soil profiles also are not out of the question within the depths that might be penetrated by suction caisson foundations. This could also be problematic for installation of suction foundations, particularly where sand underlies clay.

All three of the foundation alternatives presented are feasible for at least some portion of the range of expected conditions 3 to 5 miles (5 to 8 kilometers) off the Cuyahoga County shore. When other factors unrelated to subsurface conditions, such as fabrication, transport and installation methods/equipment, are considered; monopiles appear to be the preferred foundation alternative for the Pilot Project. However, the final selection should be made once site specific investigations have been performed. The additional exploratory work should include geophysical surveys of the selected turbine sites and, ultimately, soil boring and sampling within the footprint of each turbine foundation. Representative samples should be tested for index properties (particle size, Atterberg Limits, moisture content), shear strength and consolidation properties. Depending on the locations selected and anticipated conditions; consideration might also be given to performing cone penetrometer testing and/or vane shear tests as part of the field exploration.

6.4 Effects of Icing, Wind, and Waves

(Unless otherwise indicated, information in this section from the GLWEC Desktop Study on the Effects of Icing, Wind, and Waves, Germanischer Lloyd, November 2008)

6.4.1 Introduction

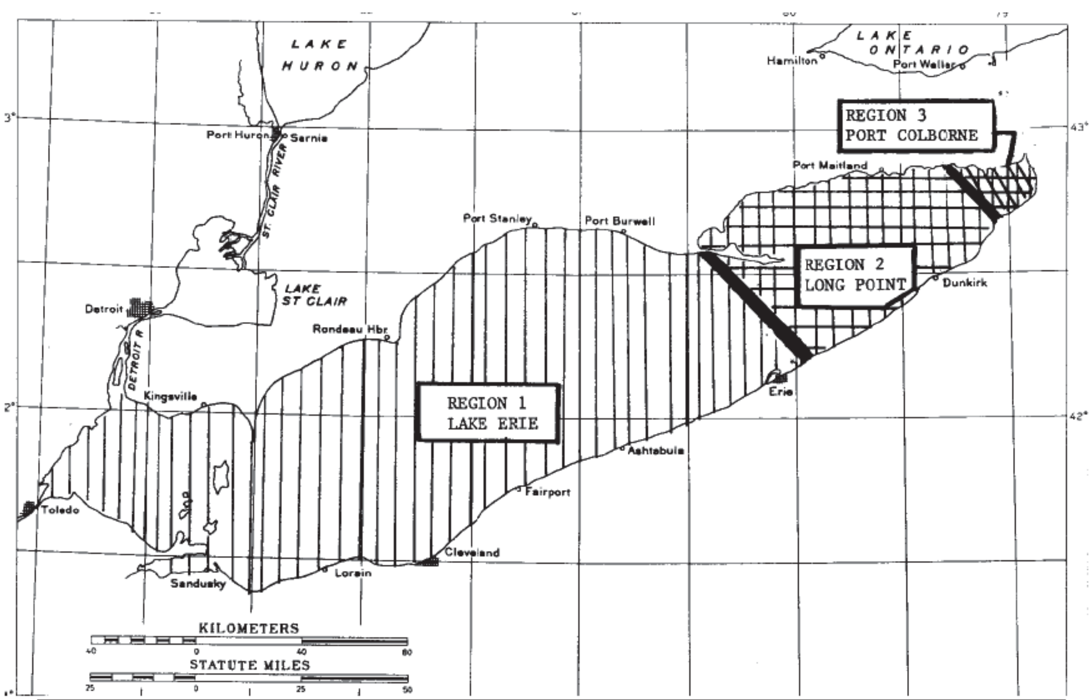
The aim of this section on ice, wind, and waves is to describe the environmental conditions with regard to these parameters in Lake Erie, focusing on the location of the Pilot Project. Furthermore GL is identifies and assesses the usefulness of previously collected data to evaluate the effects of ice, wind, and waves on platforms and wind turbines of the GLWEC Pilot Project.

6.4.2 Effects of Ice – Ice Evaluation of Lake Erie

6.4.2.1 General Ice Growth Description

With regard to lake ice, Lake Erie can be divided into 3 regions: Lake Erie (region 1), Long Point (region 2), and Port Colborne (region 3). The proposed location for the pilot offshore wind project close to Cleveland is located in region 1, as it is shown in Figure 6-27.

Figure 6-27: Lake Erie – Illustration of Three Ice Regions

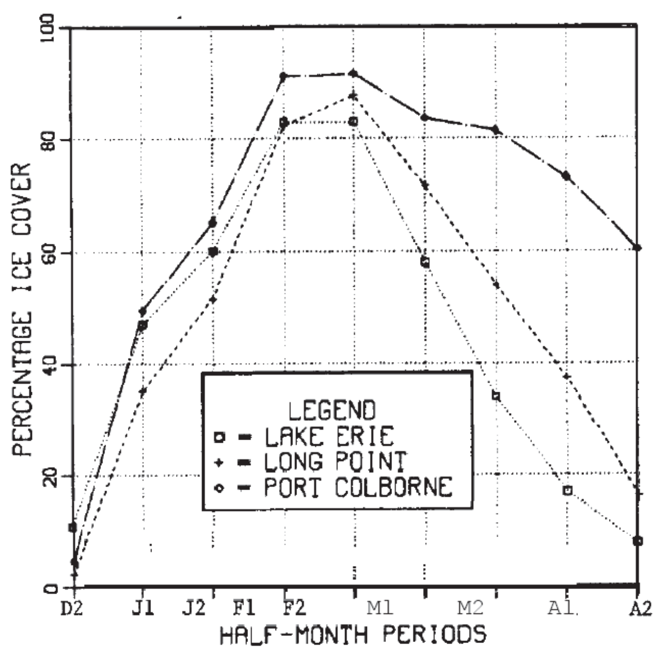


The average regional ice cover indicates trends in ice cover formation and decay on Lake Erie. During the ice formation period—on average the second half of December through first half of February—the percentage of the region covered by ice is usually greater in regions 1 and 3 (Lake Erie and Port Colborne eastward) than in region 2 (Long Point eastward). This is apparently a direct result of the deeper water and associated greater heat storage in region 2. Starting the second half of February and lasting through the second half of April, ice cover extent is greatest for region 3, followed by region 2; it is smallest in region 1. This pattern is due to the fact that the ice cover normally first breaks up and is then lost in the West Lake Basin. Ice cover loss gradually moves eastward across the lake in March and April, and it is common for wind, which mainly blows West-East, to transport ice floes into the East end of the lake in spring, resulting in the observed pattern of greater ice coverage in regions 2 and 3 in comparison to region 1 (see Figure 6-28).

A comparison of the Lake Erie region and Long Point indicates a higher probability of greater ice cover extent for region 1 until the end of January and afterwards a higher probability of greater ice cover extent for region 2. Regional trends in ice cover probability during March and April indicate that there is a higher probability of greater ice cover in region 3 relative to either region 2 or region 1 in the spring.

Figure 6-28 illustrates the average ice cover in percentage for the period from second half of December until the end of April. The months are split in half months, i.e. for an example J1 stands for the first half of January and J2 for the second half of January. Figure 6-28 shows that the lake is practically fully covered with ice between mid February and mid March.

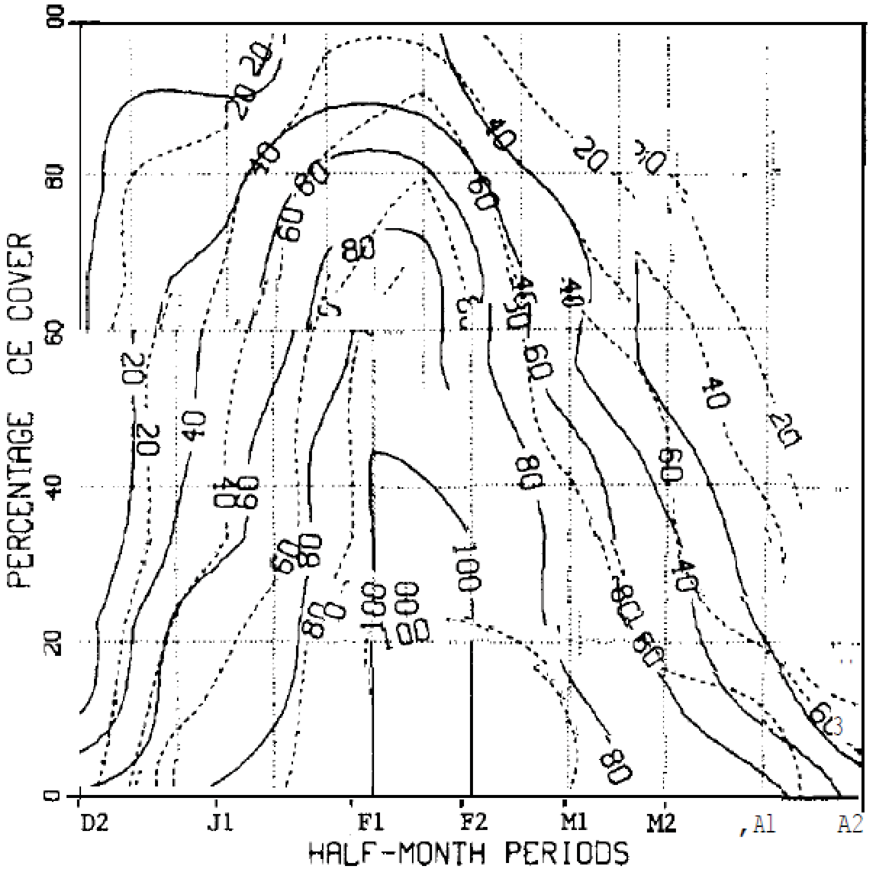
Figure 6-28: Average Regional Ice Cover



Minimum ice cover values indicate that in some years, all three lake regions are virtually free of ice in early and late winter. According to the lowest values recorded, until the end of January, for example, less than 10 percent of the Lake regions are covered by ice and less than 1 percent is covered by the last half of March. During February, however, minimum annual ice cover extent varies from 30 to 50 percent across the three regions. In the first half of March, minimum annual ice cover in regions 1 and 3 is 10 percent or less, while in region 2 it is 26 percent. The greater minimum annual ice cover in region 2 during the second half of March may be a result of the observed breakup pattern and the size of the region, i.e. ice cover.

The ice cover normally breaks up in the west end of the lake first and, under the influence of west winds, ice is often shifted into the east end of Lake Erie. Region 3 does not reflect this trend because it is much smaller than region 2. Trends in maximum and minimum ice cover values are reflected in the contour charts of ice cover exceedance given in Figure 6-29. The minimum ice cover values define the locations of the higher ice cover exceedance isopleths and the maximum ice cover values. Figure 6-29 shows a comparison of the maximum ice cover values of the Lake Erie region 1 and Long Point region 2.

Figure 6-29: Isopleths of Percentage Ice Cover Exceedance, Comparison of Isopleths Lake Erie and Long Point (dashed line)



6.4.2.2 Ice Thickness Distribution

In the following, freeze-up has been defined as that time when approximately 5 cm of ice has formed and continues to grow. If a few centimeters of ice formed, subsequently deteriorated, and re-formed at a later date, freeze-up was reported at the later date. Breakup is considered to have occurred when the ice is either gone or is in such a deteriorated state as to cause no problem to even small boat traffic. Throughout the report, the first, second, third, or last week of the month is referenced. Days 1 to 7 of each month constitute the first week, 8 to 15 the second, 16 to 23 the third, and 24 to 31 the last. All of the statistics in this report are based on this timeframe. Information is provided on a lake-by-lake and station-by-station basis.

On the basis of the limited statistical data available it appears that the nearshore-zone ice growth rate was nearly equal for all the Great Lakes. Lake Ontario has the highest average growth rate (9 mm/day); the other lakes have an average of 8 mm/day. In contrast, ice dissipation rates show high values for the upper lakes (Lake Huron:17 mm/day, Lake Michigan: 16 mm/day, Lake Superior:14 mm/day) and low values for the lower lakes (Lake

Ontario: 12 mm/day, Lake Erie: 11 mm/day). As might be expected, ice cover on the upper lakes lasted longer, averaging 104 days. On the lower lakes, the season was about 3 weeks shorter, averaging 82 days.

In comparison with the above data, average ice growth rates on a small pond in New Hampshire varied from 5 mm/day to 9 mm/day. Average ice dissipation rates varied from 17.5 mm/day to 23 mm/day. It is apparent that the growth rates in the Great Lakes compare favorably with the higher rates in the small body of water, and dissipation rates on the Great Lakes tend to compare favorably with the lower end of the range for the inland lake.

“White ice” (mode of formation often unknown) thickness was computed as a percentage of total ice thickness for each year at each station, and the values followed fairly predictable patterns. Lake Superior stations averaged the highest percentage of white ice (25 percent). Lake Ontario stations averaged a lower percentage of white ice (21 percent). Lakes Michigan and Huron were equal in terms of average white ice percentages (17 percent).

Lake Erie stations averaged the lowest percentage (7 percent). An examination of white ice contributions to total ice thickness for individual years at each of the Great Lakes stations indicates an even higher variability than on Post Pond in New Hampshire. In some cases, Great Lakes ice was reported to be nearly all white ice.

Figure 6-30: Locations of Ice Stations (400 and 408 closest to Pilot Project)

Four reporting stations are provided in the Lakes Erie/St. Clair analysis (Figure 6-30). For the planned Pilot Project the stations 400 and 408 are the nearest available stations and therefore their measurements are described in more detail:

- Marine Lake-Erie Harbor (400)
- Marblehead-Catawba Island (408)

The average time of freeze-up for all stations was the last week in December. No large variance of average freeze-up dates was noted between individual stations. The average time of freeze-up at individual stations varied from the third week in December at Brest Bay through the last week in December at all other stations. Dates of maximum ice amounts showed a similar lack of variation. Ice thickness reached a maximum (whole-lake average) in the first week in February. Average ice thicknesses for a particular station reached a maximum as early as the last week in January at Brest Bay and as late as the second week in February at New Baltimore, Mich., on Lake St. Clair. Maximum ice thickness averaged 33 cm for all stations and varied from 29 cm at New Baltimore to 35 cm at Brest Bay. Average breakup dates varied little from station to station. The average breakup date for all stations was in the second week in March. The average breakup date at individual stations varied from the first week in March at Marblehead, Ohio, to the second week in March at Marine Lake, Brest Bay, and New Baltimore. Probably the freeze-up, breakup, and maximum ice dates vary so little because of heat budget factors associated with Lakes Erie/St. Clair, which are very shallow compared to the other Great Lakes.

Ice growth rate for all stations averaged 8 mm/day, the same as for Lakes Superior, Michigan, and Huron. The lowest average growth rate (6 mm/day) was found at New Baltimore and the highest (9 mm/day) at Marblehead. The average ice dissipation rate for all stations on Lakes Erie/St. Clair was 11 mm/day, which is the lowest for all of the Great Lakes. Average ice dissipation rates for individual stations varied from 9 mm/day at New Baltimore on Lake St. Clair to 12 mm/day at Marine Lake. Average whole-lake ice duration was 74 days. Average ice duration was considerably lower than for any of the other Great Lakes, varying from 64 days at Marblehead to 83 days at Brest Bay. White ice as a percentage of total ice averaged only 7 percent for all stations, the lowest percentage for all of the Great Lakes. The lowest average of white ice (2 percent) was recorded at Brest Bay and the highest (14 percent) at Marblehead.

6.4.2.3 Analysis of Data for Two Selected Stations

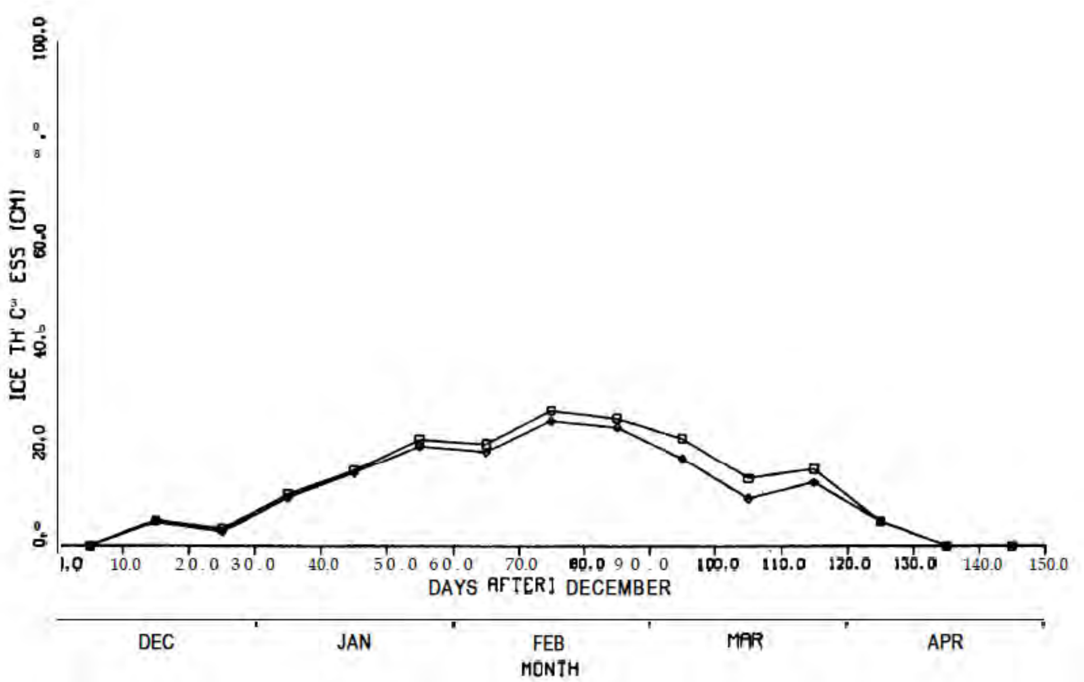
Within the following sections the data analyses (1965-1975) of the two selected stations, station 400 (Marine Lake-Erie Harbor) and 408 (Marblehead-Catawba Island) are described.

Marine Lake-Erie Harbor

The Marine Lake station (42°08’N, 80°08’W) is near the dock area of the Presque Isle State Park Marina (Station 400, see Figure 6-30). It is sheltered from the waves of Lake Erie. Water depth at the station is less than 3.0 m. The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the third week in January. The average time of maximum ice thickness was the first week in February; times varied from the second week in January through the last week in February. Maximum ice thickness averaged 32 cm, varying from 15 cm to 61 cm. The average time of breakup was the second week in March; times varied from the last week in February through the third week in March.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 12 mm/day. The number of days from freeze-up to maximum ice thickness averaged 42 days (a 28-70 day range), and from maximum ice thickness to breakup, 27 days (an 11-68 day range). Ice cover duration averaged 69 days and varied from 39 days to 105 days. White ice averaged only 8 percent of total ice and varied from 0 percent to 30 percent. Figure 6-31 shows low total and clear ice thicknesses at this station but a surprisingly lengthy ice season. The area between the two curves is the average thickness of white ice.

Figure 6-31: Average Total Ice (upper curve) and Clear Ice (lower curve) Thicknesses at Marine Lake-Erie Harbor, 1965-79

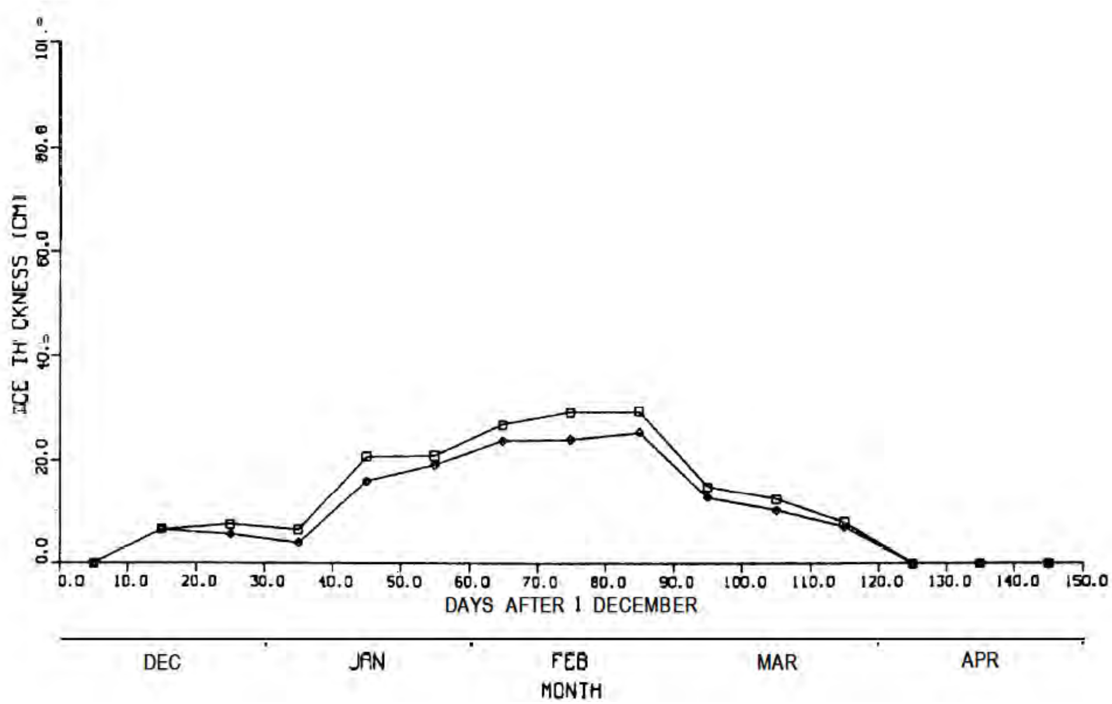


Marblehead-Catawba Island

The Marblehead station (41°33'N, 82°52'W) is directly north of the town of Catawba Island and southwest of Mouse Island (Station 408, see Figure 6-30). It is exposed to the main body of Lake Erie. Water depth at the station is 4.5-6.0 m. The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the second week in January. The average time of maximum ice thickness was the first week in February; times varied from the second week in January through the third week in February. Maximum ice thickness averaged 34 cm, varying from 10 cm to 71 cm. The average time of breakup was the first week in March; times varied from the second week in February through the third week in March.

Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 12 mm/day. The number of days from freeze-up to maximum ice thickness averaged 37 days (a 21-63 day range), and from maximum ice thickness to breakup, 29 days (a 11-46 day range). Ice cover duration averaged 66 days and varied from 33 days to 101 days. White ice averaged 14 percent of total ice and varied from 0 percent to 32 percent. Figure 6-32 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

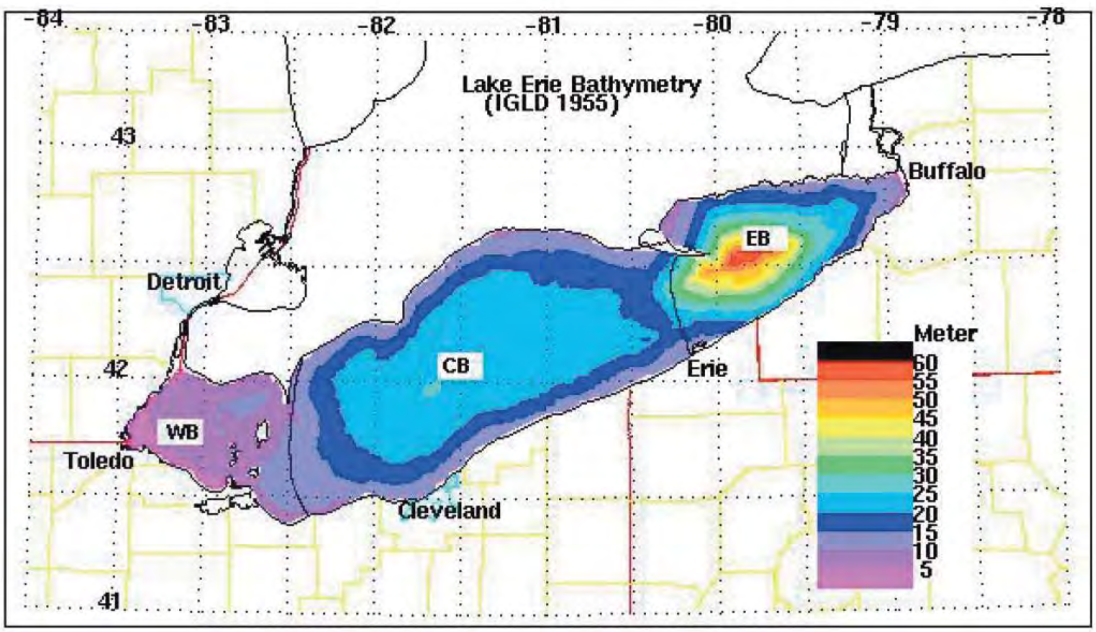
Figure 6-32: Average Total Ice (upper curve) and Clear Ice (lower curve) Thicknesses at Marblehead-Catawba Island, 1965-79



6.4.2.4 Ice Concentrations for Lake Erie

Spatial averages of ice concentrations for the west, center, and east basins of Lake Erie (Figure 6-33) are available for the winter seasons 1898-2002. Daily basin-averaged ice concentrations are based on modeled data for winters 1898-1972 and on observed data for winters 1973-2002. Daily, monthly, and annual basin-averaged ice cover concentration, dates of first ice, dates of last ice, and ice season duration are calculated for each basin for each winter season from 1898 to 2002, as are computer animations that portray spatial patterns of the seasonal progression of ice cover extent for the 30 winters 1973–2002. All of these data are accessible as ASCII files and graphs on the Internet at: http://www.glerl.noaa.gov/rsch/erie/data/Spatial/Ice/Ice.html as part of the Climatology of the Physical Environment in Lake Erie Project, and are considered as part of this report although not shown here. This report summarizes the data sources and methods used to create these data and present and discuss the results of a graphical analysis of selected spatial and temporal data characteristics.

Figure 6-33: Lake Erie Basins: West (WB) Center (CB), East (EB), and Bathymetry



First Ice

The shallower west basin is the first to form ice. The extreme late dates of first ice in the 1930s, the late 1940s to early 1950s, and late 1990s and early 2000s are due to winters without ice, the date of first ice for these winters was arbitrarily set to May 31. The cause of the gradual increase to a later date of first ice in the west basin from the late 1950s to the 1970s is not known, it may be an artifact of the blending of modeled and observed data.

Dates of first ice in the west basin generally occur in the second half of December while dates of first ice in the center and east basins usually occur in January. Dates of first ice tend towards later dates in the center and east basin from the late 1970s to 2002. The late 1970s and early 1980s were periods of above-average seasonal maximum ice cover in the Great Lakes. The winters in the 1980s and 1990s had several strong warm El Niño events (1983, 1987, 1992, 1998) and an exceptionally mild (non-El Niño) winter in 2002. The combination of severe ice cover in the late 1970s and milder winters in the 1980s and 1990s explains the tendency in the center and east basins. A similar tendency is not observed in the west basin, because ice formation requires shorter periods of low air temperatures in the west basin due to its shallower depth and lower heat storage.

Last Ice

The effect of winters without ice cover in the early 1930, early 1950s, and late 1990s to early 2000s are associated with trends toward earlier ice loss dates. Loss of ice cover occurs first in the west lake basin, followed by the center basin, and last in the east basin. The average date of last ice during the winters 1973-2002 occurred during the last half of March, i.e., round mid-March in the west basin to the end of March in the east basin. Variations around these dates indicated by the standard deviation are on the order of 2 to 3 weeks. There is a marked trend toward earlier dates of last ice starting in the late 1960s and continuing through the end of the century. This decline is associated with a general increase in spring temperatures and earlier ice out dates in the Great Lakes during the last 40 winters. This is part of a century scale trend toward earlier ice loss dates in the Northern Hemisphere that started in the mid 1800s marking the end of the little ice age.

Ice Duration

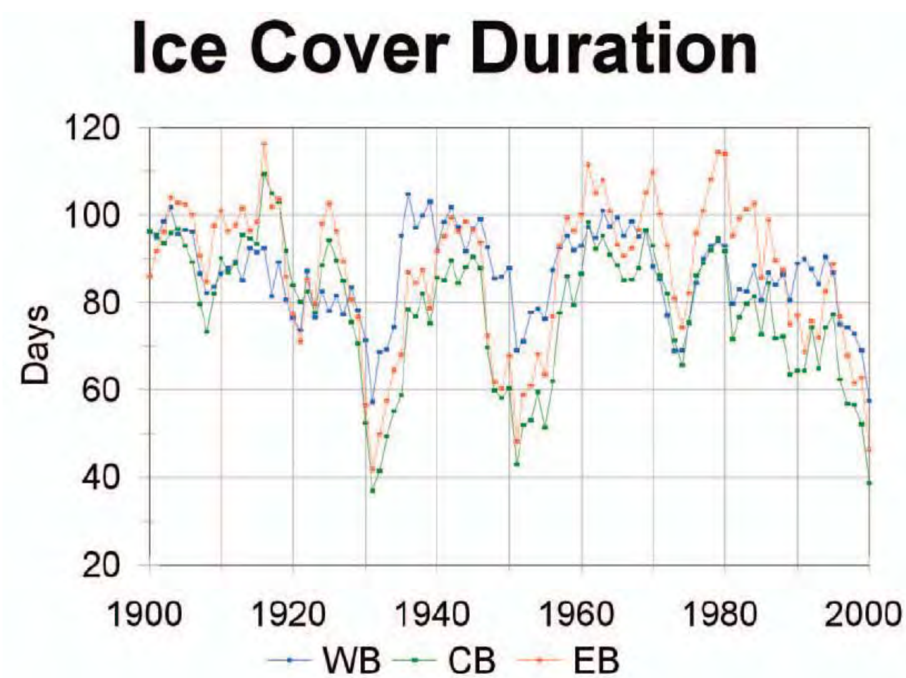
The earlier ice formation in the west basin tends to be set off by earlier ice loss there, so the duration of ice cover, unlike dates of formation and loss, appears to be similar among the three basins. Some exceptions occurred from 1900 to about 1915 and 1960 to about the mid 1980s where the east basin tended to have greater duration of ice cover. In terms of temporal trends, there is a marked trend for lower ice cover duration over the century, with a notable decline from the early 1960s onward with some reversal in the early and late 1970s. During the winters 1973-2002 it averaged near 80 days in the east and west lake basins and near 70 days in the center basin. The variation about these averages increases going from the west basin, where it is 3 weeks, to the east basin where is closer to 5 weeks.

Seasonal Average Ice Cover

The effects of mild winters, e.g., winters without ice cover in center and east lake basins noted earlier and others with low ice cover, manifest themselves as local minimums on the plots of seasonal average ice cover on all three lake basins (Figure 6-34). The winters of the early 1930s and early 1950s are more prominent on the east basin in the duration based seasonal averaged ice cover because the 182-day based seasonal averaged ice cover includes the default date for no ice cover, i.e. May 31. However, other local minimums in the curves and by implication mild winters occurred the last half of the 1900s, around 1920, in the mid 1970s, the late 1980s to early 1990s, and the late 1990s to 2002. The contemporary 30-winter averages range from 24% to 29% for the 182-day season and from 51% to 61% for the period of ice duration, with the west basin having the highest values.

Variations around the contemporary period were also lowest for the west basin (11.6% for the 182 day period to 15.8% for the period of ice duration). A prominent decline in seasonal average ice cover is observed from the late 1970s to 2002. These trends are similar to those described for the dates of first/last ice and ice duration and for the same reasons.

Figure 6-34: Ice Cover Duration, 5 year Running Mean

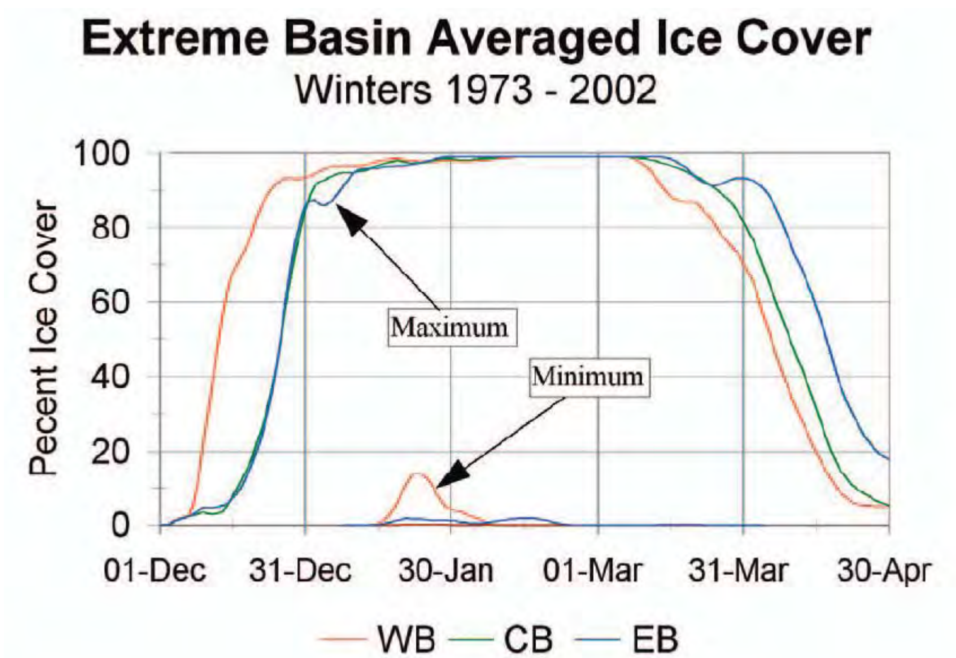


6.4.2.5 Extreme Ice Cover

The composite extremes, maximum observed ice cover on a given day and minimum observed ice cover on a given day over the 30-winter base period provide an estimate of the limits of ice cover under the climate regime of the past 30 years. Figure 6-35 shows that there can be large deviations from the “typical” ice cycle. Extensive ice covers can form in the west basin the first half of December and in the center and east basins during the second half of December. All three basins can have in excess of 90% ice cover starting late

December (west basin) or early to mid January (center and east basins) through the first half of March (west basin) or the second half of March (center and east basins). The winters of the late 1970s and 1994 and 1996 provide good examples of winters that helped to set the upper limits (severe winters). The composite daily maximums show that rapid loss of ice extent occurs in the first half of April but that the east basin can still have well over 50% ice cover in mid-April and over 20 percent ice cover by the end of April. In fact, the eastern end of the east lake basin can have ice cover well into May some years. The composite daily minimum ice cover extent curves show that with the exception of the west basin during the last half of January, all three basins can be virtually ice free during any day in the winter season. The 1998 and 2002 winters provide good examples of winters that help set these lower limits.

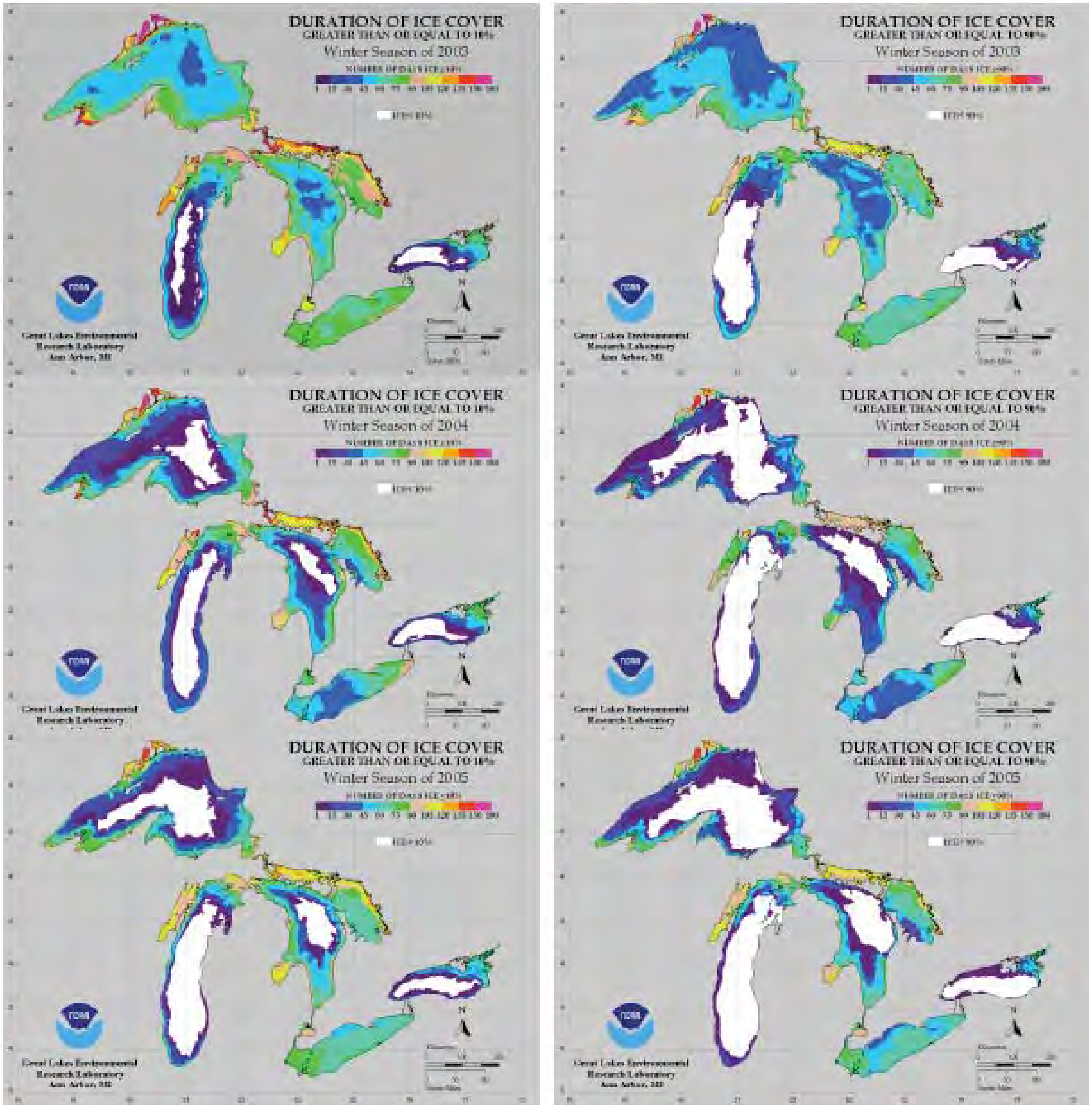
Figure 6-35: Seven-Day Moving Average of Observed Daily Maximum and Minimum Ice Cover for West (WB), Center (CB), and East (EB) Basins



6.4.2.6 Latest Ice Information 2003 – 2005

The dates of last ice cover in areas with ice on Lakes Superior, northern Michigan, Huron, and the eastern half of Lake Erie were in general later in 2003 relative to 2004 and 2005. The follow up of the latest available ice data confirms the earlier mentioned trends and show no significant differences to earlier measurements.

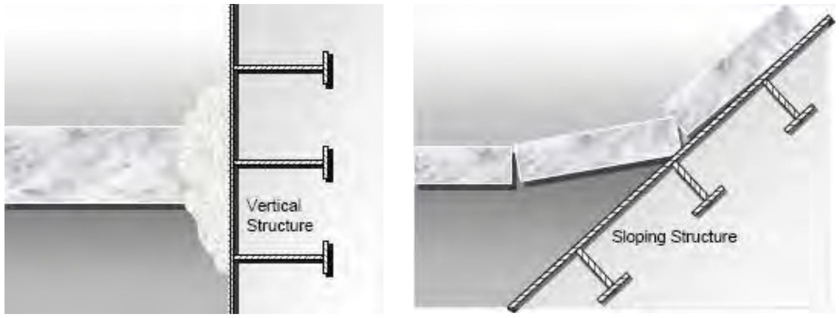
Figure 6-36: Dates of Last Reported Ice ≥ 10% (left) and ≥ 90% (right) for 2003, 2004, and 2005



6.4.2.7 Ice Failure and Support Structure

The mode of ice failure against the structure has a significant effect on the magnitude of the ice action. The failure mode for sea or lake ice (e.g. crushing, shear, flexure, creep) depends on parameters such as ice thickness, presence of ridges, ice velocity, ice temperature and structure shape.

Figure 6-37: Examples of Ice Failures



a) Crushing failure b) Flexural failure

Structure geometry is an important factor in determining ice actions. Key design features include the structure type (multi-leg, monopile or caisson), vertical or sloping waterline geometry (see Figure 6-37), the plan shape of the structure and the plan dimensions.

The profile of the structure is a key issue. Structures with vertical walls in the waterline region (e.g. monopiles) generally experience larger ice actions than sloping ones for similar waterline dimensions. Constructive measures to reduce ice actions include the equipment of vertical structures with ice deflectors. Braces or appendages should not be exposed to ice actions.

The moving ice (mainly wind driven), which hits and passes the vertical pile of an offshore wind turbine will generate large ice forces (Figure 6-38). Dynamic structure response is generally associated with ice crushing failure.Vertical piles in particular are likely to be endangered by so-called ice induced vibrations if they are not equipped with a cone in the water line. Under certain circumstances the frequency of the ice failure may be in correlation with one of the pile’s eigenfrequencies depending on ice drift speed, ice thickness, ice strength and the size of the ice floes hitting the pile.

Figure 6-38: Crushing Failure on Vertical Structure

Possible solutions to reduce the ice loads and ice induced vibrations include the equipment of vertical structures with cone-shaped ice deflectors in the waterline. Generally the (static) ice loads can be reduced by the factor three on sloping structures compared to those on vertical structures. But due to the fact that an ice cone broadens the structure in the waterline, the ice load reduction might be less. Often the ice load even remains the same, but at a reduced frequency.

Ice cones can slope either inward going upward, for example on a gravity foundation (Figure 6-39) or outward going upward, as shown in Figure 6-40 and Figure 6-41 (in the following referred to as “ inverted ice cones”). Correspondingly, forces on the foundation due to ice can be either downward or upward, depending upon the direction of sloping. Upward forces exert a lifting force on the foundation, an effect which is especially unwanted when using a gravity foundation.

Inverted ice cones have the advantage of minimizing the ice freezing on the structure and therefore significantly reducing the resulting forces. They also lead to better access possibilities, as the upper horizontal cone edge can be used as access platform.

Figure 6-39: Gravity Foundation with Sloping Profile at Water Line

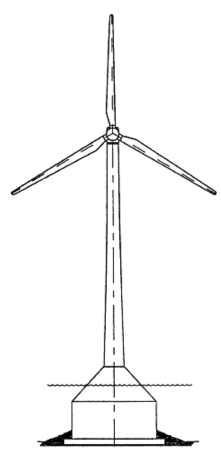


Figure 6-40: Monopile Foundation with Ice Cone at Water Line

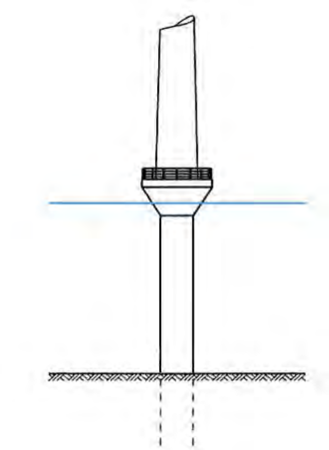


Figure 6-41: Middlegrunden Turbines with Ice Cones

Regarding dynamic ice forces it is currently assumed that they will also be reduced by an ice cone, i.e. the frequency of the ice load will be much lower, meaning significantly different from the eigenfrequency of the structure.

Subject to final site specific investigations, monopiles currently appear to be the preferred foundation alternative for the Pilot Project. With regard to the ice conditions in Lake Erie an ice cone should be considered on the pile in the waterline to break up ice, reduce loading on the structure and avoid or minimize ice induced vibrations. The ice cone could be part of the transition piece and its upper edge could form the access platform. The cone should be designed as inverted ice cone (upper diameter > lower diameter), similar to the sketch in Figure 6-40.

6.4.3 Effects of Wind Conditions

Offshore wind turbine types are designed according to generic external conditions. Concerning the wind conditions, offshore wind turbines are intended to withstand safely the conditions as defined in the turbine class definitions.

The applied standard for the evaluation of the external conditions is the Guideline for the Certification of Offshore Wind Turbines, edition 2005. Thus, the classification of the proposed sites is according to the turbine classes as presented in the GL Guideline and Table 6-4. For an offshore wind turbine the definition of wind turbine classes in terms of wind speed and turbulence parameters is the basis for design of the topsides structure (turbine machinery) of the turbine type. Wind speed values and turbulence intensity parameters are intended to represent the most characteristic values of many different sites and do not give a precise representation of any specific site. The goal is to achieve wind turbine classification with clearly varying degrees of robustness governed by the wind speed and turbulence intensity parameters. Table 6-4 specifies the basic parameters which define wind turbine classes according to the GL Guideline.

Table 6-4: Basic Parameters for Wind Turbine Classes

Wind turbine class	I	II	III
- V_{ref} [m/s]	50	42.5	37.5
- V_{ave} [m/s]	10	8.5	7.5
- A I_{15} (-)	0.18		
- *a* (-)	2		
- B I_{15} (-)	0.16		
- *a* (-)	3		
- C I_{15} (-)	0.145		
- *a* (-)	3		

V_{ref} = reference wind speed
V_{ave} = annual average wind speed over many years at hub height
A = category for higher turbulence intensity values
B = category for medium turbulence intensity values
C = category for lower turbulence intensity values
I_{15} = characteristic value of the turbulence intensity at 15 m/s
a = slope parameter for turbulence characteristics

In the following sections, the design conditions of the generic wind turbine classes are compared to the conditions at the proposed site locations (Configurations 1 to 8). The deviations between the different external conditions and the proposed site locations are displayed and conclusions for the structural integrity are discussed. This pre-evaluation of important siting criteria associated with wind conditions avoids costly iterative pre-construction studies that otherwise would be required at each site or turbine location.

The meteorological conditions detailed below are assessed with respect to their influence on the structural design of the turbine:

- Annual average wind speed
- Wind speed distribution
- Wind direction distribution
- Turbulence intensity (mean and characteristic values)
- Extreme wind speed
- Wind shear
- Air density and Temperature range
- Wake effects

For this preliminary stage no detailed layout is considered as turbine type and size have not been determined.

6.4.3.1 Annual Average Wind Speed

An evaluation of two years of wind data (10/2005 – 10/2007) is provided in Section 4. A met mast located on the Crib measures wind speed and direction at heights of 30 m, 40 m and 50 m. The annual average wind speed retrieved from the measurement at 50 m height is 7.35 m/s. The wind speeds for the proposed turbine layouts are in the range between 6.4 to 8.2 m/s at 70 m height.

The nine proposed turbine layout locations are correlated to the annual average wind speeds and the resulting turbine classes are shown in Table 6-5. The associated Weibull parameters for the proposed turbine locations are presented and discussed in the next section.

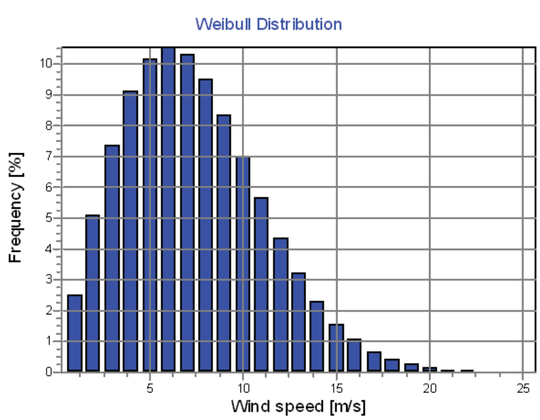
Table 6-5: Annual Average Wind Speed at 70 m Hub and Resulting Turbine Classes

Wind farm location	Mean wind speed	Turbine class
Configuration 1:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 2:	7.6 m/s to 8.2 m/s	GL turbine class II
Configuration 3:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 4:	7.0 m/s to 8.0 m/s	GL turbine class II
Configuration 5:	6.6 m/s to 7.0 m/s	GL turbine class III
Configuration 6:	6.6 m/s to 7.0 m/s	GL turbine class III
Configuration 6A:	6.8 m/s to 7.2 m/s	GL turbine class III
Configuration 7:	6.4 m/s to 6.6 m/s	GL turbine class III
Configuration 8:	6.8 m/s to 7.2 m/s	GL turbine class III

6.4.3.2 Wind Speed Distribution

The wind speed distribution at the site is significant for wind turbine design because it determines the frequency of occurrence of the individual wind speed bins. A Weibull distribution is given in the Lake Erie Wind Resource Assessment in and shown in Figure 6-42. The wind speed distributions are described as a joint frequency direction distribution. The values for the Weibull distribution have been evaluated explicitly.

Figure 6-42: Wind Speed Distribution for the A5 Anemometer at 50 m Height and Underlying Weibull Data



Weibull Data

Sector	A-parameter	Wind speed	k- parameter	Frequency
	[m/s]	[m/s]		[%]
0 N	6.62	5.88	1.859	7.7
1 NNE	7.61	6.74	2.057	7.9
2 ENE	8.24	7.31	1.994	8.2
3 E	5.29	4.69	2.395	3.6
4 ESE	4.78	4.24	2.044	3.1
5 SSE	7.19	6.37	2.244	8.2
6 S	8.13	7.20	2.253	10.0
7 SSW	9.06	8.08	2.892	12.6
8 WSW	9.74	8.64	2.448	14.3
9 W	9.91	8.78	2.104	9.9
10 WNW	8.91	7.90	1.970	8.1
11 NNW	8.49	7.52	2.224	6.4
All	8.32	7.37	2.079	100.0

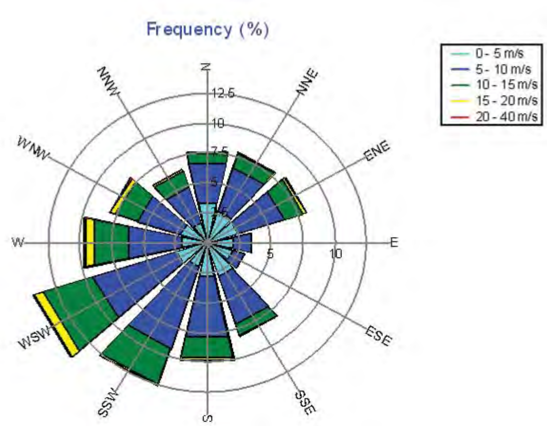
The Weibull shape parameter (k) is assumed to not deviate significantly with increasing height. The shape parameter does also not change significantly for the different wind farm locations (configurations) as the terrain orography and roughness are very similar for the different wind farm locations. Figure 6-42 shows a good representation of the site by the two parametric Weibull distribution figures. Thus, for the preliminary study the overall shape parameter of 2.079 can be used and will be assumed for all individual turbine locations.

For the next phase the influence of the coast on the k value should be evaluated to determine if the near shore locations (configurations 5, 6, 6A and 8) have different wind speed distributions compared to the configurations 1 to 4 and configuration 7. The influence of the expected variations of the k value on the turbine loading is to be considered as negligible.

6.4.3.3 Wind Direction Distribution

The wind rose in Figure 6-43 shows the main wind direction as WSW. The wind direction distribution is found to be plausible taking into account global wind directions, and is assumed for all turbine locations. The main importance of the wind direction distribution for the structural integrity of the wind turbines is the occurrence of the wake effect situation. This parameter is discussed within section 6.4.3.8.

Figure 6-43: Frequency Rose for Crib Data



6.4.3.4 Ambient Turbulence Intensity

The ambient turbulence intensities (TI) need to be calculated as 10 min mean values and have to be comparable to the design parameter of the turbine class. Section 4.2.2.4 states ambient turbulence intensities at a height of 50 m. The ambient turbulence intensity varies between 5% and 11% depending on the wind direction calculated under consideration of wind speeds greater than 4 m/s. According to the applicable standard the characteristic turbulence intensity at a wind speed of 15 m/s should be determined from measured data obtained at wind speeds greater than 10 m/s. The ambient values presented in Section 4.2.2.4 are more conservative and can be used to calculate characteristic turbulence intensity.

The characteristic value of the turbulence intensity is calculated using the mean value and adding the standard deviation of the turbulence intensity. The procedure corresponds to the

IEC 61400-1, 2nd Edition. This is relevant as the purpose is to estimate values for a preliminary classification of the proposed sites into GL turbine classes.

The measurement data of anemometers A5 and A6 (both at 50m height) have been used as input for a calculation of the ambient turbulence intensity at a hub height of 80 m. The mean ambient turbulence intensity is calculated to 8.8 %. The respective standard deviation of the turbulence intensity amounts to 2.5 percent. Thus, the characteristic turbulence intensity at the point of measurement (Crib station) is assumed as 11.3 percent.

The ambient turbulence intensity can be applied for all turbine locations at each site. Here, it can be expected that the ambient and characteristic turbulence intensity will increase with decreasing distance from the shore. Thus, the turbine locations farther from shore are less severe concerning the structural integrity of the design.

The characteristic turbulence intensity, as mentioned above, is estimated to be approximately 11.3 percent at 80 m height. Thus, turbulence class C (14.5 %) will not be exceeded at the measurement mast. For the different site locations, the transferred characteristic TI would behave as indicated in Table 6-6, leading to the illustrated preliminary classifications of the proposed sites into GL turbine classes with respect to turbulence intensity.

Table 6-6: Characteristic TI at 50 m Hub at the Proposed Site Locations

Wind farm location	Characteristic TI	Turbine class
Configuration 1, 2, 3 and 4	≤ 11.3 %	GL turbine class C
Configuration 5, 6, 6A and 8	≥ 11.3 %	GL turbine class B
Configuration 7	~11.3 %	GL turbine class C

If the turbines proposed are designed according to IEC 61400-1, 3rd edition, the characteristic turbulence intensity TI stated here is not applicable due to different definition of the design value.

In the discussed turbulence intensity values no wake interactions between the wind turbines have been considered so far. The discussion of wake effects follows in Section 6.4.3.8 Wake Effects.

6.4.3.5 Extreme Wind Speed Conditions

The extreme wind conditions are used to determine the extreme wind loads acting on the wind turbines. These conditions include peak wind speeds due to storms and rapid changes in wind speed and direction.

For this study only the reference wind speed (50 yr reoccurrence, 10min mean) is determined in order to get an indication of the severity of the sites. The calculation is performed using the Weibull scale parameter A [m/s] and the Weibull shape parameter k [-] as input values, following the approach as described in the EWTS II documentation. The reference wind speed estimated at 50 m for the measurement mast is 33 m/s. This value needs to be transferred to the proposed hub height of 70 m. Assuming a wind shear profile as suggested in the GL Guideline (α= 0.14) a value of 35 m/s is obtained.

From the Building Code (ASCE Standard ASCE/SEI 7-05) a value of approx. 38 m/s at 70 m height is obtained. Thus, the turbine classes II and III are the present base from the measurement data at the Crib station.

Due to the deviations of mean wind speed and therefore the Weibull parameters, the reference wind speeds between the different locations will also vary. The estimated reference wind speed at 70 m hub height at the proposed site locations and the resulting GL classification is given in Table 6-7. The values in Table 6-7 are estimated with the EWTS II method stated above based on the mean wind speed data presented in Section 6.4.3.1 Annual Average Wind Speed and 6.4.3.2 Wind Speed Distribution.

Table 6-7: Extreme Wind Speed at 70 m Hub at the Proposed Sites

Wind farm location	Extreme wind speed	Turbine class
Configuration 1:	35.3 m/s	GL turbine class III
Configuration 2:	36.2 m/s	~ GL turbine class II
Configuration 3:	35.3 m/s	GL turbine class III
Configuration 4:	35.3 m/s	GL turbine class III
Configuration 5:	30.9 m/s	GL turbine class III
Configuration 6:	30.9 m/s	GL turbine class III
Configuration 6A	31.8 m/s	GL turbine class III
Configuration 7:	29.1 m/s	GL turbine class III
Configuration 8:	31.8 m/s	GL turbine class III

Generally, it must be noted that the EWTS II method is subject to high uncertainties and the calculated values should be treated with caution. A more scientific procedure is recommended as development of the wind farms advances.

Additionally, the gust amplitude is not discussed as no detailed data is available at the moment. Due to the low reference wind speed values, gust wind speeds are not considered to be the design drivers. It is most likely that gust factors between 1.2 and 1.4 will apply to this region.

Furthermore, a closer look on the measured wind data could give information about possible occurrences of extreme wind direction changes in short time periods. These possible extreme wind direction changes can give rise to the extreme loading the wind turbines will be exposed to.

6.4.3.6 Wind Shear

The wind shear value has been calculated out of measurements from the Lake Erie Wind Resource Assessment in. The measurements resulted in a Hellmann Exponent for the wind shear in the range of 0.04 – 0.067. These values are comparably low and likely a result of the flow disturbances due to the Crib building below the measurement mast.

Calculating the shear values (heights 30 to 50 m) by considering the surface roughness present at the site during normal (calm) sea a range of 0.082 to 0.089 is obtained.

The extreme wind shear is not evaluated in detail but is considered to play a major role for this site as the normal shear values are very low. Variations of the wind shear between the suggested wind farm locations are not considered as they are not expected to play a major role for the turbine suitability.

Further investigation is recommended in order to retrieve more reliable information about the wind shear at the site. This could for example be done by a LiDAR (Light Detection And Ranging) measurement, or CFD modeling of the wind flow around the Crib to learn more about the influences on the measured wind shear results.

6.4.3.7 Atmospheric Density

The mean atmospheric density at the site must be defined as it is an important parameter for the site specific load calculation. The mean air density at 50 m measurement height derived from the measurement on the Cleveland crib measurement mast is 1.204 kg/m^3. Thus the site air density is slightly less severe than the density normally used for wind turbine design (1.225 kg/m^3). The mean temperature at the site at 50 m height measured over the two years measurement period is 10.64°C.

Variations of the air density between the suggested wind farm locations are unlikely. The variation of the air density with the wind speed might be of interest for the later stages to verify the actual storm wind pressure.

6.4.3.8 Wake Effects

The wake effects can be treated as part of the site conditions. In deviation to the other site conditions the wake effects are not only depending on the site and "terrain" but also on the turbine type, turbine behavior and layout. For the fatigue load examination the consideration of wind farm influence is necessary. The wind farm influence is based on the turbine locations, the distribution of wind speed, wind direction and the characteristic turbulence intensity at the site.

The wind farm influence is considered using the method developed by Sten Frandsen. The method results in a correction of the characteristic site turbulence intensity to a design value ("effective turbulence intensity") due to the wake effects in the wind farm. The characteristic turbulence intensity for the proposed site at 50 m hub height is used for the calculations. The method developed by Sten Frandsen is used to consider the wake effects of neighboring wind turbines during normal operation. The original formulas, proposed for standard and given in the Frandsen paper, are as follows:

$$I_{eff} = \frac{\sigma_{eff}}{V_{hub}} = \frac{1}{V_{hub}}\left[\left(1 - N\,p_w\right)\hat{\sigma}^m + p_w \sum_{i=1}^{N} \hat{\sigma}_T^m(d_i)\right]^{\frac{1}{m}};\; p_w = 0{,}06$$

where

$\hat{\sigma}$ *is the ambient estimated turbulence standard deviation*

$$\hat{\sigma}_T = \sqrt{\frac{V_{hub}^2}{\left(1{,}5 + 0{,}3 d_i \sqrt{V_{hub}/c}\right)^2} + \hat{\sigma}^2}$$ *is the maximum center-wake, hub height turbulence standard deviation,*

d_i *is the distance, normalised by rotor diameter, to neighbouring wind turbine no. i,*

c *is a constant equal to 1 m/s,*

I_{eff} *is the effective turbulence intensity*

N *is the number of neighbouring wind turbines, and*

m *is the Wöhler curve exponent corresponding to the material of the considered structural component.*

These formulas have been used for the case of uniform wind direction distribution and uniform wind farm layout (turbines build in a row). Neighboring wind turbines up to 10 rotor diameter distance have been taken into account to consider the wake interactions. This approach has been chosen due to the preliminary stage of this study.

The calculated values of the effective turbulence intensity are presented in Figure 6-44 and Figure 6-45 for the S/N slope of m = 10. The values of the effective turbulence intensity calculated with m = 10 can be used for comparison against design conditions of components built from material with related S/N slopes, e.g. the rotor blades. Whereas the values calculated with m = 5 would be representative for components built from material such as steel with respective S/N slope, e.g. the tower. Those are not considered here. The comparison is conservative as long as the S/N slope of the material is lower than m = 10. Two “layouts” have been considered for a normalized distance of 4 rotor diameters (4 D) and a normalized distance of 3 rotor diameters (3 D).

Figure 6-44: Wake Effects Considering 4D Spacing

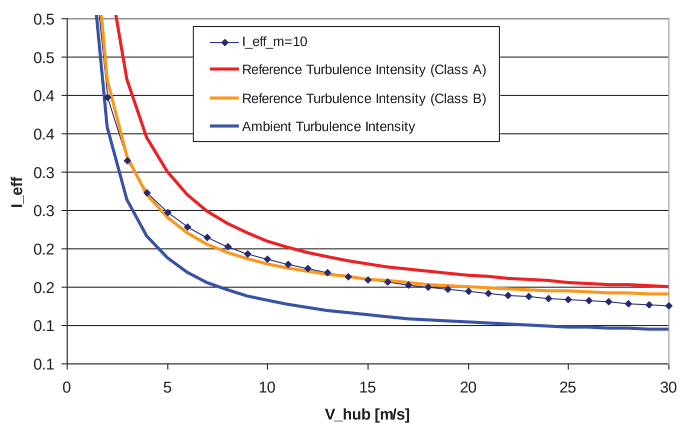
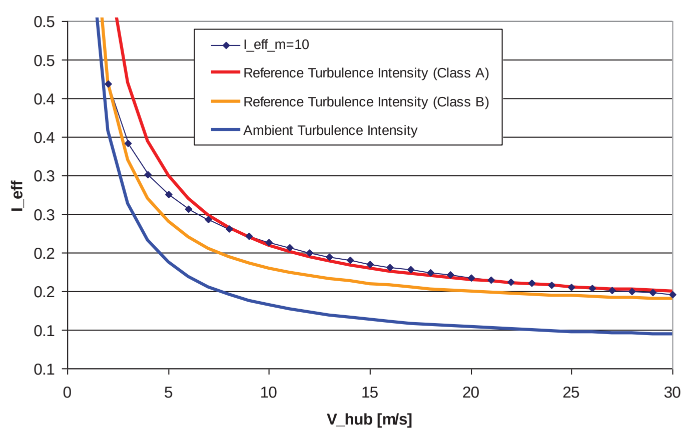


Figure 6-45: Wake Effects Considering 3D Spacing



The results for the effective turbulence intensity for m = 10 partly exceed the limits of the turbulence category A (18%) when a layout with a normalized distance of 3 rotor diameters is used. Thus, appropriate planning of the layout is crucial in defining suitability with regard to wake effects.

It must be noted that the calculation method used here neglects the influence of the actual wind direction distribution as well as the deviation of characteristic turbulence intensity with wind direction. By judging the actual wind direction and the actual distribution of the characteristic turbulence intensities, the results of this preliminary calculation are found to give a good representation of the actual wake effects on turbine loading.

The effective turbulence intensity will strongly depend on the distance between the individual turbines and the actual turbine design. Thus, at this early stage no detailed investigation for the individual configurations has been carried out.

6.4.3.9 Summary of Wind Conditions

The most important site conditions from the wind source are summarized in Table 6-8. Furthermore, the basic design parameters for GL wind turbine class are presented for comparison.

As can be seen from Table 6-8, the site specific wind conditions at the proposed Lake Erie Offshore Center site are below the requirements of GL wind turbine class II. Thus, concluded from this point of knowledge, a wind turbine fulfilling the GL class II requirements should be suitable for the project.

The overall impression of the site Lake Erie is that the wind conditions tend to be gentle with respect to the structural integrity of the turbines. Only the wake effects might become a design driving factor for the turbine layout as discussed in Section 6.4.3.8, especially when a layout with close distances between the turbines is chosen. From the information available at this stage, distances between the wind turbines of 4 D or more are recommended.

