

Locating Wind Energy Facilities in Michigan's Coastal Counties

**FINAL REPORT OF THE WEST MICHIGAN
WIND ASSESSMENT**



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Final Report of the West Michigan Wind Assessment

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Issue Context and Policy Questions

Introduction

Michigan's energy landscape is changing. In 2012, Michigan was home to 641 utility-scale wind turbines in eleven counties with a total capacity of 978 MW [1]. On the other hand, Michiganders may soon see fewer smokestacks on the horizon. Michigan has the second oldest fleet of fossil fuel plants in the nation with an average age of about 50 years and some of its oldest plants will be closed [2]. Consumers Energy has announced that it will shut down its B.C. Cobb power plant in Muskegon on January 1, 2015 and it will not pursue a new coal-fired power plant in Bay City [3]. The growth in wind energy and the closing of some of the state's oldest coal-fired sources are visible signs of change in Michigan's energy landscape. These changes in the landscape reflect shifts in Michigan's energy infrastructure which will have implications for Michigan's environment, economy, and society.

Residents of the West Michigan region enjoy a high quality of life. The 2010 Gallup-Healthways Well-Being Index ranked West Michigan's Holland-Grand Haven corridor as second in the nation in overall well-being [4]. The well-being index includes indicators of, among other things, economic growth, public health, and environmental quality. Each of these indicators is influenced by the region's energy infrastructure, such as through investment in new facilities, the effect of air pollution on public health, and the impact of electricity generation on aquatic ecosystems. On the other hand, new electricity infrastructure development could be perceived as a locally unwanted land use, whether it is coal, nuclear, natural gas or wind. Depending on the type or source of electricity and whether the facilities are appropriately sited, new electricity development could negatively affect the well-being of area residents or it could be a catalyst for improving the region's economic, social, and environmental conditions.

Michigan residents also share a strong connection to the Great Lakes. In a 2003 survey sponsored by the Joyce Foundation, Michigan residents were more likely than residents of other Great Lakes states to "strongly express a personal responsibility for the Great Lakes." The survey also found that throughout the Great Lakes states, electricity-related activities, including air pollution and water use by power plants, were identified as a threat to the Great Lakes (37 percent and 22 percent, respectively) [5]. Improvements to Michigan's electricity system that enhance environmental quality, such as air and

water pollution reduction and water conservation, are consistent with responsible stewardship of the Great Lakes and its surrounding watersheds.

The closing of outdated fossil fuel plants presents a challenge for Michigan: what to replace the generating capacity with. The options are limited to the following:

- Reduce demand through energy efficiency
- Upgrade transmission and import electricity from other parts of the state or region
- New or expanded coal-fired plants, with or without carbon capture and storage
- New or expanded natural gas plants
- New or expanded nuclear plants
- New renewable capacity, such as wind, solar, or biomass

These choices are not mutually exclusive and can, in fact, complement one another. Each of these energy choices has its benefits and drawbacks. This report focuses on these energy choices as they are related to wind energy. The benefits and drawbacks of wind energy are often not equally distributed across the landscape. That is, the benefits tend to accrue to the broader population while the drawbacks tend to be more localized, though host communities can also reap benefits. The following analysis presents key challenges and options for reducing the costs to local communities and enhancing the benefits.

The West Michigan Wind Assessment project was commissioned by Michigan Sea Grant's Integrated Assessment program to investigate the social, economic, environmental, and technical dimensions of wind energy development in Michigan's coastal counties. The project team focused on a four county study area along the Lake Michigan shoreline, including Oceana, Muskegon, Ottawa, and Allegan counties. The target audience for this final report and associated issue briefs includes decision-makers in local and state governments, diverse commercial interests such as tourism and fishing, and concerned citizens. The best available science about the many dimensions of wind energy was summarized and distributed in a non-technical format that was accessible to a broad audience.

New generation and transmission infrastructure will be built in Michigan to meet current and future needs for a reliable system. The Integrated Assessment (IA) process specifically acknowledges that challenges faced at the local level are components of challenges at national and global scales. In this sense any assessment of wind energy in coastal West Michigan must take into account that wind energy is just one component of the entire region's electricity system. The IA therefore framed the assessment in terms of two policy-relevant questions, one broad, high level question and one specific question.

- How can we create a 21st century electricity system that enhances the quality of life in coastal communities and the quality of the Great Lakes?
- How can wind energy development in West Michigan contribute to this system?

This report directly answers the second of these questions by providing specific, policy-relevant options for integrating wind energy into the regional electricity system. In doing so it provides some guidance towards the first higher level question. While the benefits and challenges of wind energy development in West Michigan influences, and is influenced by, factors outside of Michigan, a complete assessment of these national and global factors is beyond the scope of this assessment.

The project team identified four main objectives for the West Michigan Wind Assessment that flow from the second, more specific framing question. If wind energy is to contribute to a sustainable 21st century energy system in West Michigan, then decision-makers and the public need policy-relevant information about how wind energy has or has not been integrated into energy portfolios elsewhere. The public involvement and attitudes toward wind energy are especially important. The lessons from these worldwide successes and failures can be applied to West Michigan. Decision-makers and the public also need information about the latest science and best practices in the field of wind energy including its economic, social, environmental, and technical dimensions. They also need this information in an accessible format. Finally, the IA process is driven by stakeholder engagement. The IA engaged a wide range of stakeholders from across the study area to solicit topics for investigation, give feedback on issue briefs, participate in a guided discussion forum (Delphi Inquiry), and generally provide guidance on the conduct of the IA. These four objectives are summarized below.

1. Identify trends and lessons from Michigan and around the world regarding public attitudes toward wind energy development.
2. Apply trends and lessons to the West Michigan study area.
3. Explore the potential of economic, social, environmental, and technical policy and management options to reduce wind energy siting conflicts.
4. Encourage stakeholders to participate early in the wind farm siting process.

West Michigan's wind resource

Westerly winds blow across Lake Michigan toward the coastal counties of the study area. The strong, consistent winds offshore provide an outstanding wind resource. Once onshore, however, the wind speed tends to slow so that the best winds tend to be concentrated in the western half of the coastal counties and at higher elevations elsewhere (Figures 1 and 2). Wind resources of 6.5 meters per second (m/s) or greater at 80 meters high are in general suitable for energy development. The NREL map of Michigan wind speeds shows that many coastal areas in West Michigan have winds that exceed 6.5 m/s (rust color on the map) indicating that they could be viable for energy development [6].

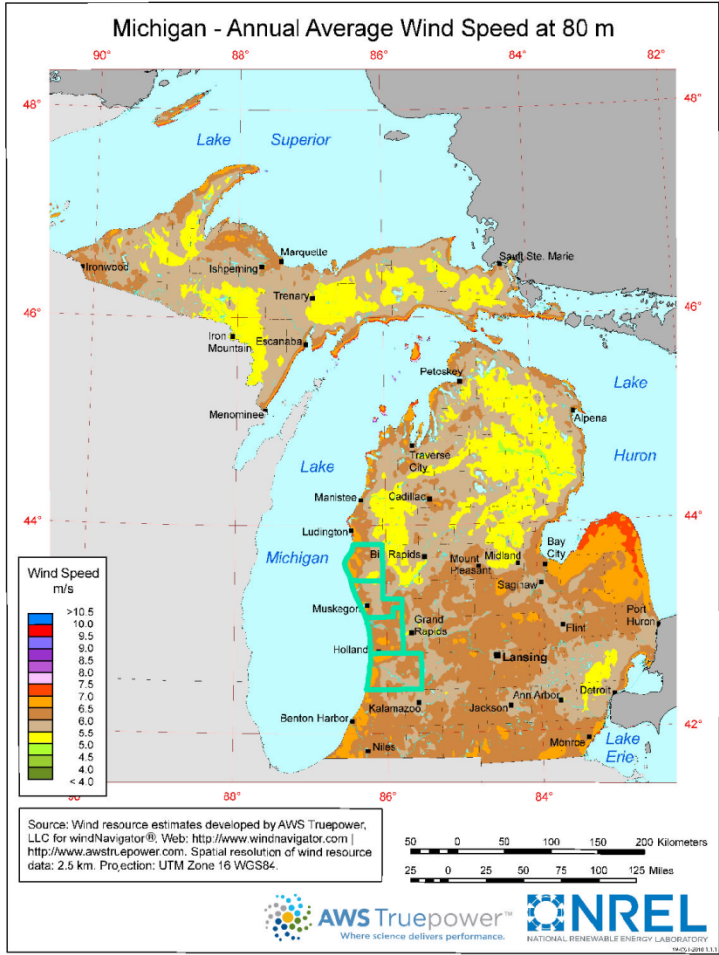


Figure 1: Michigan's average annual wind speeds at 80 meters above ground, highlighting (in teal) the four-county study area in West Michigan [6].

