Land-Based Wind Energy and the Environment

POTENTIAL IMPACTS FOR WILDLIFE AND THE WEST MICHIGAN LANDSCAPE

WEST MICHIGAN WIND ASSESSMENT ISSUE BRIEF #11

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The West Michigan Wind Assessment is a Michigan Sea Grant-funded project analyzing the benefits and challenges of developing utility-scale wind energy in coastal West Michigan. More information about the project, including a wind energy glossary can be found at the website, www.gvsu.edu/wind.

Introduction

Producing electricity by any process with any fuel, affects the West Michigan environment in some way. Comparative studies have shown that the nature and magnitude of environmental impacts varies among the electricity-generation processes, whether fueled by coal, natural gas, solar, water, wind or another energy source [1, 2]. These disparate impacts occur throughout the life cycle of the electricity-generation process, from extracting fuel to constructing the facility to managing residues leftover from the process. The life cycle impacts of electricity production are also dispersed geographically—meaning some of the environmental benefits may be experienced globally while the adverse impacts might be confronted locally. However, when these different electricity-production processes are compared, wind energy presents less harm to the environment overall than most other sources, but especially when compared to electricity generated from fossil fuels [1, 2].

Overall, wind energy presents less harm to the environment than electricity generated from fossil fuels.

This issue brief summarizes some of the environmental impacts associated with land-based (as opposed to offshore) wind energy development. The brief focuses on how wind turbines may affect wildlife, including collisions with wind turbines and compromised habitat, and wind energy's landscape impacts. The brief concludes with a discussion of local, state and federal regulation of land-based wind energy from an environmental perspective.

The environmental impact of offshore wind energy development as well as several other issues, are discussed in separate issue briefs. The potential for reducing air pollution, including greenhouse gases, is explored in the West Michigan Wind Assessment issue brief *Reducing Air Pollution and Carbon Emissions in Michigan Using Wind Energy* [3]. Effects on the human environment, such as noise and shadow flicker, are presented in the issue brief *Wind Power and Human Health: Flicker, Noise, and Air Pollution* [4].

Wildlife and Wind Energy

Poorly sited wind energy has the potential to harm wildlife, particularly local bird and bat populations. Determining the magnitude of any impacts from wind energy development on wildlife and the use of effective mitigation techniques will require ongoing research both in West Michigan and elsewhere.

Concerns About Birds

The impact on bird populations will vary over time and space and at different stages of development, though most major bird advocacy organizations support properly sited wind energy.

The impact on bird populations from electricity generation can be either direct, such as through physical injury from collision with structures, or indirect by upsetting normal behavior or altering habitat [2, 5, 6, 7]. The risks to bird populations from generating electricity varies over time and space and at different stages of energy development. Understanding what factors shape the nature of these impacts on birds is inadequately studied and remains challenging. Heightened research on wind energy and its impacts, especially through computer modeling, is beginning to reveal patterns for improving the reliability of predicting risk to bird populations with regards to wind energy projects [7].

Although impacts to birds are a substantial environmental 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" [8]. The Audubon Society 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 [9]. On the whole, many bird advocacy groups recognize that no source of electricity is free from environmental harm and support well-designed wind energy projects.

Direct Effects of Wind Turbines on Birds

Documented bird mortality rates at wind farms range from zero to more than 30 bird deaths per turbine per year, reflecting the variability in different factors influencing research results.

Over time, wind farm developers and regulators are learning lessons on minimizing bird collisions with turbines in wind farms. Research at wind farms around the country has shown that in most cases wind turbines have had a low collision impact on local and migratory bird populations [10]. Documented bird mortality rates at wind farms range from zero to more than 30 bird deaths per turbine, per year [10, 11, 12]. This range reflects differences in research design, as well as variability in wind farm factors, such as layout, turbine height, weather conditions, location, topography, species, number of birds, behavior of birds and time of year [12, 13].

The wildlife workgroup of the National Wind Coordinating Collaborative, a consensus-based network of stakeholders, regularly reviews state-of-the-art research on the potential impacts of wind development on birds, bats and other wildlife. In 2010, the group updated its last review to reflect results from new studies [14]. The updated review, as summarized below, separates the research into three areas:

- What Studies Have Shown—Conclusions widely supported by peer-reviewed studies with broad consensus
- What is Less Well Understood—Ideas reached by some field studies but either the evidence is too limited or there is contrary evidence or controversy

among researchers
- Areas Where Little is Known—Questions to which even tentative conclusions cannot yet be reached

The wildlife workgroup of the National Wind Coordinating Collaborative in 2010 summarized research into the categories of broad consensus, limited/ contrary evidence, and questions without tentative conclusions.