Table 6-8: Site Specific Conditions at Lake Erie and GL Class II Conditions for Comparison

Type of Condition at Lake Erie	Value & Unit	GL Class II
50-year extreme wind speed (at 70 m height, 10-min mean)	~ 38 m/s	42.5
Annual average wind speed (at 70 m height, 10-min mean)	up to 8.2 m/s*)	8.5
Shape parameter k (50 m height)	2.08	2.00
Characteristic turbulence intensity (at 50 m height, 10-min mean, at 15 m/s)	11.3 %	18 / 16 / 14.5 % (Category A / B / C)
Wind shear during normal conditions (Hellmann Exponent)	0.09	0.14
Mean air density (at 50 m height)	1.204 kg/m³	1.225 kg/m³
Air temperature at 50 m height	~10.64°C	

*Considering the nine configurations and corresponding wind maps

6.4.4 Effects of Waves

6.4.4.1 Requirements for the Assessment of Waves and Marine (Limnic) Conditions

The requirements for the assessment of the waves and other marine conditions are stated in the GL Guideline for the Certification of Offshore Wind Turbines, edition 2005, Section 4.2.3. It is stated that for the definition of the loads and structure design the oceanographic (marine conditions) data relevant for the installation site shall apply. Environmental design conditions are to be specified in a way that they cause the most adverse effect on the relevant probability level on the structure. For the purpose of combination with the operating conditions, the external conditions are subdivided into normal and extreme. Normal external conditions are in general those events which have a probability of being exceeded once a year or more often. Extreme external conditions on the other hand are events with a probability of being exceeded once in 50 years.

In Section 4.2.3.1.1 of the GL Guideline it is defined that the wave conditions to be applied for the design have to be defined under consideration of the long term statistics. They shall be based on measurements performed at the site or on hindcast studies supported and validated by long-term measurements near the site where the installation is planned.

In general, the approach is that a hindcast study is performed for the site. The results of this hindcast study are validated against measurements performed near the site, in an area with conditions similar to those of the site, if possible. An error analysis is required and if significant deviations occur, the parameters of the hindcast shall be adjusted and a new run is to be performed. The measurement period shall be sufficiently long to obtain reliable data for at least 6 months. In general a measurement period of two years is required to reach a full set of reliable data. Seasonal variations can contribute significantly to the wave data and consequently the measurement period shall take account of this influence.

If long-term measurements (several years) near the site exist, they can directly be used as an input for models analyzing the propagation of waves, under consideration of bathymetry and wind conditions. These methods (e.g. SWAN) should be calibrated with a second set of measurements. These can be temporary measurements for a relative short period, sufficient only to calibrate the analysis model. This method is the recommended method in lakes with long-term measurements available as is the case for Lake Erie.

If the actual external conditions are not sufficiently known, then the offshore wind turbine can be designed according to one of the wind turbine classes specified in GL-Guideline section

4.2.2.1, the wave parameters may be taken according to the mean wind speed assuming fetch and considering the water depth by applying correlation formulations. Before erection of the turbine, however, it shall be ensured that the design conditions adequately cover the prevailing external conditions at the site.

In addition to the wave conditions, water level variation and water current shall be analyzed. All these values are highly dependent on the bathymetry of the site and the surrounding area. The exact requirements for the marine data to be analyzed are specified in the GL-Guideline and summarized in the following list.

- 50-year and 1-year extreme sea states, significant wave heights, elevation
- Scatter diagram, preferably (Hs ,Tp , θ), Hs being the significant wave height, Tp the peak period of the sea state and θ the dimensionless duration of the wave
- Wind-wave correlation (Wind speed, significant wave height and eventually period). Optimally for different directions
- Proposed 50-year maximum wave height
- Wave spectrum (if not standard)
- Tidal, storm surge, wind generated and wave induced surf currents
- 50-year and 1-year current
- Mean water level (MSL)
- Highest and lowest water levels:
    - 50-year highest still water level (HSWL)
    - 50-year lowest still water level (LSWL)

6.4.4.2 Assessment of Marine Conditions

Within the following sections marine data derived from the document review are presented and, where possible, the relevant parameters extracted.

6.4.4.3 Bathymetry

Section 3.1.2 indicates that water depth varies between 13m and 17m in the Project area. Water depths are of high importance for load calculation and support structure design. Bathymetry directly influences the wave heights and current speed to be considered in the design. As a consequence, the final design basis shall contain water depths from measurements at all turbine locations. For the present study a preliminary value for the mean water depth of 15m is assumed.

6.4.4.4 Water Density

Section 6.2.3.1 states distinct water layers within Lake Erie in summer. Density variations in these layers prevent them from mixing with one another, essentially creating layers with very different chemical and physical characteristics. The separation of water into the layers may occur in offshore waters deeper than 49 to 60 feet (15-18m) to the bottom of the lake.

In absence of any information an assumption of a water density α=1.0kg/m^3 is made. Within further stages of the project, the mean water density derived from the layers is a parameter which is needed for the hydrodynamic load calculation.

6.4.4.5 Water Levels

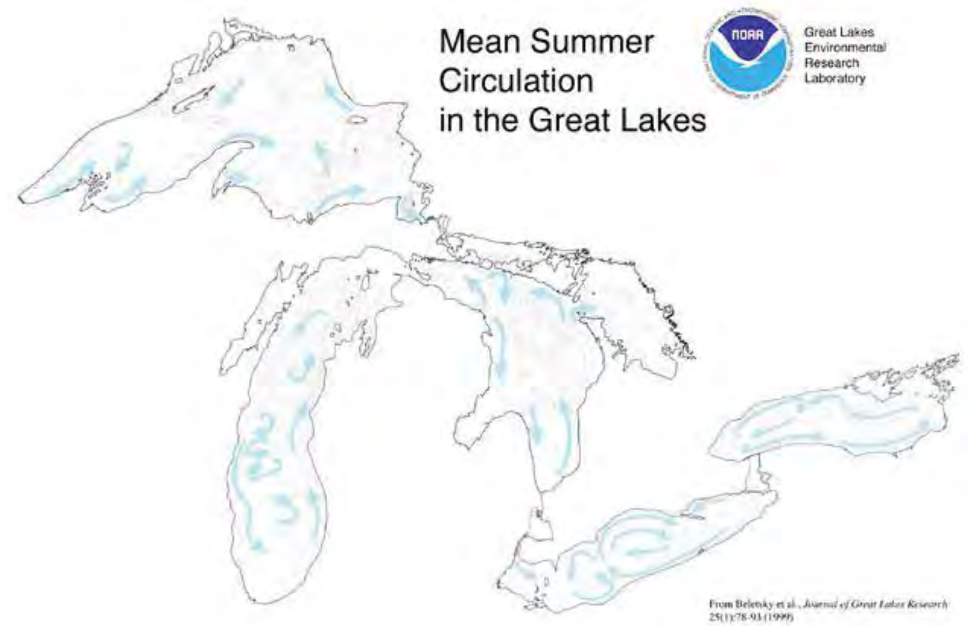
The long-term mean surface elevation of Lake Erie, based on data from 1860 to present, is approximately 571 feet (174 m) above sea level. Over this same period, the average lake level has generally fluctuated between elevations of 568 and 574 feet (173 and 175 m). Short-term changes in lake level (several feet over a few hours) can occur due to strong winds associated with changing weather systems. During severe storm events, differences in water levels of more than 16 feet (4.8 m) have been observed between Buffalo and Toledo. No such data has been found for the Cleveland region, but it can be expected that short-term changes of water levels can also exceed several feet (m).

As a result a normal water level change of ±1m and an extreme water level change of ±2.4m from mean water level can be considered in a preliminary analysis.

6.4.4.6 Currents

Currents occur in all of the Great Lakes. Winter currents are generally stronger than the summer currents that are illustrated in Figure 6-46. The broad-scale offshore water masses are defined by gyres, open-lake hydrodynamics, and large scale inflows. The Central basin of Lake Erie appears to be structured by two dominant gyres east to west. The western gyre typically circulates counter-clockwise, while the eastern gyre generally circulates in a clockwise direction. Additionally, wind induced surface currents may occur.

Figure 6-46: Mean Summer Circulation in the Great Lakes



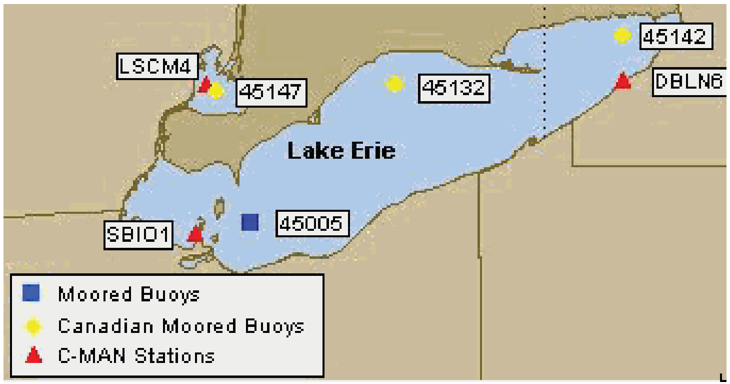
Currently, there are no data available concerning water current velocity for any of the potential wind turbine sites. Therefore a site recommendation on basis of current velocity cannot be made. Nevertheless, it is not assumed that currents could become a decisive factor in hydrodynamic loading, so none of the specified locations can at this point be excluded due to water currents.

6.4.4.7 Assessment of Existing Information Regarding Waves

In Section 6.3.3.3 basic information is given on the kind and direction of waves in the area. The waves are wind driven in the predominant southwest-northeast wind direction. This is supported by the Lake Erie wind resource analysis stating that the wind is blowing along the long axis of the lake.

From the existing material it is assumed that the NOAA National Data Buoy Center observations at Station 45005, W ERIE (buoy) historical data are the best information source for wave analysis. Although the buoy is 28 nautical miles NW from Cleveland and 40 km from the outmost corner of the project area (see Figure 6-47), the wave data may be assumed representative for the coastal area of Lake Erie and the project area. The buoy is described as 3-meter discus buoy with DACT payload at position 41.677 N 82.398 W (41°40'36" N 82°23'54" W).

Figure 6-47: NOAA 45005 Buoy and Location

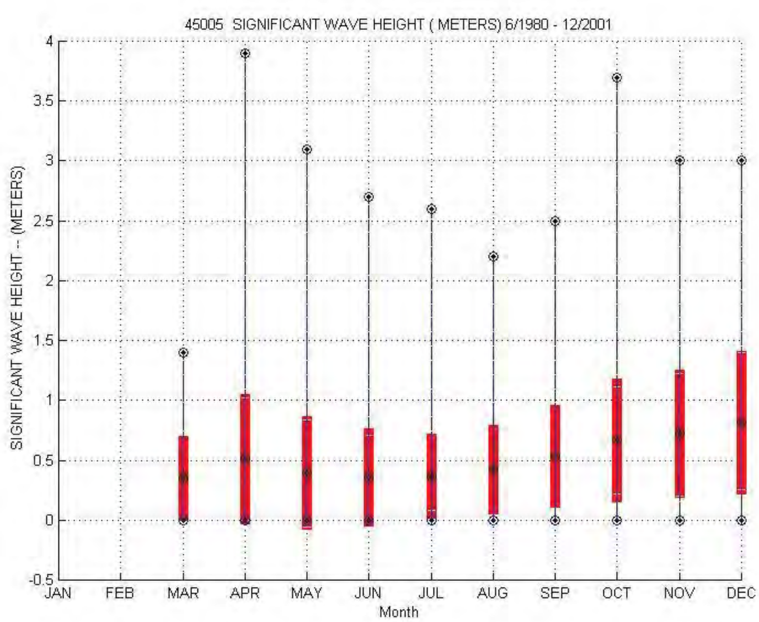


The buoy characteristics are:

Site elevation:	173.9 m above mean sea level
Air temp height:	4 m above site elevation
Anemometer height:	5 m above site elevation
Barometer elevation:	173.9 m above mean sea level
Sea temp depth:	0.6 m below site elevation
Water depth:	12.6 m
Watch circle radius:	36 yards

According to the wave data evaluation from the NOAA buoy (Figure 6-48) the mean significant wave height at the buoy location varies from 0.3 m to 0.8 m, a typical value for a lake of this size and water depth.

Figure 6-48: Significant Wave Height at NOAA Buoy 45005



What is of interest for the design is the extreme value of the significant wave height which can reach heights of about 4m. This is near the water depth limiting height of about 6 m at the buoy location. In the documentation the data are analyzed on a monthly basis and no “classical” scatter diagrams, giving the significant wave height and peak period relation are given. Furthermore, for offshore wind turbines, the relation of wind speed and wave height is needed for design. As a result, an analysis of the historical data from 1981 to 2007, available from the buoy was performed.

In Section 6.3.3.3 the “seiche”-effect is mentioned, comparable with storm surge seen in coastal conditions. This oscillation of up to 6.7 m is mainly affecting the western and eastern coastal areas of the Lake Erie. The seiche is considered as a long wave with periods over 10 hours and in the analysis it can be treated like a tidal variation. It is assumed that the wave characteristics in the project area are not affected by the seiche.

It shall be considered that during the winter months, mainly January and February, the project area is covered by ice and no waves occur.

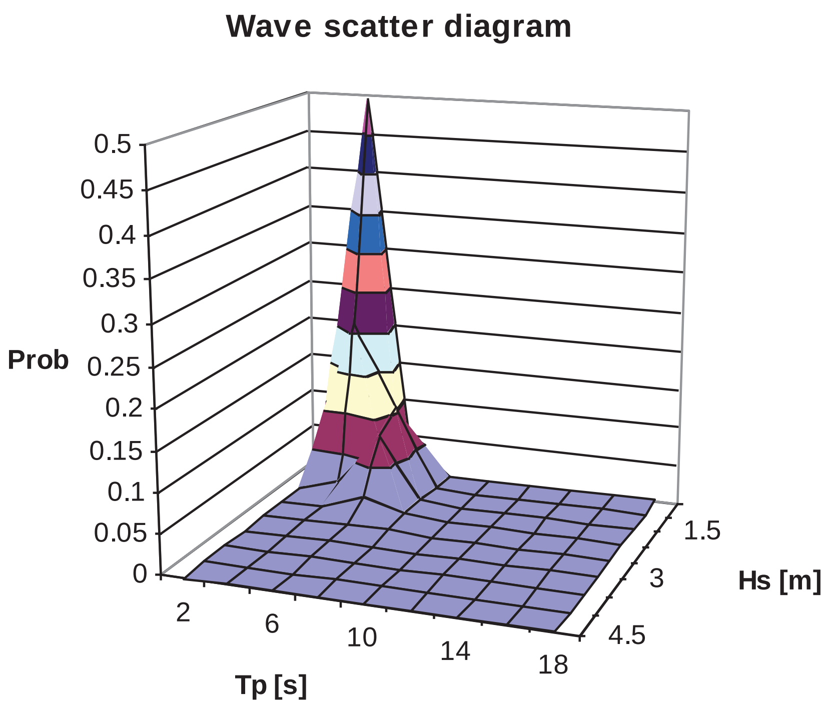
6.4.4.8 Analysis of Buoy Data

From the NOAA-database, the data from buoy 45005 were analyzed to derive the principal values required for load analysis. From these data first a wave scatter diagram from 28 years of data was derived. Figure 6-49 shows a distribution of the significant wave height and peak period with a single peak at about 4s and a peak significant wave height at about 1m. This is a typical situation for a fetch limited area like Lake Erie. From the form of the distribution it is assumed that classic methods of offshore engineering are applicable, meaning that single peak wave spectra as the JONSWAP or Donelan spectrum can be used.

Table 6-9: Scatter Diagram of Significant Wave Height (Hs) vs. Peak Period (Tp), in Hours

Hs [m]	Tp [s]														
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	SUM
4-4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5-4	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
3-3.5	0	0	2	4	10	0	0	0	0	0	0	0	0	0	16
2.5-3	0	0	41	61	9	0	0	0	0	0	0	0	0	0	111
2-2.5	0	0	367	340	9	0	0	0	0	0	0	0	0	0	716
1.5-2	0	10	2171	596	2	0	0	0	0	0	0	0	0	0	2779
1-1.5	0	1542	8543	469	0	0	0	0	0	0	0	0	0	0	10554
0.5-1	0	22290	11095	138	0	0	1	0	0	0	0	0	0	0	33524
0-0.5	107	51417	4641	44	62	1	2	2	0	1	0	0	2	0	56279
SUM	107	75259	26860	1652	95	1	3	2	0	1	0	0	2	0	103982

Figure 6-49: Wave Scatter Diagram, Probability vs. Significant Wave Height and Peak Period, NOAA buoy 45005



In a similar way a scatter diagram showing the relation between hourly mean wind speed at 10 m height and significant wave height is derived. This distribution is compared to generic formulations from the GL-Guideline in Table 6-10.

Table 6-10: Scatter Diagram of Significant Wave Height vs. Wind Speed at 10 m height, in Hours

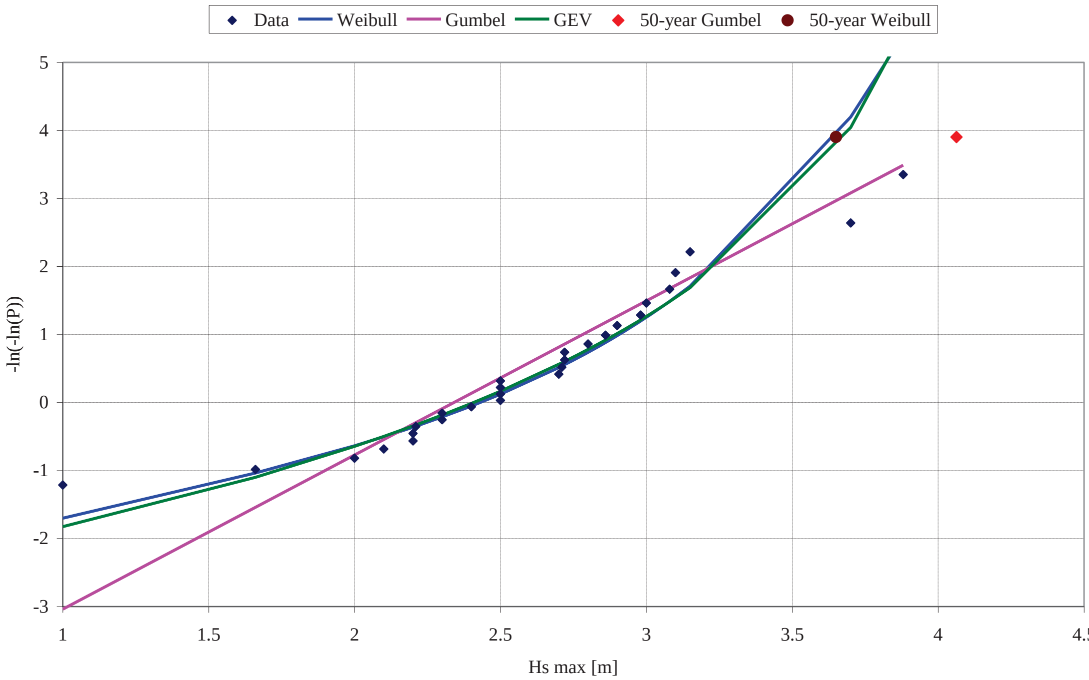
Hs [m]	v [m/s]											
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	SUM
4-4.5	0	0	0	0	0	0	0	0	0	0	0	0
3.5-4	0	0	0	0	0	0	0	2	1	0	0	3
3-3.5	0	0	0	1	0	0	2	8	4	1	0	16
2.5-3	0	0	2	5	5	10	22	25	33	9	0	111
2-2.5	0	0	1	21	58	210	184	174	61	3	0	712
1.5-2	0	3	36	248	642	806	724	246	16	0	0	2721
1-1.5	16	129	669	2247	3764	2730	656	50	2	0	0	10263
0.5-1	550	2988	8983	12943	6442	850	56	5	0	1	0	32818
0-0.5	9034	19096	19192	6513	578	69	9	1	1	0	0	54493
SUM	9600	22216	28883	21978	11489	4675	1653	511	118	14	0	101137

From the time series of the 28 year measurements the annual maxima were extracted and an extrapolation of the extreme significant wave height was performed to derive 50-year recurrence values. Figure 6-50 shows the distribution of the annual maxima and the fit using extreme value distributions (Gumbel, Weibull and Generalized Extreme Value distribution - GEV). The maxima are plotted against the double logarithm of the annual probability of occurrence

$$P_x = 1 - \frac{1}{T}$$

with T being the return period in years. This means that the 50-year return period event has a probability of 0.98.

Figure 6-50: Extrapolation of Extreme Significant Wave Height



As a result, the 50-year extreme significant wave height according to the different distributions is:

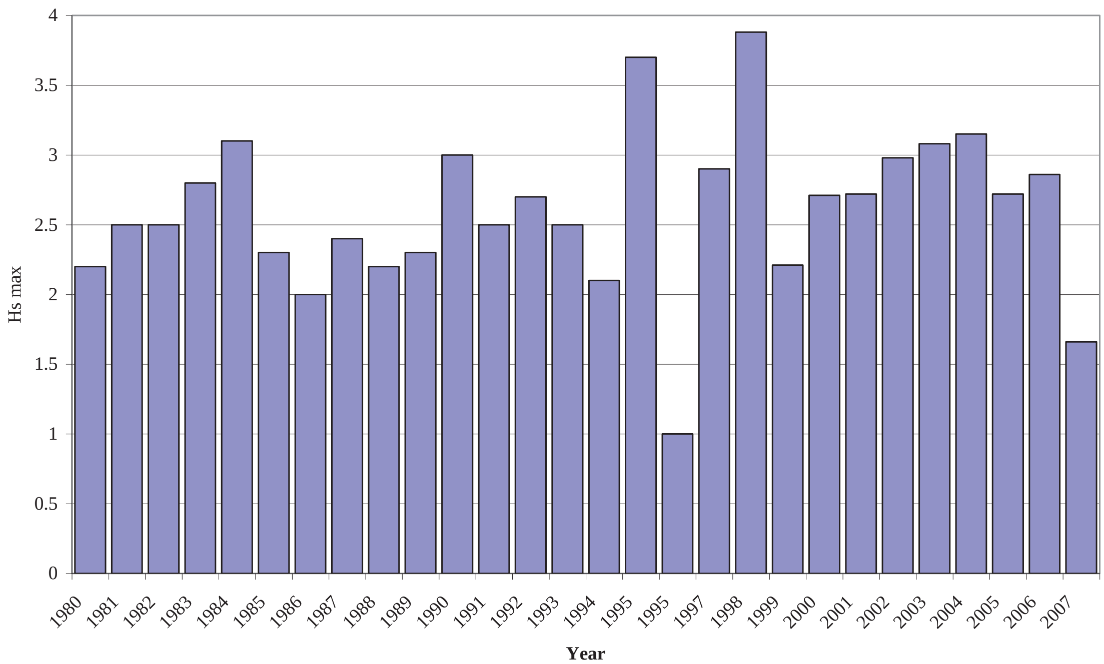
Distribution	Gumbel	Weibull	GEV
$H_{s,50\text{-}year}$	4.1m	3.7m	3.7m

From the bulk of the data one would assume that the three-parametric Weibull distribution is giving the best fit, and that the two highest values are effects not corresponding to the distribution. In contrast the Gumbel distribution has the worst fit in terms of standard deviation but is the most conservative and shows a good fit with the highest values. As a consequence, for the preliminary analysis, it is proposed to use the conservative value from the Gumbel distribution.

The extreme wave height and period can be derived from this value using the GL Guideline. The resulting wave height is at about 7.8 meters, below the depth limiting height for the site of about 9.5m to 10m. The extreme waves at Lake Erie will be shallow water influenced waves with occasional occurrence of breaking.

As can be seen in Figure 6-51, the yearly extremes do not show a long-term trend, except some smaller variation with a period of about 7 to 8 years.

Figure 6-51: Variation of Extreme Significant Wave Height Between 1980 and 2007



6.4.4.9 Analysis According to Simplified Methods of GL-Guideline

According to the GL Guideline Chapter 4, Section 4.2.3.1.2, paragraph (14), a simplified method to derive wind-wave-correlation can be used. The method is described in Appendix 4.E of the Guideline and is based on the JONSWAP spectrum as well as on the TMA formulation of the wave spectra for shallow waters. According to that for not fully developed sea states the influence of the time and fetch x the wind is acting may be considered with:

The dimensionless time of wind: $\theta = g / u \cdot time$

and the fetch: $\xi = g / u \cdot x$

with g the acceleration of gravity and u the hourly mean wind speed at 10 m above the sea surface.

The dimensionless peak frequency is $\nu = \frac{\omega_p}{2\pi} \cdot \frac{u}{g} = \max\left(0.16;\, 2.84 \cdot \xi^{-0.3};\, 16.8 \cdot \theta^{-\frac{3}{7}}\right)$

the value of the Phillips constant is then $\alpha = 0.028 \cdot \nu^{2/3}$

the peak period $T_p = \frac{u}{g} \cdot \frac{1}{\nu}$

and the significant wave height is $H_s = 0.0094 \cdot \nu^{-\frac{5}{3}} \cdot \frac{u^2}{g}$

In the present case the fetch is the limiting factor and is directly derived from the Lake Erie drawings. The directions considered are the North-East and the North directions showing the longest fetch. It is assumed that the site is open to wind generated waves in East-West direction. Wave loading at southerly wind directions is assumed to be negligible. The fetch to be considered is about 100km to the North, 250km in NEE-direction and about 70km in West direction.

For finite water depth a self-similar spectral shape (TMA-Spectrum) can be used. Its general validity was checked against measurements (Texel, Marsen, Arsloe).

$$S_{\eta,TMA}(\omega) = S_{\eta,JONSWAP} \cdot \Phi_k(\omega_d)$$

and

$$\omega_d = \omega \sqrt{\frac{d}{g}}$$

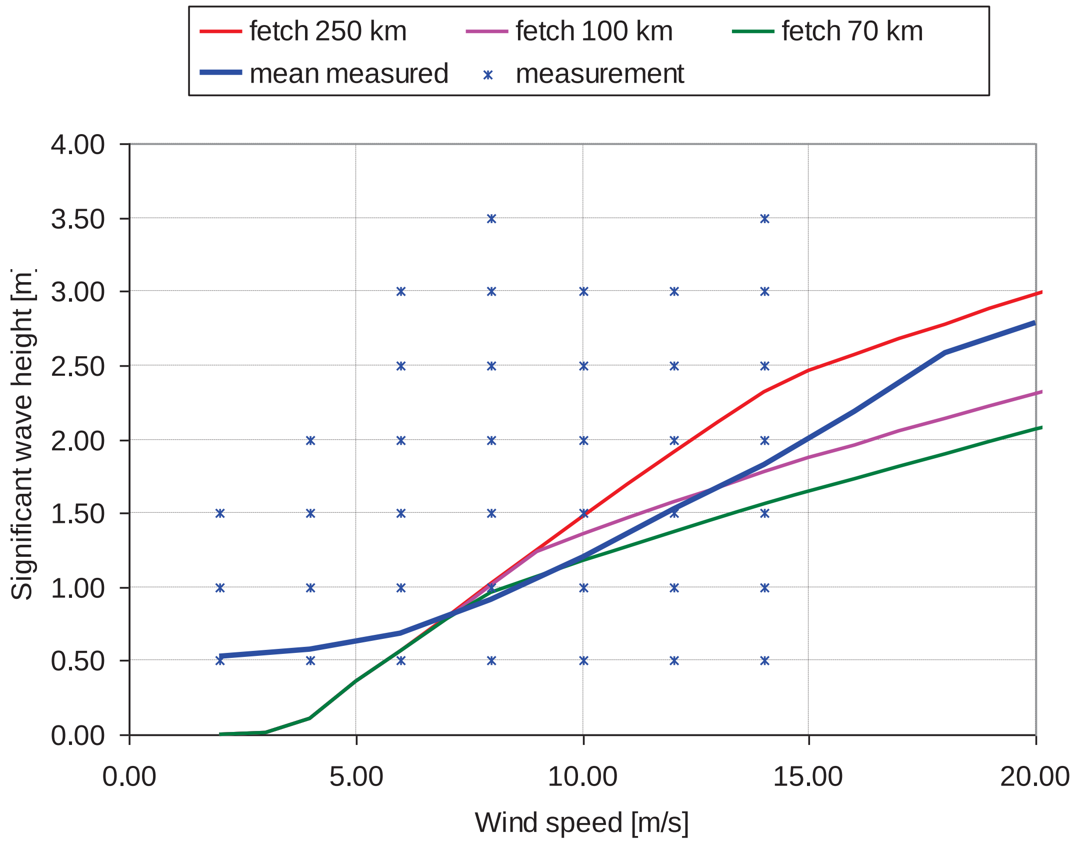
with

Φk	=	transformation factor
ωd	=	depth dependent frequency
d	=	water depth

$$\Phi_k(\omega_d) = 0.5 \cdot \omega_d^2 \quad \text{for} \quad \omega_d \le 1$$
$$\Phi_k(\omega_d) = 1 - 0.5 \cdot (2 - \omega_d)^2 \quad \text{for} \quad \omega_d > 1$$
$$\Phi_k(\omega_d) = 1 \quad \text{for} \quad \omega_d > 2$$

The resulting significant wave height from the calculation using the TMA-JONSWAP formulation and a water depth of 12m and the measurement are shown in Figure 6-52. In addition the mean significant wave height as a function of wind speed, measured at the NOAA buoy 45005 is shown. In the case shown not only the water depth is limited but the distance to the coast is relatively low. The result is that the sea state is not fully developed and the wave heights are limited by the finite water depth. From the external data considered it is clear that the importance of water depth, fetch and time should be taken into account. The figure shows that a good correlation between the measured values at the buoy and the simplified assumptions is achieved. As a result the use of the measured values is proposed.

Figure 6-52: Wave Height Comparison



6.4.4.10 Resulting Design Values

From the reviewed data, the following design values are derived:

Table 6-11: Preliminary Wave Design Parameters

Mean water depth	d	=	15	m
Water depth variation	Δd	=	±2	m
Water density	ρ	=	1.0	kg/m3
High still water level (1-year)	HSWL1	=	+1	m
Low still water level (1-year)	LSWL1	=	-1	m
Highest still water level (50-year)	HSWL50	=	+2.4	m
Lowest still water level (50-year)	LSWL50	=	-2.4	m

Sub surface current	us	=	?	m/s
Wind induced current	uw	=	acc. To GL Guideline	
Mean significant wave height	Hs,mean	=	0.82	m
50-year significant wave height	Hs, 50	=	4.1	m
50-year sea state peak period	Tp50	=	7.2-8.5	s
50-year wave height	Hmax	=	7.8	m
50-year wave period min	TDmin	=	7.2	s
50-year wave period max	TDmax	=	9.2	s
1-year significant wave height	Hs, 1	=	2.5	m

For fatigue analysis the wave scatter diagrams from the NOAA buoy 45005 can be used. The water depth is similar to the site and it is assumed to be transferable to the site. It shall be considered that for the southerly directions SWW to SEE no significant wave loading is expected.

The design values stated in this report should be considered as first and preliminary conservative estimates. Should the project prove feasible and enter the planning phase, it is recommended to perform further analysis and measurements (see Section 6.4.6.1).

6.4.4.11 Comparison of Wave Heights in Different Offshore Environments

Compared to offshore conditions in the German North Sea and Baltic Sea, extreme wave conditions in Lake Erie are moderate, as can be seen in the table below.

Table 6-12: Weibull Exceeding Probability of Significant Wave Heights in Different Locations

	Recurrence period	
Threshold value significant wave height in:	**1 year**	**50 years**
Lake Erie	2.5 m	4.1 m
Baltic Sea	4.8 m	6.8 m
North Sea (Light Vessel “FS Deutsche Bucht“)	6.2 m	8.7 m

Maximum wave heights (50 years) can be derived from these values. The maximum wave height is 7.8 m for Lake Erie compared to 13.8 m for the Baltic Sea and 16.2 m for the North Sea.

This means that the extreme wave loads affecting the turbines are smaller in comparison to the loads influencing the turbine design of offshore wind farms in the German North and Baltic Seas. Without having done any calculations it can currently be assumed that the extreme wave loads will not be the design driving factor. Waves might play an important, but not the dominant role with respect to the fatigue loads.

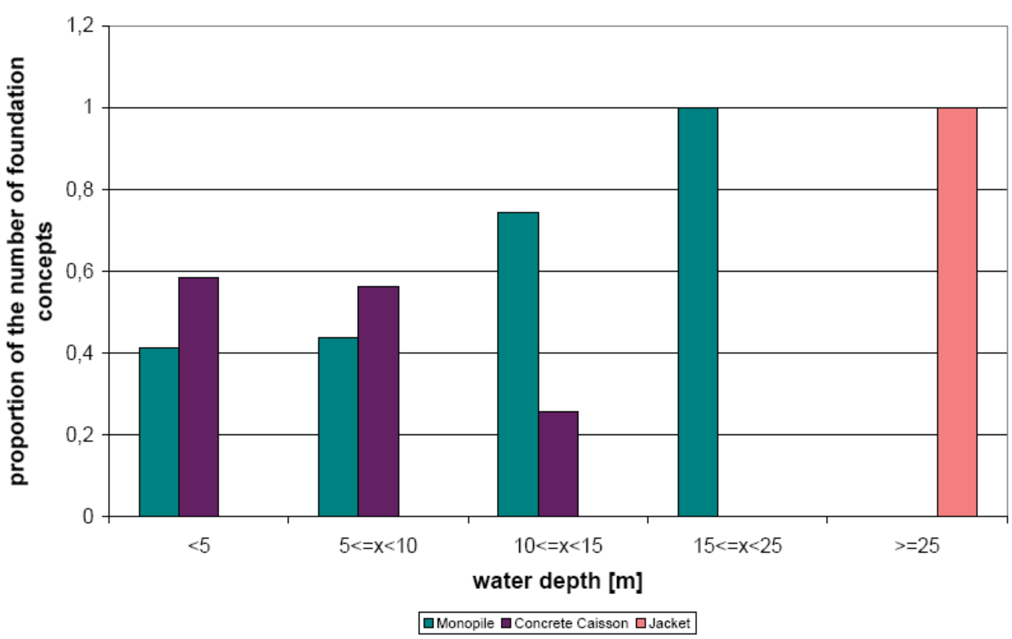
6.4.5 Influence of Environmental Conditions on Foundation Concept

The choice of a suitable foundation for an offshore wind turbine depends on several factors, such as turbine size, soil conditions, water depth, loads from wind, waves, ice, etc., feasibility and costs.

The existing environmental conditions at the potential Lake Erie demonstration project site have considerable influence on the turbine substructure design. The soil conditions and water depth will influence the principal design selection (monopile, gravity base, jacket or others). Further the metocean conditions influence loads and thus the detailed design and the scantlings. Other environmental conditions like temperature will influence material selection.

The most common foundation types currently used for support of offshore wind turbines are monopile and gravity base foundations. Figure 6-53 shows the preferred foundation concepts at different water depths. While gravity base foundations and monopiles are used up to 15 m or 25 m respectively, deeper waters (> 25 m) require alternative foundations, including multi-legged or lattice structures like tripod, tri-pile, jacket or even floating structures.

Figure 6-53: Foundations in Use by Water Depth



For the GLWEC Pilot Project, which will be located in a water depth of up to 17 m, gravity base foundation and monopile will have to be examined more closely. Due to preliminary soil information from previous studies but subject to final site specific investigations, monopiles currently appear to be the preferred foundation option for the Pilot Project. Welded steel structures such as tripod or jacket could be suitable as well, but as they are very expensive due to their complex fabrication process they will probably not be an economic alternative.

In general it is assumed that wind and wave conditions, together with the mutual interference of the turbines in the wind farm will be the design drivers for the fatigue limit state. Here it should be stated that the biggest part of the turbine design and its structure are fatigue driven. Additionally the case of dynamic ice loading has to be considered. If locking of the ice breaking frequency with the natural frequency of the structure occurs, significant structure vibrations will result. Often these sea ice induced vibrations are the design driver for fatigue and extreme substructure loading. As sloping structures in the water line are leading to reduced static loads and will be able to avoid or minimize ice induced vibrations, an ice cone should be considered on the pile in the waterline (see Section 6.4.2.7).

The extreme loads may be the result of different sources. For the present site, it could be assumed that the extreme loads (bending moments) on the foundation will result from the extreme wind speeds. The extreme bending moments at the mudline, in conjunction with the soil conditions, will be the design driver for the pile penetration depth and thus the overall required pile size. Lake ice load is another extreme load which can be decisive for the design. In this case not only the pile size will be influenced but, if an ice cone is required, the general design too.

The waves and the extreme wave height, together with the water level changes, are important for the final height of the access platform. As a function of wave height, period and pile diameter the run up of the water or direct slam of the waves have impact on the design pressures on the platform. The wave and wind probability distributions have significant influence on the offshore turbine accessibility (weather windows) and consequently maintainability and availability.

Finally it is assumed that the principal design driver will be lake ice.

6.4.6 Summary and Recommendations with Respect to Ice, Wind, and Waves

Regarding ice conditions the proposed locations for the GLWEC Pilot Project close to Cleveland can be considered as one of the more moderate areas of the Great Lakes, with respect to expected ice thicknesses.

The screening of the available documents indicates that an average level ice thickness of around 30 to 35 cm has to be expected, and the maximum level ice thickness is approx. 50

cm. The maximum expected rafted ice thickness may be around 60 cm with an average ice cover duration of around 66 to 69 days varying from 33 to 105 days, starting around the middle of December.

There is a marked trend towards earlier dates of last ice starting in the late 1960s. This decline is associated with a general increase in spring temperatures and earlier ice out dates in the Great Lakes during the last 40 winters.

Other ice parameters, like compressive and bending strength are not mentioned in the screened documents, but in general a bending strength of 750 kPa and a compressive strength of 2 – 3 MPa should be assumed.

The wind conditions have been investigated and evaluated. The annual average wind speed (at 70 m height, 10-min mean) can be stated to be up to 8.2 m/s, the 50-year extreme wind speed (at 70 m height, 10-min mean) is ~ 38 m/s. These and other main parameters lead to the result, that the site specific wind conditions at the proposed Lake Erie Offshore Center site are below the requirements of GL wind turbine class II. Thus, concluded from today's point of knowledge, a wind turbine fulfilling the GL class II requirements should be suitable for the project.

The overall impression of the Lake Erie site is that the wind conditions tend to be gentle with respect to the structural integrity of the turbines. Only the wake effects might become a design driving factor for the turbine layout, especially when a layout with small distances between the turbines is chosen. From the information available at this stage, distances between the wind turbines of 4 x rotor diameter or more are recommended.

No significant differences in wind conditions between the different proposed wind farm locations are expected. Thus, energy yield is expected to play the key role in the determination of a site.

With regard to waves and other limnic conditions (e.g. water depths, water levels, water density, currents) first design values were derived from the reviewed data and documents. Buoy data from the NOAA buoy 45005 were analyzed to derive the principal values and a first wave scatter diagram. Results of this analysis are a mean significant wave height of 0.82 m and a 1-year significant wave height of 2.5 m. To describe the extreme conditions the 50-year values were derived. The 50-year significant wave height is 4.1 m with a 50-year maximum wave height of 7.8 m.

Compared to offshore conditions in the German North Sea and Baltic Sea, extreme wave conditions in Lake Erie are moderate. Maximum wave heights (50 years) in Lake Erie reach 7.8 m which is less than half as high as extreme waves e.g. in the German North Sea.

This results in smaller extreme wave loads affecting the future turbines compared to the loads influencing the turbines of offshore wind farms in the German North and Baltic Seas. Without having done any calculations it can currently be assumed that for the Lake Erie location the extreme wave loads will not be the design driving factor. Waves might play a role with respect to the fatigue loads, not being the dominant source of load.

The existing environmental conditions at the potential Lake Erie demonstration project site have considerable influence on the turbine substructure design. The soil conditions and water depth will influence the principal design selection (monopile, gravity base, jacket or others). Further the metocean conditions (including ice) influence loads and thus the detailed design and the scantlings.

Generally wind and wave conditions, together with the mutual interference of the turbines in the wind farm, will be the design drivers for the fatigue limit state. If ice induced vibrations occur they will be the design driver for fatigue and extreme substructure loading. To avoid or minimize ice induced vibrations, an ice cone should be considered on the pile in the waterline. Extreme loads (bending moments) on the foundation will probably result from extreme wind speeds. The extreme bending moments at the mudline, in conjunction with the soil conditions, will be the design driver for the pile penetration depth and thus the overall required pile size. Ice load is another extreme load which can be decisive for the design. In this case not only the pile size will be influenced but, if an ice cone is required, the general design too. Finally it is assumed that the principal design driver will be lake ice.

6.4.6.1 Future Considerations with Respect to Ice, Wind, and Waves

With regard to ice the profile of the wind turbines sub structure is a key issue. Structures with vertical walls in the waterline region (e.g. monopiles) generally experience larger ice actions than sloping ones for similar waterline dimensions. In addition to the ice forces the dynamic structure response associated with ice failure has to be taken into account. In case the project will prove feasible and enter the planning stage, investigations and analyses of the interaction of turbine, foundation and ice failure with regard to ice induced vibrations and the wind turbine’s eigenfrequencies will be essential.

Generally, the incorporation of the ongoing wind measurement data is recommended in order to get more reliable results, especially with respect to extreme wind speeds and wind shear.

LiDAR and CFD modeling of the Crib are possible options in this respect.

The design values concerning wave and other hydrographic parameter stated in this report can be considered as first and preliminary conservative estimates. Should the project prove feasible and enter the planning phase, it is recommended to perform a bathymetry analysis in the project area as well as a hind cast analysis regarding waves, currents and water levels at the site.

It is further recommended to use NOAA 45005 buoy wind and wave data as an input to the model. The hind cast should be validated with local measurements, best directly at the site. The local measurements should cover about one year of data to reach optimal results including seasonal variations.

7 Conceptual Design of Pilot Project Turbines and Potential Offshore Research Platform

(Unless otherwise indicated, information in this section from GLWEC Conceptual Design Report, Germanischer Lloyd, January 2009).

7.1 Introduction

Sufficient knowledge of the wind resource and icing conditions as well as other environmental conditions is required to minimize the risk associated with offshore wind farms especially in cold climates. The GLWEC Feasibility Study provides compiled information to date. Further measurements and investigation (i.e. LiDAR at the Crib) are ongoing.

One purpose of the conceptual design report is to identify, whether design relevant data are lacking and to show possible options to achieve them. A good opportunity could be a research platform at the test site.

Within the first part of this section general requirements for offshore platform and wind turbines will be provided. The second part deals with currently operated offshore measurement platforms in German waters. From this experience, environmental conditions, technical and other requirements (space, energy, technical equipment, data collection and transfer, etc.), safety aspects as well as economic aspects will be described and a functional specification given. The last part describes the requirements for turbine selection and foundation design both in general and with regard to the GLWEC and covers also related items such as offshore access.

7.2 Design Requirements for Offshore Wind Turbines and Met Masts

When designing offshore wind turbines for a specific site, it is necessary to assure that type-certified wind turbines and particular support structure designs meet the requirements governed by site specific external conditions. Therefore special guidelines have been developed. Within “project certification” services it is assured that the requirements of e.g. GL Wind guidelines, local codes and other requirements relevant to the site are met.

7.2.1 Guidelines and Standards

A number of international and national guidelines and standards have been developed with regard to wind turbines, wind farms and offshore structures.

One of the first steps is to define the guidelines or standards which have to be applied. For particular elements, components or procedures not specifically covered by the chosen guideline, other rules and guidelines may be applied where appropriate and agreed upon.

For the proposed GLWEC Pilot Project it is recommended to consider the following guidelines and standards in design of turbine/met mast, structures and site assessment in the order listed below.

Table 7-1: Relevant Guidelines for Offshore Wind Turbines in Ice Conditions

Germanischer Lloyd: Guideline for the Certification of Offshore Wind Turbines, edition 2005. Rules for Classification and Construction, IV – Industrial Services, Part 2 – Offshore Wind Energy, Hamburg.
Germanischer Lloyd: Fixed Offshore Installations, edition 2007. Germanischer Lloyd Rules for Classification and Construction, IV – Industrial Services, Part 6 – Offshore Technology, Chapter 3, Hamburg.
Germanischer Lloyd: Guideline for the Construction of Fixed Offshore Installations in Ice Infested Waters, Germanischer Lloyd Rules for Classification and Construction, IV – Industrial Services, Part 6 – Offshore Installations, Chapter 7, Hamburg.
IEC 61400-3: Wind Turbines. Part 3: Design requirements for offshore wind turbines, IEC TC88 WG3: CDV, July 2007 (committee draft for voting.)
ISO/CD 19906: Petroleum and natural gas industries -- Arctic offshore structures. TC 67/SC 7. Draft version.
GL Wind Leitfaden 067: Zertifizierung von Windenergieanlagen für Extremtemperaturen (hier: Cold Climate), Rev. 2, 2005, Hamburg.

7.2.2 Site Conditions and Design Basis

Offshore wind turbines are subjected to oceanographic, meteorological and electrical conditions which may affect their loading, durability and operation. To ensure the appropriate level of safety and reliability, the environmental, electrical and soil parameters as well as other relevant parameters have to be taken into account in the design and should be explicitly stated in the design documentation.

Environmental design conditions are to be specified in a way that they cause the most adverse effect on the relevant probability level on the structure. For the purpose of combination with the operating conditions, the external conditions are subdivided into normal and extreme. Normal external conditions are in general those events which have a probability of being exceeded once a year or more often. Extreme external conditions on the other hand are events with a probability of being exceeded once in 50 years.

Within the Preliminary Site Review Report (Section 3) and the Desktop Study on the Effects of Ice, Wind and Waves (Section 6.4), several preliminary parameters have been estimated or determined, though for some parameters further investigations are necessary. They include

- Site and wind farm configuration
- Soil properties
- Wind and meteorological conditions
- Marine/Limnic conditions including bathymetry, waves, currents, etc.
- Ice
- Electrical Grid Connection

7.2.3 Load Assumptions

Within the further planning process the design driving load cases are to be defined with reference to the site conditions and the operation and safety system of the wind turbine.

In the analysis one distinguishes between the fatigue loads for the verification of fatigue strength and the extreme loads for the verification of the ultimate bearing capacity (ultimate strength, buckling…). The fatigue loads have to represent the operation of the wind turbine over a period of 20 years, which is the designated service life. The extreme loads have to consider all events, which could lead to high loads. A number of load cases are to be considered – some events within the load cases are the 50-year gust, 50-year wave, extreme angular incident flow, ship impact, extreme operating gust, etc.

The combination of external conditions and design situations (e.g. normal, fault, transport installation is to be considered. The respective partial load safety factors are to be observed. The calculation methods, e.g. simulation procedure, number of simulations and combinations of wind and wave loads have to be described and as the case may be simplified assumptions motivated.

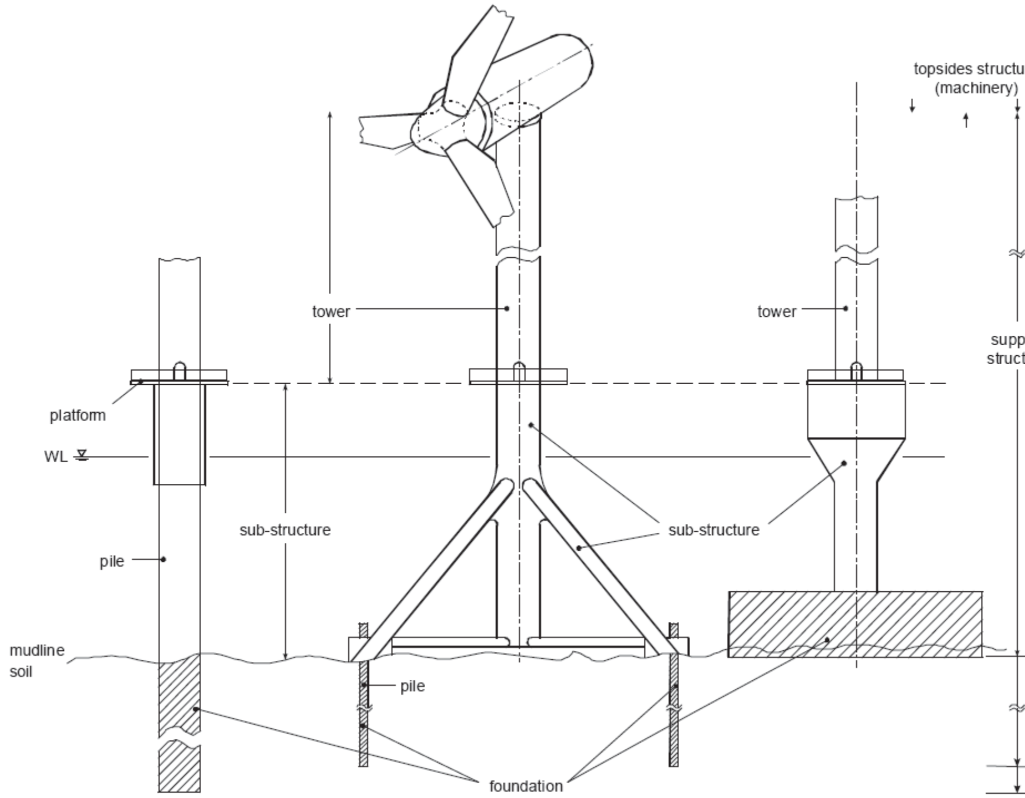
After definition and assessment of the load cases the load calculations have to be carried out in consideration of the complete structural dynamics.

Finally a load comparison of type certified loads with the site specific loads is to be performed. The outcome of the load comparison is to show that the site specific loads are more benign than the type certified loads. Otherwise stress reserve calculations for the machinery components or rotor blades affected are to be performed and assessed.

7.2.4 Site Specific Design of Support Structure

The support structure bears the machinery part of the wind turbine and consists of tower, substructure and foundation (Figure 7-1). For a met mast the support structure can be inferred from the parts below the platform deck.

Figure 7-1: Definition of Offshore Wind Turbine Structures



The assessment of the support structure is performed on the basis of the site specific loads, which were assessed before. The following calculations/verifications are to be performed:

- Derivation of the horizontal and vertical soil parameters from the soil investigation report
- Determination of resonance frequencies of the complete system (in consideration of the soil stiffness as well as stiffness and mass distribution for support structure and machinery)
- Examination of the conformity of resonance frequencies as considered in load simulations with those analyzed for variations of measured water depths/ soil stiffnesses and support structures within the wind farm
- Dents and buckling
- Punching shear
- Loss of static equilibrium, e.g. overturning of the foundation
- Ultimate strength
- Fatigue strength
- Acceptable deformations
- Corrosion protection

- Consideration of inspectability and maintenance when choosing fatigue material safety factors
- Connections (e.g. bolted, welded and grouted joints)
- Scour (scour protection, acceptable scouring, intervals for the examination of scour protection / scour depth)
- Verification of „ship friendly design of the substructure“ (if required e.g. by authorities)

Verifications of ultimate and fatigue strength are to be carried out for all load carrying structures and connections (welded connections, bolted connections and grouted connections). For the soil the general bearing capacity, base failure, and if relevant dynamic-cyclic strength and deformations are to be verified.

7.3 Offshore Measurement Platform

7.3.1 Demand for an Offshore Measurement Platform

Sufficient knowledge of the wind resource and icing conditions as well as other environmental conditions is required to minimize the risk associated with offshore wind farms especially in cold climates. A lot of data has been gathered, reviewed and compiled in several reports during the current project phase. Further measurements and investigation are ongoing.

Wind measurements have been performed since September 2005 and continue to date. A meteorological (met) measuring tower was installed by the Cleveland Water Intake Crib, reaching a measuring height of 50 m at its top. juwi has evaluated the existing data and provided summary meteorological parameters and discussion concerning wind speed, wind direction, wind shear and Weibull factors.

Currently a ZephIR LiDAR is being used on the Crib. It is a technology that has already shown good results in other offshore environments, e.g. on FINO 1. It allows up to five levels for measurement, with a maximum height of 150 m. The LiDAR measurements will give additional information of the wind conditions in higher heights and will be correlated to the met tower data.

Ideally, wind measurements are performed at hub height of future wind turbines (and also at different levels above lake level) and as close as possible to the future site of the turbines. This could be done by an offshore met mast or a LiDAR on a fixed offshore structure. The use of a LiDAR system on the Crib may prove sufficient; however future developers or financiers may not accept LiDAR as a measuring system. This seems to be unlikely as the technology is proven, but it is a factor that has arisen in the past. Should the LiDAR be unacceptable then the installation of a met mast would be another option.

For the proper design of the turbine foundations it would be useful to measure the ice thickness and the ice force created by the breaking ice, e.g. by applying strain gauges to a test structure. The Crib as test structure for ice load measurements could be considered, but it might also be worth having a test and measurement structure at the future turbine location to obtain these data. Experience with ice measurements has already been made within the European project STRICE (Measurements on STRuctures in ICE). Within this project a lighthouse in the Swedish Baltic Sea was equipped with comprehensive measurement equipment (Figure 7-2) to determine ice forces, ice drift velocity, ice drift direction, ice thickness and other ice parameters as well as meteorological and hydrographical parameters. The measured data provide a good body of knowledge for the description of the ice conditions at the site; however the structure's response is also a very important factor that cannot be determined by measurements at any structure.

Figure 7-2: Ice Measurements on a Lighthouse in the Swedish Baltic Sea (Project STRICE)

Wave data have been measured by NOAA 45005 buoy. They can be used as input for a model, but it is recommended to validate the model with local measurements, best directly at the site. The local measurements should cover about one year of data to reach optimal results including seasonal variations.

Generally, it is likely that some measurements can be performed easily and with probably good results from the Crib, but for further large-scale offshore wind farm design, data from the actual site will be preferred. Erecting an offshore meteorological platform is still an option that should be considered, although in areas where ice is likely, further challenges exist.

7.3.2 Design Criteria

The design of an offshore measurement platform as well as of an offshore wind turbine depends on a variety of criteria. On the basis of currently operated and planned measurement platforms and met masts in German waters the main criteria can be described as follows:

1. **Environmental conditions at location and resulting loads:**

Environmental conditions such as water depth, currents, wind, waves, soil conditions, ice, etc. and the resulting loads have major influence on the design.

2. **Purpose and research program:**

The aim of the structure such as wind measurements and the research program make demands on space, energy, technical equipment, etc. These demands also influence size and weight of the structure.

3. **Requirements from technical program and equipment:**

Apart from space for technical equipment, measurement- and technical devices may also have requirements on the maximum movement (deflection) of platform deck or top of met mast, e.g. for proper wind data or for a reliable data transmission by directional radio link, which requires a precise positioning of the antennas. This influences the maximum allowed deformation and stiffness.

4. **Safety rules and regulations:**

Safety rules and regulations have an influence on the design, as their requirements have to be met.

5. **Costs and economic efficiency:**

Also costs and economic efficiency are important factors that mainly influence e.g. the selection of a foundation type.

7.3.3 Currently operated German Measurement Platforms

A number of measurement platforms and met masts are already operating in German waters to measure a great variety of environmental data, primarily meteorological and oceanographic parameters. But also the structures' response to wind and waves as well as biological aspects such as bird migration and marine growth on underwater structures are investigated.

In Table 7-2 and Table 7-3 primary characteristics of German measurement platforms are summarized. They are located at different distances from shore and in different water depths. This as well as the measurement program carried out, influences their structure and equipment.

Table 7-2: Measurement Platforms in the North Sea

Project name	Project-developer/ operator	Commis-sioning	Total height (above C.D.)	Water depth	Distance from coast	Founda-tion	Super-structure	Heli pad	Ice cone
Research Platform FINO 1	GL	September 2003	101 m	28 m	45 km	Jacket	Platform 16*16 m	yes	no
Met Mast Amrumbank West	Essent Wind D GmbH und Amrumbank West GmbH	April 2005	90 m	23 m	35 km	Monopile	Container, 4 m side length	no	no
Research Platform FINO 3	FuE GmbH, FH Kiel	planned: 2009	120 m	23 m	80 km	Monopile	Platform 13*13 m	yes	no

Table 7-3: Measurement Platforms in the Baltic Sea

Project name	Project-developer/ operator	Commis-sioning	Total height (above C.D.)	Wate r depth	Distance from coast	Founda-tion	Super-structure	Heli pad	Ice cone
Met Mast Sky 2000	1. SHOW VG	2003	22 m	21 m	13 km	Monopile	Container, 4 m side length	no	no
Research Platform FINO 2	Schifffahrts-institut Warnemünd e	May 2007	101 m	24 m	31 km	Monopile	Platform 12.2*12.2 m	no	no
Met Mast Arkona-Becken-Südost	AWE GmbH	March 2007	95 m	24 m	35 km	Concrete gravity base with steel shaft	Platform with container	no	yes

Several types of foundation are used. The predominant foundation structure is the monopile (Figure 7-4) due to its simplicity and for economic reasons. In contrast, for FINO 1 (Figure 7-3) a jacket structure was chosen as FINO 1 is located in deeper water (28 m) and exposed to high extreme wind and wave conditions. There were also specific requirements from the technical program with regard to maximum allowed deflection, and both monopile and tripod couldn't meet these requirements at reasonable prices. In the Baltic Sea also a gravity base foundation is used (Figure 7-5), due to difficult soil conditions with the risk of large boulders and also for economic reasons.

Figure 7-3: FINO 1 (Jacket)

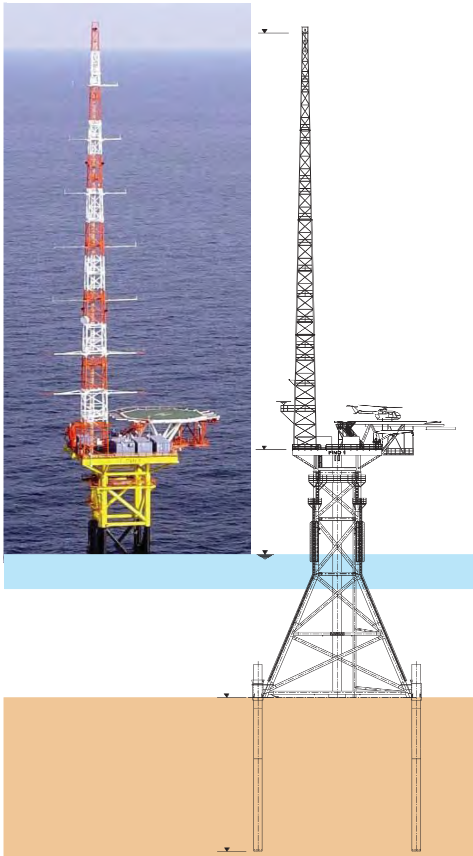


Figure 7-4: FINO 3 (Monopile)

Figure 7-5: Met Mast "Arkonabecken Sudost" (Gravity Base)

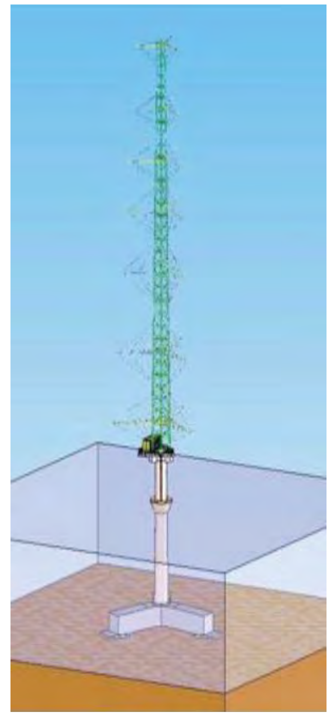


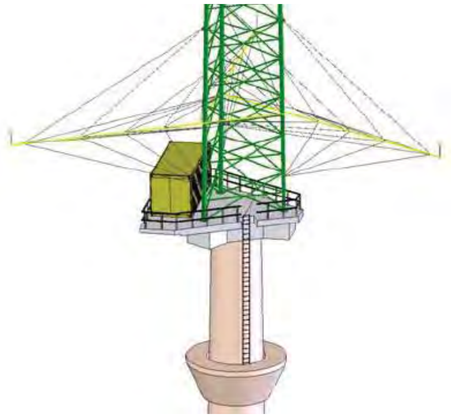
Table 7-4 shows the main dimensions (length, diameter and wall thickness) of existing monopile foundations for research platforms and measurement masts.

Table 7-4: Main Dimensions of Existing Monopile Foundations

	Length of monopile [m]	Diameter of monopile [m]	Wall thickness of monopile [mm]
Met Mast Amrumbank West	66	2.15 – 3.5	35 - 78
Research Platform FINO 3	55	2.7 – 4.7	45 - 70
Met Mast Sky 2000	55	1.5 – 3.0	n.s.
Research Platform FINO 2	50.5	2.7 – 3.3	48 - 64

Two of the platforms are equipped with helicopter pads as a consequence of the large distance from shore (45 and 80 km) and an offshore environment with high waves. Only one met mast ("Arkonabecken Südost") in the Baltic Sea is equipped with an ice cone as only at this location severe ice conditions may occur. The ice cone is a concrete structure mounted to the steel shaft (Figure 7-6).

Figure 7-6: Ice Cone and Platform of Met Mast "Arkonabecken Sudost“



(Photo: Züblin)

7.4 Specification for an Offshore Research Platform

Within the following section a general description of the necessary specification details for a research platform will be given. They are derived from experiences with other research platforms and adapted to the Lake Erie location where possible and necessary.

7.4.1 Site Specific Data and Design Basis

As already stated, several environmental parameters necessary for design were estimated or determined in former studies, while further investigation will be necessary. The latter include the final siting as well as seabed studies. Especially the seabed studies will provide the prerequisite for calculations of the foundation structure for the platform. But also the other environmental conditions such as wind, waves, currents, ice, etc. are important for the platform design. The existing “metocean” data will be compiled and summarized in a “Design Basis”.

Preliminary design parameters with regard to wind, waves and ice as well as other meteorological and hydrological conditions were estimated within the Desktop Study on the Effects of Wind, Waves and Ice (Section 6.4). They are compiled in Table 7-5.

Table 7-5: Site Specifc Conditions and Design Parameters

Type of Condition at Lake Erie			Value	Unit
50-year extreme wind speed (at 70 m height, 10-min mean)			~ 38	m/s
Annual average wind speed (at 70 m height, 10-min mean)			up to 8.2	m/s*)
Shape parameter k (50 m height)			2.08	
Characteristic turbulence intensity (at 50 m height, 10-min mean, at 15 m/s)			14.0	%
Wind shear during normal conditions (Hellmann Exponent)			0.09	
Mean air density (at 50 m height)			1.204	kg/m^3
Air temperature at 50 m height			~10.64	°C
Mean water depth	d	=	15	m
Water depth variation	Δd	=	±2	m
Water density	ρ	=	1.0	kg/m^3
High still water level (1-year)	HSWL1	=	+1	m
Low still water level (1-year)	LSWL1	=	-1	m
Highest still water level (50-year)	HSWL50	=	+2.4	m
Lowest still water level (50-year)	LSWL50	=	-2.4	m
Sub surface current	us	=	?	m/s
Wind induced current	uw	=	acc. To GL Guideline	
Mean significant wave height	Hs,mean	=	0.82	m
50-year significant wave height	Hs, 50	=	4.1	m
50-year sea state peak period	Tp50	=	7.2-8.5	s
50-year wave height	Hmax	=	7.8	m
50-year wave period min	TDmin	=	7.2	s
50-year wave period max	TDmax	=	9.2	s
1-year significant wave height	Hs, 1	=	2.5	m
Average level ice thickness			30 to 35	cm
Maximum level ice thickness			50	cm
Maximum expected rafted ice thickness			60	cm
Average ice cover duration			66 to 69	days
Minimum ice cover duration			33	days
Maximum ice cover duration			105	days
Bending strength			750	kPa**)
Compressive strength			2 – 3	MPa**)

*) considering the proposed layouts in Figure 3-14 and Figure 3-15 and the corresponding wind speed map
**) general assumption

7.4.2 Sub Structure and Foundation

In many cases it is useful to investigate alternate foundation variants which finally indicate which structure would be the most suitable for the given purpose, water depth and other environmental conditions. Both the financial and structural results (e.g. low extension) have to be favorable.