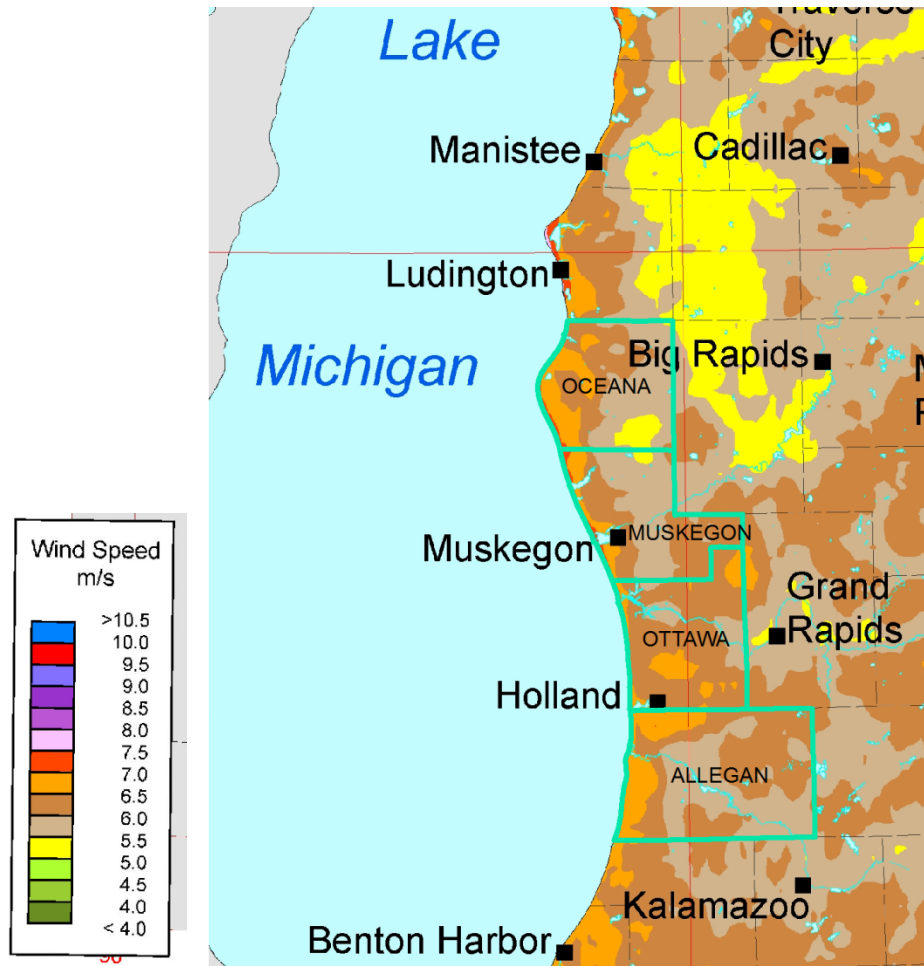


Figure 2: The western half of the study area (outlined in teal) supports great wind speeds with some areas approaching or exceeding 7 m/s at 80 m above ground [6].

New state policies spurred interest in wind energy

Though a few relatively small wind turbines have been operating in Michigan since the 1990s, the primary driver of renewable energy expansion is Public Act 295, the Clean, Renewable, and Efficient Energy Act of 2008 (PA 295). Governor Granholm signed the act into law with the aim of diversifying energy resources, enhancing energy security through the use of indigenous energy resources, encouraging private investment in renewable energy and efficiency, and improving air quality [7]. Most importantly, PA 295 established a ten percent renewable energy standard for the state. Under the act, electricity providers must source ten percent of their electricity sales from renewable sources by 2015. The West Michigan Wind Assessment’s *Status and Trends* report provides more details on PA 295 and the renewable energy standard [8].

The electricity providers affected by this Act are primarily turning to wind energy to meet their renewable energy requirements because wind energy is the most cost-effective, scalable energy option for the region. Eighty-seven percent of new renewable energy generation in Michigan since 2009 has been wind energy [1].

Wind energy is already part of Michigan's energy portfolio and projects have been proposed in the West Michigan region. If Michigan is to be successful in meeting the 10 percent renewable energy target in a cost-effective manner, wind energy will need to be part of the mix. The challenge is to minimize the conflicts and costs (priced and unpriced) that wind energy imposes while retaining the benefits it brings. We recognize that wind energy is not the only energy choice available, and it is not appropriate or desirable in all places and circumstances. The following section outlines some of the key issues as well as some options for addressing those issues.

Key Issues in Wind Energy Development for West Michigan

Economic dimensions

Key Issue: Energy costs and economic development potential

West Michigan citizens have expressed concerns about the cost of wind energy, including production costs and effects on electricity rates, but also they want to know about wind energy's economic development potential. The West Michigan Wind Assessment team investigated these issues in two briefs [9, 10].

The cost of wind energy includes both direct production costs and external costs, also called spillover or indirect costs. The project team estimated the total production cost of electricity (including external costs such as pollution) in West Michigan over a 20-year project life cycle from three sources: wind, coal, and natural gas. Tax incentives and subsidies were not included in the analysis. The team found that natural gas had the lowest total unsubsidized cost (\$61/MWh), followed by wind (\$74/MWh). Coal had the highest total cost (\$78/MWh) (Figure 5). All costs were reported as year 2010 dollars. These findings are consistent with a report from the Michigan Public Service Commission. The commission found that levelized contract prices (a different measure than production cost) for wind energy were, on average, \$80/MWh compared to a benchmark contract price for coal of \$107/MWh. Contract prices for wind energy in Michigan continue to fall and the most recent contracts were less than \$55/MWh [9]. Wind energy in Michigan is less expensive than coal.

Citizens have voiced concerns about the potential spillover effects of wind energy on property values and the IA team addressed this concern. The project team reviewed ten peer-reviewed journal articles and theses about the impact of wind energy development on residential housing prices. All of the studies using actual sale prices came to the same conclusion: there is no evidence of consistent, meaningful property value reductions from constructed wind turbines. When presented with choices involving hypothetical wind farms, however, survey participants expressed a preference for views without wind farms. This suggests that, all things being equal, people would rather not have a view of a wind farm. That preference, however, is not strong enough to measurably influence home sale prices.

The electricity utilities are allowed to pass along to customers the cost of implementing the PA 295 renewable energy standard. The price of wind energy is consistently lower than utilities expected. For example, Consumers Energy, the main electric utility in West Michigan, has dropped its renewable

energy surcharge to \$0.52/month from \$2.50/month. The energy optimization component of PA 295 resulted in \$3.55 in avoided energy costs for every dollar spent on energy optimization [1]. The combination of energy optimization and renewable generation has not harmed Michigan electricity consumers.

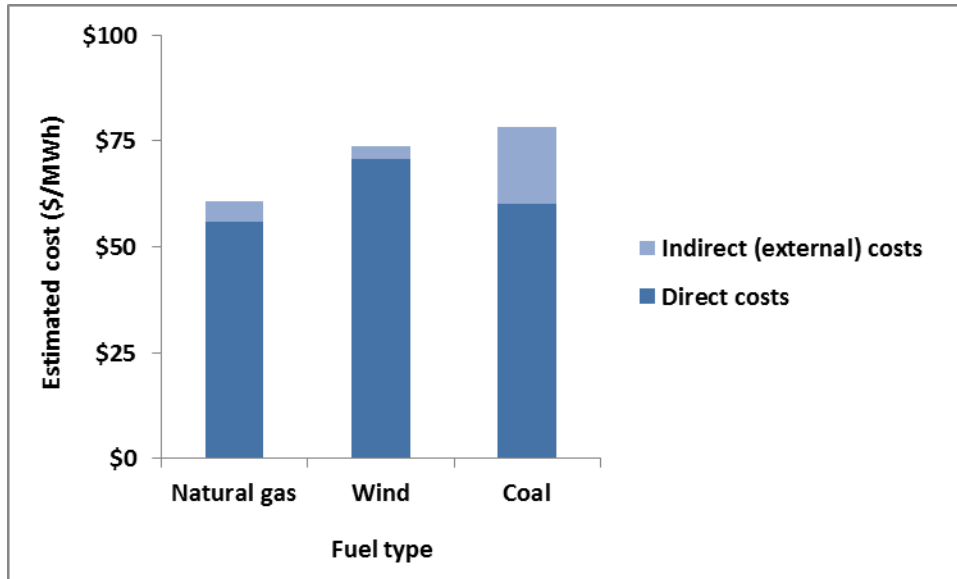


Figure 3: Wind energy's total production cost is lower than that of coal, but higher than that of natural gas (cost reported in year 2010 dollars).