What Studies Have Shown

- Wind turbines can kill birds and bats.
- Fatality rates vary widely across wind resource areas.
- Most birds killed at wind turbines are songbirds.
- Bird deaths from turbine collisions have a much smaller cumulative impact on songbird populations than other human-related causes, such as collisions with windows.
- Federal Aviation Administration (FAA) lighting recommended for installation on commercial wind turbines does not increase collision risk for bats and migrating songbirds.
- Bird and bat behavior and their level of site use are most significant in assessing potential fatality risk.
- Siting wind turbines away from where raptors concentrate may reduce raptor collision rates.

What is Less Well Understood

- Pre-development site evaluation may reduce potential negative impacts on birds and bats.
- Newer turbines may reduce raptor collision rates, but effects on songbirds are uncertain.
- Tubular towers, as opposed to lattice towers, may reduce raptor collision rates at wind facilities.
- Siting turbines in areas of low prey density may reduce raptor collision rates at wind facilities.
- Waterbird and waterfowl collision risk at land-based wind facilities is typically low.

Areas Where Little is Known

- What is the cumulative impact of bird and bat collisions on some species and local populations?
- Are lower fatality rates for migrant songbirds and bats at wind turbines in farmlands compared to those in forested sites caused by the differences in habitat type?
- Does turbine height have an impact on the collision rate for songbirds or bats?
- Can wind turbines be designed to make them easier for birds and bats to detect and avoid?
- To what extent will wildlife become habituated to wind facilities?
- Do topography, geography, land cover and resource proximity influence fatality rates?
- To what degree does siting wind facilities within migratory routes contribute to collision risk?

Habitat alteration from wind energy development may prevent bird species from using that location for essential activities, such as breeding, nesting or feeding.

Indirect Effects of Wind Turbines on Birds

In contrast to impacts on reduced bird populations from collisions with turbines, habitat alteration from wind energy development can present a more significant impact to wildlife. Altering the habitat and displacing birds and animals, is a threat to the continued survival of many bird species in the United States [2, 5, 15, 16]. An altered or degraded habitat may prevent bird species from using that location for essential activities, such as breeding, nesting or feeding. Energy development, including wind energy, can lead to habitat alteration and the associated effects on birds and other wildlife populations.

Changes in habitat quality may be less obvious than a drastic change in land use. The extent of human activity, such as increased noise or barriers that restrict the movement of birds and other wildlife may degrade habitat quality. If the change is substantial, sensitive species may avoid the area.

During migration, more than 5 million songbirds, representing over 300 species, follow the Lake Michigan flyway and may be susceptible to both the direct and indirect impacts of wind energy.

Energy development activities can also affect invasive species, predator populations and parasites [15]. In time, some bird and other wildlife species may adapt to changes in their environment, including the presence of wind turbines, but the capacity for and rate of adaptation for many species is unclear. Altering the habitat is an important aspect to consider, but doesn't usually get the same attention that collision does.

West Michigan's Bird Populations

The West Michigan region supports not only a wide variety of resident species, but also serves as an important bird migration corridor along the Great Lakes/ Mississippi flyway. It is during these seasonal migrations that many ornithologists believe birds may be most susceptible to both the direct and indirect impacts of wind energy [10]. During migration, more than 5 million songbirds, representing over 300 species, follow the Lake Michigan flyway connecting Canada to the Caribbean and Central and South America (Figure 1). Inland areas as well as the lake's shoreline are a significant corridor for migrating birds and provide a variety of stopover habitats for resting and refueling.

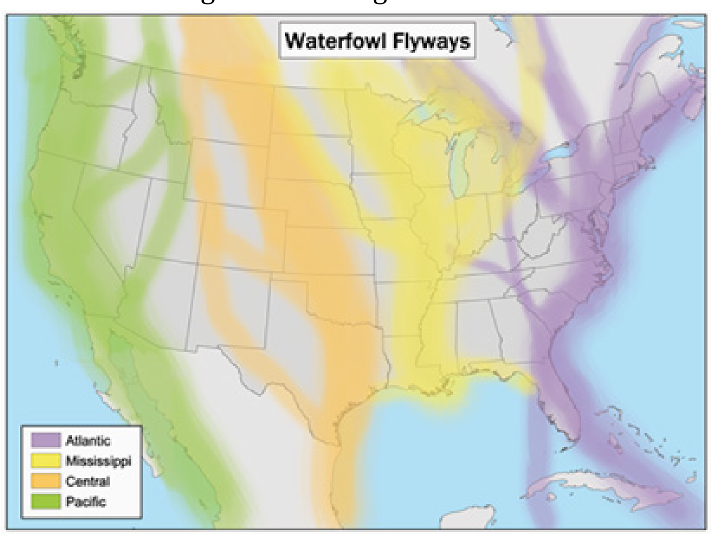

Figure 1: The West Michigan region occupies part of the Mississippi flyway. Credit: Based on USFWS maps, Wikimedia Commons.