Special features such as ice cones and boat landing have also to be considered during the sub structure design. It will also be necessary to have various attachments to be mounted to the structure, such as vertical ladders, brackets for measurement equipment, and a corrosion protection system.

7.4.3 Platform Deck

Usually a platform deck is fixed to the sub structure in a height, which results form design water plus wave crest plus gap. The size of the platform structure has to be determined, so that it is possible to accommodate all necessary housings or containers. They will house measuring equipment, living/working space (including emergency accommodation), energy supply, e.g. diesel/generator set with batteries as well as further equipment.

7.4.4 Helicopter Pad

It has to be carefully considered, whether it is necessary or useful to equip the platform with a helicopter pad. This assures a large time window to access the platform, even in the event of rough weather or ice. The helicopter pad should be situated 5 m above the platform for safety reasons and equipped with e.g. a stairway unit, safety nets all around and navigation lights.

7.4.5 Wind Measurement Mast

Important feature of all measurement platforms is a high wind measurement mast, reaching a total height of approximately 100 m above C.D. at its top, which is similar to the hub heights of future offshore wind turbines. Usually a welded steel lattice mast structure is used and equipped with fold-away booms, where the meteorological sensors are installed. The “met mast” can be climbed by a vertical ladder and has resting landings every few meters. Various antennas as well as navigation lights will be attached to the mast.

Wind measurements in cold climate can be challenging. Many factors can reduce their quality and availability. Anemometers might stop or slow down, wind vanes might stop, iced-up booms or lightning spikes might affect the measurements.

To avoid the effects, heated sensors are recommended at sites with frequent icing. Because most heated sensors have disadvantages like high mass and sensitivity to vertical wind, conventional cup anemometers should also be used. A significant difference in measured average wind speed will indicate the time during which the unheated sensor is iced up [16].

As mentioned before the LiDAR-system mounted on the platform without a met mast could be used as an alternative to anemometers mounted on a met mast.

7.4.6 Equipment

Further equipment on a platform is necessary, e.g. for safety reasons. The necessity for other equipment might also arise through the requirements of the measurement program.

A platform should be equipped with a crane unit which allows the transport of material. Depending on the crane, it might also be able to lift containers or personnel.

The electric equipment is needed to ensure the power supply. Most platforms are operated independently and therefore have an energy supply centre with e.g. a diesel generator set. It is necessary to operate a redundant system in case one of them fails. To estimate the needed power it is necessary to draw an energy balance in advance, which covers all consumers.

It is very important to have comprehensive safety equipment available on the platform, including a fire protection/ extinguishing equipment, life rafts, lifebuoys, immersion suits, lifejackets, etc.

7.5 Offshore Wind Turbines

7.5.1 Preliminary Pilot Project Locations and Wind Turbine Considerations

With a maximum capacity of 20 MW, and considering all preliminary siting criteria described in Section 3, different turbine configurations are possible depending on turbine type. Assuming that the pilot wind farm consists of turbines from a single manufacturer, the following technical designs are possible for a 20 MW project using commercially available offshore wind turbines:

- Four 5.0 MW turbines (REpower, Multibrid or BARD)
- Six 3.0 MW turbines (Vestas)
- Eight 2.5 MW turbines (Clipper or others)

- Eight 2.3 MW turbines (Siemens)
- Five 3.6 MW turbines (Siemens)

7.5.2 Requirements on Wind Turbine

7.5.2.1 Type Certification

On requirement that has to be met is that the selected wind turbine has a valid Type Certificate. It guarantees that the turbine is designed in conformity with the design assumptions, specific standards and other technical requirements. A type certification covers a design assessment of load assumptions, operation and safety concepts as well as condition monitoring system, rotor blades incl. static blade test, machinery, electrical engineering and lightning protection, witnessing of commissioning at one of the first wind turbines as well as tower (optional). It also makes sure that the design-related requirements have been implemented in production and erection, that the QM-System is certified and that prototype measurements have to been carried out.

7.5.2.2 Offshore Suitability

Offshore wind turbines are often referred to as wind turbines of a high wind class (GL class I or II) that have been adapted to marine conditions. This means that the routing of the air flow and climate control is designed in a way, that no salty air and moisture gets in contact with inner parts of the machine to avoid corrosion.

At the potential GLWEC offshore location, freshwater conditions are present, meaning that an increased risk of corrosion due to salt water and air doesn't play a role. From this point of view an offshore wind turbine is not necessarily required, though offshore wind turbines have other features which are of advantage also.

7.5.2.3 Wind Class

The site specific wind conditions at the proposed GLWEC locations are below the requirements of GL wind turbine class II. Thus, concluded from this point of knowledge, a wind turbine fulfilling the GL class II requirements should be suitable for the project.

7.5.2.4 Icing

Icing may significantly influence energy production. There is no verified method for estimating ice-induced production losses, but simple approaches have been presented that can reasonably evaluate the effects of extreme low temperatures. Additional costs that are related to working conditions, construction, and site access, can be limited with careful planning. Cold climate wind energy projects can maintain high safety standards.

Even located offshore, ice from the rotor blades may pose a safety hazard. Ice must be detected and other precautions taken.

7.6 Foundations for Offshore Wind Structures

The most common foundation types currently used for support of offshore wind turbines are monopile and gravity base foundations. In deeper waters (> 25 m), alternative foundations have to be considered, including multi-legged or lattice structures like tripod, tri-pile, jacket or even floating structures.

General advantages and disadvantages for three selected foundations types are listed in Table 7-6.

Table 7-6: Advantages and Disadvantages of Three Foundation Types 0 (modified)

Foundation type	*Advantages*	*Disadvantages*
Gravity steel structure	No piling Can be removed completely and possibly repositioned All parts visible for inspection	Seabed preparations required Time consuming welding details Space requirements at construction site Transportation complex
Monopile steel structure	Simple High degree of production automation No preparations of seabed Good track record in offshore Wind	Requires heavy duty piling equipment Not suited for geotechnical location with large boulders Not suitable for combination of deep water and big wind turbine
Tripod steel structure	Adaptable to increased water depth A minimum of preparations required at site prior to installation	Specialized fabrication methods Not suitable for geotechnical location with large boulders Not suitable for shallow water depths (< 6 m)

Within the Geotechnical Report (Section 6.3) potentially suitable foundation types for the GLWEC Pilot Project have been discussed, focusing on monopile, gravity base and suction caisson foundations.

Considering the currently available site specific data and geological information as well as factors such as fabrication, transport and installation methods/equipment, monopiles appear to be the preferred foundation option for the Pilot Project. This conclusion is also supported by the Preliminary Site Review Report and Desktop Study on Icing, Wind, and Waves.

Suction buckets are a possible alternative if the soil strata thickness in a single location is not sufficient for a piled foundation. It must be kept in mind that experience with suction buckets and other “cutting-edge” designs can by no means be compared with standard solutions. One suction bucket foundation was supposed to be installed in the German North Sea for an offshore wind (test) turbine, but the installation failed due to technical problems. Gravity foundations are probably not advisable for the GLWEC Pilot Project because of the softness of the upper soil layers. Both jacket and tripod foundation could be alternatives. They are welded structures which are especially suitable for big wind turbines in deep water. But it has to be taken into account that these structures are more cost intensive than monopile structures as a result of the complex fabrication process.

Final foundation selection should be made once site specific investigations and conceptual design calculations have been performed.

7.6.1 Ice and Foundations

Structures with vertical walls in the waterline region (e.g. monopiles) generally experience higher ice loads compared to sloping ones for similar waterline dimensions. The ice breaking capability of the foundation will influence the loading. Winters with severe icing conditions will determine dimensioning for maximum ice thickness. The possibility of ice drift needs to be considered, as it might trigger structural vibrations.

Vertical piles in particular are likely to be endangered by so-called ice induced vibrations. Under certain circumstances the frequency of the ice failure may be in correlation with one of the pile’s eigenfrequencies (lock-in phenomenon). This can result in a significantly reduced lifespan of the foundation.

Possible solutions to reduce the ice loads and ice induced vibrations include the equipment of vertical structures with cone-shaped ice deflectors in the waterline (Figure 7-7). Generally the (static) ice loads can be reduced by the factor 3 on sloping structures compared to those on vertical structures. But due to the fact that an ice cone broadens the structure in the waterline, the ice load reduction might be less. Often the ice load even remains the same, but at a reduced frequency.

The interrelation between ice thickness, ice velocity and resulting frequency due to ice failure can be described as follows: The lengths of the ice debris at an ice cone is generally three times the ice thickness in average, e.g. with an ice thickness of 0.6 m the length will be 1.8 m. Assuming a velocity of 0.65 m/s the resulting frequency will be 0.65/1.8 = 0.36 Hz.

Figure 7-7: Gravity Foundation with Sloping Profile at Water Line

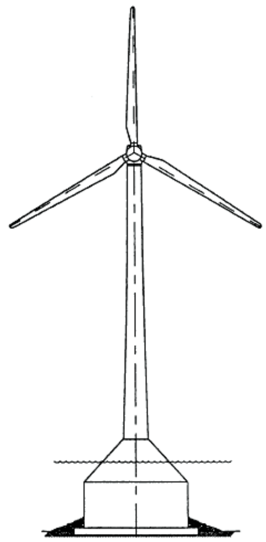


Figure 7-8: Middlegrunden Turbines with Ice Cones

Ice cones can slope either inward going upward, for example on a gravity foundation (Figure 7-7) or outward going upward, as shown in Figure 7-8 and Figure 7-9. Correspondingly, forces on the foundation due to ice can be either downward or upward, depending upon the direction of sloping. Upward forces exert a lifting force on the foundation, an effect which is especially unwanted when using a gravity foundation.

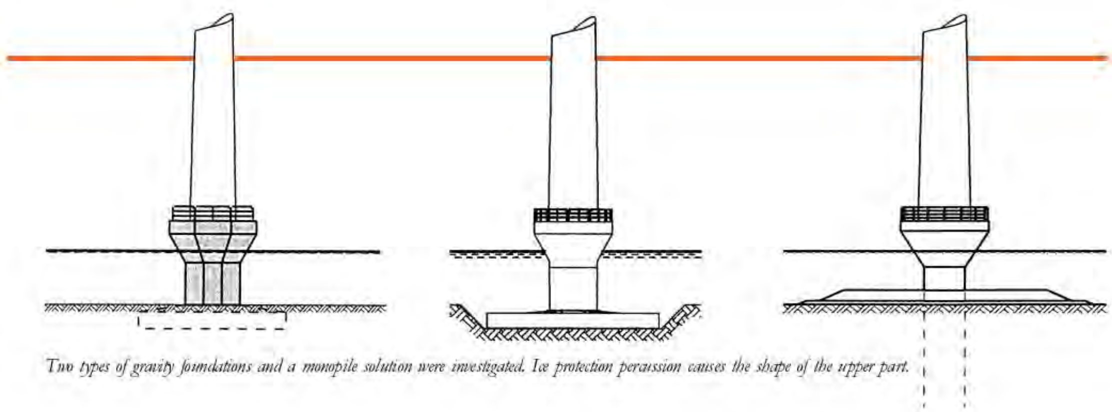
Ice cones sloping outward going upward have the advantage of minimizing the ice freezing on the structure and therefore significantly reducing the resulting forces. They also lead to better access possibilities, as the upper horizontal cone edge can be used as access platform. The water depth for this layout should exceed 5 m to avoid ice deposits on the sea or lake floor.

Regarding the dynamic ice forces it is currently assumed, that they will also be reduced by an ice cone, i.e. the frequency of the ice load will be much lower, much different from the eigenfrequency of the structure. Recent laboratory and field investigations showed that under certain very rare circumstances also cone shaped structures can experience high vibrations in resonance frequencies, resulting from shear failure of the ice plate. Due to icing the waterline geometry can change from sloping to vertical and lead to the same effects that vertical constructions experience.

Another concern in the cone design is the required cone height. A large cone will result in increased wave loads. Basically the cone geometry needs to ensure that no crushing of ice takes place on the vertical pile.

For existing offshore wind turbines modified foundation shapes have already been used to break up ice and reduce loading on the structure. One example is the Danish offshore wind farm Middelgrunden. At Middelgrunden ice can be very significant. A working group of experts concluded that foundations have to be designed for a 60 cm thick drifting ice-flow of 2 by 2 kilometers, which is moving with a speed of 0.65 m/s. During the design phase of these turbines three foundation concepts were seriously considered (Figure 7-9): A ballasted steel-caisson (left), a solid concrete plate (middle) and a monopile (right).

Figure 7-9: Three Foundation Concepts for Offshore Wind Farm Middlegrunden



The chosen concept of foundation is based on a heavy round concrete plate (middle), as this design turned out to be the most economic one. The solution chosen to face the ice challenge is an ice cone mounted at the level of sea surface. The ice cone will break an ice-flake pressing against the foundation, and reduce ice-loads by a factor of 5-10, meaning that ice-loads are no longer a design driver.

7.6.2 Foundation for the Pilot Project

Subject to final site specific investigations, monopiles currently appear to be the preferred foundation alternative for the Pilot Project. This foundation type can be used both for a measurement platform and a wind turbine, though its characteristics will differ considerably depending on the structure mounted on it. With regard to the ice conditions in Lake Erie an ice cone should be considered on the pile in the waterline to break up ice, reduce loading on the structure and avoid or minimize ice induced vibrations. The ice cone could be part of the transition piece and its upper edge could form the access platform. The cone should be designed sloping outward going upward (upper diameter > lower diameter), similar to the right graphic in Figure 7-9.

7.6.3 Durability and Corrosion Protection

The exposure to offshore environments with ice conditions is not the same for steel and concrete, but makes high demands on both materials. For steel, low temperatures raise the problem of brittle fracture and low energy absorption, not only of the steel plates but also of welds. Today reliable low-temperature-rated steels and welding procedures are commercially available.

External steel plates are subjected to abrasion from the ice and corrosion. Usual corrosion protection systems include

1. **Coating systems**

Adequate corrosion coating systems are to be provided in the splash zone and above.

2. **Cathodic protection**

In the submerged zone a corrosion protection by cathodic protection is required.

3. **Corrosion allowance**

An additional corrosion allowance at the splash zone is provided. The size of the allowance will be decided on according to local experience.

Abrasion removes the products of the corrosion protection system, exposing fresh surfaces so that new corrosion can commence. There are special coatings available on the market (e.g. dense epoxy and dense polyurethane coatings). They give excellent protection to the steel surface and reduce friction and adfreeze bond. These coatings require touch up every year or two, which leads to an increased O&M effort.

For concrete structures, the concrete needs to been designed to be of very high quality, with low permeability and optimal entrained air.

7.7 Access to Offshore Structures

Offshore access in general is difficult and cost intensive. This is even more the case when ice conditions are present. For met mast and turbine installation as well as for O&M, over-the-ice transport must be considered and may be very costly or even impossible. The preferred construction time of an offshore wind farm or met mast will be during the warm season. This requires a careful development of time schedules.

To access wind turbines/met masts in a frozen or semi frozen environment, options to be considered include hovercrafts, helicopters and ice breakers. In some regions ice roads can be built to enable access by ordinary land vehicles. Such roads are reinforced by removing the snow and if needed, by sluicing, and need to be clearly marked to enable driving in low visibility conditions. Currently the access by helicopter is seen to be the most suitable option for the GLWEC Pilot Project, especially as an airport is nearby. But the other options should also be investigated.

Turbine access in rough seas must also be addressed, though waves seem to be moderate in Lake Erie compared to other offshore environments. Icing combined with rough seas especially increases the risks for the service craft. The icing of boats that weigh less than 500 tons and move faster than 15 knots is not well studied or understood. Many factors, including salinity, humidity, wave height, temperature, wind speed, and boat size, contribute to the icing process, which can cause vehicles to flounder. Using sheltered locations, travelling with the wind and waves, and reducing speed to avoid breaking waves decreases the risk of icing.

Access to offshore platforms when ladders are iced up can be quite dangerous (Figure 7-10), especially during adverse weather. In high ice environments other methods of turbine access will have to be determined.

Figure 7-10: Ice Formation on Access Ladder

Figure 7-11: Access by Helicopter

Recent offshore wind turbines are often equipped with an access platform on the top of the turbine nacelle, a so-called helicopter hoist (Figure 7-11). Persons can be lowered from a helicopter to the platform and then enter the nacelle for maintenance work. Such an arrangement is useful when water conditions are too rough to allow safe docking of a boat or when ice conditions make it impossible to reach the turbine by boat. It has to be considered though that size and weight of spare parts or equipment are limited.

7.8 Conclusion of Conceptual Design

When designing offshore wind turbines for a specific site, it is necessary to assure that type-certified wind turbines and particular support structure designs meet the requirements governed by site specific external conditions. Within this conceptual study recommendations are given as to which guidelines can be applied to assure safety and structural integrity of the future GLWEC Pilot Project. The requirements on site conditions and design basis, load assumptions and site specific design of support structure are described in general.

There is potential demand for an offshore research platform in Lake Erie. Former data collection and evaluation show that a good body of knowledge on environmental data exists. Necessary preliminary design parameters have already been estimated or determined, but there is still a lack of knowledge in some fields.

It is likely that further investigations and data collection from the Crib may be sufficient for the Pilot Project, but for further offshore wind farm design, data from the actual site will be preferred. These include especially wind, wave and ice data. Erecting an offshore meteorological platform is an option that should be considered, although in areas like Lake Erie, challenges due to ice have to be faced. Future soil investigations will be necessary, but they do not require a research platform.

As this conclusion still leaves the option for a measurement platform, further information about recent platforms in German waters were given and a basic functional specification described.

On the basis of a comparison of actual wind data requirements it was concluded that for a future pilot project wind turbines of GL wind class II will be suitable. As Lake Erie has freshwater conditions, offshore wind turbines with high wind class and special air routing systems will not necessarily be required.

Concerning the foundation design it can be stated that currently a monopile structure seems to be the most suitable foundation concept for the GLWEC project, both for wind turbines and for a measuring platform. Because of severe ice conditions an ice cone should be mounted to the vertical structure in order to reduce ice loads and minimize the risk of ice induced vibrations.

Special regard should be given to the access system. A helicopter pad on the nacelle increases the accessibility significantly, as during winter access by boat or other means is difficult or impossible.

8 Interconnection and Offshore Cabling

8.1 Onshore Interconnection Options

(Unless otherwise indicated, information in this section is from the GLWEC Onshore Interconnection Report, Black & Veatch, November 2008).

Black & Veatch were tasked to identify the most feasible locations to interconnect the Pilot Project with existing onshore electrical infrastructure. Because the Project Site would be located close to downtown Cleveland, there are several physical features to consider for interconnection, including buildings, Burke Lakefront Airport, Browns Stadium, marinas, parks, and others. Based on existing infrastructure and physical features, Black & Veatch developed the following criteria for determining preliminary interconnection options:

- Proximity of interconnection facility to project site
- Interconnection facility parameters
- Available voltage levels, reserve capacity, etc.
- Physical limitations for adaptation/expansion
- Interconnecting entity's input and preferences

The Cleveland area is currently supplied electricity by two different utilities: Cleveland Public Power (CPP) and Cleveland Electric Illuminating Company (CEI). CPP ranks as the largest municipality-owned electric utility in Ohio. Their service area extends throughout and beyond Cleveland and provides electric service to approximately 80,000 residential, commercial, and industrial customers. CPP operates a distribution-only system, and purchases electricity via three 138 kV interconnection points. Electricity is then distributed throughout their internal network on 69 kV, 13.8 kV, 11.5 kV, and 2.3 kV lines spread across 36 substations. Other than small emergency generation units installed near critical loads, CPP does not currently have independent or self-operated generation on their system.

CEI is a subsidiary of FirstEnergy Corp. and is involved in the generation, transmission, and distribution of electricity. CEI's footprint is solely in the Cleveland and surrounding areas, though FirstEnergy Corp. owns six other subsidiary companies operating in Ohio, Pennsylvania, Michigan, Maryland and New Jersey. The majority of the CEI system includes 138 kV overhead and underground transmission lines, 36 kV overhead distribution lines, and 11 kV underground feeders. Around the perimeter of the city, CEI operates additional 138 kV lines as well as 345 kV which connect their large power plants to the grid.

The interconnection voltage was also considered in the screening, as it is typically assumed that higher costs are associated with higher voltage interconnection. Interconnection at high voltages may also require addition equipment, and can potentially add further to the electrical losses due to added step-up transformer impedances. In this case, Black & Veatch believes that interconnecting at 138 kV would not be justified based on the total generating capacity of the Project. In addition to high capital costs, a high-voltage interconnection requires more physical space than lower voltage interconnections. It also typically includes more detailed, costly and stringent interconnection procedures and studies with organizations outside of the municipality or utility. Therefore, only interconnection possibilities below 138 kV were considered.

8.1.1 Analysis of Interconnection Options

Initial locations were chosen based on their proximity to the Project site, voltage levels, and preliminary information and suggestions provided by CPP and CEI. The three potential interconnection locations that met the initial screening criteria are:

1. CEI - Lakeshore Substation
2. CPP - Lake Road Substation
3. CEI - Oglebay Norton tap

8.1.1.1 CEI Lakeshore Substation

Facility Description

The substation’s main facilities provide electricity through a 138 kV ring-bus, and out on several 138 kV transmission lines. In addition, a portion of the electricity is stepped down to 11 kV and serves local residential, commercial, and small industrial loads via underground cable. Figure 8-1 shows the large footprint of the area and the available facilities for interconnection.

Figure 8-1: CEI Lakeshore Power Plant and Substation

The CEI Lakeshore Substation sits on a large plot of land owned and operated by FirstEnergy generation. Though the land sits on the shore just south of the highway, the substation facilities are located directly behind the power plant and adjacent to the railroad tracks.

Interconnection Strategy

According to CEI, an 11 kV interconnection at CEI Lakeshore Substation is the preferred interconnection location over the Oglebay Norton Tap (36 kV). The interconnection point would take place inside the 11 kV switchgear building, and require equipment to step the voltage of the submarine collection system (34.5 kV) down to 11 kV.

Figure 8-2: CEI Lakeshore Substation Interconnection Strategy

Since the highway lies between the water and the power plant, there exist limited options for easily routing the submarine cable to a point where it can easily transition onshore. The routing shown above allows for the submarine cable to cross underneath the highway. From here, the submarine cable transitions to typical underground 35 kV cable across the power plant property where it will be transformed down to 11 kV with new 34.5-11 kV step down transformers for interconnecting directly to the 11 kV bus. The following are major equipment involved with this interconnection location:

- 35 kV underground cable
- Two (2) 35-11 kV step-down transformers
- Two (2) 11 kV breakers and relaying

CEI recommended interconnection at 11 kV because it currently has spare breaker positions that are not being utilized. However, interconnection on the 11 kV bus requires the purchase of CEI's specific 11 kV breaker and protection package, which are capable of handling up to half of the anticipated full output of the Project, therefore requiring the Project to split into two circuits at the point of interconnection. This can be done either by running two separate submarine collector circuits, or splitting a single collector circuit at the transformation point. Due to costs, two submarine circuits are not recommended.

Constructability and Limitations

Perhaps the most impacting feature of this interconnection option relates to the routing of the submarine cables as it approaches the shoreline. The highway that parallels the coast has two main overpasses over the cooling channels for the power plant. These channels can provide easy access to the power plant property while avoiding routing of typical underground cables beneath the highway. However, the installation procedures and equipment used to install submarine cables may not be able to work beneath the low clearances of the highway.

Interconnection Procedures

The interconnection process and procedures for interconnection at the CEI Lakeshore sub will be similar to that of the CEI Oglebay Norton tap. Interconnecting the project at 11 kV will involve filling out an official interconnection request through CEI.

Once requested, CEI will perform a "Feasibility Study", followed by a "Facilities Study". The "Feasibility Study" will look at the overall feasibility based on the general parameters of the generating facility and interconnection option. Once the location is deemed feasible, they will perform a "Facilities Study" which is a detailed study that determines the exact limitations and cost for necessary upgrades and new equipment to accommodate the interconnection.

Similar to any other type of interconnection study, CEI charges a fee to perform the studies. Their traditional rate is approximately $5 per kW, however CEI indicated that it may be possible to acquire a lower rate based on the unique nature and value of the GLWEC Pilot Project. CEI provided Bruce Remmel and Mike Thorn as the primary contacts for coordinating the interconnection process.

8.1.1.2 CPP Lake Road Substation

Facility Description

The CPP Lake Road Substation is the closest facility to the project site and is located directly on the Lake. This facility was previously a CPP-operated generating facility, but is currently used as a distribution substation. CPP purchases and receives electricity from the 138 kV lines, and then steps the voltage down to 69 kV and 11 kV for providing underground service. Figure 8-3 provides an aerial view of the Substation and the available facilities for interconnection.

Figure 8-3: CPP Lake Road Substation Facilities

Interconnection Strategy

Discussions with CPP indicated that there are plans for significant upgrades to this substation in the near future that will take up much of the space to the west of the current buswork. However, the area between the CPP building and water has sufficient room for new construction and facilities. Mr. Barton recommended interconnecting the project at 69 kV would be the most viable option at this substation. This option would require a 35-69 kV step-up transformer and would interconnect directly to the 69 kV bus. A diagram showing the potential location of facilities within the substation yard is shown in Figure 8-4.

Figure 8-4: CPP Lake Road Substation Interconnection Strategy

CPP currently has plans to expand the existing facilities into the area outlined in red and suggested that interconnection equipment for the project could potentially be located in the area outlined in blue. As shown, the 35 kV submarine cables will approach the sub from the Northwest, at which point they transition to open-air facilities similar to those currently being used elsewhere in the sub. The electricity would then be stepped up to 69 kV and routed to the ultimate interconnection point at the existing 69 kV bus.

Interconnecting the project as shown above would require the following major equipment:

- 35/69 kV switchgear for project substation
- 34.5-69 kV step-up transformer
- 69 kV underground cable from project substation to existing 69 kV bus
- Additional 69 kV switchgear at interconnection point
- 69 kV metering

Constructability and Limitations

Once the submarine cables reach the shore, Black & Veatch expects the construction of new facilities to be typical of any small substation. The ability to construct the project substation at the water's edge eliminates having to route cables through congested areas. CPP indicated there are no future plans for this portion of the property, which also eliminates most impacts on construction due to tight work spaces.

It is expected and assumed that the Project could generate up to 20 MW. CPP indicated that the existing 69 kV facilities are currently lightly loaded and the full output of the project would not likely need significant upgrades to existing facilities. However, detailed studies coordinated by CPP will determine the exact limitations of the system should the project move to a more advanced development stage.

The interconnection facilities and constructability for this site are typical of small onshore wind projects where there the generation is stepped-up to high voltage at a project substation.

Interconnection Procedures

The interconnection process for this option will be outside of the typical process for large wind energy projects and result from negotiating exclusively with CPP. Since CPP currently purchases and receives their power from the bulk transmission grid, procedures and requirements for interconnecting a modern generating facility may not be up-to-date, or even in place. Even though CPP has operated generation on their grid in the past, it is possible that the procedures and negotiations with CPP regarding interconnection specifics may require additional effort to determine contractual obligations and operational constraints for the project.

Discussions with Rich Barton at CPP that the study process would be initiated through Robert Bonner, Assistant Commissioner.

8.1.1.3 CEI Oglebay Norton Tap

Facility Description

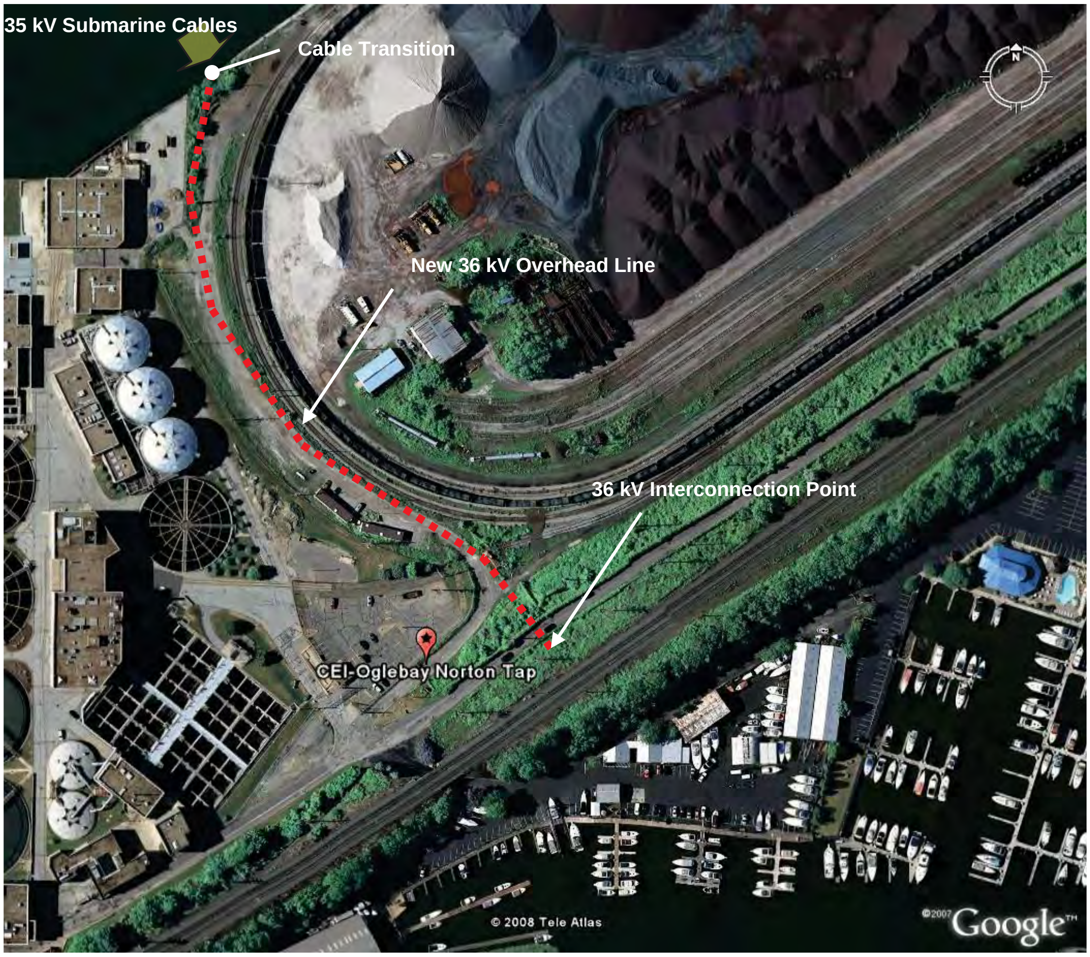
The CEI Oglebay Norton line is located on Whiskey Island and is an existing overhead 36 kV line that runs along the railroad tracks within close proximity to the water. Currently, this radial line is lightly loaded and CEI indicated that it could essentially be tapped anywhere along the main feeder at an area near the railroad track. For the purposes of this study, Black & Veatch assumed a location based on anticipated routing of new facilities. However, a specific pole location for the tap will be determined by CEI following detailed studies associated with the interconnection request process. The area surrounding the railroad tracks is a common right-of-way for other overhead electric lines. A photograph of the Oglebay Norton line as well as other existing facilities is shown below in Figure 8-5. The main feeder line can be seen in the background running left-right along the railroad tracks.

Figure 8-5: CEI Oglebay Norton Tap

Interconnection Strategy

Since the exact interconnection location will not be known until further studies are performed by CEI, Black & Veatch chose an interconnection point at the main feeder line adjacent to the railroad in order to capture all of the potential impacts of this interconnection option. Due to the interconnecting facility voltage being operated at 36 kV, Black & Veatch also assumed and recommends that the submarine collection system be operated at 36 kV. Figure 8-6 illustrates the interconnection strategy which entails the submarine cables transitioning to a new overhead 36 kV line, and routed to the main feeder location by the railroad tracks.

Figure 8-6: CEI Oglebay Norton Tap Interconnection Strategy



Since this interconnection option is not within a substation, there will be certain protection and communication equipment that will be necessary to meet CEI's requirements. Doug Disterhof from CEI's Protection and Planning department indicated that the following major equipment would be required for this type of interconnection:

- Overhead 36 kV distribution line and equipment
- Pole-mounted 3-phase breaker/recloser
- New fiber communication path back to substation
- 36 kV metering

For equipment that is not located directly in their substation yard, CEI will require the ability to "transfer-trip" the generating facility off of their system in the event of a fault or other special circumstance. This transfer-trip capability can only be enabled by installing a new fiber cable from the point of interconnection to the corresponding substation which is 9-10 miles away at an estimated cost of $35k per mile (per CEI). This interconnection option does not require any transformation of the voltage, which avoids other high costs associated with purchasing a transformer.

Constructability and Limitations

Routing of the new overhead portion of the collection system once the submarine cables reach the shore will provide a challenge due to the existing railroads. The route shown in Figure 8-6 indicates a likely route, but the exact feasible routing will require negotiations with the land owners and planning during the design phase. There are several other overhead distribution lines in the area which will need to be accounted for in the routing of the new line.

It may be necessary to bring the submarine cables to the channel-railroad crossing for the onshore transition. From here, the new distribution line could follow the railroad tracks down to the interconnection point. However, the routing of the submarine cable will have to take into account channel dredging that takes place frequently.

According to CEI, the line currently has sufficient reserve capacity to interconnect the full output of the project. However, there may be near-term load growth elsewhere on this radial feeder that may lower the allowable amount of generation and/or require further upgrades at the substation. Again, once the study process has been initiated, these details, requirements, and limitations will be determined.

Interconnection Procedures

A 36 kV interconnection will require CEI to purchase the electricity generated from the wind project. The project's size being under 20 MW and utilizing a medium-voltage interconnection will also avoid standard procedures governed by the Federal Energy Regulatory Commission (FERC) and application submission to the Midwest ISO (MISO). Due to the very high volume of wind energy projects requesting interconnections, the MISO queue for interconnection studies can take up to two years or longer. Avoiding interaction with MISO by utilizing a medium-voltage interconnection point will likely allow the project to finalize an interconnection agreement in a much quicker timeframe.

8.1.2 Recommendations and Cost Estimates

In order to make a recommendation for a single interconnection point, Black & Veatch developed final screening criteria to help baseline each option for comparison. The following represent the critical elements considered for choosing a single interconnection point:

- Constructability
- Anticipated system impact
- Cost of required equipment

Constructability issues and definitions are discussed in previous sections for each interconnection option. The anticipated system impact is based upon discussions with CPP and CEI and reflects the amount of significant upgrades outside of the direct facilities that will likely result from utilizing each interconnection option. "Minimal" impact is defined where no major system upgrades are anticipated, while "Marginal" indicates that it is unclear but likely that system upgrades will be required. "Significant" is defined as requiring major system upgrades. Table 8-1 shows a comparison of the three analyzed interconnection locations using these criteria.

The estimates detailed in Table 8-1 are based on general pricing data from manufacturers and recent projects. The costs reported in Table 8-1 do not incorporate the anticipated costs of submarine cables (see Section 8.2.5) or account for any changes required in their operation. The costs reported above can also be affected by requirements regarding facility siting, routing, permitting, and minor additional equipment as a result of detailed studies by the utilities. Any fees associated with the interconnection studies of these three options have not been included.

Table 8-1: Screening and Cost Estimates for Interconnection Options

	CEI-Lakeshore Substation	**CPP-Lake Road Substation**	**CEI-Oglebay Norton Tap**
Constructability	Complex	Typical	Complex
System Impact	Significant	Minimal	Marginal
Main Transformer(s)	$1,000,000	$650,000	N/A
Other Major Equipment	$140,000	$150,000	$80,000
Communications	N/A	N/A	$350,000*
Construction	$160,000	$200,000	$70,000
Total Cost	**$1,300,000**	**$1,000,000**	**$500,000**

*Fiber Communications costs provided by CEI, and price quoted includes construction costs assuming 10 miles. Note: Costs associated with interconnection studies through CEI or CPP not included.

Regarding constructability, the three sites were judged relative to Black & Veatch's experience of typical wind projects of similar size. The ranking also incorporates the overall installation of necessary equipment and upgrades including the routing of submarine cables at transition points near the shoreline. The anticipated system impact of each option was based on the amount of reserve capacity and indirect impact of adjacent systems based on information provided by each utility. Costs are reported as estimates for major equipment involved.

Based on the criteria established, Black & Veatch recommends interconnecting the project at CPP's Lake Road Substation. Not only is this facility close to potential wind turbine locations, it also has minimal loading on the existing facilities. There is sufficient room for the constructing of new facilities with few offshore to onshore obstacles.

Though the CEI Oglebay Norton tap ranks second per the final screening criteria, this option was least recommend by CEI. This interconnection option needs relatively little equipment at the interconnection point making it the lowest cost option, but is greatly complicated by the requirement of CEI to install up to 10 miles of new fiber optic cable. In addition, the amount of reserve capacity on the line is more sensitive to small changes than the 69 kV facilities at CPP Lake Road. Future increases in line loading that were unforeseen at the time of this study and could ultimately add to the required upgrades and associated costs for this option. The routing of new facilities to the point of interconnection may also add on to the costs to gain right-of-way access.

The CEI Lakeshore Substation 11 kV interconnection option is the most expensive option of the three, but is CEI's preferred location. The high cost of this option is primarily due to the complexity of the interconnection and the requirement to split the generation between two separate feeders at the 11 kV bus. Additionally, the point of interconnection requires a significant amount of underground cable to be routed through the power plant property, which could pose additional constructability issues with existing buried infrastructure. This location is also the furthest from the wind turbines and could also add further complications to the installation of the submarine collection system near the shore.

8.2 Offshore Cabling System

(Unless otherwise indicated, information in this section is from the GLWEC High Voltage Cabling System Design Report, Senergy-Econnect, November 2008).

Senergy Econnect Ltd was commissioned to develop and consider, as part of the overall feasibility work, a selection of conceptual cable design options for the GLWEC offshore Pilot Project turbine array, subsea shorelink electrical connection, and onshore electrical connection. Potential cabling to the three onshore interconnections addressed in Section 8.1—the CEI Lakeshore Substation, CEI Oglebay Norton Tap, and CPP Lake Road Substations—were included in the analysis. Additionally, two potential Pilot Project turbine configurations were included (Configurations 1 and 7 from Figure 3-14 and Figure 3-15). For each eight-turbine Pilot Project – Onshore Interconnection scenario, the following potential cable arrays were addressed:

- Wind turbines connected in cascaded format with one outgoing wind farm collector cable feeder to the shorelink
- Wind turbines divided into two interlinked groups of wind turbines with two outgoing wind farm collector cable feeders to the shorelink
- Wind farm divided into two interlinked groups of wind turbines with one outgoing wind farm collector cable feeder to the shorelink

For the three-turbine configuration, alternative cabling designs were not assessed as the variation in alternatives above is not expected to yield much benefit given the few turbines involved.

8.2.1 Underlying Assumptions

The following assumptions are made with respect to the offshore cabling system design:

- At this stage of the project, the size, make and number of turbines have not been finalized. For the purpose of this assessment, a wind farm capacity of 20MW comprising of 8 x 2.5MW wind turbine generators (WTG) has been assumed. A further study for a wind farm capacity of 15MW comprising of 3 x 5MW generators has also been considered.
- The cable design of the HV system for each connection point is treated separately since the voltage rating at each connection point is different although a single industry standard cable design rated at 36kV will be used in all cases. Cables have therefore been sized based on calculations using the actual operating voltage for the specific connection configuration (i.e 34.5kV or 36kV)
- Steady state voltage limits for systems rated at 34.5kV or 36kV system voltage are maintained within +/-6% of nominal

- Load currents are based on the turbines operating at full load, within a range of 0.95 leading and 0.95 lagging power factors and with nominal voltage ratings of 34.5kV (for CEI Lakeshore and CPP Lake Road options) and 36kV (for CEI Oglebay Norton Tap)

8.2.2 Exclusions from the Assessment

This assessment excludes the following:

- The cost of the wind farm infrastructure, i.e. turbine transformers, turbine switchgear, onshore switchgear, buildings and structures
- The effect of operation of the wind farm on electrical grid system fault levels, voltage rise, voltage step, stability and power quality assessments as these assessments
- An assessment of losses attributed to the turbines and associated turbine transformers and grid transformers
- Assessment of the wind turbine low voltage (LV) cables between the wind turbine generators and the wind turbine transformers inside the wind turbine tower as these are normally specified by the wind turbine manufacturer as part of the wind turbine package. This assessment therefore covers the external inter-turbine connection high voltage (HV) power cables, and the wind farm collector cabling system leading to the grid connection point
- The assessment is based only on estimated **supply** cable cost of the HV power cables obtained from cable manufacturers and Senergy Econnect's database and **excludes** the installation costs of cable runs as these costs are subject to onsite variations and detailed surveyed cable routes

8.2.3 Pilot Project Locations in Relation to Interconnection

Based on their Preliminary Site Selection (Section 0), juwi provided initial preliminary locations for the Pilot Project. The two locations of focus in this analysis are shown in Figure 8-7. It is should be noted that possible cabling configurations presented for the two turbine configurations could apply to other potential Pilot Project locations, with variations only in cable lengths.

With reference to Figure 8-7, cable route layouts have been designed to avoid the harbor breakwall and utilize available water channels to access onshore connection points.

Figure 8-7: Potential Interconnection and Pilot Project Locations

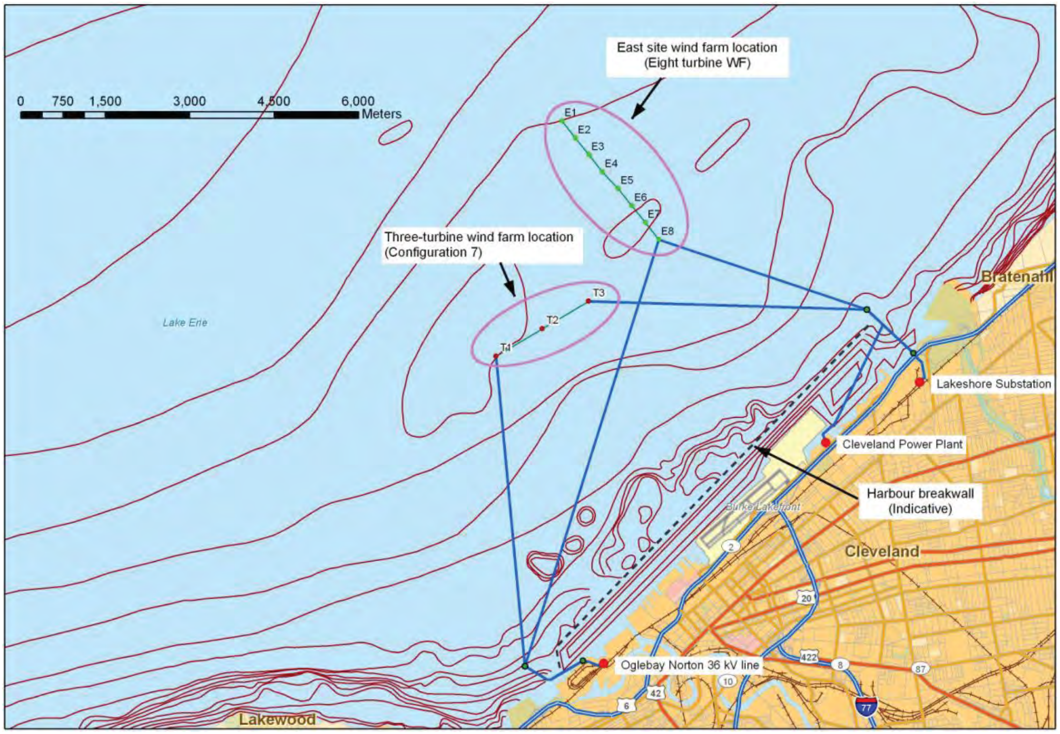


Table 8-2 provides a desk top assessment of the distances in miles between the turbine locations, and between the proposed wind farm locations and the proposed connection points at Lakeshore Substation, CPP Substation and on the Oglebay-Norton 36kV Overhead Line (OHL).

Table 8-2: Estimated Distance from Potential Pilot Project Locations to Connection Point

Proposed Wind Farm Location	From	To	Estimated Direct Route Distance (miles)	Notes
East site (E1 – E8)	WTG01	WTG08	1.68	Offshore
	Inter-turbine distance		0.24	Assume WTG's equally spaced
	WTG08	Lakeshore Shorelink	3.2	Offshore
	WTG08	Cleveland Public Power Substation	3.9	Offshore
	WTG08	Oglebay Shorelink	5.3	Offshore
	Lakeshore shorelink	Lakeshore Substation	0.3	Onshore
	Oglebay Shorelink	Oglebay – Norton 36kV OHL	0.2	Onshore
Three-turbine site (T1-T3)	WTG01	WTG03	1.2	Offshore
	Inter-turbine distance		0.6	Assume WTG's equally spaced
	WTG03	Lakeshore Shorelink	3.8	Offshore
	WTG03	Cleveland Public Power Substation	4.5	Offshore
	WTG01	Oglebay Shorelink	3.8	Offshore
	Lakeshore shorelink	Lakeshore Substation	0.3	Onshore
	Oglebay Shorelink	Oglebay – Norton 36kV OHL	0.2	Onshore

8.2.4 Conceptual Design of Pilot Project Collector System

8.2.4.1 Design Philosophy

The first step in the process is to establish the preferred voltage level of grid connection. The second step is to estimate the maximum number of turbines that will be connected to each of the main array cables. Once the maximum loading of the individual turbine cable groups has been determined, the number and size of the main array cables, and approximate length can be derived.

The design of the wind farm collector and interconnection system layout is achieved by starting with typical arrangements such as radial and loop arrangements. Having determined the basic structure, the design is optimized by an iterative process which takes into account both performance and capital cost of the collector cable array. The final step in the process is to consider the cost and technical issues associated with the provision of additional redundancy in the wind farm collector system. The results of this are presented and discussed.

8.2.4.2 Cable Type

Single core and three core cables are readily available on the market. However the active power export of the wind farm, and the need to minimize the number of separate cables exposed to potential damage and cable laying costs, means that cables between the turbine towers, and the offshore-onshore export feeder should be of the three core construction. For long length subsea applications, three core designs are far superior as losses in the cable armor wires, and the resulting de-rating of the cables, are considerably less. The external magnetic and secondary electric fields outside three core designs of cables are also considerably less than those for single core cables. Single core designs have therefore not been considered further in this assessment.

Armored polymeric insulated cables are widely used to provide the low maintenance, highly secure high voltage system connection typically required for wind farms. At system voltages rated up to 36kV, ethylene propylene rubber (EPR) and cross-linked Polyethylene (XLPE) insulated cables are usually employed for subsea connections as they have a proven track record of resistance to water ingress, an extended life expectancy and a high AC voltage breakdown strength.

XLPE insulated cables are used for land and subsea AC systems up to 400kV and above. At 36kV they are accepted as the standard design for most applications worldwide. As a result, the 36kV three core XLPE designs have been considered for subsea cables in this report.

Stranded copper conductor cables rather than the less expensive aluminum alternative have been considered in this assessment due to the following:

- Copper conductor cables have greater current carrying capacity per unit cross-sectional area thus reducing installation complexity
- Copper conductor cables have greater resilience to damage during installation
- Copper conductor cables have a superior resistance to corrosion should the armoring become damaged resulting in the conductor being exposed to seawater (given the generally long lead times to effect offshore cable repairs)

The cable type recommended for the onshore installation from the shorelink (Transition pit) to the point of connection is a 36kV XLPE single core cable with stranded copper conductor.

8.2.4.3 Desktop Cable Route Survey

The shortest theoretical cable routes have been used in the assessment, however the final cable routes and lengths will be subject to a detailed lakebed survey and an onshore cable route survey to identify any potential obstacles to the proposed cable route.

From the Great Lakes GIS data, major obstacles in the area for the proposed cable routes include but are not limited to:

Harbor Breakwall

The existence of a harbor breakwall along the Lake Erie shoreline presents a major obstacle to the proposed cable route to access either the CPP substation or the Oglebay 36kV onshore connection points. Two potential cable route options exist to overcome the harbor breakwall obstacle, namely:

1. Directly crossing the harbor wall using horizontal directional drilling (HDD) technology to pre-install a cable duct under the harbor breakwall foundation, and then pulling the cable in the duct from a selected point offshore before the breakwall to a point onshore. As a consequence of using HDD and considering the distance to be drilled, this option is likely to be relatively expensive. Figure 8-8 shows the harbor breakwall. A full detailed engineering survey and feasibility study would need to be conducted to assess the feasibility of this option before it can be implemented

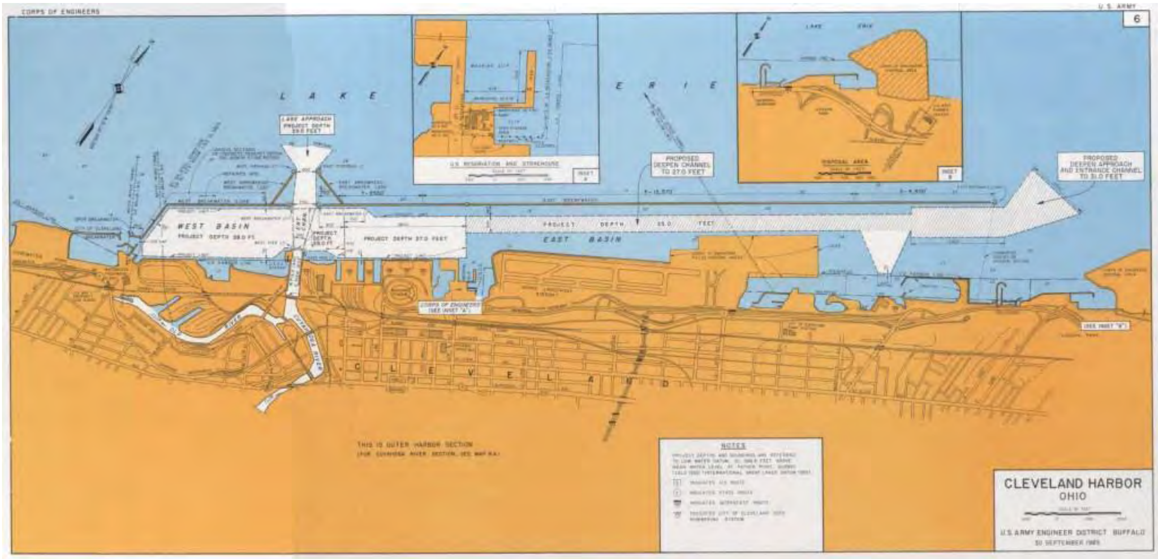
Figure 8-8: Harbor Breakwall and other Features

2. As an alternative to (1), there is an access area at the northern end of the breakwall and two other access openings near the southern end of the breakwall to create water channels which can be utilized for the installation of the subsea cables to access the shorelinks near the CPP Substation and Oglebay. Although using these access channels will entail longer cable runs, it is expected that the increased cost of extra cable lengths and the associated installation costs will not be higher than the costs involved in performing HDD suggested in (1) above. The only disadvantage with this option is the possibility of dredging activities in these water channels. To ensure the safety of buried cables, consultation with the US Army Corps of Engineers—responsible for dredging in federal channels—is needed during the design stage. Figure 8-9 illustrates the federal channel (in white) subject to dredging.[5] Final cable routes will likely need to avoid the areas subject to dredging, or include sufficient burial depths[6].

[5] Figure 8-9 and USACE dredging reference inserted by juwi

[6] Update and hydrographic surveys for recent dredging can be found here: http://www.lrb.usace.army.mil/WhoWeAre/WaterMgmt/survey/survey.html

Figure 8-9: Federal Channel and Area Subject to USACE Dredging (in white)



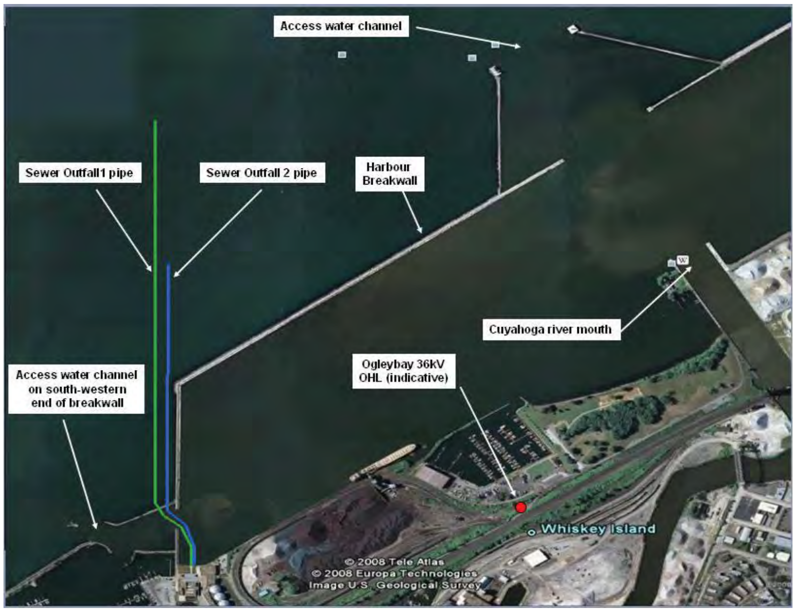
Source: US Army Corps of Engineers

Sewer Outfall and Water Intake Pipes

From the point the outfall pipes cross beneath the harbor breakwall, Outfall 1 (in green in Figure 8-10) is approximately 5-12 ft beneath the lakebed while Outfall 2 (in blue) is right at the lakebed in places, or only 2-3 ft beneath the lakebed. On the shore side of the breakwall, Outfall 1 is approximately 12-17ft below, and Outfall 2 is approximately 7-17ft below the lakebed (NEORSD). Figure 8-10 shows the layout of outfall 1 and 2 pipes. The proposed burial depth of the collector cables is 4.9ft (1.5m). For the Ogelbay Norton option, it is therefore recommended that crossing these structures should take place on the shoreside of the harbor breakwall

Consultation with the Northeast Ohio Regional Sewer District would be necessary to ensure no damage to the pipes during the installation of the subsea power cables

Figure 8-10: Acces Water Channels and Sewer Outfalls

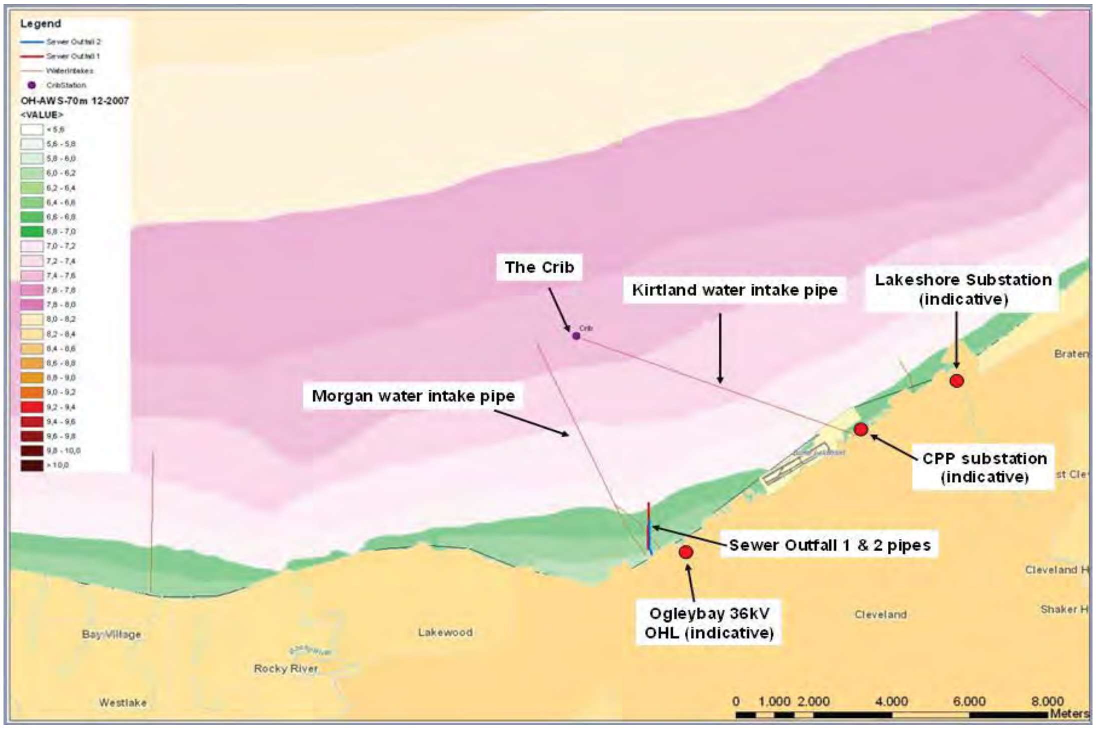


The Kirtland water intake runs from the Crib to an onshore point close to the CPP plant. Available information suggests that the water pipes for this water intake are buried approximately 50 to 60 ft (i.e. 15.2 to 18.3m) below the lakebed (Cleveland Water Department), which is well clear of the 4.9ft (1.5m) burial depth which has been proposed for the subsea cables. Figure 8-11 shows the water intake pipes existing within the Lake Erie waters that could present major obstacles to the proposed cable routes.

The Morgan water intake runs from a point on the lakebed as a single pipe for a significant length before splitting into two sections which terminate onshore to the south-west of the proposed Oglebay 36kV connection point. Available information suggests that the water pipes for this water intake are buried approximately 50 to 60ft (i.e. 15.2 to 18.3m) below the lakebed. The western section approaches about 35 feet (i.e. 10.7m) burial depth at its most shallow areas (Cleveland Water Department). The burial depths along the pipes are therefore well clear of the 4.9ft (1.5m) burial depth which has been proposed for the subsea cables. Figure 8-11 shows the water intake pipes existing within the Lake Erie waters that could present major obstacles to the proposed cable routes

Consultation with the Cleveland Water Department would be necessary to ensure no damage to the pipes during the installation of the subsea power cables

Figure 8-11: Intakes and Outfalls in Relation to Interconnection Locations



Considering the above, it is recommended that further confirmation of the existence or absence of other potential hazards or obstacles along the proposed cable routes be made in a detailed engineering lakebed survey to include but not limited to:

- Adverse geology (sharp rocks etc)
- Shipwrecks
- Dumping grounds
- Ships anchoring (and dragging their anchors)
- Underwater pipelines and other cables, etc
- Dredging activities
- Other existing or planned offshore development
- Water intake and sewer outfall pipework

Information available on public domain website for Lake Erie (www.on.ec.gc.ca/solec/nearshore-water/paper/part1.html) indicates that ''The temperature of the nearshore waters at the lake bed in summer in all five Lakes (of the Great Lakes) exceeds 15ºC and may reach 25ºC in portions of Lake Erie''. Lake Erie is the shallowest of the Great Lakes and also has the warmest water temperature. Therefore, in this assessment a maximum ground (lakebed) temperature of approximately 25ºC has been assumed as a worst case. Cable manufacturer manuals specify a permissible maximum cable conductor temperature of 90ºC, and an operating temperature range of minus 30ºC to +70ºC for the subsea cables.

The burial depth should be determined from a risk assessment of damage (e.g. from anchors / fishing, dredging, etc) along with an assessment of lakebed soil conditions to determine burial techniques, costs, risks and therefore the optimum burial depth at different sections of the cable route. However if burial depths higher than the recommended 4.9ft used in this report are to be used, then further derating of the cable would be necessary to determine the optimum load current applicable to the section of the cable. While cable burial depths of up to 8.2ft below the lakebed can be implemented, the major limiting factor would be the ground temperature which can be higher than 40ºC at such deeper levels. This scenario would result in significant derating of the cable and would consequently require the use of larger cable sizes than would be normally required at a nominal depth of 4.9ft.

8.2.4.4 Proposed Pilot Project Cable Array Options

In this section three fundamentally different layouts are proposed for the possible eight-turbine layout. The proposed cabling options (i.e. Options 1, 2, and 3) have been categorized according to where the main outgoing collector cable connects to (i.e. Option1-Lakeshore Substation, Option 2-CPP Substation, and Option 3-Oglebay-Norton 36kV OHL), while the distinction between the sub-items (a), (b) and (c) in each option have been categorized according to the specific cable array configuration as illustrated in Figure 8-12, Figure 8-13, and Figure 8-14.

Figure 8-12: Eight-Turbine Cable Array Configuration (a)

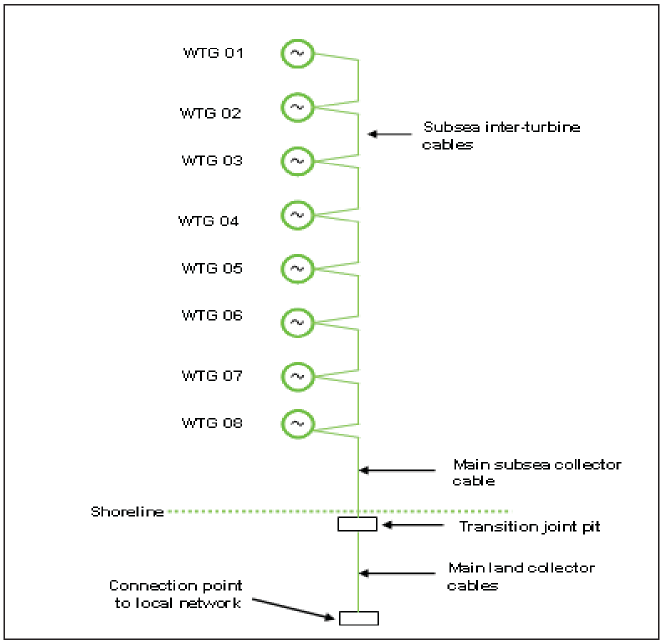


Figure 8-13: Eight-Turbine Cable Array Configuration (b)

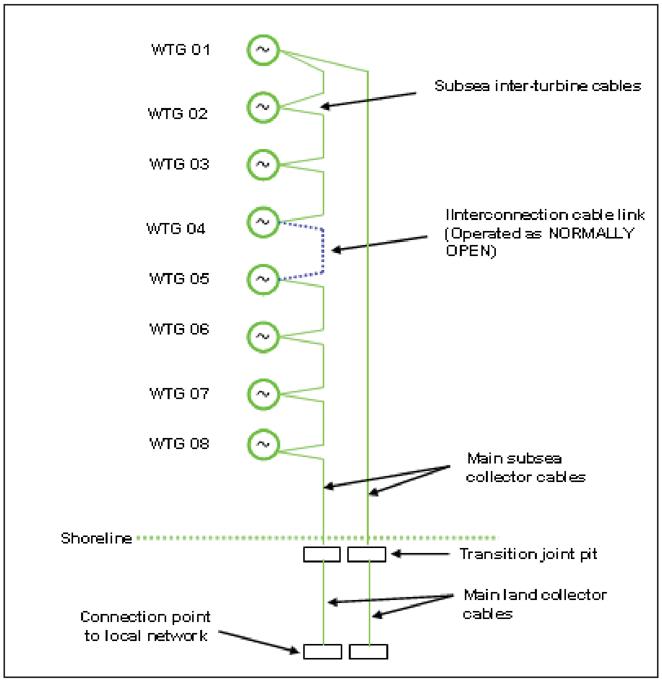


Figure 8-14: Eight-Turbine Cable Array Configuration (c)

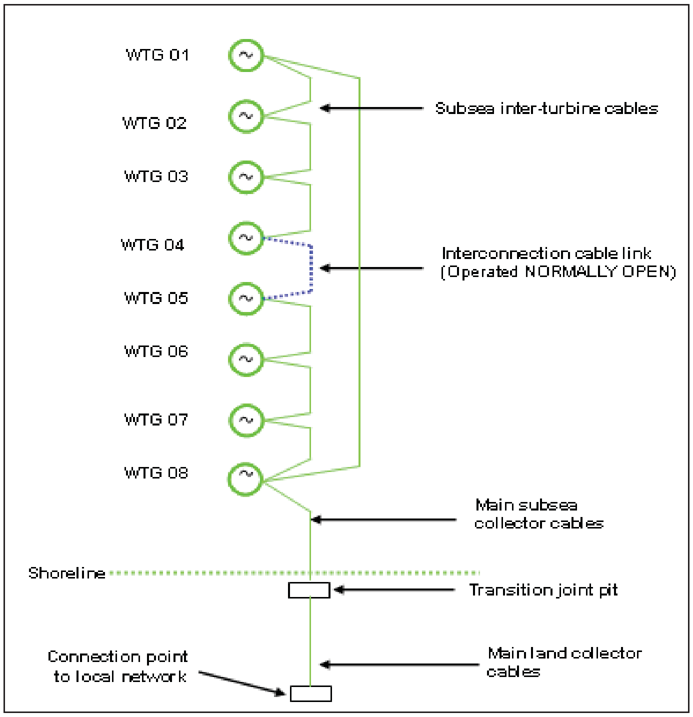


Figure 8-15 and Figure 8-16 shown below illustrate the cable array configurations used in Option 4, where Option 4 (a) represents the connection of the three-turbine wind farm at Lakeshore Substation, 4 (b) at the CPP Substation, and 4(c) onto the Oglebay-Norton 36kV OHL.

