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# Floating Laser Pulse Technology: A Strategy for Great Lakes Hub Height Offshore Wind Assessments

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# Floating Laser Pulse Technology: A Strategy for Great Lakes Hub Height Offshore Wind Assessments


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## Introduction

The principal purpose of this project is to conduct a wind assessment study of Lake Michigan and to advance the body of knowledge that will allow successful offshore commercial wind energy development on the Great Lakes. The project involves the permitting and installation of the first offshore wind power assessment meteorological (MET) facilities in Michigan's Great Lakes, utilizing Laser Pulse Technology (LPT). In addition to validating the technology, other important research that will contribute to the deployment of offshore wind technologies are being undertaken based on the guidelines established by the Michigan Great Lakes Wind Council (GLOW Council). The project has created opportunities for public dialogue and community education about offshore wind resource development.

Project collaborators include: U.S. Department of Energy, Michigan Public Service Commission, WE Energies, Sierra Club of the Great Lakes, Grand Valley State University, University of Michigan, Michigan Technological University, and Michigan State University.

## Objective

The goal of this 3-year, ongoing project, is to advance the development and deployment of offshore commercial wind energy on the Great Lakes by collecting and analyzing data that is essential to wind industry investment decision-making. Mutually beneficial objectives of the collaborators include: deploy equipment to gather extended-season, hub height, offshore wind data; correlate offshore LPT based wind assessment data with conventional on-shore MET tower data; and perform meteorological and environmental studies that will contribute to the advancement, deployment, and greater understanding of offshore wind development technologies.

## Scope of Work

While valuable lessons can be learned from current offshore wind turbine installations, the Great Lakes area poses particular challenges to the development and deployment of offshore wind, particularly with respect to the climatology of the region. A first step towards fully understanding the potential of offshore wind energy generation in the Great Lakes area requires a more detailed analysis of the wind resources available, and their variability in time and space. To this effect, the following activities were undertaken to support the permitting and installation of wind assessment facilities in Lake Michigan designed to capture offshore wind data on an extended season basis.

**Phase One:** Issue a call for proposals (RFP) to seek private co-funding for the project, including proposals to design, engineer, procure, construct and deploy a new offshore MET facility .

