TRANSMISSION-RELATED POLICY OPTIONS TO FACILITATE OFFSHORE WIND IN THE GREAT LAKES

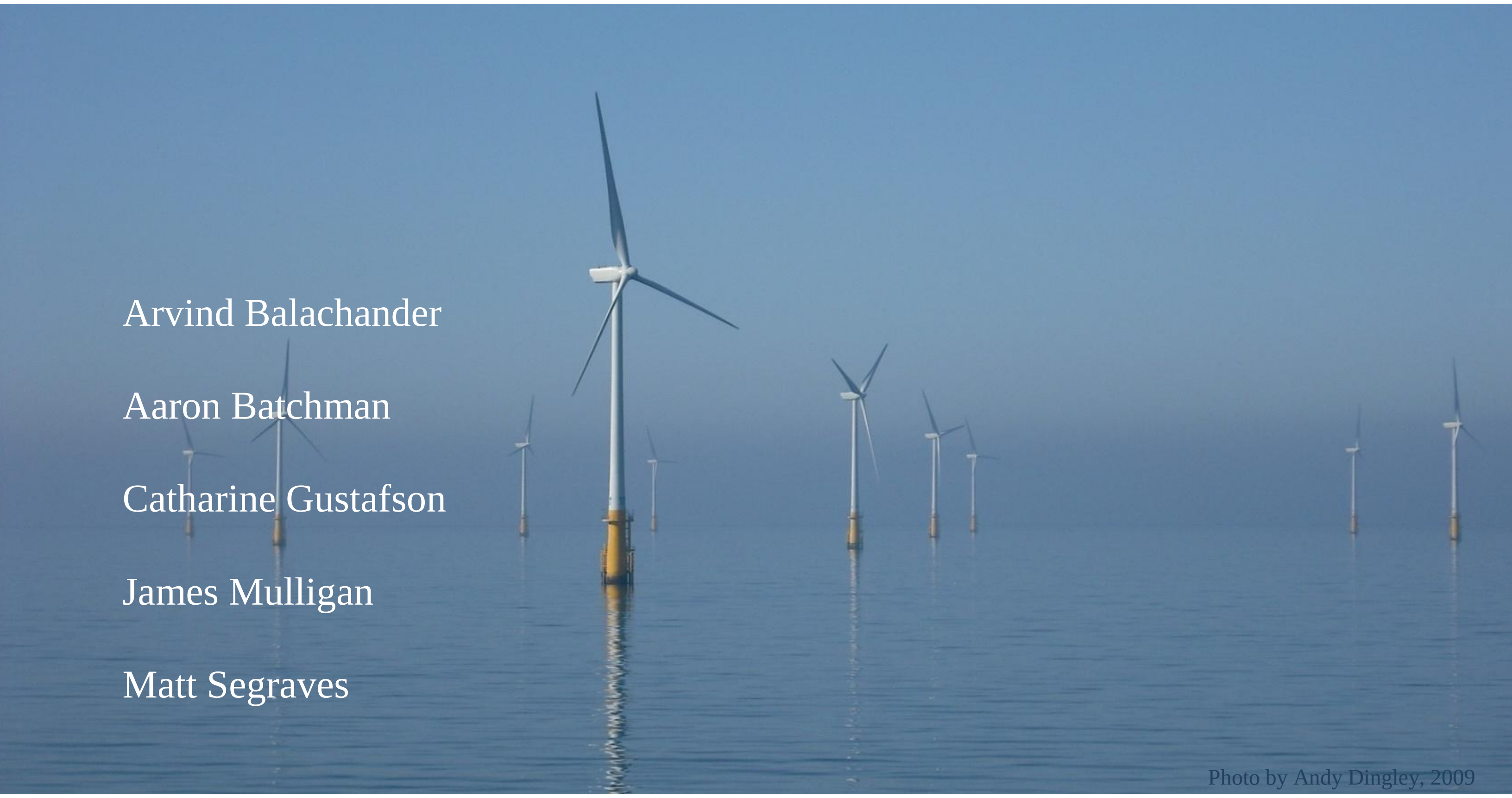

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Photo by Andy Dingley, 2009

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EXECUTIVE SUMMARY

Overview

Offshore wind power has the potential to play a substantial role in the renewable energy portfolio of the Great Lakes Basin in the coming decades. The Great Lakes are home to a high-quality wind resource that could displace large amounts of non-renewable power generation, having positive environmental and economic impacts in the region. To capitalize on this renewable energy solution with minimal infringement on Great Lakes communities and ecosystems, policymakers in the region must understand the transmission component of offshore wind development. Where it is binding, the transmission constraint can be a major determinant in renewable energy siting decisions, preventing developers from optimizing wind facility location based on economic, social, and environmental parameters alone. Transmission infrastructure, however, has local social and environmental implications of its own. Consequently, strategic transmission planning presents an important opportunity to minimize economic costs and social and environmental impacts of offshore wind integration.

In late 2009 the Great Lakes Wind Collaborative, a multi-sector coalition of wind energy stakeholders from the bi-national Great Lakes region, identified a knowledge gap related to transmission needs for offshore wind. This report is intended to be a timely response to this knowledge gap. It aims to answers the research question,

> “What transmission-related options are available to policymakers and industry to facilitate offshore wind development in the Great Lakes while maximizing net economic, social, and environmental benefits?”

To answer that question, this report provides a discussion and preliminary analysis of anticipated transmission constraints that offshore wind development in the Great Lakes will likely encounter; a comprehensive breakdown of barriers to developing new transmission including cost, planning, permitting, and environmental barriers; and an array of transmission-related policy options designed to facilitate offshore wind integration while maximizing net benefits for the Great Lakes region. Taken as a whole, this report is intended to provide the information that regional policymakers, developers, and other stakeholders need to think strategically about the transmission component of Great Lakes offshore wind development in the mid- to long-term.

Methods

Synthesis: The research team reviewed existing information pertaining to transmission constraints for offshore wind development; onshore and offshore transmission costs, environmental impacts, and planning barriers; and examined existing policy mechanisms designed to facilitate renewable energy integration.

Expert consultation: The research team consulted with regional, national, and international experts from across a range of sectors and disciplines, including offshore wind developers, transmission planners/developers, utilities, environmental organizations, academics, local municipalities, and state, regional, and national regulatory bodies.

New analyses: The research team conducted original spatial and quantitative analysis to identify potential opportunities for integrating offshore wind power where transmission constraints are likely to be low.

Findings: The Problem

When Transmission will Constrain Offshore Wind Development in the Great Lakes

A review of European experience with offshore wind transmission reveals that, while early-stage development may not encounter substantial transmission constraints, ultimately major onshore upgrades will be needed to integrate offshore wind power. For example, Belgium is investing in a USD$200 million project to expand transmission capacity from the coast to inland population centers from 650 MW to 2 GW. The Netherlands has existing transmission capacity to integrate 2 GW of offshore wind power but would require a $390 million USD investment (or up to $1.1 billion if cables are buried below ground) to integrate an additional 4 GW from offshore wind. While the UK is integrating 8 GW of offshore wind power with minimal transmission upgrades, its plans to integrate an additional 25 GW likely will require a multi-billion USD investment in the onshore grid.

In addition to the need for onshore upgrades, offshore transmission can also constrain siting decisions, depending primarily on distance from shore, project scale, and other factors. Because submarine cable and offshore substations are substantially more expensive than onshore infrastructure, the offshore component can be a major factor in transmission planning for offshore wind. For example, expansion plans in the UK (25 GW) would require additional investment of many billions to build an offshore grid to support this extensive offshore wind development.

An important distinction between onshore and offshore wind is that high-quality offshore wind resources are typically found in close proximity to load centers such as large cities. This is particularly true in the Great Lakes region (more so than in Europe), as many of the industrial and population centers in the region are located near or on the lakes' shores. In general, this geographic advantage should reduce the transmission required to integrate offshore wind relative to onshore wind.

Spatial analysis shows that 60 GW of offshore wind power capacity could be installed within 15 miles of major lakeside population centers in the basin.[i] Yet, the ability of developers to capitalize on this opportunity is far from certain, particularly given the viewshed impacts of near-shore wind facilities and thus potential for local opposition. Imposing a 6-mile shoreline exclusionary buffer reduces that developable power to 15MW.

An alternative option to integrate offshore wind power with minimal transmission constraints is to utilize existing transmission capacity currently reserved by lakeside power plants in the basin. Like load centers, power plants in the region tend to be concentrated near the shoreline. Many of these plants are baseload electricity providers and consistently operate substantially below full capacity due to age or other factors. These plants have a substantial amount of typically unused transmission capacity that is accessible within 5 miles of the lakes. Spatial analysis shows that 20 GW of wind power capacity could be installed offshore within 15 miles of the shoreline where

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[i] This calculation uses 10 MW per square mile as an estimate of developable wind power. Only lake areas with depth greater than 30 meters and shipping lanes with a one mile buffer are excluded. Calculation does not consider wind speed. A radius of 15 miles is used to minimize offshore transmission infrastructure needed to deliver power to shore. In some cases, 15 miles may be too far for economical offshore transmission, depending on project scale and other factors.

these plants are located. Imposing a 6-mile shoreline exclusionary buffer to lessen viewshed impacts reduces that potential to 11 GW.

Together, development potential near lakeside cities (load centers) or power plants, where transmission capacity may not be a substantial constraint, is estimated to be 68 GW without a shoreline buffer, and 16 GW with a 6-mile shoreline buffer. This is the “minimal-constraint” opportunity to develop offshore wind from a transmission infrastructure perspective, as shown in Figure 1 below.

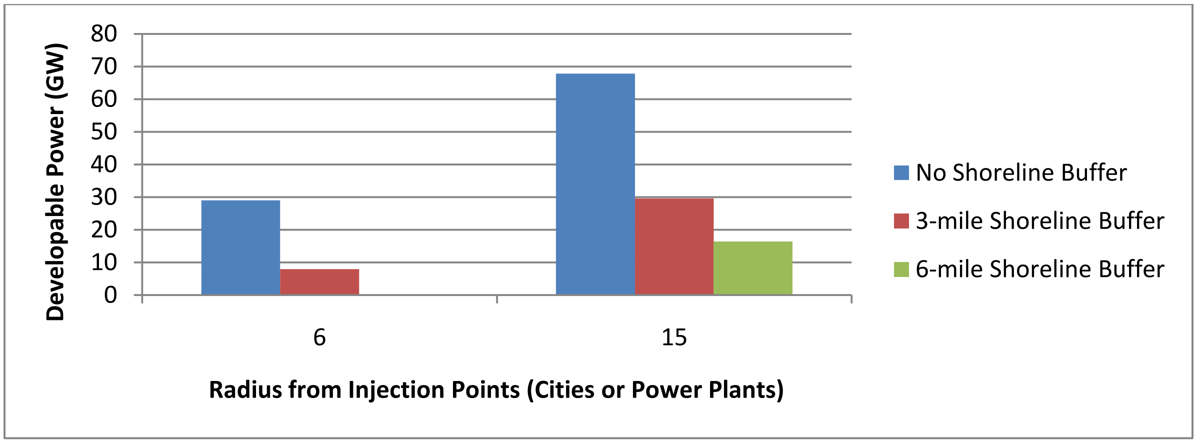


Figure 1: “Minimal Constraint” Development Opportunity. “Developable power” represents the upper bound power capacity that could be installed in lake area within the specified radii of city or power plant “injection points,” with the specified shoreline buffer excluded to simulate viewshed concerns, and with depth less than 30 meters to accommodate current wind turbine foundation technology. Note that developable power reduces sharply with increasing shoreline buffer.

These estimates are an upper bound because they include areas that may not be available for wind development. The calculation assumes a high-quality wind resource in all locations, and does not consider such exclusion criteria as airports, military zones, environmentally sensitive areas, bird migration routes, shipwrecks, and others. Additionally, some of the individual areas included in these sums may have development power potential that exceeds integration potential without major transmission upgrades. On the other hand, these estimates consider only near-load and near-power plant areas as proxies for areas with sufficient transmission for power integration; they omit integration potential (spare transmission capacity) that may exist in other near-shore areas. Nonetheless, these estimates of “minimal-constraint” integration opportunity are likely to be high.

An aggressive growth scenario for the offshore wind industry in the Great Lakes is likely to exceed this "minimal-constraint" opportunity, mirroring European experience. While the UK is the world leader in installed offshore wind capacity at roughly 1.3 GW, the UK plans to install an additional 1 GW per year over the next five years. Given that the Great Lakes region has not yet begun to deploy offshore wind, matching the world leader's rate of growth may seem aggressive. On the other hand, growth rates may substantially improve in the coming decades, as costs of offshore wind come down and technology advances. The Great Lakes region could conceivably attain a 1 GW per year *average* installation rate over the next 20 years. This is not a forecast, but an estimate for a high growth scenario for Great Lakes development. Under such a high growth scenario, offshore wind development in the Great Lakes is likely to exceed the "minimal-constraint" integration opportunity with regard to transmission infrastructure. In other words, the transmission constraint will ultimately be binding in the Great Lakes as it has been in Europe. Exactly where and to what extent this will be true is an important area for further research, which would require examination of detailed transmission data as compared to ideally developable areas in the Great Lakes.

Barriers to Transmission Development

Transmission is costly to build, difficult to plan and permit, damaging to the local environment, and often opposed by local communities. Part 2 of the report describes these major barriers to building both offshore transmission to deliver power from the turbines to the onshore connection, as well as onshore transmission to deliver power to load centers.

Offshore transmission components (submarine cable and offshore substations) are substantially more expensive than onshore counterparts, primarily due to more expensive offshore installation and the additional technical components needed for protection in underwater environments. While transmission is not the leading source of capital costs for projects built to date, these costs can have a real impact on the delivered cost of electricity at the margins. Additionally, transmission costs can be potentially prohibitive for some sites depending on the distance from shore, state of the onshore grid, scale of the project, cost allocation rules, and other factors. Cost allocation (who pays) for transmission infrastructure to deliver power from a project's interconnection point to load also plays a critical role in determining whether a project will be economic or not. Build-out of large transmission projects in the Great Lakes Basin is complex because four different independent transmission system operators (ISOs) have authority to approve new transmission projects and dictate cost allocation rules. Collaboration between these ISOs is limited at best.

Grid planning for wind power is also plagued by the classic chicken-egg dilemma. Transmission companies have little incentive to build new transmission until it is needed by new generation. On the other hand, wind developers are unlikely to site a project where adequate transmission does not yet exist—or to site a project so large that major system upgrades would be needed. Yet, once the offshore wind industry develops as the onshore industry has, approved wind projects will need a relatively short lead-time to become operational, compared to the seven to ten years currently required to plan, permit, and construct a typical transmission project. Only recently have regional transmission planners in the basin begun to proactively identify areas for upgrades to accommodate future wind power generation on land. This type of planning can be applied to offshore wind development as well. If regional planners do not resolve this chicken-egg dilemma, offshore wind is likely to be relegated to areas where transmission constraints are already minimal. Such a pattern of development may minimize new transmission cost, but may or may not minimize overall project costs or be consistent with social and environmental values in the basin.

Transmission development can also have real social and environmental impacts, primarily related to viewshed disruption, onshore habitat fragmentation, coastal habitat disturbance, and lakebed disturbance. While these impacts can be minimized with careful planning, siting and permitting, transmission projects in general can pose major barriers to development. Siting new infrastructure requires new rights of way and permitting can be fraught with political conflict related to social and environmental impacts. These steps may be easier for transmission offshore, where developers can deal with a single land owner (the state/province) and infrastructure is largely unseen underwater, although some states do not yet have permitting processes in place for offshore transmission.

Findings: The Solution Set

Policy Objectives

Ultimately, policy options and mechanisms to achieve desired outcomes are matters for deliberation and decision by policymakers and stakeholders throughout the basin. This report identifies a number of policy options designed with the following broad set of commonly held policy objectives in mind:

- Facilitate Timely Transmission Expansion: Strategic transmission planning could facilitate the necessary transmission expansions to deliver clean, renewable offshore wind power to load.
- Minimize Economic Cost: Transmission-related policies can both minimize overall costs to the region and ensure that the distribution of those costs is such that no single group is overburdened.
- Minimize Environmental Impacts: Minimizing the primarily local environmental impacts associated with siting offshore transmission and enabling wind facility development outside of environmentally sensitive areas would bolster the net environmental benefits of offshore wind development.
- Minimize Social Impacts: Minimizing the impact of offshore wind development on the general aesthetic beauty of the Great Lakes, a valuable cultural and economic resource, can ensure positive net social benefits from the creation of clean energy jobs and environmentally related social benefits.
- Maximize Regulatory Efficiency: Transmission permitting processes that are mindful of the public trust and legally robust can promote effective project planning, build public confidence, and mitigate legal challenge to developers.

Policy Options

Policy Focus 1: Utilize Currently Unused Transmission Capacity Reservations

Conventional lakeside generation facilities in the basin are aging and often operate consistently below full capacity, utilizing less than their full transmission capacity reservations. Many of these facilities are located in close proximity to the shoreline and could serve as injection points for new offshore wind facilities if a substantial portion of corresponding transmission is not being used. Transferring consistently unused transmission capacity to new offshore wind facilities may preclude the need for substantial onshore transmission upgrades. Ultimately this pattern of development could allow offshore wind to be scaled up to utilize the full transmission capacity for conventional generating units, replacing those units as they are run at lower capacities and ultimately retired.

There is substantial offshore wind power development opportunity in close proximity to these conventional facilities. Figure 2 below details developable wind power in lake area within various radii of lakeside power plants. These are upper bound estimates because they do not include exclusions for environmentally sensitive areas, military zones, areas with nominal wind speeds and other exclusion areas. Note that Ontario has been omitted, as all coal plants are being decommissioned and all associated transmission capacity has reportedly already been reapportioned. Quebec also does not appear, since Quebec does not have any land on the shoreline of the Great Lakes.

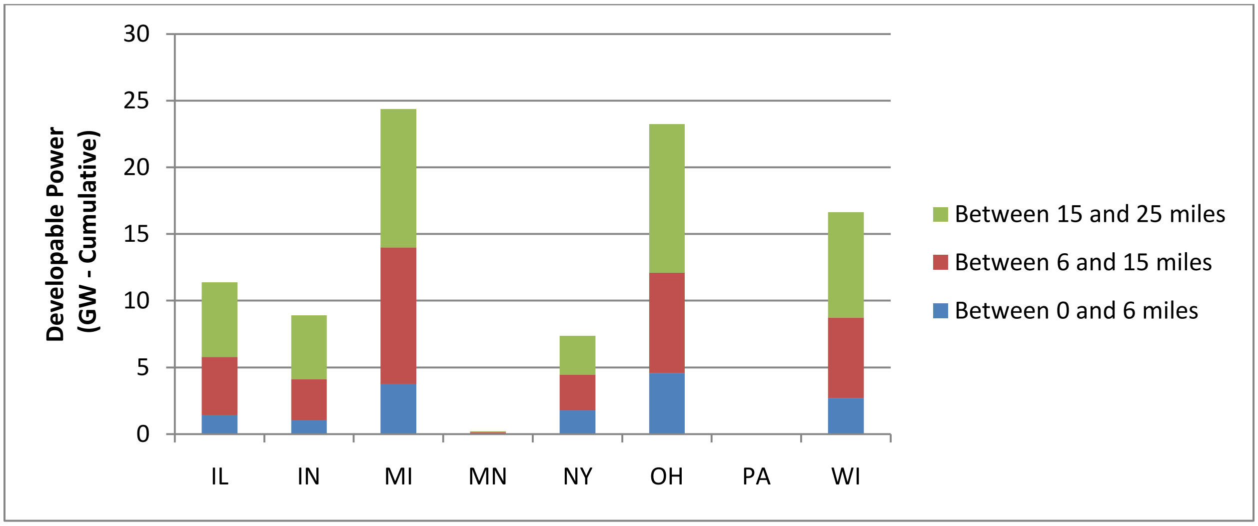


Figure 2: Developable Power Capacity by Distance from Power Plant. Assumptions include no Shoreline exclusion buffer, siting in lake areas with <30m depth, and 10 MW per square mile of developable lake area.

Figure 3 below shows how that developable power would change if a 6-mile shoreline exclusion buffer were imposed.

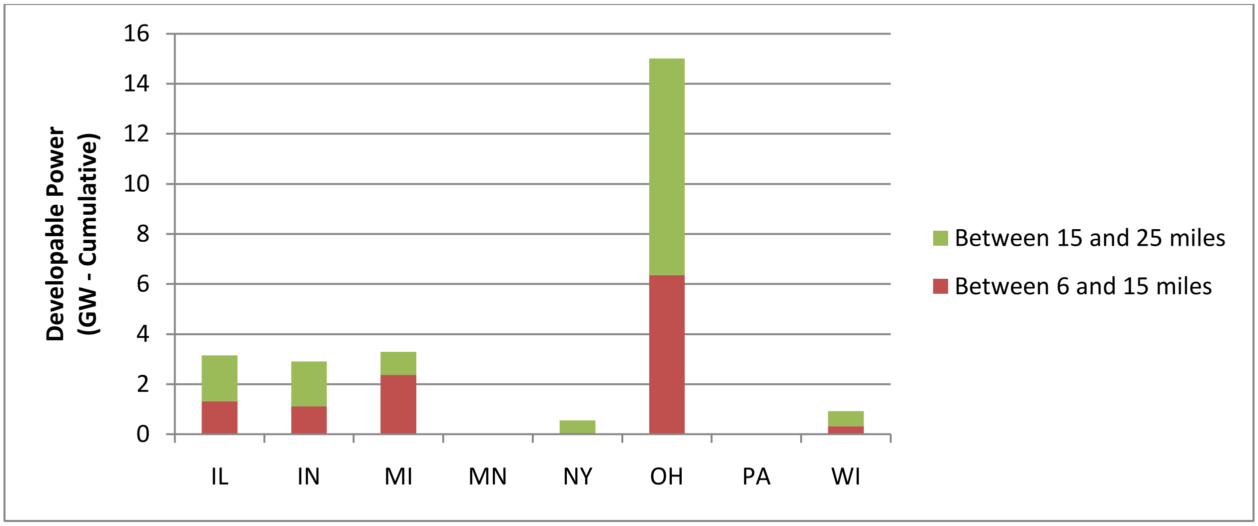


Figure 3: Developable Power Capacity by Distance from Power Plant, with 6-mile Shoreline Exclusion Buffer (lake area with <30m depth, assuming 10 MW per sq mile of developable lake area)

In all, if no shoreline buffer is excluded, 64 GW of offshore wind power could be potentially developed within a 25-mile radius of these power plants. Unused grid capacity includes approximately 12 GW of transmission originally built for coal plants, 1.5 GW for nuclear facilities, and possibly additional unused capacity for other types of plants.

This is a low-cost strategy with an immediate impact on the ability of developers to integrate offshore wind into the onshore grid and avoid the negative social and environmental impacts from transmission upgrades. More research is needed to determine the most efficient and equitable mechanism for grid reservation transfer from current holders to offshore wind facilities. There may be an important role for policymakers to play in facilitating these transfers.

Policy Focus 2: Promote Offshore Transmission Grids

Complex offshore transmission configurations, depending on their design, can deliver several economic, social, and environmental benefits. By bundling several wind farms into a single high-voltage connection to shore, developers who would otherwise have to absorb the full expense of connecting to the onshore grid could benefit from a shared offshore grid. This would improve the viability of far offshore development, thus also reducing public viewshed concerns. Offshore grids can also reduce impacts to sensitive riparian habitats by minimizing the number of cables that must be sited over critical near-shore habitat. Finally, by building transmission projects with multiple economic value, broad allocation of costs may be more justifiable and regulatory issues may be minimized. Apart from integrating renewable energy sources, these transmission projects could provide economic value by relieving congestion between areas that have inadequate transmission capacity between them. Additionally, these projects could facilitate energy trading between areas that have a substantial electricity price differential. These projects also improve the reliability of the grid by connecting new generation sources, by adding new transmission, and through associated onshore upgrades. Building offshore grids could substantially reduce the net cost of offshore wind integration. In certain cases, economic savings from energy trading and congestion relief alone may be able to fund the build-out of an offshore network connection.

Policymakers have a role to play in promoting investment in offshore transmission grids. Establishing streamlined mechanisms for inter-jurisdictional permitting is essential, given that offshore grids are likely to cross state, ISO/RTO, and national boundaries. Offshore grids pose higher upfront costs and in some cases greater financial risk than simpler configurations. However, they can be built in multiple stages and have diverse sources of value—adding to the complexity of project financing, but opening these grids up to the possibility of broad cost allocation to region ratepayers. Developing efficient, flexible, and equitable cost-sharing mechanisms can help transmission and generation developers to navigate these financing challenges.

Policy Focus 3: Promote Offshore Wind Zone Planning

Designating offshore wind energy resources zones can target grid investments to accommodate offshore wind, thereby cracking the chicken-egg dilemma discussed previously and reducing development risks. The designation process affords the opportunity to integrate multiple criteria in site selection (e.g. wind resource quality, grid capacity, future load, transmission expansion cost, public receptiveness, environmental impact and others). Several European countries have employed this approach to encourage and coordinate offshore wind development. This policy is also proving to be successful for onshore wind in Michigan, where transmission planning for targeted zones is accelerated by expedited permitting for grid improvements. The designation process would give a pro-active role to regulators and wind energy stakeholders as specific offshore areas for development are designated, rather than relying on traditionally reactive permitting processes. This may help to ensure optimal development in locations that are consistent with the public trust doctrine. A collaborative process, similar to the one envisioned in Figure 4, can be employed to ensure that the concerns of all stakeholders are addressed. Wind zones also have the benefit of clustering wind facilities in a few areas, leaving more of the Great Lakes viewshed unaffected. The close proximity of wind facilities in wind zones also enables multiple developers to share core infrastructure like offshore substations and connections to the onshore grid.

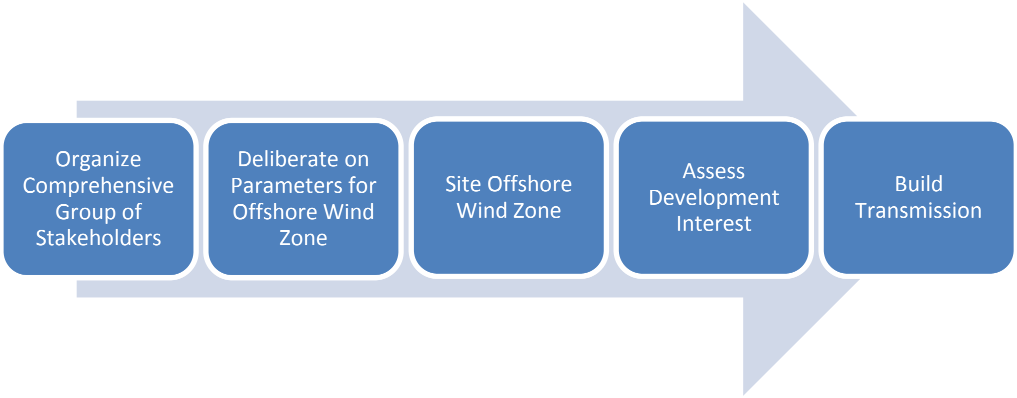


Figure 4: Flow chart of High-Level Steps for the Offshore Wind Zone Collaborative Process

Policy Options at a Glance

The matrix below summarizes at a broad level the benefits of three policies at focus in this report.