For the three-wind turbine wind farm, no alternatives to the layout configurations at each connection point have been considered as the variation in the layout configuration is not expected to yield much benefit given the number of WTGs involved.

(*For further discussion of redundancy considerations and individual cable array options, refer to Section 7.10 of the GLWEC Offshore Cabling Report, Senergy Econnect, November 2008)*

Figure 8-15: Three-Turbine Cable Array Configuration (Options 4a & 4b)

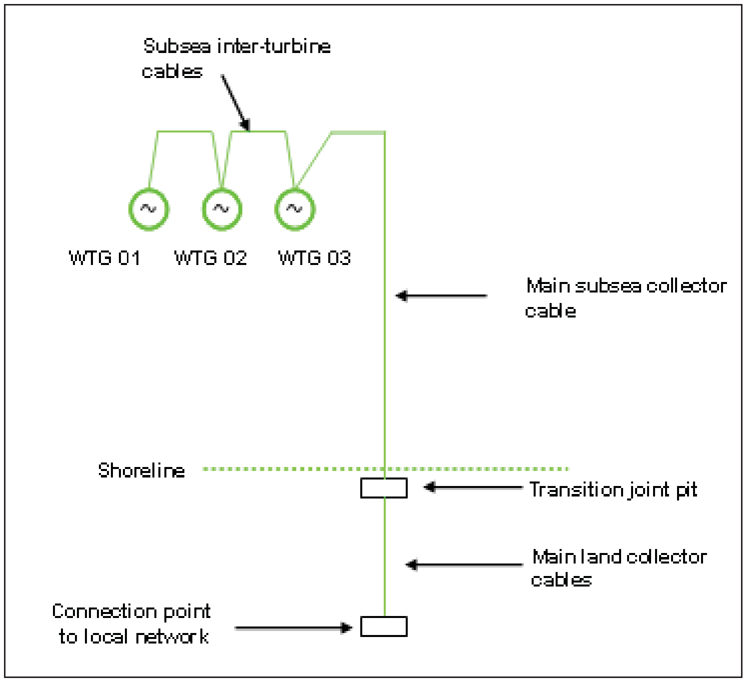
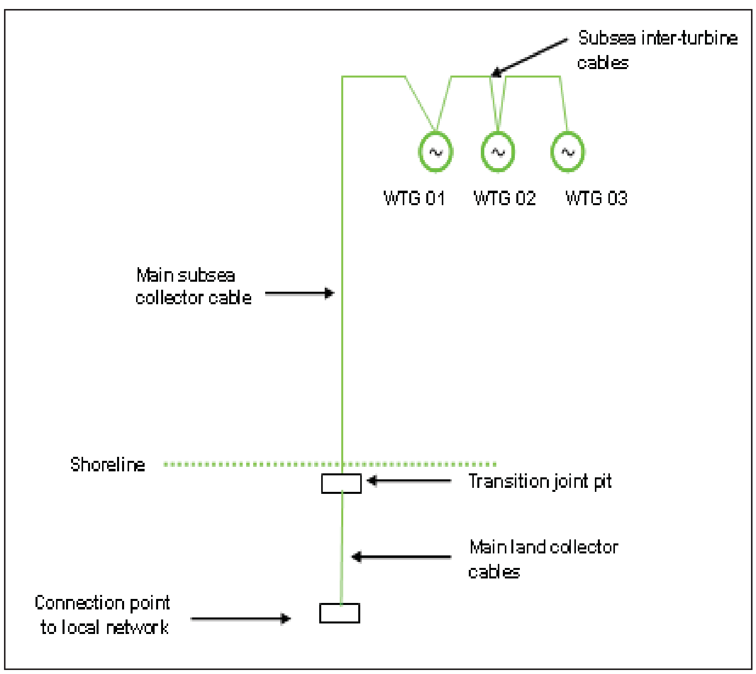


Figure 8-16: Three-Turbine Cable Array Configuration (Options 4c)



8.2.4.5 36 kV Collector System Cable

The minimum cable size is dictated by the expected maximum loading of the turbine array and the operating voltage level of the cable array under consideration. It can be observed that with minimum thermal cable rating as the sole selection criterion, it is possible for cables with sizes ranging from 95mm2 to 150mm2 to be used throughout the wind farm 36kV collector system array, depending on the number of turbines connected to each array and the collector array operating voltage. Larger cables are needed where the cable grouping de-rating factor for two circuits that are installed in a single cable trench is applied. This aspect is however not applicable in this case as only a single circuit in the cable trench is proposed.

The larger cable sizes are also necessary when designing the most optimized lifetime costs of a cable array configuration where both the capital supply costs and the lifetime losses of the cable array configuration are taken into account. Therefore cable sizes of 185mm2 and 240mm2 have been considered in the assessment.

It is neither practical nor cost effective to select an 'optimal' cable size for each section of the collector cable circuit between two wind turbines, as this selection would result in the need to order small amounts of several different cable sizes. In order to achieve practicality and cost effectiveness in the wind farm collector cabling system design and considering the size of the wind farm under study, a maximum of two different subsea cable array conductor sizes for each layout have been allowed for, in addition to the land cable conductor size in each option.

Due to the short cable lengths involved in the three-turbine wind farm cable array, only a single subsea cable conductor size has been allowed for in addition to the land cable conductor size in each option considered.

8.2.5 Evaluation of 36 kV Collector System

8.2.5.1 Introduction

For each of the Pilot Project – interconnection scenarios, consideration is given to the number of wind turbine 36kV collector circuits (loading current), underground cable optimum routes, prospective fault levels within the wind farm, agreed levels of redundancy, performance and life time costs (supply cost of cables plus cost of losses) of the copper conductor cables. The cable sizes have been optimized for carrying the specified power transfers in each inter-turbine and main cable array.

Estimated 36kV cable data and supply costs obtained from reputable cable manufacturers and Econnect's data base, have been used for the cable selection and optimization, and the assessment provides a cable selection that is representative of the cables that would be supplied for this project.

Value of Energy over the lifetime of the project is accounted for in the cable optimization assessment. Assumptions for value of energy are as follows:

Table 8-3: Data for Calculating Capitalized Value of Energy

Value of exported energy	Value of energy	US$150 per MWh
	Rate of escalation	3%
Financial parameters	Project lifetime	25 years
	Project discount rate	10% per annum

The wind farm load factor (or capacity factor) is a dimensionless factor which represents the wind farm generated power in a given year as a percentage of the wind farms potential full output power. The load factor is accounted for in cable optimization, and is a function of various factors:

- the wind regime at the site
- the turbine power curve
- the turbine reactive power characteristic

8.2.5.2 Results and Conclusions

Utilizing information from previous subsections, the total budget supply cost of the 36kV subsea and land cables, life-time cost of energy and total budget cost (supply cost + lifetime cost of losses) of the proposed cabling system for Options 1, 2, and 3, has been estimated using copper conductors.

The total budget costs for each option are summarized in Table 8-4 below with the lowest cost for each connection point or option highlighted in brown.

Table 8-4: Cable Budget Cost Summary

Connection Option	Array cable operating voltage	Estimated installed capacity	Total budget cost US$(million)*	Estimated cost per MW installed US$(x1000)*
Option 1 –Connection of eight turbine wind farm at Lakeshore Substation				
1 (a)	34.5kV	20MW	4.400	220
1 (b)	34.5kV	20MW	9.604	480
1 (c)	34.5kV	20MW	6.314	316
Option 2–Connection of eight turbine wind farm at CPP Substation				
2 (a)	34.5kV	20MW	4.858	243
2 (b)	34.5kV	20MW	10.516	526
2 (c)	34.5kV	20MW	6.648	332
Option 3–Connection of eight turbine wind farm onto Oglebay – Norton 36kV OHL				
3 (a)	36kV	20MW	6.094	305
3 (b)	36kV	20MW	12.933	647
3 (c)	36kV	20MW	8.046	402
Option 4–Connection of three turbine wind farm (Lakeshore /CPP / Oglebay)				
4 (a)	34.5kV	15MW	3.812	254
4 (b)	34.5kV	15MW	4.182	279
4 (c)	36kV	15MW	3.539	236

**It must be noted that the total budget costs indicated include only the estimated cable supply costs based on general pricing data obtained from reputable cable manufacturers and Senergy-Econnect's data base, and the costs of losses, and do not cover the cable installation costs as these would be subject to detailed lakebed surveys. The above costs have therefore been included only for the purpose of relative cost comparisons for different options in order to optimize the wind farm collector cabling system design.*

The assessment in this report has been based on a base value of energy of US$150 per MWh, and the wind farm load factor range of 28% to 35%. A sensitivity analysis carried out in this assessment has showed that a load factor of 35% yields a worst case scenario. It is therefore possible that smaller size cables could be used for the wind farm collector cable system if the wind farm load factor is maintained at or about 28%.

It is also worth noting that whilst Options 1(a), 2(a) and 3(a) are cheaper compared to other cable array configurations for each connection option, these do not offer redundancy. All connection proposals in Option 4 also do not offer redundancy. However if partial or full redundancy is required, the cable lengths (and therefore capital costs) would increase significantly, although the cable sizes would most likely remain the same in each option.

Eight-Turbine Pilot Project

By comparison, and considering Options 1, 2 and 3 for the connection of the eight wind turbine turbines, it can be seen that the supply cost of cable, lifetime cost of cable losses and the total (supply cost + lifetime cost of losses) using 36kV with copper conductors is the least expensive for Option 1(a) utilizing the cable sizes shown in Table 8-5 below:

Table 8-5: Optimized Cable Selection for the Eight Turbine Array

Connection option	Wind Farm Inter-turbine subsea cable array	Subsea collector cable to Lakeshore shorelink	Land cable
Option 1 (a) -Connection to Lakeshore Substation	95mm^2 (1x3core cable)	240mm^2 (1x 3core cable)	240mm^2 (3x 1core cable)

Option 1(a) requires about 1.7 miles of 95mm2 inter-turbine connection cable, 3.7 miles of 240mm2 main collector subsea cable and approximately 0.5 mile of 240mm2 land cable.

Three-Turbine Pilot Project

By comparison, and considering Options 4(a), 4(b) and 4(c) for the connection of the three wind turbine turbines, it is noted that the supply cost of cable, lifetime cost of cable losses and the total cost (supply cost + lifetime cost of losses) using 36kV with copper conductors shown in Table 8-6 provides the least expensive option.

Table 8-6: Optimized Cable Selection for the Three Turbine Array

Connection Option	Wind Farm Inter-turbine subsea cable array	Subsea collector cable to Oglebay shorelink	Land cable from shorelink to Oglebay/Norton 36kV OHL
Option 4 (c) -Connection to Oglebay-Norton 36kV OHL	240mm^2 (1x3core cable)	240mm^2 (1x 3core cable)	240mm^2 (3x1core cable)

This connection option, 4(c), requires about 5.4 miles of 240mm2 inter-turbine connection cable and main collector subsea cable and approximately 0.2 miles of 240mm2 land cable.

Following the wind farm collector cable optimization and selection assessment detailed in this report as part of the overall feasibility for the GLWEC Pilot Project, it is concluded that the collector cable array for the Pilot Project with eight wind turbines be implemented using the subsea cables with 95mm2 and 240mm2 copper conductors as shown in Table 8-5 above. Connection of the East site eight-turbine layout to the Lakeshore Substation provides the lowest project lifetime cost option, and therefore the most optimum connection option.

It is also concluded that the collector cable array (subsea and land) for the Pilot Project with three wind turbines be implemented using the cables with 240mm2 copper conductors as shown in Table 8-6 above. Connection of the three-turbine offshore wind farm to the

Oglebay-Norton 36kV OHL provides the project lifetime least cost option, and therefore the most optimum connection option.

It should be noted that while cost optimization leads to preferred onshore interconnection options, a final determination for interconnection location will depend on a variety of factors, including power purchase agreement, detailed lakebed surveys, and interconnection studies.

8.2.6 Offshore / Onshore Cable Installation

8.2.6.1 Offshore Cable Installation Equipment

The installation of subsea cables requires specialized ships with sophisticated dynamic positioning systems and Remotely Operated Vehicles (ROV's). These vessels are tailored to suit the various installation requirements (cable type, sea depth, type of ROV, etc) and are fitted with cable handling facilities including a large rotating platform to store the cable and feed it to the cable laying equipment.

Jointing of the subsea cables should be minimized as far as possible in order to avoid introducing contaminants that may affect the efficacy of the insulation and lead to early failure. Transporting and loading these long, heavy lengths of cable onto the ships requires careful planning. Since these long lengths of cable are not easily transported, the cable laying ship will be required to load additional cable at a port that is close to where the cable was originally manufactured.

8.2.6.2 Offshore Cable Installation Overview

Detailed surveying of the cable route is required to determine the burial conditions required for the array cables. As well as the geology of the seabed, route considerations must be taken into account of existing services (e.g. oil and gas pipelines, telecom cables, water intake and sewer pipes, etc) and special features such as environmentally sensitive areas at the cable landing points, etc. The result of the survey should enable selection of optimal ship/ROV combination for the local conditions.

Subsea cables are protected with steel armor, however this may not afford sufficient protection against hazards such as seabed variations, dredging and fishing activities, dropped or dragged ship anchors and other heavy objects.

Burial of subsea cables is the best form of protection against most hazards and the burial depth depends on the degree of protection required. In this assessment a burial depth of 4.9ft (1.5m) below the seabed surface has been used which is a typical burial depth for such installations. The degree of cable protection may also be increased by means of rock cover over the cable route. The degree of protection required is obviously specific to the location under consideration and will require a detailed engineering assessment of the lakebed conditions which will include, but not limited to, the identification of the types and the locations of potential hazards. Such an assessment is outside the scope of this report. It is however noted that according to information available on the public domain website, Lake Erie has the highest density of shipping traffic compared to the other Great Lakes. In addition, it is the shallowest and roughest of these lakes and also contains the most known shipwrecks, hence the requirement for a detailed seabed survey at the detailed design stage of the project.

The array cables are generally located within the wind farm area and as such are partly protected by the presence of the wind turbines themselves. Hazards that are nonetheless likely to be encountered for both wind farm interconnection cables and the main offshore-onshore export cables, include but are not limited to; fishing activities, vessel traverses, anchoring of work vessels under strict anchor placement controls, heavy lifting operations due to installation or maintenance of equipment (and dropped objects may also be possible during this stage), and sediment movements (i.e. leading to possible exposure of cables).

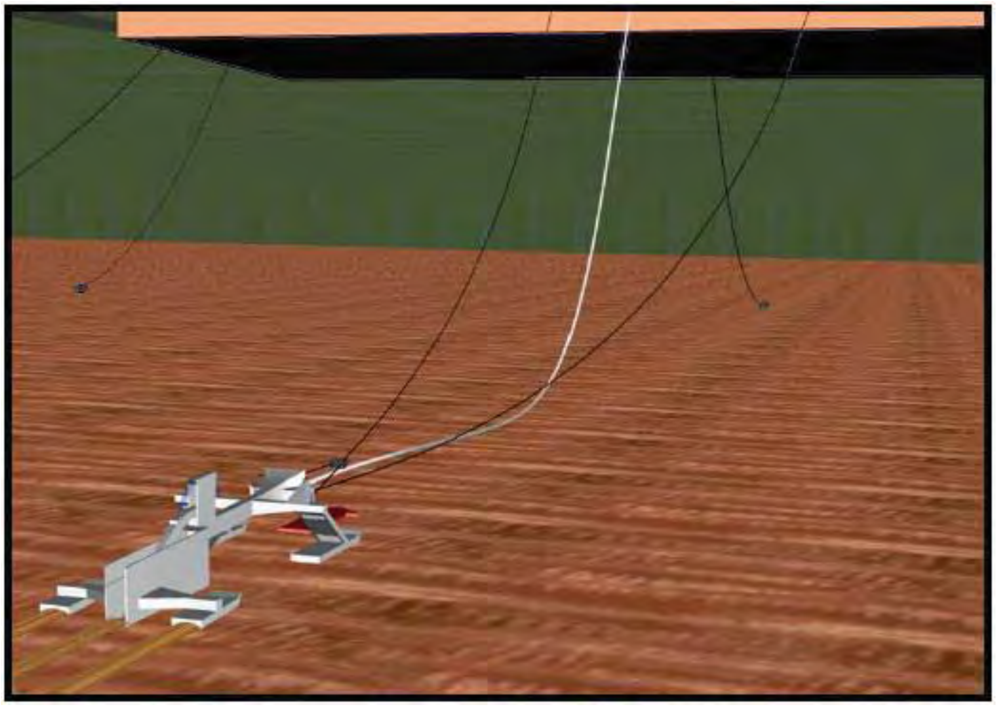
A detailed cable installation study will be required to determine the most adequate burial depth to be used for the installation of the wind farm 36kV reticulation system, especially in the water channels where heavy dredging may exist.

For subsea cable burial, the two main cable installation techniques are plowing and jetting.

Plowing

Figure 8-17 below shows a schematic diagram of a plowing operation.

Figure 8-17: Plowing Operation



With this installation technique, the cable is fed down from the ship to a barge, through the plow and onto the seabed. The blade of the plow protrudes below the seabed surface. The plow is pulled towards the laying vessel and the blade displaces the lakebed in a manner similar to a conventional farming plow and allows the cable to fall into position.

With this method, the lakebed disturbance is kept to a minimum and very little sediment is generated. However, controlling a plow can be difficult and the risk of cable damage is high, particularly if a laying problem is encountered. A review of the plant inventories held by subsea cable installers has shown that many plows are not suitable for use with larger cable sizes of diameters of 200mm and above. New large capacity plow designs may have to be developed.

Jetting

An alternative to plowing is the use of water jetting. Figure 8-18 below shows water jetting in progress.

Figure 8-18: Jetting Equipment in Operation

Although jetting causes more sediment disturbance it is however accepted as a subsea cable installation technique in many parts of the world. The typical width of a jetted trench is 300mm. With a burial depth of say, 3.28feet (1m), a volume of 0.3m^3 of seabed is displaced for each meter length of cable. Users of jetting equipment claim that often up to 100% of the trench is back filled by the sediment settling back down. However, this is highly dependent upon the sea current. In any case the original seabed compaction would not be restored and considerable sediment displacement is a possibility.

As with plowing, new designs of jetting equipment suitable for cables with 200mm diameter and above, is under consideration. In general, with the exception of rock, plowing is suitable for most types of seabed material. The higher the shear force of the seabed, the greater is the weight of plow that is required and the greater is the required pulling tension.

'Light' jetting can be used for sand and some light to medium clays. Sometimes several passes are necessary to obtain the required burial depth. In the event that rock is encountered on the seabed, the use of rock cutting equipment will be necessary. Plows with saws can be used for softer rock types and ploughs with cutting wheels can be used for harder rocks. However under the circumstances, seabed disturbance and noise are likely to be greater than when conventional plows or jetting equipment are used.

8.2.6.3 Offshore Cable Burial

For the main cable runs back from the end turbine in a string towards the shorelink, plowing could be used for most of the way. For the inter-turbine cables, it is likely that access would be difficult for a plow and the risk of cable damage would be high. Therefore it is recommended that jetting should be used for these connections. Several passes of the jetting equipment may be necessary to achieve the required depth. Adjacent to the base of the turbine or shorelink structures, rock placement could be used if required.

An alternative to the above methodology is to use a combined cable laying and burial machine. This is shown in Figure 8-19 below and the cable drum can be seen mounted on the machine. The choice of machinery would be dependent upon the lakebed conditions.

Figure 8-19: Combined Subsea Array Cable Laying and Burial Machine

8.2.6.4 Onshore 36 kV Cable Installation

For the connection between subsea three core cables and single core onshore cables, a large transition pit (shorelink) will need to be constructed close to the onshore landing point and above the high water mark.

From this point to the proposed point of interconnection, the cable will be direct buried in trefoil formation (touching), at a nominal burial depth of 2.6ft and will be bonded and earthed at both ends in accordance with applicable standards. The integrated optical fiber cable from the transition pit will be run separately from the power cable (no longer integrated as in subsea cables) although it will be within the same cable trench as the single core land cables.

As part of a detailed route survey, the soil should be analyzed for its thermal properties. If it is suitable (i.e. its thermal resistivity is consistent and in line with the design parameters that have been used to in this report for the calculation of the cable ratings) it can be used to backfill the trenches after installation. If it is not suitable it should be dumped and replaced with some selected sand that does possess the required thermal properties. The soil should be checked to ensure it is free from sharp stones that could cause cable damage. In practice, it would be expected that some selected sand would be necessary.

9 Test, Certification, and Advanced Research Centers

(Unless otherwise indicated, information in this section taken from the GLWEC Market Research Report, Germanischer Lloyd (GL), April 2009).

9.1 Market Research

This section assesses the market potential and demand for creating a Great Lakes Wind Energy Center ("GLWEC") in Cuyahoga County, Ohio, including the following possible elements:

(a) Pilot Offshore Project Site (defined as a 5-20 MW wind turbine Pilot Project with 2-8 wind turbines installed in Lake Erie near Cleveland)

(b) Test Center (defined as a facility that allows manufacturers to test new product designs)

(c) Certification Center (defined as a facility to certify the technical acceptability of new wind-related equipment)

(d) Advanced Research Center (defined as a facility for innovative wind energy research and technology development by public, private and/or academic institutions);

The objective of the market research was to evaluate the market interest for using the GLWEC and to identify the types of facilities and/or equipment that would make it attractive to potential academic or industry users.

9.1.1 Survey / Questionnaires

GL Renewables prepared two questionnaires with the objective of identifying the market demand for the GLWEC along with potential associated facilities, specifically three facilities: a test facility, certification facility and a research facility. The first questionnaire was prepared for a target audience consisting of turbine manufacturers and component manufacturers, while the second questionnaire was prepared for a target audience comprised of certification bodies.

9.1.1.1 Turbine Manufacturers

GL Renewables contacted ten turbine manufacturers for the survey. Only two manufacturers completed the questionnaires and returned them to GL. To protect confidentiality, these manufacturers are referred to as Turbine Manufacturer 1 and Turbine Manufacturer 2.

Overall, the respondent Turbine Manufacturer 1 demonstrated particular interest in all three facilities as well as the Pilot Project associated with the GLWEC. In fact, Turbine Manufacturer 1 might be willing to provide turbines for the Pilot Project at a reduced price. Regarding the use of the test facility, even though Turbine Manufacturer 1 is currently performing full-scale, comprehensive testing of its turbine, the respondent did express an interest in using and paying for the services offered by the test and research facilities. Human resources and logistics were the respondent’s primary concern, and his preference would be to utilize resources used by the GLWEC.

Turbine Manufacturer 2 also responded in a positive manner relating to all areas of the GLWEC stating that their primary areas of interest would be the electrical testing of the nacelle and in general nacelle mechanical testing although the trend in MW design seems to be moving towards larger MW capacity machines. The level of interest expressed in the questionnaire was extremely high and very positive. Their primary concern of Turbine Manufacturer 2 seemed to be focused around the quality of the personnel involved in all areas of the GLWEC project.

9.1.1.2 Component Manufacturers

GL Renewables contacted seventeen component manufacturers for the survey. Of these, ten did not respond, two refused to participate, and five completed the questionnaires. To protect confidentiality, the companies are referred to as Component Manufacturer 1 through 5.

Overall, the respondents from the five component manufacturers showed little interest in the GLWEC and its associated facilities. This lack of interest is due to the fact that most of the companies have their own testing facilities, which, for the most part, they generally seem to prefer. Moreover, given that the testing of the components is often performed on the turbines themselves, the involvement of the component manufacturers in such a facility is dependent on which facility their clients (the turbine manufacturers) decide to use. In other words, the component manufacturers have no say in what site is selected by the turbine manufacturers to test or certify the turbine.

Two of the respondents expressed interest in the R&D facility. Of these two respondents, one was willing to have permanent R&D staff in Cleveland, while the other was not.

Interest for participating in the offshore Pilot Project varied significantly, with some respondents showing little interest, and others showing a great deal of interest. Since no consensus was reached among the respondents, a conclusion cannot be drawn about overall market potential.

It is worth noting that the two companies who declined to complete the questionnaire both cited confidentiality concerns as their primary grounds for not sharing their opinions.

9.1.1.3 Local Supply Chain

With respect to developing a local supply chain, Turbine Manufacturer 1 and 2 would consider purchasing components from the Cleveland area on the proviso that quality standards and delivery times were acceptable. The components that interest them most are bearings, casting components, and drive trains in the case of Turbine Manufacturer 1 and gears, bearings, castings, towers, anemometers and more in the case of Turbine Manufacturer 2.

Only one component manufacturer, namely Component Manufacturer 4 from Germany, expressed their interest in procuring certain parts or work such as castings, machining of smaller items and painting in the southern Great Lakes region, provided that technical capability and quality were right. The other four responding component manufacturers showed no interest, mainly due to the additional logistic constraints of having an overseas supplier.

9.1.1.4 Certification Bodies

In addition to sending questionnaires to both turbine and component manufacturers, GL Renewables also contacted six certification bodies. Of the six, three responded to the survey.

While all three respondents concurred that a market exists in North America for turbine certification, none felt that they would be likely to use the proposed facilities. The overriding belief was that certification would be more likely to occur at another site selected and defined by the project team. In general the turbine manufacturers define where their type certification is undertaken and they specify where the component certification should be undertaken.

9.1.2 Market Demand for GLWEC

9.1.2.1 Pilot Project

In the questionnaire, turbine manufacturers were asked whether they would be willing to donate or supply turbines for the Pilot Project. The answers received were relatively positive: while no turbine manufacturer offered to donate turbines, both of the written responses indicated a positive response and one offered to possibly supply turbines at a reduced cost. Some of the component manufacturers mentioned that they would be interested in possibly donating cash or supplying components for the project. The majority of the component manufacturers had a positive attitude toward this aspect of the project.

A primary objective of the Pilot Project can be seen as being essentially a manner in which the consciousness of wind is raised within the local area. The Pilot Project according to Germanischer Lloyd's findings would not prove to be a viable option for foundation testing or in general for turbine testing, however a case could be made that the offshore market is growing rapidly in Europe and at the moment there is no specialized facility dedicated to the development of offshore access techniques and the training of personnel in the access techniques. Germanischer Lloyd concludes that there is a potential market for these services as they would reduce the operational and maintenance cost of a project dramatically. The Pilot Project should generate O&M costs of approximately $0.064 to $0.079 per kWh and a support structure of six skilled staff would potentially be required to undertake operational tasks. The detailing of the project is crucial and will define exactly the level of staffing and the revenues generated. Another factor that may prove a beneficial result of the Pilot Project is the possibility to use it as an attraction for seminars where by participants would actually be able to see a functioning turbine on location.

It has also been discussed whether a measurement platform would be another option to encourage the wind industry to invest in the local area. While a meteorological measurement platform would be used by potential developers and generates data which can be utilized or sold, it is not certain that it would raise the profile of the wind industry locally. However it would be useful to assist future developers to determine their potential return on investment and to have a database from the actual turbine location – and the fact that reliable data existed for this part of Lake Erie could attract offshore wind development along the Ohio coast line. The LiDAR system which is planned to be installed on the Crib site will potentially deliver wind data which can be correlated with long term stations around Lake Erie. The point was also raised as to whether there is a potential to test foundation structures for ice flow and icing. For the proper design of the turbine foundations it would be useful to apply strain gauges to a test structure to measure the ice force created by the breaking ice. The crib as test structure for ice load measurements could be considered, but it might also be worth thinking of a test and measurement structure at the future turbine location to obtain these data. Though the measurements will provide valuable data for further calculations, further modeling and in depth computational analysis will be necessary.

9.1.2.2 Test Center

The test center proposal was met with interest from the turbine manufacturers that responded. Primary testing subjects mentioned were varied and covered all the major areas of the turbine. As such GL reviewed the turbine manufacturers' responses and also looked at other test facilities. The primary potential areas for testing are seen as prototype testing, offshore Pilot Project, condition monitoring systems, measurement of environmental conditions, calibration of test equipment and site assessment. This has been demonstrated by the other worldwide test centers operating in these fields, as such competition would be higher. There could be a demand for an offshore O&M training center in combination with the Pilot Project. This alone would not prove to be too attractive to potential customers but when combined with access technique research then there may be a larger potential market. The component manufacturers did not feel the need to test in the USA.

9.1.2.3 Certification Center

The certification center proposal was met with a positive confirmation that the manufacturers contacted would be interested in utilizing a facility located within the USA. Currently it is not a mandatory requirement to certify turbines or projects within the USA, however as the industry grows investors and developers will push to standardize the quality of the components, certification will probably become mandatory for all offshore project within the next 5-10 years and this may be pushed by a legal requirement or by the fact that investors and developers wish to lower the risk profile of their investment. Taking this fact into account, and the fact that the industry in Europe has seen the need for a third party verification/certification process, a facility in the USA could prove profitable as a long term investment. As stated above the response from the manufacturers was positive, but also mitigated with a statement that they define the key requirements of a certification center as being an extremely skilled staff delivering on time and to a high quality which is why GL suggests that Cuyahoga County should consider partnering with an established certification body should they wish to proceed with this part of the project as this would give them an established reputation which would result in a faster potential growth rate for this business area. The strategy illustrated later in this document is based on the certification process developed and utilized within GL. This process was taken as it is a proven business model which has given GL a market share of over 50% of the type certification market. GL also contacted and discussed these points with several certification bodies and the consensus from the respondents was that they personally could not see a potential for a certification center in the northern USA. However GL feel that there is a potential for a center in the USA and would possibly be interested in being involved at a future date.

9.1.2.4 Advanced Research Center

The research center is seen by GL to be the least viable aspect of the project primarily due to the turbine manufacturers' trend towards developing their own research facilities in house, which has been illustrated by Vestas and also by Siemens. The confidential nature of the manufacturers' development projects makes collaboration with an external body that does not have a proven reputation a higher risk. GL feel that the market for a research center does exist, the time frame, however, for the building of a reputation would be best served by working closely with an established body and using their reputation in order to market the centers capabilities. The areas where research should potentially be undertaken should be in the areas where the other research institutes are not extremely active. These areas are primarily wind energy integration, offshore deployment and operating and maintenance (O&M). As mentioned earlier, combining the offshore Pilot Project with the research center to generate a center where offshore personnel could be trained is seen as a potential market. This could be combined with research into various access techniques.

9.1.2.5 Summary Table of Market Research

Table 9-1 provides a summary overview of findings from market research for the GLWEC.

Table 9-1: Summary of Market Research

	Pilot Project	Test Center	Certification Center	Advanced Research Center
Market requirement	There is no perceived need for a Pilot Project in Lake Erie; however this would raise the profile of the wind industry and this may be seen as a desirable goal. The potential power generated would also be available to generate revenue.	There is a limited market need for an independent test center.	The need for a certification center is perceived as being required currently only for type certification but in the future for project certification as the financial institutions look to minimize their investments risk profiles.	There are areas where the research market has not been fully developed and there is a potential market need here.
Component manufacturers' requirements	Interest was shown by various component manufacturers, some of whom expressed an interest in possibly assisting financially or through the donation of components.	Generally the component manufacturers' interest in a test center was negative and they did not perceive the need to test their products in the USA.	Component manufacturers stated in general that the component certification center is specified by the turbine manufacturers.	Generally the component manufacturers were positive regarding the opportunity and seemed willing to pay for services.
Turbine manufacturers' requirements	Interest was expressed and turbine manufacturers stated the possibility of reducing their turbine prices should the project go ahead.	Turbine manufacturers seemed interested in testing although GL feel that the smaller manufacturers would be more likely to utilize the facility.	The turbine manufacturers stated they would be interested but highly qualified personnel were the key concern.	Both of the turbine manufacturers responded positively to a research center with personnel being one of the key factors.
Investment costs	Refer to Section 11 of this report			
Earning potential	Refer to Section 11 of this report			
Overall rating excluding finances	The Pilot Project would be seen as potentially viable if the object is to generate	From the responses received and GL's experience of working	GL believe that it would be essential for a successful center to	Generally GL feel that a research center could prove

	electricity and raise the profile of the wind industry. If the object is to test turbines in situ then GL do not feel that this is a viable area for the GLWEC project.	with turbine manufacturers the viability of a test center would be completely dependent on which area testing will be undertaken.	be partnered with an established Certification body. But overall the positive responses indicated a center could be viable.	viable but the specific area of expertise will be the key to the center's success. As will the selection of research personnel.

9.2 Pilot Project Operational Activities

9.2.1 Potential Component Suppliers

Potential suppliers shown in Table 9-2 have experiences in construction of offshore wind farms. These companies are mostly operating in Europe, which is a result of the fact that most of the offshore wind developments currently are in Europe. The majority of these companies are internationally active with branch offices in North America, or their main offices are in North America and branch offices in Europe.

Table 9-2: Possible Component Suppliers for the Pilot Project

Component	Potential Supplier
Offshore Wind Turbine 5 MW including Towers and Blades	- REpower Systems AG - Areva - Multibrid GmbH - BARD Engineering GmbH
Offshore Wind Turbine 2.3 to 3.6 MW including Towers and Blades	- Clipper - Siemens Power Generation -Vestas
Substation	- Areva T&D - ABB - Siemens Transmission and distribution Ltd - Eletra - Agrilek
Jacket Foundation	- Burntisland Fabrications Ltd.
Tripod Foundation	- Aker Kvaerner
Tri-Pile Foundation	- Cuxhaven Steel Constructions / BARD Engineering GmbH
Monopile Foundation	- Bladt Industries A/S - Bilfinger Berger - Aker Kvaerner - Ballast Nedam - Smulders Group - Tower Tech (a Broadwind Company)
Cable	- ABB - AEI - Nexans - NSW GmbH & Co. - Prysmian - JDR Cable Systems - Scanrope Subsea AS

9.2.2 Onshore Personnel

In order to operate the offshore Pilot Project, specialized skill sets and personnel are required. These are listed in Table 9-3.

Table 9-3: Personnel for Office / Administration Building and Storehouse / Work Shop

No.	Staff	Field of Activity	No. of Employees
1	Business Manager	Coordination & administration, internal and external financials, recruitment of staff	1
2	Engineers	Project management, supervisory during offshore operations, purchase material and spare parts	2
3	Technicians	Inspections, maintenance, repair maintenance of facilities and equipment	2
4	Team Assistant	Assistance & support	1
	Total		6

Overall, there could be six full time employees in this proposal. The business manager would take responsibility for both the Pilot Project and the personnel. This includes tasks of coordination and administration as well as the finances but could also comprise marketing and the development of positive public opinion regarding offshore wind and the Pilot Project. Management support from one of the two proposed engineers could be available relating to the operation & maintenance strategies, documentation and quality management. The engineer could be responsible for analyses, monitoring and verifying the wind farms performance against appropriate key performance indicators and the coordination of O&M operations. The main work area for the second engineer could lie in offshore inspection, testing and maintenance of the equipment and wind turbines in cooperation with one of the two technicians. The second engineer could also be responsible for the coordination of offshore procedures and for the purchase of needed consumables and spare parts. The field of operation of the second technician is to carry out the O&M and the repair works if necessary. The aforementioned employees should receive administrative support from one Team Assistant.

9.2.3 Onshore Facilities

In order to provide a scope for the Pilot Project, it is necessary to consider facilities such as an office building, storehouse, and workshop. Example facilities are provided in Table 9-4.

Table 9-4: Example Onshore Support Facilities

Office & Administration Building			
No.	Facilities	Details	No.
1	Offices	1 for Business Manager, 1 for engineers and 1 for the Team Assistant	3
	Reception	For visitors	1
	Meeting and Briefing Room	1 large room for 10 persons	1
	Server, Archive & Library	For documentation, expert magazines, technical literature, server	1
Storehouse & Work Shop			
No.	Facilities	Details	No.
2	Storehouse	Required area depends on the amount and dimensions of stored components (approx. 150 - 300 m²)	1
	Work Shop	Connected to storehouse, required area approx. 50 - 80 m²	1

It should be pointed out that the size of the required office facility relates to the amount of personnel and the storage capacity for spare parts, which depends on the O&M strategy. There is an important difference if the O&M strategy includes the storage of major wind turbine components like drive chain, bearings, generators or transformers or includes only the storage of supply materials such as hydraulic fluids, oil filters and protection painting. Major wind turbines need much more storage area than supply materials. Based on this fact the size range of the required storehouse area should be between approx. 100 and 300 m². For reducing rental and logistic costs it would be advantageous if the workshop was connected to the storage facility. For quick and easy access to the offshore wind turbines, the facilities should be located near a harbor or an area with harbor access.

9.2.4 Equipment

To cover all of the O&M issues related to running an offshore wind farm, the equipment detailed in Table 9-5 is required. It includes information about the furniture, office equipment and software in the Office and Administration Building but also the estimated hardware in the storehouse and workshop.

Table 9-5: Equipment for Onshore Facilities

Office & Administration Building			
No.	Equipment	Details	No.
1	Furniture	Work desks	6
		Chairs	23
		Shelves	6
2	Office equipment	Server and network	1
		Desktops	1
		Laptops & docking station	5
		Printer (b/w, or if color is needed 1 color laser)	1
		Phones (one for Business Manager, Team Assistant, storehouse, workshop)	5
		Mobile Phones	5
		PDA's	1
		Office supplies	a. n.

3	Software	Operating system (licenses)	6
		Server software	1
		Office software	6
		Wind farm/turbine monitoring and performance software 3	3
		Wind farm/turbine maintenance software 3	4
		Financial software	2
		Other special software	a. n.
Storage Facility & Work Shop			
No.	Equipment	Details	No.
1	Storehouse	Shelves	1
		Heavy lift unit	1
		Spare parts	a. n.
		Rent of external equipment	a. n.
2	Workshop	Milling machine	1
		Lathe	1
		Electrical drill	1
		Work bench	1
		Test rig for electrical devices	2
		Diverse other tools	a. n.
		Materials	a. n.

The equipment for the office building is clearly defined. More important is the proposed equipment for the storehouse and workshop. The storage facility is required for items such as drive chain components, bearings, generators or transformers, bolts, hydraulic pumps along with expendable items such as oil, lubricants, filters, etc. The major wind turbines components need much more storage area than only supply materials. When making the decision regarding the O&M strategy for the offshore wind farm, failure databases should be taken into account. Replacements for components, which frequently fail and cause financial losses, should be readily available and located in the storage facility. The decision to store larger wind turbine components is based on their availability and costs. Large turbine components result in higher costs for the storage facility (larger area is needed). But the advantage of having larger components in3 the storage facility is that there will be no long waiting times caused by location of many turbine manufacturers and suppliers in Europe and lead times. The final decision for the O&M strategy lies with the project owner(s) and should be made with the aid of qualified technical advisors.

For transport and storage of the spare parts, a forklift and sling crane will be required. Their dimension in lifting capacity should be adapted to the weights of spare parts. For very heavy turbine components and offshore transport, external equipment could be rented (mobile crane, truck, helicopter and offshore support & maintenance vessels). A purchase of such equipment is expensive and, due to the size of the investment, would prove unviable.

The workshop should include equipment to enable the repair of small components by the technicians. A milling machine or lathe for metal works is optional but work benches, tools

[3] SCADA, SMS, CMS

and measurement instruments are required for the repair of actuators, oil pumps or electrical components.

9.2.5 Operations and Maintenance Cost Overview

The operation and maintenance (O&M) effort for offshore wind turbines is difficult to accurately ascertain and the cost differential can be quite large. As such one of the major issues when operating offshore wind farms is to optimize the O&M effort by developing suitable maintenance and logistic strategies. The term operation and maintenance costs comprises of all the expenditures that occur when operating a wind farm inclusive of maintenance and repair. Costs for the operation and maintenance of an onshore wind farm represent a significant annual contribution to these costs which is often underestimated. O&M costs can be categorized as follows:

- Administrative costs
- Maintenance Costs
  - Preventive maintenance costs
  - Corrective maintenance costs
  - Cost for equipment and repair processes
- Additional Costs
  - Insurance
  - Electrical purchase
  - Lease costs
  - Reserves

The largest part of the O&M costs are corrective and scheduled maintenance. Reducing costs essentially entails finding the right strategy to prevent unexpected failure of components, being prepared in case of failures and reducing down times caused by failures. These reductions will follow through into lead time, travel time and repair time as well as advanced booking periods.

Administrative Costs

The easiest way to determine the arising expenses for the operation of an offshore wind farm is to consider the extent to which it is required to ensure a full 24-hour remote monitoring and management service. Operation of offshore wind farms comprises of each wind turbine down to the busbar connection, electrical systems from the busbar connection to the delivery point (inter array cable, offshore substation, export cable, onshore substation), and general management, administration and reporting duties as specified by the owner/manager.

Generally, the management would be the initial point of contact for all events that require on-site operator intervention. Services such as remote monitoring interrogate the SCADA system daily and evaluate data with respect to the farms condition. A standby service would be needed to react to all fault alerts and to put into action any required activities to prevent or mitigate the consequences of these failures. To provide these services, qualified personnel are required who are capable of making decisions based on technical data. Further services which should be covered by the operational agreement are the resetting of remote and local trips, the route of site visits to carry out visual inspections of the wind turbine and the corresponding area as well as to make provisions for all equipment required to provide the services. Depending on the number of turbines and also on the number of shifts, it can be determined how many operators, engineers and additional employees are needed to provide a comprehensive operating service.

The considered staff will lead to facility and equipment costs such as computers and office furniture. It will also be reasonable to store critical wind turbine components in order to ensure that should a failure occur then the down time will not be dependent upon lead times.

Maintenance Costs

Preventive Maintenance Costs

Preventive maintenance costs can be estimated by evaluating the maintenance effort related to offshore wind turbines and their corresponding area. The effort for calendar based maintenance of an offshore wind turbine includes a comprehensive system and structure check which should be carried out every second year. During the inspection consumables such as lubricants and filters should be replaced and minor failures should be repaired. It is good practice to review the turbine with a team consisting of two technicians. The foundation can be monitored using divers autonomous underwater vehicles (AUVs). Calendar based maintenance should be performed in seasons where the weather conditions are suitable to operate to avoid waiting times. Usually, it possible to use a personnel transfer vessel to bring technicians and minor parts/consumables to the offshore wind farm. The travel time depends on the vessel speed and the time to get access to the turbine. It is also common to use a helicopter hoist if installed when only inspections are required by dropping off a technician via a winch to the turbine nacelle. The resulting costs for scheduled maintenance of the wind turbine include material costs, labor costs, equipment costs as well as revenue losses due to down times.

Preventive maintenance of submarine cables should be undertaken every third year by using an appropriate vessel with a remotely operated vehicle (ROV). The results achieved by the ROV can be directly evaluated on-site by experts. With regards to the costs, the range depends on the effort to maintain the cables. Normally, it is sufficient to survey the cable routes. In case of failures or indications of failures additional costs will follow.

In order to maintain the offshore substation, the same strategy should be used as for the turbines, which is essentially a preventative strategy. The maintenance effort comprises inspection of the structure, and transformer unit, minor failures should be repaired immediately. The interval of the inspection should be annually due to the importance of the transformer station. Failures which result in down times of the substations will affect the whole wind farm performance.

Corrective Maintenance Costs

A failure that occurs unexpectedly and causes down time for the wind turbine has to be repaired as soon as possible. Therefore it is necessary to define maintenance categories and failure classes in order to be prepared in the event a failure occurs. For example, a generator might fail in various modalities such as burned windings, a failure of the generator bearings or wear of the carbon brushes. The corresponding range of repair actions can vary from replacement of small parts like the carbon brushes to the replacement of the entire generator.

The goal is to determine all critical components which may cause wind turbine down time. Subsequently the corresponding repair and maintenance actions can be considered. It might be that most of the failures have something to do with electrical components and the control system, but it has to be proved that not the quantity of failures counts but rather the impact of the failure and the corresponding consequences. The replacement effort for a simple sensor will be less than the replacement effort for a major component like the gearbox, but the annual failure frequency rate may be much higher. It must be estimated how often a failure of a particular component occurs per year. The critical major components are listed in Table 9-6. Other elements of an offshore wind farm which can fail and cause down times such as the substation, as well as inter array and export cables. A possible approach for the defined maintenance categories might be:

- Repair and inspection interior
- Repair and inspection outside
- Replacement of small parts
- Replacement of large parts
- Replacement of major components

The crew size and the required equipment/material have to be defined. The equipment personnel transportation is needed; depending on the maintenance category, it might be necessary to retain additional equipment like repair, transportation and jack-up vessels. Vessel costs include daily rates and mobilization/demobilization fees. Lead times for spare parts and advanced booking periods for large equipment should also be taken into account, as this will result in down times and therefore in revenue losses.

In general, the down time of a wind turbine can be specified by the time which is needed to return the system back to operation and operational status. This comprises of logistic times (lead times and advanced booking periods); waiting times due to bad weather conditions; travel times to get access to the turbine; and finally the repair time to fix the turbine. Waiting times can be determined by evaluation of the weather data (wave height and wind speed) in combination with the operation limits of the transportation devices.

The corrective maintenance costs determinations should result into following costs sections:

- Labor costs
- Material costs
- Equipment costs
- Revenue losses due to down times

Table 9-6: Critical Components of an Offshore Wind Farm

No.	Section:	Component:
1	Rotor system	Rotor structure
2	Rotor system	Rotor blades
3	Rotor system	Pitch system
4	Nacelle:	Main bearing
5	Nacelle	Main shaft
6	Nacelle	Gearbox
7	Nacelle	Brake system
8	Nacelle	Generator
9	Nacelle	Transformer
10	Nacelle	Inverter
11	Nacelle	Controls
12	Nacelle	Sensors
13	Nacelle	Hydraulics
14	Nacelle	Yaw system
15	Tower	Structure
16	Tower	Power electronics and controls
17	Foundation	Foundation structure
18	Foundation	Scour protection
19	Foundation	Corrosion protection
20	Cables	Inter-array cables
21	Cables	Export cables
22	Offshore substation	Substation structure
23	Offshore substation	Transformer
24	Offshore substation	Scour protection

The maintenance effort will also be affected by the system integration of the components. It is of immense importance to emphasize the consequences of failures, e.g. it is necessary to disassemble the whole drive train in order to replace only the generator.

Equipment and Repair Processes

The following Table 9-7 lists a summary of maintenance and inspection devices in order to overview the effort of corrective and scheduled maintenance. Starting with personnel transfer to the wind farm, this can be obtained by using personnel transfer vessels or a helicopter if the wind turbine is equipped with a helicopter hoist. Depending on the crew size, a small fast boat or a large vessel can be used. The personnel transfer vessel type and size limits the tools, consumables and small spare parts that can be utilized.

Table 9-7: Maintenance Equipment

Equipment type	Unit	Rate [US $]	Mob. / Demob. [US $]	Advanced book. period [hrs]	Operating limits		Speed [kn]
					Wave [m]	Wind [m/s]	
Personnel trans. vessel	day	2,500	0	0	2	12	18
Large pers. trans. vessel	day	3,750	0	0	2	12	16
Small repair vessel	day	6,250	15,000	72	1.5	10	12
Large repair vessel	day	10,000	25,000	192	1.5	12	10
Cargo barge	day	43,750	35,000	240	2	16	8
Helicopter	hour	2,500 – 3,750	0	24	-	~25	~220 km/h
Jack-up barge (large, crane)	day	125,000	100,000	720	2	16	4
Crane ship	day	93,750	75,000	720	2	15	8.5
Cable inspection vessel	day	62,500	50,000	168	1,5	12	12; (2 operation)
ROV (cable inspection)	day	18,795	12,500	168	-	-	12; (2 operation)

For larger parts an additional repair vessel is required whereas two vessels should be considered depending on the max. tonnage. A small repair vessel should be capable of transporting ~15 t and a large repair vessel ~50 t. Parts exceeding these weights can be transported with a cargo barge. All components which can be lifted using the nacelles internal crane would not require any additional hoisting or positioning equipment. Larger and major components will need these devices which will result in increasing equipment costs. To survey the submarine cable routes an appropriate vessel is needed with a remotely operated vehicle. Maintenance and repair of the scour protection can be carried out by a rock placement vessel.

Additional Costs

Insurances

Another cost factor deals with insurances which are inevitable to ensure professional damage cover for a wind farm and its assets. Generally, there are three main types of insurance, namely liability insurance, machinery breakdown and interruption of operation insurance, and machinery insurance. Besides these insurances there are also further specified insurances such as the director's and officer's liability insurance in order to ensure insurance protection which covers financial losses due to activities of various organizations (executive committee, management, supervisory board, adviser etc.) and of executive employees (attorney etc.). It is also common from the insurer's side to provide different insurances in one package which covers all foreseeable risks.

Electrical Purchase

Wind turbines require an electrical power supply for control equipment such as pitch and yaw drives. Electrical supply does also apply for substations and the electrical charges are an expense factor that has to be considered when estimating operation and maintenance costs. The electrical consumption of a wind turbine depends on the turbine type and size.

Lease Costs

When operating an offshore wind turbine the land which is occupied usually has to be leased. Land rental has to be paid for the wind turbine and the operating buildings (transformer station). These costs vary greatly from country to country and may also be affected by local authorities.

Reserves

The life time of a wind turbine does not end not with expiration of the building permission but with the decommissioning process and the restoration of the wind turbine site to the legally defined condition. In order to ensure this restoration and to mitigate the loss of revenue during the operational phase, financial provisions should to be made. Usually, there are different possibilities to accrue reserves based on the point of time. Hence, reserves can be set up after commissioning of the wind turbine, during the turbines operational period or at the end of operational activities.

9.3 Test Center Evaluation

In order to evaluate the Test Center's feasibility, Germanischer Lloyd reviewed five internationally known research and test centers. These are the National Renewable Energy Laboratory (USA), Energy Research Center of the Netherlands, RISØ National Laboratory

(Denmark), National Renewable Energy Center (Spain), and the Center for Renewable Energy Sources (Greece).

9.3.1 Study of Existing Research / Test Centers

9.3.1.1 National Renewable Energy Laboratory (NREL, USA)

NREL capabilities in R&D lie in design review and analysis, software development, modeling and analysis, system and control analysis, technical support, utility integration assessment and wind resource assessment.

Low Wind Speed Technology

NREL are involved in projects with focus on sites with low wind resources. The wind speeds at this site average about 5.8 m/s at a height of 10 m. The efforts in this field of R&D is based on the fact that vast areas of the Great Plains from central and northern Texas to the Canadian border and areas found along many coastal areas in the Great Lakes are sites with low wind speeds. Related projects are Low Wind Speed Technologies and WindPACT.

For the low wind speed project NREL is responsible for the theoretical support through applied research and feedback from performance testing. The supported works are concept and scaling studies, component development and low wind prototype development and are carried out by industry and are listed below.

Design and Case Studies

Advanced pitch systems, medium-voltage variable-speed drive technology, LiDAR for turbine control, rotor aerodynamics controls, design/operating offshore environments in coastal areas of the US and the Great Lakes, O&M cost model, design and demonstration of on-site fabrication systems, offshore floating concepts as well as anchor foundations for offshore wind turbines

Component Development

Advanced power electronics for low wind turbines, convoloid gearing, sweep-twist blade design, drive train designs. Prototype Development: Northern Power Systems, Clipper, Multi-Megawatt Turbine for GE.

Advanced Component Technology

Testing advanced blades and drive trains for low-wind-speed turbines is the key area of R&D in component development. NREL conducts studies relating to the design of rotor blades from 80 to 120 meter, drive trains and hybrid towers. They consider size, costs and the applicability of the regarded design concepts. Additionally, NREL sets a focus on rotor blade logistics. The aims of NREL's R&D are the design and definition of a size range of components and wind turbines, the fabrication and testing of advanced components, identification and solution of upcoming problems within the industry and improvement of knowledge transfer between involved researching parties. The main goal of pushing R&D in component testing of low wind-speed turbines is the reduction of their costs.

Baseline Cost of Energy

Department of Energy "DOE" uses a detailed Discounted Cash Flow Return on Investment (DCF ROI) model to calculate the costs of energy (COE). A spreadsheet-based model, called the Financial Analysis Tool for Electric Energy Projects (FATE-2P), was developed for NREL and can model a number of commercial project ownership approaches. All program analyses are done on the basis of current financing trends and are representative of corporate or balance sheet financing. The Wind Program refers to this as GenCo (Generation Company) financing.

Acceptance Projects (Information and Outreach)

"As part of its effort to advance wind energy technologies and increase development, NREL publishes information and conducts outreach efforts to help industry stakeholders as well as the general public understand the benefits of wind energy and the technical and non technical barriers that impede development."

Utility Grid Integration

An important field of R&D deals with the integration of wind farms into the existing supply grids. The natural variability of the wind resource causes unsatisfactory predictions of power inputs into the grid and results in inefficiently routine grid operations. For this reason NREL conduct R&D to improve the understanding of the economic and operational effects of wind generation on the electric supply system. With regard to the effects of wind on regulation, load following, scheduling, line voltage and reserves on the grid. More information on Operational Impacts and Integration Studies, Wind Plant Modelling and Interconnection, Transmission Planning and Analysis and Wind Resource Assessment and Forecasting at www.nrel.gov.

Environmental Issues

NREL conducted two studies concerning the potential effects of wind farms on the environment. The impact on species of grassland shrub steppe and bats were the main subjects.

International Research with IEA

NREL supports several international research efforts conducted under the International Energy Agency (IEA): (1) HAWT Aerodynamics and Models for Wind Tunnel Measurements, (2) Dynamic Models of Wind Farms for Power Systems Studies, (3) Offshore Wind Energy Technology and Deployment, (4) Integration of Wind and Hydropower, (5) Power System Operation with Large Amounts of Wind Power.

9.3.1.2 Energy Research Center of the Netherlands (ECN, NL)

Aero Elastics & Wind Farms Aerodynamics

For the field of aero elastics and aerodynamics ECN develop and improve design tools. They are made for simulation and model wind conditions, interactions between turbines and wave fields in (offshore) wind farms and, consequently, structure dynamics to each single wind turbine. This also includes the theoretical modeling of wake effects with CDF. The tools are capable of designing wind farms and forecasting wind power and energy output. This function addresses the requirements of offshore wind farm operators who need to provide accurate predictions of their wind farm output 24 hours in advance to minimize imbalance penalties imposed by the grid operator. Validation of the tools is based on results of practical experiments in wind tunnels and small-scale wind farms with no large commercial risk. ECN conduct up-scaling of measurements for large wind farms. Furthermore, the ECN is currently working on the development of a dynamic wind atlas for the Dutch part of the North Sea.

Condition Monitoring and Measurement Techniques

ECN carries out the development of prototype and commercial wind turbines relating to aerodynamics, aero elastics, structural dynamics and control of the complete wind turbine. This includes R&D in condition monitoring as well as measurement techniques. Starting with the condition monitoring system, ECN has set its focus on R&D of blade monitoring, automatic measurement and analysis. A part of this R&D field is the detection and registration of bird collisions. The experimental research will contain: (a) power performance measurements, including energy output estimation, (b) mechanical load measurements for design and certification purposes or (c) analysis of dynamic behavior (vibration, noise measurements, testing large multi-MW wind turbine, resource assessment and an extensive collection of meteorological data).

Wind Turbine Control

The ECN undertake R&D in wind turbine controls, especially in developing tools for wind turbine control algorithms that will be applicable for integrated control and safety systems (offshore wind turbines). This means optimized feedback, fault tolerant, extreme event and optimal shutdown controls. Goals of the improved wind turbine control systems should be increased turbine stability, reliability and availability, the minimization of turbine loads caused by waves or extreme weather conditions and additional energy output. All goals contribute to reducing wind turbine operating costs.

Wind Farm Operation and Maintenance

ECN conducts R&D in the field of O&M costs for large (offshore) wind farms, including maintenance needs, wind farm availability and the resulting energy output. They take weather forecasts, logistics, contracts and short-term and long-term guarantees into account. Over the past few years, ECN has developed a system for analyzing these maintenance aspects for large offshore wind farms.

9.3.1.3 RISØ National Laboratory for Sustainable Energy (RISØ, DK)

Wind Power Meteorology

R&D of physical models and calculation methods in wind power meteorology, such as turbulence, climatology, atmospheric flow and boundary layer. The physical models and calculation methods are used for the prediction of a turbine's power production and lifespan.

Aero Elastic Modeling

RISØ carries out R&D in aero elastic modeling (physical and mathematical models) for design of a wind turbine and its materials. The models are based on aerodynamics, structural dynamics and control. The aim of the models at RISØ is to conduct research into lifespan, safety and energy output of wind turbines.

Optimization and Cost Reduction

The economics of a wind turbine are increasingly dependent on the operational phase of its lifespan. Therefore RISØ researches possible design and modeling methods as well as tools to map operational uncertainties, and to optimize operation and maintenance strategy. The main goal should be to improve production revenue by reducing the number of stoppages and overall downtimes.

New Concepts, Components and Materials

Another R&D field is the development of new materials, components and concepts, which produce new and improved properties for accelerated technological development. RISØ conducts research into components such as the gear train and generator using new materials.

Wind Power and the Energy System

R&D through simulation tools allows the modeling of wind turbines within the overall system. The main purpose is to consider the impact of wind power on the energy. RISØ analyses the control properties of individual wind turbines as well as entire wind farms and develops new concepts for modeling and controlling the entire electricity network. RISØ operates an experimental electricity network, SysLab, which may be scaled up using simulation models, thus enabling us to gain valuable insights into real-life energy systems.

Offshore Wind Power

Research into fields such as geophysics and meteorology are conducted by RISØ to calculate the impact of weather conditions on offshore wind farms. With the results, RISØ researches improving wind turbines reliability and reducing the need for maintenance and repair. This is due to an increasing number of offshore wind farms subject to complications such as wind turbine access, operation and maintenance and the exposure to harsh weather conditions in a highly corrosive environment.

9.3.1.4 National Renewable Energy Center (CENER, ES)

Wind Turbine Analysis and Design (ADA)

CENER develops tools and methodology for wind turbine and component design. The tools are especially created for analysis of aerodynamics and aero elasticity, structural mechanics, control and dynamic systems, plus material and manufacturing processes. The development and optimization of manufacturing processes for wind turbine components made of composite materials is another important R&D area at CENER. For IEA: HAWT Aerodynamics and Models from Wind Tunnel Measurements and Offshore Wind Energy Technology Deployment.

Wind Resource Assessment and Forecasting (EPR)

CENER is carrying out R&D to improve the performance of long time wind resource modeling based on direct measurements or on global model data. Therefore CENER researches new measurement techniques (LIDAR), but also for new statistical models for characterization of extreme winds, simulations of the wind field with a fluid dynamics model (CFD), average conditions, turbulence and flow inclination along with simulations for the effect of wind turbine wake by means of CFD. CENER not only focuses on long-term wind modeling but also on the estimation of energy production for a wind installation in the short-term. These estimations should make energy management easier for the electrical system operators but advanced statistical models are required to detect and eliminate systematic prediction errors, the combination of different atmospheric situations and the application of CFD to the wind prediction in complex terrain.

Marine Wind Energy

CENER is one participant in IEA research for "Offshore Wind Energy Technology and Deployment". CENER currently undertakes R&D for offshore wind farm modeling codes in shallow waters and deep waters (floating structures). This includes R&D on offshore structure modeling and support in the design of new technology for use on offshore plants. CENER works on the validation of the CFD tool (Fluent) for uses in the offshore environment within the framework of the IEA Program "UPWIND". Within the framework of the European Project VI Framework Program "POW WOW", the validation of the prediction models in offshore environment has been executed. Additionally, CENER is part of several task forces, which develop international standards and guidelines.

9.3.1.5 Center for Renewable Energy Sources (CRES, GR)

Aerodynamics and Wind Resources

CRES offer services in wind energy resource assessment. This work includes the estimation of wind-potential over complex terrain. In view of this, CRES developed a numerical tool for micrositing of turbines.

Design of Wind Farms

For analysis and design of horizontal axis wind turbines CRES developed an aero elastic simulator under the codename "ALKYONE".

Pilot Project

CRES operates a demonstration wind farm in complex terrain topography. The aim of the project is the installation of five wind turbines with a capacity of 3 MW for the evaluation and demonstration of wind turbine available technologies. The benefits of implementing this project are focused especially on the experiences of operating a wind farm in complex terrain topography, the evaluation of novel control systems, re-definition of operational strategies for the maximization of power input in electrical grids and the development of techniques and solutions for the minimization of production cost.

9.3.2 Recommended Facilities for a Test Center

The experts at Germanischer Lloyd believe that the important fields of work for the potential Test Center lie in wind turbine prototype tests, component testing and site measurement/assessment. To illustrate this, Table 9-8 shows more details of each of the test areas.

Table 9-8 illustrates the different potential work areas for the Lake Erie Test Center. A third column introduces our expert opinions concerning the possibility of an external test facility being used by manufacturers. The sign '+' indicates that there is a potentially good market, '0' for moderate market interest and '-' for small/very limited potential market.

Table 9-8: Possible Test Areas for an Offshore Test Center

No.	Test Areas	Details	Chance for Request
1	Prototype Test	Power curves & quality, loads on blades, loads on structure, loads on drive train, loads on substructure, behavior of grid losses, noise and fire protection system	+
2	Offshore Pilot Project		+
3	Component Test	Rotor blades (static & fatigue), gearboxes, breaks, drive chain, hydraulic system, generators/ transformers/ converters	-
4	Condition Monitoring System (CMS)	Monitoring of in operation conditions and failure prediction	+
5	Measurement of Environ. Conditions	Wind (offshore & onshore), wave conditions, icing*, temperature, spray*	+
6	Calibration of Test Equipment	Anemometer[7]	+
7	Site Assessment	In conjunction with point 5	+
8	Training Center for Offshore O&M	Training center for maintenance, installation, techniques, rescue methods, access-techniques	0
9	Offshore O&M	Checking of maintenance procedures trials of access-techniques	0

Below are more detailed descriptions of the test areas detailed in Table 9-8:

1) Two approaches could be utilized to undertake prototype testing, these are:

    a) Locating prototypes in the Pilot Project means that the short distance between the prototypes and the potential Test Center enables fast intervention and low travel costs, so if problems occur with the measurement equipment or the prototype itself, rapid reaction is possible. This would also form a good Pilot Project to promote the center and acquire new customers for prototype testing. The main disadvantage of this option is the limited area for prototype tests.

    b) Locating the measurement equipment for the prototypes in situ worldwide would enable the testing of more prototypes at the Pilot Project; however this does not generate power for the local community or promote the center. Nevertheless, it is a better business solution for the prototype testing.