**Phase Two:** Once funding is in place, begin preconstruction activities, including the permitting process.

**Phase Two:** Deploy MET facility at multiple Lake Michigan Locations.

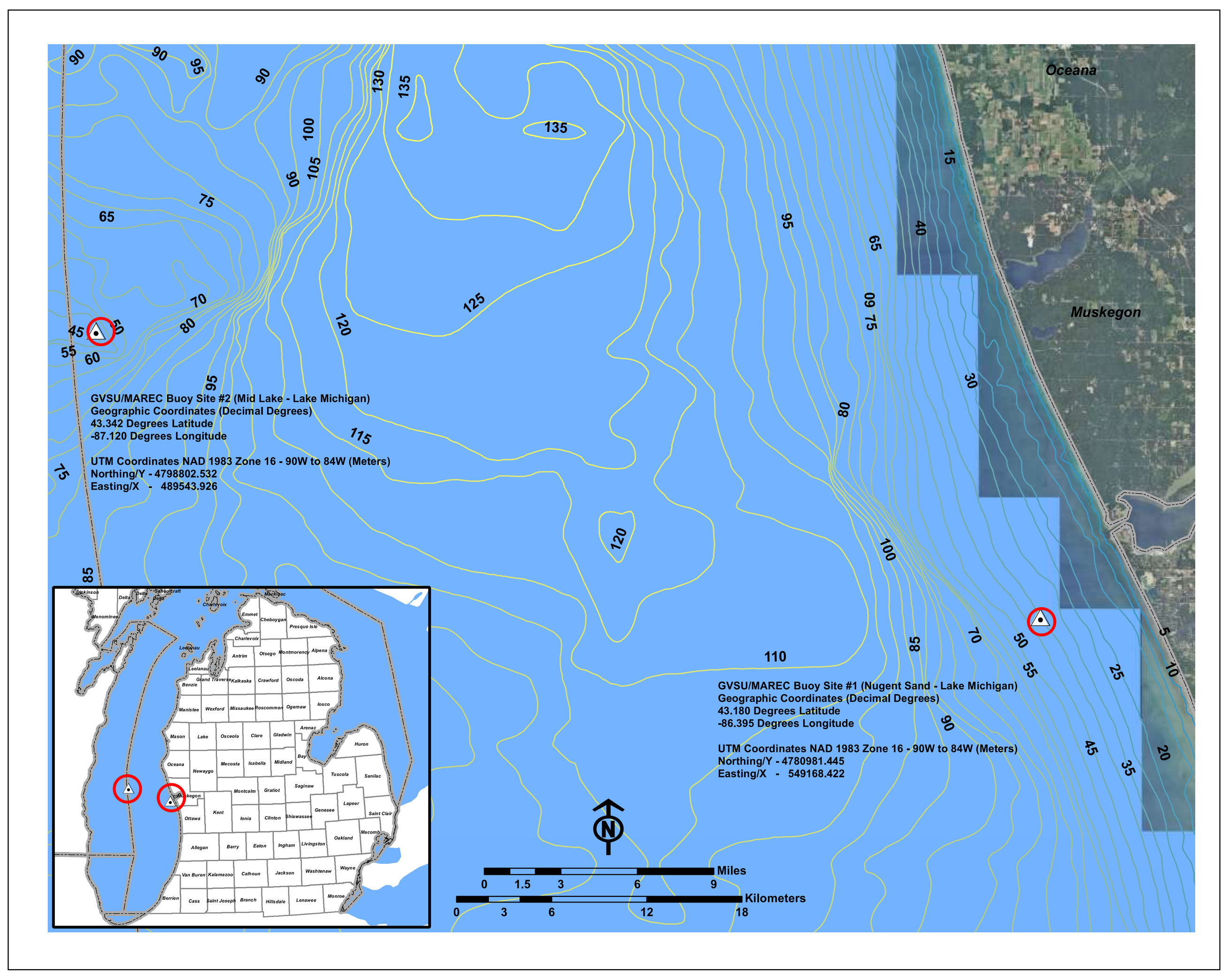
**Phase Three:** Validate laser wind sensor; gather and analyze data; present results.

The issues studied and reported on include:

- Demonstrate MET facility siting and permitting of systems;
- Deployment of offshore MET equipment and research instrumentation specifically linked to commercial scale wind industry development;
- Calibrate offshore LWS and correlation with shoreline cup anemometer MET instruments;
- Assess LPT capability to establish hub height measurement of wind conditions at multiple locations on Lake Michigan;
- Utilize an extended-season (9-10 month) strategy to collect wind data and weather conditions on Lake Michigan;
- Test wireless data transmission technology from offshore structures;
- Field-validated sound propagation model and analysis of offshore sound from shoreline locations;
- Document the presence or absence of bird and bat species near wind assessment facilities;
- Document the presence or absence of benthic and pelagic species near wind assessment facilities;
- Development of real time analysis and mesoscale model/simulation input to generate meteorological fields and wind estimates for large portions of the Lake Michigan.

## Mid-Lake Location

Located 35 miles offshore in 165' of water. During the 2012 season, the research buoy experienced three significant storms with sustained winds of 60 mph, gust to 70 mph, and 28' seas.




## On-Board Equipment

To select the appropriate MET facilities for Lake Michigan, GVSU issued a request for proposals to construct a fixed spar tower equipped with anemometers and other sensors. Two competitive bids were received and the lowest bid was $12 million dollars, well in excess of the funds available. All bids were rejected and a second request for proposals was issued that did not restrict proposals to a fixed spar. Three proposals were received, one for a floating Nomad buoy, and two for a floating spar buoy. After considerable deliberation with the Research Leadership Team and negotiations with the proposing vendors, the WindSentinel was selected based on cost, flexibility of hardware installation, and ease in movement.