Building and operating a wind farm requires large investments in machinery and labor which has an economic development impact. The project team used the National Renewable Energy Laboratory's "Jobs and Economic Development Impact" (JEDI) tool to estimate the economic impact of wind energy development in West Michigan. The team found that a generic 100 MW wind farm in West Michigan with no local manufacturing content would have a \$54.7 million impact during the construction phase and an additional \$5.1 million annual impact during the operational phase (Table 3). About 492 people could be employed (directly and indirectly) in the construction phase and about 30 (directly and indirectly) when the wind farm is operating. The team's economic impact estimates were consistent with new data from constructed wind projects in Michigan. For example the 100 MW Lake Winds Energy Park, located in a county adjacent to the study area, was reported to contribute more than \$4 million in direct payments to local vendors for construction services and materials. More than 150 workers were employed in the wind farm's development and construction [10].

Table 1: JEDI output for a 100 MW wind farm in West Michigan – no local content.

Category	Jobs	Output
<i>During construction period</i>		
Project Development and Onsite Labor Impacts	75	\$4,794,040
Turbine and Supply Chain Impacts	294	\$36,694,178

Induced Impacts	123	\$13,214,710
Total Construction Period Impacts	492	\$54,702,928
<i>During operating years (annual)</i>		
Onsite Labor Impacts	6	\$413,992
Local Revenue and Supply Chain Impacts	8	\$2,996,326
Induced Impacts	16	\$1,665,776
Total Annual Operating Period Impacts	30	\$5,076,094

Options: Using locally manufactured content increases local economic development

Using even a small percentage (10%) of locally manufactured content substantially increases the project’s economic development impact. For example if 10% of the wind turbine components were manufactured in West Michigan, the economic development impact would increase to \$93.2 million during the construction period, up from \$54.7 million.

The West Michigan region has 519 MW of wind energy projects in the planning stage (as of 2010). If all of these were built and assuming no local content, the economic development impact would be \$283.9 million for the construction period and \$26.3 million annually during wind farm operation. If 10% of the turbine components were manufactured locally, the construction period impact could be as high as \$483.9 million. There are some options now for local content, such as turbine blades manufactured in Holland, Michigan by Energetx. Muskegon’s L3 Combat Propulsion Systems is developing a direct-drive turbine.

Other options for increasing economic development could include local or community ownership of wind farms and negotiating better leases and “good neighbor” payments to landowners who live adjacent to a property with a wind turbine.

Social dimensions

The social dimensions of wind energy development include everything from public policy at local and state levels to public perceptions. These issues are about human relationships: connections among community members, between people and the technology, and between residents and the land. There are often no technical fixes to these issues. Mitigating the conflicts requires navigating and strengthening those dynamic relationships which in turn requires trust and respect among all parties.

Key Issue: A patchwork of regulations

The issue brief *Wind Energy Deployment: Global Lessons for West Michigan* [11] highlighted the tradeoffs between local control and a more top-down, centralized control of wind energy development. Local control of wind energy siting has its benefits and drawbacks. Local control allows for place-specific siting regulations, acknowledges local attitudes toward the technology, and empowers communities to protect the health and welfare of their residents as they see fit. Planning laws can regulate, but cannot ban, otherwise legal activities including wind turbines. On the other hand, local control of siting results in a patchwork of regulations the complexity of which could stymie wind energy development. For

example, wind energy ordinances in the study area regulating the maximum allowable noise range from 45 dB(A) to 65 dB(A) and some townships have no regulation at all (Figure 6).

Options: Local autonomy and regional collaboration

The status quo encourages local townships to adopt wind energy ordinances that, to various degrees, restrict the type and location of wind energy development. Wind farms often span multiple townships and therefore would be required to comply with multiple sets of regulations. The diversity of ordinances, ranging from no zoning to comprehensive regulation, adds a level of complexity that may hinder development of an otherwise suitable wind resource.

A possible solution to the challenge is to encourage adjacent townships to collaborate and voluntarily adopt similar wind energy zoning ordinances. Such collaboration could be facilitated by an organization like the West Michigan Strategic Alliance, whose mission is to catalyze regional partnerships around sustainability and quality of life issues.

Key Issue: Protecting public health

Wind energy development affects quality of life in a number of ways, including impacts from shadow flicker and noise. These concerns were address in the issue brief *Wind Power and Human Health: Flicker, Noise and Air Quality* [12].

Many townships in the study area regulate shadow flicker, turbine noise, and other aspects of wind energy development but it is highly variable. The critical issue is striking the right balance between protecting the welfare of people living in the immediate vicinity of wind farms while fostering the air quality improvements that wind farms can bring. The capacity of local zoning board to effectively regulate wind energy development has also been a challenge. For example, regulating turbine noise requires considerable input from acoustic experts.

Options: Base standards on long-term average sound levels

Technical information about wind energy has been made available to planners and zoning boards through the West Michigan Wind Assessment issue briefs, Michigan State University Extension, and other technical outreach endeavors.

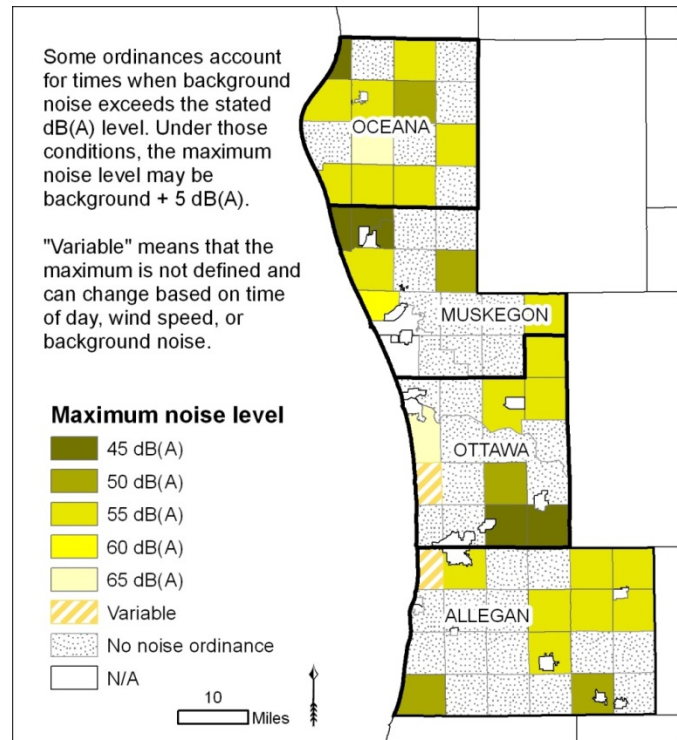


Figure 4: The degree of regulation is highly variable. For example, turbine noise regulations in the study area range from 45 dB(A) to 65 dB(A).

Most wind energy noise ordinances are based on instantaneous maximums that must not be exceeded. For example, some West Michigan townships have turbine noise ordinances that range from 45 dB(A) to 65 dB(A), as well as 5 dB(A) above background noise levels (Figure 6). This maximum noise level cannot be exceeded for any length of time.

Ordinances based on instantaneous maximum noise levels are not consistent with the best science on noise management. Rather than instantaneous maximums, the World Health Organization uses yearly average night noise level to assess noise-related health impacts [13]. The National Association of Regulatory Utility Commissioners (NARUC) likewise recommends basing wind turbine noise regulations on long term average sound levels. The NARUC handbook makes the following recommendations:

“Based on the observed reaction to typical projects in the United States, it would be advisable for any new project to attempt to maintain a mean sound level of 40 dBA or less outside of all residences as an ideal design goal. Where this is not possible, and even that level is frequently difficult to achieve even in sparsely populated areas, a mean sound level of up to 45 dBA might be considered acceptable as long as the number of homes within the 40-45 dBA range is small. Under no circumstances should wind turbines be located in places where mean levels higher than 45 dBA are predicted by preconstruction modeling at residences” [14].