2) Inclusion of performance curve and quality proof testing as well as loads on blades, structure, drive train and substructure could be recorded. The Test Center could also prove the turbine behavior in case of grid losses, the amount of noise emissions and efficiency of the fire protection system, etc.

3) Proof of components like rotor blades, gearbox, drive trains or generators could be the secondary work field of the Test Center. The establishment of the Test Center

[7] Cup, sound navigation and ranging [Sonic], sonic detection and ranging [sodar], light detection and ranging [lidar]

should not include component testing. To plan, develop and install such a facility would involve a great deal of expense and risk, and the amount of possible generated revenue is very limited. Most manufacturers and suppliers for the wind energy sector already have their own test facilities in Europe. Our experts foresee that if manufacturers and suppliers build up production facilities in the US, they would invest primarily in a high proof of quality through desktop analysis, and not in testing. It is not foreseen that manufacturers will invest in a test center – as the scale of the components increases this becomes uneconomical. Furthermore, their will to share test facilities is estimated as very low. For products that require testing it is believed that smaller manufacturers would not use a test facility due to the fact that they are buying fully developed products. Large manufacturers have their own test centers and would not be interested in the use of such a facility.

4) General testing of condition monitoring systems (CMS) is regarded as a potentially viable work area.

5) The Lake Erie Test Center could gather important information through the measurement of environmental conditions like wind, wave and temperature but also of icing and spray. Especially the last two measurement areas are considered as definitely interesting due to the lack of available data within these areas.

6) The test facility could be responsible for the calibration of test equipment like anemometers, as an example for cup, sonic, Sodar and Lidar anemometers. This is perceived as a potentially viable market due to the significance of the wind data in the development of the industry and the necessity of having accurate measurements.

7) In connection with point number 5, Site Assessment is regarded as a potential field of work. This could include the analysis of various potential sites with regards to the wind conditions, topography, layout and soil analysis, etc.

8) The establishment of an offshore access training center within the Test Center for O&M access procedures and installation techniques is seen as an interesting work area. This includes the possibility of training in rescue methods and access techniques for offshore wind farms. The marine industry and oil and gas industry already have training centers, which may be used for access techniques but nothing as yet is specifically targeted at wind industry access techniques.

9) Offshore O&M techniques in conjunction with the offshore access training center represent a potential business area for the Test Center. To test and develop different types of access techniques for maintenance procedures, as access to a wind farm is potentially one of the largest problems facing operators because it limits the operation and maintenance schedule.

9.4 Certification Center Evaluation

9.4.1 Draft Strategy for Certification Services

The strategy detailed below for certification services is based upon GL's certification services. These services are used as a basis for a certification strategy as they are widely regarded as having the highest standards in the industry. A market share of over 50 percent of the certifications market illustrates the validity of this system as a potential strategy for certification.

This is split into two main segments: these are “Type Certification” and “Project Certification”, type certification certifies the machine and project certification certifies the project in its actual location. Both are detailed below.

9.4.1.1 Type Certification

The type certifications function is to confirm that the design of the investigated turbine meets the demands of state-of-the-art guidelines and technical requirements. It shall be proved that the design documentation is in conformity with the manufacturing processes, component specifications, inspections, test procedures and corresponding documentation of the components covered by the certification guideline.

Within a type certification for an offshore wind turbine it is permitted to exclude the support structure (tower, substructure, foundation). In this case the influence of a virtual support structure has to be taken in consideration in the load assumptions.

To obtain the type certificate four steps are necessary:

- A-design assessment
- Quality management system of the manufacturer
- Implementation of the design-related requirements in production and erection
- Witnessing of the test operation of a prototype

These steps encompass the final assessment, which results in the type certificate. On completion of the certification process the certification body will issue the ‘Statement of Compliance’ based on the A-design assessment, the implementation of the design-related requirements in the production and erection phases of the project and the prototype tests result in the final ‘Type Certificate’.

Design Assessment of the Turbine

C-Design Assessment

The C-design assessment covers a prototype assessment and is used to erect the prototype of an offshore wind turbine. In general, power and load measurements shall be performed at the prototype and compared with the calculated values. The C-design assessment is based on a complete plausibility check of the loads, the rotor blades, the machinery components plus the tower and foundations. National or local regulations may require that the tower and foundations be subjected to a complete analysis.

For each type of offshore wind turbine one C-design assessment is produced. Modifications to the turbine type, such as changes to rotor blades, different operating modes, etc., which strongly influence the loading will require another prototype turbine version and another C-design assessment.

The relevant documents to be submitted for the C-design assessment are as follows:

- General description of the offshore wind turbine
- Description of the control and safety concepts
- Description of the safety system and the braking systems
- Complete calculation of the loads
- Main drawings of the rotor blade, including structural design and blade connection
- General arrangement drawing of the nacelle
- Drawing of the hub, main shaft and the main frame
- Listing of the primary components to be used (e.g. main bearing, gearbox, brake, generator etc.)
- Main drawings of support structure
- Site conditions and soil investigation report (optional)
- Description of the electro technical installations
- Name and address of the owner
- Planned location of the prototype
- Calculation documents for the support structure (in certain cases necessary)

On conclusion of the measurements, the measurement reports and the comparisons with the design values shall be submitted to the certification body.

The scope of the assessment covers the check of the safety system for the offshore turbine and the existence of two independent braking systems, the plausibility check of the blade root, hub and tower by means of comparison of the extreme and fatigue loads, and the plausibility check of the rotor blades and the machinery components in the drive train by applying the expertise gained in the dimensioning of similar turbines.

The C-design assessment is usually valid for two years or 4000 equivalent full load hours. When all the criteria stated in the C-design assessment have been met, the B-design assessment can then be submitted for the offshore wind turbine.

A- and B-Design Assessment

The A-design assessment is performed in the case of no outstanding items from the B-design assessment. The validity is indefinite. If there are any modifications made without the consent of the certification body to the design of components that form part of the design assessment, the A-design assessment becomes invalid.

The B-design assessment may contain items that are still outstanding, as long as these items are not directly safety-relevant. The validity period of this assessment is limited to one year and all offshore wind turbines erected in this period have to be reported to the certification body.

The A- and B-design assessments are based on the following certification reports:

- Load assumptions
- Safety system
- Rotor blades
- Mechanical structures including nacelle housing and spinner
- Machinery components
- Tower and foundation
- Electro technical components, including lightning protection
- Manuals for erection, commissioning, operating, maintenance
- Commissioning

The basis for these certification reports is built up through various assessments and tests, such as:

- Assessment of loads and safety concepts
- Assessment of the design documentation and the manuals
- Rotor blade tests
- Prototype trial of the gearbox at the test bench
- Witnessing of the commissioning

Before issuance of the A-design assessment, a blade test and a prototype test of the main gear box at a test bench must be completed. Furthermore, the commissioning procedure on one of the version's first offshore wind turbines to be certified must be witnessed.

Implementation of Design-Related Requirements

The objective is to ensure that the requirements stipulated in the technical documentation with regard to the components are observed and implemented in the production and erection. This verification is carried out once by the certification body. For standard production, it is normal to undertake external surveillance. The extent of the surveillance depends on the standard of the quality management and must be approved by the certification body. The description of the quality management in production and erection must be summarized and presented in a document for the corresponding component or assembly. Changes in the procedure regarding the production quality or component properties must be reported to the certification body. In the case of major changes the descriptive documents must be submitted for renewed examination and, if necessary, a repeated personal inspection must be carried out.

Quality Management System (QMS)

Within the scope of the quality management, the manufacturer shall prove that he meets the requirements of ISO 9001 regarding the design and manufacture of the turbine. This can be done by a certification of the quality management systems by an accredited certification body.

Prototype Test

The prototype test within the scope of test operation comprises the following points:

- Measurement of the power curve
- Measurement of the noise emission
- Measurement of the electrical characteristics
- Test of the turbine behavior
- Load measurements
- Prototype trial of the gearbox

On completion of the measurements an evaluation and documentation of the measurements, a plausibility check of the measurement results and a comparison of the measurement results with the assumption in the design documentation has to be performed. The measurement reports shall be submitted to the certification body.

9.4.1.2 Project Certification

Type Certificate

For the project certification a valid type certificate for the designed turbines in the wind farm is needed.

Site Assessment

The site assessment includes the examination of the environment-related influences on the offshore wind turbine and the mutual influence of the offshore wind farm configuration. For site assessment, the following influences are considered:

- Wind conditions
- Marine conditions (bathymetry, waves, tides, correlation of wind and waves, sea- ice, scour, marine growth, etc.)
- Soil conditions
- Site and wind farm configuration
- Other environmental conditions, such as salt content of the air, temperature, ice and snow, humidity, lightning strike, solar radiation, etc.
- Electrical grid conditions

These influences on the site conditions will be assessed for plausibility, quality and completeness of measurements reports and accreditation of measurement bodies or institutes.

Site-Specific Design Assessment

Based on the specific external site conditions, the site-specific design assessment will include the following steps:

- Site specific load assumption
- Comparison of site specific loads with those from the type certification
- Site specific support structure (tower, sub structure and foundation)
- Modification of the machinery part and rotor blades in relation to type certification (if modifications exist)
- Stress reserve calculation for the machinery part and rotor blades, if load comparison indicates higher loads than for the type certified machinery components

Surveillance of Manufacturing

Before the surveillance of manufacturing starts, the quality management requirements according to ISO 9001 must be met by the manufacturers.

The extent of the surveillance of manufacturing and the number of samples to be surveyed are regulated by the standard of the quality management measures, and must be approved by the certification body. In general, the following actions and approvals will be performed by the certification body:

- Inspection and testing of materials and components
- Scrutiny of quality management records such as test certificates, tracers, reports
- Surveillance of manufacturing, incl. storage conditions and handling, by random sampling
- Inspections of the corrosion protection
- General appearance
- Damages

Surveillance of Transport and Installation

Before work begins, the transport and installation manuals must be submitted, including the special circumstances of the site. These documents will be checked for compatibility with the assessed design and with the transport and installation conditions (climate, job scheduling, etc.) prevailing at the site. The extent of the surveillance activities and the amount of samples to be surveyed depends on the quality management measures of the companies involved in transport and installation. In general the following activities must be carried out:

- Approval of transport and installation procedures
- Identification and allocation of all components of the offshore wind turbine in question
- Checking of the components for damage during transport
- Inspections of the job schedules (e.g. for welding, installation, grouting, bolting up)
- Inspection of prefabricated subassemblies, and of components to be installed, for adequate quality of manufacture, insofar as this has not been done at the manufacturers works
- Surveillance of important steps in the installation on a random-sampling basis (e.g. pile driving, grouting)

- Inspections of grouted and bolted connections, surveillance of non-destructive tests (e.g. welded joints)
- Inspection of the corrosion protection
- Inspection of scour protection system
- Inspection of the electrical installation (run of cables, equipment earths and earthing system)
- Inspection of sea fastening and marine operations

Surveillance of Commissioning

Surveillance of the commissioning is to be performed for all offshore wind turbines in the farm and shall finally confirm that offshore wind turbines are ready to be operated and fulfill all applicable standards and requirements.

Before starting the commissioning, the commissioning manual and all tests planned must be submitted for assessment and after the commissioning the manufacturer shall prove that the offshore wind turbine has been erected properly and, as far as needed, tested to ensure that the turbine will run safely. In the absence of such proof, appropriate tests shall be carried out when putting the offshore wind turbine into operation.

The scope of the surveillance covers witnessing by the surveyor of approximately 10 percent of offshore wind turbines during the commissioning phase. The remainder must be inspected after commissioning and the relevant records scrutinized.

Within the scope of commissioning, all relevant functions of the offshore wind turbine with regard to operation and safety functions must be tested. This testing comprises the following tests and activities:

- Functioning of the emergency push button
- Triggering of the brakes by every operating condition possible in operation
- Functioning of the yaw system
- Behavior at loss of load
- Behavior at overspeed
- Functioning of automatic operation
- Checking the logic of the control system’s indicators

In addition the following items must be examined during commissioning surveillance by visual inspection of the entire offshore wind turbine:

- General appearance
- Corrosion protection
- Damages
- Conformity of the main components with the certified design and traceability/ numeration of the same

Periodic Monitoring/Inspection

To maintain validity of the project certificate, maintenance of the offshore wind turbine is carried out in accordance with the approved maintenance manual. The condition of the offshore wind turbines is monitored periodically by the certification body. The intervals for the periodic monitoring are defined in the inspection plan and to be agreed with the certification body. The length of the intervals may vary depending on the age and the condition of the offshore wind turbine.

Major damage and repairs must be reported to the certification body and all alterations need to be approved by the certification body. The periodic monitoring shall check the following components:

- Foundation and scour protection
- Substructure
- Tower
- Nacelle
- All parts of the drive train
- Rotor blades
- Hydraulic/ pneumatic system
- Safety and control systems
- Electrical installation

A- and B- Levels of Project Certification

The project certificate will be issued after accomplishment of the previously mentioned steps. Different surveillance steps for manufacturing, transport, installation, commissioning and periodic monitoring apply to the A- and the B- project certificates:

A- Project certificate:
Surveillance is to be undertaken covering 100 percent of the offshore wind turbines, which means that all wind turbines of the offshore wind farm must be monitored. Surveillance shall cover the support structure and essential parts of machinery, blades and electrical systems.

B- Project certificate:
Surveillance is to undertaken covering 25 percent of the offshore wind turbines on a random sample basis, which means that a minimum of 25 percent of offshore wind turbines must be monitored. Surveillance shall cover the support structure and essential parts of machinery, blades and electrical system. If the surveillance should reveal major failures, deviations from the certified design or deviations in the quality management, the number of turbines to be monitored will be doubled.

9.4.1.3 Draft Time Schedule for Establishment of a Certification Center

Germanischer Lloyd’s research concerning the establishment of a certification center is shown in Table 9-9. It lists the main phases in connection with anticipated times of the establishment.

GL divides the implementation of the certification center into five phases. These are engineering, planning and contracting phase, followed by the installation of buildings (if no applicable buildings are available at site), then the recruiting phase for personnel, the initial start-up with part certification and the last phase in which profitable work is possible. This is usually four to five years from the beginning of phase one.

Table 9-9: Time Schedule for Establishment of Certification Center (in years)

No.	Options		Phase description
	I	II	Option I: Construction of new certification facilities Option II: Rental of facilities
1	1	0.5	Engineering, planning and contracting
2	1.5 - 2	-	Installation of building
3	1 – 1.5	1 – 1.5	Recruiting and training of personnel
4	2	2	Initial start-up with part certification and work flow optimization
5	5	5	Profitable work
Note: times could decrease with co-operation with an experienced certification body (back office)			

The duration of the first phase is roughly one year. It includes the engineering, planning and contracting for the certification center. This covers the planning phase before construction of the building such as the design and permissions but also the definition for work areas of the certification center, including work, the schedule of responsibilities and the regulations of financial as well as personnel aspects.

After the first phase, the construction and installation of the required office building follows. This lasts for approximately six months to one year but depends largely on the construction supervisor and the project team. This covers the development of site, excavation of the foundation pit, structural work and the interior construction. This process takes around 1.5 to 2 years.

Additional notes for Option II: In this case, the planning, procurement and construction of the certification center's office building is not relevant. The timeframe could be shortened by up to one year in comparison to Option I.

The personnel for the potential certification center have to be recruited and trained. GL's advice is to recruit experienced personnel right from the start. A broad distribution of knowledge between professionals of similar education could be of an advantage. As an example for the construction and structure engineers: one should be a mechanical engineer with a knowledge of plastics and composites for rotor blades, and another should be a civil engineering for foundations and two engineers should be knowledgeable in steel structures for offshore foundations and footings as well as for the tower. The time required for this phase is estimated to be about one to one and a half years.

An early co-operation with an experienced certification body could facilitate the development and accelerate the introduction of the certification center. In addition, the incidence of errors could be minimized due to the extensive experience of the certification body's personnel. For this purpose the certification body must have some years of practice in the field of wind energy certification. The new certification center could take on the sales, customer-based tasks and undertake several functions in project and type certification, leaving initially the majority of the certification process to be undertaken by the certification body. The certification body would not only support the certification center in general but also conduct knowledge transfer. As time progresses, the certification center could extend their capabilities and order volume, so that after a few years independence from the certification body could be achieved. To install faith in the certification center's capabilities, the certification market the certification body should be visible to the customer.

9.4.2 Recommended Facilities for a Certification Center

This subchapter describes the estimated resources and facilities for the proposed certification center. This includes consideration of the required building and rooms, equipment for certification and inspections and, finally, personnel.

9.4.2.1 Building and Room

The certification center does not require a special building to be able to conduct certifications for wind turbines but it should have an office character. If there is an in-house test laboratory for machinery oil & fluids, an office building is the best option for the certification center.[8] There are two options to provide working room. One is to rent an office building or part of it in Cleveland, Ohio. The second is to construct a new building in which the test, research and certification center are located.

[8] This laboratory test machinery oils and fluids of the gear box or drive chain and then could forecast possible failure rates in % for a defined time period

Table 9-10: Building and Rooms

Building and Rooms	Description	No.
	Offices	9
	Reception	1
	Meeting room(s)	2
	Archive	1
	Library	1
	Sub total	14
	Extension reserve (no specific functions)	9
	Total	25

The building should have room for approximately 14 to 16 people in the start-up phase. A reserve for 10 to 15 additional staff would be a good option, should the certification center extend their scope of work or the volume of orders. Table 9-10 give an estimation of the number of rooms required. For the certification center offices are needed in which the experts can carry out their work. The number of employees should be limited to a maximum of 3 per office to ensure productivity. Guests could be received in a reception area whereas separated meeting rooms are needed to consult customers and to provide space to discuss important matters in a confidential environment. The archives contain research material, certification documents of past projects for reference. The library includes specialist books, professional journals, guidelines, standards or regulations.

9.4.2.2 Equipment

Table 9-11 deals with the proposed equipment of the certification center. It includes content about the furniture, office equipment (IT), software and materials to inspect wind turbines.

Table 9-11: Certification Center Equipment

Equipment	Details	No.
Furniture	Work desks	14 - 16
	Chairs	14 - 16
	Shelves	14 - 16
Office Equipment	Server and network (Intranet)	1
	Desktops / notebooks	14 - 16 / 4
	Printers	2 - 3
	Telephone system	14-16
	PDA's and mobile phones	4
	Documentation signets and stamps	4
Inspections	Personal safety equipment	-
	Video endoscope, digital camera, though- book	-

Software	Bladed	2
	Structure analysis (FEM)	3 - 4
	Load analysis	3 - 4
	Microsoft Office	14 - 16
	Administrative/financial software	-

Every office shall be equipped with work desks, chairs and shelves for each expert. The number of desks correlates to the number of experts. In addition, all employees need a PC and telephone. Four notebooks, PDA's and mobile phones ensure personnel can work and be available on business trips. Three printers should be enough for scanning, coping and print reports and examination documents. If the certification center includes a department for the inspection of wind turbines, the inspectors will need personal safety equipment, tools and video endoscopes to examine the gearbox or other rotational elements. The software is important and a vital aid for the examination of wind turbines: Software packages allow users to carry out performance and loading calculations for the design and certification of wind turbines. Structure analysis software for "finite element method" is needed to simulate load cases on structure of the wind turbine tower, foundation, etc. A server and an intranet are essential to administer and share documents as well as for internal communication. Last but not least, the certification administrative needs software that enables access to central business data, such as customer orders, invoices, production capacity, etc.

9.4.2.3 Personnel

The next section lists the required personnel and their education / function for the certification center. It estimates the required personnel for the start-up phase and does not include personnel distribution after future expansions.

Table 9-12: Certification Center Personnel

Qualification and Expertise	No.
Business Manager	1
Team Assistant	2
Head of Departments/Project Manager	2
Mechanical Engineer(s)	3-4
Electronic Engineer(s)	1
Electrical Engineer(s)	1
Construction and Structure Engineer(s)	3-4
IT-Specialist	1
Sum	14-16

The labor of the proposed certification center could be distributed like in Table 9-12. A business manager should be located on top of the organization chart. He would be responsible for planning, organization, coordination and controlling of the certification center. A qualification as a Master of Business Administration or experience as an industrial engineer will be of advantage. The Business Manager should be supported by two Department Heads or Project Managers who not only coordinate and manage wind turbine certifications but are also responsible for order acquisition. In addition, the certification center could consist of about 10 technical experts with experience in mechanical, electronic and civil engineering. Their distribution is shown in Table 9-12. The complete personnel at the certification center should be supported by two Team Assistants. To implement and maintain the IT-System, server and internal communication, an IT-Specialist with an education in system administration or an equal qualification is imperative.

9.5 Advanced Research Center Evaluation

9.5.1 Introduction

The offshore wind energy sector is a rapidly changing industry and a new player with distinct industrial and political development requirements. Due to better environmental conditions, namely higher and steadier mean annual wind speeds, the offshore wind technology promises to be a real option in modern power generation and reduction of greenhouse gas emissions. The first generation of offshore wind turbines have been onshore turbines adapted to offshore conditions (oceanographic and meteorological). This resulted in immense costs such as operating and maintenance costs and low reliability of the wind turbine system. In order to utilize the benefits of the offshore wind resource and make this technology more advantageous, even in comparison to onshore wind turbines, the offshore wind technology faces a number of challenges.

This document gives an overview of opportunities for innovative prospective R&D in the offshore wind energy sector, in order to reduce existing costs and increase the wind turbine availability on the one hand, as well as to be prepared for intensive offshore wind exploitation in the future. Fundamentally, the R&D opportunities can be divided into the following topics:

- Wind condition evaluation (wind resources, design wind conditions, and forecasting)
- Wind turbines technology
- Wind energy integration
- Offshore deployment
- Operating and maintenance
- Research infrastructures

Each topic can be subdivided into further research objectives and activities. Furthermore, short-, medium- and long-term research priorities can be defined. In order to meet these priorities, research fields need to be established.

9.5.2 Research Priorities

9.5.2.1 Wind Condition Evaluation

The development of more efficient methods for the determination and evaluation of wind resources, as well as the identification of appropriate regions where the wind resource is largely untapped, is one of the major topics to enable more cost-effective wind farm deployment. To meet these requirements, existing technologies must be improved, in order to give geographic coordinates prognoses of annual energy yields, design conditions due to the occurred wind and short-term forecasting schemes with regard to energy yield and wind conditions can be made. The predictions should have as little ambiguity as possible.

According to wind condition evaluation, the three main priorities wind resources, design wind conditions, and forecasting can be subdivided into five supplementary research topics, which are:

- Internal wind farm wake effects and wake effects of wind farms in the vicinity
- Offshore meteorology
- Extreme loads due to high wind speeds
- Wind profiles at high altitudes
- Short-term forecasting

Remote sensing such as SODAR or satellites and computational fluid dynamics methods are adequate tools for the investigation and application to meet the research requirements. Additionally, a numerical wind atlas containing annual and seasonal/monthly mean wind resources and extreme wind conditions would favor the situation worldwide. Variability and uncertainty estimation, which are based on the accuracy level, should also be included in the comprehensive wind atlas.

Other parameters such as the wind speed frequency distribution to provide precise energy calculation can be derived from the calculated/measured data. To cover a wide range of the wind spectrum, turbulences should be taken into consideration. Finally, if the collaboration between the wind energy sector and wind measurement providers is encouraged, synergy effects can be achieved.

Subsequently, the supplementary research topics are listed in Table 9-13 including their objective, research priority, impact and an assessment of which facilities are involved in the specific research fields.

The “Notes” column in the following table has details of the various institutes involved in research. The following abbreviations relate to this column:

A = National Research Energy Laboratory (NREL, USA)

B = Energy Research Center of the Netherlands (ECN, NL)

C = RISØ National Laboratory for Sustainable Energy (RISØ, DK)

D = National Renewable Energy Center Spain (CENER);

E = Center for Renewable Energy Sources (CRES)

Table 9-13: R&D Opportunities for Wind Conditions

No.	Topic	Objective	Research Priority	Impact	Notes
1	Wakes	Improve the understanding of internal wind farm wake effects and wake effects of wind farms in the vicinity; use of the knowledge in design and financial analysis	Gathering and analysis of measured data to understand the physics of wakes and to improve calibration and validation of models	Wakes are a knockdown factor that causes power losses up to 5-10%	B D NREL not involved
2	Offshore meteorology	To achieve the roadmaps of prospective offshore wind power generation, immense development is necessary; improved knowledge in offshore conditions like waves/wind; development of methods to determine external design conditions and methods adapted to the offshore environment; assessment of wind resource and short-term forecasting	Method establishment for determining external offshore design conditions and basic knowledge about offshore atmospheric effects; development of models for resource assessment, wind potential studies, accurate offshore short-term forecasting, fully integrated wind/wave/interaction models, fixed and floating platforms and satellites for rapid/low-cost measurement methods using remote sensing techniques	Optimal use of the offshore wind resource reduces cost of power generation, technical and economic risks; better integration into the power grid due to accurate and reliable forecasting; no met mast necessary	B C D NREL not involved
3	Extreme wind speeds	Generate wind atlas including guidelines for the determining the 50-year extreme wind speed and statistics	Combination of re-analyzed global wind models to establish a global extreme wind data base; increase of the spatial resolution due to improved methods (CFD); development of measure – correlate-predict methods; investigation between 50-years extreme winds and 3-second gust values; generation of classification scheme for extreme high frequency wind changes and proper statistical prediction; short term prediction of high frequency wind gusts	Increase of the economic efficiency; improve the mechanical loads and enabling of optimal site-specific wind turbine design	B D NREL not involved
4	Wind profiles at high altitudes	Investigation and modeling of the wind profile beyond the surface layer (above 100 m); formulation of model of entire boundary layer and specification of wind profile characterizing parameters	Gathering and analyzing data to get more knowledge of the boundary layer and wind profile dimensioning parameters; implementation of CFD modeling; R&D on international standards for remote sensing techniques	Information of wind profiles above 100 m are required with increasing turbine sizes; more efficient siting, better energy yield and improved structural integrity	NREL not involved
5	Short-term prediction	Combination of the numerical weather	Data collection and research on new measuring	Better grid operations due to	B C

No.	Topic	Objective	Research Priority	Impact	Notes
		prediction model and the wind power forecast model	techniques in order to enable short-term forecast for system integrity and safe grid operation; improve system accuracy (average and extreme errors); investigation of uncertainties; implementation into day-to-day power system management, integration options from real measurements into numerical models	information about the wind power feed-in ad the grid nodes (transmission and distribution level)	D NREL not involved

9.5.2.2 Wind Turbine Technology

The object of intensive R&D on wind turbine technology is to achieve improved cost efficiency for the whole system, which will result in more competitiveness to other power generating devices. The aim of this research engagement will be the detection of uncertainties as well as cost reduction. The range should comprise any area that influences the cost of generating energy, especially capital expenditures, operation and maintenance costs, the efficiency of the entire wind turbine system, and finally wind turbine availability in terms of reliability, accessibility to the offshore wind farm and lifespan. Besides capital and operational expenditures, system decommissioning has to be taken into consideration.

The integrity of all the different components and subsystems is an important challenge turbine and component manufacturers have to face. The main emphasis of research activities is technical disciplines based on design integrity and operation of the wind turbines. This research approach comprises of the following.

- Rotor aerodynamics
- Mechanical structure and advanced materials
- Drive train
- Electrical devices
- Control systems
- Innovative concepts and integration
- Accessibility
- Condition monitoring systems
- Operation and maintenance
- Standards
- Decommissioning
- Climate conditions

On the whole, the trend in offshore wind turbine technology follows increasing dimensions, both of wind turbine dimension and wind farm size. The complexity of the entire system is also increasing, which influences wind farm operation. Due to the fact, that the natural boundaries cannot be foreseen, R&D will always play an important role in this technology.

Subsequently, the supplementary research topics, including their objective, research priority, impact and an assessment of which facilities are involved in the specific research fields, are listed in Table 9-14.

Table 9-14: R&D Opportunities for Wind Turbine Technology

No.	Topic	Objective	Research Priority	Impact	Notes
1	Rotor aerodynamic	Increasing size and complexity of wind turbines means, that rotor design models must include physical aspects such as aerodynamic phenomena	Creation of advanced CFD and aerodynamic models for large rotor systems; verification of advanced models	The rotor system is the first element in the energy conversion chain, which affects immensely the main loads for the rest of the wind turbine structure and the energy production	A B C D E
2	Mechanical structure and advanced materials	Improvement of the structural integrity containing improved estimation of design loads, advanced materials, optimized design, verification of structural strength and component reliability (blades, gearbox)	Improve knowledge of design loads; research and identification of physical properties of advanced materials; design development and verification methods for structural strength and component reliability	More structural efficiency and optimum use of materials will have a positive influence on the lifetime cost of energy	A B C D
3	Drive train	Development of improved constructional configuration concepts to reduce installation and replacement times, as well as the equipment effort; increase of efficiency in the energy conversion chain	Improve of drive train configuration and development of suitable assembling methods for installation/ maintenance and repair activities; reduction of power losses in the energy conversion chain due to improved components and their integration concepts	Decreasing the installation and maintenance effort will have a positive influence on the lifetime cost of energy	A C
4	Electrical devices	Development of better electrical component and better sealing for extreme climatic conditions; improve of impact on grid stability and power quality; decrease grid effect on wind turbine	High voltage electronics to increase efficiency and reduce costs; improve reliability with better sealing; increase system efficiency and improve power quality due to better power converters; development of new light-weight, low-speed and low maintenance generators including high temperature super conductors; development of grid code requirements	Positive impact on the lifetime cost of energy and enhancement of grid compatibility	A
5	Control systems	Development of advanced control strategies, new control devices and sensors to optimize the balance between performance loading and lifetime	Increase of electricity output and capacity factor for wind turbine and farm; reduction of mechanical loads on the structure; development of control algorithms to ensure aerodynamic stability, and new control sensors (Lidar) as well as integrated control	New and improved wind turbine designs; better confidence in reliability over the lifetime	A B C D E

No.	Topic	Objective	Research Priority	Impact	Notes
			and maintenance strategies		
6	Innovative concepts and integration	Research on highly innovative wind turbine concepts suitable for offshore conditions due to improvements in technology and higher risk strategies	Development of innovative wind turbines and subsystem concepts like the rotor design; development of integrated design methods	Optimization of the entire wind turbine system; reduction of the lifetime costs of energy	A C
7	Accessibility	Development of sophisticated access system s to ensure the access to the wind farm in case of rough weather conditions (wind speed, wave height)	Development of access methods depending on the offshore conditions and turbine/foundation type; implementation of the methods for further offshore wind farms	Positive impact on the lifetime cost of energy; reduction of waiting times	NREL not involved
8	CMS	Development of advanced condition monitoring systems to prevent unexpected failures	Development of components specific sensors, control devices and data handling procedures	Positive impact on the lifetime cost of energy and component reliability	B NREL not involved
9	O&M	Optimize operating and maintenance strategies in order to increase availability and reliability of the wind turbine system	Development of failure detection methods and investigation into the physical effect of faults and their development; implementation of monitoring devices for fault prediction; development of maintenance strategies regarding preventive maintenance and risk-based inspection using monitoring	Increase of confidence in prediction of O&M costs over the life time and reduction of these costs	B C NREL not involved
10	Standards	Continue the process of standard development for the wind turbine design with regard to safety and performance aspects as well as to allow technical development	Background research on new design standards with integration of gained experience from operational offshore wind farms	Confidence in future investment of offshore wind farms and their development/operation	NREL not involved
11	Decom.	Development of strategies for the decommissioning of offshore wind farms	Research on and adoption opportunity of existing strategies from the offshore oil and gas sector; investigation of the handling and disposal of advanced materials (composite materials); assessment of the environmental impact; methods to quantify the additional costs	Enhanced confidence in the technology and consideration of additional costs; establishment of new markets	NREL not involved
12	Climate conditions	Harsh climates such as dry or extremely cold regions have to be taken into consideration when designing new wind turbines and components	Development of materials which resists extreme climates and climate changes: development of special equipment to prevent failures due to climate conditions such as icing	Improvement of wind turbine reliability	C NREL not involved

9.5.2.3 Wind Energy Integration

The roadmap of several countries shows a large prospective development in offshore wind activities. Therefore the large-scale integration of offshore wind power becomes a significant subject when ensuring a consistent electricity supply. In order to realize these plans it is vital to increase capacities and invest in transmission and distribution grids. Currently there are no electrical grids present in the sea to connect large-scale offshore wind farms. On the other hand, the existing onshore networks are not capable of meeting the prospective plans for large-scale offshore wind farm deployment. The layout and basic structure of the grids as well as the operating methods have to be adapted to large amounts of variable electricity supply.

For these reasons, the main research topics comprise:

- Offshore wind farm capabilities
- Grid planning, integration and operation
- Energy and power management

Alongside this development it must be taken into consideration that the existing electric infrastructure and a lot of power plants are reaching the end of their lifespan as electricity demand continues to grow by around 1.5 percent each year. Subsequently, the supplementary research topics, including their objective, research priority, impact and an assessment of which facilities are involved in the specific research fields, are listed in Table 9-15.

Table 9-15: R&D Opportunities for Wind Energy Integration

No.	Topic	Objective	Research Priority	Impact	Notes
1	Offshore wind farm capabilities	Enabling high penetration of large offshore wind farms while treating them as power plants to be integrated as conventional power stations; assessment of impacts to determine cost-effective ways of ensuring reliability at high wind penetration levels; approach to grid code requirements	Grid code requirements for cost-effective and reliable power systems; higher wind power penetration must be compatible with grid code requirements; suitable methods for verification of specific capabilities such as fault ride through as well as methods of proving compliance	Better understanding of integration of large offshore wind farms will lead to more reliable and efficient electricity supply	NREL not involved
2	Grid plan integration and operation	Extension and reinforcement of grid infrastructure and interconnections through planning and early identification of bottlenecks; verification of existing rules	Research on acceleration of the sustainable extension and reinforcement of the existing grids; improved operation and interoperability (development of tools for data acquisition)	More reliable and efficient energy supply, efficient grid structures	C NREL not involved

No.	Topic	Objective	Research Priority	Impact	Notes
		Development of methodologies to determine transmission capacities and panning tools to enable the design of an efficient grid structure and assess grid connections	Development of models and simulation tools for transient grid stability investigations; generation of transmission studies for offshore wind power; development of new power system structures (agent-based systems)		
3	Energy and power management	Establishing long-term reserves; exploration and quantification of existing flexibility in power systems as well as demand-site management; development of virtual power plants and prediction tools such as systems operation; promotion of probabilistic decision methods with regard to variable production, variable demand and variable storage capacity	Development of improved system and portfolio management tools; assessment of the impact of high wind penetration on power system operations and generation capacity; assessment and demonstration of benefits and costs in order to provide additional services and power balancing for higher wind conditions;	Increased power system reliability for high wind penetration; increased power system efficiency; improved value of wind power	A C

9.5.2.4 Offshore Deployment

The deployment of offshore wind farms is one of the major challenges companies involved in this sector have to face. On the one hand, one target is to reduce the overall costs to be more competitive with other renewable power generation technologies and of course conventional power generation systems, and on the other hand there are safety and environmental aspects, which have to be considered. Every activity that has to be carried out with respect to offshore deployment must be undertaken safely, with no harm to people, environment or equipment. The safety of staff involved in offshore installation activities mostly depends on their education level. Well-trained and educated personnel are equipped with the expertise and skills to carry out their work safely ensuring that neither people nor the environment will be harmed. Keeping these aspects in mind, the research topics for offshore wind farm deployments can be prioritized into:

- Substructures
- Assembly and installation
- Decommissioning
- Electrical infrastructure
- Wind turbines

Global collaborations in offshore wind power-related R&D as well as faster deployment procedures will also serve the market.

Subsequently, the supplementary research topics, including their objective, research priority, impact and an assessment of which facilities are involved in the specific research fields, are listed in Table 9-16.

Table 9-16: R&D Opportunities for Offshore Deployment

No.	Topic	Objective	Research Priority	Impact	Notes
1	Substructures	Development of new substructure designs depending on the water depth and oceanographic/ meteorological conditions as well as improved manufacturing processes	Development of new and improved materials and manufacturing technologies with regard to welding, casting and concreting activities; development of more efficient manufacturing processes and procedures including automation and robotics	Reducing the unit-costs of substructures; increasing the application range (deeper waters) and the component reliability	A D
2	Assembly and installation	Development of improved onshore and offshore transportation concepts; development of safe, efficient and reliable installation processes which are easy to replicate	Optimizing existing assembly and installation methods; Development of new installation concepts, integrating ease of installation into the substructure and turbine design through a life-cycle approach; (needs for improved vessels and equipment)	Reducing costs, minimizing risks, ensuring standards and delivering investor confidence	NREL not involved
3	Decom-missioning	Development of strategies for the decommissioning of offshore wind farms	Research on adoption opportunity of existing strategies from the offshore oil and gas sector; investigation of the handling and disposal of advanced materials (composite materials); assessment of the environmental impact; methods to quantify the additional costs	Enhanced confidence in the technology and consideration of additional costs; establishment of new markets	NREL not involved
4	Electrical infrastructure	Development of improved cable design, technologies and installation processes; development of interconnected offshore grid systems; research on pre-installation of cables to the substructure	Development of improved design tools and life-cycle approaches with regard to cable technologies, installation methods and grid infrastructure	Cost reduction and improvements in operational reliability	NREL not involved
5	Wind turbines	Development of improved wind turbine design and component quality (also due to sharing of experiences)	Development of onshore and offshore test facilities to ensure that the wind turbines are properly tested before being commercial deployed offshore	Cost reduction and improvements in operational reliability	A C D

9.5.2.5 Operations and Maintenance

Reducing operation and maintenance costs is a key issue for prospective commercial offshore wind farm activities. Especially costs due to unexpected failures (known as corrective maintenance costs) need to be accurately predicted. Additionally, sophisticated access systems will improve the transportation of spare parts and personnel to wind farms. The operating and maintenance research field can be subdivided into:

- O&M strategies
- Accessibility
- Condition monitoring
- Key components

Subsequently, the supplementary research topics, including their objective, research priority, impact and an assessment of which facilities are involved in the specific research fields, are listed in Table 9-17.

Table 9-17: R&D Opportunities for O&M

No.	Topic	Objective	Research Priority	Impact	Notes
1	O&M strategies	Development and improvement of O&M strategies	Development of advanced condition and risk-based maintenance	Positive impact on the lifetime cost of energy; reduction of waiting times	B C NREL not involved
2	Accessibility	Development of sophisticated access systems to ensure wind farm access in rough weather conditions (wind speed, wave height)	Development of access methods depending on the offshore conditions and turbine/foundation type; implementation of the methods for further offshore wind farms	Positive impact on the lifetime cost of energy; reduction of waiting times	NREL not involved
3	Condition monitoring	Development of advanced condition monitoring systems to prevent unexpected failures	Development of components specific sensors, control devices and data handling procedures	Positive impact on the lifetime cost of energy and component reliability: reducing the need for scheduled local checks	B NREL not involved
4	Key components	Identification of key components for O&M costs	Development of concepts that key components can be replaced with minimal dismantling and minimal use of external lifting equipment; implementation of redundancies	Positive impact on the lifetime cost of energy; reduction of waiting times; reducing maintenance and repair times	B NREL not involved

9.5.2.6 Research Infrastructure

The research infrastructure is needed to support the thematic priorities which can be subdivided into:

- Wind conditions
- Wind power systems
- Wind energy integration
- Offshore deployment and operation

In order to enhance the current knowledge of wind flow in offshore and near-shore environments, extensive wind measurement campaigns are required including wind speed, direction and turbulence at different heights and positions. With regard to wind power systems, it has to be considered, that wind turbines are extremely large machines as such the research infrastructure is also large and cost-intensive specifically wind tunnels or blade fatigue testing facilities. Collaboration between research facilities and turbine/component manufacturers would be needed to achieve testing in this field. Further facilities are required for testing the grid compliance of wind turbines and wind farms. Thereby, two types can be differentiated, mobile facilities or specific locations. Research activities include grid code requirements for cost-effective and reliable power systems, active and reactive power control, fault ride through and monitoring of voltage dips. The foundations for the development of R&D skills in generating offshore wind power have been laid by extensive development activities for renewable energies as well as oil and gas. This existing infrastructure should be used for the offshore wind technology. Furthermore, the offshore attributes of the oil and gas sector must be adapted to offshore wind activities to meet the needs of a growing industry.

9.5.2.7 Function of Additional Notes to Current R&D

Table 9-13 through 9-20 contain extra columns for additional notes. Each note describes actual research conducted by established centers, for the R&D topic in the appending row of the table. Five R&D centers were taken into account for consideration:

- National Research Energy Laboratory (NREL, USA)
- Energy Research Center of the Netherlands (ECN, NL)
- RISØ National Laboratory For Sustainable Energy (RISØ, DK)
- National Renewable Energy Center (CENER, E)
- Center for Renewable Energy Sources (CRES, EL)

If an R&D topic is listed without additional notes, it could be of primary interest for the proposed research center. In such a case, the appearance of competition from another R&D

facility is not definite but the related R&D topic is expected to be an important work area for the wind energy sector. The R&D topics with additional notes could also be of research priority, if the R&D is not already being conducted by one of the established research centers. Table 9-18 gives an overview about R&D in these research centers. The first impression is that there is no research topic not previously or currently investigated by one of the R&D facilities. Nevertheless, the given notes in this section will show that many points for R&D are still open.

Table 9-18: R&D Areas of Established Research Laboratories of the Wind Energy Sector

No.	Work Area	NREL	ECN	RISØ	CENER	CRES
1	Wind Conditions	X	X	X	X	X
2	Wind Turbine Technology	X	X	X	X	-
3	Wind Energy Integration	X	-	X	-	-
4	Offshore Deployment	-	-	X	X	-
5	Operation and Maintenance (O&M)	-	X	X	-	-

(x) is area of research, (-) is not an area of research

9.5.3 Protocol for Sharing Confidential Information

This protocol has been generated according to existing protocols for sharing of information between various different entities. A lot of this information contains personal details about people who use services and their confidential information.

9.5.3.1 Introduction

The purpose of this document is to provide a framework for the secure and confidential sharing of information between research centers, local manufacturers and wind turbine developers for an advanced research center within the “GLWEC”.

The protocol informs all bodies involved in the same research project about how information is shared and how this sharing will be managed.

The data, which will be shared, contains information about innovative wind energy R&D. The object of this is to develop the offshore wind industry and expand the onshore wind industry and to improve the components for wind turbines.

With respect to information that will be provided for the public domain, it has to be mentioned that research facilities are potentially subjected to disclosure requirements when projects are financed by public authorities. This can result in a conflict of interests between research facilities and wind turbine/component manufacturers. Therefore it is of particular importance to ensure the exchange of information in order to ensure that everybody involved in a project has the same level of information.

Organizations involved in sharing/providing information both among themselves and to public have a legal responsibility to ensure that their use of information is lawful, properly controlled and that company rules and policies as well as individuals rights are respected. This balance between the need to share information to provide quality service and protection of confidentiality is often a difficult one to achieve.

This protocol contains the principles that could be adopted whenever the participants have to share information.

All those who have agreed to represent organizations, which are involved in the advanced research center “GLWEC” should agree to use a protocol of this nature. The protocol should be reviewed by all participating organizations and all involved organizations should agree to follow the rules which have been set out in the protocol when using and sharing information. Furthermore the protocol sets out how the collaboration in sharing confidential information will be performed.

9.5.3.2 Aims and Objectives of the Protocol

The aim of this protocol is to provide a framework for the participating organizations and to establish and regulate working practices between these organizations. It is intended that all parties will use the protocol. To provide a consistent, coherent and innovative wind energy R&D program for the offshore wind industry and to expand the offshore wind industry, as well as to improve components of wind turbines, it is necessary for all organizations to coordinate their work so that they can work effectively and efficiently together. This includes the communication among one another and the exchange of data to ensure every member knows the current status of the project they are involved in.

These aims include:

- To guide partner organizations on how to share personal information lawfully
- To explain the security and confidentiality laws and principles of information sharing
- To increase awareness and understanding of the key issues
- To emphasize the need to develop and use information exchange agreements
- To support a process for will monitoring and reviewing all information transfer
- To encourage flows of information
- To protect partner organizations from accusations or wrongful use of sensitive personal data
- To identify the lawful basis for information sharing

All participating organizations will be expected to promote staff awareness of the major requirements of information sharing. This will be supported by the production of appropriate guidelines where required that will be made available to all staff via the partners' intranet sites and/or via other communication media.

With regard to working relationships the protocol sets out, when sharing information, that all parties:

- respect each other's independence
- cooperate when necessary or appropriate
- work together in a cooperative and constructive manner
- work openly and transparently

9.5.3.3 Information Covered by the Protocol

All data with regard to the advanced research center "GLWEC" could be covered by this protocol. This information can be handled via electronic devices such as computer systems or manually in form of reports.

9.5.3.4 Information Sharing Agreements

A key aspect of the protocol is the adoption by organizations of a common standard for procedures for the sharing of information. This is intended to give organizations confidence when they share information.

The scope and content of specific information sharing agreements should be consistent with the principles set out within this protocol. Information sharing agreements should contain:

- The parties to the agreement including the signatory
- The purposes for which information needs to be shared
- References to relevant statutory and common law
- An assessment of the impact on the information sharing agreements of organization – specific codes of practice, standard operating procedures and guidance
- Detailed arrangements for obtaining, sharing, using and disclosing information

9.5.3.5 Legal Framework

The principal legislation concerning the protection and use of confidential information depends on the particular country, in this case the United States of America. GL is not authorized as a legal advisor. Clarification should be taken from suitable legal advisors.

9.5.3.6 Organizational Responsibility

Each organization is responsible for ensuring that their organizational and security measures protect the lawful use of information shared under this protocol.

Each organization will accept the security levels on supplied information and handle the information accordingly.

Each organization accepts responsibility for independently or jointly auditing compliance with the Information Exchange Agreements in which they are involved within reasonable time-scales.

Every organization should make it a condition of employment that employees will abide by their rules and policies in relation to the protection and use of confidential information. This condition should be written into employment contracts.

Every organization should ensure that their contracts with external service providers abide by their rules and policies in relation to the protection and use of confidential information.

Every organization originally supplying the information should be notified of any breach of confidentiality or incident involving a risk or breach of the security of information.

Each organization should have documented policies for retention and secure waste destruction.

9.5.3.7 Individual Responsibilities

Every individual working for the organizations listed in the information sharing agreement is personally responsible for the safekeeping of any information they obtain, handle, use and disclose.

Every individual should know how to obtain, use and share information they legitimately need to do their job.

Every individual has an obligation to request proof of identity, or takes steps to validate the authorization of another before disclosing any information.

Every individual should uphold the general principles of confidentiality, follow the rules laid down in the company confidentially statement and seek advice when necessary.

Every individual should be aware that any violation of privacy or breach of confidentiality is unlawful and a disciplinary matter that could lead to their dismissal. Criminal proceedings might also be brought against that individual.

9.5.3.8 Safe Information Sharing Procedures

The transference of information between the organizations must follow these principles and it is advisable that each organization has these policies and procedures in place for staff information and guidance.

All possible precautions should be taken to ensure information is received, stored and communicated in areas, which are accessible to only those persons who are privileged to have access to the confidential information in their pursuance of the organization's business.

Take measures to prevent casual viewing of information, including where possible, and reasonable. Paper documents (client files, other paper records, correspondence etc.) should be kept securely, either in their allocated place of repository or in secured rooms/offices/cabinets. All sensitive records must be stored face down in public areas and not left unsupervised at any time. Unauthorized persons should not be allowed into areas where confidential information is held unless supervised.

All incoming mail should be opened away from public areas. Outgoing mail, for external transfer, containing personal information, should be sealed securely, addressed correctly and marked private and confidential for the attention of the addressee only.

Email must not be used for sending sensitive or confidential information across the Internet unless an encryption facility is used. Where no encryption between the organizations is available, email must not be used.

All confidential information must be disposed of safely. Paper documents must be shredded or torn into small pieces, but in all cases must be placed in a confidential waste container / sack for collection. Computer disks, CDRs, processors and other devices containing confidential information must have this information deleted before disposal.

9.5.3.9 Review Arrangements

A process of review will be undertaken during the initial phases of implementation to monitor the use of the protocol and document issues or problems that arise. Changes will only be made to the protocol if issues that arise are deemed to be significant.

The first formal review will be held between six and twelve months after implementation, on a date to be agreed by the parties to the protocol. Subsequent reviews will then be carried out annually unless legislative changes or other significant events require more immediate action.

Prior to the review, all parties to the protocol will be asked to submit feedback on the use of the protocol and to put forward proposals for amendments and for addressing any issues that may have arisen. Appropriate guidance (for example, legal advice), will be obtained in relation to any proposed major changes.

9.5.3.10 File Sharing System

The file sharing system should include a communication board and enable data exchange. In order to ensure that all participants have the same knowledge of the project it would be helpful to provide a server to which every participant has access to, and is allowed to store data and manage documents. A market research on existing tools yielded the following results.

9.5.3.11 ConjectPM

ConjectPM (URL: http://www.conject.com/en/) is a web-based platform developed especially for construction and real estate projects and ideally displays your processes involved. On this platform you can manage all of your projects using individual virtual project spaces. In each project stage, you can determine which project participants may work together. As a result, you have your projects under complete optimal control.

Access to the platform is possible using any modern PC with a web browser and Internet access. Installation or software is not required. ConjectPM enables companywide collaboration with the highest level of security, for example:

A firewall protects against unauthorized access. Authentication requires user name and password. Each attempt at unauthorized access is logged. Data transfer with 128-bit SSL encryption. Only selected employees of Conject have access to the systems. Access is logged and encrypted (VPN, highest security). Data is only accessed in order to monitor the system and provide customer support.

Unlimited functions that make life easier for Power-Users are found in the platform’s various application modules. Newcomers, on the other hand, will find the platform very clearly laid out.

ConjectPM is the only platform that supports the classic directory structure, as well as several categorizations with basic filter functions for drawings and other documents. The platform's application modules are so intertwined that you can attach other documents or conversations to your documents and thus specify relationships.

Table 9-19 ConjectPM Costs

ConjectPM Professional Package Description	per User/Month
1 - 9 Licenses	€ 99
10-19 Licenses	€ 89
20+ Licenses	€ 79
ConjectPM Basic Package Description	€ 39

9.5.3.12 GoToMeeting

GoToMeeting (URL: https://www1.gotomeeting.com/) is a Web conferencing tool that allows you to meet online rather than in a conference room. It's the easiest and most cost-effective way to organize and attend online meetings. Patented technology enables co-workers, customers and prospects to view any application running on your PC in real time. Users have the flexibility of meeting in person or online. This tool enables you to conduct presentations with a prospective customer, perform live demonstrations in real time, collaborate on documents with your colleagues and provide training to customers and employees.

Price:

You can subscribe to GoToMeeting on a monthly basis, or select an Annual Plan and save 20 percent. Either way, you can always expect unlimited, easy-to-use online meetings at a predictable flat rate.

Table 9-20: GoToMeeting Potential Costs

Buy a Plan Now	Monthly Cost	Total Annual Cost
Monthly Plan	$49.00	$588.00
Annual Plan (Save 20%!)	$39.00	$468.00 Best Value

Other benefits:

One flat fee lets you host unlimited online meetings with up to 15 attendees per meeting. There is no need to purchase licenses for meeting attendees because all attendees can meet for free. Save money with free phone conferencing, VoIP or both.

These are two proposed systems for the sharing of data and information, the system utilized for GLWEC should be custom-designed for the purpose of the center.

9.5.4 Proposition for a Permanent Research Center

When talking about the purposes of a permanent research center, it is necessary to differentiate between the structure of the research center including the research priorities, the different facilities and equipment as well as the staff. The research center can be divided into four departments:

- Department for Administration
- Department for Offshore Deployment
- Department for Wind Conditions
- Department for Turbine Technology

9.5.4.1 Department for Administration

The listing of the employees, their field of activity and the corresponding equipment of the administration department are all shown in Table 9-21.

Table 9-21: Department for Administration

No.	Staff	Field of Activity	Equipment	No. of Employees
1	Business Manager	Corporate governance	Laptop & Docking Station, PDA, Mobile Phone, Phone, Desk, Office, Chair (3), Shelves	1
2	Head of d Department	Coordination & administration	Laptop & Docking Station, PDA, Mobile Phone, Phone, Desk, Office, Chair (3), Shelves	1
3	Secretary	Management assistance	PC, Phone, Desk, Office, Chair (2), Shelves	1
4	Team Assistant	Support	PC (2), Desk (2), Phone (2), Office, Chair (2), Shelves (2),	2
5	Financial Accounting & Controlling	Intern and extern financials	PC, Phone, Desk, Office, Chair, Shelves	1
6	Knowledge-based Management	Project and data management	PC, Phone, Desk, Office with HR, Chair, Shelves (3)	1
7	Human Resources	Recruitment and coordination of staff	PC, Phone, Desk, Office , Chair (2), Shelves	1
8	Materials Management and Purchase	Purchase	PC, Phone, Desk, Office with financial accounting & controlling, Chair, Shelves	1
9	IT- Expert	IT- Administration, server, help desk	PC, Phone (2), Desk, Office, Chair (2), Shelves	2
10	Concierge	Reception	Mobile Phone, Phone, Desk, Reception, Chair (2)	1

11	Facility Manager	Maintenance of facilities and equipment	Mobile Phone, Phone , Desk, Service room , Chair, Shelves	1
12	Students	Assistance in document management	PC (2), Phone (2), Desk (2), Office, Chair (2), Shelves	2

The department of administration consists of the business manager who leads the research center, a secretary to assist the management and the head of the department who coordinates the administration. Furthermore there are two Team Assistants to support the project work, an employee for the financial concerns, an employee who is responsible for project data and knowledge management, an employee for Human Resources, a purchaser for materials and equipment, two IT-experts, a concierge service, a facility manager as well as two students to assist the document management.

9.5.4.2 Department for Offshore Deployment

The major issues of the department for offshore deployment, namely assembly, installation and electrical infrastructure are summarized in Table 9-22. Two researchers are needed to carry out the work.

Table 9-22: Department for Offshore Deployment

No.	Topic	Objective	Equipment	No. of Employees
1	Assembly and Installation	Development of improved onshore and offshore transportation concepts; development of safe, efficient and reliable installation processes which are easy to replicate; optimizing existing assembly and installation methods	Desktop PC with appropriate software	Researchers: 1
2	Electrical Infrastructure	Development of improved cable design, technologies and installation processes; development of interconnected offshore grid systems; research on pre-installation of cables to the substructure	Desktop PC with appropriate software	Researchers: 1

9.5.4.3 Department for Wind Conditions

Another research priority that should be taken into consideration is wind conditions. The research topics comprise investigations on wakes of wind farms and wind farms in the vicinity, a knockdown factor which can cause up to 10 percent of energy loss, the offshore meteorology including the development of methods and models for the resource assessment; investigations on extreme wind speeds in order to establish a global extreme wind data base, short term predictions as a combination of numerical weather prediction models and the wind power forecast models and finally climate conditions. Investigations into harsh climates such as extremely cold regions have to be considered when designing new wind turbines and components. Table 9-23 gives a detailed overview of the department of wind conditions. It is recommended to involve five researchers in order to cover the five research topics.

Table 9-23: Department for Wind Conditions

No.	Topic	Objective	Equipment	No. of Employees
1	Wake	Investigation on internal wind farm wake effects and wake effects of wind farms in the vicinity by gathering and analysis of measured data in order to understand the physics	Desktop PC with appropriate software, i.e. CFD	Researchers: 1
2	Offshore meteorology	Development of standard models for resource assessment, wind potential studies, accurate offshore short-term forecasting models, fully integrated wind/wave/interaction models, fixed and floating platforms and satellites for rapid/low-cost measurement methods using remote sensing techniques	Desktop PC with appropriate software	Researchers: 1
3	Extreme wind speeds	Combination of re-analyzed global wind models to establish a global extreme wind data base; Generate wind atlas including guidelines for the determining the 50-year extreme wind speed and statistics	Desktop PC with appropriate software, i.e. CFD	Researchers: 1
4	Short term prediction	Combination of numerical weather prediction models and the wind power forecast models based on advanced or new measurement techniques to improve system integrity and safe grid operation	Desktop PC with appropriate software	Researchers: 1
5	Climate conditions	Harsh climates such as dry or extremely cold regions have to be taken into consideration when designing new wind turbines and components; Assessment of climate regions and conditions	Desktop PC with appropriate software	Researchers: 1

9.5.4.4 Department for Turbine Technology

The fourth department includes research on the wind turbine technology with regard to electrical devices, the accessibility of offshore wind turbines, condition monitoring systems and operation & maintenance analysis.

Table 9-24: Department for Wind Turbine Technology

No.	Topic	Objective	Equipment	No. of Employees
1	Electrical Devices	Development of improved electrical component due to better sealing for extreme climatic conditions; improve of impact on grid stability and power quality; decrease grid effect on wind turbine	Desktop PC with appropriate software, laboratory, materials, testing rigs	Researchers: 1 Technicians: 1
2	Accessibility	Development of sophisticated access systems to ensure the access to the wind farm in case of rough weather	Desktop PC with appropriate software, collaboration with	Researchers: 1

No.	Topic	Objective	Equipment	No. of Employees
		conditions (wind speed, wave height)	prototype producer	
3	CMS	Development of advanced condition monitoring systems to prevent unexpected failures; development of components specific sensors, control devices and data handling procedures; development of advanced control strategies and control devices	Desktop PC with appropriate software, laboratory, materials, testing rigs	Researchers: 1 Technicians: 1
4	O&M	Development and optimization of operating and maintenance strategies in order to increase availability and reliability of the wind turbine system; implementation of monitoring devices for fault prediction and also failure detection methods; identification of key components in order to reduce the dismantling/disassembling process; implementation of redundancies	Desktop PC with appropriate software	Researchers: 1

A detailed listing of the research priorities and the corresponding staff is shown in Table 9-24. The department also includes two labs with testing rigs. In order to cover these topics, four researchers and two technicians for the lab should be considered.

9.5.4.5 Support

Personnel

In order to maintain the four departments mentioned several employees are required. These are detailed in Table 9-25. Overall, there are 25 full-time employees.

Table 9-25: Personnel Needs

Qualification and Expertise	No.
Business Manager	1
Head of Departments	1
Researchers	11
Technicians	2
Secretary	1
Team Assistant	2
Financial accounting & controlling	1
Knowledge-based management	1
IT-expert	2
Human Resources	1
Materials Management and Purchase	1
Facility Manager	1
Concierge	1
Sum	**25**

Facilities

In order to provide all aforementioned research priorities with the proposed employees, it is necessary to consider the facilities such as offices, meeting rooms, etc. listed in Table 9-26.

Table 9-26: Facility Needs

	Facilities	Details	App. No.
	Offices		14
	Reception		1
	Meeting Room	1 large room for 10 persons, 1 small room for 5 persons	2
	Archive		1
	Library		1
	Laboratory	This would be dependent on the desired research areas	1

Equipment

The required equipment to cover all of the research issues is detailed in Table 9-27. It includes information about the furniture, office equipment, software and the lab equipment.

Table 9-27: Equipment Needs

	Equipment	Details	No.
	Furniture	Work desks	29
		Chairs	35
		Shelves	27
	Office equipment	Server and network (Intranet)	1
		Desktops	12
		Laptops	13
		Printers (2 black/white and 1 color laser)	3
		Phones	30
		Mobile phones	6
		PDA's	2
		Xerox machine	1
		Office supplies	n. a.
	Software	Operating system (licenses)	25
		Server software	1
		Office software (licenses)	25
		Structure analysis	n. a.
		Load analysis	n. a.
		Simulation and numerical computing software	n. a.
		Lab workbench	n. a.
		ERP	25
		Financial software	1
	Lab	Test rigs for electrical devices	2 -3

	equipment	Work bench	2
		Tools	n. a.
		Materials	n. a.

9.6 Conclusions

9.6.1 Conclusion Pilot Project

With respect to market demand, answers received on questionnaires were relatively positive. While no turbine manufacturer offered to donate turbines, both of the written responses (Turbine Manufacturer 1 and 2) indicated a positive response and one offered to possibly supply turbines at a reduced cost. Some of the component manufacturers mentioned that they would be interested in possibly donating cash or supplying components for the project. The majority of the component manufacturers had a positive attitude toward this section of the project. GL foresee the main objective of the Pilot Project to raise awareness of wind energy in the local area. The Pilot Project in GL's opinion would not prove to be a viable option for foundation testing or in general for turbine testing, however a case could be made that the offshore market is growing rapidly in Europe and at the moment there is no specialized facility dedicated to the development of offshore access techniques and the training of personnel in the access techniques. GL feel that there is a potential market for these services as they would reduce the operational and maintenance cost of a project dramatically.

To ensure the efficient and smooth running of the Pilot Project, an onshore support facility with associated staff and equipment is necessary. The support team should consist of approximately six employees taking responsibility of project management, purchase of spare parts, inspections and repair maintenance, and will require offices, storehouses and work shop facilities with the appropriate equipment.

The operational and maintenance cost for the Pilot Project is split into several parts, namely the cost for administration, preventive maintenance, corrective maintenance, insurance, electrical purchase, lease costs and reserve funds. The preventive and corrective maintenance contributes to the largest part of the costs; this can be reduced through the use of a suitable maintenance strategy which will lead to shorter downtimes of the turbines.

9.6.2 Conclusion Test Center

The feasibility of the test center is evaluated by reviewing internationally known research and test centers. Highlighting existing research activities facilitates the determination of actual research deficits and therefore the potential demand for the GLWEC. Existing research fields comprise for instance component and technology concerns, aero elastics & wind farms aerodynamics, cost reduction, as well as wind assessments and forecasts.

The evaluation of actual test priorities shows the possible facilities required for a test center. These needs are summarized in nine different potential work areas. These are prototype test, offshore Pilot Project, component test, condition monitoring system, measurement of environmental conditions, calibration of test equipment, site assessment, training center for offshore O&M as well as offshore O&M. An expert rating is also provided using three assessment criteria, namely potentially good market, moderate market interest and small/very limited market interest. Recommendations outline the primary potential areas for testing as prototype testing, offshore Pilot Project, condition monitoring systems, measurement of environmental conditions, calibration of test equipment and site assessment. These are areas where research is currently being undertaken.

9.6.3 Conclusion Certification Center

The certification center proposal was met with a positive confirmation that the manufacturers contacted would be interested in utilizing a facility located within the USA. Currently it is not mandatory to certify turbines or projects within the USA, however as the industry grows investors and developers will push to standardize the quality of the components, as such GL feel that within the next 5-10 years certification will become mandatory for all offshore projects and this may be pushed by a legal requirement or by the fact that investors and developers wish to lower the risk profile of their investments. Taking this fact into account, and the fact that the industry in Europe has seen the need for a third party verification/certification process, GL believe that a facility in the USA would prove profitable as a long term investment. As stated above the response from the manufacturers was positive, but also mitigated with a statement that they define the key requirements of a certification center as being an extremely skilled staff delivering on time and to a high quality, as such GL feel that Cuyahoga County should consider partnering with an established certification body should they wish to proceed with this part of the project as this would give them an established reputation which would result in a faster potential growth rate for this business area. The strategy illustrated later in this document is based on the certification process developed and utilized within GL. This process was taken as it is a proven business model which has given GL a market share of over 50% of the type certification market. GL also contacted and discussed these points with several certification bodies and the consensus from the respondents was that they personally could not see a potential for a certification center in the northern USA.