The WindSentinel Buoy is a Nomad style platform buoy, 20' long with a 10' beam. The GVSU configuration includes the following equipment:

- Vindicator Laser Wind Sensor using laser pulse technology (LPT). The Vindicator can be set to measure wind speed and direction at six different heights or range gates. The GVSU's range gates are set at 75m; 90m; 105m; 125; 150m; and 175m.
- Watchman 500 data controller that collects over 200 data parameters per second. The raw data is sorted and 1 second data is converted to 10 minutes averages for transmission to shore and the project servers.
- Orientation and position system including compass engine and GPS (D+)
- Data Transmission is accomplished by use of one to three on board systems; wireless cell phone, Imersat and Iridium satellite systems.
- Power systems include solar panels, wind turbine, and a back-up generator with a 24 volt, 135 amp alternator. A bank of 40 batteries stores the energy. The system is designed to operate without assistance for 6-9 months.
- Bird and Bat SM2 acoustic sensors
- Other Sensors including a directional wave sensor, relative humidity and temperature, water quality monitor, barometric pressure, 2 anemometers, water temperature, and AIS system.

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**http://scholarworks.gvsu.edu/marec/**

## Results

### THE WIND RESOURCE

The table and charts below summarize the data collected by the Laser Wind Sensor..

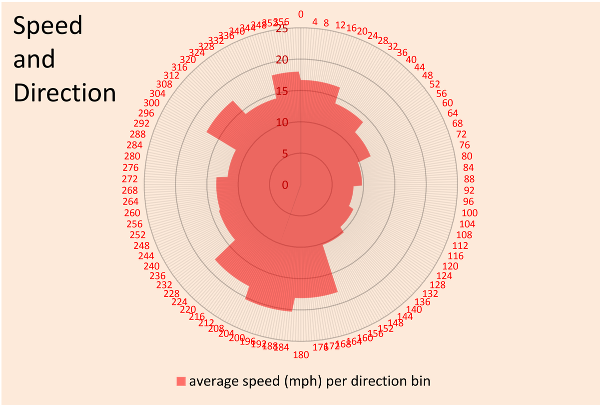
**Location:** Lake Michigan – Mid-lake Plateau (4320.5100N, 8707.2057W)
**Date:** August 1 through August 31, 2012 (UTC)
**Range Gates 1-6:** 75, 90, 105, 125, 150, 175 meters
**Cup Anemometer (2):** Are mounted on the buoy, 3m above the water surface
**Observations:** 10-minute averages transmitted, 1- second data stored on the buoy and retrieved manually
**Number of Observations:** 31 days at 24 X 6 observations per day = 4464 observations
**Missing Observations: As** shown in table 4.
**Good Observations: As** shown in table 4.

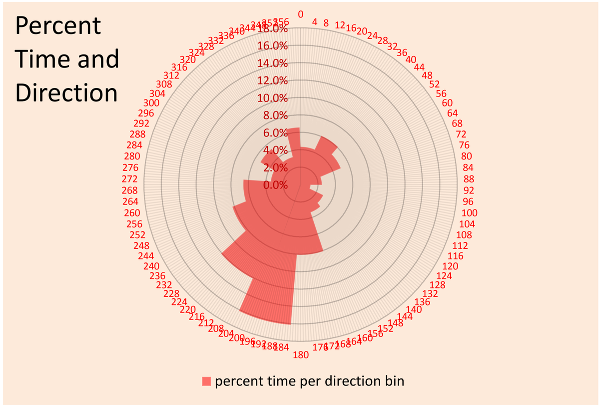
The information below shows the horizontal wind speed and the energy generated for each range gate. The amount of energy generated depends on the turbine employed, in this case the Gamesa Elioca G58 850kW. It was assumed the turbine always faced the wind.