Townships adopting noise ordinances that reflect the current state of the science – using long-term average sound levels rather than instantaneous maximums – may be better able to protect public health and safety while allowing for responsible wind energy development.

Key Issue: Public perceptions and policies for offshore wind energy

The potential for offshore wind energy development in Lake Michigan, the offshore regulatory framework, and public perceptions were addressed in two issue briefs: *Offshore Wind Energy: Public Perspectives and Policy Considerations* [15] and *Citizen Views on Offshore Wind: Benefits, Challenges and Information Gaps* [16]. The latter brief documented the facilitated group discussion (Delphi Inquiry) conducted by the project team.

The Great Lakes offer outstanding wind resources, but to date no offshore wind farms have been constructed in the region or anywhere else in North America. Studies of offshore wind farms in Europe found that acceptance increased as wind farms are moved further from shore and as people are exposed repeatedly to the view. The local context is also an important consideration: more developed seascapes are generally more acceptable sites for offshore wind farms than more natural areas. While NIMBY (not in my backyard) is a commonly used description for local opposition to offshore wind energy, social scientists have found more nuanced reasons for support of and opposition to offshore wind energy. Concepts like cultural models and place attachment better describe the complexity of public attitudes, both for and against.

Michigan presently has no statute specifically regulating offshore wind energy development in its Great Lakes. A policy “dry run” in 2008 found that the so-called “joint permit” between the Michigan Dept. of Environmental Quality and the Army Corps of Engineers, which is used to review submerged lands development for water intake structures and piers, was sufficient to assess the impact of an offshore

wind farm. The “dry run,” however, did illuminate the lack of a framework for leasing the bottomlands for an offshore wind farm. The present lack of a clear leasing framework does not necessarily prohibit offshore wind energy development from occurring, but the current arrangement is not optimal. The dry run participants recommended that a proper leasing framework be created.

The IA team convened a panel of local experts in various fields to discuss the benefits and challenges of offshore wind energy development in Lake Michigan. The discussion was organized as a Delphi Inquiry, a facilitated, iterative dialogue designed to reach an informed consensus on a complex topic. The Delphi Inquiry was designed to answer the question “Under what conditions, if any, would West Michigan communities find offshore wind energy development acceptable?” At every point in the iterative dialogue, participants were given the option to say that offshore wind energy is never appropriate in Lake Michigan. Thirty-five geographically and professionally diverse participants from five lakeshore counties participated in the Delphi. They offered ideas about five aspects of offshore wind energy in Lake Michigan:

- 1) The benefits, if any, to local communities;
- 2) Ways in which communities can capture those benefits, if any;
- 3) The challenges facing offshore wind energy;
- 4) Ways of mitigating the challenges, if any; and
- 5) Information gaps.

Details of the Delphi Inquiry can be found in the *Citizen Views on Offshore Wind* issue brief [16].

Options: Recommendations for sustainable offshore development

At the request of Governor Granholm, the Michigan Great Lakes Wind Council (GLOW Council) assessed the public opinion on offshore wind energy development in Michigan’s Great Lakes, identified the “most favorable” sites for development, and made policy recommendations [17]. The GLOW Council’s policy recommendations included collecting rents and royalties from offshore wind energy projects and directing those revenues to a Great Lakes Wind Energy Trust Fund. The fund would support research and monitoring efforts, promote renewable energy and efficiency, and administer the offshore wind regulation program.

The Delphi Inquiry participants were organized into county groups and they reached consensus (defined as 80% agreement) on many aspects of offshore wind energy development. The participants agreed on many of the challenges facing offshore wind energy and information gaps, but there was little agreement about how offshore wind energy could benefit local communities. None of the county groups agreed on the idea that offshore wind energy in Lake Michigan is unacceptable under any circumstances. Every county group agreed that the visual impact of an offshore wind farm is a major concern.

Summarizing the responses across the county groups, participants in the Delphi Inquiry found that offshore wind energy development in Lake Michigan could be acceptable to the participants if:

- It reduces pollution and dependence on fossil fuels;

- Coastal communities benefit from the projects;
- The public has ample opportunity to participate in the siting process;
- The visual impact is minimal;
- Property values and tourism are not significantly harmed;
- Projects do not lead to substantial utility rate increases;
- Projects do not harm wildlife, recreation, and fishing activities; and
- Technical challenges are overcome, such as ice build-up and transmission limitations.

The Delphi Inquiry proved to be a useful method for facilitating group discussion on what has become an emotionally charged issue in West Michigan. The findings offer guidance for those seeking to develop wind farms in Lake Michigan as well as for regulators, coastal communities, and concerned citizens.

The above recommendations assume that offshore development is legal and, in some way, desirable. Other options which have been proposed include:

- A moratorium on offshore wind energy development. In 2011 the Province of Ontario issued a moratorium on offshore wind energy development in provincial waters until some scientific uncertainties can be addressed.
- A complete ban on offshore wind energy development. Several Michigan legislators, including some from West Michigan, proposed legislation that would ban offshore wind energy development in Michigan's Great Lakes. Though the legislation did not pass, it does indicate that there is a constituency that opposes offshore wind development in any form.

Environmental dimensions

Wind farms, like every other electricity generation technology, have some negative environmental impact. The benefit of wind energy is that it can displace dirtier, more polluting forms of electricity generation. The degree of benefit depends on how much, and what kind, of source it displaces. The potential for wind energy to displace more polluting fuels was reviewed in a separate brief, *Reducing Air Pollution and Carbon Emissions in Michigan Using Wind Energy* [18]. The positive and negative environment effects, in particular land use changes and wildlife impacts, were assessed in the issue brief *Environmental Impacts of Land-based Wind Energy in West Michigan* [19]. The environmental impacts of potential offshore wind energy in Lake Michigan were reviewed in *Offshore Wind: Environmental Benefits, Challenges, and Consequences* [20].

Key issue: Reducing air pollution from the electricity sector

The potential for wind energy to improve air quality and public health was explored in a limited way in the *Wind Power and Human Health* issue brief [12]. It became clear, however, that the issue needed further assessment to include not only conventional air pollutants like sulfur dioxide but also carbon emissions. The brief *Reducing Air Pollution and Carbon Emissions in Michigan with Wind Energy* described the topic in depth [18].

The *Toll from Coal* report from the Clean Air Task Force estimated that air pollution from Michigan’s coal-fired power plants cause more than 600 premature deaths in Michigan each year, 186 of which are attributed to West Michigan’s coal plants [21]. The report cited the J.H. Campbell plant in Ottawa County to be among the top ten in the nation in terms of health impacts (Table 2).

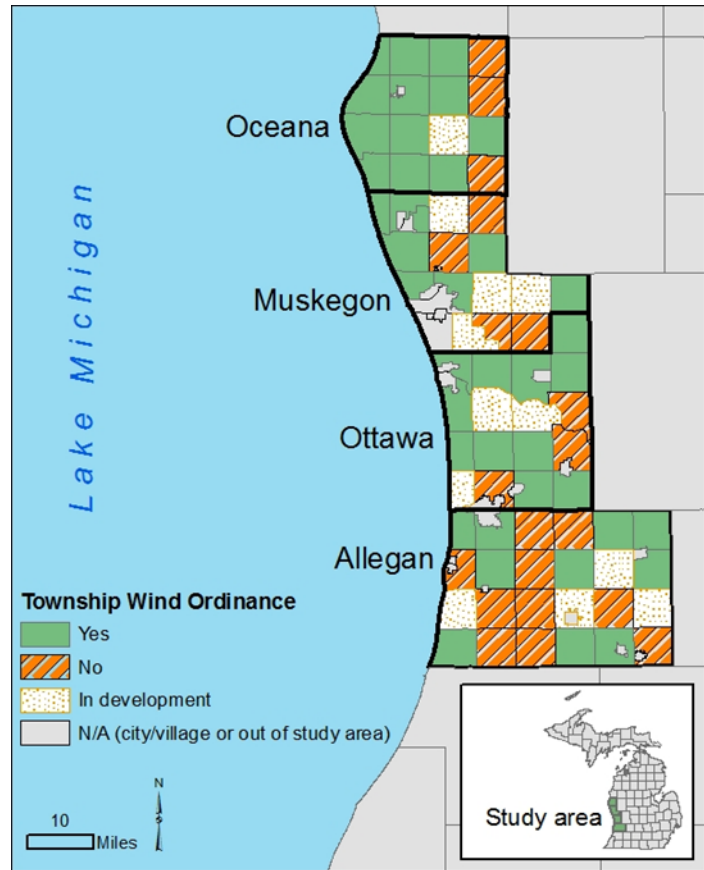


Figure 5: Just over half of West Michigan townships have enacted a wind energy zoning ordinance.