From 2007-2010 during the West Michigan Wind Assessment study period, birders reported sightings of five species in the study area that are listed as either threatened or of special concern in Michigan.

Since 2007, professional naturalists and amateur birders have gathered along the Lake Michigan shore to document the annual bird migration. The West Michigan Wind Assessment analyzed bird sightings at 12 shoreline locations over 18 dates in the spring and fall from 2007-2010. Five of the survey locations were in the West Michigan Wind Assessment study area:

- Little Sable Point, Oceana County
- Pere Marquette Park, Muskegon County
- Grand Haven Pier, Ottawa County
- Holland State Park, Ottawa County
- Douglas Public Beach, Allegan County

The effect of wind turbines on bat populations has not been clearly determined, but bat deaths tend to peak at wind facilities during the late summer and early fall migration.

Of all 12 observation locations, the top three for total number of birds observed were all in the West Michigan Wind Assessment study area: Pere Marquette Park, Holland State Park, and Douglas Public Beach. Pere Marquette Park had the highest total number of sightings (33,981 birds). The most commonly observed species was the long-tailed duck (*Clangula hyemalis*). Birders at the 12 observation locations reported sightings of six species that are listed as either threatened or of special concern in Michigan (Table 1). Of these six, all but the trumpeter swan were observed in the West Michigan Wind Assessment study area.

The bird survey results, while preliminary and limited to the shoreline, show that coastal West Michigan supports a large number of migrating birds, some of which are threatened or of special concern in Michigan. Wind energy development in the coastal zone, both nearshore and offshore, should take precautions to minimize the potential risks to West Michigan's bird populations.

Common Name	Scientific Name	Michigan Conservation Status
Trumpeter Swan	*Cygnus buccinator*	Threatened
Common Loon	*Gavia immer*	Threatened
Caspian Tern	*Sterna caspia*	Threatened
Black Tern	*Chlidonias niger*	Special Concern
Common Tern	*Sterna hirundo*	Threatened
Foster's Tern	*Sterna forsteri*	Threatened

Table 1: Six listed species were observed migrating along the Lake Michigan shoreline.

Concerns About Bats

Options for mitigating the impact of wind farms on wildlife include changing the cut-in-speed, reducing operational hours during low-wind conditions, adjusting lighting systems, and radar systems to detect nearby wildlife and stop the blades.

Until fatalities began to be reported recently, bat deaths at wind farms were not recognized. Consequently, data on mortality rates for bats remains uncertain and the effect wind turbines have on bat populations has not been clearly determined. After 2003, an unexpectedly high number of bat fatalities was discovered at wind energy installations on ridgelines in West Virginia and Pennsylvania [2, 13]. Bat deaths tend to peak at wind facilities during the late summer and early fall migration. The hoary bat, eastern red bat and silver-haired bat (all present in Michigan) tend to be most often killed or injured by wind turbines.

A study conducted for the Bats and Wind Energy Cooperative (BWEC), an alliance of state and federal agencies, private industry, academic institutions and non-governmental organizations working to minimize wind turbine bat mortalities, showed that by changing the cut-in-speed—the lowest wind speed for generating electricity—and reducing operational hours during low-wind conditions, there were nightly reductions in bat fatality ranging from 44 to 93 percent [17].

Other options for reducing fatalities range from simple solutions, such as adjusting lighting to be less attractive to wildlife, to more complex solutions, such as radar systems that stop blades when a group of birds or bats are flying close to the turbines. Several research partnerships continue to seek methods for reducing this impact on wildlife. Such research will also provide new findings to help inform the siting of new wind energy projects; improve methods to assess impacts of wind development on birds and bats; and evaluate the effectiveness of impact avoidance, minimization or mitigation measures [14].

Wildlife Conservation and Wind Energy in West Michigan

The West Michigan region supports numerous endangered and threatened species, as well as species of special concern. The Michigan Natural Features Inventory (MNFI) catalogs locations of known or probable populations of species that are conservation priorities. The MNFI's biorarity index aggregates the locations of all kinds of endangered, threatened or special concern species (plants, birds, mammals, etc.) and provides an estimate of whether such a species is likely to be found in a given area [18]. The West Michigan region includes several areas that have a high probability of supporting an endangered, threatened or special concern species, including Muskegon and Allegan counties (Figure 2).