Benefit	(1) Unused Grid Reservations	(2) Offshore Grids	(3) Wind Zone Planning
Low Upfront Financial Investment	✓ ✓ ✓	--	✓
Reduced Long-term Economic Costs	✓ ✓ ✓	✓ ✓	✓ ✓
Expedited Planning/ Permitting	✓ ✓	--	✓ ✓ ✓
Multiple Economic Value	--	✓ ✓	--
Reduced Overall Offshore Transmission Footprint	--	✓ ✓	✓ ✓
Reduced Overall Onshore Transmission Footprint	✓ ✓ ✓	✓	✓
Reduced Overall Viewshed Impacts	--	✓	✓ ✓

Conclusions

Transmission is often an afterthought in renewable energy development. Yet, without adequate transmission to deliver power to load centers, projects that are viable based on every other criterion cannot be built. In the Great Lakes, transmission is likely to constrain offshore wind development, as it has in Europe. Because transmission takes longer to plan, permit, and build than wind facilities, inadequate transmission means that offshore wind development will likely slow and developers may have to site in suboptimal locations. Strategic transmission planning can actually drive offshore wind siting decisions to encourage development in ideal locations, based not only on project economics, but also on social and environmental criteria.

Region-wide collaboration in the Great Lakes basin and strategic transmission policy can help to relieve the transmission constraint while satisfying a broad array of policy objectives. There is enormous wind potential in the Great Lakes that could provide the region with a significant percentage of its power from this clean and renewable source. The three policy options analyzed in detail in this report can contribute to the advancement of offshore wind in the Great Lakes and the transmission needed to deliver it, while minimizing costs and environmental and social impacts. Because transmission constraints can have a real impact on offshore wind siting decisions, transmission planning can serve as a powerful leverage point to incorporate multiple objectives in future offshore wind development decisions.

Contents

INTRODUCTION

This report is an exploration of the role of transmission as a limiting factor for offshore wind development in the Great Lakes. First, transmission issues are framed within the larger set of challenges facing offshore wind, including cost, siting, and regulatory hurdles. Then the complexity of the "transmission constraint" is discussed, as well as the opportunity it presents for a strategic, collaborative transmission planning process. This process is envisioned as the appropriate mechanism for answering the overarching research question: How do we plan transmission in a way that leverages the economic, social, and environmental benefits of offshore wind while minimizing its impacts? A long-term, strategic planning process would seek to minimize regulatory hurdles, aggregate viewshed impacts, habitat disturbance, public discontent, and the cost of offshore wind energy. The driving tenet of this report is that the offshore wind industry may struggle to achieve some of these goals without comprehensive transmission planning.

General principles are proposed to guide transmission planning for offshore wind in the Great Lakes in this light, and the remainder of the report is dedicated to an in-depth exploration of three policy and development options that are consistent with these economic, environmental, and social principles.

Why Offshore Wind in the Great Lakes?

No offshore wind projects have yet been built in the United States or Canada, although many are in the planning and permitting phase. Offshore wind power is about twice as expensive as onshore wind power, ($0.11-0.40/kWh[ii], and $0.05-0.08/kWh respectively[1]), despite substantial advances in offshore technology over the last 20 years, including cost reductions.[2] However, offshore wind has several advantages over onshore wind that make it attractive for the Great Lakes region. This section describes those advantages.

[ii] Depending on capital cost estimates and discount rates.

High Quality Offshore Wind Resource in the Great Lakes Region

The Great Lakes are home to a significant wind resource. The wind blows at higher speeds and more consistently over water than over land. A wind resource map of the Great Lakes basin is shown below in Figure 5.

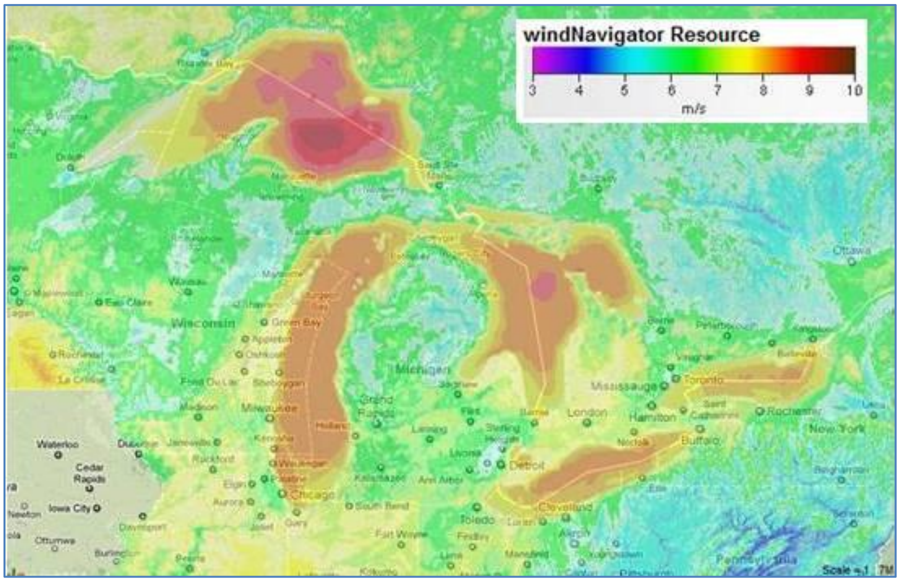


Figure 5: Average Wind Speeds in the Great Lakes Region at a 80 meters height. This shows that wind resources are substantially more robust offshore than onshore throughout the region.[3]

Stronger wind speeds are highly attractive for energy production due to the fundamental properties of fluid dynamics. The simplified theoretical equation for a wind turbine power production is as follows[4]:

$$P = \tfrac{1}{2}\rho\pi r^2 V^3 \qquad \text{(Eq. 1)}$$

P = power in wind,

ρ = density of air

r = blade length,

πr^2 = swept area of turbine blades

V = wind velocity

Note that the power is proportional to the cube of the wind speed. Thus, deploying a wind farm in an area with higher wind speeds dramatically increases the power output.

In addition to characteristically stronger wind, the offshore environment presents other technical benefits that result in higher energy yield than could be achieved onshore. The Great Lakes provide large areas free from any structures, such as buildings and trees. The absence of structures provides two main benefits: 1) reduced air flow turbulence and 2) proportionally longer blades. The energy embodied in a uniform laminar flow (non-turbulent wind) can be more effectively captured by a turbine, based upon fluid dynamic principles. The lack of nearby structures also allows for turbines with proportionally longer blades than onshore models. On an open lake, the turbine blades can sweep closer to the surface due to the lack of potential impacts with neighboring structures. Longer turbine blades result in a larger cross section of wind area from which to capture energy and thus more power output (as shown in the Eq. 1 above).

Offshore Wind's Proximity to Load

Offshore wind is promising in the Great Lakes because of the close proximity of the resource to load. Population centers in the region are largely concentrated directly on the shoreline, as illustrated in Figure 6 below.

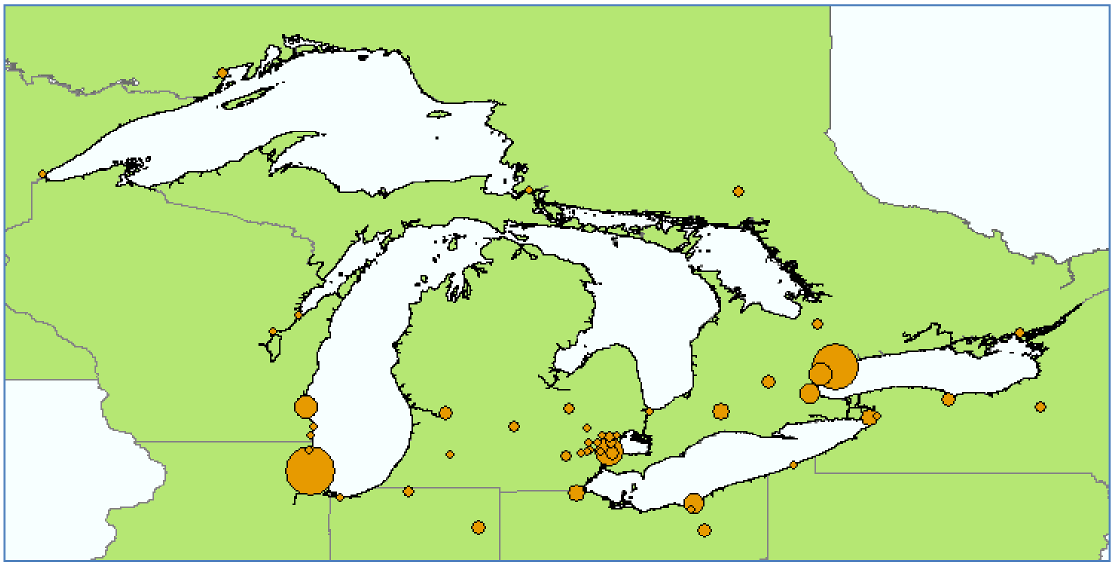


Figure 6: Load centers in the Great Lakes Region—Load centers in the Great Lakes region are typically near-shore, which can reduce transmission needs to integrate offshore wind because wind resources are generally robust throughout.[5]

Accessing onshore wind resources, which tend to be far away from load centers, requires the construction of new transmission lines. One grid expansion proposal is designed to transmit onshore wind power from the Dakotas, Minnesota, and Iowa to load centers in the western part of the Great Lakes basin. The “Green Power Express,” shown in Figure 7 below, includes roughly 3,000 miles of extra-high voltage (765 kV) transmission estimated to cost $10-12 billion.[6,7]

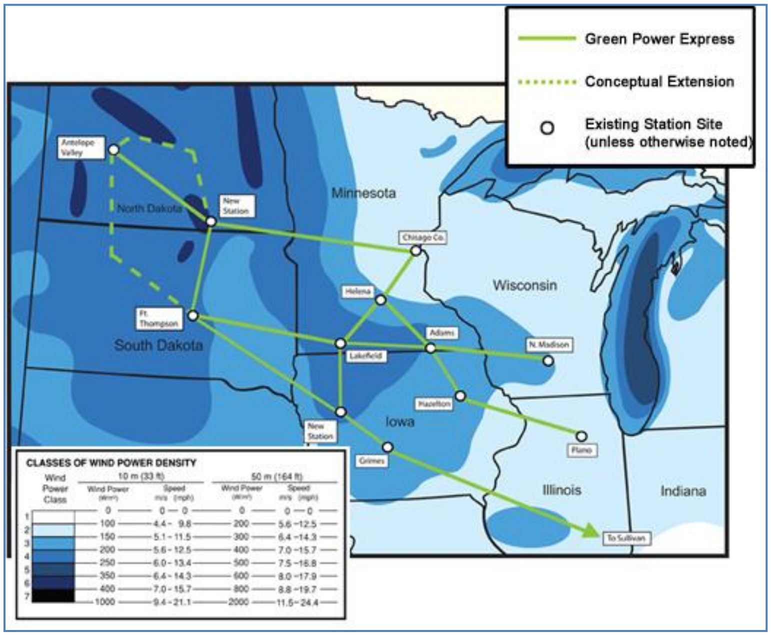


Figure 7: ITC’s Green Power Express. This transmission project proposal to bring wind energy from the Dakotas to load centers in the Midwest is expected to cost $10-12 billion. It exemplifies the significant transmission need posed by onshore wind development.[8]

On the other hand, accessing offshore wind resources may require only minor onshore grid upgrades. While widespread offshore wind development in the Great Lakes poses its own transmission challenges, massive onshore upgrades like the “Green Power Express” are unnecessary given close proximity to load of high-quality offshore wind resource.

Land Use Constraints of Onshore Wind as a Driver for Offshore Wind

A major driver of offshore wind in Europe is the shortage of available land for onshore wind development.[9] While the Great Lakes region typically has a much lower population density than European nations,[10] land use constraints may play a significant role in the future as onshore wind developers use up the best sites. Furthermore, far offshore wind facilities have the potential to minimize viewshed, noise, and environmental impacts relative to onshore wind facilities.

Projects can be sited beyond the horizon where they cannot be seen or heard, and where migratory birds are more likely to be at altitudes above turbine height.[11] Depth is a major constraint to far offshore development in the near-term (proven technology to date allows development only in waters less than 30 meters deep). Submarine transmission lines are also a constraint, as we discuss later in this report.

Great Lakes Wind Generation Potential in Area Less than 30 Meters Deep

If there were no economic, social, or environmental barriers to development (i.e., all Great Lakes bottomlands could be developed), the Great Lakes alone could produce more than 175 GW of power in the waters less than 30 meters deep.[12] If only a *third* of this water was used to site wind projects due to such constraints, these projects would meet NREL's entire projected offshore wind need under their '20% Wind by 2030' scenario for the entire United States.[13] As deepwater turbine foundations become economically viable, developers will be able to access typically stronger winds farther offshore, which would greatly expand this estimate.

Challenges Facing Offshore Wind

Cost Challenges

Perhaps the greatest barrier facing deployment of offshore wind in the Great Lakes and elsewhere is its present cost. Despite the advantages of a larger, more consistent wind resource and siting opportunities closer to load, the **levelized cost**[iii] of energy generated from offshore wind has typically been 2 times that of onshore wind[14]—although the Energy Information Administration projects that gap to decrease to 1.3 times in 2016. Further, onshore wind (5-8 cents/kWh) is more costly than traditional, non-renewable sources of energy like coal within the present market and legislative framework.[15] This price differential puts offshore wind at a considerable disadvantage, even under state/provincial or Federal incentives for renewable energy. This section offers an account of what makes offshore wind energy more costly than onshore and the potential for those costs to decrease over time. The section also discusses the potential for achieving economies of scale to reduce those costs in the short-term.

[iii] See Glossary for explanations of terminology in bold type face.

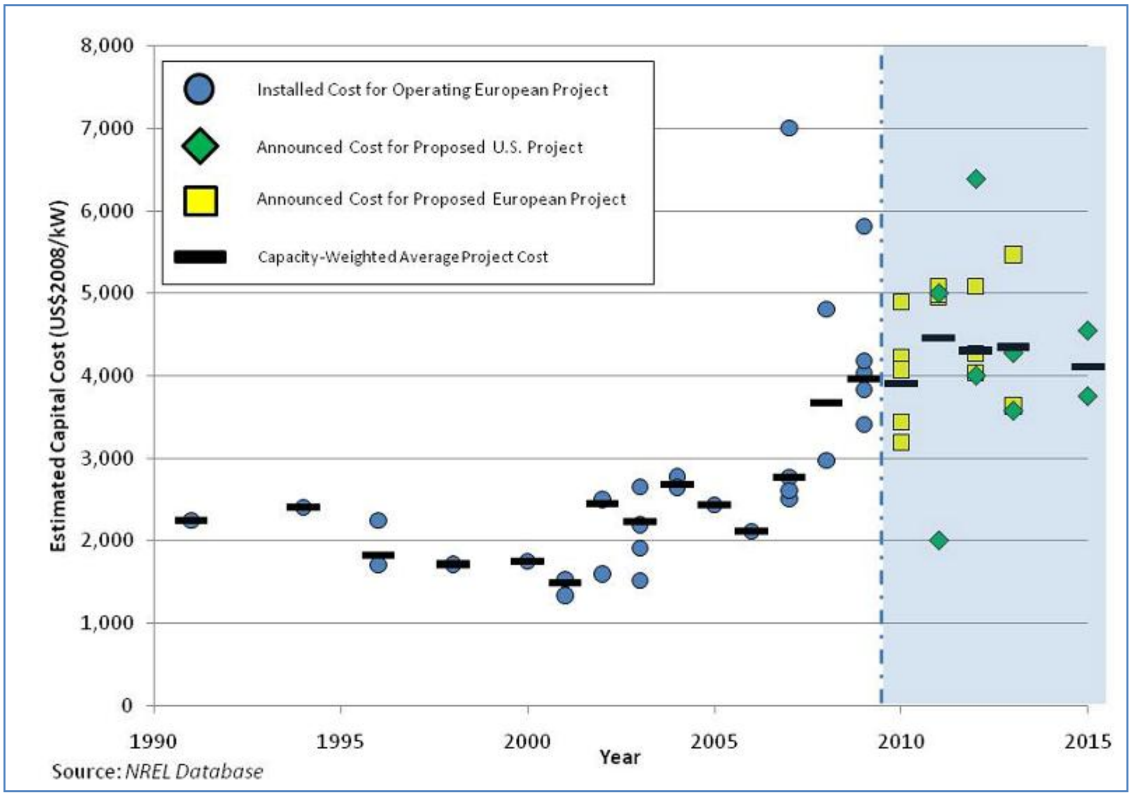
Comparative Analysis of Onshore and Offshore

Most of the cost differential between onshore and offshore wind is due to higher capital, operation, and maintenance costs. While onshore turbines cost roughly $2 million/MW, compared to $3 to 4 million/MW for larger offshore turbines,[16] turbines typically comprise less than half of capital costs for offshore wind—compared to nearly 70 percent of onshore costs.[17] The foundations and support structures needed for offshore turbines, the added expense of special underwater cables to electrical and grid infrastructure costs and the logistics of installation and operation and maintenance add considerable cost to an offshore project. These expenses together (base of station and operations and maintenance) represent the largest portion of costs for offshore projects (57-71 percent). Operations and maintenance costs, comprising roughly a quarter of the levelized cost of energy among offshore projects to date, exceed those of onshore projects two to three fold. [18] Additional technical and logistical challenges in the Great Lakes—such as the need for deepwater and ice-resistant foundations and the lack of supporting infrastructure like specialized installation vessels[19]—promise to further disadvantage wind projects offshore relative to those onshore.

Cost Reduction Curve

Experts expect offshore wind costs to decrease over time, although the full extent of that cost reduction potential is unknown. The International Energy Association predicts offshore wind will see a 38% cost reduction by 2050. Offshore wind technology is still young and has yet to take advantage of cost reductions from mass production and installation and other production and operational experience. The cost of onshore wind turbines has decreased by a factor of three since the 1980s.[20] Some of these learning curve effects for onshore wind are already reflected in offshore wind costs, given similarities between the two technologies. However, offshore wind poses several novel challenges as well. It is therefore reasonable to expect further cost declines as the industry becomes more adept at handling those challenges. Much of this learning curve is likely to be driven by European development—targeted at 150 GW by 2030.[21] Some of those benefits, however, are driven by the development of more robust manufacturing infrastructure and will therefore not translate for U.S. projects unless the industry grows domestically as well as in Europe.

In the short-term, cost reductions are less certain. In fact, over the past few years capital costs have *increased* by 56 percent (see Figure 8 below). NREL researchers attribute these cost increases to fluctuations in exchange rates, increased demand coupled with limited supply capacity, higher profit margins for manufacturers and developers, increased siting complexity and knowledge of technical risks, and higher material prices.[22] Despite these fluctuations, costs for offshore wind projects are expected to decline over the long-term.[23]



Source: *NREL Database*

Figure 8: Offshore Wind Project Capital Cost, 1990 to 2015 ($/KW). This figure shows how offshore wind project costs have increased recently and are expected to continue increasing in the near-term. NREL researchers attribute these cost increases to fluctuation. [24]

Economies of Scale for Large Projects

In the near-term, offshore wind projects can lower costs by achieving economies of scale. The potential for economies of scale in the offshore wind industry is presently unknown. NREL researchers were unable to find any evidence of cost reductions per kWh among larger offshore facilities in operation to date, likely attributable to a small sample size and a lack of consistent data. However, despite the present lack of empirical evidence, it remains clear that spreading costs for permitting activities, installation and maintenance vessels, grid connection, and other upfront expenditures over a larger generating capacity would result in a lower cost per kWh.[25] Larger projects may also benefit from decreasing marginal costs of infrastructural components like transmission cables, which are cheaper per unit energy delivered as capacity increases.[26]

Viewshed and Environmental Siting Challenges

Challenges facing offshore wind in the Great Lakes are compounded by a number of siting challenges—and the political tensions they engender among actors in the political landscape. While there is a long list of siting considerations for offshore wind projects,[27] perhaps the greatest siting challenges involve viewshed and environmental impacts. Project developers can plan around other siting constraints like shipping lanes or military zones with ease. More difficult is avoiding sites with significant environmental impacts or little local receptivity, given the uncertainty of these criteria for developers early in the planning phase, especially for the latter. This section briefly describes the potential for viewshed and environmental impacts when siting offshore wind facilities and discusses the political ramifications for project developers.

Impacts of Offshore Wind on the Viewshed

Offshore wind poses unique viewshed challenges—and solutions. Offshore wind turbines are larger and often higher than typical onshore turbines (max height 90-120 meters[28]), which are limited by the size of land-based transportation services, and are completely isolated on the horizon (i.e., there are no trees or mountains to block to the view). As a result, they affect a larger viewshed than onshore turbines. Perhaps more importantly, many people expect an unobstructed view when they look out over the water. The view over the lakes plays an important role in local and regional pride and identity. It also lures tourists and cottagers back to lakeside communities every year, serving an important role in lakeside economies. Consequently, local residents may perceive greater stakes in an offshore wind project proposal than an onshore project. However, the offshore wind industry can potentially deliver the ultimate solution to viewshed impacts by siting projects far enough offshore that they cannot be seen from land. We will discuss that potential and the technical and economic challenges it poses later in this report.

The impact of a wind farm on the viewshed itself is clear. Simulations can be generated to illustrate what a proposed project would look like at various distances on the horizon. Less clear for local residents is the impact of viewshed changes on lakeside tourism, property values, and general quality of life. Research to date, most notably a study by the Berkeley Renewable Energy Laboratory, has found no or minimal impact of wind facilities on property values.[29] A study by the Rhode Island Coastal Resources Management Council concluded that negative impacts on tourism would likely be minimal or temporary.[30] A University of Delaware study found that roughly a quarter of out-of-state tourists would avoid a beach with a wind installation within 10km (about 6 miles).[31] On the other hand, the same study found that over 65 percent were likely to visit a beach in order to see an offshore wind farm and over 44 percent would pay to take a boat tour of the facility. Also, reported beach avoidance declined for wind facilities farther from shore.[32]

Political Implications of Viewsheds Affected by Offshore Wind Projects

While the aforementioned preliminary findings should be reassuring for both wind developers and local residents in communities with proposed wind projects, concerned local residents may struggle to be at ease given the infancy of this research and the value of the coastal resource to their communities. This may be compounded by the pervasiveness of misinformation in the public sphere regarding the impacts of wind generation facilities.[33] Meanwhile, other local residents may welcome renewable energy development for its economic and environmental benefits and any compensation that coincides with offshore wind development.

These tensions played out in Ludington, MI, where Scandia Wind proposed a 1,000 MW offshore wind project planned to occupy a 100 square mile stretch within 3.7 miles of shore.[34] Scandia ultimately withdrew its proposal in the face of unrelenting vocal opposition among local residents. Much of the opposition stemmed from viewshed concerns.[35] Local tensions are also apparent in the Great Lakes and St. Lawrence Cities Initiative—an organization of coastal mayors. The organization has thus far failed to reach a consensus position on offshore wind, in part due to the extent of division among and between communities and the high stakes involved.[36] The Great Lakes Commission is undertaking a study to more fully understand what drives public perceptions of offshore wind in lakeside communities. In the meantime, experiences like Scandia Wind's in Ludington are a testament to the importance of viewshed impacts to local residents, and the importance to developers of local receptiveness.

Local communities in most states/provinces do not have zoning authority over development in the lakes, although that may change (for example, House Bill 6564 in the Michigan legislature would prohibit wind projects within 3 miles of shore and give local communities zoning authority over wind projects proposed within 6 miles of shore, and state agencies authority for any projects further than 6 miles from shore[37]). Nonetheless, local receptiveness (in particular, the absence of a network of opposition) is an important political and legal ingredient for a successful project—a theme echoed not only in the Ludington experience but also a more systematic examination of case studies from Europe.[38] Unease about tourism and property value impacts—as well as the subjective and personal measures of aesthetic beauty and quality of life—pose significant challenges to prospective developers. Rigorous consultation and education measures by developers and state-level officials and experience from early projects may help to alleviate some of this unease.

Impacts of Offshore Wind on the Environment

Offshore wind can be a win for the environment in terms of improved air and water quality and abated greenhouse gas emissions. However, poorly sited offshore wind facilities can pose a number of environmental risks. Wind turbines, like sky scrapers and housecats, can be deadly obstacles for migrating birds. Turbines can also cause avoidance behavior in migratory birds.[39] They are also known to be a cause of mortality for bat populations, which are already facing stressors like white-nose syndrome.[40]

Installation of foundations and cables can temporarily suspend soil sediments—and, in some cases, soil contaminants—in the water column, stressing local aquatic life.[41] The cable connection to shore can affect more sensitive coastal habitats like dunes, wetlands, and near-shore aquatic life.[42] To the extent that connecting an offshore facility to the grid requires expanded onshore transmission infrastructure, these projects can have impacts in the form of habitat disruption as well. Finally, turbines, offshore substations, transmission cables, and installation and maintenance vessels contain fluid pollutants that may be leaked accidentally during construction, operation and maintenance, and deconstruction.[43]

Despite these risks, experience to date with offshore wind facilities has shown minimal environmental harm.[44] Many of these impacts can be avoided or minimized by siting offshore projects away from known migratory bird pathways and locations of batactivity, testing for soil contamination and installing components in times of low current, and taking precautions to mitigate risks of accident. However, some level of localized impact is bound to persist.

Political Implications of Environmental Impacts of Offshore Wind

Unlike viewshed concerns, which tend to mobilize previously unorganized interests, environmental concerns are likely to mobilize existing environmental organizations. These organizations have diverse core missions, ranging from wildlife and habitat protection to public health—and at different scales (local, regional, or national). These distinctions are important for understanding potential conflict around environmental concerns, as they affect how various environmental organizations are likely to respond to offshore wind proposals.

Organizations like Ducks Unlimited, for example, may hold duck habitat preservation as a more central element of their core mission than regional public health or global climate change. Consequently, given its limited resources, Ducks Unlimited is more likely to devote resources to opposing projects that pose risks to waterfowl populations than they are to supporting projects that do not.[45] Local environmental groups dedicated to the preservation of bird or bat species locally will be even more inclined to oppose offshore wind proposals despite their regional and global environmental benefits in reducing greenhouse gas emissions and promoting energy independence. In contrast, organizations like the Sierra Club, for whom coal-fired electricity generation is a central, mobilizing concern, are more likely to actively support the advancement of offshore wind.[46]

The uncertainty in the project approval phase regarding localized environmental impacts enlarges the window for conflict from the environmental community. Some of the local impacts may not be well understood for a specific project area until after construction. Even where those impacts are understood, various stakeholders (including those within the environmental community itself) may differ in what they consider to be “acceptable” impacts. How much weight should be given to the costs relative to the benefits will be an inevitable point of contention. As with viewshed-based conflict, opposition from environmental groups can delay a project and increase costs for a developer, but also ensure that projects are sited where local environmental impacts are minimal—thereby maximizing the net environmental benefits of offshore wind development. Ongoing research to better understand impacts and to better design components to mitigate those impacts will help to alleviate these sources of political conflict. In the meantime, including environmental organizations in collaborative decision-making efforts can mitigate much of this conflict while ensuring that impacts are minimized.