Table 2: The Clean Air Task Force estimated that West Michigan coal plants lead to more than 180 premature deaths each year [21].

Coal-fired power plant	Location	Annual public health impact		
		Deaths	Heart attacks	Asthma attacks
B.C. Cobb	Muskegon County	34	55	580
J.B. Simms	Ottawa County	2	4	39
J.H. Campbell	Ottawa County	140	230	2,300
J. DeYoung	Ottawa County	10	16	180
<i>Total</i>		<i>186</i>	<i>305</i>	<i>3099</i>

Options: Displacing polluting sources with wind energy

West Michigan has a range of energy options, including maintaining the status quo. If the aging coal fired power plants continue operation without pollution control upgrades, we can expect the health toll to continue unabated. New regulations to control mercury and other pollutants are leading utilities to shut down some of the oldest, most polluting facilities like the Cobb plant [3]. The loss of generating capacity will likely be made up of some combination of the following sources:

- Enhanced energy efficiency
- New, cleaner coal facilities
- New natural gas plants
- New nuclear plants
- Renewable sources including wind, but also solar or biomass
- Electricity imports from other region

Each of these valid options presents its own unique set of benefits and challenges. This report focuses on the wind energy option but recognizes that other options may be more or less appropriate for the region. As reported in the *Reducing Air Pollution* issue brief, studies from Europe and North America indicate that wind energy does in fact displace coal and natural gas and reduces pollution. The peer-reviewed science indicates that wind energy can be integrated into the electricity grid and doing so reduces emissions of carbon dioxide (CO₂). The addition of wind energy by a mandate like a renewable energy standard, in the absence of other air quality regulations, was less effective at reducing conventional air pollutants like sulfur dioxide (SO₂) and nitrogen oxides (NO_x), though reductions did occur. Combining a renewable energy standard with a carbon tax can lead to wind displacing the most carbon intensive fuels (i.e. coal), which also leads to greater reductions in SO₂ and NO_x [22]. This finding highlights the need for comprehensive energy policy at the state and federal levels.

Using actual figures from the Midwestern power grid (including Michigan), researchers found that each megawatt-hour of wind energy added to the electricity grid reduced the emissions of SO₂, NO_x, and CO₂ [23]. Based on the estimates in the paper, Michigan could achieve measurable reductions in key pollutants by using wind energy to fulfill the remaining 6.1 percent of the ten percent renewable energy standard (as of 2009):

- 4.0% less SO₂
- 5.9% less NO_x
- 6.9% less CO₂

The details of these calculations can be found in the *Reducing Air Pollution* issue brief. Reducing SO₂ and NO_x pollution in particular will improve human health and reduce the number of premature deaths, heart attacks, and asthma attacks in West Michigan and in downwind areas.

Key Issue: Climate Change

Climate refers to the long-term patterns of temperature and precipitation. Researchers associated with the Great Lakes Integrated Science and Assessments Center (GLISA) documented the changes in climate occurring across the Midwest, including Michigan. The Midwest's observed warming trend over the 20th century was linked to the following:

- A one-week increase in the length of the frost-free growing season;
- Shorter periods of ice cover on interior lakes and decreased ice extent on the Great Lakes;
- Greater overall precipitation and increased occurrence of heavy downpours [24].

Though data are sparse, there does not seem to be any measurable trend in surface level wind speeds [24].

The GLISA team has identified numerous ways in which the observed and predicted climate changes will affect Midwestern ecosystems and society. The team contributed ten peer-reviewed white papers to the National Climate Assessment. The key findings from each white paper were summarized in a fact sheet, a few of which are:

- Agriculture may benefit from longer growing seasons but may be at greater risk from weather extremes and pest outbreaks;
- Warmer temperatures may shift energy demands increasing energy used for summertime cooling but decreasing energy used for wintertime heating;
- The number of heat-related deaths and illnesses may rise with the increased risk of heat waves, as may insect-borne diseases like West Nile virus and Lyme disease;
- Winter tourism and cold-water fish species may suffer from rising winter temperatures but summer tourism may benefit [25].

The observed and predicted climatic changes at the Midwest regional level are the result of global warming and local factors such as land use change. The Second National Climate Assessment states that “global warming is unequivocal and primarily human-induced. Global temperature has increased over the past 50 years. This observed increase is due primarily to human-induced emissions of heat-trapping gases” [26 p. 13]. In 2009, Michigan’s electricity sector was responsible for more than 68 million metric tons of heat-trapping CO₂ – about 40 percent of the state’s total emissions [18].

Options: Reducing carbon emissions

Climate change is already present and measurable. Preventing the worst effects of climate change at a global scale requires reducing the emission of heat trapping gases at local scales. The issue brief *Reducing Air Pollution and Carbon Emissions in Michigan with Wind Energy* [18] explained how wind energy displaces more carbon-intensive energy sources. On a national scale, a 20% wind scenario can stabilize carbon emissions which, in a “no new wind” reference case, would otherwise increase. The team also reviewed 12 peer-reviewed articles all of which concluded that wind energy can be integrated into the electricity grid and doing so reduces carbon emissions.

The potential for reducing carbon emissions was estimated using two methods. The first approach used the EPA’s Green Power Equivalency calculator for a hypothetical wind farm in Michigan. A 100 MW wind farm in Michigan could reduce CO₂ emissions by 197,000 tons of per year, assuming a 25 percent wind capacity factor. That reduction is equivalent to the annual carbon emission of more than 22,000 average US homes. The second approach used empirical estimates of electricity generation and emissions from the Midwest electricity grid. The 138 MW of installed wind energy capacity in 2009 produced slightly more than 300,000 MWh of electricity. This output corresponds to a reduction of 246,000 tons of CO₂ for the year. Scaled to a 100 MW wind farm, this method estimates 178,000 tons of CO₂ which is similar to the EPA estimate of 197,000 tons for the hypothetical wind farm. These results demonstrate that wind energy does reduce CO₂ emissions from Michigan’s electricity grid [18].

Key Issue: Wildlife impacts from wind energy

Documented bird mortality rates at wind farms range from zero to more than 30 bird deaths per turbine per year [27, 28, 29]. This range reflects the variability in the different factors that might influence research results, such as research design, wind farm layout, turbine height, weather conditions, topography, species, number of birds, behavior of birds, and time of year [30]. In a survey of 45 utility scale wind farms from across the county, the median rate of bird mortality was about 2 birds/MW/year. Twenty-one of the 45 wind farms had bird mortality rates below 2 birds/MW/year [31]. Most utility scale wind turbines are about 1-2 MW in size, which would correspond to 2-4 bird deaths per turbine annually.

West Michigan lies along an important migratory corridor. Bird counts led by professional naturalists show that thousands of birds fly along the West Michigan coast during migration seasons. Six threatened or special concern species have been observed flying along Lake Michigan. All but the trumpeter swan were observed in the West Michigan study area (Table 4). Wind energy development should be sensitive to these and other migrating and resident bird populations.

Table 3: Six listed species were observed migrating along the Lake Michigan shoreline.

Common name	Scientific name	Michigan conservation status
trumpeter swan	<i>Cygnus buccinator</i>	Threatened
common loon	<i>Gavia immer</i>	Threatened
Caspian tern	<i>Sterna caspia</i>	Threatened
black tern	<i>Chlidonias niger</i>	Special concern
common tern	<i>Sterna hirundo</i>	Threatened
Forster's tern	<i>Sterna forsteri</i>	Threatened

Turbines can also kill bats, especially during the late summer and early fall migrations. The rate of bat mortality at some wind farms can be higher than the rate of bird deaths. In a survey of 45 utility-scale wind farms, the median bat mortality rate was less than 5 bats/MW/year [31]. The hoary bat, eastern red bat, and silver-haired bat (all present in Michigan) tend to be the most affected by wind turbines. Bat ecology in general is not well understood, and the precise causes of bat fatalities at wind farms even less so. This is an active area of research. Many bats are facing dramatic and disturbing population declines due to a disease called white nose syndrome (WNS). WNS is not associated with wind turbines, but makes the case for bat conservation that much stronger.