Wind Speed (meters per second) and Energy (kWh/time unit) by Range Gate

| Range Gate | Number of Obs. Possible = 4,464 | % Good Obs. | Average Horizontal Wind Speed | Average Horizontal Wind Speed -- 1 Obs. per hour | Average Horizontal Wind Speed -- Difference | Average Power (kW) | Average Daily Energy (kHh) |
|---|---|---|---|---|---|---|---|
| 1 | 4,229 | 94.70% | 6.9 | 6.9 | 0 | 306 | 7,346 |
| 2 | 4,244 | 95.10% | 7.1 | | | 315 | 7,571 |
| 3 | 4,243 | 95.00% | 7.2 | 7.1 | -0.1 | 320 | 7,684 |
| 4 | 4,214 | 94.40% | 7.1 | 7.1 | 0 | 316 | 7,595 |
| 5 | 2,986 | 66.90% | 7.1 | | | 310 | 7,437 |
| 6 | 1,466 | 32.80% | 8.5 | | | 418 | 10,036 |
| Buoy Cup | 4,452 | 99.70% | 5.4 | 5.4 | 0 | 171 | 4,111 |

The wind rose graphs show the wind speed by direction as well as the percent of time the wind was blowing in each direction for Range Gate 4




### EQUIPMENT VALIDATION

**Paired-t Analysis for the >6.7m/s, No Enhanced Turbulence Data Set**

| Data Set | Mean Difference (m/s) | Standard Deviation (m/s) | Coefficient of Variation | $R^2$ | Number of Differences (n) | 99% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| **>** 6.7 m/s no enhanced turbulence | -0.028 | 1.1 | -39 | 65% | 416 | -0.17 | 0.11 |

The magnitude of the mean difference is less 0.1m/s. This difference is neither operationally significant nor statistically significant (a=0.01) as the 99% confidence interval for the true mean difference contains zero. Again, the coefficient of variation is much greater than 1 indicating that the mean difference is due to random variation. Thus, validation evidence is obtained for wind speeds greater than 6.7m/s and no enhanced turbulence. The correlation coefficient of 65% is due to a few large differences seen at high wind speeds (Figure 5) as would be expected.

### EVIDENCE OF BAT ACTIVITY

The current Lake Michigan Offshore Wind Study is the first systematic assessment of bat and bird activity in offshore areas of Lake Michigan in relation to wind energy development. To the best of our knowledge, these represent the first such recordings made in offshore ("over the horizon") areas in the Great Lakes. The first three species are known long-distance migrating bats, while the eastern pipistrelle has been described as associated with water.

| Group/Species | # of Calls |
|---|---|
| | |
| High Frequency Group | 535 |
| Low Frequency Group | 228 |
| "All Calls" (High + Low) | 763 |
| | |
| eastern red bat (*Lasiurus borealis*) | 21 |
| hoary bat (*Lasiurus cinereus*) | 45 |
| silver-haired bat (*Lasionycteris noctivagans*) | 17 |
| eastern pipistrelle (*Perimyotis subflavus*) | 9 |

## Conclusions

- Floating Laser Wind Sensors are capable of high quality recordings of the wind resource with no operational or statistical significance in recording technology vs. anemometer cups
- This is the first study of Turbulent Kinetic Energy (TKE) offshore by the University of Michigan and Michigan Technological University During storms, mean TKE increases with height above water.
- Sufficient winds exist over Lake Michigan to generate 7,684 kWh using a 850 kW turbine at 125 meters high
- This is the first offshore study of Birds and Bats by Michigan State University's Natural Features Inventory. Birds and Bats do frequent the middle of Lake Michigan.
- Based on the wind resource, and the depths of Lake Michigan, future turbine placement will most likely incorporate floating technology
- The most appropriate locations will enable direct routing of transmission cables to existing generating and transmission facilities located along the Michigan shoreline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