Permitting Challenges

Another major challenge facing offshore wind in the Great Lakes is the complexity of the regulatory framework for state/provincial and Federal permitting. This section describes that framework in broad detail and the challenges it poses for offshore wind development. The section also includes an overview of the efforts by regulators to resolve some of those challenges.

Description of the Permitting Process for Offshore Wind

In the U.S., siting the wind project itself requires permits from the U.S. Army Corps of Engineers (USACE) under Section 10 of the Rivers and Harbors Act and Sections 401 and 404 of the Clean Water Act. In Canada, the equivalent of USACE is the Ministry of Transportation, which operates under the Navigable Waters Protection Act. The Federal review often requires input from a network of other Federal agencies, including the US Fish and Wildlife Service (USFWS), the US Environmental Protection Agency (USEPA), the US Coast Guard, and the Federal Aviation Administration—or, in Canada, the Ministry of Fisheries and Oceans and the Ministry of Environment. Federal permitting actions will require environmental impact statements under the National Environmental Policy Act (NEPA) in the US, or the Canadian Environmental Assessment Act (CEEA) on the Canadian side.[47]

Under the Submerged Lands Act, the bottomlands of the Great Lakes are held in trust by the states for the people under the Public Trust Doctrine. Submerged lands are similarly held by the province of Ontario, although there is no equivalent to the Public Trust Doctrine in statute or judicial precedent in Canada. Accordingly, siting permits must also be obtained from state/provincial environmental or natural resource agencies.[48]

More permits and studies are required for grid interconnection. For grid interconnection in MISO for example, generators first submit an interconnection request to MISO, which costs between

$10,000 and $120,000 depending on the size of the generator.[49] Then a feasibility test determines if system upgrades are minimal, which means the project can skip the system planning and analysis phase. If the project passes either of the previous phases it then must go through the definitive planning phase, which requests a security deposit depending on the size of the project, to essentially test the financial feasibility of the project. Larger generators will need to apply through the FERC "Pro Forma" process as well, which includes an interconnection request ($10,000), a feasibility study ($10,000), a system impact study ($50,000), a facilities study ($100,000), and finally a generator agreement. Further, any rate increases need to be approved by the state PUCs via the utility.[50]

Implications of Permitting Process on the Development of Offshore Wind

This is a multi-step process involving multiple regulatory bodies at the state/provincial, regional, and federal levels. The process requires significant coordination between and among a long list of public agencies on the one hand, and project developers on the other. Furthermore, the permitting process requires substantial work be done by developers to study potential impacts of their proposal. Given the infancy of offshore wind in the Great Lakes, the permitting process is as-of-yet untested from start to finish by an actual project. In fact, many states still lack enabling legislation to permit an offshore wind facility. Nor are states or even federal agencies able to prescribe a firm, specific list of studies to be conducted or criteria to be used in permitting decisions. Ontario has awarded feed-in tariff contracts ($0.19/kWh) for offshore wind projects in the Great Lakes, and has made efforts to streamline the permitting process, [51] but recently suspended the contracts stating freshwater technical concerns.[52]

In all, the permitting process is expected to add years to the project planning phase and considerable uncertainty for developers. This, in turn, can impact a developer's ability to obtain project financing. In one particularly infamous example from the east coast, a permit to construct a meteorological tower in the Atlantic was held up by environmental agency staff because the developer failed to provide estimates of the expected emissions of the installation vessel (for the eight day project). The developer was unable to provide the data because it did not yet know which vessel it would use for the project.[53] In the minds of some developers, resolving these regulatory hurdles is paramount to the future of offshore wind in the Great Lakes.[54]

Onshore-Offshore Comparison of the Permitting Process

Regulatory challenges are arguably greater for wind power offshore than onshore, primarily because the framework is untested and unrefined—or in some cases, does not yet exist. Offshore wind siting poses a different set of environmental concerns, and corresponding permitting guidelines are still being developed. Additionally, the Public Trust Doctrine in the U.S. provides legal standing to ordinary citizens to challenge offshore wind permitting decisions. This type of challenge can bog down the regulatory process itself and threaten wind projects even after necessary permits have been granted.

Current Improvement of the Permitting Process

Regulators across the basin are working to establish clear, detailed requirements for developers, drawing on the groundwork laid by the former Minerals Management Service (MMS) for siting on the outer continental shelf. In Michigan, the legislature is considering a bill that would establish such requirements, based in part on the work of the Michigan Great Lakes Offshore Wind Council (GLOW)—which included state regulators, offshore wind developers, environmental groups, and public representatives.[55] State regulators are also working to harmonize their requirements—to the extent possible—with Federal permitting processes. The latest manifestation of that effort was a Chicago workshop co-hosted by the Council on Environmental Quality (CEQ), US Department of Energy (USDOE), and the Great Lakes Wind Collaborative, which brought together over 100 people from Federal agencies, state government, energy companies, state public service commissions, wind developers and manufacturers, non-profit organizations and other industry experts.[56] According to the Ohio Department of Natural Resources Director, Sean Logan, “private investors will jump through hoops so long as, at a minimum, those hoops are legitimate, do not move, are not on fire, and they know what’s on the other side”.[57]

Inadequate Policy Incentives as a Challenge

Given the current weak demand for electricity generation[iv] and the high cost of offshore wind in the short-term, offshore wind developers will struggle to obtain power purchase agreements without adequate policy incentives.

[iv] See “Electricity Demand in the Great Lakes Region” Text Box for information about changes in electricity demand during the recent recession.

Electricity Demand in the Great Lakes Region

Electricity demand in the Great Lakes region fell with the recession. Figure 6 below shows the electricity generation before the recession in 2007 and the electricity generation in 2009 for the Great Lakes States individually, the aggregated Great Lakes States, and total United States. It should be noted that the eight Great Lakes States account for approximately 25% of the U.S. electric power industry. Thus, regional offshore wind resources have great potential to affect the national electricity portfolio.

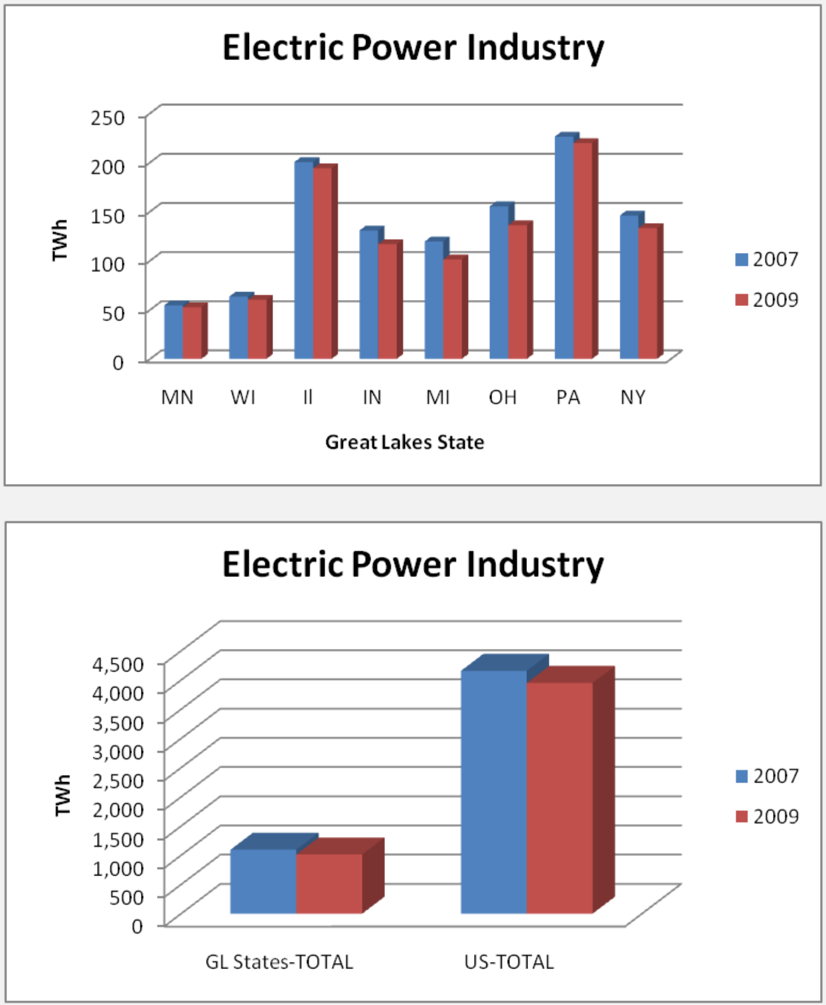


Figure 9: Electric Power Industry in 2007 Compared to 2009—This shows how demand decreased during the economic recession. Source: EIA.

Table 1 displays the percent decrease in electricity during the recession years. The national average was approximately a 5% decrease; however the Great Lakes Region experienced on average a 7.5% decrease, with Indiana, Michigan, and Ohio experiencing a greater than 10% decrease in electricity generation. While a portion of the decrease can be attributed to energy efficiency programs, much of the decrease is related to the economic downturn. Consequently, the Basin has sufficient generation capability to meet current demand.

Current Great Lakes Region RPS Goals

A Renewable Portfolio Standard (RPS) mandates that utilities meet a specified percentage of their electricity portfolio with renewable sources, a portion of which can be met with energy efficiency technologies. Currently, 32 states and the District of Columbia have adopted an RPS.[58] Motivation for enacting an RPS is diverse. For example, states may desire to reduce fossil fuel use, improve air quality, diversify electricity mix, create green jobs or encourage technology development. Structures, conditions, timetables and eligible renewable resources vary significantly between states' RPSs. Additionally, some RPS legislation credits pre-existing renewable generation while others range from crediting renewable projects have are in pre-construction stages to only crediting projects for which the planning process has yet to begin.

In the Great Lakes basin, every state except Indiana has some form of an RPS in place and Ontario has an aggressive feed-in tariff program (shown in Table 1). See Appendix A: Renewable Portfolio Standards (RPS) - Descriptions by State) for detailed description of RPS standards in the Great Lakes region. The renewable electricity targets are non-uniform within the Great Lakes Region. Minnesota and Illinois are the only states that promote wind specific mandates in their RPS.

Table 1: Great Lakes States RPS Goals Compared to 2008 Generation Data. This table shows how most states in the Great Lakes basin will need to substantial increase renewable generation to meet their RPS goals.

State	**RPS Goal**	**2008 Total Generation**	**2008 Renewable Generation**	**2008 % Renewable Generation**
		thousand MWh	thousand MWh	%
MN	30% by 2025	54,763	6,578	12.0
WI	10% by 2015	63,480	3,370	5.3
IL	25% by 2025	199,475	3,174	1.6
IN	NONE	129,510	948	0.7
MI	10% by 2015	114,990	3,956	3.4

OH	12.5% by 2014	153,412	1,010	0.7
PA	10% by 2020	222,350	5,353	2.4
NY	25% by 2013	140,322	30,042	21.4
Total GL	N/A	1,078,302	54,431	5.0
Total U.S.	NONE	4,119,388	381,044	9.3

Effect of Energy Efficiency on RPS Goals

It should be noted that RPS legislation often includes energy conservation measures, such as energy efficiency resource standards (EERS). Such requirements would actually decrease the gap between existing and target renewable electricity. Such trends can be included in forecasting models, so as to accurately design future RPS mandates and corresponding renewable electricity generation growth. For example, the Wisconsin Public Service Commission Task Force estimated that the electricity sales in 2025 would be 106,000,000 MWh if no new energy conversation policies are adopted and 85,000,000 MWh if recommended policies are adopted.[59] Here, energy efficiency measures contribute a 20% reduction in forecasted electricity demand. Figure 10 visually displays the magnitude of influence of RPS with EERS can have on the electricity demand. Energy efficiency legislation will undoubtedly reduce the required offshore wind development, even with growing economies.

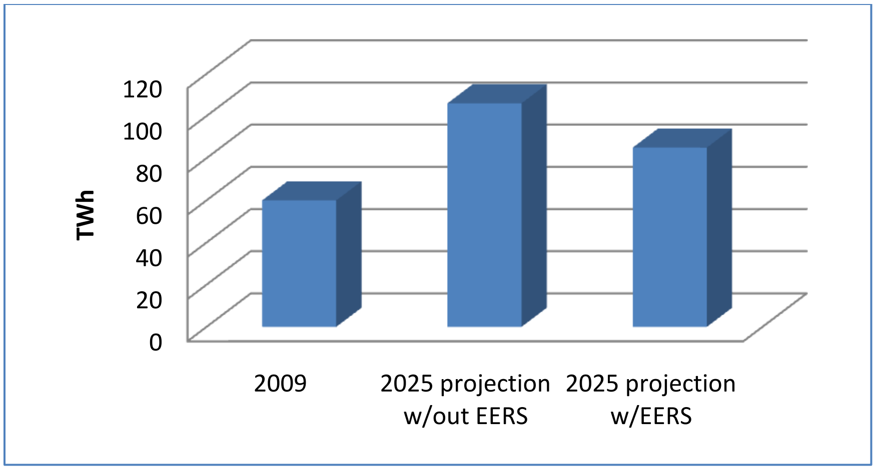


Figure 10: Effect of EERS on Electricity Demand for Wisconsin. This figure shows how energy efficiency resource standards can substantially reduce energy demand.[60]

Additionally, RPS policies promote more robust EERS programs. If renewable energy is relatively expensive when compared to conventional energy, increasing the RPS target raises the cost-effective level of energy-efficiency investment.[61] It can be expected that as RPSs are inevitably strengthened, a greater relative reduction in electricity demand will result.

Great Lakes Region RPS Goals and Offshore Wind Development

Berkley Labs estimates that from 2001 to 2007, roughly 65% of the total wind additions in the U.S. were motivated, at least in part, by state RPS policies.[62] As summarized above, the Great Lakes region depends upon wind power to fulfill a significant portion of renewable electricity requirements. However, there is great opportunity for offshore development to contribute to RPS and FIT goals (See Table 2 below for offshore wind power potential in the Great Lakes).

Table 2: Offshore Wind Potential in the Great Lakes at Various Depths with Various Shoreline Buffers. This analysis shows that the Great Lakes have substantial offshore wind power potential. [63]

	Wind Farm Nameplate "Peak" Power Based on Depth and Shoreline Buffer (GW)*											
	<30m			30-60m			60-90m			Total		
	No buffer	6 mi buffer	15 mi buffer	No buffer	6 mi buffer	15 mi buffer	No buffer	6 mi buffer	15 mi buffer	No buffer	6 mi buffer	15 mi buffer
Lake Erie	66.4	36.7	15.0	4.9	3.9	0.3	0.1	0.1	0.0	71.4	40.8	15.3
Lake Huron	63.1	11.9	0.2	45.9	31.6	14.1	34.0	31.1	20.2	143.0	74.6	34.5
Lake Michigan	45.5	7.3	0.1	22.8	13.6	2.1	28.9	26.7	18.2	97.3	47.6	20.3
Lake Superior	22.5	0.9	0.1	17.5	3.7	0.2	16.4	7.0	0.7	56.5	11.7	1.1
Lake Ontario	13.4	1.1	0.0	7.6	2.3	0.0	7.9	5.5	0.1	28.9	8.9	0.1
Total	210.9	58.1	15.4	98.7	55.1	16.7	87.4	70.4	39.2	397.1	183.5	71.3

*This table uses 10 MW/mi^2 to convert area to power potential.

Problems with Current Patchwork of RPSs

Figure 11 below illustrates how RPSs in the Great Lakes region are proposed to increase over time. For the purpose of comparison, each RPS is normalized based on the percentage of state electricity sales to which it is applicable. It should be noted that some states include existing renewable generation facilities and others refer to only new facilities.

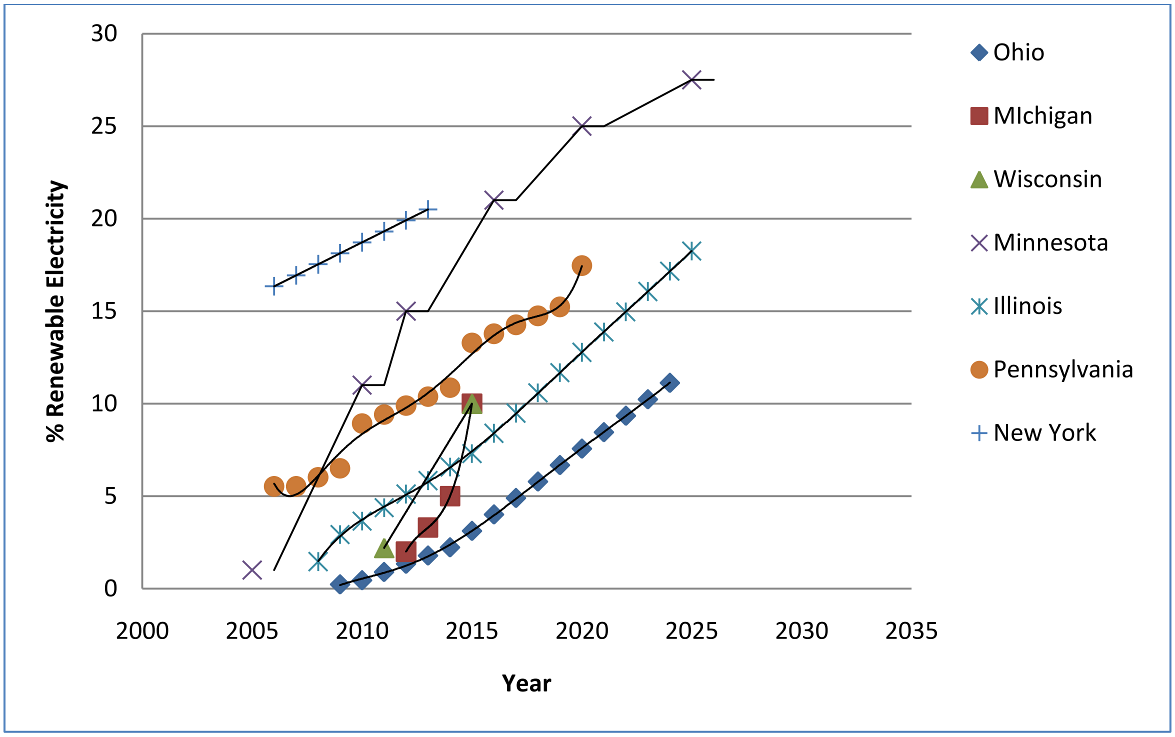


Figure 11: Comparison of Normalized RPS over time for Great Lakes States. This chart exemplifies the patchwork of regulatory frameworks throughout the Great Lakes region.[64]

The patchwork of RPSs in the Great Lakes Region results in lost opportunity in terms of offshore wind development. Unfortunately, since onshore wind is cheaper and still accessible regionally, state RPS's have not spurred development offshore. Michigan, for example, will meet 80-85 percent of its RPS with onshore wind alone.[65] Developers and investors need a reliable and clear policy signal to promote renewable electricity generation development. Governments could aim to correct market distortions made by this patchwork of state RPS with goals of introducing some uniformity and predictability in the renewable energy market while helping to diversify the nation's electricity fuel mix, and reducing fossil fuel imports to the region.[66] The nature of offshore wind development in the Great Lakes requires that states and provinces will need to cooperate in order to promote such economic, technological, and political benefits.

Policies to Promote Offshore Wind in the Great Lakes

A Federal RPS

According to one developer, "Onshore wind is driven by state RPS's. Offshore is driven by the bet that there will be a Federal RPS."[67] A Federal RPS would impose a minimum RPS on all states. In June 2009, the U.S. House of Representatives approved legislation that included a 20 percent minimum standard for renewable electricity generation nationally by 2020. In July 2009, the Senate Energy and Natural Resources Committee produced a bill that would set a goal of 15% renewable electricity generation by 2020.[68] Some Great Lakes States, like New York and Minnesota have enacted RPS's that are stronger than this potential national mandate. For the other six states this national RPS would augment existing state legislation. However, a Federal RPS would increase the potential for offshore wind development not necessarily because it would increase the portfolio requirement for renewable energy in Great Lakes states, but because states without access to renewable energy sources—particularly those in the southeast—may need to purchase renewable energy from generators in other states.

Long-Term Financial Incentives

Growth in onshore wind development is expected to flatten out around 2015 when Production Tax Credits (PTCs) expire and when projects funded by the American Recovery and Reinvestment Act (ARRA) are completed.[69] In the past decade, the wind development and the expiration of PTCs have been correlated (see **Error! Reference source not found.** below). Similar to the problems with a patchwork of RPSs in the region, developers and investors need a clear and predictable price signals.

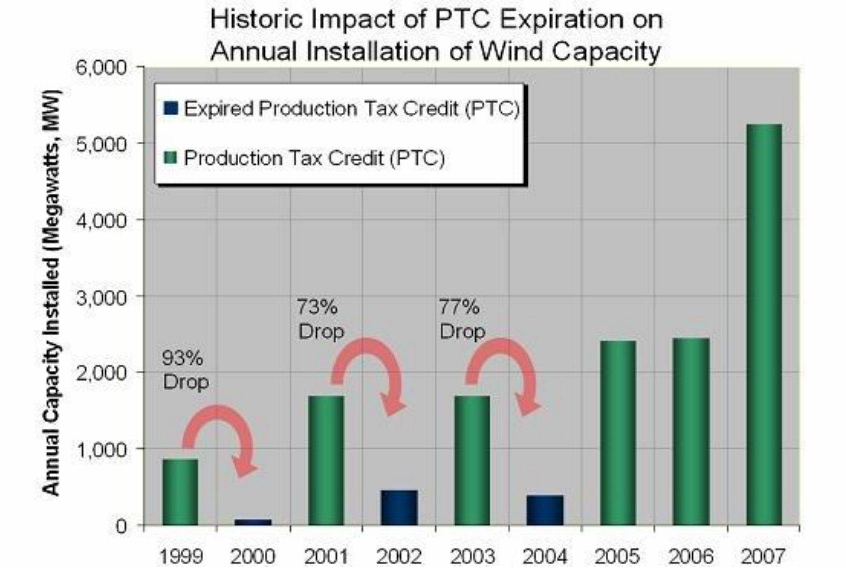


Figure 12: Historic Impact of PTC Expiration on Annual Installation of Wind Capacity. This figure shows how regulatory incentives drive the renewable industry. [70]

Consumer Green Power Option

Many utilities are now offering consumers the option to pay a premium on their energy bills to support the development of renewable electricity generation development. This has both an immediate and persistent impact on the renewable share of capacity in a state.[71] For example; New York's RPS projects that 1% of the renewable generation will be supported by the green power option. Policies to require electric providers to offer the green power option can play a substantial role in developing high cost offshore wind development in the Great Lakes.

Carbon Price

Development incentives may also be obtained through policy mechanisms that put a price on carbon emissions, such as a cap and trade scheme or a tax on carbon. A price on carbon would make renewable energy technologies, like wind and solar, more competitive with those reliant on carbon intensive fossil fuels, like coal and natural gas. The exact price per ton of carbon emissions that would efficiently incentivize the "right" amount of renewable energy is difficult to determine. To resolve this issue, recent legislation proposed in congress, if passed, would start with a low price and then increase price, with advance notice, until the desired outcomes were realized.

PART 1: THE TRANSMISSION CONSTRAINT

WILL TRANSMISSION CONSTRAINTS LIMIT OFFSHORE WIND DEVELOPMENT IN THE GREAT LAKES?

Overview

Capacity and location of existing transmission infrastructure have emerged as major limiting factors for wind power development *on land,* where the most productive wind resources tend to be situated significant distances from load centers.[72] Transmission needed to get power to load often either does not exist, or is already being utilized near its rated capacity.[v] Where transmission capacity is limited, the costs of necessary system upgrades can be prohibitive unless broadly allocated to electricity consumers regionally ("socialized"). Even where upgrade costs are socialized, new transmission is likely to be constructed only when a system benefit, such as accommodating new power generation, is sufficient to justify the costs.[73]

The transmission outlook for offshore wind in the Great Lakes encounters additional complexities. Depending on the location and scale of development, offshore wind in the Great Lakes may face varying degrees of transmission challenges. Such challenges include the need for extensive new submarine transmission installations, limited onshore injection points,[vi] or inadequate onshore transmission to reliably move the generated power to load. **Near-shore**[vii] projects sited close to load centers and injection points with sufficient **headroom** are unlikely to face substantial transmission constraints. On the other hand, transmission may be a limiting factor for projects sited farther away from load centers and robust injection points, or far-offshore. Finally, even if projects are located close to load centers, costly transmission upgrades

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[v] Transmission capacity may be actually utilized by existing generators or reserved to be utilized by those generators.

[vi] Locations where the facility's output can be fed into the power system without causing electrical disruptions.

[vii] "Near-shore" is defined for the purposes of this report in terms of cost, rather than distance. A number of factors affect the cost of submarine cable—most notably length, but also type of cable used, voltage, depth, ambient water temperature, cost of installation and maintenance, and others (which will be discussed in a later section of this report). "Near shore" is defined as within a short enough distance to shore that, given the other factors affecting cost, the capital costs for the transmission connection to shore do not represent more than 10 percent of total project costs. Depending on the project size and the other factors mentioned above, "near-shore" could be as close as 3 miles for small projects, or as far as 15 miles for larger projects.

may be necessary if the infrastructure serving those areas is not able to accommodate the additional power and maintain grid reliability. These infrastructural issues are discussed later in this section.

Part 1 describes the factors affecting the transmission required to support offshore wind in the Great Lakes including proximity to load, available injection points, onshore transmission capacity, and scale of development. Experiences from Europe are used to illustrate transmission constraints in practice where offshore wind projects are currently being operated and developed. Part I then attempts to anticipate constraints posed by *existing* infrastructure in the Great Lakes at a broad level, through a preliminary analysis of offshore wind development potential in areas that meet "low probability of transmission-constraints" criteria laid out in this section. This "minimal constraint" integration potential is quantified and juxtaposed with a potential "high growth" scenario for the offshore wind industry in the Great Lakes. This analysis is intended to describe the factors affecting transmission constraints and to broadly characterize the extent to which developers in the Great Lakes may encounter those constraints.

The European Experience

Offshore wind development in Europe faces typical transmission constraints, with some exceptions. In the early stage of the industry's development, relatively small offshore wind projects were connected to distribution systems and treated as "**negative loads"**, rather than being connected to the transmission system in the same way as a major generator.[74] However, as larger projects were connected to the transmission system, this change "led to increased costs for grid reinforcement, constraints on operation, and additional administrative burdens."[75]

Transmission Grid vs. Distribution Grid

The "transmission" grid includes the high-voltage lines used to transport large volumes of energy long distances from generation facilities to urban areas, industrial sites and end-use customers.