Options: Wildlife-sensitive wind development

Though bird impacts are a concern, most major bird advocacy organizations support properly sited wind energy. For example, the Audubon Society “strongly supports wind power as a clean alternative energy source that reduces the threat of global warming” [32]. Audubon also notes that the specific aspects of a particular wind farm, including location, can have negative effects and must be evaluated carefully. The American Bird Conservancy “supports wind power when it is bird-smart” and subject to mandatory

siting standards [33]. On the whole, many bird advocacy groups recognize that no source of electricity is free from environmental impacts and support well-designed wind energy projects.

One option for wildlife sensitive wind development is to follow the US Fish and Wildlife Service's (FWS) guidelines. The FWS has encouraged science-based approaches for assessing wildlife impacts of wind farms. These voluntary guidelines recommend a "tiered approach" for assessing potential wildlife impacts and incorporating site-specific conditions. A progressive decision-making process is utilized where more information and more detail are requested at higher tiers to reach a risk-based decision. Each tier contains questions to help identify potential issues tied to a project phase. Responses enable the developer and reviewer to decide if they have enough information and reason to proceed with a wind energy project based on its possible wildlife impacts [34].

Another option is to take steps to reduce bat fatalities when feasible. Avoiding known bat habitats is the preferred siting option, but turbines can also be operated to minimize impacts on bats. For example, research has shown that bat deaths are more likely to occur during times of light breezes when bats are out foraging for insects and the turbines just begin to spin. Insects and bats that feed on them are less likely to be flying when the wind speed increases. Researchers have shown that increasing the "cut-in" speed (the speed at which the turbine begins to spin) can reduce bat deaths substantially.

Key issue: Impact on aquatic ecosystems and fisheries

As reported in the issue brief, *Offshore Wind: Environmental Benefits, Challenges, and Consequences* [20], the construction and decommissioning of wind turbines can result in short-term disturbances to fisheries, particularly from driving the steel monopiles for the turbine foundation. The noise can cause fish, such as Atlantic salmon, to avoid areas up to about one mile from the pile-driving activity. Construction activity can also disturb sediments, which in some locations could contain pollutants.

Once the offshore wind farm is constructed and operating, the negative impacts on the aquatic environment are relatively minor and there can be positive impacts as well. The submerged turbine foundation can provide three-dimensional habitat for some fish species, potentially including lake trout and yellow perch. The structures may also serve as habitat for invasive species such as round gobies and zebra and quagga mussels.

More water is withdrawn from the Great Lakes to support electricity production than for any other use. The intake of water for power generation kills hundreds of thousands of adult game fish each year in the Great Lakes. Mercury pollution from coal-fired power plants contaminates aquatic ecosystems and leads to fish consumption advisories across the region.

Options: GLOW Council siting recommendations, pollution reduction, and Coast Guard regulations

Several options exist for not only reducing the environmental impact of offshore wind energy, but also for improving the environmental conditions of Lake Michigan more generally. The Michigan GLOW Council considered important fishing habitats, including reefs and spawning areas, when it proposed the "most suitable" areas for offshore wind energy development in Michigan's Great Lakes [17]. These "most suitable" sites should be considered first when proposing an offshore wind farm. Developers

considering locations outside of the designated “most suitable” zones should also consider and seek to mitigate potential impacts on fisheries.

The American Wind Association, in collaboration with the US National Renewable Energy Laboratory and others, has released best practice guidelines for the planning, installation, operation, and decommissioning of offshore wind turbines [35]. Following these best practices can help minimize the environmental and social impacts throughout the offshore wind farm life cycle, particularly during the construction phase.

Offshore wind farms can enhance the aquatic environment especially when it substitutes for more polluting energy sources like coal. When wind energy displaces coal, it decreases the mercury pollution released into the air that eventually finds its way into the aquatic food web. When wind, offshore or onshore, displaces “thermo-electric” generation (i.e. coal and nuclear power), it reduces the cooling water intake required. Reducing the intake of millions of gallons of water prevents the deaths of millions of fish, including important game fish.

Options also exist for managing potential conflicts between wind energy and commercial fishing. Exclusion zones have been enacted in, for example, the Netherlands, where fishing is prohibited inside the wind farm boundary. In the US, however, an exclusion zone is not standard policy. The nation’s only permitted offshore wind farm, Cape Wind in Massachusetts, will not have an exclusion zone during operation.

The US Coast Guard is charged with maintaining the navigational safety and uses of the navigable waters of the United States. In this capacity, the Coast Guard assists the lead permitting agency to develop plans to ensure navigational safety, including proposals for offshore wind farms. The Coast Guard states that, because the navigational risk factors for offshore wind farms “vary significantly from location to location, it is not possible to create a “one-size-fits-all’ policy. Rather [wind energy developers] should use a risk-based approach when evaluating the impact [the wind farm] will have on the particular waterway being considered.” [36] In addition, a Coast Guard official stated in an interview about a proposed wind farm along the Atlantic coast, “The Coast Guard has been stating in writing, since 2008, that there would be no excluded grounds around the turbines...we do not plan to restrict those areas” [37].

The Coast Guard will evaluate the navigational safety issue on a case-by-case basis. The Coast Guard is not requiring exclusion zones around offshore wind farms, and there is no precedent for such a zone in the US. This case-by-case deliberation would apply to any offshore wind development in the US portions of the Great Lakes.

Technical dimensions

Wind energy presents some technical challenges ranging from electricity grid integration to impacts on radar systems. The West Michigan Wind Assessment project team investigated these technical challenges and reported on them in two issue briefs: *Electricity Transmission and Wind Energy* [38] and *Effects of Wind Farms on Navigation* [39].

Key Issue: Integrating wind energy in to the electricity grid

Wind is an intermittent resource and as a result electricity production fluctuates across hours within a day and across seasons. While all electricity generating technologies require backup capacity (“operating reserve”) wind energy generally requires more operating reserve than, for example, coal or nuclear plants.

The Midwest Independent System Operator (MISO), which operates the electricity grid for Michigan and other Midwestern states, analyzed the impact of operating wind turbines on the electrical grid. MISO came to the following conclusions about integrating wind into the Midwestern grid:

- Wind is very constant at daily average level but shows substantial variation across hours within a day.
- Peak electricity production from wind turbines tends to run opposite the daily patterns of electricity demand (e.g. wind declines during morning when demand is rising).
- The capacity factor¹ across the MISO region for the first half of 2009 was 31.6 percent.
- Variability at current (2009) levels of wind generation can be managed with existing reserve capacity. A drop as great as 21% of the installed wind capacity (1400 MW) over four hours in the morning can be absorbed.
- An increase wind generation capacity from 6,600 MW (in 2009) to 15,000 MW in the MISO region would pose challenges particularly during the morning ramp-up and evening ramp-down times [40].

Options: Deploying “smart grid” technologies

Grid operators have several options for managing the intermittent nature of wind energy. For example, a more robust transmission network can help deliver electricity from the point of production to consumers. Energy storage, whether a hydro-power reservoir, compressed air (underground), or advanced batteries, can provide a buffer against the fluctuations in wind energy production.

The “smart grid” – electricity infrastructure that combines transmission with communication – is another option that can help integrate intermittent, renewable resources into the grid, alleviate grid congestion, and enhance energy conservation. The beginnings of the smart grid are coming to West Michigan in the form of smart meters. Smart meters communicate, through cell phone networks or similar technologies, with the utility at intervals throughout the day. Customers can read up-to-the-minute energy usage in their own homes and manage usage accordingly. Consumers Energy, the regional

¹ Capacity factor is the ratio of actual output and maximum potential output for a wind turbine or other electricity generator and is expressed as a percent. For example, a turbine that produced 3,000 megawatt-hours and had a maximum potential output of 10,000 megawatt-hours would have a capacity factor of 30% (3,000/10,000).

electric utility, has already installed 60 smart meters in a Grand Rapids neighborhood on a trial basis. Preliminary data show that using smart meters has already reduced the amount of electricity used by a business or homeowner, which in turn is saving energy, money, and emissions [41]. The utility is planning on installing smart meters on most homes in Ottawa and Muskegon counties beginning in 2012.