Certification services in terms of wind energy conversion systems are covered by type certification and project certification. The type certification certifies the machine while the project certification certifies the project in its actual location. The establishment of a certification center can be divided into five phases: Engineering, planning and contracting, installation of buildings, recruitment and training of personnel, initial start-up with part certification and work flow optimization, profitable work. The duration for the establishment varies between four and five years depending on the decision to rent or construct a building for the certification center facilities. In the start-up stage, the certification center should comprise of a team of 14-16 employees with the associated office facilities and equipment. Germanischer Lloyd foresee this part of the GLWEC as only being seriously viable if the backing of an established certification body is present.

9.6.4 Conclusion Advanced Research Center

The research center is seen by GL to be the least viable section of the project due primarily to the trend by the turbine manufacturers to develop their own research facilities in house. The confidential nature of the manufacturers' development projects makes collaboration with an external body which does not have a proven reputation a higher risk. GL feel that the market for a research center does exist however the time frame for the building of a reputation would be best served by working closely with an established body and using their reputation in order to market the centers capabilities. The areas where research should potentially be undertaken should be in the areas where the other research institutes are not extremely active. These areas are primarily wind energy integration, offshore deployment and operating and maintenance (O&M). As mentioned earlier a combining the offshore Pilot Project with the research center to generate a center where offshore personnel could be trained is seen as a potential market. This could be combined with research into various access techniques.

In order to determine opportunities for innovative prospective R&D in the offshore wind energy sector an analysis of the current trends has been conducted including wind condition (evaluation of wind resources, design wind conditions, and forecasting), wind turbines technology, wind energy integration, offshore deployment, operating and maintenance, as well as research infrastructures.

Each of these topics have been subdivided into other supplementary research topics which are summarized according to their topic, objective, research priority, impact and which institutes are involved in the certain research activity. The three main areas that seem to be of interest to the GLWEC project seem to be wind energy integration, offshore deployment and operating and maintenance (O&M). The reasons why these topics seem viable are that they are not being investigated by all of the major research centers, even though the need is perceived as being there. Therefore firstly GL can see there being an opportunity to enter the market in a stronger position. Secondly the growth of the offshore sector in Europe is starting to demand the reduction of the deployment costs to reduce investment costs of projects which lowers the risk profile of projects and encourages further investment. Thirdly, the reduction of O&M costs can greatly increase the earning potential of a project as this is a serious factor offshore. GL perceives there to be a definite potential to enter the market in this area.

The sharing of confidential data between research centers, local manufacturers and wind turbine developers for an advanced research center within the GLWEC requires a secure framework which informs all bodies involved in the same research project about how information is shared and how this sharing will be managed. In order to establish the secure sharing of confidential information, a protocol is established including aims and objectives, agreements, responsibilities, sharing procedures, arrangements, as well as two examples of existing file sharing systems.

10 Permitting and Regulatory Considerations

10.1 Introduction and Scope

As intended by the Scope of Work for the Feasibility Study, juwi collaborated with the County and its regulatory legal counsel, McMahon DeGulis LLP, to do the following:

a. Determine any and all regulatory requirements necessary to construct and operate the Wind Power Demonstration Site; and,
b. Develop as much information and data as possible that are necessary to meet such regulatory requirements and to prepare necessary permit applications for submittal at the earliest possible date.

10.2 Applicable Regulatory Requirements

McMahon Degulis and juwi have concluded that the four major regulatory agencies for the Pilot Project are Ohio Department of Natural Resources (“ODNR”), Ohio EPA (“OEPA”), the United States Army Corps of Engineers (“ACE”), and the United States Fish and Wildlife Service (“FWS”). Due to recent Ohio legislation, the Ohio Power Siting Board will also need to approve any wind facility 5 MW or greater by issuing a Certificate of Authority.

Other regulatory agencies that will need to be consulted and potentially permit the Pilot Project, include, but are not limited to, the Federal Aviation Administration, the United States Coast Guard, and the Ohio Historic Preservation Office. A chart showing the applicable regulatory agency and their programs is provided below in Table 10-1.

Several meetings have occurred with ODNR, OEPA, ACE, and FWS, respectively, to promote a collaborative and coordinated regulatory process. Overall, the agencies are receptive to a model that recognizes the Pilot Project as a public project that also represents the will of the community, and that the agencies are committed to do their utmost to see that the Project can be built while being faithful to the letter and spirit of their respective jurisdictions and regulatory mandates. Critically, these agencies also understand the goal of doing sufficient pre-construction regulatory study, but that more significant study can follow installation of one or several turbines. This process is consistent with the notion of a small-scale “pilot” project. Environmental risks are minimized by the scale of the project, and long-term research can be conducted to validate potential/predicted impacts and the viability of larger-scale wind energy development on the Great Lakes.

This last point is especially relevant to the environmental review required by National Environmental Policy Act ("NEPA") to secure the Clean Water Act Section 404 permit administered by ACE. To date, ACE and other agencies that may provide input into the NEPA process have acknowledged that a shorter environmental assessment *may* only be required prior to construction given the small size and research nature of the project. If not, then a much more expensive, time consuming and comprehensive environmental impact statement may be required.

The "post-Feasibility Study" phase of the process envisions further consultation with the agencies on specific permitting issues, preparing permit applications and shepherding the permits through the relevant agencies. This coordinated process is intended not only to provide necessary permits for the Pilot Project, but "set the table" for responsible development of commercial projects.

10.3 Feasibility Study Results and the Permitting Process

The data gathered in the Feasibility Study will assist the permitting and regulatory process significantly. For example, to obtain rights to negotiate submerged land leases with ODNR, an application needs to be submitted through the Office of Coastal Management. The Feasibility Study anticipated the major requirements for information to be submitted in that application. Similarly, the Feasibility Study was specifically designed to meet the ACE requirements for environmental assessment and impact under NEPA. Comparing the Feasibility Study to areas of inquiry required for alternative energy projects in the Outer Continental Shelf indicates that the Feasibility Study also correctly anticipated the issues expected to be raised in detained negotiations.

Despite information from the Feasibility Study being useful for permitting, there should be no illusions that obtaining the necessary permits will be easy. Undoubtedly, there will be significant work to fill evolving gaps and to complete the necessary negotiations and permit applications to the satisfaction of all governmental and community stakeholders. While the Pilot Project is small in scale, there is no previous experience with permitting wind energy projects in the Great Lakes. This leaves open questions and processes to be refined as the Project moves forward.

Given that the Pilot Project is a "first of its kind", and as the regulators have requested, the Feasibility Study will be made available before any formal applications for permits are submitted. Collaborating with the regulators and working through the findings of the Feasibility Study prior to submission of permit applications will give the applications both the best chance for success and reduce the costs and time necessary to prepare applications.

While significant data gaps are not expected, there most likely will be some more work necessary to prepare completed applications for permits and approvals.

Working in this sequence with the regulators is important because the regulatory requirements applicable to the Pilot Project were still being developed while the Feasibility Study was underway and, to a certain extent, are still under development even now. For example, ODNR has developed a map of areas of Lake Erie that describes that agency's preliminary views of the ease or difficulty of siting offshore wind power projects in specific locations for purposes of issuance of submerged land leases (see Section 3.3). This tool, while helpful, is still preliminary and does not address all site-specific issues or stakeholders. Continued consultation with ODNR, other agencies, and various stakeholders will be required to jointly determine a process for responsibly siting wind energy facilities on Lake Erie. As the process evolves, in addition to gaps that may be identified following regulatory review, a number of important issues will need to be refined prior to submittal of formal applications.

Table 10-1: Applicable Regulatory Programs and Agencies

Potential Regulatory Programs for Wind Power on Lake Erie			
Permit/Authorization Name and Description	**Required Information**	**Expected Agency Review Time**	**Contact Information**
US Army Corps of Engineers Construction Permit (Section 10 and/or 404) – construction activities in lakes, rivers, streams, wetlands; 33 CFR 320 to 330 **KEY REGULATORY ISSUE ASSESSMENT PER NATIONAL ENVIRONMENTAL POLICY ACT**	❖ Design drawings for facility ❖ Purpose statements and description of overall project ❖ Permit application triggers need for environmental assessment or environmental impact statement—requiring information on existing environment, expected impacts and alternatives	2 to 18 months depending on permit type issued Potentially expedited for "pilot" project	United States Army Corps of Engineers (Buffalo District)
Water Quality Certificate- Section 401 of the CWA to be issued by Ohio EPA; triggered by application for U.S. Army Corps of Engineers Construction Permit (Section 404 only)	❖ Complete application ❖ Drawings for facility ❖ Description of overall project ❖ Delineation on wetland areas ❖ Information on existing environment, expected impacts and alternatives analysis	6 to 12 months	OEPA- Division of Surface Waters Randy Bournique 122 South Front Street P.O. Box 1049 Columbus, Ohio 43216-1049 Phone: 614.644.2013 http://www.epa.state.oh.us/dsw

Potential Regulatory Programs for Wind Power on Lake Erie			
Permit/Authorization Name and Description	**Required Information**	**Expected Agency Review Time**	**Contact Information**
Federal Endangered Species Consultation - issuance of COE Construction or NPDES permit if it has potential effects to federally threatened species or critical habitat; Section 10 (Exceptions) of the Endangered Species Act (ESA)	❖ Detailed biological assessment of potential impacts	Indeterminate	U.S. Fish and Wildlife Service Reynoldsburg Ecological Services Field Office 6950 American Parkway, Suite H Reynoldsburg, OH 43068-4127 614.469.6923 http://midwest.fws.gov/Reynoldsburg/
ODNR Division of Watercraft – this Division should be contacted for any proposed project that would potentially impact navigation on Lake Erie; the Division's focus includes boating safety, access, education, and law enforcement	❖ Project description ❖ Project location, with maps	Approximately 1 month (project specific)	ODNR- Division of Watercraft Chief, Division of Watercraft 2045 Morse Road A-2 Columbus, OH 43229-6693 Phone: 614.265.6480 http://www.dnr.state.oh.us/watercraft/
Ohio Power Siting Board (OPSB) Certificate- the OPSB is responsible for approving the construction of energy projects in Ohio, including electric generating facilities of at least 5 MWs, electric transmission lines of 125kV or greater and pipelines capable of transporting gas at pressures above 125 psi	**Pilot project will reach threshold under new Ohio House Bill 562**- Required filing information will vary according to the project and the type of filing (i.e., construction notice, letter of notification, application); details on required contents are included in the Ohio Administrative Code, Chapter 4906-17	Approximately 8 to 12 months for applications, expedited schedules may be an option for pilot projects	Ohio Power Siting Board 180 East Broad Street Columbus, OH 43215 Phone: 866.270.OPSB (6772) http://www.opsb.ohio.gov/

Potential Regulatory Programs for Wind Power on Lake Erie			
Permit/Authorization Name and Description	**Required Information**	**Expected Agency Review Time**	**Contact Information**
Consultation with the Office of Aviation and FAA (Ohio Department of Transportation)**-** consultation with the Office of Aviation can assure that the project does not introduce any safety issues for air traffic and potential FAA approval	❖ Project description ❖ Project location, including longitude and latitude readings ❖ Proposed structure heights ❖ Identification of nearby airports	Varies according to site and proximity to runway and landing patterns, but can be one of the most difficult to expedite	Ohio Department of Transportation- Office of Aviation 2829 West Dublin- Granville Road Columbus, OH 43235-2786 Phone: 614.793.5040 http://www.dot.state.us/Aviation/
ODNR Division of Natural Areas and Preserves- this Division should be contacted if the proposed project would be located on or would impact a State Scenic River, State Nature Preserve, or property owned by the Division; Division can provide information of presence or absence of rare and endangered species, scenic rivers, and state nature preserves within the vicinity of the proposed project	❖ Project description ❖ Project location, with maps ❖ Description of proposed structures ❖ Summary of construction activities ❖ Environmental/biologica l assessment	Approximately 1 month (project specific) – in concert with other ODNR review if necessary	ODNR- Division of Natural Areas and Preserves Chief, Division of Natural Areas and Preserves 2045 Morse Road F-1 Columbus, OH 43229-6693 Phone: 614.265.6543 http://www.dnr.state.oh.us/dnap/

Potential Regulatory Programs for Wind Power on Lake Erie			
Permit/Authorization Name and Description	**Required Information**	**Expected Agency Review Time**	**Contact Information**
ODNR Division of Wildlife- this Division would be involved with the review of any project that has potential impacts to wildlife and their habitat; compensatory mitigation may be required if projects impact rare or endangered animals, aquatic or terrestrial, in the state, compensation may be required if wildlife species are killed.	❖ Project description ❖ Project location, with maps ❖ Summary of construction activities ❖ Environmental/biological assessment ❖ Construction schedule ❖ Note evolving protocols and cooperative agreement for onshore projects	Bird and marine ecology issues will require significant time and attention	ODNR- Division of Wildlife Chief, Division of Wildlife 2045 Morse Road G-3 Columbus, OH 43229-6693 Phone: 614.265.6300 http://www.dnr.state.oh.us/wildlife/
ODNR Division of Geological Survey- this Division should be consulted with regards to suitability of the placement of structures and possible impacts to geological processes	❖ Project description ❖ Project location, with maps ❖ Description of proposed structures ❖ Summary of construction activities	Weather dependent re: ability to do test borings	ODNR- Division of Geological Survey Chief, Division of Geological Survey 2045 Morse Road C-4 Columbus, OH 43229-6693 Phone: 614.265.6576 http://www.dnr.state.oh.us/geosurvey/default.htm

Potential Regulatory Programs for Wind Power on Lake Erie			
Permit/Authorization Name and Description	**Required Information**	**Expected Agency Review Time**	**Contact Information**
Ohio Department of Natural Resources (ODNR) Office of Coastal Management- permits and other regulatory programs administered by this office include submerged land leases, state & Federal consistency, and shore structure permits.	❖ Wind Turbine Favorability Map issued ❖ New process for submerged land lease applications	Allow at least 6 months for responses and processing	ODNR- Office of Coastal Management Chief, Office of Coastal Management 105 W. Shoreline Drive Sandusky, OH 44870 Phone: 419.626.7980 http://www.dnr.state.oh.us/coastal/regs/default.htm
National Pollutant Discharge Elimination System (NPDES) Permit- Clean Water Act Section 402; Ohio Revised Code 6111.03(J); discharge of wastewater to surface waters; required prior to operation, recommend prior to construction	❖ Application Forms 1 and 2D with Antidegradation Addendum ❖ Water balance diagram ❖ Expected wastewater flows and characteristics ❖ Water pollution control equipment and systems	4 to 9 months	Ohio EPA- Division of Surface Waters District Offices http://www.epa.state.oh.us/dsw

11 Project Economics

11.1 Economic Assessment of the GLWEC

(Unless otherwise indicated, information in this section from the GLWEC Economic Assessment, Germanischer Lloyd, April 2009).

11.1.1 Introduction

This section provides an analysis of the costs associated with the Great Lakes Wind Energy Center (GLWEC) in Cuyahoga County, namely an offshore wind Pilot Project, a Test Center, a Research Center, and a Certification Center.

A total of 8 different Pilot Project scenarios were evaluated, which were combinations of the following sub-components:

- Wind farm size and turbine type:
  - Scenario 1 : 8 x 2.5 MW turbines, total 20 MW nominal capacity (Layout L1)
  - Scenario 2 : 3 x 5 MW turbines, total 15 MW capacity (Layout L7)
- Interconnection:
  - Scenario 1: Connection to the CEI Lakeshore Substation
  - Scenario 2 : Connection to the Cleveland Public Power Lake Road Substation
- Onshore facility
  - Scenario 1: 150 m2 storehouse and workshop
  - Scenario 2: 300 m2 storehouse and workshop

Additionally, this study also assesses the cost of three centers with the aim of promoting research on offshore wind energy technology, as well as certification services: a Test Center, a Research Center and a Certification Center. The estimates are prepared in cooperation with Helimax and based on scopes of facilities developed within the market research (see Section 9). All values are in 2008 US dollars, except when noted otherwise.

11.1.2 Pilot Project Costs

11.1.2.1 Considerations and Assumptions

This section will identify and provide details on the hypotheses and assumptions used for establishing the capital cost estimate for the different offshore wind farm scenarios (two (2) WTG power rating options), HV collector bus and cabling and connection-to-grid installations.

The budgetary cost estimates and prices provided were established based on the following literature:

- Senergy Econnect Consulting, Hexham UK: JUWI Lake Erie Offshore Wind Farm: HV Cabling system design, 09.19.2008 draft document and 05.11.2008 revision (final);
- Great Lakes Wind Energy Center Feasibility Study: Preliminary Site Review Report (GL and juwi, October 2008)
- Great Lakes Wind Energy Center Feasibility Study: Market Research (GL, November 2008)
- REpower Systems Inc., M. Seidel. D. Gosch: Technical challenges and their technical solutions for the Beatrice Wind Farm Demonstrator project in 45m water depth (reference), 2006;
- Final cable distances confirmation from juwi/JWGL: e-mail received Nov. 14, 2008. Attachment with the e-mail: table titled «Final Cabling Distances» confirming cable lengths to consider in the cost estimate
- Black and Veatch report (November 2008)

Unless otherwise expressed in the text or on the cost estimate spreadsheets and tables provided with the report, all costs are indicated in 2008 USD.

Since this project would be the first offshore wind farm in operation in North America, the most important difficulty arising in establishing an accurate cost estimate at this stage is that technology for fabrication and installation is mostly located in Europe. Companies, manufacturers or fabricators of major components dealing in this particular market were hesitant to provide prices, even budgetary with regards to the following questions:

- Costs for transportation and delivery of turbine and foundation components and subsea cables;
- Costs for installation in the USA and the state of Ohio;
- Fluctuations in currency exchange rates;
- Possibilities for sub-contracting part or all of the scope of supply;
- Workmanship and labor qualifications and availability in North America in offshore installations;
- Specifics in legal and insurances aspects to consider for North American operations.

However many European fabricators with high-level experience and knowledge in the offshore business have shown a strong interest in providing firm bid prices should this project be approved and enter conceptual design stage.

Balance of Plant (BOP) costs are included in the wind farm overall budget, i.e. costs for subsea and onshore cables, wind turbine installation and connections, connection to main grid, SCADA and onshore facilities construction for O&M.

At this stage of the project, the overall budget has a significant level of uncertainty considering the limited amount of engineering and site studies. For example, without at least preliminary geotechnical studies, topographic land and sea maps, subsea and onshore cable route layout, at this time it should be expected that the BOP costs will be refined and firmed up as the project advances.

11.1.2.2 Wind Turbines

While a number of turbine manufacturers were contacted, given the current market situation (end 2008) it was expected that getting prices from manufacturers would be a challenge. GL's experience and knowledge of offshore wind turbines was used to estimate the price for 2.5-MW turbines and 5-MW turbines.

Without the help of comparative data due to the absence of equivalent installations and works in North America, figures provided for shipping, harbor handling, and other logistics in the cost estimate were calculated based on similar works (i.e. for caissons and shoring) with provisions added for offshore work and transportation to site, including all materials, tooling and equipments. Figures for cargo barges and jack-up barge costs were provided by GL and are based on European data. Electrical work and commissioning were based on expert opinions from GL and Helimax engineers.

Our budgetary cost estimate for the wind farm construction has been performed using the following data, information and assumptions:

- All major equipments fabricated and delivered from Europe, f.o.b. Cleveland Harbor. Two (2) shipments only for WTG and foundation assemblies, i.e. one cargo load per Wind Farm configuration, have been assumed;
- Facilities for handling, loading, unloading and hauling WTG components (tower sections, nacelle, generators, gearboxes, blades, etc…) of sufficient capacity (depending on the chosen turbine type 100 to 260 tons) are available at Cleveland harbor; the Cleveland Port website indicates that they have cranes able to lift up to 200 tons; given that the heaviest component of the project would be approximately 65-70 tons, it is assumed that the Port facilities are adequately equipped.
- Facilities and spaces for storing WTG components between unloading and offshore installation are available at Cleveland harbor;

- Jack crane barge, cargo barges, cable laying vessels and all other marine equipments available in North America;
- Labor force, material and equipments for monopile caissons concrete mixing and filling available in the Cleveland area;
- Local labor force assumed for performing WTG and tower erection and on-site assembly with supervision from WTG fabricator personnel.

11.1.2.3 Monopile Foundations

Manufacturing, installation and connection costs were estimated based on correspondence with Bladt Industries, the only foundation supplier that responded to the Request for Budgetary Price (RFBP). Four other monopile foundation suppliers were contacted but did not respond to the request: Bilfinger Berger, Aker Kvaerner, Ballast Nedam. Smulders Group.

Without the help of comparative data due to the absence of equivalent installations and works in North America figures provided for shipping, harbor handling, etc. in the cost estimate were calculated based on similar works (i.e. for caissons and shoring) with provisions added for offshore work and transportation to site, including all materials, tooling and equipments. Figures for cargo barges and jack-up barge costs were provided by GL and area based on European data. Electrical work and commissioning were based on expert opinions from GL and Helimax engineers.

Regarding the offshore construction costs for monopile foundations, the information received from the manufacturer in order to establish an estimate was not complete. We therefore assumed the following construction method for cost estimation purposes, based on similar offshore works (i.e. oil rigs). These assumptions shall be revised accordingly further to project approval through conceptual and detailed design:

- Drilled steel caissons (one per monopile), 15m depth in seabed; 4800mm diameter for 2.5MW WTG and 6000mm diameter For 5MW WTG;

Based on correspondence with Bladt industries, an additional option was considered. Given that the Erie lakebed is clay it should be assumed that the monopiles would be filled with concrete:

- Concrete filled with reinforcement, concrete compression strength (fc') to be determined;
- Concrete to be mixed in mobile plant on barge (aggregates, cement, water and admixtures mixed in-situ);

- Includes shoring through driven steel sheets to support the walls of a trench and prevents caving in.
    - This option has to be investigated after geotechnical studies have been performed and give more information about the soil conditions.

Workmanship rates used for budgeting are union rates. Rates were considered the same as those in Europe: On average American hourly wages are higher than in Europe but fringe benefits are less. Productivity rates were considered to be equal.

11.1.2.4 Onshore Connection to Grid and Electrical Collector Bus

Of the seven cabling suppliers contacted for an RFBP (ABB, AEI, Nexans, NSW GmbH & Co., Prysmian, JDR Cable Systems, Scanrope Subsea AS), budgetary prices for supply, design and fabrication, F.O.B. Plant, were only received from JDR Cable System, Houston TX USA, for subsea and onshore HV and FO cable systems. The installation costs for the subsea collector cabling system were provided by GL and RSMeans Costworks software - Heavy Construction, ed.2008;

Regarding cable lengths and distances to consider in our cost estimate, we used the following:

- For inter array 2.5MW turbines 36kV cables: distance between turbine provided by juwi/JWGL on 11-14-2008 (document entitled “Final Cabling Distances”) is 384m.; 60m added for drops and risers assuming a 15m water depth, for a total of 444m in between turbines;
- For inter array 5MW turbines 36kV cables: distance between turbine provided by juwi/JWGL on 11-14-2008 (document entitled “Final Cabling Distances”) is 960m.; 90m added for drops and risers assuming a 15m water depth, for a total of 1050m in between turbines;
- Cable distances from wind farm to substation (2 scenarios) were provided by juwi/JWGL

The cable sizes and gauges in between turbines and outgoing to shore for connection-to-the-grid were taken from the Senergy Econnect report (Section 8.2).

We have assumed the following hypotheses for subsea and onshore HV (36kV) cables pulling and connection-to-the-grid, at this stage, in cost estimating the procurement and construction costs for the two alternatives proposed by GL/JUWI.

- No capacitor, DVAR or series compensation equipment included in the budgetary price. Only a protection study shall determine if compensation is required and its scope;

- Sufficient space available at both Cleveland Public Power HV station and Lakeshore Substation or implementing and construction of the necessary equipments for tie-in to grid (no yard enlargement);
- From the Black & Veatch report, we assumed at Cleveland Public Power/Lake Road substation, the supply, installation and pothead connections of a 3-phase 69kV cable between the new switchyard bus section connecting from the wind farm to the substation existing 69kV bus. The length of cable would be approximately 135m;
- Local labor force assumed for performing WTG and collector bus electrical components connections including 600V and 36kV cables terminations, transformers and generators;
- Cable layout assuming no drilling through the harbor wall;
- Soil bearing capacity for foundation design is assumed to be ≥100kPa (2000lbs/ft2);
- No piling assumed for foundation;
- No well-point system assumed for drainage during construction;
- For the Lakeshore Substation connection, two (2) 11kV feeders would be necessary for connection to the grid. A typical 11kV circuit will carry about 9 to 10MW of power. Both scenarios imply outputs of more than 10MW (15 and 20 respectively);
- Commissioning to be performed by manufacturers personnel for 36kV cables and terminations Hi-Pot and dielectric tests with assistance from local labor force;
- For SCADA connections and wind farm C & P, 36kV offshore and onshore cables include a sheath Fiber Optic cable inserted within insulation layers.

GL's opinion is that the connection should be made to the 69 kV high voltage (HV) transmission grid, not the 11kV low voltage (LV), primarily because of better reliability and possibilities of energy billing upon power rating factor, therefore a higher revenue output to the Owner. However, interconnection will depend mostly on negotiations with Cleveland Public Power or Cleveland Electric Illuminating / FirstEnergy regarding power offtake.

11.1.2.5 Engineering and Management Costs

At this stage in the project development cycle, engineering and construction management costs are usually assessed upon an overall percentage of the total project budget. For a project of this scope, the total related budget ranges between 5 and 6.5% of the total BOP costs, depending upon site conditions, labor availability, project duration, etc. Our estimate shows these costs to be 4.6 to 6.1% (without contingencies) of the BOP estimated capital costs, which is within acceptable range to the acknowledged value for this cost item at this stage.

11.1.2.6 Reserves and Contingencies

The Capital and BOP budget includes a 15% contingency of the total capital cost estimate. The percentage allowed for contingencies shall decrease with conceptual and detailed design and scope of work being more specifically defined.

11.1.3 Estimated Total Project Costs

The summary of the capital costs is presented in Table 11-1 below. For completeness, it is important to note that the costs for the onshore facility (discussed in the following section) are included. For detailed costing tables of the two project scenarios refer to Appendix A of the GLWEC Economic Assessment. It should be mentioned once again that the total project cost estimates include a 15% contingency.

Table 11-1: Summary of Pilot Project Estimated Costs

	8 x 2.5-MW turbines (L1)	3 x 5-MW turbines (L7)
Connection to CPP - 150m2 onshore facility		
Turbines	$38,473,159	$36,205,949
Balance of plant	$50,998,899	$40,152,438
Onshore facility	$1,947,916	$1,947,916
Total	**$91,419,974**	**$78,306,303**
Connection to CPP - 300m2 onshore facility		
Turbines	$38,473,159	$36,205,949
Balance of plant	$50,998,899	$40,152,438
Onshore facility	$3,179,249	$3,179,249
Total	**$92,651,307**	**$79,537,636**
Connection to Lakeshore SS - 150m2 onshore facility		
Turbines	$38,473,159	$36,205,949
Balance of plant	$50,344,367	$39,046,452
Onshore facility	$1,947,916	$1,947,916
Total	**$90,765,442**	**$77,200,317**
Connection to Lakeshore SS - 300m2 onshore facility		
Turbines	$38,473,159	$36,205,949
Balance of plant	$50,344,367	$39,046,452
Onshore facility	$3,179,249	$3,179,249
Total	**$91,996,775**	**$78,431,650**
Approximate cost per MW installed	**4.6 M$**	**5.2 M$**

As depicted, the total project cost for the L1 scenario is in the range of 91-93 M$, suggesting a per MW cost of approximately 4.6 M$. The total project cost for the L7 scenario is in the range of 77-80 M$, suggesting a per MW cost of approximately 5.2 M$.

For comparative purposes, Helimax (2008) estimated that a large-scale offshore project in the Great Lakes (in Canada) would range between 3.5 and 4.5 M$CA/MW (2.78 and 3.57 M$US/ MW), without interconnection costs. Providing a precise cost at this stage remains a challenge given the possible fluctuations in BOP and turbine costs.

For information related to potential revenue from the Pilot Project, and funding and financing options, see Section 11.2.

11.1.4 Estimated O&M Costs

The O&M budget depends on a range of variables such as the type of technology, location of the site, distance to port, local meteorological conditions, the statistical long-term failure rates of major components, the cost to repair or replace these components, labor costs, the number of repair crews, the type and number of vessels available to access the site, as well the type of O&M program implemented by the project proponent. According to our review of several wind farm projects and various cost analyses, the median cost values of an offshore wind farm between 200 and 300 MW, located within 20 km from the shore in Europe, would range between 2.5 ¢/kWh and 4 ¢/kWh.

Seeing the small size of the Pilot project which will entail higher fixed costs, longer break-in period by using turbine technology without offshore track record and greater maintenance, the O&M costs are expected to be significantly higher. Thus the cost range for the 2.5-MW turbine is 7.90 to 8.25 ¢/kWh and 6.34 to 6.61 ¢/kWh for the 5-MW turbine (2008 US$). These numbers are based on GLIS' O&M tool and take into account the energy production of the two wind farms. See Appendix E of the GLWEC Economic Assessment for more detail on the O&M cost divided by preventive maintenance, corrective maintenance, administration, and other cost. For the preventive and corrective maintenance costs are divided into expenses for service and construction vessels ("equipment cost"), spare parts ("material cost") and for personnel ("labor cost"). The O&M cost calculation consists of the expenses for preventive maintenance, corrective maintenance and additional costs like environmental impact assessment, land fees, and administration cost. The preventive and corrective maintenance costs are calculated on the basis of failure rates for the main components of the wind turbine and represent the average cost per annum accounted over the full life time of the project. These failure rates are based on the operational data of smaller turbine types than designed in this pilot project. Therefore the failure occurrences assumed in this report are conservative with regards to the applied learning curve and better performance of the new turbine generations. Cost driving factors of small offshore wind pilot projects are the absence of a stock for larger components, which leads by failure occurrence to long waiting periods, and the comparable high costs for the administration and O&M equipment which can be reduced due to the economies of scale for larger offshore wind farms. In addition the limited turbine access during the lake icing period and the occurrence of rotor blade icing lead to larger down times and lower energy yields.

Table 11-2 presents the estimated O&M costs for each project assuming an inflation rate of 2.5%, a start of operation in 2010 and a project duration of 20 years. The average actualized cost in the last column represents the average of costs for every year, on the 20-year lifespan, in 2010 US dollars. It should be noted that these cost include expenses associated with the onshore O&M facility.

Table 11-2: Estimated O&M Costs for the Pilot Project Scenarios

Scenario	Energy yield for wind farm [MWh/year]	Estimated O&M cost [2008 cents/kWh]	Average actualized O&M cost [2010 US$]
L1 (8 x 2.5-MW Turbine)	55,254	7.9	4,590,000
L7 (3 x 5.0-MW Turbine)	39,595	6.4	2,660,000

11.1.5 Recommended Scope of Onshore Support Facilities

In discussions concerning construction of the Pilot Project, it is necessary to consider the support facility onshore (Maintenance and O&M building). This consideration includes the needs of different facilities and equipment as well as the staff required to guarantee the efficient and smoothly running of the Pilot Project. The required facilities, staff and equipment are described in Section 9.2.3 of this report.

11.1.6 Estimated Costs for Construction of Onshore Facilities

11.1.6.1 Assumptions

The onshore facilities building layouts are provided in Appendix B of the GLWEC Economic Assessment. They were conceived and designed based on the scope defined in Section 9.2.3.

The main objectives in producing the onshore facilities building draft layouts (interior and property) and section views were to:

1. Provide a physical layout to demonstrate what the building, the property and the external features would possibly be like;

2. Provide a basis for cost estimating the facilities;

3. Initiate and gather comments from the Client regarding room layout, plan views, finishes, landscaping and exterior features then make required adjustments at design stage.

With regards to the layouts and conceptual design provided with the present report, the establishment of our cost estimate integrates the following assumptions:

- Onshore facilities building assumed to be built less than 1mile (1.6km) away from 34.5kV offshore cable landing point;
- Costs for onshore facilities building property acquisition not included in the cost estimate, as this will depend heavily on local negotiations; Minimum property size estimated to be approximately 3.5 acres.
- Soil bearing capacity for concrete foundation design is assumed to be ≥100kPa (2000lbs/ft2);
- No well-point system assumed for drainage during construction;
- The option for a 300m2 storehouse/workshop – i.e. wind farm major components maintenance performed on site – includes all costs related to the installation of a 25-ton bridge crane for equipment handling, including the required additions in the building structure, steel and concrete foundations;
- Structure for the bridge crane (option 1) includes piles for columns. Piles are assumed to be driven at a depth ≤ to 15m (50ft);
- The option for a 150m2 storehouse/workshop – i.e. wind farm major components maintenance not being performed on site – does not include a bridge crane for equipment handling;
- The amount shown for contaminated soils remediation is provisional;
- No entrance gate or security system has been assumed except for facilities to accommodate the use of a security key card system. A closed-circuit TV system for property surveillance has been assumed.

11.1.6.2 Estimated Cost

As indicated above, the cost of the onshore facility (for O&M and operations of the wind farm) were included in the total project cost, and is estimated at 3.18 M$ for the 300 m2 storehouse and 25-tonne bridge crane option, and at 1.95 M$ for the 150 m2 storehouse option. Detailed breakdowns of the 2 onshore facility options, as well as the breakdown of equipment costs, are found in Appendix C of the GLWEC Economic Assessment.

It should be noted that these costs do not include the facilities for the test, certification and research centers, which are discussed below. These facilities, should they be included in this Pilot Project initiative, would be added to this main onshore facility. Costs for each of these centers are provided below.

11.1.6.3 Estimated O&M Cost for the Onshore Support Facilities

As indicated above, the O&M costs for the onshore facility is included in the general O&M cost for the Pilot Project.

11.1.7 Test Center

11.1.7.1 Recommended Scope of Test Center

The potential scope of the Test Center is described in Section 9.3.2. It is assumed that the Test Center focuses mainly on activities such as prototype testing, especially with regard to an offshore Pilot Project, testing of condition monitoring systems, measurement of environmental conditions, calibration of test equipment and site assessment.

11.1.7.2 Construction Costs

The estimation of the test center's construction costs assumed that one single facility would host the onshore O&M facility, as well as the test, certification and research centers. This was considered the most logical approach, for practical reasons and to reduce costs associated with land acquisition and building.

In total the combined onshore facility has an estimated construction cost of $15.7M, including the largest storehouse scenario in Section 11.1.5 (300 m2) which is responsible for approximately 18 % of the cost, or $2.8M. It should be noted that this "revised" cost for the O&M facility is smaller than the cost presented in Section 11.1.5, but this was expected as some construction costs are shared between the 4 uses of the combined facility. A detailed cost breakdown, based on a set of assumptions, is presented in Appendix D of the GLWEC Economic Assessment.

Based on this overall cost for the combined onshore facility, it is estimated that the Test Center represents approximately 58% of the construction costs, or $9.17M.

It should be noted that the Test Center scenario includes a large testing cell that adds significant costs, as a second bridge crane would be needed and extra storehouse space, increasing the size of the facility. The addition of a test center increases the facility size by approximately 500 m2.

11.1.7.3 Equipment Costs

Needs in equipment for the test Center will vary greatly with the type and extent of research performed at the site or on other offshore sites. Given that the exact scope for the Center has not yet been defined, estimated equipment costs for each of the main test Center's activities are provided. These costs are based on GL/Helimax experience with similar testing packages, and cost can vary greatly depending on how many units are needed, and the extent of testing (e.g. on one or several turbines, etc.). The cost for the equipment is presented in Table 11-3. The actual cost of the equipment to be purchased can vary significantly depending on the quality of the products selected as well as the exact features required.

Table 11-3: Estimated Equipment Costs for Test Center

Equipment	Details	No.	Estimated Price per Unit	Total
Furniture	Work desks	12	$1 500	$18 000
	Chairs	12	$250	$3 000
	Cabinets	12	$500	$6 000
Office equipment	Server	1	$25 000	$25 000
	Desktops	12	$1 300	$15 600
	Notebooks	6	$1 600	$9 600
	Printer	1	$4 000	$4 000
	Telephone System	12	$200	$2 400
	PDA's / Mobile Phone	6	$250	$1 500
	Documentation Signets & Signed	12	$100	$1 200
			TOTAL	**$86 300**
TESTING EQUIPMENT (cost examples)				
Offshore Pilot Project	LVRT-tester/electrical test equipment			$500 000
	Acoustical emission instruments			$30 000
Condition Monitoring System (CMS)	Oil particles counter			$5 000
	Borescope			$50 000
	On-line vibration monitoring system- Install sensor on all drive train components with network connection			$15 000
Measurement of environmental conditions	Onshore met mast - installed			$100 000
	Offshore met mast - installed			$3 000 000
	Weather/wave buoy			$70 000
	System for ice detection			$60 000
	Lidar			$300 000
	Sodar			$50 000

11.1.7.4 Estimated Operating Revenue and Operating Expenses from Test Center

The revenue and expenses from a Test Center will depend greatly on the following variables:

- Interest from the market, the potential for which is discussed in Section 9.3.2 and Section 9.6.2.

- Attracting competent resources. The success of the Test Center will depend on the quality of the business and technical resources that are attracted to staff the center. Considering the wind power industry growth rates, there are relatively few people resources available in the market, and thus hiring the appropriate staff with the necessary experience might be a challenge.
- Reputation and branding. The success of the Test Center will depend on its ability to obtain appropriate accreditation and develop a successful reputation. In order to penetrate the market more quickly, it might be valuable to align itself with the reputation of another established organization. A Test Center with a strong results-driven reputation will, over time, attract a larger clientele thereby improving the profitability of the research Center itself.
- Equipment and solutions. In order to attract a clientele, the Test Center will require leading edge equipment and facilities to provide an efficient place to perform various types of tests.

11.1.7.5 Operating Revenue

Within the context of the uncertainties described context, GL/Helimax has made the following assumptions regarding the potential revenue of the Test Center:

- The only source of revenue is the invoicing of the personnel at the Center. A non-negligible amount of revenue would likely be generated from renting the specialized equipment and space at the facility. Seeing as though the potential revenue from renting this equipment is currently unknown, no income from this source has been accounted for.
- The assumptions for the salaries of the personnel at the Certification Center are presented in Table 11-4. The salaries presented are indicative of competitive salaries for potential profiles of people that could be expected to be hired to staff the facility. Depending on the exact profile of the people hired, these salaries could be higher or lower than those assumed in the present analysis. It was assumed that the resources are local (i.e. no ex-pat salaries).
- Expected billable rates have been determined for all of the positions based on experience building a company and realistic targets. The percentage billable rates increase from year 1 to year 5 as the reputation of the facility grows. For all of the positions, the targeted billable rates range between 15% in Year 1 and 65% in Year 5. Depending on the interest from the market, the amount of competition, and the success of the Center, the actual billable rates could in fact be higher or lower.
- Grants and subsidies have not been considered.

Table 11-4: Assumptions Salary and Hourly Rate for Personnel – Test Center (Nominal 2009 $)

	Number	Annual Salary	Hourly Charge Out Rate	Percentage Billable - Year 1	Percentage Billable - Year 2	Percentage Billable - Year 3	Percentage Billable - Year 4	Percentage Billable - Year 5
Engineer/Scientist	4,0	$ 70.000	125	15%	30%	50%	65%	65%
Technician	2	$ 45.000	80	15%	30%	50%	65%	65%
Student	2	$ 30.000	40	15%	30%	50%	65%	65%
Total	**8**	**$ 430.000**						

11.1.7.6 Operating Costs

The operating costs for the Test Center are a combination of salaries and overhead costs. The number of employees and their salaries are defined in Table 11-4. The overhead costs include such things are heating, electricity, communication, compensation, and building costs. Until a more exact budget can be determined, operating costs might be assumed to be 50% of the total salaries. Due to the amount of specialized equipment that must be maintained, the overhead might in fact be higher than 50% of the salaries.

11.1.7.7 Operating Profits

Based on the assumptions described above, possible operating profits from the Test Center are presented in Table 11-5. Based on the operating revenue and costs assumptions, the Test Center could be turning an operating profit in Year 3.

Table 11-5: Possible Operating Profits – Test Center (Nominal $2009)

	Year 1	Year 2	Year 3	Year 4	Year 5
Possible Operating Revenue	$ 222 000	$ 444 000	$ 740 000	$ 962 000	$ 962 000
Possible Operating Expenses					
Salaries	$ 430 000	$ 430 000	$ 430 000	$ 430 000	$ 430 000
Overhead	215 000,0	215 000,0	215 000,0	215 000,0	215 000,0
Total	$ 645 000	$ 645 000	$ 645 000	$ 645 000	$ 645 000
Possible Operating Profit	-$ 423 000	-$ 201 000	$ 95 000	$ 317 000	$ 317 000

11.1.8 Certification Center

11.1.8.1 Recommended Scope of Certification Center

Section 9.4.2 describes the estimated resources and facilities for a potential Certification Center. This includes consideration of the required building and rooms, equipment for certification and inspections and, finally, personnel.

11.1.8.2 Construction Costs

The estimation of construction costs for the Certification Center assumed that one single facility would host the onshore facility, as well as the test, certification and research centers. This was considered the most logical approach, for practical reasons and to reduce costs associated with land acquisition and building costs.

In total the combined onshore facility has an estimated construction cost of $15.7M, based on the largest storehouse scenario in Section 11.1.5 (300 m2) which is responsible for approximately 18 % of the cost, or $2.8M. It should be noted that this “revised” cost for the O&M facility is smaller than the cost presented in Section 11.1.5, but this was expected as some construction costs are shared between the 4 uses of the combined facility. A detailed cost breakdown, based on a set of assumptions, is presented in Appendix D of the GLWEC Economic Assessment.

Based on this overall cost for the combined onshore facility, it is estimated that the Certification Center represents approximately 13% of the construction costs, or $2.05M.

11.1.8.3 Equipment Costs

Based on the equipment expected at the Certification Center, the cost for the equipment is presented in Table 11-6. The actual cost of the equipment to be purchased can vary significantly depending on the quality of the products selected as well as the exact features required.

Table 11-6: Cost for Office Equipment at the Certification Facility

No.	Equipment	Details	No.	Price per Unit	Total
1	Furniture	Work desks	16	$1,500	$24,000
		chairs	16	$250	$4,000
		shelves	16	$500	$8,000
2	Office equipment	Server and network (Intranet)	1	$25,000	$25,000
		Desktops	16	$1,300	$20,800
		Notebooks	4	$1,600	$6,400
		Printer	3	$4,000	$12,000
		Telephone System	16	$200	$3,200
		PDA's / Mobile Phone	4	$250	$1,000
		Documentation Signets & Signed	4	$100	$400
3	Inspections	Personal safety equipment	n.a.		
		Video endoscope, digital camera, thought-book	n.a.		
4	Software	Bladed	2	$40,000	$80,000
		Structure Analysis (FEM)	4	$40,000	$160,000
		Load Analysis	4	$40,000	$160,000
		Microsoft Office	16	$500	$8,000
		Administrative/Financial software	n.a.		
				TOTAL	$512,800

11.1.8.4 Estimated Operating Revenue and Operating Expenses for a Certification Center

The revenue and expenses from a Certification Center will depend greatly on the following variables:

- Interest from the market, the potential for which is discussed in Section 9.4 and Section 9.6.3.
- Attracting competent resources. The success of the Certification Center will depend on the quality of the business and technical resources that are attracted to staff the

center. Considering the wind power industry growth rates, there are relatively few human resources available in the market, and thus hiring the appropriate staff with the necessary experience might be a challenge.

- Reputation and branding. The success of the Certification Center will depend on its ability to obtain appropriate accreditation and develop a successful reputation. In order to penetrate the market more quickly, it might be valuable to align itself with the reputation of another established certification organization. A Certification Center with a strong results-driven reputation will, over time, attract a larger clientele thereby improving the profitability of the research Center itself.
- Equipment and solutions. In order to attract a clientele, the Certification Center will require leading edge equipment and facilities to provide an attractive place where to innovate and develop new solutions.

11.1.8.5 Operating Revenue

Within the context of the uncertainties described context, Helimax has made the following assumptions regarding the potential revenue of the Certification Center:

- The only source of revenue is the invoicing of the personnel at the Center.
- The assumptions for the salaries of the personnel at the Certification Center are presented in Table 11-7. The salaries presented are indicative of competitive salaries for potential profiles of people that could be expected to be hired to staff the facility. Depending on the exact profile of the people hired, these salaries could be higher or lower than the actual. It was assumed that the resources are local (i.e. no ex-pat salaries).
- Expected billable rates have been determined for all of the positions based on experience building a company and realistic targets. The percentage billable rates increase from year 1 to year 5 as the reputation of the facility grows. For all of the positions, the targeted billable rates range between 15% in Year 1 and 65% in Year 5. Depending on the interest from the market, the amount of competition, and the success of the Center, the actual billable rates could in fact be higher or lower.
- Grants and subsidies have not been considered.

Table 11-7: Assumptions Salary and Hourly Rate for Personnel - Certification Center (Nominal $2009)

	Number	Annual Salary		Hourly Charge Out Rate	Percentage Billable - Year 1	Percentage Billable - Year 2	Percentage Billable - Year 3	Percentage Billable - Year 4	Percentage Billable - Year 5
Business Manager	1	$	120.000	220	15%	30%	50%	65%	65%
Team Assistant	2	$	45.000	80	15%	30%	50%	65%	65%
Head of departments / Project Manager	2	$	90.000	165	15%	30%	50%	65%	65%
Mechanical Engineer	3,5	$	70.000	125	15%	30%	50%	65%	65%
Electronic Engineer	1	$	70.000	125	15%	30%	50%	65%	65%
Electrical Engineer	1	$	70.000	125	15%	30%	50%	65%	65%
Construction and Structure Engineer	3,5	$	70.000	125	15%	30%	50%	65%	65%
IT-Specialist	1	$	45.000	80	15%	30%	50%	65%	65%
Total	**15**	**$**	**1.065.000**						

11.1.8.6 Operating Costs

The operating costs for the Certification Center are a combination of salaries and overhead costs. The number of employees and their salaries are defined in Table 11-7. The overhead costs include such things are heating, electricity, communication, compensation, and building costs. Until a more exact budget can be determined, operating costs might be assumed to be 50% of the total salaries.

11.1.8.7 Operating Profits

Based on the assumptions described above, the operating profits from the Certification Center would be as presented in Table 11-8. Based on the operating revenue and costs assumptions, the Certification Center could be turning an operating profit in Year 2.

Table 11-8: Possible Operating Profits - Certification Center (Nominal $2009)

	Year 1	Year 2	Year 3	Year 4	Year 5
Possible Operating Revenue	$ 574 500	$ 1 149 000	$ 1 915 000	$ 2 489 500	$ 2 489 500
Possible Operating Expenses					
Salaries	$ 580 000	$ 580 000	$ 580 000	$ 580 000	$ 580 000
Overhead	290 000	290 000	290 000	290 000	290 000
Total	$ 870 000	$ 870 000	$ 870 000	$ 870 000	$ 870 000
Possible Operating Profit	-$ 295 500	$ 279 000	$ 1 045 000	$ 1 619 500	$ 1 619 500

11.1.9 Research Center

11.1.9.1 Recommended Scope of Research Center

The scope of a potential Research Center is described in Section 9.5.4. In order to propose how to form a permanent research center, the structure of the center was analyzed differentiating between research priorities, different facilities and equipment as well as the staff.

11.1.9.2 Construction Costs

The estimation of the construction costs of the research Center assumed that one single facility would host the onshore facility, as well as the test, certification and research centers. This was considered the most logical approach, for practical reasons and to reduce costs associated with land acquisition and building costs.

In total the combined onshore facility has an estimated construction cost of $15.7M, based on the largest storehouse scenario in Section 11.1.5 (300 m2) which is responsible for approximately 18 % of the cost, or $2.8M. It should be noted that this “revised” cost for the O&M facility is smaller than the cost presented in Section 11.1.5, but this was expected as some construction costs are shared between the 4 uses of the combined facility. A detailed cost breakdown, based on a set of assumptions, is presented in Appendix D of the GLWEC Economic Assessment.

Based on this overall cost for the combined onshore facility, it is estimated that the research Center represents approximately 11% of the construction costs, or $1.72M.

11.1.9.3 Equipment Costs

Based on the equipment expected at the Research Center, the cost for the equipment is presented in Table 11-9. The actual cost of the equipment to be purchased can vary significantly depending on the quality of the products selected as well as the exact features required.

Table 11-9: Cost for Office Equipment at the Research Center

No.	Equipment	Details	No.	Price per Unit	Total
1	Furniture	Work desks	29	$1,500	$43,500
		chairs	35	$250	$8,750
		shelves	27	$500	$13,500
2	Office equipment	Server and network (Intranet)	1	$25,000	$25,000
		Desktops	12	$1,300	$15,600
		Laptops	13	$1,600	$20,800
		Printer (2 b/w and 1 color laser)	3	$4,000	$12,000
		Phones	30	$200	$6,000
		Mobile Phones	6	$250	$1,500
		PDA’s	2	$500	$1,000
		Xerox machines	1	$1,400	$1,400
		Office supplies	n.a.		
3	Software	Operating system (licenses)	25	$600	$15,000
		Server software	1	$10,000	$10,000
		Office software (licenses)	25	$500	$12,500
		Structure Analysis	n.a.		
		Load Analysis	n.a.		
		Simulation and numerical computing software	n.a.		
		Lab Workbench	n.a.		
		ERP	25	$10,000	$250,000
		Financial software	1	$2,000	$2,000
3	Lab Equipment	Test rig for electrical devices	3	$10,000	$30,000
		Work Bench	2	$500	$1,000
		Tools	n.a.		
		Materials	n.a.		
				TOTAL	$469,550

11.1.9.4 Estimated Operating Revenue and Operating Expenses for a Research Center

The revenue and expenses from a research center will depend greatly on the following variables:

- Interest from the market, which is discussed in Section 9.5.4 and Section 9.6.4.
- Attracting competent resources. The success of the Research Center will depend on the quality of the business and technical resources that are attracted to staff the center. Considering the wind power industry growth rates, there are relatively few people resources available in the market, and thus hiring the appropriate staff with the necessary experience might be a challenge.
- Reputation and branding. The success of the Research Center will depend on its ability to produce results, thereby garnering a reputation for success. In order to penetrate the market more quickly, it might be valuable to align itself with the reputation of another established organization. A Research Center with a strong results-driven reputation will, over time, attract a larger clientele thereby improving the profitability of the research Center itself.
- Equipment and solutions. In order to attract a clientele, the Research Center will require leading edge equipment and facilities to provide an attractive place where to innovate and develop new solutions.
- Confidentiality and conflict of interest. The market is very concerned about maintaining its competitive advantage and ensuring secrecy with regards to its proprietary technology, methodologies, procedures, copyrights, etc. As such, the ability to maintain confidentiality and an absence of any conflict of interest will be paramount to ensure the target audience is comfortable using the Research Center. An operational procedure should be implemented to ensure complete confidentiality for the clientele. Moreover, the focus on confidentiality should be clearly stated in the mission statement.

11.1.9.5 Operating Revenue

Within the context of the uncertainties described context, GL/Helimax has made the following assumptions regarding the potential revenue of the Research Center:

- It was assumed that the only source of revenue is the invoicing of the personnel at the Center. While it might also be possible to invoice based on space rented, computer time, or a fixed rates, these sources of revenue were not considered.
- The assumptions for the salaries of the personnel at the Certification Center are presented in Table 11-10. The salaries presented are indicative of competitive salaries for potential profiles of people that could be expected to be hired to staff the facility. Depending on the exact profile of the people hired, these salaries could be higher or lower than the actual. It was assumed that the resources are local (i.e. no ex-pat salaries).

- Expected billable rates have been determined for all of the positions based on experience building a company and realistic targets. Generally, the percentage billable rate increases from year 1 to year 5 as the reputation of the facility grows. For most of the positions, the targeted billable rates range between 15% in Year 1 and 65% in Year 5. There are three exceptions, that for the business manager, the secretary and the concierge. As these three positions are not defined to be revenue generating positions but rather support roles, the percentage billable hours is lower. Depending on the interest from the market, the amount of competition, and the success of the Center, the actual billable rates could in fact be higher or lower.

- Grants and subsidies have not been considered.

Table 11-10: Assumptions Salary and Hourly Rate for Personnel - Research Center (Nominal $2009)

	Number	Annual Salary		Hourly Charge-Out Rate	Percentage Billable - Year 1	Percentage Billable - Year 2	Percentage Billable - Year 3	Percentage Billable - Year 4	Percentage Billable - Year 5
Business Manager	1	$	120.000	220	15%	15%	15%	15%	15%
Head of departments	1	$	90.000	165	15%	30%	50%	65%	65%
Researchers	11	$	70.000	125	15%	30%	50%	65%	65%
Technicians	2	$	55.000	95	15%	30%	50%	65%	65%
Secretary	1	$	40.000	45	5%	10%	15%	30%	30%
Team Assistant	2	$	45.000	80	15%	30%	50%	65%	65%
Financial accounting and controlling	1	$	65.000	120	15%	30%	50%	65%	65%
Knowledge based management	1	$	65.000	120	15%	30%	50%	65%	65%
IT - Expert	2	$	45.000	80	15%	30%	50%	65%	65%
Human ressouces	1	$	50.000	90	15%	30%	50%	65%	65%
Materials management and purchase	1	$	45.000	80	15%	30%	50%	65%	65%
Facility manager	1	$	60.000	110	15%	30%	50%	65%	65%
Concierge	1	$	40.000						
Total	**26**	**$**	**1.635.000**						

11.1.9.6 Operating Costs

The operating costs for the Research Center are a combination of salaries and overhead costs. The number of employees and their salaries are defined in Table 11-10. The overhead costs include such things are heating, electricity, communication, compensation, and building costs. Until a more exact budget can be determined, operating costs might be assumed to be 50% of the total salaries.

11.1.9.7 Operating Profits

Based on the assumptions described above, the operating profits from the research Center would be as presented in Table 11-11. Based on the operating revenue and costs assumptions, the Research Center could be turning an operating profit in Year 3.

Table 11-11: Possible Operating Profits - Research Center (Nominal $2009)

	Year 1		Year 2		Year 3		Year 4		Year 5	
Possible Operating Revenue	$	841 500	$	1 617 000	$	2 649 500	$	3 434 000	$	3 434 000
Possible Operating Expenses										
Salaries	$	1 635 000	$	1 635 000	$	1 635 000	$	1 635 000	$	1 635 000
Overhead		817 500,0		817 500,0		817 500,0		817 500,0		817 500,0
Total	$	2 452 500	$	2 452 500	$	2 452 500	$	2 452 500	$	2 452 500
Possible Operating Profit	-$	1 611 000	-$	835 500	$	197 000	$	981 500	$	981 500

11.1.10 Conclusions: GLWEC Cost Assessment

This section has assessed the cost of constructing an offshore wind energy pilot project, as well as its associated facilities, given a set of assumptions on equipment cost, turbine type, facility sizes, etc. While several contacts were made with equipment suppliers, it is important to note that few have responded and that this cost assessment will need to be validated once a more specific pilot project is presented. Site visits would also be needed to confirm costs of building such a project.

Additionally, this study assessed the cost of three centers with the aim of promoting research on offshore wind energy technology, as well as certification services: a test center, a research center and a certification center. Once again, this cost assessment was based on a set of assumptions that will need to be verified. Revenue streams for these facilities (especially the test and research center) will also need to be investigated further, as a follow-up to preliminary market potential analysis discussed in Section 9.

Table 11-12 summarizes the cost findings of this economic assessment. A line item breakdown of cost estimates can be found in the Appendices of the GLWEC Economic Assessment.

Table 11-12: Summary of GLWEC Cost Estimates

	8 x 2.5-MW turbines (L1)	3 x 5-MW turbines (L7)
TOTAL PROJECT COST		
Connection to CPP - 150m2 onshore facility	$91,419,974	$78,306,303
Connection to CPP - 300m2 onshore facility	$92,651,307	$79,537,636
Connection to Lakeshore SS - 150m2 onshore facility	$90,765,442	$77,200,317
Connection to Lakeshore SS - 300m2 onshore facility	$91,996,775	$78,431,650
O&M COSTS	$4,590,000	$2,660,000
COMBINED O&M, TEST/RESEARCH/CERTIFICATION CENTER COST	$15,745,000,	
O&M facility sub-cost	*$2,800,000*	
Test Center sub-cost	*$9,173,000*	
Research Center sub-cost	*$1,722,000*	
Certification Center sub-cost	*$2,050,000*	

11.2 Pilot Project Funding and Financing Options

(Unless otherwise indicated, information in this section from the GLWEC Funding and Financing Options Report, juwi, April 2009).

11.2.1 Introduction

Following capital and operating cost estimates of Germanischer Lloyd, juwi has identified key funding and financing considerations for the Pilot Project. Project economics are presented for Pilot Project scenarios, and sensitivity analysis is used to demonstrate the relative importance of energy production, capital and operating costs, debt structure, debt interest, tax and other incentives, and power purchase price. Key provisions of the 2009 American Recovery and Reinvestment Tax Act (Stimulus Bill) are included for consideration. Historical and forecasted regional electricity prices are presented to provide context for power purchase agreement (PPA) pricing.

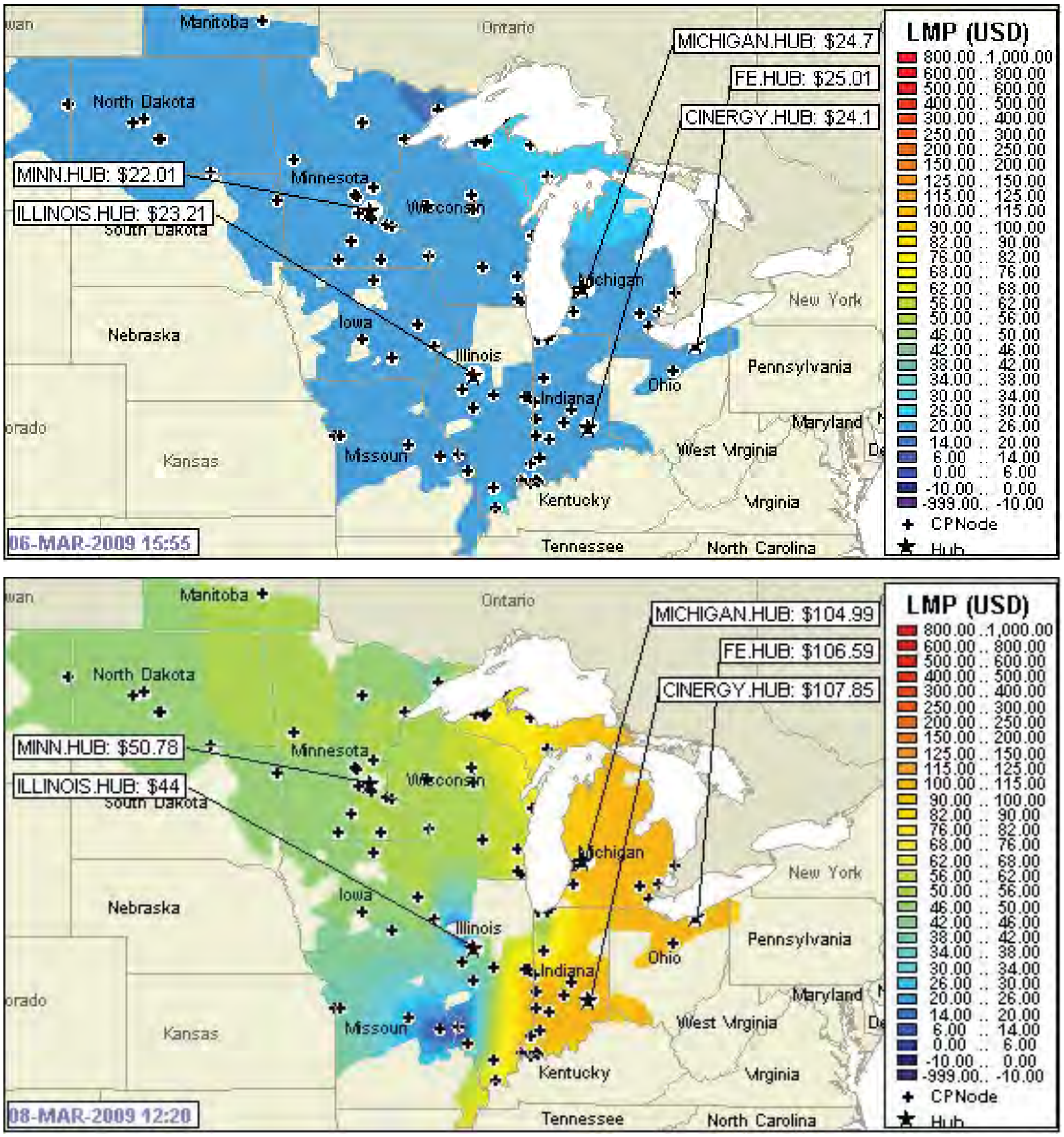
11.2.2 Electricity Market

On May 1, 2008, Governor Ted Strickland signed Senate Bill 221 into law, establishing an Alternative Energy Portfolio Standard (AEPS) for the state of Ohio. The law mandates that by 2025, at least 25 percent of all electricity sold in the state come from alternative energy resources. At least half of the standard, or 12.5 percent of electricity sold, must be generated by renewable sources such as wind, solar, hydropower, geothermal, or biomass. At least half of this renewable energy must be generated in-state. The AEPS applies only to Ohio's Investor Owned Utilities. While municipal power systems and rural electric cooperatives may opt to purchase from renewable sources, they are not mandated by the AEPS. Electricity generated from offshore wind turbines in Ohio waters would qualify for both the renewable and in-state provisions under Ohio's AEPS.

Cleveland is located in a region covered by the Midwest Independent System Operator (MISO) market. Local utilities that provide electric service are Cleveland Public Power (a member of American Municipal Power-Ohio) and Cleveland Electric Illuminating (a FirstEnergy company). In this market, the Pilot Project has two primary options for selling electricity: the Project may sell the energy directly into the wholesale market and take the clearing price, or the Project may negotiate a power purchase agreement (PPA) with a local utility or other offtaker.

Certain wholesale electricity prices are subject to short-term volatility and change on an hourly basis. Within MISO, financial transactions take place at various commercial pricing nodes, and are aggregated at regional hubs, where locational marginal pricing (LMP) is recorded in real time (see Figure 11-1).