The "distribution" grid includes the lower voltage lines that carry power to the end user residential or commercial customers after its voltage has been stepped-down at a power substation.

A study contracted by the European Commission (2005) examined the transmission-related barriers to connecting large-scale offshore wind energy to the grid in a number of European countries. The study identified several grid-related constraints, including a limited number of high voltage substations near the shore and limited spare capacity to accommodate expansion of offshore wind projects.[76] Europe has major load centers that are located at a distance from the coast. Consequently, transmission constraints typically occur when offshore wind power has to compete for limited spare transmission capacity to reach an interior load center.[77] Among the study's findings was that "large-scale deployment of offshore wind energy requires grid reinforcement. The longer this is postponed the more the deployment of offshore wind energy will be retarded."[78]

The case studies below are intended to illustrate European experiences with transmission constraints facing offshore wind development. They highlight the importance of available near-shore injection points and a robust connection from those injection points to the rest of the grid. Where those elements are lacking, integrating offshore wind has required costly reinforcements to onshore transmission infrastructure.

> ***Case 1: Belgium*** has three coastal substations, two of which (located in Zeebrugge and Slijkens) are capable of accepting output from offshore wind power facilities. The country has a 380kV grid backbone, but the two coastal substations are connected to the main grid by 150 kV lines. These lines are limited to 650 MW in their combined export capacity to nearby load centers.[79] Both lines will be used to full capacity once just three of the five current wind projects currently being developed and constructed come online.[80] Belgium has designated an exclusive zone for offshore wind development that has a development potential of up to 2 GW. In order to access those offshore resources, Belgium's system operator is planning to expand the 380kV system to directly connect to Zeebrugge. The project is expected to cost €150 million (approximately 200 million USD) and take at least five years to complete assuming a smooth permitting process, which puts the completion date toward the end of 2014.[81]

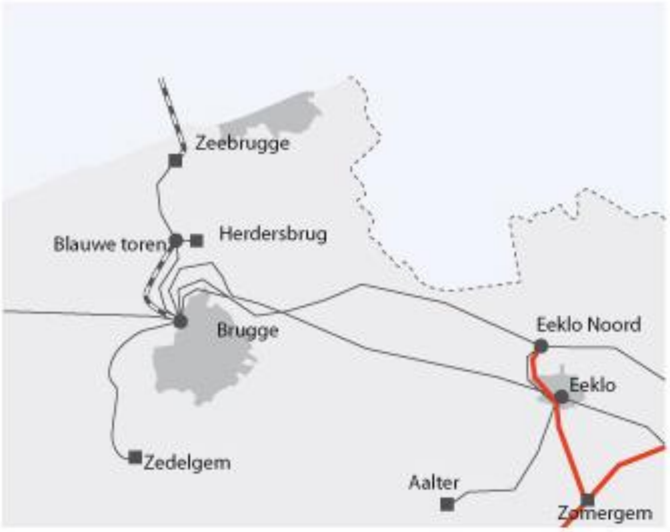
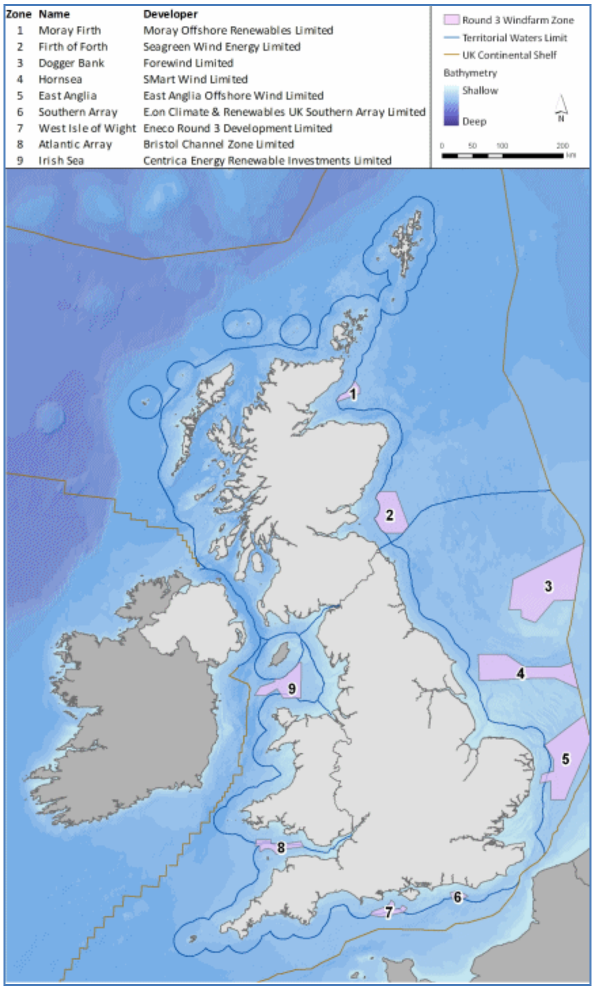


Figure 13: Belgium's Coastal Transmission Infrastructure. Belgium's transmission developer, Elia, plans to expand the 380 kV grid between the substation at Zeebrugge (upper-left) and the substation at Zomergem (lower-right). Zeebrugge is located on the Belgian coast, near an exclusive offshore wind development zone capable of hosting 2 GW of installed offshore wind power capacity. The project is expected to cost $200 million USD.[82]

Case 2: The Netherlands' most "eligible" coastal substations (located in Beverwijk and Maasvlakte) have robust 380 kV connections that as of 2004 had a combined incremental export capacity of 2 GW. While 2 GW is substantial, the country has a power development potential of 10 GW in "probable" offshore wind zones, and is moving to install 6 GW by 2020. The Netherlands has identified a number of onshore transmission reinforcements that are necessary to connect that power to load—totaling €289 million (approximately 390 million USD) if new cables are installed above ground or up to €839 million (approximately 1.1 billion USD) if up to 30 percent of new onshore cables are buried.[83]

Case 3: The United Kingdom is the world leader in installed offshore wind power (~1.3 GW). The UK has gradually scaled up procurement of competitive leases for development in three "rounds." Leases were granted in Rounds 1 and 2 for a total of 8 GW and regulators are now planning for an additional 25GW in nine separate development zones in Round 3 (shown in Figure 14 below). Development sites in the earlier rounds were chosen by developers in part based on availability of transmission access.[84] In Round 3, however, regulators expect that integrating the full 25GW will require a $1.7 billion investment in onshore transmission infrastructure—and an additional $14.8 billion for the offshore network to connect the new facilities to the onshore grid.[85] A study by the Crown Estate (a government land management agency) revealed that major reinforcement of the onshore grid (beyond new onshore injection points and connections to the existing grid) would be necessary to integrate wind from zones with capacities greater than approximately 3GW (some zones are as large as 11GW).[86]



Zone	Name	Developer
1	Moray Firth	Moray Offshore Renewables Limited
2	Firth of Forth	Seagreen Wind Energy Limited
3	Dogger Bank	Forewind Limited
4	Hornsea	SMart Wind Limited
5	East Anglia	East Anglia Offshore Wind Limited
6	Southern Array	E.on Climate & Renewables UK Southern Array Limited
7	West Isle of Wight	Eneco Round 3 Development Limited
8	Atlantic Array	Bristol Channel Zone Limited
9	Irish Sea	Centrica Energy Renewable Investments Limited

Figure 14: UK's Round 3 Zones. Currently at 1.3 GW installed offshore wind capacity, the UK is continuing to expand its capacity to 8 GW in Rounds 1 and 2. The image above shows Round 3 zones, part of the UK's long-term plan to develop an additional 25 GW of offshore wind power capacity.[87]

In each of these countries, the availability of near-shore injection points and onshore transmission capacity posed a constraint for aggressive offshore wind development. The UK case illustrates that, while early-stage development may occur with minimal transmission needs if carefully sited, costly investments in both onshore and offshore transmission infrastructure were ultimately needed to integrate offshore wind—particularly where offshore projects are concentrated. However, not all European countries have shared this experience. As described below, Sweden has had a very different experience.

> ***Case 4: Sweden*** has a long coastline and a large number of potential onshore injection points. Load centers are concentrated in the southern part of the country, in close proximity to high quality offshore wind resources. These factors have enabled relatively constraint-free interconnection of offshore wind facilities (about half a GW to date). Up to 5 GW of offshore wind power could be connected in

Sweden without encountering major transmission constraints—as long as the injected power is not concentrated (>500 MW) in small regions. In addition, the country relies extensively on hydropower generators located primarily in the northern part of the country. These generators are connected to the load in the south via several high voltage cables (shown in rough detail in Figure 15 below). These high voltage lines continue southwards providing power to Denmark,[88] Germany,[89] and Poland.[90] During times of high load and high supply potential from the hydroelectric dams, these cables can become congested and thereby constrain the delivery of this affordable power to other countries. Injecting new offshore wind power from the south may help to relieve congestion over the north-south transmission routes.

Figure 15: Sweden's Transmission Infrastructure. This transmission map details Sweden's several, large north-south transmission lines. These lines bring power from hydropower plants in the north to population centers in the south of Sweden and ultimately Poland and Germany. These north-south lines are often congested at times of peak demand. Siting offshore wind power near load centers in the south of Sweden can help to relieve that congestion by allowing more of the hydropower to flow to load centers in Poland and Germany were electricity is more costly.[91]

Rather than encountering transmission constraints, Sweden has actually received congestion relief benefits from offshore wind power. The country relies extensively on hydropower generators located primarily in the northern part of the country. Several high voltage cables connect these generators to the load in the south. These lines continue southwards to Denmark,[92] Germany,[93] and Poland.[94] During times of high load and high supply potential from the dams, these cables can become congested and thereby constrain the delivery of the cheapest power to other countries. Injecting new offshore wind power from the south can help to relieve congestion over the north-south transmission lines. As southern Sweden's demand for hydropower decreases, more of this inexpensive power can be transmitted to Germany, Poland or Denmark. (See Appendix D to read more about congestion and congestion relief).[95] These four European cases show that transmission capacity and near-shore substations may need to be upgraded to accommodate offshore wind power; on the other hand, they show that offshore wind can relieve congestion under certain circumstances.

The extent to which the Great Lakes region will face the type of transmission constraints seen in the UK, the Netherlands, and Belgium depends on the growth of installed offshore wind capacity, the location of that installed capacity relative to major load centers, and the strength of the existing grid. This question is the focus of the remainder of Part 1 of this report.

Offshore Wind Development and the Existing Grid in the Great Lakes Region

A study like the one contracted by the European Commission, with a similar level of detail, has not been conducted for the Great Lakes basin—perhaps in part due to the early stage of offshore wind development in the U.S. and the lack of publicly available data regarding substation and transmission line location and capacity. However, the following section envisions situations in which offshore wind development is and is not likely to be constrained by *existing* transmission infrastructure, based on a number of identifiable factors. This section does *not* consider advanced transmission expansion options that may be achievable with minimal constraints—those options are considered in Part 3 of this report.

The simple criteria below can be used to determine whether an offshore wind project is likely to encounter transmission infrastructure constraints. The extent of necessary infrastructure expansion needed will depend on the size and location of the project. In some cases, upgrades may be a limiting or prohibitive factor for offshore wind development. Due to the cost and siting challenges of upgrades, which are discussed in greater detail in Part 2 of this report, site selection by developers may be constrained by the degree of required transmission upgrades. Projects that do not meet these criteria may require substantial new or upgraded transmission infrastructure to deliver power to load:

1. a) Local demand is large enough and equipped with adequate grid infrastructure to absorb and integrate offshore wind power, *or*
   b) There is adequate transmission infrastructure that connects the injection point to a distant demand that is capable of absorbing and integrating the offshore wind power, *and*
2. a) Near-shore substations are available, have sufficient headroom, and are otherwise feasible connection points, *or*
   b) Direct high voltage connection to distant load is economically feasible, *and*
3. Submarine transmission is economically feasible.

These criteria offer a simple conceptual model for thinking about potential transmission constraints when developing an offshore wind project. A number of details are important to consider when applying these criteria. In the first criterion, demand must not only be large enough to justify the additional generation capacity from an offshore wind facility (including at its peak production), but also have existing infrastructure that is capable of effectively managing variable wind power injection. Wind power may reach its peak when demand is low and typically satisfied with baseload power.

Additionally, wind integration may stress transmission infrastructure in the area. Varying wind speeds and intermittent winds lead to voltage fluctuations in output. Transformers on the grid may need to stabilize voltage more frequently to accommodate wind than to accommodate more consistent sources of energy like coal, nuclear, or hydropower. Adding large amounts of wind to the system may increase the need for voltage stabilization and thus shorten the lifetime of transformers. This problem is further exacerbated if the demand is a “load pocket,” an area that is relatively isolated from the external grid.[96] The presence of robust grid connections and well-planned balancing areas improve the ability to smooth out these voltage fluctuations.

The second criterion above identifies the importance of access to existing, near-shore substations, given cost and permitting barriers to constructing new substations. However, in the absence of available near-shore injection points, offshore wind projects may be able to connect directly to a distant load center with a new HVDC line. The cost of HVDC cable and the difficulties associated with securing new ROWs for the connection may make this option infeasible in some cases.

The criteria above illustrate a number of hypothetical scenarios in which transmission is unlikely to be a constraining factor for offshore wind. For example, near-shore wind projects will have lower submarine transmission costs than far-offshore projects. A developer must consider the trade-off between a project's distance from shore and a project's size, which dictates output and revenue stream used to cover the cost of any additional submarine transmission. Projects sited in areas with available headroom at the injection points will avoid the cost and siting barriers of constructing or upgrading new substations. Projects close to large load centers will not need long-distance transmission infrastructure to deliver power, whereas remote projects will depend on grid infrastructure having the spare capacity, or will require costly grid upgrades. In lieu of detailed transmission data, this basic framework can indicate where the "low-hanging fruit" are located in the Great Lakes from a transmission perspective.

Preliminary Analysis: Opportunities for "minimal-transmission-constraint" offshore wind integration

Below, two categories of "minimal-transmission-constraint" development opportunities (near-shore areas close to cities or close to available transmission capacity from existing power plants) are identified and quantified in terms of power potential. While there may be opportunities for "minimal constraint" power injection elsewhere on the existing grid, these two injection opportunities are used for this analysis in lieu of detailed transmission data.

Opportunity 1: Near-shore areas with high local demand

Several of the metropolitan areas in the basin have sizeable power demand. The location of several lakeside load centers close to offshore areas with excellent wind resources and technically and economically feasible depths provides near-term development opportunities to supply renewable power to these areas. Offshore wind projects proposed near these load centers can use **radial connections** shore with relatively low-cost **alternating current (AC)** cables. The load centers' substations can serve as grid injection points.

Below, Figure 16 shows load centers (shown as orange dots sized based on population size) adjacent to lake area with a depth of fewer than 30 meters (shown in light blue). Note that the map and table below were produced with a one-mile buffer exclusion placed on shipping lanes. However, other relevant social and environmental criteria, such as airports, shipwrecks, spawning beds, coastal wetlands, and others, were not applied. As a result, actual developable area is likely to be substantially smaller than shown below. See Appendix E for close-up figures of each lake. Not considered here are industrial centers, which are also loci of high demand.

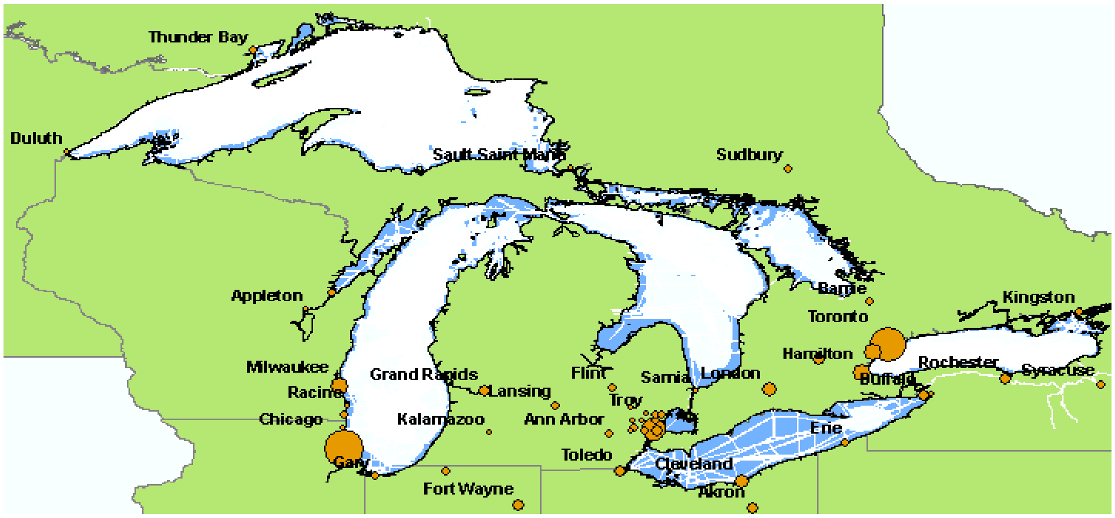


Figure 16: Great Lakes Depth of 30m or Less Relative to Population Centers. The Great Lakes Basin—more so than Europe—has several large cities located directly on the shoreline, in close proximity to high-quality offshore wind resources. Cities are indicated with orange dots, with size matched to population. Depth is a major limiting factor throughout much of the basin. However, Chicago, Detroit, Toledo, Cleveland, Erie, and Buffalo, for example, are located in close proximity to shallow waters (indicated in light blue). As deepwater foundations and floating turbine technology are tested on a commercial scale, other cities will have improved access to offshore wind resources.[97]

Below, Table 3 shows lake area with depth 30 meters or less within a 6-mile radius[viii] of lakeside population centers in the basin. Only shipping lanes (with one mile buffer) are excluded from area calculations. Area is converted to nameplate capacity potential using a 10MW per square mile estimate, which assumes installation of approximately one 3.6 MW turbine per square

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[viii] The 6-mile radius represents a rough approximation of the distance at which the cost of the cable connection to shore is expected to comprise roughly 10 percent of capital costs for a medium-sized project (a few hundred MW). For larger projects, connection over a longer distance may be feasible without hitting that threshold. Furthermore, the 10 percent threshold by no means indicates a *prohibitive* cost level.

kilometer.[ix] Low- and high-end estimates for energy production per year are derived using a 0.3 and a 0.45 capacity factor assumption, respectively. While prime offshore locations can yield capacity factors toward the higher end of this range, the locations analyzed below do not consider wind speed or consistency. The low end estimate is included to be conservative. Given the importance of capacity factor for wind power economics, offshore wind development is not expected where wind resources yield capacity factors toward the low end of this range.

Table 3: Offshore Wind Potential within Six Miles of Load Centers in the Great Lakes (no shoreline buffer)

State/ Province	City	Area (sq mi)	Nameplate Power Potential (MW)	Power Potential: .3 -.45 CF (GWH/yr)	Percent of Total Generation in state[98x]
IL	Chicago Area, IL-IN	265	2,650	7,000 - 10,500	
	Total	**265**	**2,650**	**7,000 - 10,500**	**3-5%**
IN	Michigan City	67	670	1,800 - 2,600	
	Total	**67**	**670**	**1,800 - 2,600**	**1-2%**
MI	Benton Harbor/St. Joseph	96	960	2,500 - 3,800	
	Holland	39	390	1,000 - 1,500	
	Muskegon	76	760	2,000 - 3,000	
	Bay City	75	750	2,000 - 3,000	
	Monroe	27	270	770 - 1,100	
	Port Huron	74	740	1,900 - 2,900	
	Detroit	175	1,750	4,600 - 6,900	
	Total	**562**	**5,620**	**14,800 - 22,200**	**13-20%**
MN	Duluth	30	300	800 - 1,200	
	Total	**30**	**300**	**800 - 1,200**	**1-2%**
NY	Buffalo (Lake Ontario)	24	240	600 - 1,000	
	Buffalo (Lake Erie)	132	1,320	3,500 - 5,200	
	Rochester	77	770	2,000 - 3,000	
	Total	**233**	**2,330**	**6,100 - 9,200**	**4-7%**
OH	Lorain/Elyria	96	960	2,500 - 3,800	
	Sandusky	86	860	2,300 - 3,400	
	Toledo	22	220	600 - 900	
	Cleveland	189	1,890	5,000 - 7,500	
	Total	**393**	**3,930**	**10,300 - 15,500**	**7-11%**
ON	Thunder Bay	63	630	1,700 - 2,500	

[ix] Note that the National Renewable Energy Laboratory assumed one 5 MW turbine per square kilometer in its September 2010 "Large-Scale Offshore Wind Power in the United States" report. Use of 3.6 MW here is intended to be conservative, given that wind speed data are not considered here.

[x] Net Generation for the entire state, not just the cities listed in the table. Yearly generation baseline is December 2009-December 2010.

	Sault Saint Marie	13	130	300 - 500	
	Norfolk	347	3,470	9,100 - 13,700	
	Belleville	13	130	3,300 - 5,500	
	Hamilton	73	730	1,900 - 2,900	
	Kingston	25	250	700 - 1,000	
	Toronto	54	540	1,400 - 2,100	
	Oshawa	46	460	1,200 - 1,800	
	Total	**634**	**6,340**	**16,700 - 25,000**	**12-17%**[99,xi]
PA	Erie	163	1,630	4,300 - 6,400	
	Total	**163**	**1,630**	**4,300 - 6,400**	**2-3%**
WI	Green Bay	41	410	1,100 - 1,600	
	Sheboygan	49	490	1,300 - 1,900	
	Racine/Kenosha	92	920	2,400 - 3,600	
	Milwaukee	107	1,070	2,800 - 4,200	
	Total	**289**	**2,890**	**7,600 - 11,400**	**12-18%**
GRAND TOTAL		**2,636**	**26,360**	**69,300 - 104,000**	

Table 3 above illustrates the development potential close to load centers. Figure 17 below details how this power potential, in aggregate, varies with radius from city and shoreline exclusion buffer.

[xi] Ontario electricity demand for 2010. Months are not specified.

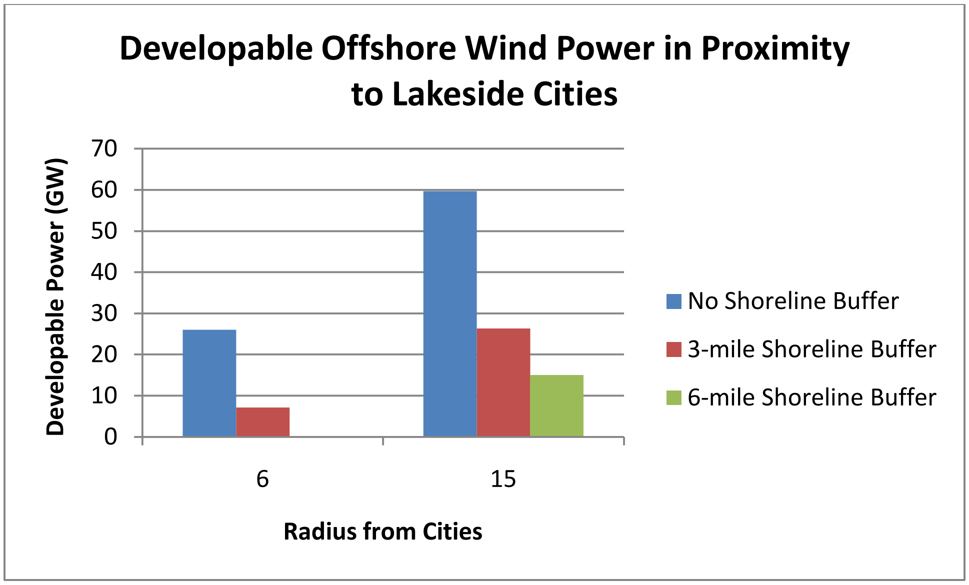


Figure 17: Developable Offshore Wind Power in Proximity to Lakeside Cities. There is an enormous potential for offshore wind in close proximity to major lakeside cities. However, this potential is substantially diminished as shoreline exclusion buffer is increased. Also note that this developable power potential excludes only shipping lanes with a one-mile buffer and does not consider wind speed. Lake area is converted to developable power using a 10 MW per square mile estimate.

These are areas that may not be significantly constrained by transmission availability. Several important caveats apply to the data presented above. First, several exclusion criteria, such as distance to shore, airports, shipwrecks, and environmentally protected areas, are not considered in the area calculations, and would certainly reduce the developable area. These criteria will not equally affect the developable area for each city presented above. Moreover, wind speed and consistency (capacity factor) are primary drivers of a wind facility's cost of energy. While wind resource quality is fairly good throughout the lakes, it is not evenly distributed. Some of the area presented above may be characterized by deficient wind resource quality (particularly given that all of these areas are near-shore, where wind speeds tend to be lower). Consequently, these calculations are for illustration only, and should be used for further analysis only after the application of detailed wind speed data and the full set of exclusion criteria.

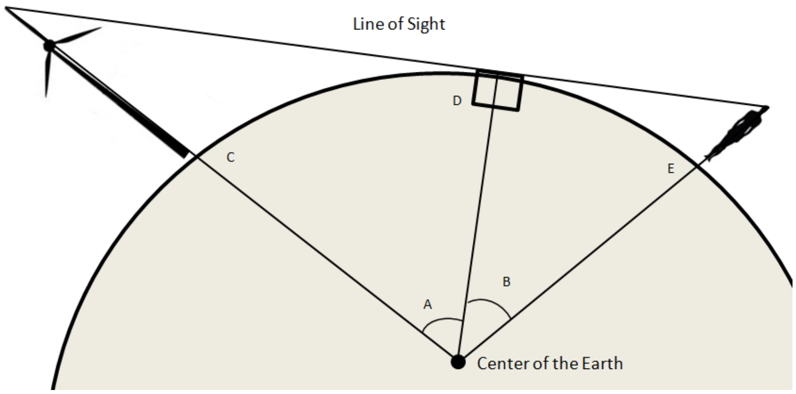
Second, although close proximity to large load centers reduces the need to transmit power over long distances in theory, some load centers may lack the capability of integrating large amounts of variable wind power. For example, if a city's energy portfolio is heavily comprised of inflexible base load power (coal and nuclear), large-scale wind integration may be difficult in the near-term until more flexible (dispatchable) generation is available.

On the other hand, however, the data above include only large urban areas directly on the shoreline. There are additional load centers located a short distance inland (e.g. Grand Rapids, MI) that could serve as load centers for near-shore offshore wind development with limited onshore transmission needs. Inclusion of those load centers would tend to increase the bottom-line “minimal-constraint” development potential shown in Figure 17 above.