Preliminary research suggests that wildlife deaths associated with electricity generation are higher for fossil fuel generation, per-GWh and for total impact, than for wind energy.

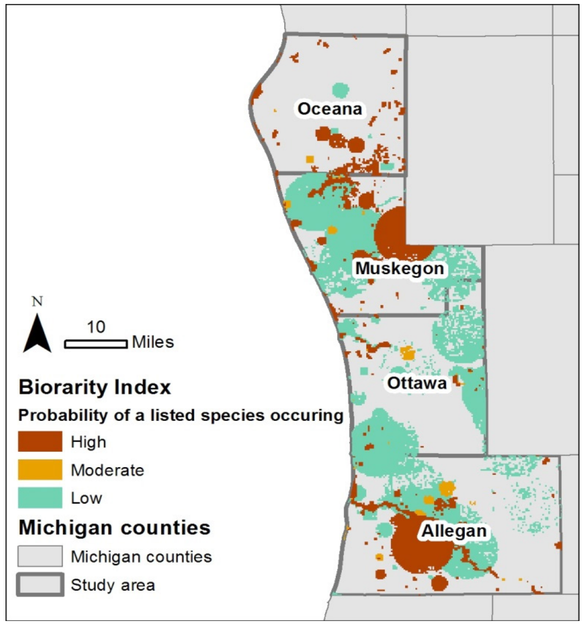

Figure 2: Muskegon and Allegan counties have large areas that are likely to support endangered, threatened, or special concern species.

In 2011, the USFWS issued voluntary guidelines recommending a "tiered approach," with more information requested at higher tiers, for assessing potential wildlife impacts and incorporating site-specific conditions.

Wildlife Impacts from Conventional Electricity Sources

Bird deaths from wind turbines have attracted much attention, but little research has explored rates from conventional forms of electricity production, especially fossil fuels [19]. One preliminary analysis found that wind farms in the United States are responsible for about three bird and bat deaths per gigawatt-hour (GWh) of electricity production. In comparison, fossil-fuel electricity production resulted in about five bird deaths per GWh, primarily from the environmental impacts of fossil fuels such as acid rain, coal mining and climate change [20, 21]. Though the work is preliminary and has some flaws, it illustrates that traditional coal and gas power plants also negatively impact bird populations and the size of this impact could be comparable or larger than the number of bird collisions at wind farms.

Toward "Wildlife Smart" Wind Energy

In addition to selecting a location that reduces the risk of wildlife fatality, there are several approaches to preventing or decreasing the death rate when turbines are in operation. At the request of the U.S. Fish and Wildlife Service (USFWS), the Wind Turbine Guidelines Advisory Committee (WTGAC) was organized to recommend science-based approaches for assessing wildlife impacts from land-based wind energy developments.

An environmental impact assessment may be prescribed to evaluate the potential environmental consequences of a wind farm, and must take into account the cumulative environmental impacts of the proposed action.

Thermo-electric generation facilities withdraw more water from the Great Lakes to cool equipment than all other uses combined.

Fish can be killed during water withdrawal and used cooling water is returned to the environment often at a higher temperature, which can impact aquatic organisms and their habitats.

In 2011, when issuing their draft guidelines, the USFWS adopted many of the WTGAC's recommendations, with some modifications. These voluntary guidelines support a "tiered approach" for assessing potential wildlife impacts and incorporating site-specific conditions. A progressive decision-making process is used where more information and more detail are requested at higher tiers to reach a risk-based decision.

Each tier, as listed below, contains questions to help identify potential issues tied to a project phase. Responses help the developer and reviewer decide if they have enough information and reason to proceed with a wind energy project based on its possible wildlife impacts [15].

- Tier 1 – Preliminary, landscape-level, evaluation or screening of potential sites.
- Tier 2 – Broad characterization of several possible project sites.
- Tier 3 – Pre-construction field studies to document conditions and predict project impacts.
- Tier 4 – Post-construction monitoring of effects on wildlife.
- Tier 5 – Other research to evaluate and address adverse habitat impacts.

In order to anticipate the potential environmental consequences of any significant development, such as a wind farm, an official environmental impact assessment may be prescribed by local, state or federal requirements. Some environmental impact assessments, especially those required under federal regulations, must take into account the cumulative environmental impacts of the proposed action [13].