Figure 11-1: MISO Territory and Hub Locations, Two Real-Time Pricing Scenarios (in $/MWh)



Source: http://www.midwestiso.org/page/LMP+Contour+Map+(EOR)

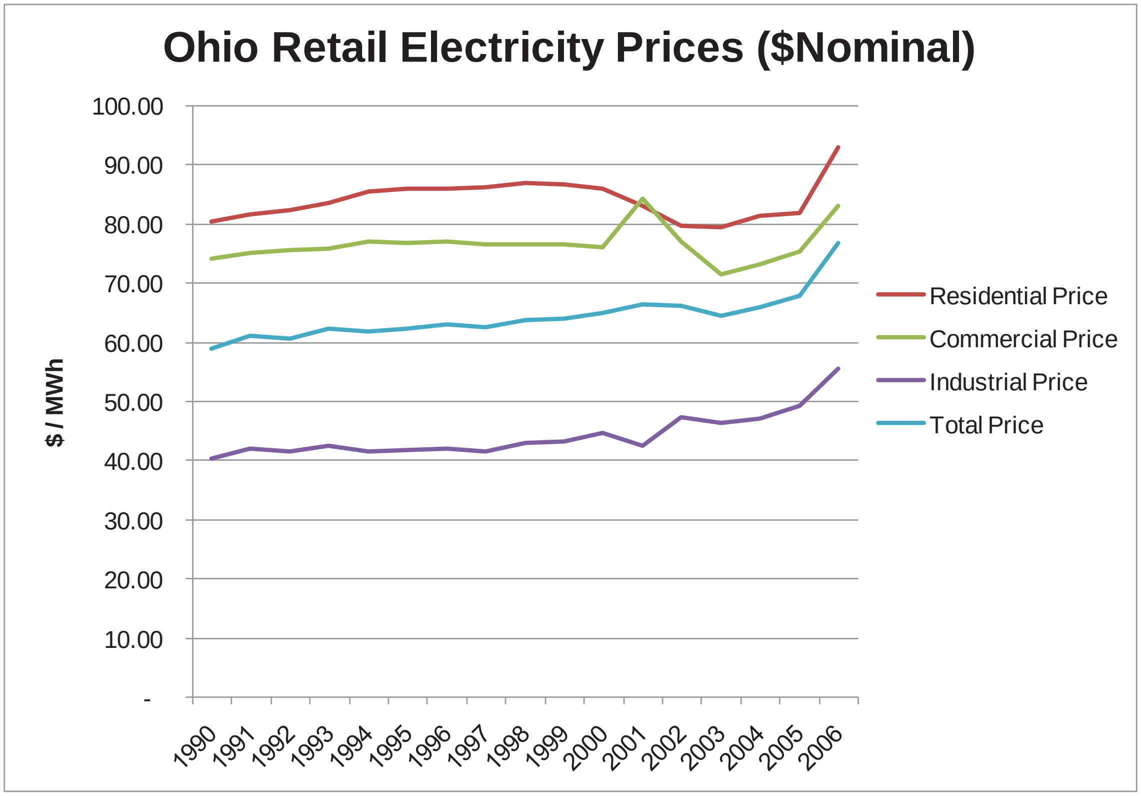
The closest MISO hub to Cleveland is the FirstEnergy (FE) Hub. Because wholesale electricity prices fluctuate, to accurately project revenues from the Pilot Project it would be necessary to develop a model to forecast price into the future based on current forward pricing, generator retirements, load forecast, natural gas price influences, coal price influences, new generation projects and capital availability. Additionally, the revenue from the project will be related to the dependence/independence of the fluctuations of the wind resource at the site with both the fluctuations of the load and the fluctuations of other distributed generating sources. For these reasons, it is strongly advisable that the Pilot

Project negotiates a PPA with a fixed electricity price with one or more buyers over the project lifetime. The majority of wind farms currently being built in the US are financed under a PPA arrangement. Economic modeling used in this report assumes a fixed electricity price over time, varying only with escalation.

11.2.3 Historical Pricing

As a reference for power purchase amounts for the Pilot Project, it is useful to understand electricity prices within the region. Figure 11-2 illustrates Ohio retail electricity prices by sector for the period 1990-2006.

Figure 11-2: Ohio Retail Electricity Prices, 1990-2006 (nominal $)

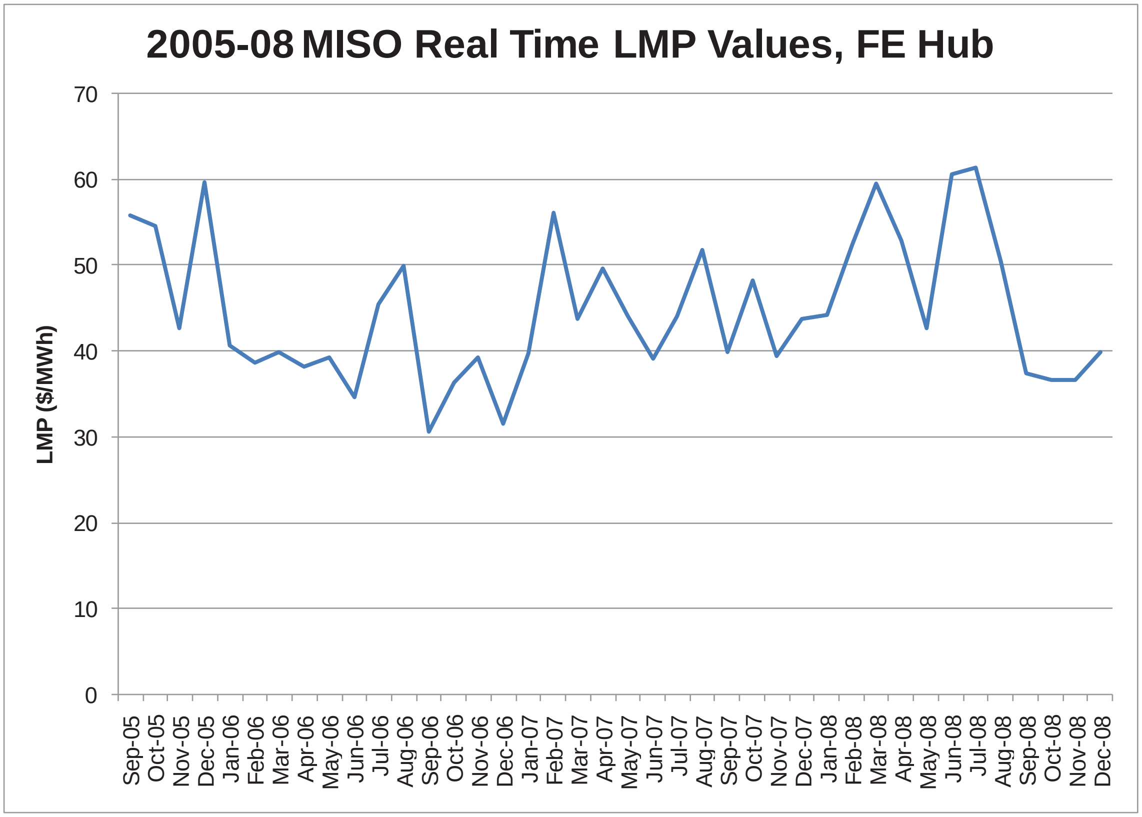


Source: Energy Information Administration, "Retail Sales of Electricity by State by Sector by Provider", http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html

The price of electricity for the residential sector is most expensive, followed by the commercial and industrial sectors, respectively. As a weighted average across sectors, the average total price of electricity in Ohio increased from $58.90 / MWh in 1990 to $76.80 / MWh in 2008 , representing an increase of 30.4% over sixteen years, or 1.9% per annum.

Figure 11-3 demonstrates the volatility in wholesale electricity pricing at the FE Hub, especially compared to retail pricing presented in Figure 11-2.

Figure 11-3: Locational Marginal Price at the FE Hub, 2005-2008 (real time)



Source: Midwest ISO Real-Time LMPs,
http://www.midwestmarket.org/home/Market%20Reports/?type=rt_lmp&list=month

Between September 2005 and December 2008, while there is a general upward trend, prices fluctuate dramatically on a month by month basis. As explained above, wholesale prices vary according to a number of factors, but especially relevant are the prices of fossil fuels including coal, which is the primary power generation fuel in Ohio and the Great Lakes region, and natural gas, which is used for peaking power and which drives pricing mostly during summer months. As an example, wholesale electricity prices spiked drastically in the summer of 2008, commensurate with the increase in fossil fuel prices at the time. As prices for fossil fuel dropped in the fall 2008, wholesale electricity prices also fell below $40 / MWh.

One significant advantage of generating electricity from wind is that operating costs are not highly dependent on changing fuel prices, as they are with coal or natural gas plants. Although wind is variable, there are no significant fuel costs for generation, and therefore long-term pricing contracts are possible with wind power generation.

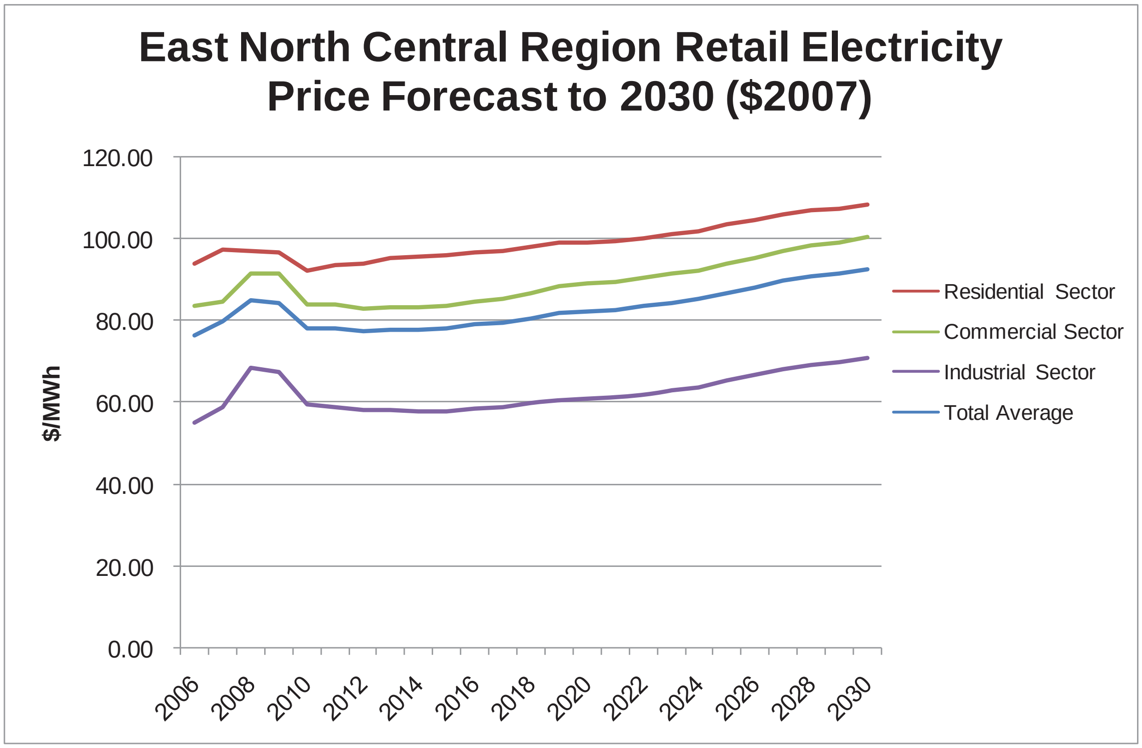
11.2.4 Price Forecasts

Modeling future electricity prices is complicated by a variety of factors, especially in states with at least partially competitive electricity markets such as Ohio. Variation with respect to fuel prices and mix, transport costs for fuels, heating and cooling degree day changes, supply and demand forecasting, and market/regulatory requirements – such as Ohio's AEPS – lead to considerable uncertainty in future pricing. Additionally, the current recession is expected to place short-term downward pressure on electricity demand and prices.

The US Energy Information Administration's Annual Energy Outlook 2009 forecasts retail electricity prices by region to 2030. Figure 11-4 illustrates that near-term, electricity prices are expected to decrease in the East North Central Region (which includes Ohio), primarily due to decreased demand from the current recession. As a baseline forecast, the total average retail electricity price is expected to increase almost 10 percent in real terms between 2009 and 2030, or on average 0.5 percent per annum. This forecast places the total average price at $92.74 / MWh in 2030 (in 2007 constant dollar terms).

Again, it should be noted that EIA and other forecasts are subject to significant uncertainties. Further, while competitive pricing will undoubtedly be a factor in an offtaker's decision to purchase renewable energy—and hence why pricing helps frame economic considerations for the Pilot Project—other factors will be considered. Increasingly, utilities are viewing the purchase of renewable energy as a hedge against impending carbon legislation at state or federal level(s). Increasing Renewable Energy Credit (REC) values – currently valued around $15-$20 / MWh in Ohio – or the possibility of a carbon tax will benefit renewables tremendously relative to fossil generation. Potential offtakers will ultimately use internal criteria to determine willingness to purchase renewable energy at a certain price. Combined with market requirements and other incentives, renewable energy and offshore wind are increasingly attractive as part of Ohio's overall electricity supply.

Figure 11-4: Baseline Retail Electricity Price Forecast for East North Central Region ($2007)



Source: Energy Information Administration, Annual Energy Outlook 2009, *http://www.eia.doe.gov/oiaf/aeo/index.html*

11.2.5 Costs and Assumptions

Capital and operating cost estimates provided by Germanischer Lloyd are the basis for economic projections included herein (see Section 11.1). Capital cost estimates are based on three primary variables:

1. Interconnection location: CPP Lake Road Substation or CEI Lakeshore Substation
2. Project size / turbine configuration: Layout 1, consisting of 8 x 2.5 MW turbines, 20 MW total, or Layout 7, consisting of 3 x 5 MW turbines, 15 MW total
3. Size of an onshore operations / test facility: 150 m^2 facility vs. 300 m^2 facility

Cost information is summarized in Table 11-13 and Table 11-14.

Table 11-13: Project Configuration and Estimated Capital Cost

	ID	Total MW	Net Capacity Factor – Pct	Cost – $Million	Grid Connection Point	Onshore / Test Facility Size
LAYOUT CONFIGURATION	**1a**	20 MW	31.53	$91.4	CPP Lake Road Substation	150 Square Meters
	1b	20 MW	31.53	$92.7	CPP Lake Road Substation	300 Square Meters
	1c	20 MW	31.53	$90.8	CEI Lakeshore Substation	150 Square Meters
	1d	20 MW	31.53	$92.0	CEI Lakeshore Substation	300 Square Meters
	7a	15 MW	30.13	$78.3	CPP Lake Road Substation	150 Square Meters
	7b	15 MW	30.13	$79.5	CPP Lake Road Substation	300 Square Meters
	7c	15 MW	30.13	$77.2	CEI Lakeshore Substation	150 Square Meters
	7d	15 MW	30.13	$78.4	CEI Lakeshore Substation	300 Square Meters

Table 11-14: Estimated O&M Costs for GLWEC Pilot Project

Scenario	Annual Wind Farm Energy Yield	Estimated O&M Cost [2010 Base]	Average Annual O&M Cost [2010 US$]
L1 (8 x 2.5-MW Turbine)	55,254 MWh	$0.083 / kWh	$4,590,000
L7 (3 x 5.0-MW Turbine)	39,595 MWh	$0.067 / kWh	$2,660,000

Energy production assumptions follow wind resource and availability assessments, and are provided in Table 11-15.

Table 11-15: Layout Specifications and Energy Production Estimates

	Layout 1	Layout 7
Project Size	20 MW	15 MW
Wind Turbine Configuration	8 x 2.5 MW	3 x 5.0 MW
Manufacturer	Clipper	REpower
Turbine Orientation	330° to 150°	250° to 70°
Distance Between Turbines	384 m (1,260 ft)	960 m (3,149 ft)
Hub Height	80 Meters	80 Meters
Availability – Percent	86.6	86.6
Electrical Losses – Percent	2	2
Park Efficiency – Percent	96.5	98.4
Net Production	55,254 MWh	39,595 MWh
Net Capacity Factor – Percent	31.53	30.13

11.2.6 2009 Stimulus Package

The 2009 American Recovery and Reinvestment Tax Act (Stimulus Package) contains several provisions relevant to funding and financing options for the Pilot Project. Namely, the most relevant to the GLWEC are:

- Production Tax Credit Extension through December 31, 2012
    - Currently valued at 2.1 ¢/kWh
- Temporary option to claim the Investment Tax Credit in lieu of the PTC
    - Valued as 30% of qualifying tangible property
- Temporary option to claim the ITC in the form of a grant from the Department of Treasury
    - Provided construction begins in 2009 or 2010, and facility is placed in service no later than 2012
- Advanced Energy Investment Credit
    - More relevant to potential manufacturing facilities than Pilot Project
- Clean Renewable Energy Bonds
    - Low interest bonds available to public power producers
- Renewable Energy Loan Guarantees
    - Backed by the US Department of Energy
- Direct Simulus Spending

The relative import of these provisions is illustrated through sensitivity analysis presented in the following sections. For further explanation of these provisions, refer the the GLWEC Funding and Financing Options Report, juwi, April 2009. Evolving details regarding allocation and administration of direct stimulus will be available on several websites, including http://www.energy.gov/recovery/ (DOE Recovery website), http://www.eere.energy.gov/ (DOE Energy Efficiency and Renewable Energy), and http://recovery.ohio.gov/ (Ohio Recovery website).

11.2.7 Pilot Project Economics

While the development and construction of the GLWEC Pilot Project appears technically feasible, a crucial question is whether the Project might be financially viable given present and future market dynamics and funding opportunities. Forecasting those market dynamics with reasonable certainty is a challenge. Consequently, the primary purpose of this section is to provide a sense for what might be required financially to support Pilot Project economics.

While many factors influence the Project economics, this section outlines key factors most dramatically affecting the Project's economic attractiveness. Those factors include total installed capital cost, power purchase agreement (PPA) pricing, net capacity factor, level of debt leveraging, debt interest cost, the operations and maintenance (O&M) cost to service and maintain the facility once in service, and the ability to take advantage of the incentives outlined in the previous section.

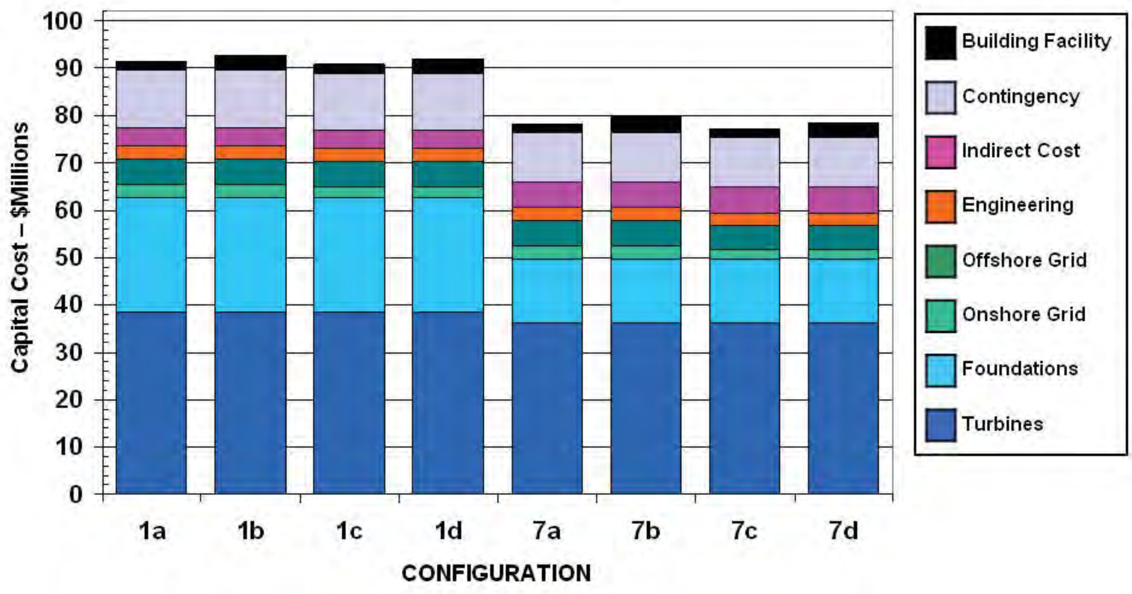
11.2.7.1 Capital Cost

As noted previously, cost estimates have been drawn up for two potential Pilot Project turbine configurations. Layout 1 involves eight 2.5 MW turbines, for a total project size of 20 MW. Layout 7 involves three 5 MW turbines, for a total project size of 15 MW. Each of these layouts has grid connection points either at the Cleveland Public Power Lake Road Substation or Cleveland Electric Illuminating Lakeshore Substation. The Onshore Facility size is either 150 or 300 square meters. Consequently, given these differing variations and the turbine layout, project installed cost is estimated to range from $77.2 million to $92.7 million.

As illustrated in Figure 11-5, procuring and installing foundations and turbines represents a sizable portion of the capital cost for each Project variation. The cost per megawatt installed ranges from $4.54 million for Configuration 1c to $5.30 million for Configuration 7b. Broadly speaking, these costs per megawatt installed are currently about 75-100 percent higher than land based wind farm installations.

It should be noted that due to the uncertainty of construction and installation cost in the Great Lakes, the cost estimates also contain a significant contingency element – 15 percent for each of these variations. Consequently, on a per megawatt installed basis, about $600 – $700 thousand has been built into the cost estimates to account for this uncertainty. Project economics herein include the contingency.

Figure 11-5: Capital Cost by Major Cost Element – Dollars in Millions

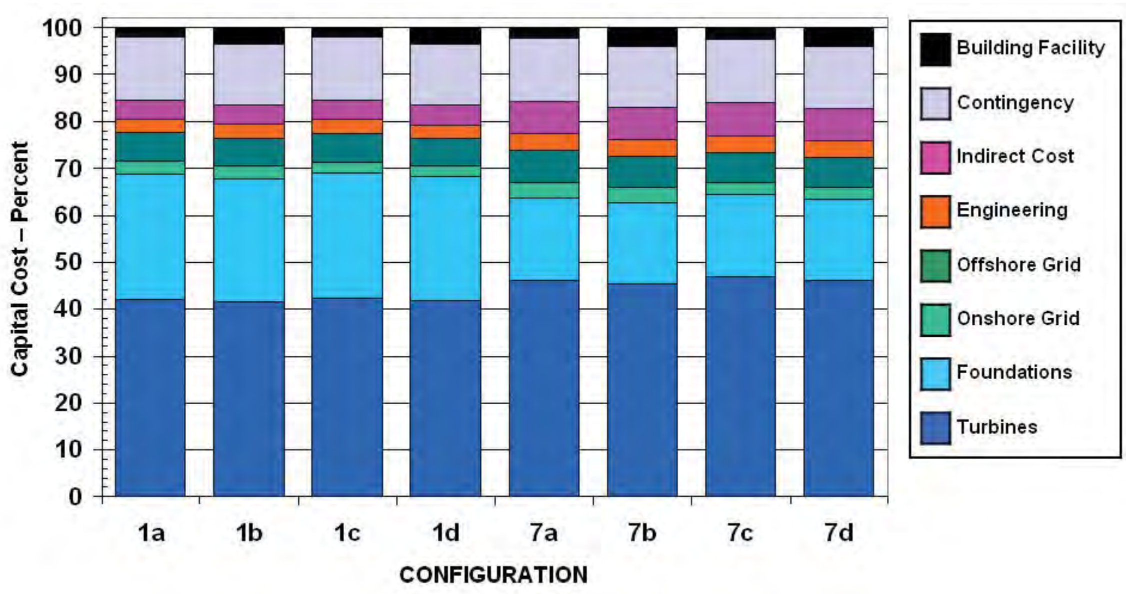


While the construction costs denoted above are sizable, it should also be noted that other necessary finance-related items – such as capitalized financing, development fees, and insurance fees – could drive these cost even higher. Estimates by juwi for capitalized financing assuming a 12-month construction cycle currently range from $2.8 – 3.3 million, though will be dependent on the financing available at the time the project would move into the construction phase.

At this time, given the dynamic nature of the markets and economies, it is somewhat difficult to estimate the precise implications of the finance-related costs. However these particular costs and fees might account for 10-15 percent of the all-in capital cost, so the amount is not insignificant.

To provide a flavor of the various proportions of the cost elements, Figure 11-6 below illustrates each on a percentage basis. Note again that anywhere from 63-69 percent of the total costs are accounted for by turbines and the offshore foundations, while another 15 percent of contingency has been added in for each of the layout configurations.

Figure 11-6: Capital Cost by Major Cost Element – Percentage Basis



11.2.7.2 Baseline Project Economic Runs

Table 11-16 below provides an outline of the key baseline economic components and their sources.

Table 11-16: Baseline Assumptions

Assumption Type	Description / Study	Source
Capital Cost	GLWEC Economic Assessment – March 2009	Germanischer Lloyd
Annual O&M Cost	GLWEC Economic Assessment – March 2009	Germanischer Lloyd
Energy Production	GLWEC Final Wind Report – December 2008	juwi
Target Return	10 Percent DCFROE / Sensitivity Analysis	juwi
PPA Pricing	Varies – Price Necessary To Achieve Desired Return	juwi
Debt Leveraging	60 Percent Debt Baseline / Sensitivity Analysis	juwi
Debt Interest	6 Percent Interest Baseline / Sensitivity Analysis	juwi
Tax Depreciation	MACRS Appropriate	juwi
PTC / ITC Incentives	Production Tax Credit Baseline / Sensitivity Analysis	juwi

Variability in assumptions presented in Table 11-16 will ultimately impact project economics. At this stage of feasibility analysis, it is helpful to have a consistent framework for discussion of key factors. Accordingly, the majority of economic model runs assume a standard 60 percent debt leveraging and 10 percent target Discounted Cash Flow Return On Equity

(DCFROE). Holding these parameters constant allows for rationale comparison and subsequent sensitivity analysis on individual key factors.

Figure 11-7: Baseline Project Economics Results

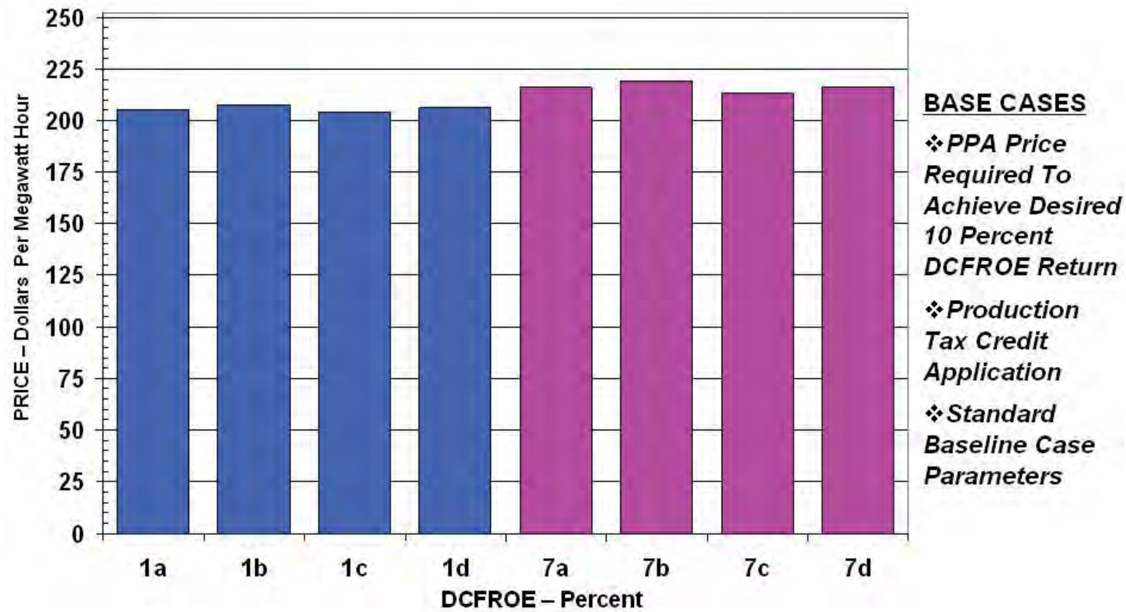


Figure 11-7 above illustrates the PPA price needed to achieve a desired leveraged Discounted Cash Flow Return On Equity (DCFROE) return for each of the eight baseline Project cases. These baseline economics assume the Production Tax Credit. Key findings are as follows:

- The required PPA price for each of the Layout 1 cases are all within 1-2 percent, largely because the differences in installed capital cost for each case on a per megawatt installed basis are similarly close.
- While there is slightly more spread for the individual cases for Layout 7 – again because the absolute capital cost differences on a per megawatt installed basis are a little greater – there is a more pronounced difference when comparing Layout 1 and Layout 7 results. The initial PPA price required for Layout 7 cases are about $9-15 per megawatt hour higher than Layout 1 cases, roughly a difference of 4-7 percent.
- In part, the comparative results are not unexpected because the cost per megawatt installed for the Layout 7 cases are higher and the Net Capacity Factor is lower than in Layout 1. Consequently – from a project economics vantage – it would appear Layout 1 would be more economically attractive.

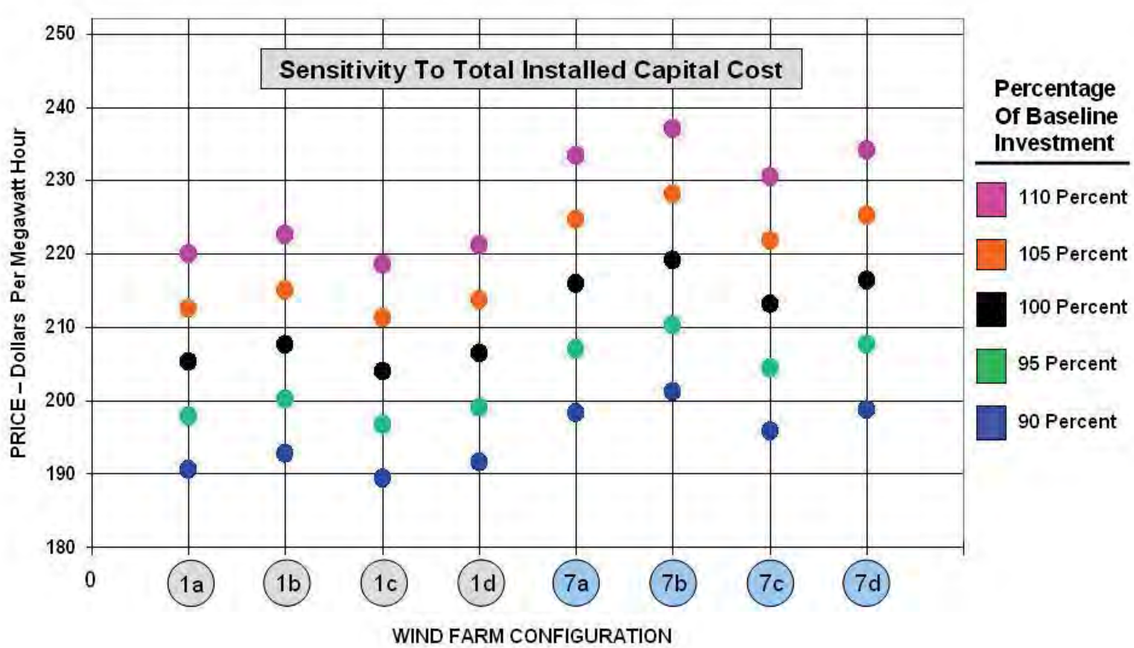
- To some degree however, the results for Layout 7 are tempered by the lower O&M cost per kilowatt hour, since the baseline O&M cost for Layout 1 cases is about 8.3 ¢ / kWh compared to 6.7 ¢ / kWh for Layout 7.

11.2.7.3 Investment Sensitivity

Following the Baseline Cases, additional case runs were undertaken to determine the relative impact of changing the total installed cost of each of the eight Baseline Cases. Accordingly, the all-in investment amounts were varied by +/- 5 and 10 percent from Baseline investment levels for each case. In turn, utilizing standard Baseline assumptions, the required initial PPA price was ascertained to produce a targeted leveraged DCFROE of 10 percent.

Figure 11-8 illustrates the impact on PPA price of variability in capital cost. Broadly speaking, for Layout 1 cases, for every 1 percent change in initial investment cost, the initial required PPA price commensurately changes about 0.7 percent, in turn equating to about $1.50 per megawatt hour. Layout 7 cases are slightly more sensitive to the change in initial investment cost. In these instances, for every 1 percent change in initial investment cost, the initial required PPA price commensurately changes about 0.8 percent, in turn equating to about $1.75 per megawatt hour. Most likely the slightly lower net capacity factor and the somewhat higher cost per megawatt installed for the Layout 7 project cases are what leads to this higher sensitivity.

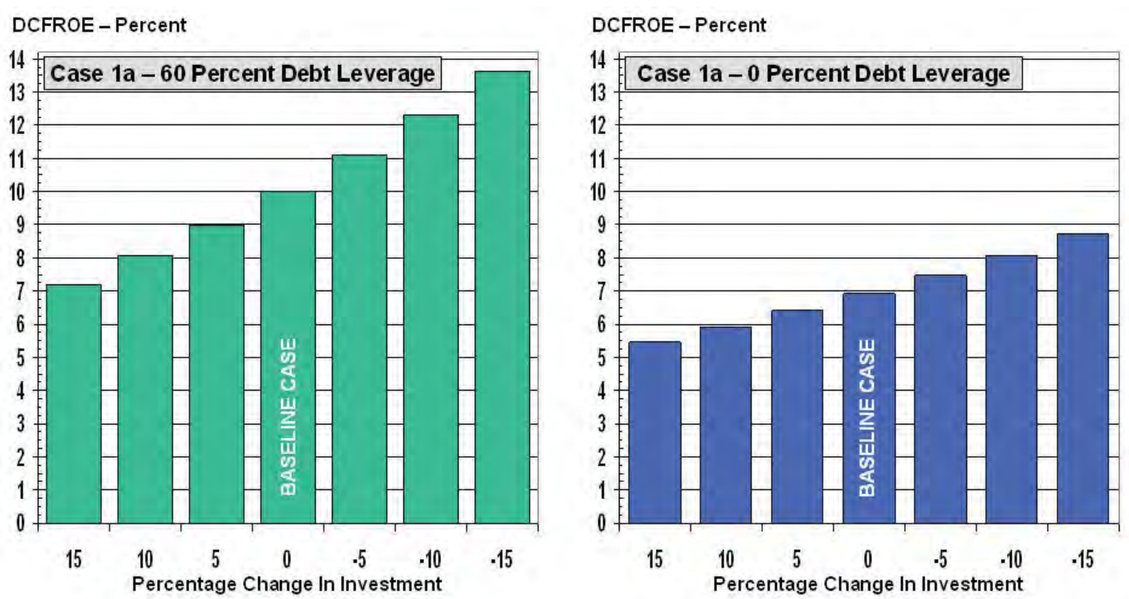
Figure 11-8: Investment Sensitivity – PPA Price Required to Maintain 10 Percent Return



A slightly differing way of testing the sensitivity of project rate of return to changes in initial capital investment is illustrated in Figure 11-9. Utilizing the Layout 1a case as a test, the all-in investment amount was varied by +/- 5 and +/- 10 percent from Baseline investment level. This time however, the initial PPA price for the Baseline case of roughly $205 per megawatt hour was held constant, in turn with the intent to determine what would happen to the DCFROE result. In the leveraged case scenarios, as the initial cost increases, the rate of return drops about 1 percentage point for every 5 percent increase in cost.

While decreasing the initial cost conversely increases the rate of return – again about 1 percentage point for every 5 percent decrease in initial investment – the rates of return increase at a slightly quickening pace as investment amount decreases. While there are probably varying factors influencing this, what is more telling is the importance of reducing the installed cost to help make the project more economically attractive.

Figure 11-9: Percentage Change in Investment Impact on Project Return



As discussed in Section 11.2.7.7, the level of debt leveraging materially affects project economic attractiveness. But as further illustrated in Figure 11-9 – even when removing the effects of debt – the project is relatively sensitive to changes in initial investment. Roughly speaking, for every one percent change in initial investment cost, the unleveraged rate of return commensurately -shifts about 0.1 percentage point.

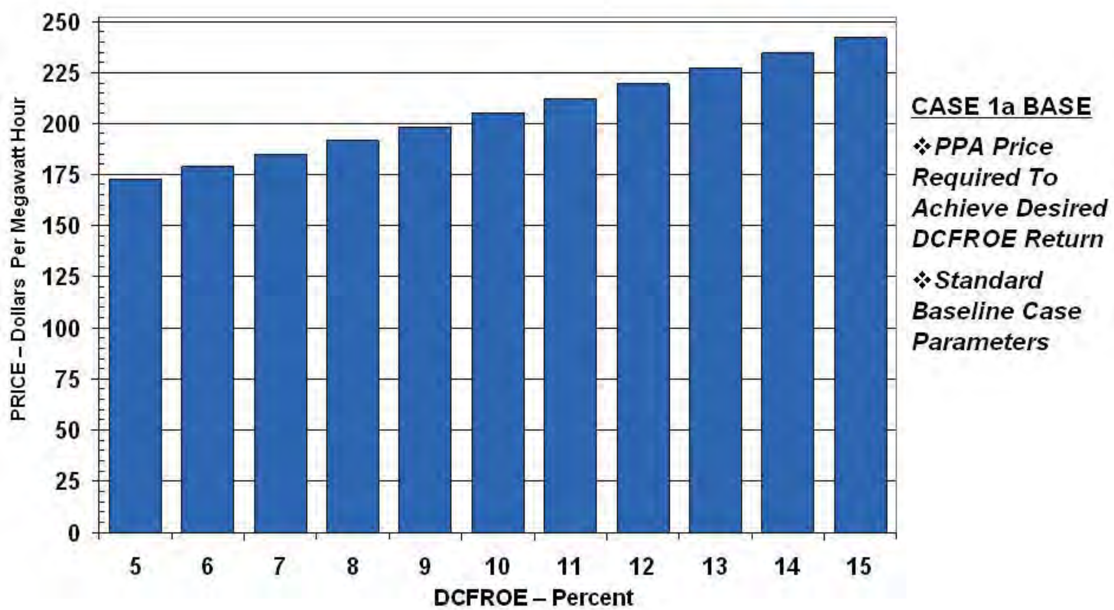
11.2.7.4 PPA Pricing and Target Return

Another factor of interest is what type of profitability expectations a potential owner might require, and how that in turn would affect the requisite initial PPA price. Utilizing the Layout

1a case as a test as well as the standard set of Baseline assumptions, cases were run for required leveraged returns of 5-15 percent, so as to establish what PPA pricing is necessitated.

Figure 11-10 illustrates the results of that assessment. Generally, as the equity return target changes by 1 percentage point, the needed change in the PPA price is commensurately $6-8 in initial price per megawatt hour. And not surprisingly, as the required equity rate of return is elevated, an even higher incremental PPA price increase is required to support DCFROE return expectations.

Figure 11-10: PPA Price Required to Achieve Required DCFROE Result

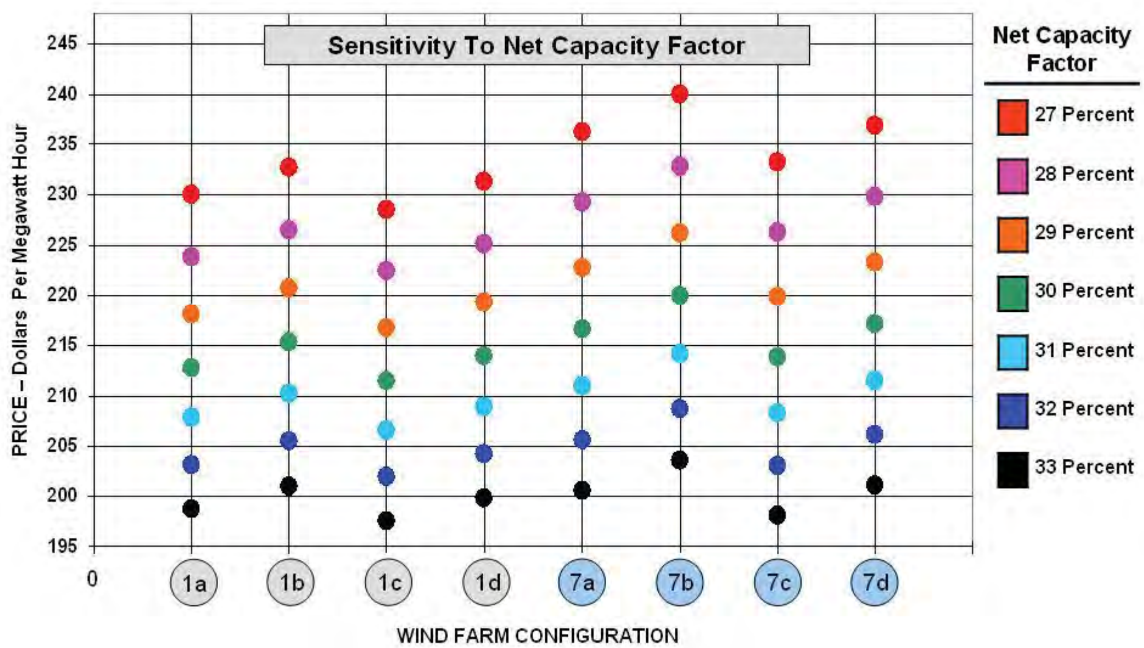


11.2.7.5 Net Capacity Factor

The economics of all wind energy projects are dependent on the strength of the local wind regime. The forecasted energy production and related net capacity factor are therefore crucial to the financial attractiveness of the project.

Each of the Baseline layouts was therefore evaluated to determine how the change in net capacity factor might impact project economics. Those results are illustrated in Figure 11-11 below.

Figure 11-11: Net Capacity Factor Sensitivity – PPA Price Required to Achieve 10 Percent Return



As illustrated, there is a clear relationship between required PPA price and the net capacity factor. All of the Baseline cases have required PPA prices closely clustered roughly around $200 per megawatt hour where the net capacity factor is 33 percent. This occurs even though there are significant differences in the cost per megawatt installed among the various layout cases. Most likely this is because the higher O&M cost factors for Layout 1 cases are offsetting the lower cost per megawatt installed, while the reverse is the situation for Layout 7 case runs. On the other hand, the identical accelerated tax depreciation treatment, effects of debt leveraging, as well as the impact of the production tax credit are likely working to drive a clustering of all the various cases around a similar basis point.

Notably, however, as the net capacity factor is systematically reduced, the requisite PPA price increases at an increasing rate, both on an absolute as well as percentage basis. This can be expected since the revenue stream to achieve the required leveraged 10 percent return must still be approximately the same – given all other factors being constant – but the net energy production denominator is decreasing at an increasing rate on a percentage basis.

Furthermore, it appears that again the Layout 7 cases require a slightly, but increasingly higher initial PPA price every time the net capacity factor is reduced by one percentage point, when compared to Layout 1 cases. Generally the required PPA price for Layout 1 changes $4-6 per megawatt hour for every one percent change in net capacity factor, while the required PPA price for Layout 7 changes $5-7 per megawatt hour for every one percent change in net capacity factor. Likely the higher cost per megawatt installed for Layout 7 cases is largely driving this, though it is somewhat being offset by a lower annual O&M cost for the same cases.

Still, as is the case with all wind energy projects, energy production based on the local wind regime is clearly going to be critical to the economic attractiveness of the Pilot Project.

11.2.7.6 Operations & Maintenance Cost

The Germanischer Lloyd GLWEC Economic Assessment notes that review of several wind farm projects and various cost analyses generally indicates the median Annual Operations & Maintenance (O&M) cost for an offshore wind farm between 200 and 300 MW and located within 20 kilometers from the shore in Europe ranges between 2.5 ¢ / kWh and 4 ¢ / kWh – which themselves are significantly higher than the O&M cost of onshore projects. In that same study, Germanischer Lloyd projects O&M cost estimates ranging from approximately $2.7 million annually for the Layout 7 configurations to $4.6 million for the Layout 1 configurations. Commensurately, in terms of O&M cost, these equate to 6.7 ¢ / kWh to 8.3 ¢ / kWh respectively for the two configurations, in 2010 dollar-terms on an average levelized basis for a project lifetime of 20 years. These higher costs are attributable to a variety of issues, including economies scale as well as some of the technical challenges for accessing and servicing an offshore wind energy project in the Great Lakes.

As illustrated Figure 11-12, a larger proportion of the cost in Layout 1 is directly attributable to higher cost for corrective maintenance – largely for nacelle equipment and the rotor system – or roughly 63 percent of the average annual O&M cost for the two combined. And while anticipated corrective costs for the nacelle equipment and rotor system is about the same on a per turbine basis for the Layout 7 configurations, that configuration is expected to have a higher percentage of the total cost attributed to administrative operator costs on a percentage basis.

Figure 11-12: O&M Cost Components

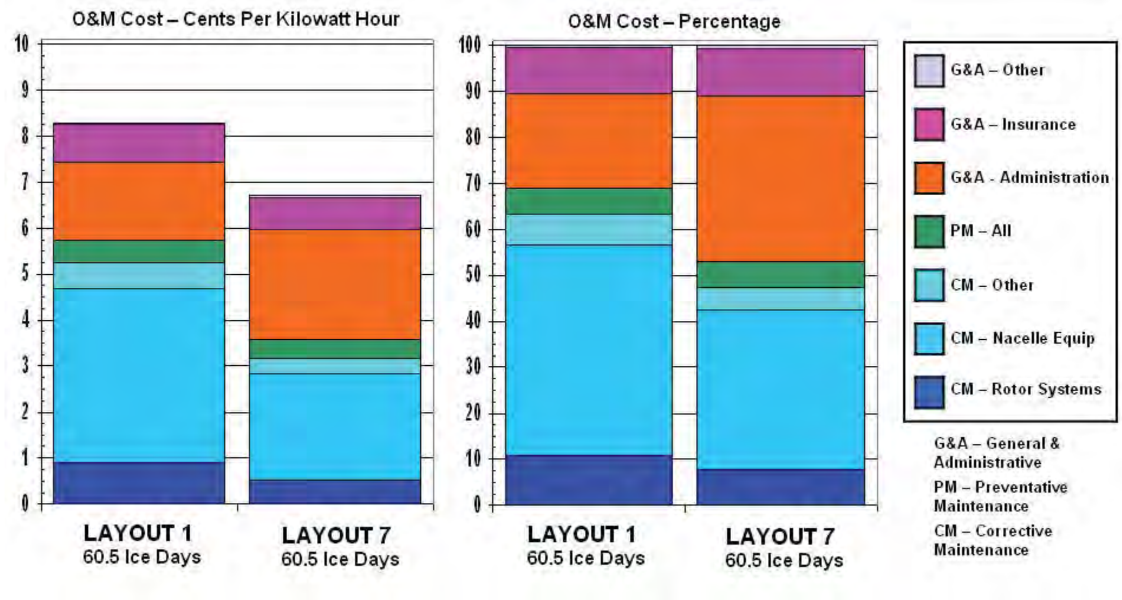
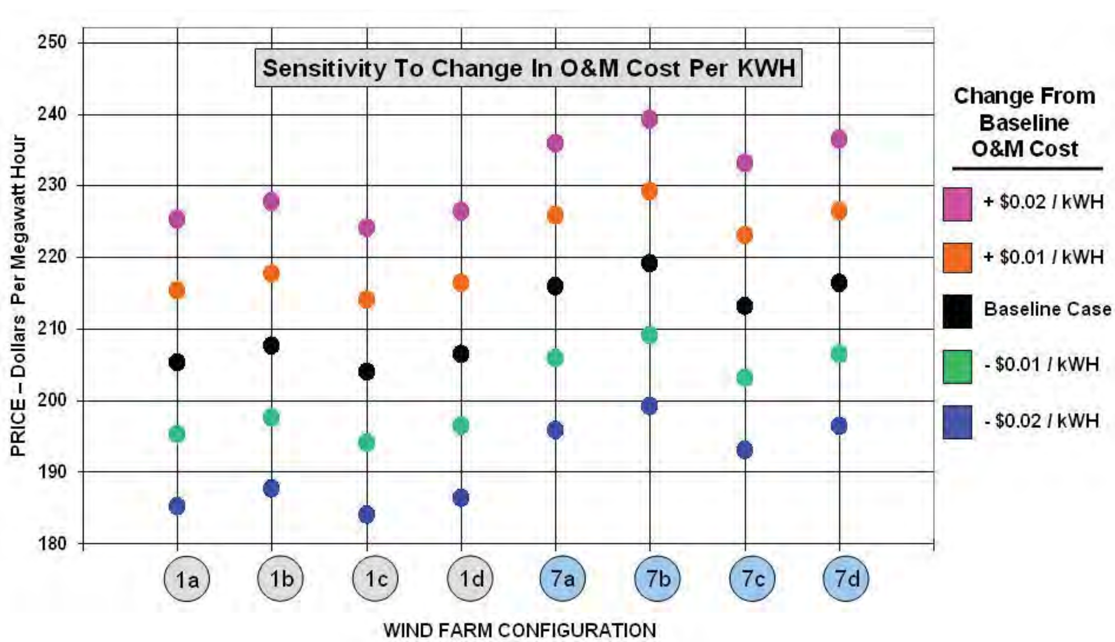


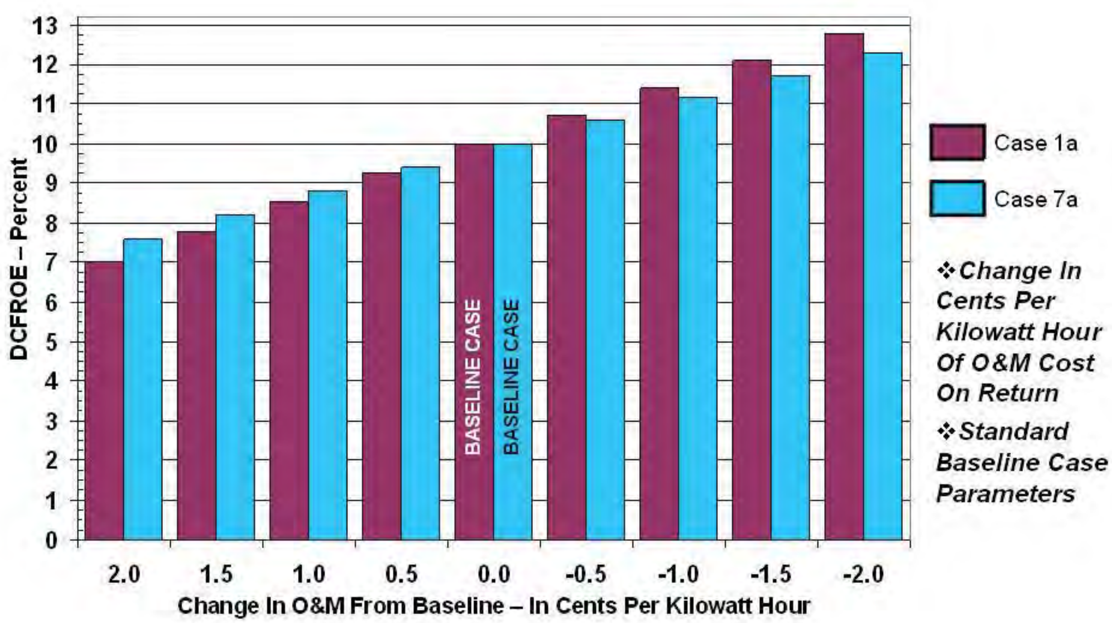
Figure 11-13 illustrates what range of initial PPA price might be necessitated should the initial O&M cost increase or decrease by increments of one cent per kilowatt hour. Given that the revenue stream and the O&M cost stream in the Baseline cases were both escalated at the same inflation rate – 2.5 percent per year – then not surprisingly the change in the PPA price exactly tracks O&M at $10 per megawatt hour for every one cent change in the O&M cost per kilowatt hour. One thousand kilowatt hours multiplied by one cent equals $10 of cost for one megawatt hour.

Figure 11-13: O&M Cost Sensitivity Analysis



To get a better sense for the relative influence changes in O&M cost have on the project economic return, the initial PPA price was held constant for two case examples – Layout 1a and Layout 7a – while the O&M cost was varied. As exhibited in Figure 11-14, the return roughly changes about 1.5 percentage points for every one cent change in the initial O&M cost for Layout 1 cases. For Layout 7 case runs, the correlation is about 1.2 percentage points for every one cent change in the initial O&M cost. The wider span of results for Layout 1 is in part likely due to the higher net capacity factor for those cases. Consequently, as the O&M cost changes on a per kilowatt hour basis, the change in total absolute O&M cost ranges more greatly, therefore similarly affecting the project economics results. Regardless, it appears that the O&M cost will have a material influence on the financial attractiveness of the project.

Figure 11-14: Change in O&M Cost Impact on Project Return

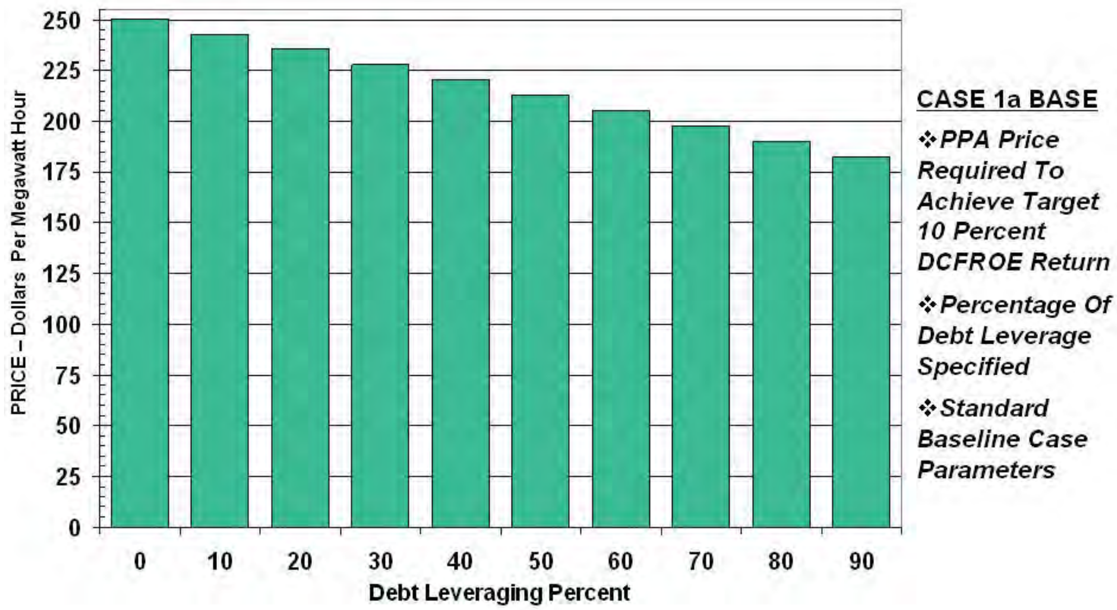


11.2.7.7 Debt Leveraging

Historically, the level of debt leveraging has been an important factor of many wind energy projects. In today's economic climate, however, fewer banks are providing loans and fewer investors are asking for loans. Thus a much greater percentage of projects are equity financed. With higher fixed costs, no previous projects in the Great Lakes, and being a small project with higher PPA prices that increases dependency on wind conditions, risk associated with the Pilot Project is not likely to attract banks willing to provide debt. One caveat is provided through potential Renewable Energy Loan Guarantees under the Stimulus Act. A loan guarantee for the Pilot Project might help not only decrease financing costs—

through potentially lower debt interest, see Section 11.2.7.8—but also help attract bank financing by reducing risk.

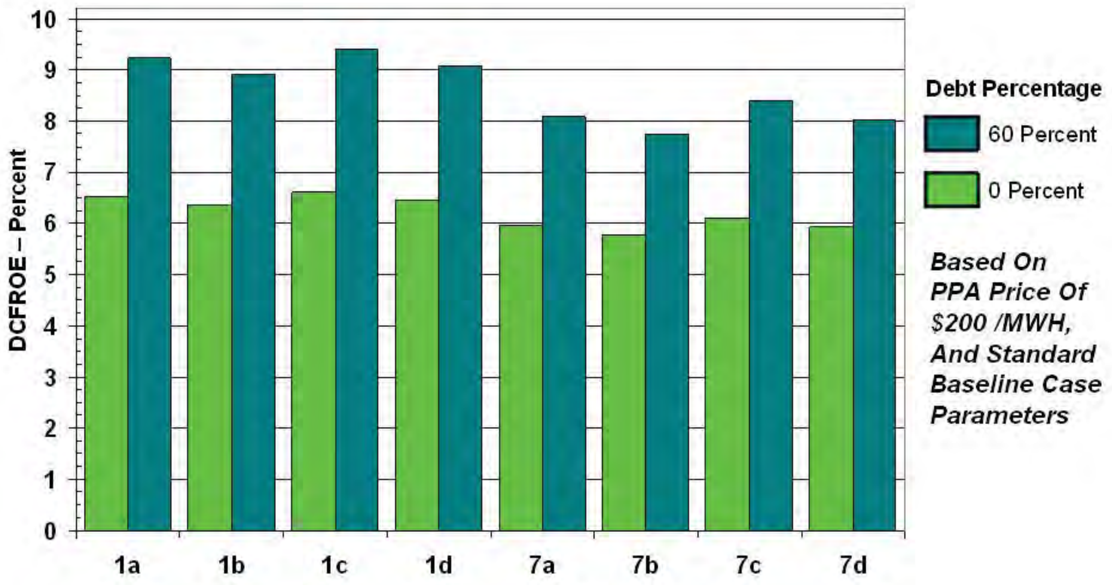
Figure 11-15: Leverage Percentage Sensitivity Analysis



To illustrate the possible impact of debt leveraging, the level of debt was varied at 10 percent increments for the Layout 1a Baseline case – again holding all other factors constant – to determine what initial PPA price would be necessitated to produce a targeted DCFROE return of 10 percent. Results are presented in Figure 11-15 above. Interestingly, for every 10 percent increase in the total level of debt financing, the required initial PPA price incrementally decreased approximately $7.50 per megawatt hour. While naturally the percentage change therefore varied, the necessary PPA price changed was about 3-4 percent for every 10 percent change in the total level of debt financing.

Evaluating the impact of debt leveraging in another slightly different manner, each of the Baseline cases for Layout 1 and Layout 7 were compared with 0 percent of the total cost being funded by debt, as well as at a 60 percent debt financing level, this latter case being the standard assumption. Furthermore, the initial PPA price was held constant at $200 per megawatt hour. The results are outlined in the following Figure 11-16.

Figure 11-16: Unleveraged Analysis



In both instances of leveraging at 60 percent debt financing or completely unleveraged, the resulting rates of return are consistent: there is an inverse relationship between Layout cost on an installed per megawatt basis and the resulting rate of return. Furthermore, the unleveraged returns ranged from a low of 5.8 percent for the highest costing configuration Layout 7b to a high of 6.6 percent for the lowest costing configuration, Layout 1c.

Additionally – while the differential varied from case to case – generally the adding of 60 percent debt financing to each of the Layout case runs added about 2-3 percentage points to the overall leveraged equity return.

While additional comparisons could be undertaken, this review indicates that debt leveraging could be of material importance to the Pilot Project. However, risk mitigation mechanisms such as loan guarantees will likely be required to attract debt providers. Under current market conditions, the Pilot Project may not be bankable.

11.2.7.8 Impact of Debt Interest Cost on Rate of Return

Similar to the level of debt leveraging, the cost of debt also is typically an important factor of most capital projects. And again given the relative capital requirements projected for the Great Lakes offshore project, ability to secure low cost debt could be vital.

Figure 11-17: Debt Interest Rate Sensitivity Analysis

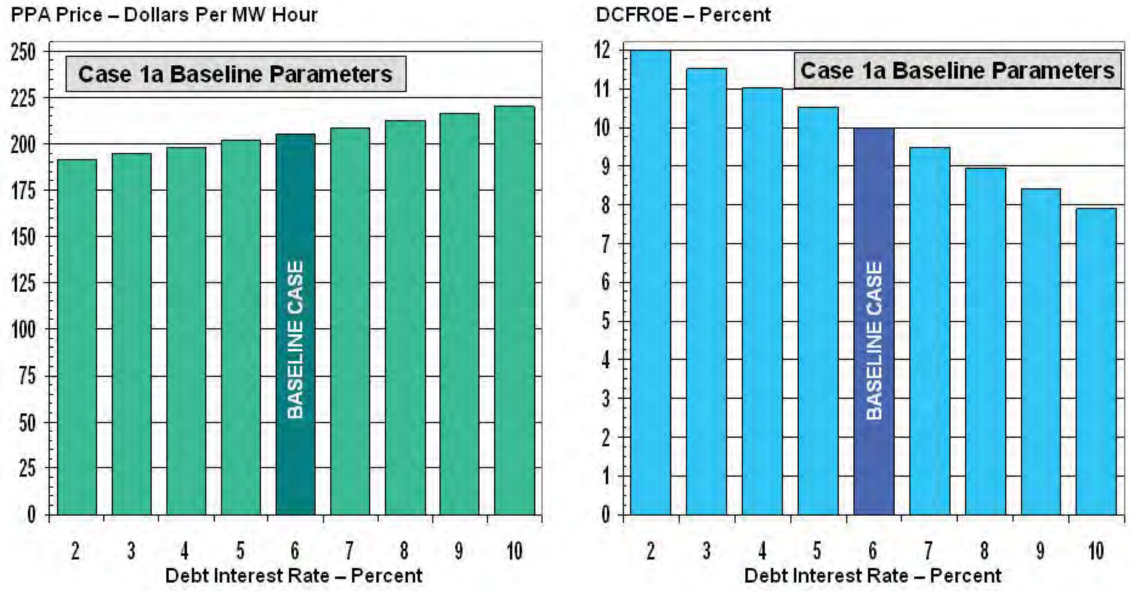


Figure 11-17 illustrates in two respects the benefit derived by being able to procure low cost debt. Focusing on the chart on the left side of Figure 11-17– where the targeted 10 percent equity rate of return is maintained – as the interest rate increases, the required initial PPA price also increases at a progressively escalating rate. Roughly speaking, for each one percent increase in the interest rate, the initial PPA price steps up starting at $3.25 per megawatt hour from the 2 percent debt interest rate, and eventually closes in on $4 per megawatt hour as the interest rate approaches 10 percent.

The results are not surprising. As the interest rate increases, progressively more revenue is needed to offset the ever larger interest payment, therefore necessitating increasingly higher initial PPA prices so as to produce the desired 10 percent targeted equity return.

This is further borne out by results indicated in the right hand chart of Figure 11-17 where the initial PPA price is held constant and the interest rate is varied. As the interest rate decreases, more of the revenue is effectively left to be channeled to the equity stakeholder, thereby producing higher equity returns.

Accordingly, what bears reiterating is that the 2009 American Recovery and Reinvestment Tax Act includes provision to expand the amount of new Clean Renewable Energy Bonds available for qualified facilities such as wind or biomass owned by public power providers, governmental bodies or cooperative electric companies. Should a prospective owner of the Pilot Project be eligible for Clean Renewable Energy Bond financing, there should be an opportunity to secure lower cost debt, and in so doing making the Pilot Project more economically viable.

11.2.7.9 Production Tax Credit versus Grant or Investment Tax Credit

Section 11.2.6 of this document summarized the pertinent basics of the 2009 American Recovery and Reinvestment Tax Act passed in February 2009. That Act contains several provisions relevant to funding and financing options for a potential Great Lakes offshore Pilot Project. As discussed previously, one of the Act's provisions was to extend the previous Production Tax Credit placed-in-service sunset date by three years to December 31, 2012. This in itself should be very helpful to parties interested in planning, developing, and constructing wind energy projects.

The Act also provides taxpayers with facilities that would otherwise be eligible for the production tax credit, such as wind facilities, the ability to elect the 30 percent investment tax credit under Section 48 in lieu of the production tax credit. Consequently the ITC option appears to provide much higher degree of certainty of cash return, a substantial advantage for wind facilities. One of the clear advantages of the ITC is its being based on initial cost instead of the highly variable electricity production over a 10-year period.

The Act also authorizes the Secretary of the Treasury to provide grants for property eligible in lieu of the Production Tax Credit under Section 45 or the Investment Tax Credit under Section 48. The grant – available to certain types of renewable energy projects including wind facilities – amounts to 30 percent of the cost of the eligible renewable assets. Property must however be placed in service in 2009-2010. Alternatively, if placed in service after 2010, construction must begin in 2009 or 2010, and the project in-service date must be no later than 2012 to be eligible. This requirement will therefore have to be factored into any strategy for financing the Pilot Project.