Despite the important caveats described above, the total area very roughly indicates substantial development opportunity for offshore wind in locations where transmission constraints may be minimal. The potential developable power in the total area (26 GW) is about half of NREL’s assumption for U.S.-based offshore wind under a 20 percent wind by 2030 scenario (NREL assumed most of that offshore wind would be developed on the Atlantic coast).[100] Tapping even a third of that potential (9 GW) would power over 2.5 million homes, based on an average of 11,040 kWh/home annually.[101]

Wind facilities visible from shore (near load centers and in more remote areas) will impact the viewshed from shore. The potential consequences of that impact for tourism, property values, and general aesthetics may lead local communities to oppose project proposals within sight of shore. These issues arose in Ludington, MI, where Scandia Wind proposed a 1,000 MW offshore wind project to occupy a 100 square mile area within 3.7 miles of shore.[102] Scandia ultimately withdrew its proposal in the face of vocal opposition from local residents, much of which stemmed from viewshed concerns.[103]

Calculating Distance to the Horizon to Determine Line of Sight



Assume the distances from the Center of the Earth to points C, D, and E are equivalent. The Line of Sight between the wind turbine and the human is a tangent, meaning it makes a right angle with the radius of the earth where it meets the horizon (at point D). Trigonometry can be used to calculate the angles A and B, which can then be used to find distance over the surface of the earth.

Arc CD = ({Inverse Cosine (Length: Center of the Earth to D / [Length: Center of the Earth to C + Height of Turbine])}/360 Degrees) * Circumference of the Earth

Arc DE = ({Inverse Cosine (Length: Center of the Earth to D / [Length: Center of the Earth to C + Height of Human])}/360 Degrees) * Circumference of the Earth

→Arc CE = Arc CD + Arc DE

Assuming:

- Radius of the Earth = 3956.6 mi
- Circumference of Earth = 24859.8 mi
- Height of Human = 6 feet

If the turbine is 400 feet tall (approximately the height of a GE 3.6 MW turbine) Arc CE = 27.5 mi

If the turbine is 600 feet tall (approximately the height of a proposed 10 MW turbine) Arc CE = 33.0 mi

However, turbines may not be visible at much shorter distances than 27 miles due to general visibility (air quality). According to NRG Bluewater Wind, turbines as close as 15 miles offshore in Delaware would only be visible on the clearest days, which typically occur in the winter—an off-season for beach-related tourism.

Local tensions are also apparent in the Great Lakes and St. Lawrence Cities Initiative—an organization of coastal mayors. The organization has not been able to reach a consensus position on offshore wind, in part due to the division among and between communities.[104] The Great Lakes Commission is undertaking a study to more fully understand what drives public perceptions of offshore wind in lakeside communities. In the meantime, experiences like Scandia Wind's in Ludington illustrate the importance of viewshed impacts to local residents, and the importance to developers of local receptiveness.

The ability of wind developers to capitalize on the opportunities near the load centers shown in Figure 17 will depend in part on the receptiveness of the public in those communities. Imposing a 3-mile shoreline exclusion buffer on major cities reduces the developable capacity within 6 miles of those cities from 26 GW to 7.5 GW. However, increasing the radius to 15-miles (while maintain the 3-mile shoreline exclusion buffer) puts developable capacity at 26.3 GW. Currently, it is unclear whether industrialized load centers like Milwaukee, Chicago, Gary, Toronto, or Cleveland would be more receptive to near-shore wind development than Ludington. Legislation proposed in Michigan (HB 6564, 2010), which owns 40 percent of the Great Lakes, would prohibit offshore wind development within 3 miles of shore and allow development between 3 and 6 miles conditional on local consent.[105] Similarly, Ontario moved in 2010 to prohibit development within 5 kilometers of shore (about 3 miles) before cancelling development plans altogether in 2011 pending further study.[106] If provisions like these are passed, or if the level of public opposition seen in Ludington, MI occurs in communities around the basin, developers may be forced farther offshore. This would likely (but not necessarily) introduce the transmission issues cited earlier.

Opportunity 2: Near-shore areas with available onshore transmission capacity

Output from remote offshore wind projects delivered to shore will require long-distance transmission infrastructure with spare capacity to move power to load centers. Where this infrastructure exists, a transmission stability analysis is required to determine whether the system is able to integrate power from a new offshore wind project. However, the presence of large power plants with low capacity factors can be used to indicate spare transmission capacity. In the Great Lakes basin, a number of large power generators are remote from load centers, but are connected to adequate transmission capacity to deliver the power.

Because most combustion-based power plants use water for cooling, they are often located near a body of water, often at the Lakes’ shores. Plants that are running consistently below maximum capacity may be logical injection points for offshore wind, using the spare transmission capacity already in place for the existing power plant. As these plants retire and their grid reservations are released, the spare capacity potentially available to wind developers will only increase.

Calculations show that approximately 35 GW of spare transmission capacity are currently unused, on average, at power plants located within 5 miles of the Great Lakes shoreline.[xii] Within a 6-mile radius of the closest shoreline point from each of these power plants,[xiii] there is enough lake area to develop, in aggregate, 12.2 GW of offshore wind power in waters fewer than 30 meters deep. This assumes a 3.6 MW wind turbine[xiv] per square km and excludes *only* shipping lanes with a one-mile buffer. Including a 3-mile shoreline exclusionary buffer reduces this power potential equivalent to 3.1 GW. However, widening the power plant radius to 15 miles offshore (maintaining the 3-mile shoreline buffer) increases the power potential equivalent to 20.4 GW. These results are summarized in the Table 4 below.

Table 4: Offshore Wind Development Potential by Radius from Power Plants and Shoreline Exclusion Buffer (<30 meters deep)

Radius from Plants (mi)	Shoreline Exclusion Buffer (mi)	Area (sq mi)	Power Potential Equivalent (GW)
6	0	1,222	12.2
6	3	313	3.1
15	0	4,057	40.6
15	3	2,044	20.4
15	6	1,116	11.2

Both 6- and 15-mile radii are presented in the table above because, as previously discussed, distance to shore is only one factor in the cost of submarine transmission. Further, the extent to which submarine transmission requirements would be “constraining” for a project would depend not only on cost, but also on the economics of the specific project. Additionally, various

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[xii] This calculation is based on power plant generation data from EIA and the capacity factor data from the EPA eGRID web database and considers only those power plants that have at least 200 MW of nameplate capacity. Note that this spare capacity is more *consistently* unused at baseload facilities like coal plants. Lakeside coal plants in the basin have an average of 12 GW unused transmission capacity. However, even baseload facilities ramp up and down over time for maintenance, meaning that less than the *average* unused capacity is *consistently* available. See Part 3.1 for further discussion.

[xiii] There are 21 power plants located within 5 miles of the Great Lakes shoreline. Of those, 17 are located *directly on* the shoreline. For the remaining 4 plants, the GIS calculation presented above uses a hypothetical shoreline injection point as the center point for the 6 mile radius.

[xiv] Note that the National Renewable Energy Laboratory assumed one 5 MW turbine per square kilometer in its September 2010 “Large-Scale Offshore Wind Power in the United States” report. Use of 3.6 MW here is intended to be conservative, given that wind speed data are not considered here.

shoreline exclusion buffers are presented because they have been the proposed in different jurisdictions across the basin to reduce viewshed impacts. Table 5 below shows how these estimates change if waters with depths between 30-60 meters are included. These depths may be accessible to wind developers in the mid-term as pilot deepwater platform technology progresses to the commercial scale.

Table 5: Offshore Wind Development Potential by Radius from Power Plants and Shoreline Exclusion Buffer (<60 meters deep)

Radius from Plants (mi)	Shoreline Exclusion Buffer (mi)	Area (sq mi)	Power Potential Equivalent (GW)
6	0	1412	14.12
6	3	453	4.53
15	0	5229	52.29
15	3	3084	30.84
15	6	1809	18.09

Note that much of the lake area quantified here and converted to “development potential” overlaps with lake area quantified in Opportunity 1 above (near-shore, near-cities lake area). For example, only 3.3 GW of lake area within 15 mile radii of power plants with a 3 mile shoreline buffer are not also within the same proximity of a major city. Also note that Ontario power plants are *not* included in this analysis. While Ontario has several large lakeside power plants and is phasing out its coal plant fleet by 2014, the Ontario Power Authority has already apportioned all spare transmission capacity—including anticipated capacity from phased-out coal plants—to new renewable power projects as part of its FIT program.[107]

Using the spare capacity at the existing power plants for offshore wind power would require the transfer of FTR (Financial Transmission Rights) from the power plant to the wind farm and generator interconnection approval from the Regional Transmission Organization/Independent System Operator (RTO/ISO). We discuss this development potential in greater detail in Part 3.3 of this report.

Qualitative Analysis: Areas where transmission needs are likely to constrain offshore wind

Much of the Great Lakes' offshore wind potential is located away from load—either in remote near-shore areas or far offshore. As discussed above, near-shore power plants and cities can serve as minimal impact grid injection points. However, not all areas in the Great Lakes have these characteristics. In general, transmission needs will be potentially constraining in locations that do not meet the three criteria discussed previously. Additional study is needed to determine exactly where offshore wind developers will face these transmission capacity challenges. In the meantime, the first and most obvious indicator of constraints is the absence of adequate transmission infrastructure.

Remote near-shore areas

An examination of publicly available U.S. transmission data (seen in Figure 18 below) indicates that transmission infrastructure is weak in more remote areas, particularly in much of northern Lake Michigan and the U.S. sides of Lake Superior and northern Lake Huron.[108] Because load is smaller and more dispersed, the grid and generation units are less robust. In these areas, transmission requirements to supply wind power to load are greatest and existing infrastructure is weakest.[xv]

[xv] Note that much of Lake Superior exceeds depths accommodated by proven foundation technology. Deepwater foundations (greater than 30 meters deep) are at least a decade away from commercial deployment in the U.S. "Second generation" foundations support offshore wind turbines in waters up to 60 meters deep. They were used in a two-turbine demonstration project (Beatrice Wind Farm) off the coast of Scotland in 2007. The project is slated to expand to 184 turbines with a total generating capacity of 920 MW. According to one U.S. offshore wind developer, securing project insurance requires using components with at least a 10-year safe operational history.
Sources : Beatrice: Wind Farm Demonstrator Project Scoping Report.» Talisman Energy, n.d. Web. 20 March 2011.
US offshore wind developer. Personal Interview, June 2010.

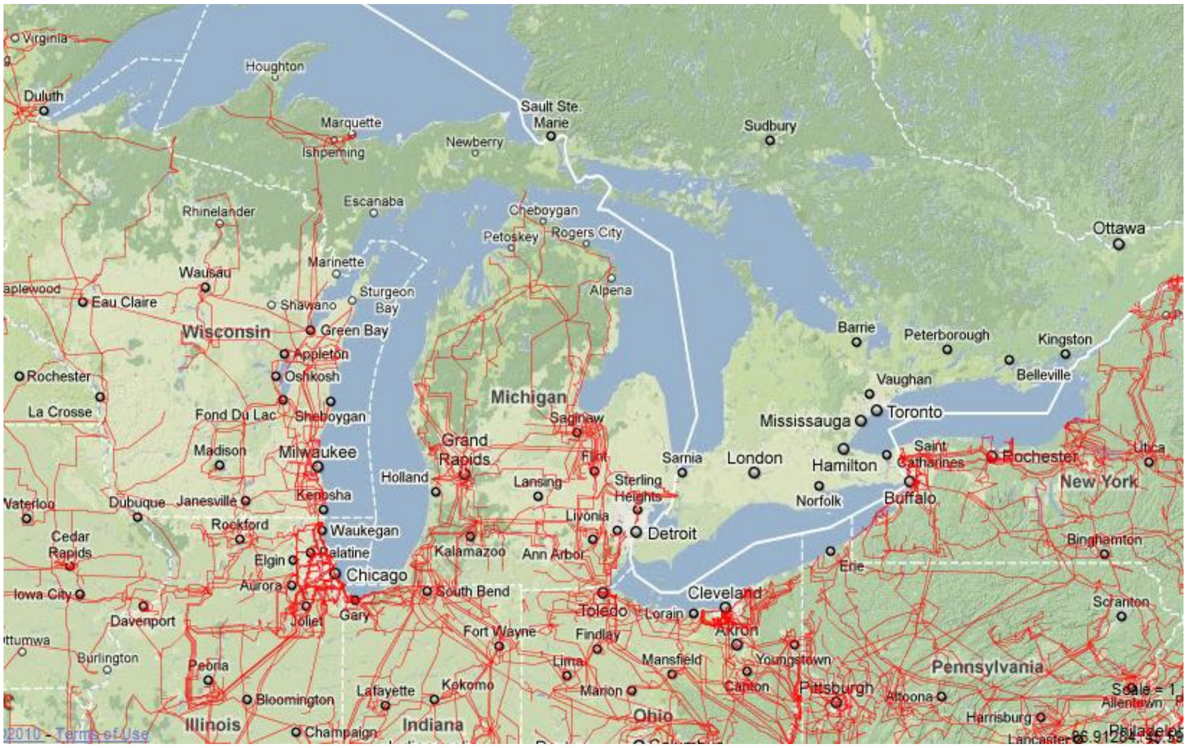

Figure 18 U.S. Transmission in the Great Lakes (>120 kV)—1997 data. The transmission system is built-up in areas with dense population—particularly along the southern portion of Lake Michigan and the south coasts of Lake Erie and Lake Ontario. In contrast, little transmission infrastructure exists in northern Lake Michigan or Lake Superior (where wind speeds are highest but waters are deepest).[109] The mere existence of transmission infrastructure is a poor proxy for "integration opportunity," given that much of the grid is used near its rated capacity already. A detailed transmission study—with up-to date data—is required to more accurately assess integration opportunity on a fine scale throughout the basin.

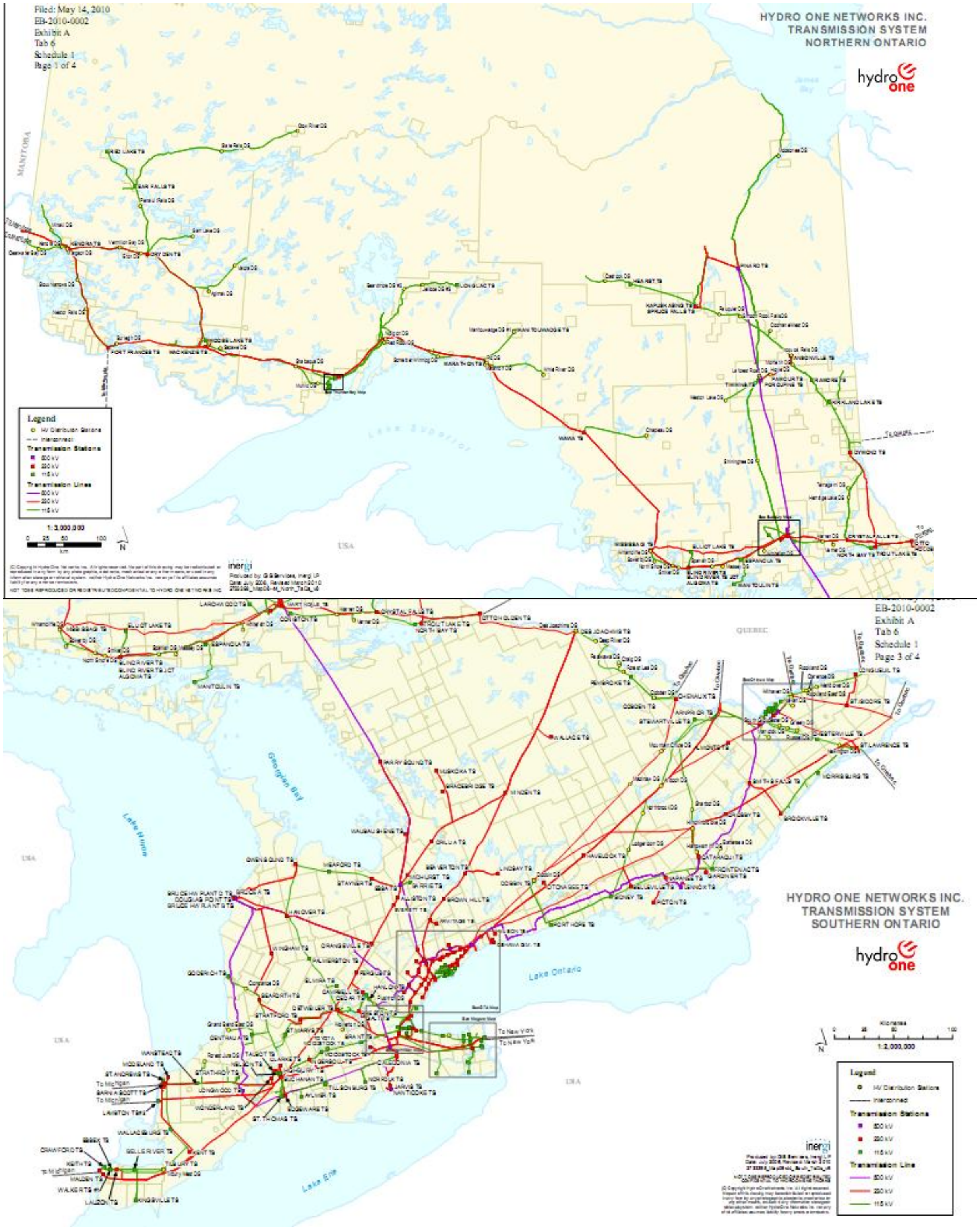

Figure 19 Transmission Maps of Southern Ontario—2010 data. [110] **Similar to the U.S., transmission in Ontario is built-up in areas of dense population. The grid is most substantial along Lake Ontario, Lake Erie, and southern Lake Huron. However, a more detailed transmission study is needed to determine coastal integration potential for offshore wind. Ontario has slowed its feed-in tariff program in part due to a lack of spare transmission capacity for new renewable projects.**

Even in areas with a robust set of high-voltage transmission lines and substations, those lines may already be used near capacity. Transmission bottlenecks can prevent generators from supplying power to load. Those generators can be required to reduce power generation in order to avoid overloading the grid.[111] Thus, even rural areas with adequate transmission infrastructure may not be "robust" in terms of ability to handle large injections of new power.

Electricity price differentials can indicate where congestion is a major problem. The Chicago-Gary corridor, for example, is historically a major transmission bottleneck, as represented in the price differential between Wisconsin and areas south and east of Chicago/Gary.[112,113] Congestion is discussed in greater detail in Appendix D.

Ontario, meanwhile, has depleted its available excess transmission capacity. The Ontario Power Authority reportedly has apportioned all remaining spare capacity to new renewable energy projects as part of its feed-in tariff (FIT) program—including three offshore wind projects before Ontario reinstated its offshore wind moratorium.[114] Consequently, any new offshore wind facility will require system upgrades—the extent of which will depend on several factors, including proximity to load.

Far-offshore areas

Developers can move projects farther offshore if constrained by factors such as public objections to viewshed impacts, or environmental impacts to critical near-shore ecosystems. The public is expected to be more receptive to projects sited farther from shore.[115] Building wind projects far offshore may mitigate some wildlife impacts as well. For example, migratory birds tend to follow coastlines and stopover at habitat areas near the shoreline, although migratory flyways are not exact, and ascent and descent angles of bird flight (which may relate to risks) are not well known.[116,117]

Far-offshore development faces a significant challenge in the form of costly submarine transmission. Added to these transmission costs are higher offshore installation and maintenance costs, and potentially more expensive turbine foundation costs in deeper water. At some point these costs may become prohibitive if bourn by developers.

Limited onshore transmission infrastructure may also constrain far-offshore projects, similarly to near-shore remote projects (as discussed above). However, depending on location, these projects may have more flexibility in terms of grid injection points and onshore transmission capacity. In some locations, a project may be within comparable distances of multiple injection points, providing options if any of those has limited capacity.

High-Growth v. Low-Growth Scenario Planning

Ultimately, the extent to which transmission poses a significant hurdle for offshore wind will depend on the wind power industry's rate of growth in the Great Lakes region. In a low-growth scenario, developers can take advantage of areas where minimal transmission upgrades will be needed. They can develop closer to shore in areas with populations that are more receptive to viewshed impacts and where the more robust existing transmission grid can accommodate additions of variable wind power. Projects can connect to shore with low up-front cost, single developer radial connections to shore, and integrate into the grid without needing to increase **coping strategies for intermittency** that may be required of high-growth scenarios. Therefore, transmission is not a primary constraint for projects facing these conditions in a low-growth scenario.

This part of the report has identified two scenarios in which transmission constraints *may* be minimal—near-shore development close to large load centers, and near-shore development adjacent to power plants with spare transmission reservations. Simple spatial analyses revealed that roughly 7.5-26.3 GW of nameplate power are potentially available in the first scenario and 3.1-20.4 GW in the second scenario,[xvi] for a total combined *unique* area of 8.3-29.6 GW. This is an extreme upper bound estimate, as it excludes only shipping lanes and a moderate 3-mile shoreline exclusion buffer. It also assumes one turbine placed in literally *every* square kilometer identified. A comparison of that "minimal transmission constraint" power potential to a reasonable "high growth" estimate for the Great Lakes indicates the extent to which—and

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[xvi] These estimates are based on lake area within 6- and 15- miles (low and high end of range, respectively) of urban areas or major power plants. Only lake area outside a 3-mile shoreline exclusion buffer and with fewer than 30 meters depth and was included. Estimates assume a 30 percent capacity factor and 10 MW of developable capacity per square mile of lake area.

perhaps *when*—offshore wind development in the Great Lakes may encounter major transmission-related constraints.

Obtaining a “high growth” estimate is difficult as there are more uncertainties involved. Total developable area, commonly cited policy goals, and current industry growth rates indicate what a reasonable high growth scenario might look like. In the near-term, developers are constrained by the 30 meter depth limit. The area in the Great Lakes meeting that criterion and a 3-mile shoreline buffer is large enough to accommodate 118 GW (excluding shipping lanes only). However, that depth limit may change as technology advances, opening up large areas farther from shore (an additional 106 GW of developable power). Thus, these numbers likely represent an unrealistic upper bound of development potential.

The National Renewable Energy Laboratory chose “20% wind by 2030” as a benchmark for high growth in the wind industry as a whole (onshore and offshore). Meeting 20 percent of projected demand in the basin (1,800 TWh, based on a 0.8 percent per year growth rate over the next twenty years[118]), would require a significant investment in wind power. If a *third* of the targeted wind generation were to come from offshore, the Great Lakes region would need to develop 39 GW of offshore wind capacity, based on a 35 percent capacity factor.

Such a goal appears aggressive in comparison to historical and projected industry growth rates, even in Europe. The United Kingdom is currently the world leader in offshore development, with 1.3 GW of the world’s 3.16 GW of total installed capacity. However, the industry has made considerable strides and the UK expects to install an additional 1 GW per year over the next five years.[119] A similar growth rate in the Great Lakes basin would yield around 20 GW by 2030. The Province of Ontario alone has received applications for roughly 20 GW of offshore wind through its FIT program; however, only 2GW are actually approved or in the permitting process (at least partly due to transmission constraints[120]).

The lowest of these three estimates—20 GW by 2030, based on projected industry growth rates in the UK—lies near the center of the estimated upper bound developable power in areas characterized above as “low-transmission constraint” (8.3-29.6 GW). Given that this upper bound assumes a turbine placed in literally every square kilometer within 6 or 15 miles of cities and power plants, excluding *only* shipping lanes and a 3-mile shoreline buffer, it is clear that development is likely to exceed these “minimal-constraint” opportunities under a high-growth scenario. Furthermore, the identified minimal-constraint areas are not necessarily the most desirable for development or may be unsuitable, based on wind speed and other factors. This places additional pressure on development outside of these minimal-constraint areas. While the role of these additional factors is an object for further research, the finding above suggests at minimum that, while *near-term* offshore wind development *may* not encounter substantial transmission-related hurdles, a high growth scenario would ultimately necessitate more complex, higher up-front cost and multi-developer **network** or **multi-nodal radial transmission configurations** to support larger projects farther offshore. Projects of this scale will require more strategic advanced planning for both the offshore transmission configuration and the onshore grid, with collaboration between multiple states and provinces.

Currently Planned Projects and Transmission

There are a number of projects being planned to generate offshore wind power in the Great Lakes, some of which will require new and upgraded transmission. There is also a substantial project up and running on Wolfe Island and another in the planning phase on Galloo Island in Lake Ontario. While these are not offshore projects, they have similar transmission requirements.

> ***Case 1 - Cleveland:*** In May 2010, Lake Erie Energy Development Corporation (LEEDCo) announced its plan to develop the first freshwater offshore wind farm in the U.S.[121] This five turbine, 20 MW demonstration project will be directly offshore from a major Great Lakes load center.[122] It is a partnership between Bechtel Corporation (a major construction conglomerate), Cavallo Energy (a private equity firm), and Great Lakes Wind Energy (an Ohio-based construction company).[123] Although transmission capacity will likely not require major upgrades given the demonstration size of the project, lessons learned from this project will be valuable for larger offshore projects, which are envisioned for this area and the City of Cleveland.
>
> LEEDCo's long-term goal for Lake Erie wind production is 1000 MW by the year 2020.[124] There is sufficient power demand in the corridor between Cleveland and Akron, approximately 30 miles south, to support the deployment of more offshore wind turbines. A number of coal plants near the shore in this area could serve as power injection points. Based on the transmission criteria discussed earlier, development of offshore wind in this area may not be limited by transmission.
>
> ***Case 2 – Trillium – Lake Ontario:*** Trillium Power Wind Corporation is planning a nearly 420 MW offshore project near Kingston, Ontario, at the eastern end of Lake Ontario.[125] Energy would be transported from two offshore substations through a 28km underwater line to an on-land transformer station near Bath, Ontario, for 230

and 500kV interconnection to the province's main grid at the Lennox Transformer station.[126] The existing 500kV line that runs close to and parallel to the northern shore of Lake Ontario could accommodate offshore wind development in the lake. However, the number of substations along this line is limited, with fewer substations on the connected 115kV lines.

This project meets the criteria discussed above: transmission infrastructure (the 500 kV line) from the injection point to a distant load is already in place, with sufficient spare capacity to accommodate new generators, *and* near-shore substations are available with sufficient capacity, *and* the cost of submarine transmission is not prohibitive.

Case 3 – Wolfe Island: The Wolfe Island wind project is located on an island a few kilometers from the shore of Kingston, Ontario. The wind facility has a total nameplate capacity of 197 MW, consisting of 86 2.3 MW turbines. The power from the Wolfe Island project is transmitted to the Ontario onshore grid at Kingston via a 7.8 km 245 kV AC submarine transmission cable combined with fiber-optics capacity. The submarine transmission cable rests on the lake bottom and is kept in place by its own weight.[127]

While this project is not an offshore project (turbines are located on Wolfe Island), the project's submarine cable connection to the land transmission system may provide potential offshore projects with lessons regarding the installation of submarine cable, and near-shore environmental impacts.

Case 4 – Galloo Island: The Hounsfield Wind Farm, proposed on Galloo Island in Lake Ontario, will have a **nameplate** capacity of approximately 252 MW.[128] The energy output would be transmitted above ground more than 40 miles on a newly constructed 230 kV line onshore to connect with a NYS Electric and Gas 345 kV transmission line in Mexico, NY.[129] The NY Independent System Operator (NYISO) has found that inadequate local transmission (115 kV) is more likely to constrain wind energy generated from the project than the absence of 345 kV lines. The existing 115 kV transmission lines need to be upgraded to support power generated from the project.[130] The Hounsfield project requires 9-miles of submarine cable to connect to the onshore transmission system.[131]

PART 2: BARRIERS TO TRANSMISSION DEVELOPMENT

Offshore wind development could occur at a number of locations in the Great Lakes without the need for significant transmission additions. However, as discussed earlier, a high growth scenario for offshore wind in the basin may expand development into areas that would require substantially increased investment in transmission facilities.