Cumulative impacts reflect the interaction between the environmental outcomes from many, small individual decisions over time. For example, the combined effects of birds colliding with wind turbines, buildings, cell-phone towers, transmission lines, and other structures might become critical to vulnerable avian populations. Another example is that the beneficial effects of a single wind farm on air emissions might be judged negligible, but when the effects of a dozen wind farms on air emissions are considered, the cumulative impact becomes substantial [7].

The assessment of cumulative effects remains a complex task. The patterns and magnitude of cumulative impacts of wind farms over large areas and for long periods are difficult to adequately analyze and reliably predict, even when modeling is used. Good baseline data and a standard assessment framework are essential for estimating how environmental effects may accumulate for any proposed action [5]. Over time, both positive and negative outcomes will become clearer as wind energy development proceeds.

Water, Fish and Electricity

Electricity generation from coal, nuclear and some natural gas power plants account for 79 percent of all water withdrawals in Michigan, and almost all of these withdrawals are directly from the Great Lakes. Thermo-electric generation facilities, as these plants are called, withdraw more water from the Great Lakes than all other uses combined [22]. Coal and nuclear power plants use substantial quantities of water each day to produce electricity and cool equipment. The used cooling water is returned to the environment at a high temperature, which can change habitat conditions and harm aquatic organisms.

Additionally, in the process of withdrawing water, fish and other aquatic organisms are killed from either impingement, where they are trapped against water intake screens, or entrainment, where they are drawn into the facility's equipment and exposed to pressure and high temperatures. Such water intakes are regulated under Section 316(b) of the Clean Water Act [23].

Reducing Water Withdrawals and Fish Deaths With Wind Energy

The U.S. Department of Energy estimates that generating 20 percent of the nation's electricity from wind energy could avoid the consumption of 4 trillion gallons of water.

One power plant on Lake Erie was found to kill 46 million fish in 2006 [24], while another study found that nearly 350,000 adult game fish in the Great Lakes are killed each year in the water intake pipes for power plants and manufacturing facilities [23]. Reducing the amount of cooling water required for the electricity sector can have a positive effect on Great Lakes fish populations.

In contrast to thermo-electric facilities, no cooling water is required for electricity generation from wind energy, reducing the overall need for cooling water in the electricity system as a whole. The U.S. Department of Energy has estimated that generating 20 percent of the nation's electricity from wind energy could avoid the withdrawal of 4 trillion gallons of water through 2030 (Figure 3) [6].

Another group reported that each megawatt (MW) of wind energy capacity can reduce the need for 0.7 to 2.1 million gallons of cooling water withdrawn by thermo-electric power plants [25]. Based on that estimate, a 100 MW wind farm in West Michigan could avoid the withdrawal of 70 to 210 million gallons of water annually from Lake Michigan.

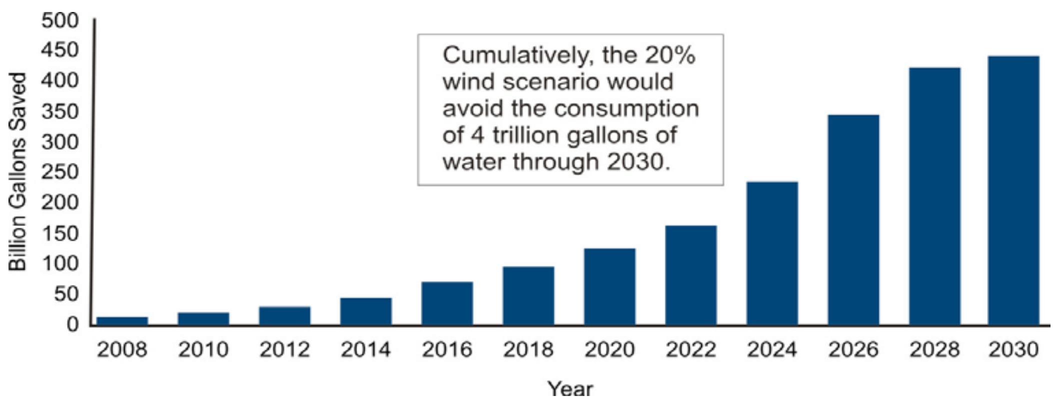

Figure 3: National water savings from the 20% wind scenario. Source: U.S. Dept. of Energy [4].

Landscape Effects From Wind Energy

Wind farms need larger tracks of land to ensure good wind exposure and minimize inefficiencies, but more than 90 percent of the land not directly used by a wind farm can co-exist with many other land uses.