Key Issue: Turbines can interfere with radar systems

Wind turbines can, under certain conditions, interfere with radar systems for air traffic control and national defense. The Federal Aviation Administration (FAA) has issued a number of “Notices of Presumed Hazard” for many proposed wind farms.

The West Michigan Wind Assessment researchers found that most of the West Michigan region lies within a zone of likely or highly likely impact of Department of Defense (DoD) radar systems (Figure 7). The DoD preliminary screening tool indicated that the only places where impact on radar would be unlikely is northern Oceana County and southern Allegan County. A large proportion of the areas designated as wind resource zones by the Michigan Wind Energy Resource Zone Board overlap with the radar impact zones.

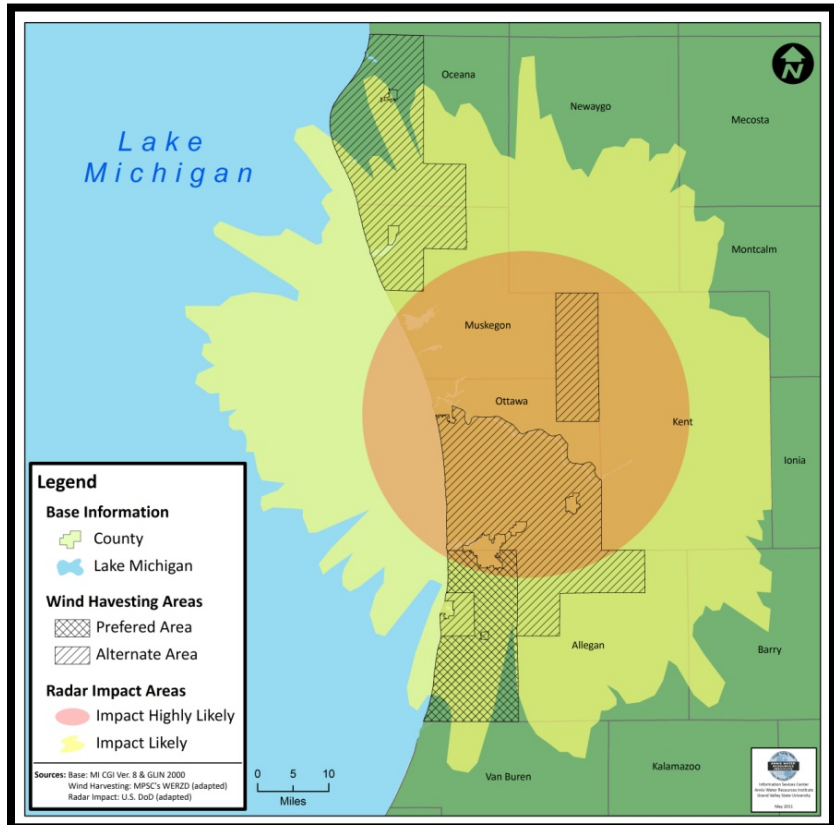


Figure 6: Preliminary studies show that, without upgrades, radar systems in West Michigan would likely be affected by wind energy development.

Options: Planning and system upgrades

With proper planning, and in some cases technological upgrades, wind farms can be sited without interfering with these navigation and defense systems. A location within a radar impact area does not mean that wind energy can never be developed in that location. One option is to change the location or layout of the wind farm to reduce the impact on radar systems. In many cases, the affected radar systems are more than 40 years old. Another option is to update the aging radar hardware and/or software to mitigate the inference. If proper measures are taken to reduce the impact to an acceptable level, the FAA could grant approval.

Summary: Key issues for wind energy in West Michigan

Infrastructure development of any kind can be challenging from social, environmental, economic and technical perspectives, and wind energy is no exception. With experience, however, researchers, planners, and developers have crafted ways of minimizing those challenges. Some, like the radar issues, have straightforward technical solutions. Other, particularly the social issues, require substantial collaboration between citizens, project managers, scientists, and government officials on a case-by-case basis. The evidence shows that in many cases, the conflicts presented by wind energy can be managed to an acceptable level.

Conclusions

The West Michigan region enjoys a high quality of life made possible in part by the energy infrastructure. This aging infrastructure, among the oldest in the country, requires additional investment in everything from generation to transmission and even “smart meters.” New sources of electricity, wind or otherwise, will bring changes to the landscape and affect West Michigan’s society, economy, and environment. The West Michigan Wind Assessment framed the challenge of energy development in Michigan’s coastal zone through two questions:

- How can we create a 21st century electricity system that enhances the quality of life in coastal communities and the quality of the Great Lakes?
- Can wind energy development in West Michigan contribute to this system?

A 21st century electricity system could enhance the quality of life and quality of the lakes of West Michigan in a number of ways, such as:

- Reducing air and water pollution and its associated health problems
- Enhancing economic development
- Being respectful of local concerns
- Enhancing satisfaction with the community

The West Michigan Wind Assessment team has objectively compared different energy options for the region and provided a suite of policy options for local and state governments as well as best practices for wind developers. Wind energy can be developed in ways that improve air and water quality while reducing noise and flicker impacts. Wind energy projects present major economic development opportunities and property value impacts are low if not nonexistent. Electricity from new wind projects in Michigan now cost less than that from a new coal plant. If conducted properly according to best practices, wind project developers and communities can collaborate for mutually acceptable outcomes.

The challenges, for developers, for communities, and for the state, are not inconsequential. Many of the air quality and water quality benefits stemming from wind energy would accrue to communities far from the wind farm’s location. Those beneficiaries might live downwind from a coal plant whose operations have been reduced because of wind development. The wind farm host community, on the other hand, shoulders the visual impacts. Though wind energy development may have net positive benefits, the distribution of the benefits and costs vary across the landscape. Policies at the local and state levels

could reduce the negative impacts on and enhance the economic benefits to local communities while preserving the benefits to the broader region.

Wind energy is not a panacea for the country's energy challenges, but it is now the most cost-effective choice, after energy efficiency, of generating low-pollution electricity. The science and global experience shows that when combined with other generation sources and emerging technologies like storage and a smart grid, appropriately developed wind energy can contribute clean, affordable, sustainable electricity in the West Michigan coastal zone.

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Appendix A: Project Description and Methods

Integrated Assessment Methods

The West Michigan Wind Assessment is funded by Michigan Sea Grant's Integrated Assessment (IA) Program and it used the IA approach to analyze the complex issue of wind energy in West Michigan's coastal zone. Michigan Sea Grant describes IA as follows:

The goal of IA is to bring together knowledge of ecosystems, people, and policy to develop tools and information that policy makers can use. Integrated Assessments summarize scientific knowledge to build consensus and guide decision making around a particular resource management, environmental, or sustainability issue [42.p. 1].

Rather than collect original data to test hypotheses, IA projects synthesize the existing science, evaluate that science in a holistic manner, and deliver policy-relevant assessments on complex issues.

The West Michigan Wind Assessment used several approaches to synthesize, evaluate, and communicate the state of the science on wind energy development, including stakeholder collaboration, publishing issue briefs, and conducting a stakeholder engagement forum called a Delphi Inquiry.

Stakeholder collaboration was a key component

The wind assessment team recruited key stakeholders from throughout the study area to serve on a steering committee. The twelve steering committee members represented the following groups.

- Township planners
- Electric utility executives
- Chamber of Commerce
- Farm Bureau
- Wind energy companies
- Offshore wind energy opponents
- Grand Valley State University's Michigan Alternative and Renewable Energy Center
- Michigan Sea Grant

The stakeholder steering committee engaged with the project team in several ways. First, the committee members contributed questions and concerns that they wanted the wind assessment team to address. Second, the committee members reviewed the issue briefs on key wind energy topics and provided feedback to the team. Third, the stakeholders participated in meetings and workshops that featured experts in particular fields, such as an environmental acoustical consultant. The stakeholders brought to the project a wide range of experiences from diverse backgrounds. Some had a great deal of experience with wind energy, while others were complete novices in terms of wind energy but were experts in their own fields. The stakeholder steering committee members were true partners in this IA.

The West Michigan Wind Assessment also worked closely with other organizations in the region on wind energy topics. Project team members collaborated with the Great Lakes Wind Collaborative (part of the

Great Lakes Commission), public meetings, and served on Michigan’s State Wind Outreach Team and Wind Working Group.

Wind energy topics were summarized in issue briefs

The project team originally planned to publish a single final report assessing the benefits and challenges of wind energy development covering the environmental, social, and economic aspects. However early on in the project it became clear that the West Michigan community needed more timely and accessible information. The Muskegon Chronicle’s editorial page wrote “We urge the researchers to speed their study along, designing it in a way that preliminary results can be released as soon as the researchers are comfortable” [43].