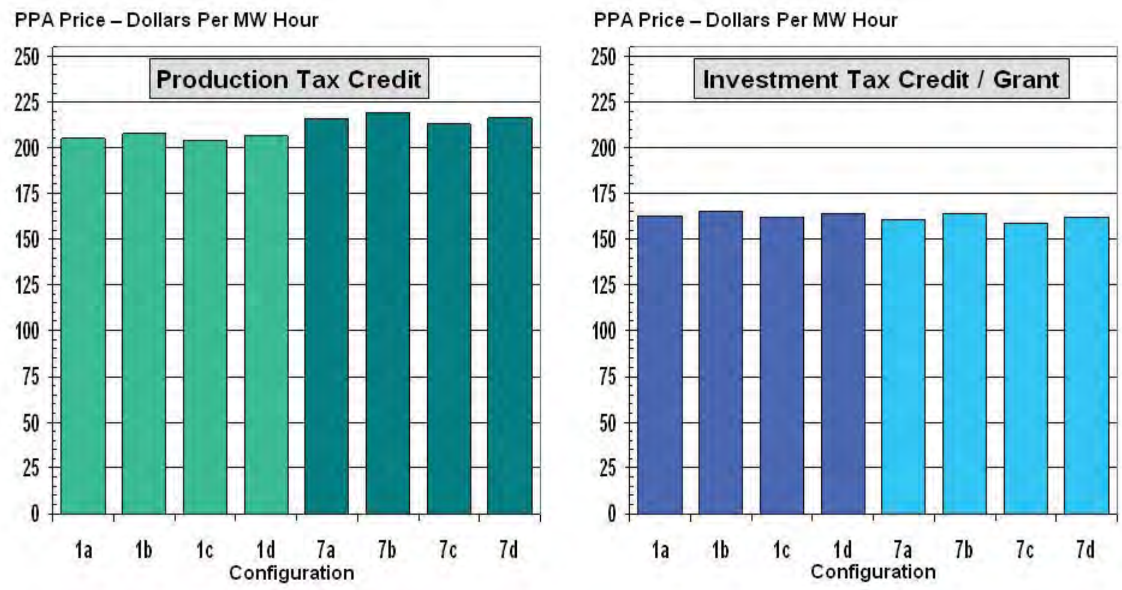
Like the ITC, one distinct advantage of the grant is the greater certainty of the cash return. However, unlike the ITC, the grant vehicle does not rely on the need of the project owner to take full advantage of the tax credits to realize the optimal impact.

Depending on the ultimate ownership structure for the Pilot Project, the ability to leverage the PTC or ITC remains uncertain. Still, project economic evaluations were undertaken to determine how utilization of the Grant or ITC option might impact the economic viability of the Pilot Project.

The majority of economic model runs utilize a standard set of baseline assumptions and estimates, including capital investments and O&M costs outlined in the Germanischer Lloyd, GLWEC Economic Assessment (March 2009), 60 percent debt leveraging and 10 percent target Discounted Cash Flow Return On Equity. The standard approach also includes ability to take full advantage of the Production Tax Credit.

There are various ways the impact of the grant or ITC might be compared to the PTC strategy. Still, to provide some sense of the relevant impact, the Baseline cases for each of the eight Layout configurations were run to determine what required PPA price would be necessitated to produce the 10 percent target DCFROE while employing the production tax credit. As illustrated in the left hand chart of Figure 11-18 below, the required initial PPA price ranges from about $204 - $219 per megawatt hour depending on the specific Layout configuration.

Figure 11-18: PTC Versus Grant / ITC Impact



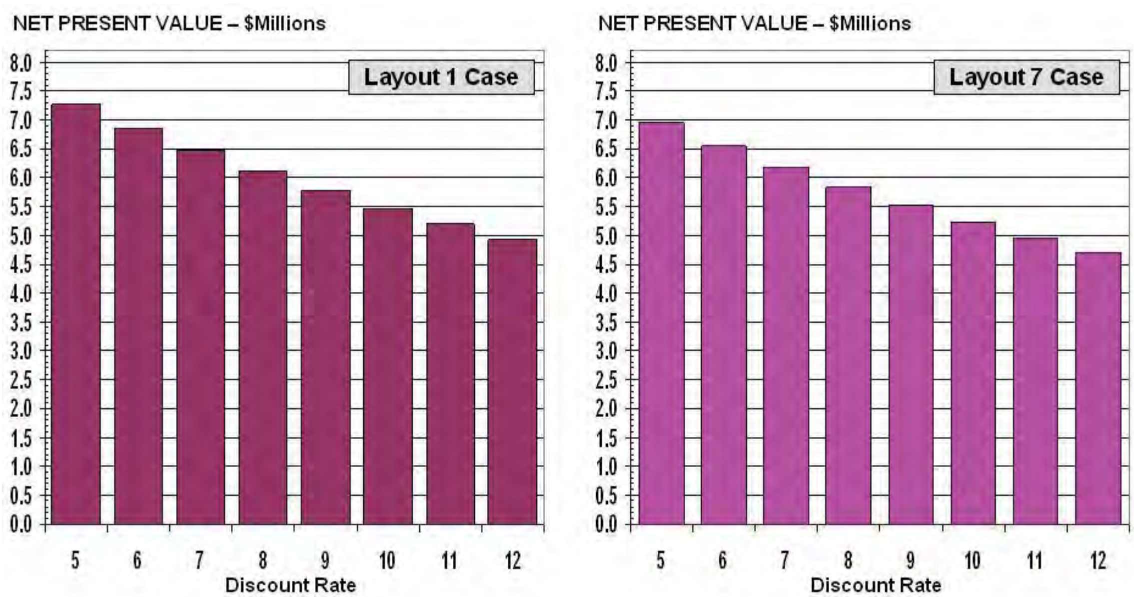
By comparison, the right hand chart of Figure 11-18 illustrates by Layout case what initial PPA price is required – all other factors holding constant – so as to produce 10 percent target DCFROE with the grant or ITC approach. In this instance, the required PPA price clusters narrowly around the $160 per megawatt hour mark – or about 20-25 percent below what was required utilizing the production tax credits. What is worth further noting is how the Layout 7 cases – higher costing on a per megawatt installed basis – are now more closely in line with results for the Layout 1 cases.

On the surface these results might be a bit surprising or even counter-intuitive. However, what appears to be a large reason why the grant / ITC produce such an impact are size and timing relative to the cash flow.

As previously noted, the installed cost for the eight Baseline Layout cases are estimated between $77.2 million to $92.7 million. Because ITC eligibility is based on tangible personal property, not all of the capital costs for these individual cases will be eligible for the 30 percent Grant / ITC. juwi's working assumption (through consultation with tax attorneys) is that approximately 90 percent of capital cost in the Baseline case is eligible. This translates to immediate cash flow impacts between $20.8 million and $25.0 million.

The Production Tax Credit impact the cash flow based on the level of actual energy production occurring over the course of ten years. The annual energy production for Layout 1 cases is estimated at 55,254 megawatt hours, while the energy production for Layout 7 case scenarios is estimated at 39,595 megawatt hours annually. As indicated in Figure 11-19 – depending on what discounting rate is employed – the Net Present Value (NPV) of the cash flow ranges from $4.9 – 7.3 million for Layout 1 cases while the NPV of the PTC cash impact for Layout 7 cases ranges from $4.7 – 7.0 million.

Figure 11-19: Net Present Value Impact of the Production Tax Credit



In short, the likely explanation for the varying impact of the PTC vs. ITC / grant is the relatively higher capital installation costs for the offshore project as well as the 30-31 percent net capacity factor and resulting forecasted energy production. While there may be some question whether the Pilot Project ultimately will be able to take advantage of the ITC / grant , it is advisable that the County further investigate this opportunity. Additionally, whether or not the ITC or Grant is employed, the results herein illustrate the relative impact on project economics of an approximately 30 percent grant. Grant funding will likely play a significant role in the overall financial attractiveness of the project.

11.2.7.10 Project Economics Summary Observations

The purpose of Section 11.2.7 is primarily two-fold: first to outline what might be required financially to justify Pilot Project economics, and secondly to determine how changes in key factors – whether operational or financial – might influence the financial attractiveness of a Great Lakes offshore project. As earlier noted, many factors will influence the project economics to a greater or lesser extent. Political and regulatory changes, energy market dynamics, and economic climate will affect the viability of the Project.

Factors shown to have the most significant impact on project economics include total installed capital cost, power purchase agreement (PPA) pricing, net capacity factor, and the capability to take advantage of the incentives in the 2009 American Recovery and Reinvestment Tax Act. While some of these may be outside of the direct control of Cuyahoga County, it is prudent to consider these impacts in formulating a development plan for the Project.

Factors having a lesser—although still significant—impact on project economics include the financing cost, and the operations and maintenance (O&M) cost. While of less material significance, these factors are not unimportant, and each will factor into overall project economics. Ultimately, and to the extent possible, the Project should utilize all viable mechanisms to reduce costs and increase financial attractiveness.

11.2.8 Possible Funding Opportunities

Specific financing mechanisms for the Pilot Project will follow the ultimate legal / ownership structure. To the extent that public vs. private, for-profit vs. not-for-profit entities are involved, different tax and financing incentives will apply. For example, access to Clean Renewable Energy Bonds implies public power companies or cooperatives, while tax incentives like the PTC or ITC apply to taxpaying entities. As the Project moves forward, it is important to maintain a range of available funding options. Table 11-17 provides an initial list of funding opportunities possible for the Pilot Project. The list is not exhaustive, but presents key considerations where further investigation is suggested.

Table 11-17: Possible Sources of Funding and Financing[9]

Funding Type	Sources and Examples
Income from Energy Produced	• PPA with a power utility • Contract with energy off-taker or behind the meter arrangement (non-utility) • Renewable Energy Credits (REC)
Grants or Loans	Different levels of government or government-run initiatives (federal, state, municipal) such as: • The Ohio Department of Development's (ODOD) Advanced Energy Fund • Grants from the Third Frontier Commission (e.g. 2009 Advanced Energy Program) • The U.S. Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE) financial assistance programs • 2009 Stimulus Package direct-dollar allocations
Partnerships	• Local utility companies such as: Cleveland Public Power (CPP), Cleveland Electric Illuminating (CEI, or FirstEnergy) • Environmental or other non-profit organizations: Green Energy Ohio (GEO), AMP Ohio • Large energy companies and wind developers such as BP, Shell, Chevron, FPL, EDP, EDF • Philanthropic foundations with a specialization in energy, power or the environment: M Foundation, Mid Ohio Regional Planning Commission (MORPC), The Cleveland Foundation, Maltz Family Foundation
Banks or Credit Unions*	Local or state banks/credit unions such as: Credit Union of Ohio, First Ohio Credit Union, Charter One, National City
Cooperative / purchase program	Other municipalities have been able to finance projects through a cooperative model or purchase program. The Pilot Project might be able to use a similar project-financing model. Some examples of such models include: • TREC Model in Toronto, Canada (residents buy shares in the wind farm) • The Mid Ohio Energy Cooperative Inc.'s Community Fund (residents willingly round up their utility bills to the nearest dollar to contribute to the fund)
Income from Operational Activities, or Project Sponsors	From turbine or turbine component manufacturers that may use the facility, donation of components, price reductions. Sponsorships may be possible from local/regional companies to support operational activities, purchase a portion of the electricity, or otherwise help defray costs.
R&D Grants	Different levels of government or government-run initiatives (federal, state, municipal) such as: • DOE / NREL • ODOD • The Cleveland Foundation • National Science Foundation or other similar grants typically available through academic institutions
University Partnerships	To help foster partnerships between universities, business, governments and community groups. Academic partners can capitalize on R&D opportunities and workforce training. • Case Western Reserve University, Energy Innovation Institute • Cleveland State University • Ohio University: Institute for Sustainable Energy and the Environment • Local community colleges and vocational schools

[9] Modified from original source: GLWEC Market Research Report, Germanischer Lloyd, April 2009.

Funding Type	Sources and Examples
Project Financing	• Large banks* that focus on energy and infrastructure, such as: BNP Paribas, Deutsche Bank, Dexia, Fortis, Heleba, HSH Nordbank, HVB, Mizuho, Nord/LB, Sumitomo, West LB • US banks* that focus on energy and infrastructure, such as: Key Bank, GE Energy Financial Services • Low interest debt through Clean Renewable Energy Bonds • Low interest debt through Cleveland-Cuyahoga Port Authority

** While example banks are provided, the level of risk associated with the Pilot Project's high capital and operating costs, combined with less electricity generation, makes the likelihood of bank financing highly questionable. For further explanation please refer to Section 11.2.7.7.*

11.2.9 Conclusions: Funding and Financing Options for the Pilot Project

This section presents an overview of key funding and financing options for the Great Lakes Wind Energy Center Pilot Project. It includes an evaluation of baseline project economics, and the material significance of key economic factors such as investment cost, debt leveraging, cost of debt, net capacity factor, O&M cost, and certain incentives under the 2009 American Recovery and Reinvestment Act. While some factors may be outside of the direct control of Cuyahoga County, information is presented to help frame economic considerations for the Project, and guide potential development plans.

The Feasibility Study assumes that a PPA would be the major revenue stream associated with the Pilot Project. The Pilot Project would demonstrate the technical feasibility of offshore wind turbines in the Great Lakes and the eventual market feasibility of commercial projects. It is widely recognized that Pilot Projects of this type will have installed costs much higher than can be expected for commercial deployment.

Key conclusions from the economic evaluation of the Project are as follows:

- Given the likely costs of an offshore Pilot Project, the energy production that might be realized, and assuming the Project were financed solely through private sector sources, it is likely that the power purchase agreement (PPA) pricing would be two to three-times current wholesale electricity market pricing in the region.
    - o Generation in terms of megawatt hours from the offshore Pilot Project is relatively small. Consequently, even with high above-market PPA price, the production cost impact on either the FirstEnergy or Cleveland Public Power supply portfolio will likely be small or negligible.

  - While PPA pricing estimates are higher than current wholesale regional electricity prices, impending carbon legislation through cap-and-trade and/or carbon tax might regional prices. Additionally, increases in fossil fuel prices—and especially natural gas—may also increase regional electricity prices near term. Because it offers a hedge against these impacts, offshore wind energy will become more economically attractive relative to other generating sources as electricity prices increase.
  - Investments associated with a Pilot Project will benefit the offshore wind industry—especially in the Great Lakes—as supporting infrastructure, methods, and equipment are developed, refined, and leveraged.

- Capital costs may be reduced by building fewer turbines or a smaller project. While this will not improve the $/MW installed cost, depending on total available funding and grants it could reduce the necessary PPA price for the Pilot Project.
- The capacity to take advantage of the incentives in the 2009 American Recovery and Reinvestment Tax Act may be particularly crucial to the Pilot Project going forward. Grant or other direct Stimulus dollar funding will improve project economics.
- The Investment Tax Credit or equivalent grant appears to make the Pilot Project much more economically attractive than the traditional Production Tax Credit mechanism. Holding other assumptions constant, the required PPA price is 20-25 percent less for the ITC / grant option compared to the PTC.
  - Although project construction may not start in 2009 or 2010, the case runs still illustrate the relative impact of an approximately 30 percent grant on the project.
- Renewable Energy Loan Guarantees in the neighborhood of 2.5 percent could work to lower PPA price significantly, perhaps by $15-20 per megawatt hour relative to current market interest rates.
  - Without loan guarantees, the relative risk of the Pilot Project is unlikely to attract debt providers
- While indirect Stimulus provisions are important, the Project will require additional sources of funding to be economically feasible. Possible sources of funding include:
  - DOE, NREL
  - Direct Stimulus dollars allocated by Federal, State or Local Government(s) County and/or other public sector support. The $28 million request by Cuyahoga County through the Ohio State Energy Program would benefit the Project significantly. For comparison, the relative impact of the ITC grant

presented in Section 11.2.7.9 was based on an estimated value of $20.8 to $25 million. It should be noted however that Stimulus or other grant money may reduce the qualifying amount for the ITC.

- Philanthropic organizations (i.e. Cleveland Foundation)
- Sponsorships or other participation by local/regional organizations or electricity customers
- Turbine manufacturer willing to provide equipment at reduced or no cost

- Overall funding and financing mechanisms will follow the legal / ownership structure of the Project. In turn, legal structure will be determined largely by extent of participation by private sector partner(s).
- Pursuing funding opportunities for the Pilot Project should be done in conjunction with broader policy efforts to better incentivize offshore wind in Ohio. Offshore wind qualifies as a renewable energy resources under Ohio's AEPS, however, if carefully done additional incentives such as elevated Renewable Energy Credits or a "carve out" in the AEPS would significantly promote the industry.

11.2.10 Further Economic Considerations

While offshore wind energy development is more capital intensive than comparable projects onshore, the offshore wind resource is also typically greater than onshore. The vast majority of wind development is currently occurring onshore, and will continue for the next several years. Arguments supporting offshore wind energy development center primarily on better wind resource, proximity of projects to load centers (especially on the Atlantic coast), better match between electricity demand patterns and offshore wind patterns, and minimized impacts on the viewshed. Additionally, as the best project sites are developed on land, developers will increasingly pursue offshore opportunities.

While the wind regime offshore of Cleveland is better than regional onshore wind regimes, higher capital and operating costs, and the Pilot Project's subscale size lead to a higher levelized cost of energy than that for onshore wind projects and commercial-scale offshore wind projects in locations with higher wind speeds.

While no wind energy projects exist on the Great Lakes, several are in the feasibility or planning stages. As is the case with many new technologies, initial investments face technical and logistical challenges and are typically higher cost and risk. As markets mature, solutions to challenges emerge, and learning curves drive costs downward. Cuyahoga County is currently at the forefront of wind energy development in the Great Lakes. A Pilot Project will undoubtedly provide solutions to technical challenges (i.e. icing) and further reinforce the viability of large-scale wind energy development. It will also encourage development of infrastructure, techniques, and equipment supporting a larger offshore wind industry in the Great Lakes. Consequently, it is reasonable to assert that project economics should not be the only factor determining whether or not to proceed with a Pilot Project.

The recent passage of the 2009 American Recovery and Reinvestment Tax Act is particularly timely, not only for the Pilot Project, but renewable energy in general. As illustrated in previous sections, the Act has a number of provisions that will likely benefit the Project. Employing a range of incentives will help reduce project costs and PPA price.

The American Recovery and Reinvestment Tax Act also includes new provisions for qualifying energy projects that re-equip, expand or establish a manufacturing facility for the production of property designed to be used to produce energy from the sun, wind, or geothermal deposits. While these particular provisions appear less applicable to the Pilot Project directly, it extends the value of tax credits to the wider supply chain of renewable energy technology, including manufacturing, investment and operational activities. In line with promoting economic development and job growth in the region, the Pilot Project will advance Cuyahoga County's standing in the offshore wind industry, especially in the Great Lakes region. Currently, northeast Ohio holds a large share of the wind turbine supply chain, providing various components from bearings to bolts. The Pilot Project will only help to attract turbine suppliers and other organizations to add to the region's manufacturing base.

Finally, the ability to attract a turbine manufacturer to participate in the Pilot Project and potentially provide turbines at a reduced cost could significantly improve project economics. To this end, we suggest continuing efforts by Cuyahoga County to attract turbine manufacturers to the area.

12 Community Stakeholder Engagement

12.1 Introduction

The County believes in the importance of providing clear, transparent, and positive messages about the findings of the report as well as potential plans for the future. To that end, BrownFlynn was engaged to develop strategies and tactics to help meet these objectives, and provide a clear guide for engaging stakeholders in any future dialogue related to wind energy development in the Great Lakes region.

At the onset of the project, BrownFlynn developed key messages about the feasibility study, conducted key message training with the Executive Committee of the Task Force, and provided Q&A documents and supporting facts about the Project. Throughout the course of the Feasibility Study, BrownFlynn has served as an information resource for media inquiries and other communications issues that surfaced over the past 14 months. BrownFlynn also developed Q&A documents and executive summaries for individual studies released during the Feasibility Study, provided (in conjunction with County staff) the media with all key documents and information as needed, and facilitated a media coffee with key media approximately mid-way through the study period.

12.2 Community Stakeholder Engagement Tactical Plan

Building upon a comprehensive stakeholder and issues mapping session with members of the Task Force Executive Committee, BrownFlynn also developed a Tactical Community Engagement Plan to educate, communicate and increase awareness of the potential for wind energy development on Lake Erie—both leading up to the press conference and following the release of the feasibility study. The recommended course of action should enable the County to reach a variety of stakeholders, raise awareness of the Feasibility Study findings, and help minimize any negative perceptions about the research project in the region.

The goals of the plan include:

- Release the Feasibility Study findings to the public through clear, concise and targeted messaging
- Raise awareness of potential economic development opportunities
- Increase public awareness and education of the potential for wind energy development on Lake Erie by building relationships with local, regional and national stakeholders and media

- Demonstrate the Great Lakes Energy Development Task Force's commitment to transparency and fiscal responsibility
- Establish the County as an advocate for responsible wind energy development and advanced energy
- Highlight success stories and positive impact on the community
- Engage local stakeholders in ongoing educational efforts

To increase buy-in, understanding, and support for potential wind energy development on Lake Erie, included in the plan are strategies and tactics for communicating with and involving key members of the community in an effort to promote advanced energy projects in the region. The tactics outlined in the following tables are intended as recommendations, and are subject to change based on a variety of factors, including new potential developments with various parties interested in the Pilot Project. BrownFlynn recommends the following tactics for engaging the public (refer to following tables):

SUMMER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Conduct comprehensive stakeholder mapping exercise	**Complete**	• Task Force Executive Committee	• Identify all potential stakeholders • Identify priority issues related to stakeholder groups • Categorize/prioritize stakeholders • Determine biggest supporters versus least supporters
Conduct internal brainstorming session	**Complete**		• Develop tactical plan • Brainstorm specific engagement tactics for identified priority stakeholders
Identify most immediate stakeholder needs that arise following Feasibility Study release	Summer 2009		• Verify outreach strategy in conjunction with press conference communication strategy (Note: BrownFlynn recommends evaluating the highest priority stakeholder needs following the Study's release and aligning the longer-term strategies outlined in this plan with those needs.)
Develop succinct messaging for ongoing stakeholder engagement	Summer 2009		• Draft and edit key messages, talking points and Q&A documents (to enhance press conference materials, but to be used separately when addressing potential long-term outlook for and education of wind energy development)
Identify project "champion(s)"	Summer 2009		• Identify and seek support from project "champions" (i.e. corporations, funders, government/public sector officials, etc.) • Provide "champions" with key messages and talking points

SUMMER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Educate local leaders to be champions	Summer 2009/ ongoing	• General public • Elected officials, politicians • Key leaders in Columbus and D.C.	• Provide ongoing project updates, talking points, fact sheets, etc. to local leaders • Encourage collaboration amongst local leaders and residents • Encourage local leaders to update residents at city council meetings, ward meetings, etc. about the status of the project • Identify any other key meetings for speaking/education opportunities
One-on-one meetings	Summer 2009/ ongoing	• Burke Airport • Port Authority • Lake Carriers Association • Great Lakes Towing • Recreational users of lake (boaters, yacht clubs, fisherman, etc.) • Others	• Conduct regular, in-person update meetings quarterly, or if deemed necessary, more frequently with priority stakeholder groups
Schedule regional/ educational town hall meetings (3 meetings: 1 East, 1 West, and 1 downtown Cleveland)	Summer 2009	• General public	• Identify location(s); consult on and attend meetings • Coordinate date(s) with key stakeholders • Publicize through the Plain Dealer, Sun Newspapers and other NE Ohio media • Distribute letter/invitation to stakeholders to attend meeting
Prepare documents for regional/educational meetings	Summer 2009	• General public	• Prepare PowerPoint presentation • Talking points • Possible Q and A (challenging questions from the audience) • Provide a take-away for audience members, research guide for getting in touch with key project members • Inform audience of future in-depth meetings/conversations

SUMMER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Train speaker(s) /presenter (s)	Summer 2009	• Steve Dever and other key project members	• Conduct presentation training • Simulate Q and A session
Hold regional/ educational meetings	Summer 2009	• General public	• Consult on and attend meeting • Communicate with media; reinforce positive messages • Create awareness among key stakeholders
Develop name and brand identity for the project	Summer 2009	• General public	• Brainstorm potential names/identity for project • Engage graphic design firm for branding work • Develop logo/identity • Determine proper application of logo/identity (i.e. stationary system, etc.)
Develop a project-specific website (separate from the County Task Force's site)	Summer 2009	• General public	• Develop interactive, educational and informative platform for project website • Apply logo/identity • Create a site-map • Draft and edit website content • Manage content/make updates
Sponsorship/visibility at local events	Summer 2009	• General public • Business Community • "Users of the water"	• Maintain a presence at local/downtown events including: o 185th Street Festival o Boat races/sailing competitions o Burning River Fest o Cleveland International Film Festival o Downtown Restaurant Week o Feast of the Assumption o Great American Rib Cook-off o Greek Heritage Festival o Ingenuity Fest o Luau on the Lake o Parade the Circle

SUMMER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Sponsorship/visibility at local events (continued)	Summer 2009	• General public • Business Community "Users of the water"	• Working with marketing/advertising departments of the following Cleveland institutions, maintain a presence at the following venues through advertising/ billboards, posters, programs, etc.: o The Cleveland Agora o Blossom Music Center o Browns Stadium o Cleveland Museum of Art o Cleveland Orchestra (Severance Hall) o Cleveland Play House o Great Lakes Science Center o The House of Blues o MOCA o Plain Dealer Pavilion o PlayhouseSquare o Progressive Field o Quicken Loans Arena o Rock and Roll Hall of Fame and Museum o Tower City Amphitheater o Wolstein Center

FALL 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Report back to community and stakeholders	Fall 2009	• General public	• Update stakeholders on community meeting, progress to date, and other relevant information • Inform audience members of resources available (phone number and voicemail, email, future meetings)
As follow-up to the 3 regional/educational meetings, reach out to residents of lakeshore communities (through ongoing meetings/ communication; timeline/schedule to correspond with project's potential progress)	Fall 2009	• Residents of the following communities: o Bay Village o Bratenahl o Cleveland o Euclid o Lakewood o Rocky River o Westlake	• Organize individual/specific meetings for each community identified • Speak to local homeowners associations • Speak at ward meetings • Provide timeline to residents and allow them to become involved in monitoring the project progress • Encourage small, face-to-face meetings with members of the community • Establish neighbor-to-neighbor club/network for informing others of progress • Engage champions of the project in each community • Organize a shoreline residents advisory council to the Task Force; or appoint/select 1 citizen representative to the Task Force
Engaging the "younger" generation	Fall 2009	• Young professionals/ young professional groups	• Reach out to already established advanced energy/innovation groups, etc. at colleges, universities, high schools and technical/trade schools in the region • Engage young professional groups to become advocates for wind energy development and other advanced energy projects (e.g. 10,000 Micro Ideas, Cleveland 20/30 Club, Cleveland.com young professional groups, etc.) • Reach out to downtown/lakeshore condo groups, homeowners associations (print publications, websites, etc.) • Organize a young leaders council to the Task Force; or appoint/select 1 young professional representative to the Task Force
Proactively engage media	Fall 2009/ ongoing	• Media ** See Addendum for media list	• Attend editorial board meetings of all major newspapers in area • Encourage open dialogue between the Task Force and members of the media • Engage the media as partners for educational events, community events, etc.
Engage environmentalists/ conservationists	Fall 2009	• Environmentalists/ conservationists	• Establish an environmental advisory council; or appoint/select 1 representative to the Task Force • Work with established outlets to raise awareness and provide updates

WINTER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
City Club Friday Forum and New Leaders' events	Winter 2009	• General public • Members of the City Club • Business Community	• Pitch an advanced energy/wind energy forum and speakers to the City Club New Leaders groups • Organize a panel of local/national leaders, advanced energy/wind energy experts, environmentalist, etc. • Encourage attendance of members and non-members
Partner with library systems (CCPL, Cleveland Public Library, independent library branches)	Winter 2009	• General public	• Host wind energy educational displays in lobby areas of libraries • Host wind workshops, community meetings in conjunction with local libraries • Engage the library to host a "Wind Month" focusing on educating residents on wind energy development
Employ social media strategies	Winter 2009	• General public	• Set up an educational/supportive Facebook group, LinkedIn group • Explore potential opportunities for SecondLife, Twitter • Consider a Task Force blog
Leverage attendance during sports games (Browns, Cavs, Monsters, Indians)	Winter 2009	• General public	• Paid advertising/promoting educational messaging on the JumboTrons, on the section dividers • Establish an educational kiosk at all sporting events (staffed by the "street team")
Guerilla marketing	Winter 2009	• General public	• Organize "street teams" of local youth, young adults to travel to cities/events to educate the public on the benefits of wind energy development (i.e. sporting events, downtown events, concerts, etc.) • Brainstorm name for street team • Have t-shirts, hats made • Train street team on messaging • Have materials printed for street team distribution
Partner with ParkWorks	Winter 2009	• General public • Nature enthusiasts	• Task Force to sponsor Movies on the Mall • Host educational events • Employ educational kiosks in parks, especially in shoreline areas
Partner with local nature centers, community centers	Winter 2009	• General public • Environmentalists / conservationists	• Make Your Own Wind Chime: make wind chimes out of recycled/recyclable materials and educate participants on wind energy • Wind Workshops: how to harness wind energy at your home

WINTER 2009 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Partner with Great Lakes Science Center	Winter 2009	• General public	• WindsDays (see above) • Host educational sessions for students, general public, etc. during summer months at the base of the wind turbine to promote wind energy development
Educate young children and partner with elementary schools	Winter 2009	• Youngest citizens of Cuyahoga County	• Promote "WindsDay" field trips to Great Lakes Science Center for wind education events (*Note: "WindsDays" could also be applied to a number of other initiatives outlined in this plan – e.g. the Library and other educational/outreach events.)* • Introduce advanced energy, wind energy into science curriculum

SPRING 2010 ACTIVITIES			
Action	**Timing**	**Audience**	**Activities & Tactics**
Leverage Cleveland's cultural heritage	Spring 2010	• General public • Artists, musicians • Gallery owners, gallery goers	• Reach out to local artists incubator to inform them of project; gauge level of support • Engage local artist groups, art students, etc. to commission art for a large public gallery, art show focused on advanced energy/wind energy • Ask a local gallery (set of several galleries) to sponsor a show focused on art interpreting wind turbines, wind energy, advanced energy, etc.
Promote education through the Cleveland Orchestra	Spring 2010	• General public • Orchestra goers • Musicians	• "WoodWinds:" an educational concert series in partnership with the Orchestra to promote wind energy awareness • Advertise in programs, through posters at Severance Hall, at Blossom Music Center
Develop and host creative events around the city	Spring 2010	• General public • Families	• Pinwheel Day on Lake Erie: invite members of the community to create pinwheels near the downtown shore of Lake Erie and learn about wind

12.3 Comprehensive Stakeholder List[10]

Business Community

- Cleveland Sports Teams
  - Cleveland Browns
  - Cleveland Cavaliers
  - Cleveland Indians
  - Lake Erie Monsters
- Component Manufacturers
  - Cardinal Fastener
  - Eaton Corporation
  - Lincoln Electric
  - Mittal Steel
  - Parker Hannifin
  - Phillips Electric
- Construction Companies and Developers
  - Developers Diversified
  - Forest City Enterprises
  - Great Lakes Construction
  - Lake Erie Construction
- Financial Community
- Greater Cleveland Partnership
  - NorTech
  - TeamNEO
- Material Suppliers (e.g. concrete, steel, etc.)
- Manufacturing Organizations
  - Magnet
  - Lorain County Manufacturing Council
  - Northeast Ohio Trade & Economic Consortium
  - Ohio Manufacturers' Association
  - Ohio Steel Council
- Ohio Trade Unions
  - AFL-CIO
  - International Brotherhood of Electrical Workers
  - International Longshoremen's Association
  - International Union of Operating Engineers
  - Iron Workers
  - Seafarers International Union
  - United Steel Workers
- Other Renewable Industries
  - Fuel-cell
  - Hydrogen
  - Solar
- Positively Cleveland (Cleveland Convention and Visitors Bureau)
- Supply Chain Organizations
  - Great Lakes Wind Network
  - Ohio Wind Working Group
- Utilities
  - Transmission
  - Potential Power Purchasers
    - Cleveland Illuminating Company/FirstEnergy

[10] This list, as identified by Task Force Executive Committee, is limited to the project's key stakeholders, and may be subject to change as the project evolves.

- Cleveland Public Power

Commercial Users of Lake Erie

- Burke Lakefront Airport
- Columbus Shipping (Westlake)
- Great Lakes/St. Lawrence Seaway
    - The St. Lawrence Seaway Management Corporation (Canada)
    - U.S. Saint Lawrence Seaway Development Corporation
- The Great Lakes Towing Company
- International Shipmasters Association
    - Cleveland
    - Toledo
- Ohio Fish Producers
- Pilots' Associations
    - Lakes Pilots' Association, Inc.
    - St. Lawrence Seaway Pilots' Association
    - Western Great Lakes Pilots
- Lake Carriers' Association
- World Shipping, Inc. (Cleveland)

Education

- Cleveland Metropolitan School District
- Cleveland Museum of Natural History
- Cuyahoga County schools (e.g. elementary, high schools)
- Great Lakes Science Center
- Higher Education Institutions
    - Baldwin-Wallace
    - Bowling Green University
    - Case Western Reserve University
    - Cleveland State University
    - Cuyahoga County Community College
    - John Carroll University
    - Lake Erie College
    - Lorain County Community College
    - Oberlin College
    - Ursuline College
- Lake Erie Nature and Science Center
- Ohio Historical Society
- University Clean Energy Alliance of Ohio

Environmental Organizations

- Citizen Action
    - Friends of Dike 14
    - Ohio Citizen Action
- Earth Day Coalition
- Earth Share of Ohio
- Earth Watch Ohio
- EcoCity Cleveland
- Environment Ohio
- Green Energy Ohio
- GreenCityBlueLake Institute
- Holden Arboretum

- Kirtland Bird Club (Cleveland)
- League of Conservation Voters
- National Audubon Society
  - Audubon Ohio
    - Audubon Society of Greater Cleveland (Cleveland)
    - Black River Audubon Society (Elyria)
    - Blackbrook Audubon Society (Mentor)
    - Firelands Audubon Society (Sandusky)
    - Western Cuyahoga Audubon Society (Cleveland)
- Natural Resources Defense Council
  - Midwest Regional Office (Chicago)
- Nature Conservancy of Ohio
- Ohio Citizen Action
- Ohio Environmental Council
- Sierra Club
  - Ohio Chapter
  - Cleveland Group
  - Toledo Group
  - Youngstown Group
- Western Reserve Land Conservancy

Foundations and Potential Funders

- Case Western Reserve University
- The Cleveland Foundation
- The Generation Foundation
- The George Gund Foundation
- Fund for Our Economic Future

Government

- Elected officials
  - City of Cleveland
  - Commissioners of surrounding counties
  - Cuyahoga County
  - Mayors and City Managers of surrounding areas
  - Ohio Congressional delegation
  - Public Information Officers
  - State of Ohio
- NASA Glenn
- National Renewable Energy Laboratory
- Politicians
- U.S. Department of Energy

Media

- **** See Section 12.4**

Pilot Project Competitors (offshore)

- Bluewater Wind (Delaware Offshore Wind Park)
- Buffalo, New York
- Cape Wind Project (Nantucket Sound)
- Garden State Offshore Energy (New Jersey)

- Great Lakes Wind Commission (Great Lakes Wind Collaborative)
- Toronto Hydro Energy Services
- Trillium Power Energy Corporation (Toronto)
- Wisconsin/Michigan

Recreational Users of Lake Erie

- Cleveland Airshow
- Fisherman
- Lake Erie Marina and Ports
- Yacht Clubs
  - Cuyahoga County Yacht Clubs
    - Bay Boat Club
    - Cleveland Yachting Club
    - Edgewater Yacht Club, Inc.
    - Forest City Yacht Club
    - Four Seasons Boat Club
    - Gordon Shore Boat Club
    - Intercity Yacht Club
    - Lakeside Yacht Club
    - The Northeast Yacht Club
    - Olde River Yacht Club
    - West Shore Boat Club
    - Wildwood Yacht Club
  - Lake County Yacht Clubs
    - Chagrin Lagoons Yacht Club
    - Fairport Harbor Yacht Club
    - Grand River Yacht Club
    - Lake County Yacht Club
    - Mentor Harbor Yachting Club
    - Mentor Lagoons Yacht Club
    - Rivers Edge Yacht Club
    - West Channel Yacht Club Inc.
    - Western Reserve Yacht Club
  - Lorain County Yacht Clubs
    - Beaver Creek Boat Club
    - Lorain Sailing & Yacht Club
    - Vermilion Boat Club

Regulatory Agencies

- City of Cleveland: Department of Public Utilities Division of Water
- Federal Aviation Administration
- Northeast Ohio Regional Sewer District
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Ohio Power Siting Board
- US Army Corps of Engineers
- U.S. Coast Guard
- U.S. Department of Homeland Security
- U.S. Fish and Wildlife Service

Residents of Cuyahoga County

- Lakefront Communities and Shoreline residents
  - Bay Village
  - Bratenahl
  - Cleveland
  - Euclid
  - Lakewood
  - Rocky River
  - Westlake

Wind Turbine Manufacturers

- International
- U.S.
- Ohio (component manufacturers)

Young Professional Groups

- City Club New Leaders
- Cleveland Bridge Builders
- Cleveland Professional 20/30 Club
- The ConnectionSeries
- Cuyahoga County Young Democrats
- Group of Aspiring Leaders at the Cleveland Clinic
- Heights-Hillcrest Regional Chamber of Commerce Young Professionals
- (i)Cleveland
- Lakewood Jaycees
- The Nature League of the Cleveland Museum of Natural History
- Ohio Jaycees
- Urban League of Greater Cleveland Young Professionals

12.4 Media Stakeholder List

Stakeholder Description	Company/Nonprofit/Group	Name
Print		
	Akron Beacon Journal	Bruce Winges
	Chagrin Valley Times	
	Cincinnati CityBeat	Steven Rosen
	Cleveland Business Connects	
	Cleveland IndyMedia	
	Crain's Cleveland Magazine	Chuck Soder
	Dayton Daily News	Steve Bennish
	Lake County Gazette	
	The Lakewood Observer	
	The News Herald	
	Plain Dealer	Tom Breckenridge
	Sun Newspapers - Beachwood Office	Mary Jane Skala
	Sun Newspapers - Berea Office	Linda Kramer
	Sun Newspapers - Metro	Linda Kinsey
	Sun Newspapers - North Olmstead	Carol Kovach
	Toledo Blade	Tom Henry
	WestLife	

Television		
	Channel 3 WKYC (NBC)	Tom Beres
	Channel 5 WEWS (ABC)	Duane Pohlman
	Channel 8 WJW (Fox)	Bill Sheil
	Channel 19 (WOIO) CBS)	Matt Stevens
	Channel 25 WVIZ/PBS	Mark Rosenberger
Radio		
	WCPN 90.3	Dan Bobkoff
	WTAM	Bill Wills
National or Environmental Media		
	Alternative Power Construction	Rob Krzys
	Earthwatch Ohio	Stefanie Spear
	GEO NEWS (Green Energy Ohio, quarterly magazine)	Kemp Jaycox
	Great Lakes Boating (blog)	Justin Hoffman
	Great Lakes Boating Magazine	Karin Malonis
	Electric Utility Week	Bob Matyi
	Industry Week	Brad Kenney
	New York Times	
	North American Wind Power	
	Power Daily, SNL Financial	Kerry Bleskan
	Renewable Energy World	
	Wall Street Journal	
	Washington Post	Peter Slevin
	Windpower Monthly	
	Wind Today	Heather Ervin
Internet/Blogs		
	Advance Northeast Ohio	
	Brewed Fresh Daily	
	CleanTechBlog	
	Huffington Post	
	NorTech	
	Ohio Means Business	
	REALNEO	Jeff Buster
Newswire Services		
	PR Newswire	
	CSRwire	

13 Conclusions and Recommendations

This report provides a feasibility analysis for creating the Great Lakes Wind Energy Center, including a 5-20 MW offshore wind energy project in Lake Erie near downtown Cleveland, and affiliated Test, Certification, and Advanced Research Centers. It includes information from deliverables produced through a one-year Feasibility Study period. Key conclusions from the Feasibility Study are presented in the following sections. Also refer to conclusions following individual sections of this report.

13.1 Siting

Based on established siting criteria and information collected throughout the course of the Feasibility Study, juwi recommends an area east of the Cleveland water intake Crib, generally between potential turbine configurations 1 and 7. Primary reasoning for this site includes:

- Sufficient wind resource for Pilot Project – estimated to be ~7.5 m/s annual average at 80 m hub height, based on Crib anemometer measurements and long term correlation. Initial LiDAR data from winter 2009 show a high degree of correlation with Crib anemometers.
- Safe distance from Burke Lakefront Airport / outside FAA cone (pending FAA review and approval)
- Close proximity to proposed most feasible interconnection locations at CPP or CEI, reducing cabling distances and associated costs
- Presumed geological conditions supporting drivability of monopile foundations and load bearing strata
- No conflict with artificial reefs or shoals, dumping grounds, known / documented shipwrecks, or other underwater features
- No presumed conflict with established sailboat race courses
- Turbines are outside Audubon Ohio Important Bird Area; avian impact is expected to be minimal
- Site should allow sufficient buffer from shipping lanes to mitigate risk of collision
- High iconic value, while preserving the above

Other potential sites in the Project area share attributes listed above, and final site determination will involve consultation with regulatory agencies and other stakeholders (i.e. Lake Carriers Association, Burke Lakefront Airport, FAA).

13.2 Technical

Overall, the results of this report conclude that construction of the GLWEC is technically feasible. The information from generalized **geologic** references together with the available site-specific data indicates that a wide range of lakebed conditions can be anticipated off the Cuyahoga County shore. While these varying conditions might make one foundation type preferable to another in a particular location, they do not preclude the siting of wind turbines anywhere within the study area. Except for a surficial layer of soft recent sediment, the area west of downtown Cleveland contains glacial till over relatively shallow bedrock. East of downtown Cleveland, the study area lies over an ancient buried river valley where bedrock is 100 feet (30 meters) or more below the lakebed. The old valley is filled with interbedded glacial related deposits of till, outwash and lacustrine sand, silt and clay of varying consistency and compactness.

Due to preliminary soil information from previous studies (strata and depth) but subject to final site specific investigations, **monopiles** currently appear to be the preferred foundation option for the Pilot Project. Monopiles have been used in similar water depths at European offshore wind projects and if driven will likely be the most economical option. Gravity base foundations are the most likely alternative, subject to soil load bearing tests. Welded steel structures such as tripod or jacket could be suitable as well, but they are very expensive and due to their complex fabrication process will probably be less economical.

For design purposes, the annual average **wind** speed (at 70 m height, 10-min mean) can be stated to be *up to* 8.2 m/s, and the 50-year extreme wind speed (at 70 m height, 10-min mean) is ~ 38 m/s. These and other main parameters result in wind conditions below the requirements of GL Wind Turbine Class II at the proposed Pilot Project site. Thus, a wind turbine fulfilling the GL Class II requirements should be suitable for the Project.

With regard to **waves** and other limnic conditions (e.g. water depths, water levels, water density, currents), first design values were derived. Buoy data from the NOAA buoy 45005 were analyzed to derive the principal values and a first wave scatter diagram. Results of this analysis are a mean significant wave height of 0.82 m and a 1-year significant wave height of 2.5 m. To describe the extreme conditions the 50-year values were derived. The 50-year significant wave height is 4.1 m with a 50-year maximum wave height of 7.8 m. Compared to offshore conditions in the German North Sea and Baltic Sea, where offshore wind projects have been built, extreme wave conditions in Lake Erie are moderate. Maximum wave heights (50 years) in Lake Erie reach 7.8 m which is less than half as high as extreme waves in the German North Sea.

Ice is expected to be the principal design driver. The proposed locations for the GLWEC Pilot Project close to Cleveland can be considered as one of the more moderate areas of the Great Lakes, with respect to expected ice thicknesses. An average level ice thickness of around 30 to 35 cm can be expected each winter, and the maximum level ice thickness is approximately 50 cm. The maximum expected rafted ice thickness may be around 60 cm. Average ice cover duration is 66 to 69 days but varies from 33 to 105 days, starting about mid-December and lasting through mid-March.

Other ice parameters, like compressive and bending strength, are not mentioned in the existing research on ice conditions in Lake Erie, but in general a bending strength of 750 kPa and a compressive strength of 2 – 3 MPa should be assumed. Because of these ice conditions an **ice cone** should be considered on the pile in the waterline to break up ice, reduce loading on the structure and avoid or minimize ice induced vibrations. The ice cone could be part of the transition piece and its upper edge could form the access platform. The cone should be designed as inverted ice cone where upper diameter is greater than lower diameter. Final design of the ice cone may require ice modeling in a cold weather laboratory. Ice thickness measurements taken at the Crib during the Winter of 2009 should ultimately help help refine design parameters.

13.3 Environmental

Given the small footprint of the Pilot Project (5-20 MW with 2-10 turbines), the potential impacts to the water quality, benthic community and fishery will be minimized. At this time, there are no **marine ecological** concerns that would limit construction and operation of the Pilot Project. Construction activities, such as building the foundation, disposal of excavated material and cable installation, will generate potential short-term impacts to the biota. Short-term impacts would include physical disturbance of the lake bottom by removing the substrate and loss of benthic fauna and displacement of fish.

Impacts caused by the excavation of spoil can include smothering of benthic organisms, suspension of sediments, increases in turbidity, and changes to lakebed height and sediment dynamics. Of these, the increases in sediment suspension and turbidity would be considered short-term impacts and any impacts to the benthic community would be temporary and limited in spatial importance. The remaining impacts are considered longer term, however, given the small size of this project, both of these impacts would be localized and neither would be expected to have effects on the dynamics of water currents, sedimentation or wave action outside the wind farm.

Cable installation effects include the potential electromagnetic disruption of larval and adult fish feeding and migration behavior. The concern of electromagnetic fields is usually minimized by using three-phase cables and burying the cable underground. No conclusive studies have been performed that demonstrate an electromagnetic effect (including no effects) on fish. On-shore disturbances from burying cable would potentially have short-term impacts to vegetation and animals present at the site.

At two to five miles (3.2 to 8.0 km) offshore, and with water depths exceeding 33 feet (10 m), very few **birds** are expected to use the waters within the Project area during most of the year. In summer, the most frequently occurring species will be Ring-billed Gull, Herring Gull, and Double-crested Cormorant, but their numbers will be much less than closer to shore. Red-breasted Merganser and Bonaparte's Gull will be two of the more common migrants using Lake Erie waters, particularly in fall migration, with occasionally large numbers offshore. Common Loon appears to occur more often in migration offshore than inshore, but its abundance on Lake Erie is relatively low. When icebound in winter, the Project site will lack waterbirds, but when ice-free, some species, mainly gulls, may forage at the Project site on occasion. Some may attempt to perch on the docking portions of the turbines.

As defined by Audubon Ohio, the Cleveland Lakefront Important Bird Area extends about one mile (1.6 km) into the lake (although distances vary with respect to the shoreline) and does not include areas where Pilot Project turbines would be located.

In migration, many birds use the airspace over Lake Erie, with most songbirds, waterfowl, and shorebirds migrating at night. Radar and other studies in the U.S. indicate that nocturnal migration occurs mostly at altitudes above the height of wind turbines, although a small percentage of birds migrate at lower altitudes. The density of nocturnal migration at Cleveland will be similar to other sites studied at similar latitudes. An analysis of archived NEXRAD radar data from the Project site has confirmed this. The NEXRAD data also confirm that no significant migratory corridor exists through the Project area.

The concentrations of migrating hawks that occur around Lake Erie are generally close to the shoreline. However, a few hawk species are adapted to crossing large water bodies during migration. The likeliest species to cross the lake include Peregrine Falcon (Ohio threatened), Osprey (Ohio endangered), and Northern Harrier (Ohio endangered), none of which come from Ohio nesting populations. The incidence of migrating hawks at the Project site is expected to be nil.

Among Ohio-listed and other special-status species, Common Tern (Ohio endangered) may occur infrequently at the Project site during fall migration. There is no reason to believe that it would be attracted to the waters of the Project site. Most of the common Ohio-listed species that migrate nocturnally over Lake Erie are from northern populations that are reasonably secure. Most of the common migrants among WatchList species are near the northern limits of their ranges in Ohio; therefore, the numbers of those species crossing Lake Erie will be minimal. The federally listed Piping Plover and Kirtland's Warbler are accidental in the Cleveland region, implying that they are rare in migration across this portion of Lake Erie.

Post-construction studies from the Pilot Project will inform future offshore wind development on Lake Erie and ensure that the resource is harnessed responsibly and with minimal environmental impacts. It is recommended that post-construction study of avian interaction be done through an established Technical Advisory Committee (TAC), which would include members of USFWS, ODNR, Cuyahoga County Board of Commissioners, representatives from the wind development community, Great Lakes Energy Development Task Force and other relevant stakeholders.

Offshore wind energy can help improve regional **air quality** and reduce emissions from regional generating facilities. Assuming approximately 45,000 MWh / year produced from the Pilot Project, and compared to Ohio's average electricity mix, the Pilot Project could potentially offset 310 tons of sulfur dioxide, 72 tons of nitrous oxide, and 41,175 tons of carbon dioxide annually during the operational stage[11].

13.4 Economic

Offshore wind energy development is more capital intensive than comparable projects onshore. Accordingly, the vast majority of wind development is currently occurring onshore, and will continue for the next several years. Arguments supporting offshore wind energy development center primarily on better wind resource, proximity of projects to load centers (especially on the Atlantic coast), better match between electricity demand patterns and offshore wind resource patterns, and minimized impacts on the viewshed. Additionally, as the best project sites are developed on land, developers will increasingly pursue offshore opportunities.

Lake Erie possesses the best wind resource in Ohio, and it is likely that offshore wind energy will contribute significantly to Ohio's electricity supply in the future. With respect to the Pilot Project, while the wind regime offshore of Cleveland is better than regional onshore wind regimes, higher capital and operating costs, and the Pilot Project's subscale size will lead to

[11] Information on Ohio's energy mix from Energy Information Administration: http://www.eia.doe.gov/cneaf/electricity/st_profiles/ohio.html

a higher levelized cost of energy than that for onshore wind projects and commercial-scale offshore wind projects in locations with higher wind speeds. For these reasons future offshore wind energy projects on Lake Erie will likely be large scale, several hundreds of MWs each. Designed to test and prove concepts, and promote technological and commercial development, the Pilot Project should not be expected to provide attractive economics as with a large-scale, commercial project.

In total, eight potential Pilot Project scenarios are evaluated, representing a range in capital investment of $77.2 - $92.7 million ($2008), and average annual operations and maintenance costs of $2.7 - $4.6 million ($2010). Capital and operating costs are much higher than comparable wind projects onshore, primarily due to higher costs associated with offshore installation and maintenance, and small scale. Due to uncertainties regarding the sites and installation in the Great Lakes, capital cost estimates herein include 15% contingencies. However, it should also be noted that development fees and finance-related costs are excluded, which might represent 10-15% of total cost.

It is assumed that Pilot Project installation will involve mobilization of jackup and other specialized vessels from North America, compliant with Jones Act provisions. It is also assumed that a helicopter and/or small service boat for personnel transport and routine service would be located in or near Cleveland harbor.

The difficulty in accessing offshore turbines, especially in icing environments, substantially increases costs associated with operations and maintenance. Additionally, due to increased down time waiting for spare parts and/or service vessels, turbine availability for energy production (see Section 5) is less than for onshore wind projects. A spare parts inventory and/or large service vessel would significantly improve offshore wind turbine availability on Lake Erie, however, high fixed costs make these uneconomical for a small scale, pilot project. Cost savings could be achieved through partnership with other offshore wind projects in the Great Lakes. The challenge of accessing offshore turbines also presents research and development opportunities to investigate new access techniques and equipment.

It is important to stress that the projected economics of the Pilot Project should not be considered to reflect the future economics of subsequent offshore wind projects in Lake Erie. Later projects will undoubtedly be larger scale, located in better wind resource areas, and able to capitalize on assets and advancements that were also made as a result of undertaking the Pilot Project.

Given the likely costs of an offshore Pilot Project, the energy production that might be realized, and assuming the Project were financed solely through private sector sources without any special grants or subsidies, it is likely that the power purchase agreement (PPA) pricing for the Pilot Project would need to be two to three-times current wholesale electricity market pricing in the region. PPA pricing estimates range between approximately $160 and $220 per megawatt hour, depending primarily on the ability to take advantage of the ITC grant through the 2009 Stimulus Act, or the traditional PTC, respectively.

While PPA pricing estimates are higher than current wholesale regional electricity prices, impending carbon legislation through cap-and-trade and/or carbon tax might increase regional prices. Additionally, increases in fossil fuel prices—and especially natural gas—may also increase regional electricity prices near term. Because it offers a hedge against these impacts, offshore wind energy will become more economically attractive relative to other generating sources as electricity prices increase. For the Pilot Project, securing grants from the Department of Energy and other organizations will significantly improve project economics. Attracting a turbine manufacturer to participate in the Pilot Project, become a leader in the future offshore wind market in the Great Lakes, and potentially provide turbines at reduced or no cost will also benefit the Project.

Investments associated with a Pilot Project will benefit the offshore wind industry—especially in the Great Lakes—as supporting infrastructure, methods, and equipment are developed and refined. A Pilot Project will undoubtedly provide solutions to technical challenges (i.e. icing) and further identify the viability of large-scale wind energy development. Consequently, it is reasonable to assert that project economics should not be the only factor determining whether or not to proceed with a Pilot Project.

The Feasibility Study assumes that a PPA would be the major revenue stream associated with the Pilot Project. The Pilot Project would demonstrate the technical feasibility of offshore wind turbines in the Great Lakes and the eventual market feasibility of commercial projects. It is thus widely recognized that the Pilot Project will have installed costs much higher than can be expected for subsequent commercial projects. While no wind energy projects exist on the Great Lakes, several are in the feasibility or planning stages. Public and other support for the Pilot Project will advance knowledge of offshore wind and reduce risk for developers and private sector investors.

As is the case with many new technologies, initial investments face technical and logistical challenges and are typically higher cost and risk. As markets mature, solutions to challenges emerge, and learning curves drive costs downward. In line with promoting economic development and job growth in the region, the Pilot Project will advance Cuyahoga County's standing in the offshore wind industry, especially in the Great Lakes region. Currently, Northeast Ohio holds a large share of the wind turbine supply chain, providing various components from bearings to bolts. The Pilot Project will only help to attract turbine suppliers and other organizations to add to the region's wind manufacturing base.

Attracting a turbine manufacturer to participate in the Pilot Project and potentially provide turbines at reduced or no cost could significantly improve project economics. Additional methods to make the Pilot Project more economically attractive include grant funding from DOE or NREL, direct Stimulus spending, grants through local, regional, or national organizations, or sponsorships or other participation by local/regional organizations and companies or electricity customers.

13.5 Test, Certification, and Research Centers

The results of market research indicate moderate demand from turbine and component manufacturers for the three Centers. With respect to the **Test Center**, viability will be completely dependent on which area testing will be undertaken. Based on surveys of manufacturers, recommended areas for testing are prototype testing, condition monitoring systems, measurement of environmental conditions, calibration of test equipment and site assessment. These are areas where research is currently being undertaken. Turbine manufacturers may be interested in testing although smaller manufacturers without established testing facilities would be more likely to utilize the Center.

The **Certification Center** proposal was met with a positive confirmation that turbine manufacturers contacted would be interested in utilizing a facility located within the USA. Component manufacturers stated in general that the component certification is specified by the turbine manufacturers. Currently, it is not mandatory to certify turbines or projects within the USA, however, as the industry grows investors and developers will push to standardize the quality of the components. Because of legal requirements or because investors and developers will seek to reduce risks it is likely that within the next 5-10 years certification will become mandatory for all offshore projects. It is recommended that Cuyahoga County partner with an established certification body to proceed with this aspect of the Project, as this would provide an established reputation which would result in faster potential growth rate for this business area. Turbine manufacturers will require highly skilled personnel.

The market for a **Research Center** does exist, however, the time frame for establishing a reputation would be best served by working closely with an established body (i.e. NREL) and using their reputation in order to market the Center's capabilities. Local / regional academic institutions should also be integrated. The areas where research should be undertaken are those not well covered by other research institutes. These areas are primarily wind energy integration, offshore deployment, and operations and maintenance (O&M). Combining the Pilot Project with the Research Center to train personnel and develop new techniques for accessing turbines is seen as a potential market.

With respect to each Center, it is recommended that Cuyahoga County partner with established research organizations, certification bodies, and/or academic institutions. These partnerships will help to further identify viable opportunities for testing and research, potential facilities, and also create a framework for how different organizations could participate.

14 Suggestions for Next Steps

The GLWEC Feasibility Study addresses many key questions regarding the technical, regulatory, and economic viability of an offshore Pilot Project in Lake Erie, and associated Test, Certification, and Advanced Research Centers. Altogether, the results of this report indicate that construction of the GLWEC is feasible, pending approval by regulatory agencies and solutions to make the project more economically viable. This section outlines recommended next steps to advance the Project.

14.1 Site Selection

Primarily to focus further technical studies and advance discussions with regulatory agencies, juwi recommends choosing one preferred site for the Pilot Project. Turbine locations may have to remain somewhat flexible through the continuing development period, however a general project boundary for preferred project location should be chosen. Siting information in this report should provide sufficient basis for a determination of preferred and alternative site(s).

14.2 Consultation with Regulatory Agencies

This report will facilitate project information sharing between the County and regulatory agencies. Consultation should continue following the release of this report, especially with the Army Corps of Engineers, Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and US Fish and Wildlife Service. Key goals of consultation should be confirmation of site(s), approach to additional pre-construction studies, if any, and preparation of applicable permit applications. Because of the small scale of the Pilot Project, environmental impacts are expected to be very minimal (see especially Sections 6.1 and 6.2). However, given no previous experience with offshore wind on Lake Erie, post-construction studies should be employed to measure impact and validate the longer-term soundness of commercial offshore wind development on Lake Erie. Recommendations are made with the knowledge that extensive post-construction surveys may be uneconomical for a small, pilot project. If these studies are to be done, funding from state and federal agencies, as well as the non-profit environmental community, should be sought. Such funding would be a significant and proactive step in the development of clean-energy solutions.

14.3 Technical Studies

Several additional technical studies will be required post-Feasibility Study and prior to construction of the Pilot Project. The list below is not exhaustive, but provides logical next steps to advance the Project into the design phase.

14.3.1 Interconnection

Interconnection studies are required prior to any new power generation facility. Following discussions with CPP and/or CEI regarding power offtake, interconnection studies and preliminary design should be initiated. CPP and CEI have both indicated that they will conduct the studies internally and not go through the Midwest ISO. There may be a cost associated with these studies, however, given the small size of the Pilot Project and County leadership, interconnection study costs may be reduced or waived.

14.3.2 LiDAR

LiDAR equipment should be used to verify wind resource measurements from the Crib meteorological tower. LiDAR data will be especially useful in determining wind shear values and refining wind speed estimates at potential turbine hub heights. juwi recommends collecting LiDAR data for a continuous period of three to six months. Cuyahoga County, City of Cleveland, and Case Western Reserve have collaborated and deployed a LiDAR unit on the Crib during the winter of 2009. Although equipment failure led to limited data retention, initial results indicate a high degree of correlation (agreement) with Crib anemometers. At the time of this report, plans exist to collect further data in the coming months.

14.3.3 Geotechnical

Following a site decision and confirmation of potential turbine locations, geotechnical investigation should commence. A seismic survey should be conducted at proposed turbine locations to detect soil layers. For the final design, Germanischer Lloyd recommends Cone Penetration Tests at each turbine location and borings at extreme locations with soil sampling and laboratory tests of the samples. The number of borings can be determined when more information on the soil is available. At present a minimum of two is recommended. The extent of the geotechnical investigation and the type and number of laboratory tests should be determined in close cooperation with a geotechnical/engineering firm that will derive the structural design values. Depending on chosen turbine locations, water depth, and drilling rig, it is possible either a jackup barge or floating barge (tethered to lakebed) could be used for the geotechnical investigations. It is expected that geotechnical investigations will be a major investment, potentially $250,000 - $750,000 for the Pilot Project depending primarily on number of borings, type of vessel and distance for mobilization, and weather contingencies.

14.4 Funding and Policies

It is assumed that funding and financing parameters will determine final attributes of the Pilot Project, especially capacity (MW) and number of turbines. To this end, it is necessary to pursue funding opportunities or otherwise reduce costs to make the project more economically viable. The 2009 Stimulus Package could provide significant benefit to the Project, particularly with respect to direct spending (especially for demonstration projects or through the State Energy Program, administered by ODOD), loan guarantees, and the potential to claim a grant equivalent to the Investment Tax Credit. These opportunities should be pursued as possible by the County or other partners. Additionally, the Project should apply for grant programs through the Department of Energy as appropriate. DOE grants can be monitored at www.eere.energy.gov and applied for at www.grants.gov.

Partnering with a turbine manufacturer could be a significant advantage for the Project moving forward, especially if turbines are available at reduced or no cost. A turbine manufacturer's participation in the Pilot Project may also increase the likelihood that they locate a facility in the Cleveland area, thereby expanding employment and otherwise creating economic development opportunities. It is highly likely that interest in larger scale development on Lake Erie will factor into the turbine manufacturer's decision to participate in the Pilot Project. The County should continue to pursue turbine manufacturers regarding their interest in locating in the Cleveland area and participating in the Pilot Project.

Pursuing funding opportunities for the Pilot Project should be done in conjunction with broader policy efforts to better incentivize wind energy in general and particularly offshore wind in Ohio. Offshore wind qualifies as renewable energy resources under Ohio's AEPS, however, if carefully done additional incentives such as elevated Renewable Energy Credits or an offshore wind "carve out" in the AEPS would significantly promote the industry. To remain a committed leader in the Great Lakes offshore wind industry, Ohio should adopt policies to make the initial build-out of the offshore wind industry economically attractive to private sector interests. Strong policies are critical to ensure that significant development of the offshore wind industry in North America occurs in Ohio. In the interest of fostering a healthy industry in Ohio, general permitting requirements and timelines should also be designed to allow projects to move forward responsibly and expeditiously.

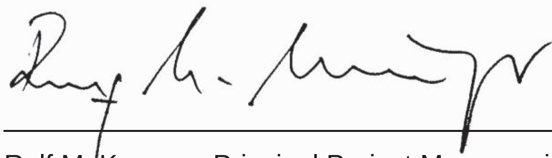
14.5 Test, Certification, and Research Centers

Cuyahoga County should partner with established research organizations, certification bodies, and/or academic institutions to pursue opportunities related to these Centers. Suggested candidates include, but are not limited to, NREL and Case Western Reserve University for research and testing, and Germanischer Lloyd for certification.

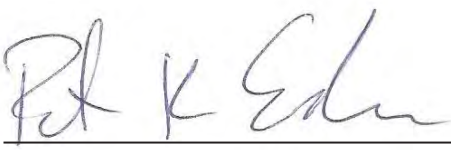
14.6 Community and Stakeholder Engagement

The success of offshore wind energy development in the Great Lakes will depend largely on community/public support, and support from various stakeholders concerned with turbine siting, environmental impact, economic considerations regarding use of Lake Erie, and other issues. To the extent feasible, Cuyahoga County should make efforts to further engage community stakeholders and educate the public about the Pilot Project and offshore wind energy in the Great Lakes. Ideas for stakeholder engagement are presented herein, although their pursuit will depend on securing sufficient resources. This recommendation is made knowing it may not be financially feasible for the County to embark on a comprehensive public outreach plan.

15 Signature Page



Ralf M. Krueger, Principal Project Manager, juwi



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