Due to its dispersed nature, wind has a lower energy density than, for example, the energy concentrated in a ton of coal. Consequently, wind farms need multiple turbines and larger tracks of land to ensure good wind exposure and to minimize inefficiencies from wake losses. If land available in an area is broken up by different land uses, then the land becomes less valuable for efficiently linking wind turbines in wind farm development [5]. Land requirements for both construction and operation must be considered when assessing the wind farm's overall resource requirements [26].

Wind farms may sprawl over large areas, but only a fraction of the land is occupied by the turbines themselves. One estimate suggested that up to 2.5 acres per turbine is temporarily engaged during construction and about 1 acre per turbine is permanently occupied during the operation phase [26]. The area between the turbines, with the exception of the turbine footprint, is available for farming, grazing, or other activities [27]. More than 90 percent of the land not directly used by a wind farm can co-exist with many other land uses with few exceptions [28].

Land use changes to accommodate wind farms are similar to those for other kinds of electricity-generating plants, including the need for road and transmission line rights-of-ways. The overall footprint of a wind farm tends to be larger, but the intensity of land use change is lower since uses between turbines are often not affected [5].

Wind energy's localized sprawling nature is more prone to land use conflicts; local communities commonly employ buffer zones or setbacks to mitigate these conflicts and manage incompatible activities.

Land Use Intensity

Unlike fossil fuel generation which relies on transportation systems to bring the fuel to the plant, wind farms must be constructed where the wind can be directly extracted. Fossil fuel electricity is disconnected from its land-intensive processes of resource extraction, such as coal mining or oil drilling. With wind energy, resource extraction and electricity production are simultaneously one and the same. Comparing the land use intensity of wind energy with other fuel sources, and the relationships between resource extraction and electricity production, can be challenging—yet illuminating.

Construction of nearly any new energy infrastructure will experience some conflict, but because wind farms usually include turbines spread over a large area and often on many people's properties, wind energy development is more prone to land use conflicts [29]. The type of land use around a proposed wind farm is likely to affect the degree of controversy. For example, wind developments that encroach on residential, recreational and protected natural areas often generate more public concern. Communities can require buffer zones or setbacks—minimum distances between a turbine and a dwelling to address these issues.

Farmland is generally highly compatible with wind energy development because it is usually flat and cleared, while forests, residential areas, and wetlands are less suitable.

Interestingly, the total land use change caused by a wind farm is often not much larger than the land area used by power plants. Constructing a wind turbine does not necessarily require any changes to the land around it. For example, farmland is, in general, highly compatible with wind energy development because it is usually flat and cleared. Farmers can graze animals or plant crops between the turbines. Significant areas of farmland are scattered throughout West Michigan (Figure 4). However, forests, residential areas and wetlands are less suitable for wind energy development and should be avoided.

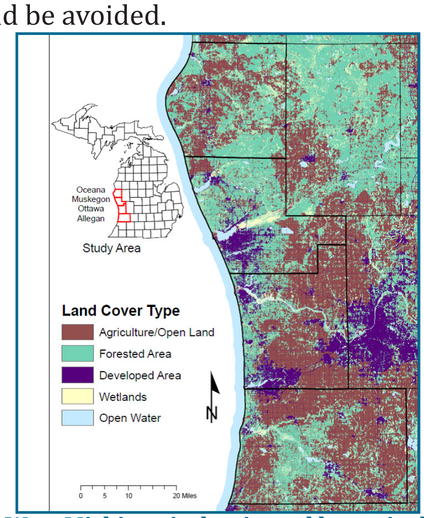

Figure 4: West Michigan is dominated by agriculture and forest with significant development as well as protected wilderness in Muskegon and Holland.

Wind energy development activities can fragment an otherwise intact landscape and harm sensitive species.

Fragmentation of Sensitive Areas

Fragmentation breaks large natural areas into smaller and more isolated land segments. Most land in West Michigan has been compromised and fragmented due to residential development, farming, logging, mineral extraction and road building. Wind farms, just like other large developments, can fragment forests, wildlife habitats and other ecosystems [31]. Wind energy development activities such as site preparation, road construction, turbine construction, and transmission line connections can fragment an otherwise intact landscape.

Such fragmentation can harm sensitive species, by reducing the amount of habitat available [26]. The risks of fragmentation can be reduced if wind farms are constructed on lands that are already modified, such as agricultural areas or former industrial sites ("brownfields") [32].

Wind farm construction presents limited distrurbances of the environment, while decommissioning is straight forward and stabilizes disturbed areas to return the landscape to its previous condition.