Transmission takes more time to plan, permit, and build than a typical wind farm, so in order to support large scale offshore wind development in the Great Lakes, transmission system expansion needs to be planned and facilities built well in advance. This section discusses the challenges to offshore wind transmission development including high costs, cost allocation of transmission, planning difficulties, and social and environmental impacts.

Costs of Transmission

Overview

While offshore wind resources in the Great Lakes are located closer to load centers like Chicago, Toronto, and Cleveland than comparable onshore wind resources, several development scenarios would require substantial transmission upgrades and expansions. Submarine transmission for offshore projects is more expensive than onshore transmission, especially if offshore projects are sited far from shore. In some cases, the onshore grid may also need to be upgraded, and in all cases, changes in power management strategies are required to integrate the variable wind power.

The costs of those changes are an important consideration for offshore wind developers given the high upfront cost of offshore wind facilities relative to onshore wind. Until offshore wind is cost-competitive with onshore wind, its growth may be mostly due to the transmission advantages from the close proximity to load centers of high-quality offshore wind resources. In areas where developers are unable to capitalize on these advantages, offshore projects may not be competitive. This section discusses how the economic costs of transmission may influence development offshore wind resources and the operational costs of integrating wind power into a balancing area (an area in which generation and load are managed). The section to follow addresses the important question of how these costs are allocated, or which entities are responsible for those costs.

Capital Costs

The capital costs of building transmission to support offshore wind can be allocated into three categories:

1) Submarine cable connection to shore,
2) Substations: offshore collector stations and new or upgraded onshore substations, and
3) New or upgraded onshore transmission lines from the onshore connection point to load.

Submarine Transmission

Submarine cables can be a major cost factor for far-offshore projects due to the high cost of installation, maintenance, and the cable itself. Laying or burying these cables requires using costly specialized equipment. In environmentally sensitive areas where burying is not feasible, the cables can be protected by placing them in pipes or concrete mattresses, or covering them with rocks.[132] Contracting for the tugs and barges needed to install these protective measures adds additional cost.

Submarine cable conductors also need to be insulated from exposure to water. Insulating the cable itself adds cost, and the insulation adds weight to the cable, requiring more expensive equipment and larger vessels to handle that additional weight during installation. Increases in water depth also add to cost in several ways.[133] First, the cable has to be designed to operate at greater pressure in deeper waters. Laying cable in deeper waters may require a larger vessel to compensate for the added weight of the suspended cable as it is installed on the lake bottom. Sub-sea vessels with remotely operated vehicles are also needed for installation, inspection, repair and maintenance of deepwater cable, which adds to the overall cost of submarine transmission.[134]

Cable voltage also affects cost; higher voltage cables cost more per mile of cable. However, lower voltage lines, which have higher transmission losses, transmit less power and typically cost more on a per unit energy transmitted basis.[135] Voltages are balanced to fit the wind facility based on nameplate capacity and the transmission distance.

Recent examples of submarine transmission projects include a line under San Francisco Bay and one from New Jersey to Long Island. The estimated total costs for these projects were approximately $505 million for the 53-mile San Francisco Bay line and around $600 million for Long Island’s 65-mile line, both around $9.5million/mile.[136] This compares to on-land transmission of less an a million to near $4 million per mile, varying due to the capacity and type (AC vs. DC) of line primarily.[137] The longest HVDC submarine cable project in the world connects the Netherlands with Norway to carry 700MW of power 580km (360 miles).[138] This project cost €600 million, or nearly $800 million (US)–a much lower cost of $2.2 million per mile.[139] This lower cost may be due to the fact that European nations are further along than the U.S. on the submarine transmission learning curve. The length of the line may also be a factor in the reduced costs per mile, because installation, which can comprise 50-60 percent of total project cost, is largely a fixed cost. Thus, additional mileage adds relatively less cost to the project.[140]

The cost of submarine cable also depends upon the type of cable used: alternating current (AC), high-voltage alternating current (HVAC), direct current (DC), high-voltage direct current (HVDC, including both classic HVDC and HVDC-VSC) or another technology. Cable technology choice depends in part on distance, both because of differences in per mile capital cost and differences in transmission losses. Looking at the cost of cable for the Cape Wind project, AC cables cost more than DC cables on a per mile basis; however, DC cables require costly AC/DC converter stations to integrate into the AC grid. Comparative cost estimates for this example show that cable and installation costs for a 115 kV AC submarine cable are roughly three times that for a 150 kV DC submarine cable ($129.5 million compared to $39.4 million for a 35 mile connection to shore). However, an AC/DC converter was estimated to cost $124 million installed.[141]

Loss of energy during transmission is an additional cost to consider. Compared to DC, AC has higher losses. While increasing the voltage with HVAC cables can reduce some of these losses, the losses in AC cables can justify the cost of converter stations to use HVDC cables beginning at distances of 30-60 miles.[142] Classic HVDC is the most cost effective at high power ranges of more than 250 MW.[143] The leading power technology provider, ABB Inc, also offers HVDC Light cables up to 320 kV (which can transport up to 1100 MW of power).[144]HVDC Light is particularly useful for connecting wind farms because of its superior ability to stabilize the AC voltage at the terminals—important for wind farms because the variation in wind speed can cause severe voltage fluctuations.[145] In fact, HVDC Light is used to connect the world's largest offshore wind facility—BorWin 1.[146] BorWin 1 is a 400 MW wind farm located 125km (78 miles) off the German coast in the North Sea, connected to shore with a 124-mile cable.[147]

Siemens is an industry leader in power transmission. In spring 2010, Siemens will complete a pioneering submarine transmission project connecting San Francisco's city electrical grid and substation near Pittsburg, California for Trans Bay Cable LLC. The HVDC Plus low-loss cable spans 53 miles (88 kilometers) and can carry up to 500 MW at a voltage of 200-kV. Innovative technical components of the systems include voltage-sourced converters (VSC) and insulated gate bipolar transistors (IGBT). Siemens HVDC Plus cable is applicable for space-constrained installations and is marketed as ideal for offshore wind farms. According to Siemens, the Trans Bay Cable project will reduce congestion and improve grid security and reliability, thus reducing the need for new generation facilities.

Siemens. (2010). Retrieved July 2010, from HVDC Plus VSC Technology: http://www.energy.siemens.com/us/en/power-transmission/hvdc/hvdc-plus/references.htm

To illustrate the impact of these submarine transmission costs on project economics, the costs can be converted to cents per kWh of electricity generated. At $4 million/mile—perhaps a conservative estimate—moving a wind facility proposal from 6 miles offshore to 15 miles offshore can add an additional $36 million plus transmission losses. For a 100 MW proposal, these added transmission costs translate to 1.06cents/kWh to 2.65cents/kWh (see Appendix D for complete calculations). The cost increase is less substantial per unit of energy as the size of the wind project increases, as shown in the graph below.

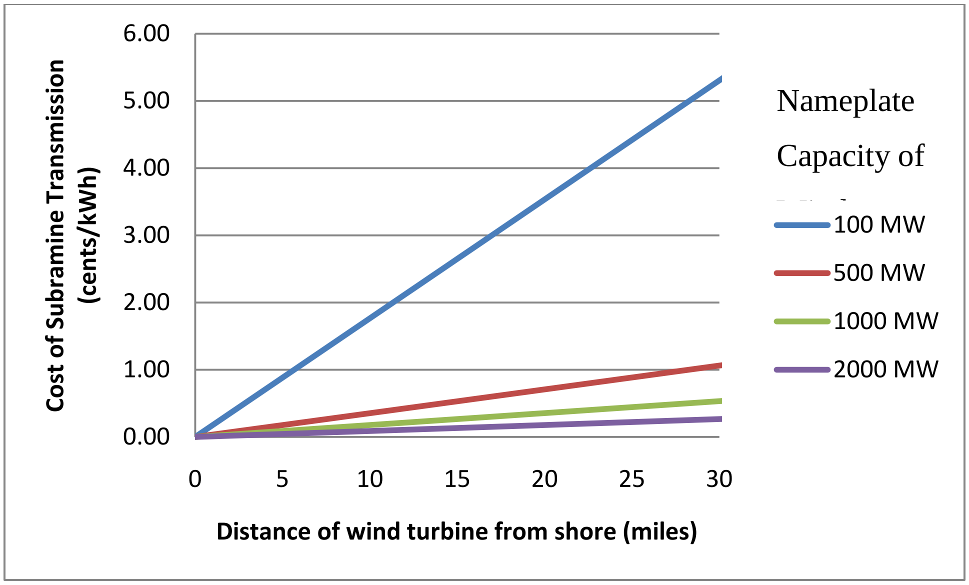


Figure 20: Relationship between Distance from Shore and Cost of Submarine Transmission based on Name Plate Capacity (100 MW typically numbers 20-35 turbines)

<u>Substations</u>

The development of offshore wind in the Great Lakes requires more than just submarine transmission cable to connect the wind farms to shore. Depending on the wind farm's location, suitable onshore grid **injection points** may not be available. In these cases, developers may require new onshore substations or upgrades to existing substations to step up the voltage produced to transmission-level voltage. Onshore substations can cost roughly $10 to $60 million, depending on size.[148] To put this amount in perspective, the largest onshore wind farm in Michigan (200 MW) cost more than $440 million to build in total, but secured a $1.1 billion agreement with DTE electricity over the next 20 years.[149] Developers may have more flexibility in choice of onshore injection points, if the project uses a DC connection to shore, since marginal cost of added distance is a smaller percentage of total cost of a DC project (because fixed converter station costs are so significant). Therefore distance is less of a constraint for DC projects.

Offshore wind developers may also require offshore substations if the project:

- Generates more than 100 MW,
- Is located more than 15 km from shore, or

- The connection to the grid is above collection voltage (e.g. more than 35 kV).[150]

Offshore substations have step-up transformers that increase the voltage of the power generated *before* transferring it to shore in order to reduce line losses.[xvii] Costs can range anywhere from $50 to $100 million per substation.[151] These units are more expensive than their onshore counterparts in part because of the complications related to installation and maintenance offshore.

Onshore Transmission

Once the power has been transferred to an onshore grid injection point, new or upgraded transmission may be needed to transmit power to load, depending on the size of the project and the robustness of the existing grid. The Lawrence Berkeley National Laboratory collected onshore transmission cost information from a number of completed and planned wind projects.[152] This 2009 report assessed 40 transmission projects or planning studies completed between 2001-2008 that involved the addition of wind power to the grid. This study found that costs vary substantially from one project to another; the project using submarine cables was the most expensive.[153]Costs vary (even between similar line sizes) for the following reasons:

- Regional factors, such as property values affecting right-of-way purchases;
- Changes in materials, energy, and labor costs over time; and
- Varying level of detail considered (some included only line costs and substations, others included costs associated with right-of-way, securing rights-of-way, construction, financing, transformers and power conditioning equipment.[154]).

[xvii] Line losses are proportional to the square of the current. For a given power level, increasing the voltage decreases the current.
High voltages result in lower current and hence lower line losses.

Table 6 Range of Equipment Cost Assumptions [Directly from Lawrence Berkeley National Laboratory Report, February 2009][155]

Equipment	Minimum Cost	Maximum Cost	Number of Samples
Transmission Lines($million/mile)			
765 kV (no description)	2	3.2	5
500 kV (single circuit)	1.5	2.2	6
500 kV (double circuit)	2	3.5	5
500 kV (no description)	0.8	2.6	10
HVDC Line (800kV)	3.7	3.7	1
HVDC Line (345 - 500kV)	1.1	3	8
HVDC Submarine Cable	4	4	1
345 kV (single circuit)	0.6	1.5	4
345 kV (double circuit)	1	2.3	5
345 kV (no description)	0.5	2.2	10
230 kV (double circuit)	2	2	1
230 kV (no description)	0.3	1.6	6
230 kV (rebuild/reconductor)	0.5	0.5	1
115 kV (no description)	0.2	0.4	2
115 kV (rebuild/reconductor)	0.1	0.3	2
115 kV (uprate)	0.05	0.4	2
Associated Equipment			
HV Substations ($million/unit)	10	60	6
DC Terminal ($million/MW)	0.1	0.2	4
DC Terminal ($million/unit)	250	500	5

The median cost of transmission from all of the scenarios analyzed in this report was $300/kW, or roughly 15% of the total cost of a wind project.[156] The projects evaluated in this report are primarily onshore projects. To put this in perspective, the capital costs of building an offshore wind project in 2011 are 30-50% higher than an onshore project.[157]

The Berkeley National Laboratory report warns that the capital cost estimates presented in most cases overestimate the cost of transmission to support wind due to the additional benefits that new transmission provides. Hence, it is essential to recognize the value of additional benefits such as:

- Improved **reliability**
- **Congestion** relief
- Additional capacity so that other new generation can be added to the network in the future.[158]

Depending on location, individual grid upgrade projects would provide different reliability, congestion relief and excess capacity benefits. The value gained from these additional benefits would thus need to be calculated on a case-by-case basis, as each depends upon the characteristics of the preexisting local grid infrastructure and the size of the new line that is built.

Overall, the capital costs for transmission are substantial. If an offshore wind farm is to maximize its total return, there are tradeoffs to be considered between initial costs, cable transmission capacity, and expected maintenance costs. GE Energy showed that "optimized electrical system design can yield incremental rates of financial return equal to, or better than, the expected return on investment for the wind farm as a total project."[159]

This GE Energy paper looks at three major factors to analyze choices between size and configuration of cables and transformer substations:

1) Losses from voltage adjustment in the substation,
2) Losses from resistance in transmission cables, and
3) Inability to deliver power to the grid injection point due to electrical system issues like cable failure.[160]

Trade-offs between cost and performance occur when designing a grid system. For example, two cables can be installed to safeguard against cable failure and reduce aggregate transmission losses; however, the additional cable adds to project costs. Likewise, installing two "half-sized" transformers instead of a single full-sized transformer can create a robust collection system; however, the additional substation and losses related to voltage adjustment would also increase costs. The GE Energy paper provides detailed formulas to evaluate these decision points and uses an example of a 100 MW facility that needs 10km of transmission to illustrate their application.[161]In its specific example, installing an additional cable would *not* be cost-effective, and installing two "half-sized" transformers (disregarding the added cost of a larger platform) would be more cost effective than installing one "full-sized" transformer.[162] This type of optimization analysis is helpful to evaluate choices that would minimize overall cost of the transmission infrastructure needed to support an offshore wind farm.

Operating Costs for Power Dispatchers

In addition to capital costs, there are operating costs associated with integrating wind power that need to be considered regardless of whether substantial new or upgraded transmission is needed. Unlike capital costs, which will vary widely with transmission needs based on project location, these operating costs will accompany all substantial wind development to some degree, and are not necessarily different for offshore wind compared to onshore. Because wind is variable, it presents new challenges relative to traditional sources that can be turned on/off or, in the case of natural gas, even ramped up and down on short notice depending upon projected power demand. System operators project power demand daily and hourly to ensure that when consumers need power, their demand is met. To meet this demand, system operators then undertake two processes:

1) Unit commitment: Selecting the least expensive electricity generators that can meet the predicted demand.
2) Economic Dispatch: Scheduling the committed generators in the most economic order.

Across the country there are about 130 balancing areas within which power supply is managed.[163] If a balancing area is small and a large amount of wind energy is added, then unit commitment and economic dispatch become more complicated, because forecasting wind power production is not yet reliably accurate.[164] Integrating wind into the dispatch schedule is not simple. It involves the prediction of the next day's power supply (wind generation) and the next day's power demand. Ramping up and down of large base load coal plants to produce more power when the wind is not blowing is expensive and even damaging to the coal plant equipment.[165] Figure 21 shows how total generation needs to adjust on short time schedules to integrate wind. Natural gas plants have this capability, but the overall flexibility added by these plants may be insufficient given the relatively small role played by natural gas in the Midwest when compared to coal. The only Great Lakes states/provinces with substantial natural gas electricity generation are New York and Pennsylvania, with 36% and 15% of their power from natural gas respectively. In the other states, coal is the primary source, with nuclear second, and natural gas ranging from 1-10% of generation. The substantial hydropower production in Ontario and Quebec may provide the flexibility needed to integrate variable wind energy, although natural gas is a smaller percentage of generation in those provinces as well. See Appendix E for specific generation by fuel/energy source for each Great Lakes state and province.

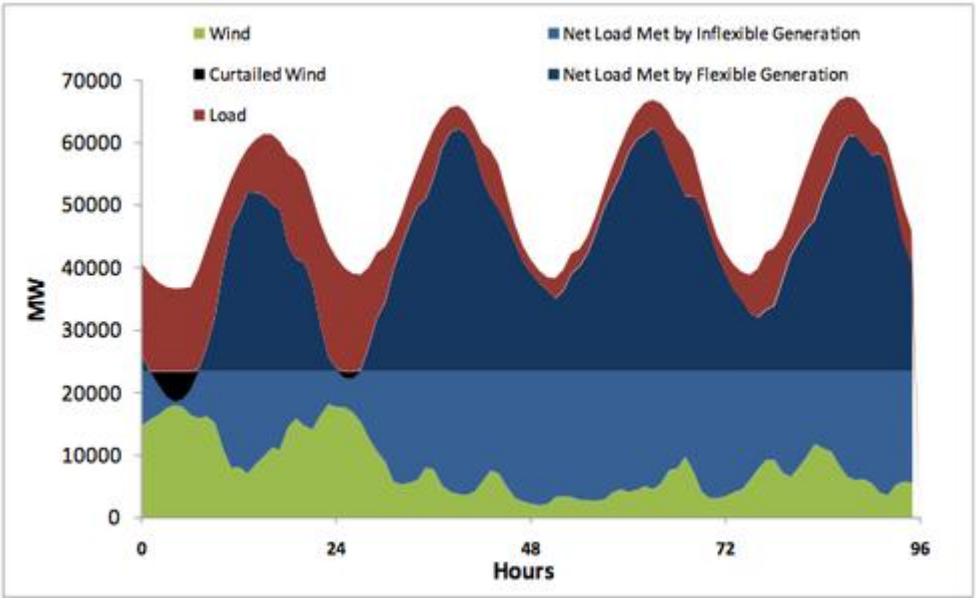


Figure 21: This is an example of an Electricity Dispatch Schedule. This exemplifies how wind energy production does not match up with demand and is in general variable and also gives a sense of the grid management grid difficulties that wind power poses.[166]

NREL estimated that the operating costs of integrating wind energy could be as large as $5.00/MWh (half a cent per kWh) of wind generation at wind capacity penetrations of up to 20%.[167] These amounts reflect the extra costs of operating other power generation sources to supply power in the event that wind power is not generated as forecasted, the additional regulatory costs of incorporating wind power, and other related costs. Overall, this cost is nominal compared to building the transmission needed to support wind, but may be a concern for regulators to ensure that large costs are not borne by other generators as a result of adding wind power.

Larger balancing areas have greater capability to integrate wind effectively. If wind power is produced in geographically diverse locations throughout a balancing area, the variability among all of the locations will be less than the variability of only one major source due to averaging.[168]

Cost Allocation

Building of transmission infrastructure is expensive, and determining who pays is a complicated and often contentious question. The cost allocation issue can make or break projects and can slow the transmission development process. A common normative judgment is that the people who will benefit from the transmission should pay for it. However, identifying these beneficiaries is difficult because the majority of our grid system is comprised of AC transmission lines, on which the direction of power flow cannot be controlled; the power will follow the path of least resistance. Power dispatch operators lack control of where power flows (when lines are connected), and thus power cannot be tracked from a specific source to a specific user. This makes allocating the costs to beneficiaries difficult, because it involves using sophisticated power flow models built by the transmission system operators (e.g., flow analysis).

An alternative cost allocation scheme is to socialize costs across many users. Any upgrade to the grid has at least a small benefit for all parties using the grid because the grid becomes more reliable for all. If the cost of transmission is to be socialized across many users, determining the subset of users who should share these costs is also difficult. This is because the grid is connected to regions with different regulating bodies, while power is usually produced and transported for use on a smaller regional scale.

In order to address transmission cost allocation on a regional basis, regional transmission organizations (RTOs) were formed to administer access to the transmission grid. As shown in Figure 22, for the areas surrounding the Great Lakes, there are four Independent [transmission] System Operators (ISOs) who serve as RTOs:

- IESO – Ontario
- Midwest ISO – parts of Michigan, Wisconsin, Minnesota, and Ohio
- NYISO – New York
- PJM – Illinois (around Chicago), Michigan (southwest corner), most of Ohio and Pennsylvania (as well as other non-Great Lakes-states)

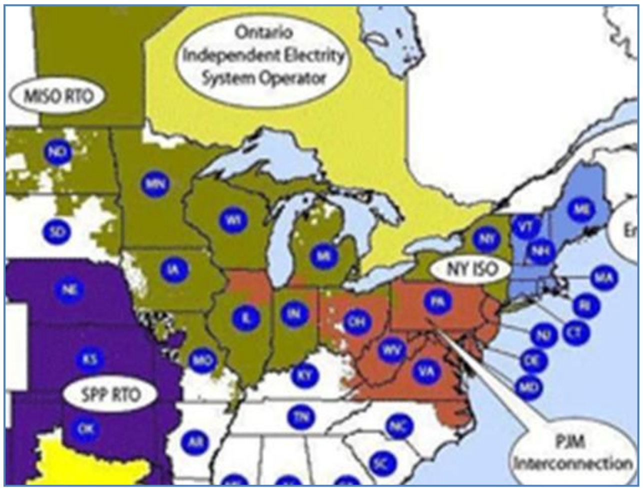


Figure 22: Map of the Great Lakes Region's RTO/ISO Service Area. Four independent transmission system operators service the Great Lakes area and thus manage cost allocation issues for electricity ratepayers.[169]

Cost Allocation Methods

Cost allocation methods are based on the various rules that RTO/ISOs use to determine who pays for new transmission and/or upgrades to existing transmission. These rules vary depending upon the RTO/ISO, reason for the project, and other factors such as the size of the line. Costs for transmission can be shared/allocated as follows:

- Between load and generation –(in the U.S., load usually pays)
- By amount of usage – (based on annual megawatt-hours used/generated)
- By peak consumption/generation – usually measured at system peak

- By flow-basis – using models to project power flow and flow change with additional transmission
- By monetary impact basis – using models to project which parties benefit from the additional transmission (such as reduction in energy prices or production cost).[170]

When deciding which of these methods to use, each RTO/ISO will evaluate the allocation methods based upon the behaviors it wishes to promote, such as locating new generation either close to load centers and/or in locations that would reduce congestion costs.[171] Factors that are considered when determining which cost allocation policies should be adopted vary among RTOs/ISOs, however the general concepts considered include:

- Understandability of how allocation works and assumptions used—Can the allocation method be simply explained to consumers? Are assumptions used simple and noncontroversial?
- Ease of data gathering for a method—Are the data needed for the calculation readily available or easily acquirable?
- Reflects system changes over time—Is the method flexible as load growth or system conditions change?
- Stability of rates—Does the method provide predictability for consumers and generators?[172]
- Incentives for generation and load—Does the method provide incentives for energy efficiency? Incentives to reduce peak usage? Incentives to locate generation close to load? Incentives to locate generation in a place that would reduce congestion?
- Public good aspects – Are increases in reliability recognized as a benefit? Is additional renewable energy recognized as a benefit? Are reduced transmission losses recognized as a benefit?

Typically, each ISO/RTO has a different allocation method based upon whether an upgrade is for **reliability** or for market efficiency (reducing congestion and lowering consumer costs). A July 2010 NREL report summarized the differences in cost allocation schemes for each of the ISO/RTOs in detail by reliability upgrades, generator interconnection upgrades, and economic upgrades.[173] The following is a summary of reliability upgrades and economic upgrades.

Table 7 RTO Cost Allocation Practices[174]

RTO	Reliability Upgrades	Economic Upgrades
Midwest Independent System Operator (MISO)	Projects 345kV and above: • 20% of costs go to all of the MISO zones, pro rata based on load • 80% of costs go to the MISO zones designated as beneficiaries based on a power flow analysis Projects 100-345 kV: • 100% of costs go to the MISO zones designated as beneficiaries based on a power flow analysis Projects below 100kV: • Paid for by the local zone in which the facility is located	All projects that pass threshold: • 20% of the costs go to all MISO zones • 80% to MISO sub-regional zones based on the benefits
New York Independent System Operator (NYISO)	Allocation depends on whether need is local, bounded, or statewide • NYC and Long Island pay 100% of projects to meet local reliability needs • Remaining statewide needs allocated to zones based on peak load • Remaining need allocated to zones that fail a reliability test	• Eligible project costs are allocated to zones by current and future prices, and allocated within zones by load • To be eligible for cost sharing, a project must pass three tests: - Cost greater than $25 million - Benefits are greater than costs - 80% of the beneficiaries vote for it
Pennsylvania-New Jersey-Maryland Regional Transmission Organization (PJM)	New facilities 500kV and above • Shared by all PJM systems New facilities less than 500kV • Allocated to zones based on power flow analysis of beneficiaries	New facilities 500kV and above • Shared by all PJM systems
Ontario Independent System Operator (IESO)	Socialized on per-unit basis across all ratepayers. Projects exceeding $500/kW are not eligible.[175]	Socialized on per-unit basis across all ratepayers. Projects exceeding $500/kW are not eligible.[176]

At present, changes are being made to current cost allocation rules. In December 2010, the Federal Energy Regulatory Commission (FERC) approved the Midwest ISO proposal to allocate 100% of the cost for certain **Multi-Value Projects** (MVPs) broadly across the region's customers.[177] There are three criteria that must be met to be classified as a MVP project. The project must:

- Be developed through the transmission expansion planning process to deliver energy in support of state or federal energy policy mandates,
- Provide multiple types of economic value across multiple pricing zones, and have a total project benefit-to-cost ratio of 1.0 or higher,
- Addresses at least one transmission issue associated with a projected reliability violation, and at least one economic based transmission issue that provides value across multiple pricing zones and generates quantifiable financial benefits in excess of the total project cost.[178]

This new cost allocation policy in the Midwest ISO is a positive step toward approving and building the transmission needed to transport renewable energy to load, especially as it identifies the co-benefits (improved reliability and congestion) of transmission upgrades necessary to integrate renewable energy.

Overall, cost allocation is a complex topic because of the numerous rules, differences between regional policies, the complexities and assumptions used in models that allocate cost, and the various viewpoints held on the theory of how costs should be allocated. Part 3 discusses how some cost allocations schemes have been amended to facilitate renewable energy and how cost allocation schemes will need to be harmonized across jurisdictions in some cases of offshore wind development.