The project team responded to this need by dividing the assessment into issue briefs, each one covering a key aspect of wind energy development. The project team published 11 issue briefs on topics such as the pollution reduction potential of wind energy, health and noise concerns, and public perceptions. The briefs are publicly available on the project website (www.gvsu.edu/wind) and were distributed to decision-makers throughout the area. The briefs are summarized in the section below, Analysis of the Issues.

Attitudes toward offshore wind explored through a Delphi Inquiry

Public engagement is a critical component of an integrated assessment. In addition to the stakeholder steering committee, the project team conducted a Delphi Inquiry on offshore wind energy in Lake Michigan. A Delphi Inquiry is “a qualitative method used to combine expert knowledge and opinion to arrive at an informed group consensus on a complex problem” [44]. The project team used the Delphi Inquiry to understand the conditions, if any, under which offshore wind energy development in Lake Michigan could be acceptable to local residents. The Delphi Inquiry proved to be an effective means of engaging key stakeholders and building consensus on this controversial topic. The results of the Delphi Inquiry were summarized in an issue brief [16] and also published in a refereed book from Michigan State University Press [45].

Project success was measured through a number of indicators

The West Michigan Wind Assessment produced a number of written reports, videos, and presentations. These were disseminated in person, through the project web site, the project Facebook page, and by email. Table 1 below highlights some metrics related to disseminating the issue briefs and other materials.

Table 4: The project team distributed information through a variety of media.

Medium	Metric
Number of web site hits (www.gvsu.edu/wind)	1,497 hits (1 January 2010 – 31 January 2012)
Number of visits to “Project Documents” web page	1,261 hits (1 January 2010 – 31 January 2012)
Number of issue brief downloads from Selected Works / ScholarWorks pages	730 downloads (6 issue briefs)

Number of video views on web site, Selected Works, and YouTube	522 views (3 videos)
Number of Facebook “friends”	160 friends
Media (TV, radio, newspaper)	More than 55 local and national pieces

During last two months of the project (December 1, 2011 – January 31, 2012) the project Facebook page reached many people in the West Michigan study area in towns like Muskegon, Grand Haven and Holland as well as Michigan cities outside of the study area (Grand Rapids, Ann Arbor). The project reached people across a wide range of ages. A number of people outside the United States were reached, including people in Canada and South Korea.

The team posted four evaluative questions on Facebook at the end of the project. The questions and survey results are presented in the chart below (Figure 3). While the number of survey respondents was small (11-15 per question), a majority of respondents agreed that the project influenced both their energy-related decisions and their opinions of wind energy. Most respondents agreed that the project was helpful to West Michigan communities and that the team acted openly and transparently.

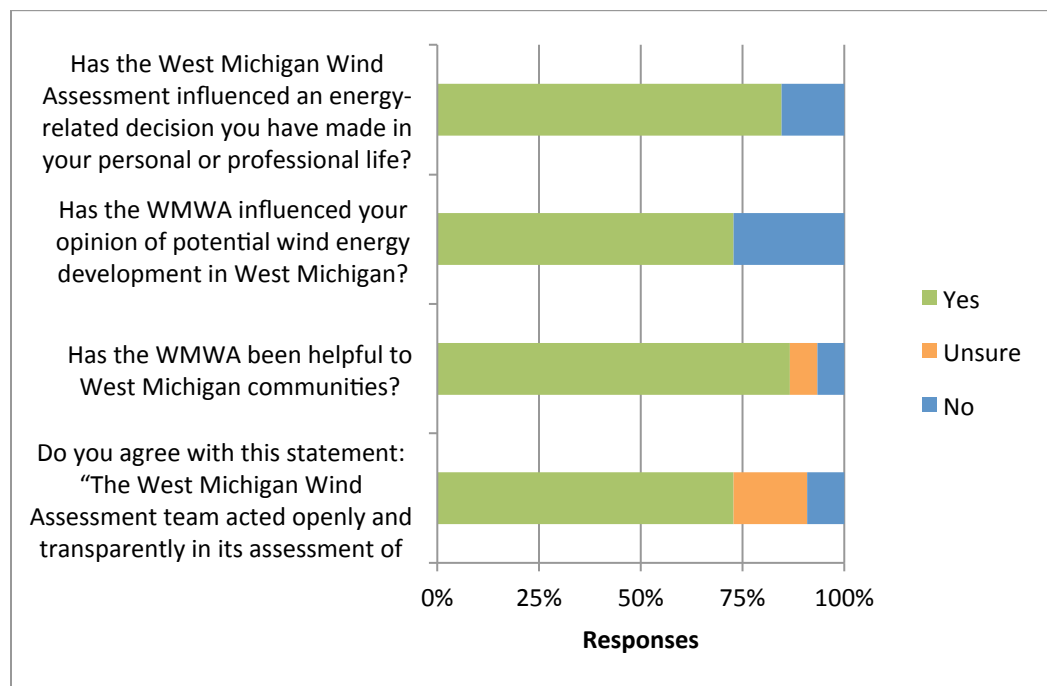


Figure 7: Responses to survey questions on Facebook. Number of responses ranged from 11 to 15.

Dr. Roopali Phadke of Macalester College used some of the West Michigan Wind Assessment issue briefs for the Michigan Wind Energy Landscape Symposium. The workshop, held during the summer of 2011, brought together key stakeholders from six townships in Manistee and Benzie counties, just north of the

West Michigan Wind Assessment study area. More information about the symposium can be found at the project website (<http://www.macalester.edu/understandingwind/symposium.html>).

The West Michigan Wind Assessment project also helped build capacity within Grand Valley State University and its collaborators. Members of the project team have continued to work on additional wind energy research and outreach projects:

- Offshore wind energy outreach and education (with the Great Lakes Commission and Michigan Sea Grant) – funded by the Michigan Energy Office and Michigan Sea Grant (<http://www.gvsu.edu/marec/offshore-wind-energy-outreach-83.htm>)
- Lake Michigan Offshore Wind Assessment Project – funded by the US Department of Energy (<http://www.gvsu.edu/marec/lake-michigan-offshore-wind-assessment-project-62.htm>)

The many metrics and anecdotes above indicate that the project has been highly successful in fostering an informed discussion of wind energy in Michigan's coastal zone.

Appendix B: Tools and Guidance

For more information about these and other wind energy topics, please consult the following resources.

Project website

West Michigan Wind Assessment web site: www.gvsu.edu/wind.

Issue briefs

These are all available on the website.

- Regional response to a statewide energy standard: Status and trends of wind energy development in West Michigan.
- Wind energy deployment: Global lessons for West Michigan
- Wind power and human health: Noise, flicker, and air quality
- Offshore wind energy: Public perspectives and policy considerations
- Citizen Views on Offshore Wind: Benefits, Challenges and Information Gaps
- Wind energy and economic development in West Michigan
- Economic costs of wind energy: Production costs and externalities
- Effects of Wind Farms on Navigation
- Electricity transmission and wind energy
- Environmental impacts of land-based wind energy in West Michigan
- Offshore wind: Environmental benefits, challenges and consequences
- Reducing air pollution and carbon emissions in West Michigan with wind energy.
- Videos – available on the website
 - Social
 - Policy
 - Environment

Social media

The West Michigan Wind Assessment Facebook page: www.Facebook.com/WestMIWind

Other resources

- Great Lakes Wind Collaborative: *Best Practices for Sustainable Wind Energy Development in the Great Lakes Region*. Web site <http://www.glc.org/energy/wind/>.
- Michigan State University, Land Policy Institute: Integrated Assessment – Wind Farm Development in Coastal Communities. Web site http://www.landpolicy.msu.edu/modules.php?name=Pages&sp_id=494.
- Understanding Wind Initiative: <http://www.maclester.edu/understandingwind/index.html>.
- Michigan Great Lakes Wind Council: <http://www.michiganglowcouncil.org/>.
- Michigan Sea Grant: <http://www.miseagrant.umich.edu/>.
- Michigan Public Service Commission: <http://www.michigan.gov/mpsc>.

- Michigan Energy Office: <http://www.michigan.gov/mdcd/0,4611,7-122-25676---,00.html>.
- National Renewable Energy Laboratory: <http://www.nrel.gov/>.

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