Wind Farm Construction and Decommissioning

During wind farm construction there are limited, often temporary, disturbances to the environment, which are not unique to wind farm installation. These disturbances may involve increased stormwater runoff, soil erosion and disruption of wildlife habitats. While construction impacts are anticipated to be short-term, localized and often easily corrected, some construction activities can present more serious problems.

Industry best practices recommend, and many communities require, that a wind farm be properly decommissioned at the end of its useful life. When compared to decommissioning a nuclear-powered or coal-fired plant, dismantling a wind farm is relatively straight forward. Turbines are expected to have a useful life of at least 20 to 30 years [26, 32]. This useful life can often be extended by "repowering" or upgrading equipment with new technology. If an upgrade is not viable, then turbines and other associated infrastructure would be decommissioned. Structures are removed and disturbed areas are stabilized with the objective of returning the landscape to its previous condition.

Larger wind turbines increase power output, but such turbines can disrupt scenic vistas; visual impact assessments and realistic photo-simulations can mitigate this impact.

Visual Impact Assessment and Mitigation

Utility-scale wind turbines are very tall, more than 400 feet in some cases. Taller turbines can access stronger, more consistent winds at higher altitudes. Longer blades increase the "swept area," the circle made by the rotating blades , which is directly related to power output. The trend toward larger turbines, however, has a downside. Such large turbines can appear out of scale with the surrounding environment and can disrupt scenic vistas. The FAA also requires lights on wind turbines so that airplane pilots can navigate safely and avoid these structures. The visual or aesthetic impact is a major concern for many communities hosting wind farms.

The Great Lakes Wind Collaborative, a multi-sector coalition of stakeholders supporting the sustainable development of wind power in the Great Lakes, recommends conducting a visual impact assessment that engages the community in the design process [32]. A visual impact assessment can include identifying visually sensitive areas and cultural landmarks, conducting public perception surveys, and generating realistic photo-simulations of alternative project designs.

Landscape architects, engineers and designers can create highly realistic simulations of proposed wind energy projects using sophisticated software tools. Citizens and regulators can also create fairly accurate simulations of wind farms using CanVis, a visualization tool available from the National Oceanic and Atmospheric Administration [33]. CanVis is a free program that requires basic computer and math skills to create the visualizations. Researchers at Grand Valley State University and the Great Lakes Commission used CanVis to create a photo-simulation of a hypothetical offshore wind farm along the Michigan coast (Figure 5) [34].

The National Research Council identified scale, number of turbines in view, visual clutter, lighting and cumulative effects as key factors in wind energy projects affecting scenic resources.

Figure 5: A portion of a visual simulation of a hypothetical wind farm along the Michigan coast. This scenario featured two rows of turbines, the closest being 6 miles from shore.

In its book Environmental Impacts of Wind-Energy Projects, the National Research Council, a non-profit providing expert advice on the nation's challenges, identified several key factors in wind energy projects that affect scenic resources, including:

- Scale: The relative height of a turbine compared to its surroundings can influence the aesthetic impact.
- Number of turbines in view: Includes both the number of turbines in the wind farm and topographic effects that might obscure some turbines from view.
- Visual clutter: Clutter can be reduced by choosing linear layouts with consistent spacing and using turbines of similar sizes.
- Lighting: FAA lighting is required for aviation safety, but lights can also impact the scenic quality and night sky.
- Cumulative effects: Maintaining areas that are free of the visual impacts of multiple wind farms is important [7].

Projects located on federal lands or with some federal involvement may need to comply with several federal laws, such as NEPA and the Endangered Species Act, and may trigger a federal environmental assessment.

The visual impact of utility-scale turbines cannot be eliminated entirely, but the impact can be reduced by following good design principles and engaging the public in the process.

Regulating Environmental Impacts of Wind Energy

Like other proposed developments, a prospective wind farm can be subject to local, state and federal environmental laws. Some of these laws may contain specific standards for an environmental impact assessment. The environmental assessment may be a lengthy process involving numerous federal, state and local authorities [6].

Federal agencies often play a minimal role in reviewing or approving most wind energy projects. Only those proposed projects located on federal lands or those with some federal involvement, such as directly receiving federal funds, are federally regulated. In these situations, the project may need to comply with several federal laws, such as National Environmental Protection Act (NEPA), Migratory

Bird Treaty Act, Bald and Golden Eagle Protection Act, and the Endangered Species Act. Under these limited circumstances, a federal environmental assessment might be triggered. The federal production tax credit for wind energy, however, does not trigger the NEPA environmental impact assessment process [7].