Planning, Siting and Permitting Transmission Challenges

Overview

In addition to the large capital required and associated cost allocation issues, there are substantial hurdles related to planning, siting, and permitting transmission projects that may slow or obstruct the development of transmission for offshore wind in the Great Lakes. The transmission planning process has traditionally been reactive to new generation, rather than implementing a strategic vision for the future that includes expansion of wind power generation.[179] Siting decisions can also be rife with political conflict related to social and environmental impacts, and permitting processes are typically slow and complicated. This section explores each of these hurdles to the level of transmission development necessary to deliver offshore wind energy.

Planning Challenges

The Chicken-Egg Dilemma

Transmission planning is subject to a classic chicken-egg dilemma. Transmission companies have no incentive to build transmission to more remote areas where there is not yet any considerable generated energy to transmit—or to reinforce existing infrastructure where the grid does not yet need reinforcing—unless cost recovery is guaranteed by regulators.[180] Such projects carry considerable uncertainty in terms of cost recovery, and for most of the basin transmission projects cannot be approved for construction and cost recovery by regulators unless the benefits at least equal the costs.[181] Consequently, new transmission to support renewable projects is unlikely to be built without an assurance that adequate generation will be built to utilize it.[182] On the other hand, wind developers are unlikely to site a project where adequate transmission does not yet exist to deliver power from the onshore injection point to load—or to site a project so large that major system upgrades would be needed.

With traditional generation sources, the answer to this dilemma was simpler. The long lead-time required for large power plants allowed for transmission to be planned concurrently, and their typical size justified case-by-case upgrades. However, onshore wind power generators take considerably less time to plan, site, and construct than a large fossil-fueled power plant.[183] The relatively short lead-time of wind development provides the impetus to strategically plan transmission in advance to accommodate long-term integration rather than to meet transmission needs of individual projects on a case-by-case basis.[184] Offshore wind development in the U.S. and Canada is still in the early stages primarily due to cost challenges and a host of other issues. While offshore wind development has yet to begin, this pre-development stage affords the opportunity to prepare the grid in advance.

The Planning Process

Transmission planning can be slow, reactive, and complex. ISO/RTOs study the system impacts of each project in the "queue". Those impacts are difficult to predict at the outset.[185] Because they depend, in part, on expectations for other new facilities, system impacts change as other projects are added to, removed from, or modified in the queue—a common occurrence given the initial uncertainty of the cost of required system upgrades.[186] Such a revolving queue can result in an iterative analysis process that can prolong approval for qualified projects. (An analysis by MISO suggested that this process could take hundreds of years under a hypothetical worst-case scenario.)[187] Resolving this issue is at the forefront of current queue reform efforts and is an important step in large-scale integration of wind—including offshore wind.

In the past, stakeholders involved in the planning process have reacted to transmission project proposals from transmission owners and new power generators. Although planning to mitigate congestion is common, only recently have the ISO/RTOs in the basin begun to proactively identify areas for transmission upgrades to accommodate future wind power generation on land.[188] As the offshore wind industry ramps up in the basin, such a proactive approach can be applied to offshore areas as well. If regional planners do not solve this problem, offshore wind is likely to be relegated to areas where transmission constraints are already minimal. Such a pattern of development would minimize new transmission cost, but may or may not minimize overall project costs or be consistent with social and environmental values in the basin.

Siting Challenges

Grid upgrades can either reinforce existing infrastructure or forge new transmission routes and build new substations, either on land or offshore. Siting new infrastructure can pose a series of environmental and social, and therefore political, challenges.

Socio-Political Siting Challenges

New transmission routes must obtain **rights of way** (ROWs). While offshore ROWs must be obtained from only one "land" owner (the state/province), obtaining the necessary environmental permits can be costly in terms of both time and money (discussed later in this section). On the other hand, transmission routes over land require obtaining ROWs from multiple public and private landowners. Generally, this is not an easy task. According to Mark Lauby, Director of Reliability Assessments and Performance Analysis at the North American Electric Reliability Corporation (NERC), engineering design, licensing, and construction of the typical transmission line can take seven years or longer (often more than ten)—the real challenge being the ability to site new generation and lines where they are needed, not where they can be permitted.[189] American Electric Power, for example, took fourteen years to site a 90-mile 765kV line between Virginia and West Virginia that took only two years to construct.[190] These siting challenges play a tangible role in the planning for wind developers.

Public opposition to siting new transmission routes on land has motivated some transmission companies to pursue underground and submarine transmission routes despite the added capital cost. For example, a Toronto-based company has proposed a 370-mile line that would run under Lake Champlain and the Hudson River all the way to New York City.[191]

> ***Champlain-Hudson Power Express:*** Transmission Developers Inc. (TDI), a Canadian company, has proposed a plan to connect hydro-electric power in Canada to the northeastern U.S, namely New York City and Connecticut. Four submarine HVDC cables with a total of 2 GW of capacity are planned to run through Lake Champlain and the Hudson River, feed directly into New York City, and then continue through Long Island Sound to Connecticut. The transmission system, expected to cost approximately $1.9 billion, is considered one of the longest and most complicated submarine transmission system ever attempted.[192] The system will have a total length of approximately 380 miles, while navigating three water bodies. Because Lake Champlain is famous for shipwrecks, a straight burial path is unlikely. An archeological survey is being conducted to make sure unknown sites of archeological importance are not damaged by the project. One

important motivation to build underwater is to avoid new rights of way (ROWs) through forests and communities, which are harder to obtain than submarine ROWs because of the number of landowners involved and viewshed and other considerations associated with overhead lines.[193] The lines will be buried along railway routes where they come on land.[194] For example, to avoid re-suspending contaminated soils the cables are planned to run alongside the Hudson River for 73 miles along a railway.[195] TDI has begun the permitting process and plans to begin construction in 2012 and operation in 2014.[196]

Figure 23: Image of Champlain – Hudson Power Express Route—The first freshwater submarine transmission line in North America[197]

Ultimately, the property rights needed to site transmission routes can be taken by eminent domain. However, the mechanism for exercising eminent domain is seldom consistent with political and legal expediency. Currently, ITC Holdings is planning to build transmission to bring wind power from Michigan’s thumb region to southeastern Michigan load centers. Some of the ROWs for the project have been obtained by eminent domain, and the compensation to the landowners affected, principally farmers, may be disputed.[198,199] Adequate onshore transmission capacity is important to deliver offshore wind power to load centers that are not located directly on the coast near a wind facility. This particular line in Michigan could ultimately deliver offshore wind power from the wind rich and shallow Saginaw Bay area to load centers like Detroit.

Permitting Processes

Transmission facilities associated with offshore wind in the Great Lakes are subject to permitting processes at the federal, state, and occasionally local levels. The Great Lakes Commission has published a summary and analysis of state and provincial siting polices for land based wind farms in January 2010.[200] This document provides an overview of the difference between various state and provincial siting requirements, although some states are separately developing the specific procedures for offshore siting. Siting transmission infrastructure in the lakes requires the same permits as the actual wind facilities themselves. Onshore transmission components require similar permits, although the environmental impacts studies are clearly different. Transmission facilities also require grid connection permits. While permitting can ensure legally sufficient decision-making, the process can be resource-intensive in terms of both time and money. In fact, one offshore wind developer cited streamlining and simplifying the regulatory processes for offshore wind development as a top priority.[201]

Federal Bottomlands Permitting

In the U.S., siting of any type of structure in the Great Lakes, including transmission facilities, requires permits from the U.S. Army Corps of Engineers (USACE) under Section 10 of the Rivers and Harbors Act and Sections 401 and 404 of the Clean Water Act. The River and Harbors Act governs activities that would alter navigable waters. Section 401 of the Clean Water Act (CWA) requires USACE to certify that proposed activities will not violate established water quality standards, and Section 404 requires a permit for dredging activities associated with installing offshore wind transmission. Since this permitting would have an impact on the environment, USACE is required by the National Environmental Policy Act (NEPA) to prepare an Environmental Impact Statement (EIS) documenting the environmental impacts of the project. The US Fish and Wildlife Service has authority under the Endangered Species Act (ESA) to review projects for their impacts on threatened and endangered species and their habitats.[202] While other permits may be required from the Federal Aviation Administration and the US Coast Guard, depending on the project location and specifications, the USACE permits comprise the primary federal permitting process for siting offshore wind transmission on the US side of the basin.[203]

In Canada, the Ministry of Transport exercises somewhat similar authorities over navigable waters under the Navigable Waters Protection Act. Additionally, Fisheries and Oceans Canada regulates any activity that may negatively impact fisheries under the Fisheries Act. The Canadian equivalent of NEPA is the Canadian Environmental Assessment Act (CEAA), which requires federal authorities to undertake an environmental assessment for any major project. Finally, the Species at Risk Act is similar to the Endangered Species Act in the US, and is jointly administered by the Minister of Fisheries and Oceans and the Minister of the Environment.[204]

Siting *intra*state transmission facilities in general (either onshore or offshore) is typically not subject to federal approval; however, under the Energy Policy Act of 2005 the Federal Energy Regulatory Commission (FERC) has the authority to designate National Interest Electric Transmission Corridors in areas in the United States that are experiencing congestion. In these areas, FERC has authority to bypass state non-responsive permitting processes.[205] FERC has to date designated two such corridors, neither of which is within the Great Lakes basin.

State/Provincial Bottomlands Permitting

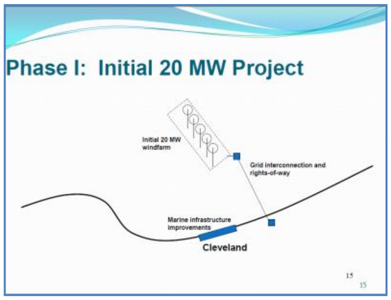
Under the Submerged Lands Act, the lakebed of the U.S. portion of the Great Lakes is held in trust by the states for the people under the Public Trust Doctrine. The province of Ontario similarly holds submerged lands, although there is no equivalent to the Public Trust Doctrine in statute, or applicable judicial precedent in Canada. Accordingly, siting permits (and leases in some cases) must also be obtained from state/provincial environmental or natural resource agencies.[206] The regulations governing placing structures on Great Lakes bottomlands are authorized by The Rivers, Lakes and Streams Act in Illinois, the Navigable Waterways Act and Lake Preservation Act in Indiana, the Protected Waters Act in Minnesota, the Dam Safety Act in Pennsylvania, Chapter 30 (Navigable Waters Protection) in Wisconsin, the Great Lakes Submerged Lands Act in Michigan, Consolidated Laws Article 15 in NY, Policy 16 of the Ohio Coastal Management Program, and the Public Lands Act of Ontario.[207]

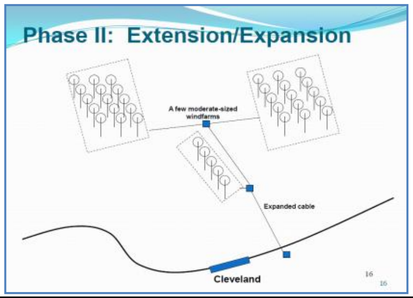
The statutory basis for this permitting process in some states, like Michigan and Wisconsin, is currently inadequate for addressing offshore wind facilities, including transmission infrastructure. In these states, the permitting process is designed for structures like docks, and permits are only available to riparian landowners.[208] In late 2010, Michigan legislators attempted to pass legislation to address this issue by creating offshore wind zoning laws, but it never was formally introduced during 2010.[209]

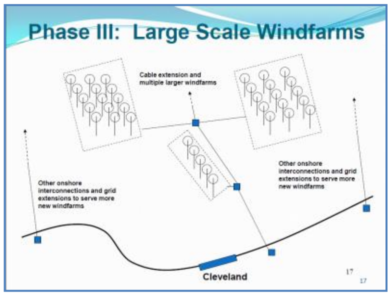
CASE STUDY: LEEDCo Offshore Wind Farm Development near Cleveland, Ohio

In May 2010, Lake Erie Energy Development Corporation (LEEDCo) announced plans for the first freshwater offshore wind farm in the U.S. The wind farm would be located near Cleveland, Ohio and consist of five 4MW offshore turbines. LEEDCo's long-term goal for Lake Erie wind production is 1,000 MW by the year 2020.

In January, 2011, LEEDCo signed an "option to lease" contract with the State of Ohio, giving them the exclusive right to pursue a submerged lands lease for the project area. LEEDCo will now gather the data necessary for the long-term leasing phase and for approval from the Ohio Power Siting Board. The lease option period under the contract is two years and can be extended up to three years, given certain performance measures are met successfully.


Phase I: Initial 20 MW Project


Phase II: Extension/Expansion


Phase III: Large Scale Windfarms

In each state/province, the permitting process for siting structures on submerged lands includes an environmental review process. On the U.S. side, this process is just one of the states' obligations under the Public Trust Doctrine. However, neither statutes nor judicial precedents support strict guidelines for what constitutes "acceptable," "justifiable," or "minimized" environmental impact.[210] This gives the responsible government agencies room for discretion, but also creates substantial uncertainty for permit applicants both in terms of the permit process itself, as well as the possibility of judicial challenge in the event that a permit is issued. The Canadian judicial system tends to give greater deference to governmental agencies than in the US. This may protect offshore wind siting decisions from excessive delays in Canadian courts.[211]

In some states, projects may need to gain local and regional approval as well. It should also be noted that, depending on the state/province and nature of the project, transmission projects may require additional permits for shoreline or sand dune construction, wetland alteration, incidental wildlife takings, road permits, and others.

Submerged Archeological Sites

Submerged archeological sites may play a role in Great Lakes bottomlands permitting. Shipwrecks have substantial cultural value to the people of the Great Lakes. To avoid permitting complications, litigation, and negative public responses offshore wind transmission could avoid disturbing any artifacts in the Great Lakes of archeological significance. The Lake Champlain-Hudson connect is currently being planned with archeological experts to avoid disturbing shipwrecks in Lake Champlain. Damage to archeologically significant sites is avoidable through careful planning. Further, remotely operated cable embedment installation equipment can navigate around shipwrecks during installation using under water cameras.[212]

Onshore Transmission Permitting

In addition to requiring new ROWs, new onshore transmission routes are subject to a number of environmental permitting processes, depending on the context of the project. Since offshore wind projects may require some new onshore transmission lines to be built, this should be taken into account in the developer's planning process.

SCANDIA WIND AEGIR PROPOSED PROJECT NEAR LUDINGTON

To provide an example of the total number of entities from which permits would be needed for an offshore project, the following lists Scandia's expected permitting requirements with certain agencies or in compliance with certain laws for its Aegir Project:

State
MI Public Service Commission
Department of Environmental Quality
Great Lake Submerged Lands
MI Endangered Species Law
Water Quality Certification

Federal
US Army Corps of Engineers
National Environmental Policy Act
US Coast Guard
Coastal Zone Management Act
Fish and Wildlife Service
Eagles Protection Act
Migratory Bird Treaty Act
National Historic Pres Act
Federal Aviation Administration

Source: Scandia Wind Offshore, The Aegir Project, PDF.

Grid Connection Approval Processes

Additional permits and studies are required to connect to the grid. This process typically requires a certificate of need and an environmental review, although the level of prescribed detail for that review varies across the states/provinces. Typically, the state public service commission (or equivalent) serves as the lead agency for permit applications and coordinates the involvement of other agencies (such as environmental agencies for environmental permits).[213]

RTOs also play an important role in the grid interconnection process, because they determine if a project is technically feasible and how its costs will be allocated. For grid interconnection in the Midwest Independent System Operator's (MISO) region, for example, generators first submit an interconnection request to MISO.[214] Then a feasibility test determines if system upgrades are minimal, which means the project can skip the system planning and analysis phase.[215] If the project passes either of the previous phases it then must go through the definitive planning phase, which requests a security deposit depending on the size of the project, to essentially test the financial feasibility of the project.[216] Proposals for larger generators must apply through the FERC "Pro Forma" process as well, which includes an interconnection request, a feasibility study, a system impact study, a facilities study, and a generator agreement.[217] Further, any rate increases need to be approved by the state Public Utility Commission via the utility.[218]

Offshore, Coastal, and Onshore Environmental Impacts from Transmission Projects to Support Offshore Wind

Although offshore wind is considered to be a clean or environmentally friendly technology to the extent that it offsets fossil fuel energy generation, building offshore wind farms and the necessary transmission will have environmental impacts. This section discusses the impacts that building transmission infrastructure can have on offshore (aquatic), coastal (the shoreline and estuaries), and onshore (continental) environments. Federal, provincial, state and local governments have permitting and approval procedures in place to minimize environmental impacts; however simple education and nominal changes in construction/maintenance practices can appreciably reduce environmental impacts on a voluntary basis. This section also discusses how carefully planned offshore wind farms can be compatible with biodiversity protection and potentially improve the offshore environment, generally.[219,220]

Offshore Environmental Impacts

This section discusses the potential environmental impacts that would be unique to offshore wind transmission projects in the Great Lakes. This section does not discuss environmental impacts that are common to commercial activity in the lakes such as: exhaust from vessels, noise and aesthetic impacts from vessels, invasive species from vessel ballast water, chemical spillage from vessels, and the impacts of anchors from vessels, all of which are not unique to offshore wind transmission projects. However, an increase in such common impacts should be considered when assessing the impacts from offshore wind projects.

General Impacts to Aquatic Ecosystems from Offshore Wind Transmission Projects

Many of the construction processes used for offshore wind transmission projects will disturb and re-suspend lakebed sediments, which may have impacts on water quality and sediment characteristics as well as disturb and displace aquatic life. Suspension of bottom materials can harm aquatic life by burying benthic species or by interfering with the respiratory mechanisms of aquatic organisms. Toxic substances can be re-suspended by construction exposing aquatic organisms to their adverse effects.[221] Although the impact of riverbed sediment disturbance on riverine benthic communities is well documented, little is known about the impacts of *lakebed* sediment disturbance on *lakebed* benthic communities. Similar to onshore transmission impacts, offshore transmission construction can impact aquatic life by contact or disturbance. Non-mobile lakebed aquatic organisms may be harmed by offshore transmission equipment and mobile lakebed aquatic life may be harmed or displaced. Protection of fish spawning grounds is a key concern for the Great Lakes, as offshore transmission construction may disturb or destroy spawning grounds, at least temporarily, by either damaging habitat, or by burying the spawning grounds with suspended sediment. Lastly, water quality may be degraded by spillage from transmission equipment, re-suspension of contaminated sediments, and most notably from any necessary dredging.[222] It is important to note that the extent of the impacts that offshore wind transmission projects will have on aquatic ecosystems will depend on the length of the transmission line and the specific habitats disturbed. Care can be taken to avoid sediment disturbance especially in areas that support fish spawning, are highly productive biologically, or where suspension of contaminants is likely to result.

Staging Areas

Staging areas will be needed for offshore wind project construction, operation, and decommissioning to handle all project components, including transmission infrastructure, transformers and cables. Project location will determine the need for construction of staging areas. A survey of the Great Lakes and St. Lawrence Seaway ports conducted by the Great Lakes Commission for the Great Lakes Wind Collaborative found that ports in the region (See Figure 24) are equipped and ready to support all aspects of offshore wind development.[223] Because these ports are adjacent to major load areas, it is likely that offshore wind development will occur in their vicinity. However, if new staging areas are necessary to support future offshore wind development there will be environmental impacts including, but not limited to: contaminant releases from runoff, accidents resulting in spillage of chemicals, debris, etc., and impacts from dredging.[224]These may not be unique to offshore wind transmission projects, but may directly result from such projects.

Figure 24: Map of the Great Lakes-St. Lawrence Seaway system, highlighting the locations of several major ports, including but not limited to the ports featured in the appendix of the GLWC Port Survey Report.[225]

Vessels

Operating the vessels necessary to construct offshore wind transmission projects will produce environmental impacts during staging, transit, and while on site. Propeller wash from ships operating at depths of twenty feet or less will **scour** the lakebed, suspending sediments and displacing aquatic organisms. If jack-up barges are used to install transmission components such as offshore substations, the jack-up legs will have a localized impact where they meet the lakebed. These supports are typically ten feet by twenty feet and will raise the vessel above the water where deployed. The legs will harm aquatic life and disturb sediments where they touch the lakebed. The lakebed penetration will be a function of vessel mass and duration of deployment (the longer the legs are used and the heavier the vessel, the more the legs will disturb the lakebed).[226]Sediment suspension from vessels will have similar impacts as discussed above.

Submarine Cable Installation

Environmental impacts during submarine cable installation will be a result of cable embedment, vessel positioning, dredging or tunneling where cables come onshore, and the temporary installation of a cofferdam. Hydro-plow embedment is the most common technique to install submarine cables in the lakebed. The hydro-plow is towed along the lake bottom and uses hydraulic pressure to fluidize the lakebed while simultaneously installing the submarine cable. This creates a trench typically four to six feet wide and eight feet deep.[227] The majority of suspended lakebed sediment is expected to settle in the trench, burying the cable.[228] The amount of suspended sediment that does not settle in the trench depends on the grain size of the substratum; large particles settle quickly (coarse sand and gravel) while fine particles (mud and clay) could be deposited over a wide area depending on currents.[229]Of the common cable emplacement technologies, burial ploughs cause the least sediment disturbance when compared to jetting systems such as tracked cable burial machines, free swimming remotely operated vehicles, and burial sleds (as of 2008).[230] To position the vessel that tows the hydro-plow and dispenses the cable, several anchors are used and continuously adjusted. This will scour the lakebed where anchors make contact or are dragged along the lake bottom. Dredging of the lakebed where cables come onshore will have the typical impacts including: temporary storage of dredged sediments on land, and release of any contaminants while dredging.[231]

Operation and Maintenance

During operation**,** scour and **heat dissipation** (or heat given off by the cables) may impact the lakebed environment. Although information is available on the effects of scour on seabed sediments from wind turbines and sea pillars, little information is available on the impacts from transmission. One study on the SwePol Link, an HVDC cable connecting Sweden and Poland, found that no mechanical disturbances to the seabed were visible one year after cable installation.[232] Scour mats (boulders or cement blocks placed over and around cables and pillars) are often used to reduce scour. These scour mats may act as new habitat for both native and non-native aquatic species. Scour from vessels during operation and maintenance is expected to be less than during construction. Wind farms are usually built with permanent moorings that would negate the need for anchors and would be used for maintenance activities for offshore substations. If the submarine cables need maintenance, impacts similar to those from cable installation will occur because the same equipment discussed above would be used.[233]A literature review conducted in 2006 of ecological research on offshore wind farms suggested further research is needed to understand the potential impacts of heat dissipation from submarine cables on aquatic habitats.[234]

Other environmental impacts to consider are the effects of artificial structures and electromagnetic fields. Offshore wind transmission infrastructure – unburied submarine cables and offshore substations – may provide habitat that could facilitate the spread of invasive species. For example, a study on the effect of gravel and boulder artificial reefs (similar to scour mats) in Lake Ontario found that invasive mussel species (zebra and quagga) abundance increased a decade after installation, as did other benthic macro invertebrate species, without substantial changes in taxa.[235]

The transmission structures may also create habitat for fish. However, some experts believe that electromagnetic fields may create avoidance behavior in electro-sensitive fishes, which would render that habitat unsuitable for such fishes. Electromagnetic fields could then present an obstacle to fish, making it harder to reach established spawning grounds and feeding areas. Because the effects of electromagnetic fields are disputed, further research is necessary. Electromagnetic fields are less appreciable when bi-polar DC submarine cables or shielded AC cables are used.[236]

Offshore wind turbines in saltwater are known to act like artificial reefs that become colonized by invertebrates, algae, and fish. However, construction and operation noises from pile driving and operating turbines, respectively, are known to induce behavioral reactions in some saltwater fish species, with detection distances ranging from 0.23-16miles.[237,238] After offshore wind turbines are built in freshwater, studies to assess such impacts may be prudent. A literature review on artificial reefs around the globe that were designed with the sole purpose of increasing fish habitat found that only 50% were successful.[239]

There is much concern over the impacts that wind turbines may have on birds and bats. Although this report focuses on transmission considerations, it is important to discuss transmission design considerations that could reduce impacts to birds and bats by directing where wind farms locate indirectly through transmission. Lake Erie, while highly suitable for offshore wind due to shallow waters and proximity to load centers, lies on the migratory path for several species of seabirds. Wind farms are a threat to birds not only from collisions but also because wind farms act as barriers on the migratory path, forcing long detours around wind farms.[240] The Nature Conservancy (TNC) is in the process of publishing a comprehensive set of recommendations for siting wind turbines in the Great Lakes that focus on reducing bird and bat mortality. Generally, research shows that siting turbines as far away as possible from bat hibernacula, migratory bird stopover sites, and other known bird and bat habitat can reduce takings. Studies have also found that the majority of bat fatalities occur when wind turbines are operating at low wind speeds. Thus, increasing turbine **cut-in** wind speeds can reduce bat fatalities by 60-80%. The TNC report acknowledges that further research is needed in many areas, such as bird ascent and descent angles, and migratory bat flight patterns.[241]

This TNC report also indicates that documented occurrences of collisions with tall structures or power lines have occurred for two federally listed bird species, the least Whooping Cranes and the Kirtland's Warblers.[242] In fact, collisions with power lines are the most likely cause of death for Whooping Cranes.[243] There are specific areas around the Great Lakes that these birds will consistently use for migrations, and siting wind turbines away from these areas should reduce the impacts on such bird populations. The TNC report lists these areas specifically. Experts suggest that weather radar and thermal infrared imagery may be an effective tool for conducting such research as well.[244,245]

Decommissioning

Generally, the environmental impacts from the decommissioning of offshore wind transmission are expected to be similar to cable installation, if the cables are removed during decommissioning (see above for details on these installation/removal practices and for associated environmental impacts). However, it is possible that some non-native material may be left on the lakebed such as fragments of cement and rock from the removal scour mats, depending on the extent they have deteriorated or are buried.[246] Environmental impacts associated with leaving the cables in place need to be evaluated and compared to removal during decommissioning.

Impacts to Coastal Ecosystems

Where offshore submarine transmission connects to shore, coastal ecosystems will be impacted. Many coastal ecosystems, including but not limited to estuaries and wetlands, are considered sensitive, although some are more fragile or ecologically valuable than others.[247] Coastal habitat may be lost during land clearing or placement of fill material during construction phases.[248] Impacts may include isolating wetlands from their water source, habitat fragmentation, reduced infiltration, and increased runoff. Beach or dune substrates may be difficult to stabilize and erosion may occur adjacent to cable routes.[249] If cement, rock or other hard permanent structures are used in the coastal environment to reduce erosion, beach and intertidal habitat may be lost and shoreline and hydrologic processes can be altered.[250]

Permits generally require temporary erosion control measures such as sediment barriers or silt fences to be installed during the clearing and grading phases to reduce sedimentation. After the onshore transmission cable system is installed, the temporary sediment barriers can be monitored until permanent erosion control measures are installed.[251] If underground cables are used, biodegradable insulation can minimize contamination risks from insulation leakage. Generally, connecting transmission to shore through sensitive ecosystems should be avoided. Sensitive habitats to be avoided in particular include wetlands, least disturbed dune systems, and locations that support populations of rare plant and animal species.