In Michigan, there is no state permit for wind farms and often only a few state agencies play a limited role in regulating the environmental aspects of wind energy development [35]. An environmental permit may be needed for a wind farm, like any construction project, if it were to alter sand dunes or wetlands, or cause substantial soil erosion and sedimentation. An environmental impact assessment is often not triggered by these state requirements.

Michigan wind energy is regulated primarily through zoning ordinances that may stipulate setback distances and acceptable noise levels, with local environmental analyses suggested by the state.

Wind energy in Michigan is regulated primarily through local zoning ordinances. More than 40 of the 73 townships in the West Michigan Wind Assessment study area have enacted some kind of utility-scale wind energy zoning ordinance. The zoning ordinances may stipulate setback distances and acceptable noise levels [4]. Local governments, however, may not have the authority to consider and address many aspects of the environment, such as wildlife. Environmental analyses at the local level, including bird population studies, are suggested by wind energy guidelines from the State of Michigan, Ottawa County and the Great Lakes Wind Collaborative. These guidelines, however, do not have the force of law.

Given the relatively narrow regulatory scope of state and local agencies, it appears that when new wind installations are reviewed, no single entity considers the wider environmental impacts of wind energy on a regional or "ecosystem" scale, a scale that often extends beyond local jurisdictions [13]. Thus, these wider impacts should be considered in planning and development of a wind farm proposal.

Conclusions

Wind energy development offers significant environmental benefits, however, much consideration needs to be taken to mitigate potential negative impacts such as wildlife deaths and land use intensity.

Responsible wind energy development offers significant environmental benefits and represents an important strategy for diversifying the state's energy supply, combating the effects of air pollution and climate change, and reducing the state's dependence on fossil fuels.

Wind turbines, especially if built in poorly sited locations, do have the potential to kill birds and bats at unacceptable levels. The threat to bats is less well understood and potentially larger than the threat to birds. Bird advocacy organizations, such as the Audubon Society and the American Bird Conservancy, have voiced their support for wind power when appropriate steps are taken to lessen the risks for birds and bats, including rigorous pre-construction surveys and operational changes like raising the turbines' cut-in speeds. Preliminary studies suggest that fossil fuel sources kill more birds per unit of electricity generated than wind farms, when indirect effects like climate change are considered.

Many bird species migrate along the Lake Michigan shoreline. Several threatened or species of special concern have been spotted along the West Michigan coast. Muskegon and Allegan counties also support large areas where endangered, threatened or special concern species may be present. While presence of listed species migrating or residing in the area is not necessarily incompatible with wind energy development, special care should be taken to minimize impacts in these areas in particular.

Relative to the other options available to generate electricity, wind energy offers the greatest potential to improve West Michigan's environmental stewardship.

Wind energy, unlike thermo-electric generation, requires no water to generate electricity. Substituting wind energy for fossil fuels would not only reduce withdrawals of Great Lakes water, but may also reduce the number of fish killed in water intakes at power plants.

Wind farms sprawl over many acres, but an individual turbine's footprint is less than 3 acres. Wind energy development is more compatible with agriculture and brownfields than some other land uses, such as high-density residential areas. Farmers can plant crops between turbines within a wind farm. The West Michigan region has a large area of farmland, some of which may be appropriate for wind energy development.

The visual impact of wind farms is an important design consideration. The Great Lakes Wind Collaborative and the National Research Council have identified best practices and design principles for reducing a wind farm's aesthetic impact. Visual simulation is an important part of the public engagement process.

In Michigan, wind energy is primarily regulated through township zoning ordinances, which generally do not address wildlife or pollution issues. State and federal statutes covering wildlife and pollution may be triggered for wind turbine construction under particular circumstances. Environmental assessments, including studies of potential bird and bat impacts, are considered a best practice and are encouraged by state guidelines, but are not always required.

If widely adopted, wind energy could help address several complex environmental issues involving fossil fuels, such as global climate change. However, the environmental benefits, such as improved air quality, should be carefully weighed against other effects, such as the impacts for wildlife or the aesthetics of a particular landscape. Cumulative consequences and overall tradeoffs should be estimated and considered. Although assessing the environmental effects of wind energy is still an active area of research, many of the concerns can be reduced through careful siting and design of wind developments using information and techniques that are already available.

No matter what energy source is used to generate electricity, aspects of the West Michigan environment will be compromised in some way. However, relative to the other options available to generate electricity, wind energy offers the greatest potential to improve the region's overall environmental stewardship. With more research and experience at siting wind farms, the possibility of reducing the environmental impacts associated with wind energy continues to grow.

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