Environmental Impacts Onshore

Transmission over land causes onshore environmental impacts during construction, operation, and decommissioning. These impacts are typically most severe if new ROWs are needed to deliver power to load because vegetation must be cleared to build new lines. A one mile corridor 100 feet wide results in a loss of 12 acres of habitat when a power line is sited—a considerable impact for one mile of transmission.[252]

When new ROWs are cleared, soil erosion is often a negative consequence, as well as fragmentation of habitat when new transmission lines divide important habitats like forests or wetlands. These newly cleared areas provide the conditions in which many invasive species can thrive, and seeds of these invasive species can spread considerable distances due to inadvertent transport by construction and maintenance vehicles and workers. Maintenance activities for onshore transmission can encourage the spread of disease, as trees are wounded each time they are trimmed to maintain the ROW, making them vulnerable to infection. Building transmission lines can destroy the habitat of endangered, threatened and protected plant and animal species. In addition to impacts on habitat, electrocution is a problem for large birds—some of which are threatened species. Experts recommend avoiding construction of ROWs through or near bird hot spots, which can be identified.[253]

Onshore transmission has been built for many years, with numerous EIS providing detailed assessments on the environmental impact from particular projects. Thus, this report mentions these environmental risks, because new onshore transmission may be necessary to support offshore wind, however the impact will vary location to location and thus needs to be evaluated on a project by project basis.

Conclusion: Environmental Barriers

Environmental impacts from building the transmission needed to support offshore wind in the Great Lakes will vary from location to location. Lakebed substrate and aquatic life will be impacted by the installation, operation and maintenance, and decommissioning of offshore transmission. Substrate will be disturbed both in the lakes and along the coasts where transmission infrastructure comes ashore. Aquatic life may be killed or displaced from its habitat by installation vessels, installation techniques or maintenance. Electromagnetic fields may also impact aquatic species, although further research in this area is needed. Sensitive coastal areas may experience increased erosion, or man-made structure to prevent erosion may cause other negative changes in coastal environments. Overall, environmental impacts from transmission are expected to be local and thus strategic siting and placement of such transmission can minimize or avoid environmental impacts on the most sensitive areas.

Although there are negative local environmental impacts from building new transmission, wind energy development has substantial positive regional/global environmental benefits. Thoughtful analysis and mitigation of the negative local environmental impacts of transmission is a key component to promoting the development of this clean, renewable energy source. However, these inevitable negative impacts of transmission cannot be evaluated in isolation from the larger region and global benefits of renewable energy.

PART 3: POLICY OPTIONS TO FACILITATE OFFSHORE WIND TRANSMISSION IN THE GREAT LAKES

Overview

Part 1 of this report offers a conceptual model for understanding where transmission-related constraints may exist for offshore wind development in the Great Lakes. Through application of that model, several "minimal-constraint" development opportunities were identified, based on transmission criteria alone. However, several important factors were not quantified (e.g. exclusion areas, wind speed, public receptiveness) and may pose prohibitive technical, political, or economic barriers to development in those minimal-constraint areas. Even without such barriers, a high-growth scenario for the offshore wind industry in the Great Lakes basin is likely to entail more development than could be supported in minimal-constraint areas. Consequently, existing transmission infrastructure may be inadequate to fully support offshore wind development in the Great Lakes. To evaluate how transmission constraints may slow offshore wind development, Part 2 of this report documents the costs, planning difficulties, and environmental impacts associated with building new transmission.

Part 3 of this report offers common policy objectives and potential strategies for policymakers and private industry to address transmission issues facing offshore wind development—including access, adequacy, cost, and social and environmental impacts. These potential strategies are geared to achieve broad economic, social, and environmental policy objectives. This report identifies several offshore wind transmission-related strategies and provides an in-depth analysis of three of those strategies: grid reservation utilization, offshore grids, and wind zone planning.

Ultimately, the process for considering policy options and the actual selection of those options are matters for policymakers and stakeholders throughout the basin. Collaborative decision-making processes can ensure that interests of a diverse group of participants are represented, making those decisions less prone to political and legal challenge. Several collaborative processes are already in place in the Great Lakes region, including the Great Lakes Wind

Collaborative[xviii] and, to some extent, those facilitated by regional transmission operators (ISO/RTOs) and state power planning agencies. This part of the report is designed to incorporate the interests of multiple stakeholders who might participate in an offshore wind planning collaborative process for the Great Lakes.

Policy Objectives

The broad-level policy objectives for offshore wind described below are used to construct and evaluate policy options presented later in this report. These objectives are intended to represent the diverse perspectives of key stakeholders in the basin.

Enable Timely Transmission Expansion

Strategic transmission planning could facilitate the necessary transmission expansions to deliver power from offshore wind projects to load. Transmission projects can take seven-plus years from project conception to operation, while offshore wind projects could take much less time (i.e., 1-2 years in ideal conditions). Timely transmission expansion is important to prevent *developers* from having to make economically, socially, or environmentally suboptimal siting decisions in order to access adequate transmission.

Minimize Economic Cost

This objective is multi-faceted. Transmission-related policies and strategies can minimize overall costs to the region and ensure that the distribution of those costs is such that no single group (e.g. developers, utilities, transmission companies or ratepayers) is overburdened. Minimizing overall costs can be accomplished with strategies designed to reduce transmission needs and costs—or by planning transmission strategically to increase the size of wind facilities. Achieving this objective is essential if offshore wind is to be a competitive energy source in the future. Amending cost allocation policy to broadly distribute the costs of transmission can reduce risk-

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[xviii] The Great Lakes Wind Collaborative (GLWC) is a multi-sector coalition of wind energy stakeholders working to facilitate the sustainable development of wind power in the bi-national Great Lakes region.

and financing-related hurdles for developers associated with projects that require substantial upfront investment, including large projects or those with complicated transmission needs. Such projects may reduce the overall cost per unit of energy, or achieve some of the objectives below.

Maximize Net Environmental Benefits

Improvements in the local, regional, and global environment are primary objectives of the state/provincial and national policies driving wind development. Replacing conventional energy generation with wind energy reduces emissions of the following threats to public health and the environment:

- Carbon Dioxide emissions (causes climate change globally)
- Sulfur Dioxide emissions (causes acid rain and human lung damage)
- Smog and small airborne particle emissions (cause respiratory illnesses)
- Mercury emissions (impairs neurological functioning, particularly in developing children)
- Arsenic emissions (a carcinogen)
- River obstruction by dams and thermal pollution in river and near-shore lake environments (disruptive for aquatic habitat)
- Risk associated with radioactivity

Minimizing the environmental impacts associated with siting offshore wind turbines and their supporting transmission infrastructure would bolster the net environmental benefits of offshore wind development. Transmission policy can help to achieve this objective by maximizing the efficiency of transmission development, setting best practice standards for transmission siting and construction, and enabling development away from environmentally sensitive areas.

Maximize Net Social Benefits

Another major impetus for offshore wind development is the prospect of growing clean energy jobs in the basin—coupled with the myriad of social benefits associated with a cleaner environment. Minimizing the impact of offshore wind development on the general aesthetic beauty of the Great Lakes, a valuable cultural and economic resource, can ensure positive net social benefits. While the implications of viewshed impacts for tourism and real estate values are debated,[254] preserving the viewshed in the basin is at minimum an important quality-of-life objective for many—and, as a result, important for the political feasibility of large-scale offshore wind development. Transmission policy can address viewshed impacts by enabling development far offshore or near communities more receptive to viewshed changes. Concentrating offshore wind development in a few areas could enable siting wind facilities further from shore by using higher capacity cables that are cheaper per unit energy delivered and have fewer losses over distance, which may also help to minimize overall viewshed impacts across the Basin.

Maximize Regulatory Efficiency

Making regulatory processes “efficient” means ensuring both effectiveness and expeditiousness. Transmission permitting processes that are mindful of the public trust and legally robust can promote effective project planning, build public confidence, and mitigate legal challenge to developers. Permitting processes that are simultaneously streamlined and harmonized between state/provincial and federal agencies can reduce the transaction costs of project development and increase certainty for prospective developers and financiers.

These objectives may not be comprehensive; however, they represent a diverse set of perspectives that influence policy-making for offshore wind development. As detailed above, transmission-related policy is one strategy to achieve these objectives, either by reducing costs and impacts for transmission development itself, or by serving as a leverage point for achieving these objectives for offshore wind development more broadly. Ultimately, these objectives will be more easily accomplished if the industry and regulators together are free to site wind facilities based purely on environmental, social, political, and cost factors, without being constrained by transmission-related factors. As discussed previously, transmission constraints may currently prevent siting decision optimization based on these parameters alone—particularly as minimal-constraint siting opportunities are exhausted in the early stages of development. To the extent that transmission planners can alleviate those constraints, offshore wind development may be able to realize maximum net economic, environmental, and social benefits for the region.

Policy Options

The policy options presented below are gleaned from interviews with transmission and offshore wind professionals working in the Great Lakes region and from a literature review that encompassed offshore wind information and analysis globally. Each policy option has tradeoffs to consider; some address multiple policy objectives while others address only one and may negatively impact progress on another policy objective. Subsequent to this list, this report focuses on three policy options, including their benefits and trade-offs.

Standard-Setting Policy Options and Best Practices for Offshore Wind Transmission

Some of the following policy options are already in place in certain states or provinces in the Great Lake region; however, they are mentioned here as options for other policy makers to consider when addressing the policy objectives discussed above.

- Encourage or require buried onshore cables where practical to reduce impacts to viewsheds and birds.[255]
- Encourage or require use of shielded AC lines or bi-polar DC submarine lines to reduce electromagnetic fields.[256]
- Encourage development and implementation of transmission designed to reduce impacts to wildlife.
- Encourage or require biodegradable substitutes for cable insulation to avoid water and soil contamination.[257]
- Encourage or require use of temporary erosion control measures such as sediment barriers or silt fences during onshore transmission clearing and grading phases to reduce sedimentation loss. After installation, encourage or require monitoring of the temporary sediment barriers until permanent erosion control measures are installed or deemed unnecessary.[258]
- Encourage or require conservation of land near transmission routes to offset impacts and prevent further habitat fragmentation.
- Encourage or require sharing of core transmission infrastructure by multiple offshore wind projects, where practicable.
- Encourage transmission upgrades that have multiple economic benefits to integrate renewables.
- Discourage or prohibit submarine transmission installation where lakebed substrates are contaminated on days with high currents. Encourage installation in gravel or sand and by burial ploughs (or best technology) where practical to further minimize suspension of sediments into the water column.[259]

- Discourage or prohibit onshore or offshore transmission construction in vital ecosystems.

Policy Options to Facilitate Offshore Wind Transmission

- **Invest in intermittency management technologies like demand control and power storage.** Over the long-term, these technologies can help to integrate wind power with other energy sources and reduce the need for additional transmission infrastructure.

- **Minimize conflict.** Offshore wind development can be a contentious topic given the potential implications for local communities and the local environment. The perception of impacts on viewshed-related quality of life, tourism, real estate values, commercial and sport fisheries, recreation, and bird and bat populations, for example, can create a conflict-laden decision-making environment. Much of the general public's perceptions are informed by common misconceptions or worst-case scenario assumptions. Both policy makers and industry can endeavor to diffuse those common misconceptions and to calm misplaced fears. Gathering and disseminating information regarding the potential for impacts (or lack thereof) can help to ensure fact-based decision-making among interested parties. However, that strategy alone is rarely effective. Far more effective is the meaningful involvement of local stakeholders in the decisions that affect their communities. Harnessing public engagement at the outset of the planning phase of a project can reassure other communities that may be involved in such decision-making down the line.[260] While this best practice is more relevant for siting decisions regarding the wind turbines themselves, transmission-related decisions are inextricably linked.

- **Establish clear permitting criteria/guidelines for transmission project planning and installation.** Permitting agencies have broad discretion to define what constitutes "necessary, justifiable, or minimized" impacts, and "consistency with the public trust" (subject to judicial challenge). The lack of clearly communicated criteria to be used in permitting processes creates significant uncertainty for project developers. These criteria can be designed to minimize impacts and, consequently, to be robust to judicial challenge—particularly on the U.S. side, where there is less deference given to regulatory agencies and where the Public Trust Doctrine provides a broad platform for judicial challenge.

- **Designate a single, lead agency to coordinate all elements or promote coordination between permitting agencies, state, provincial and federal, thereby consolidate and/or streamline grid connection and bottomlands use permitting processes.** New energy facilities require state/provincial approval to connect to the grid and federal approval where they cross state/provincial and/or national boundaries. Projects (including transmission) that will alter or occupy Great Lakes lake bottoms similarly require state/provincial and/or federal approval. Because offshore wind facilities will always require both, these processes can be consolidated or coordinated to minimize the regulatory burden on project developers.
- **Harmonize timelines between state/provincial and federal permitting requirements.** Harmonizing the permitting process timeline would enable allow applicants to submit the same environmental assessment, for example, to both federal and state/provincial agencies. It would also consolidate the period of uncertainty regarding project approval, which could simplify the task of securing project financing.
- **Allow state/provincial authorities to supersede local zoning authority while mandating best-practice public engagement.** Local communities are among the most important stakeholders in offshore wind development, given potential viewshed impacts. Consequently, meaningful incorporation of local interests in both project planning and project permitting decisions is an important measure for ensuring environmental justice, optimal project design, and political resilience. On the other hand, offshore wind development brings environmental and social benefits that may not factor into local decision-making but are regionally significant. Pre-empting the ability of the local authority to veto a wind project without fair consideration for those regional benefits can actually incentivize local communities to work meaningfully with developers to *improve* a project proposal.
- **Recognize benefits of renewable energy in transmission approval and cost allocation decisions.** There are many social and environmental benefits related to the expansion of renewable energy. Many of these benefits are difficult to quantify monetarily, yet many are broadly enjoyed by the public including cleaner air, reduced pollutants, and reduced greenhouse gas emissions. Recognizing these benefits in transmission approval and cost

allocation decisions can promote development of transmission to support offshore wind. Transmission projects designed to deliver offshore wind (and other renewable energy) can be evaluated through an expedited approval process and measured against more lenient cost-recovery requirements than conventional transmission projects. An example of a similar policy is the Multi-Value projects (MVP) policy at Midwest-ISO.[xix]

- **Establish a basis for inter-RTO and international cost allocation and transmission siting.** By enabling developers to send power to multiple load centers, policymakers can improve project economics and enable larger offshore wind farms—thereby minimizing the transmission footprint per MW ratio. At the same time, load centers can hedge against wind variability by linking to wind farms in diverse locations across the basin.
    - The siting element of this can be accomplished by working with FERC to designate the Great Lakes region as a National Interest Transmission Corridor. This would establish a compact to facilitate interstate siting which would augment transmission planners working through existing institutions like RTOs.
    - One option for cost allocation is to develop projects in diverse areas across the RTO at the same time. Socializing costs is then more easily justified because direct benefits are distributed across the RTO.
- **Promote Utilization of Existing Transmission Capacity Reservations to Integrate Offshore Wind.** Strategic siting of offshore wind facilities to take advantage of existing, unused transmission capacity reservations can reduce the need for new or upgraded transmission infrastructure. Often, conventional generation facilities near the shores of the Great Lakes are operating below the level that completely utilizes its transmission capacity reservation. By transferring the unused transmission capacity to new offshore wind facilities, projects that may have earlier been constrained by lack of transmission availability could connect to the grid with minimal onshore upgrades. Offshore wind development in a low-growth scenario could potentially be enabled by utilizing unused grid reservations alone. Transferring a portion of an existing generation facility’s grid reservation to an offshore wind

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[xix] This policy indirectly considers renewable energy by including “support of a documented public policy mandate” (like a renewable portfolio standard) as one of the criteria for the broad allocation of an MVP.

facility, or coupling, would negate lengthy transmission upgrade planning and constructions processes. Grid reservation transferring or coupling will depend on the specific fuel type of the existing generation facility. Transferring all of an existing facility's grid reservation to an offshore wind facility, or replacement, is a longer-term process appropriate when existing generation facilities, reach retirement, depending on grid management needs. Utilizing existing transmission capacity to integrate offshore wind into the grid can simplify approval time, achieve environmental and public health benefits, and minimize transmission expansion or upgrades. This option is the focus of more in-depth analysis later in this report, including a closer investigation of this opportunity with existing coal-fueled generating facilities in the Great Lakes region.

- **Promote Investment in Offshore Transmission Grids by Developing Cost-Sharing Mechanisms and a Conducive Regulatory Framework.** Complex offshore transmission configurations such as meshed radial and network configurations, depending on their design, can deliver several economic, social, and environmental benefits. By bundling several offshore wind facilities into a single high-voltage connection to shore, developers that would otherwise have to absorb the full expense of connecting to the onshore grid could benefit from a shared offshore grid. This would improve the viability for development of far offshore areas, which avoid public viewshed concerns. Bundling and development of offshore grids specifically, can also reduce impacts to sensitive riparian habitats by minimizing the number of cables required overall, and over critical near shore habitat. Finally, by building "multi-value" transmission projects (congestion relief, reliability improvement, renewable energy integration), broad allocation of costs may be more justifiable and regulatory issues may be minimized. This option is the focus of more in-depth analysis later in this report.

- **Designate offshore wind energy resources zones for targeted grid investments to accommodate offshore wind.** Wind zones would be identified with consideration not only of wind resource quality (and other factors affecting developer interest), but also grid capacity, future load, transmission expansion cost, public receptiveness, and environmental impact. Several European countries have employed this approach to encourage and coordinate offshore wind development. This policy option is also proving to be successful for onshore wind in Michigan, where transmission planning for targeted zones is accelerated by expedited permitting for grid improvements. The designation process would give a pro-active role to regulators and interest groups as specific offshore areas for development are designated, rather than relying solely on reactive permitting processes. This may help to ensure streamlined development that is consistent with the public trust. Wind zones also have the benefit of clustering wind facilities in a few areas, leaving more of the Great Lakes viewshed unaffected. The close proximity of wind facilities in wind zones also enables multiple developers to share core infrastructure like offshore substations and connections to the onshore grid. This option is the focus of more in-depth analysis later in this report.

Tradeoffs

Each of the policy options above is intended to advance one or more of the policy objectives discussed earlier in this section. However, many of these policy options represent tradeoffs—either between short- and long-term costs or between economic costs and social or environmental impacts. For example, there is often a tradeoff between effectiveness and expediency in permitting processes. Policies that tend to concentrate offshore wind development in a few areas may enable certain environmental and social benefits (e.g. wind project "bundling" for transmission infrastructure and fewer aggregate viewshed impacts) at the expense of others (e.g. more concentrated environmental and viewshed impacts in a single area). Facilitating transmission expansion and socializing its costs, if not done carefully, can represent a tradeoff between expedited development and lowest cost development. These types of tradeoffs are important considerations when evaluating the policy options. Tradeoffs are explored in further detail for three of these policy options later in this report.

Current Efforts in the Great Lakes Region

The policy options presented above are broad in scope, providing a diverse set of ideas to advance strategic development of offshore wind energy in the Great Lakes region. As of the beginning of 2011, there were a number of organizations and collaborative efforts already working on transmission siting and offshore wind issues in the region. The following is a list of some of the most significant efforts:

Great Lakes Wind Collaborative: The Great Lakes Wind Collaborative (GLWC), the collaborative body for which this report was produced, is a multi-sector coalition of wind energy stakeholders working together to facilitate the sustainable development of wind power in the bi-national Great Lakes region. The GLWC, staffed by the Great Lakes Commission, coordinates collaboration and information exchange across a broad range of sectors and disciplines to identify and address the technical, environmental, regulatory, educational and financial issues related to the deployment of wind energy resources.[261] The GLWC has workgroups focused on both transmission and offshore wind issues. GLWC stakeholders and workgroup members come from many diverse sectors including wind developers, utilities, transmission companies, government agencies, environmental organizations, academic interests and others.

Michigan Great Lakes Wind Council (GLOW Council): Appointed by the prior Governor of Michigan, Jennifer Granholm, this council was comprised of 29 stakeholders in Michigan's offshore wind development arena. State agencies, academics, the general public, tribal nations, environmental groups, transmission companies, boating groups, energy / electric companies, developers, and tourism were all represented indirectly by at least one interested party.[262] During 2009, the group identified 22 criteria that could be used to identify the most and least desirable areas in Michigan waters of the Great Lakes for offshore wind development. Taking this effort a step further in 2010, the group mapped the potential developable areas in Michigan's state waters and determined that 35% of the lake area, 13,339 square miles, would be considered most favorable for the sustainable development of offshore wind.[263] Five priority areas, known as wind resource areas (WRAs), where identified as well. Also during 2010, the GLOW council developed recommendations for model legislation to govern offshore wind development, and held a number of large public meetings across the state to gather the public's view on such development.

MISO Regional Generation Outlet Study (RGOS): This MISO study was initiated to provide stakeholders with information on how to meet their renewable energy mandates and goals by developing a transmission plan that includes reliable and economic interconnect options for renewable resources. The objective of this study is to identify the regional transmission projects, with the least cost for consumers, that both meet state RPS and load servicing entity renewable goals.[264]

Eastern Wind Integration and Transmission Study (EWITS): This report was published in January 2010 by NREL to examine the expected impacts from a 20-30% wind integration scenario on the Eastern Interconnection Transmission System. The study focused on providing information for utilities, transmission operators and planning organizations. The report provides information on wind resource modeling, transmission analysis and integration analysis.[265]

Council on Environmental Quality (CEQ) October 2010 Conference: Representing President Obama's Executive Office, the CEQ hosted a two-day conference in Chicago for wind developers, Federal and state regulators, environmental advocates and other regional stakeholders to discuss offshore wind development in the Great Lakes.[266] This workshop was co-hosted by the GLWC with a goal of promoting collaboration and coordination between private developers and state and Federal agencies. Additional activities with the CEQ are expected as offshore wind development moves forward.

PART 3.1: PROMOTE UTILIZATION OF EXISTING TRANSMISSION CAPACITY RESERVATIONS TO INTEGRATE OFFSHORE WIND

Overview

The two policy options discussed in detail in parts 3.2 and 3.3 of this report (offshore transmission grids and offshore wind zones) focus on how to plan and configure *new* onshore and offshore transmission infrastructure to support offshore wind development, given the barriers discussed in Part 2 related to cost, planning difficulties, and political resistance motivated by social and environmental impacts. However, before exercising these strategies, efforts to integrate offshore wind can take advantage of existing onshore transmission infrastructure. While early-stage development may be able to find sufficient spare capacity in the existing grid, subsequent efforts to integrate offshore wind *without* expanding the onshore grid may require the transfer of existing grid reservations from existing generation facilities in the basin to wind facilities.

This section investigates the opportunities, benefits, and challenges associated with a strategy to minimize transmission-related barriers by coupling or replacing existing near-shore generation facilities with offshore wind. First, the idea of coupling is explained qualitatively for various fuel sources. Opportunities for coupling and replacement of conventional generation facilities within the Great Lakes region are then investigated, followed by the benefits, important considerations, and policy strategies associated with this strategy.

Impetus for Utilizing Existing Transmission Capacity Reservations

As discussed in Part 1, integrating offshore wind without substantial transmission constraints requires the following conditions:

4. a) Local demand is sufficient to absorb the offshore wind power, *or*

   b) There is adequate transmission infrastructure from the injection point to a large enough distant demand that is capable of absorbing the offshore wind power, *and*

5. a) Near-shore substations are available and have sufficient capacity, *or*

   b) Direct high voltage connection to distant load is economically feasible, *and*

6. Submarine transmission and coastal connection(s) are economically feasible and socially acceptable.

As discussed in Part 2 of this report, offshore wind projects constrained by any of the conditions above potentially face slow regulatory approval processes and high transmission upgrade costs. Furthermore, permitting time and transmission infrastructure costs are both highly variable and difficult to predict, which introduces uncertainty for wind developers. In some cases, grid upgrades require new or expanded ROWs, which can be difficult to secure politically, legally, and financially. Given these issues, a coupling or replacement strategy that focuses on utilizing existing onshore transmission capacity where practicable is highly attractive.

Strategically siting offshore wind projects adjacent to near-shore conventional generation facilities that are operating at low capacity factors or retiring could negate the need for onshore grid upgrades for certain projects. Typically, existing generation facilities have grid reservations for their nameplate capacity. For example, a 1000 MW coal plant would have transmission built and reserved for its use with a capacity to carry at least 1000 MW of power to load. If this plant consistently operated at 60% of capacity, the extra 400 MW of transmission capacity would go unused because it had been specifically reserved for that 1000 MW coal plant.

Many of the conventional generation facilities in the Great Lakes are currently operated below capacity, resulting in unused grid reservations. These facilities could be coupled (or ultimately replaced) with an offshore wind project with minimal or no grid upgrades. The existing facility's grid reservation would be adjusted down to better reflect its usage, and the excess transmission capacity reservation would be transferred to a new offshore wind project. This would result in "net-zero" change of grid reservations, potentially requiring minimal transmission system upgrades. New "coupling wind projects" could be directly connected to the grid at existing substations with the appropriate upgrades. Each type of generation facility, based on fuel source, presents unique opportunities and challenges, as discussed later in this section.

Transferring Grid Reservations

The strategy discussed here could be implemented *if* grid reservations could be transferred without significant legal, financial, or administrative burden. This is a major assumption and current policies may need to be amended to facilitate transfer for use by new offshore wind facilities. Currently, FERC guidelines do allow the reassignment of long-term transmission rights (more than 10 years) to other parties;[267] however, more research is needed to understand the system of grid reservations throughout the Basin, as well as the regulatory mechanisms for and potential incentive-based barriers to grid reservation transfer.

Low Capacity Factors of Existing Generation Facilities

Generation facilities can operate at low capacity factors for a variety of reasons, such as age, demand, and cost. Within a generation facility, there may be a number of individual generation units that range in age. While the nameplate capacity remains the same, an older unit typically experiences decreased efficiency resulting in a lower capacity factor. Older units can require more routine maintenance and can fail more frequently. Another reason for operation at a low capacity factor is associated with a decrease in local demand for electricity, as seen in the Great Lakes region during the recent recession. Because supply must meet demand at all times on the grid, reduced electricity demand can cause some generators to produce below nameplate capacity. Additionally, low-cost generation units are typically dispatched more consistently to keep electricity prices down, while high-cost generation facilities often run at low capacity factors, regardless of age or efficiency, to avoid high electricity prices.

Replacement Strategy for Retiring Generation Facilities

The expansion of a coupled wind farm could lead to the partial or complete replacement of a conventional generation facility with reduction of pollutants and aging of generation facilities serving as motivation for replacement. Most generation facilities tend to be retired from operation around the age of 60 years.[268] The Great Lakes region has a large number of generation facilities that are 30 to 40 years old and are likely to retire within the next couple of decades. Figure 25 shows the age of near-shore conventional generation facilities[xx] on the U.S. side of the Great Lakes. Figure 26, Figure 27, Figure 28 and Figure 29 show the age of generation facilities by each fuel type. The Ontario government aims to close all of its coal plants by 2014 and has already reallocated the associated transmission capacity, in part, to renewable energy projects through its FIT program.[269] While Quebec lies on the shore of the St. Lawrence Seaway, the province does not actually border any of the Great Lakes. Thus, no Canadian power plants are analyzed in this section.

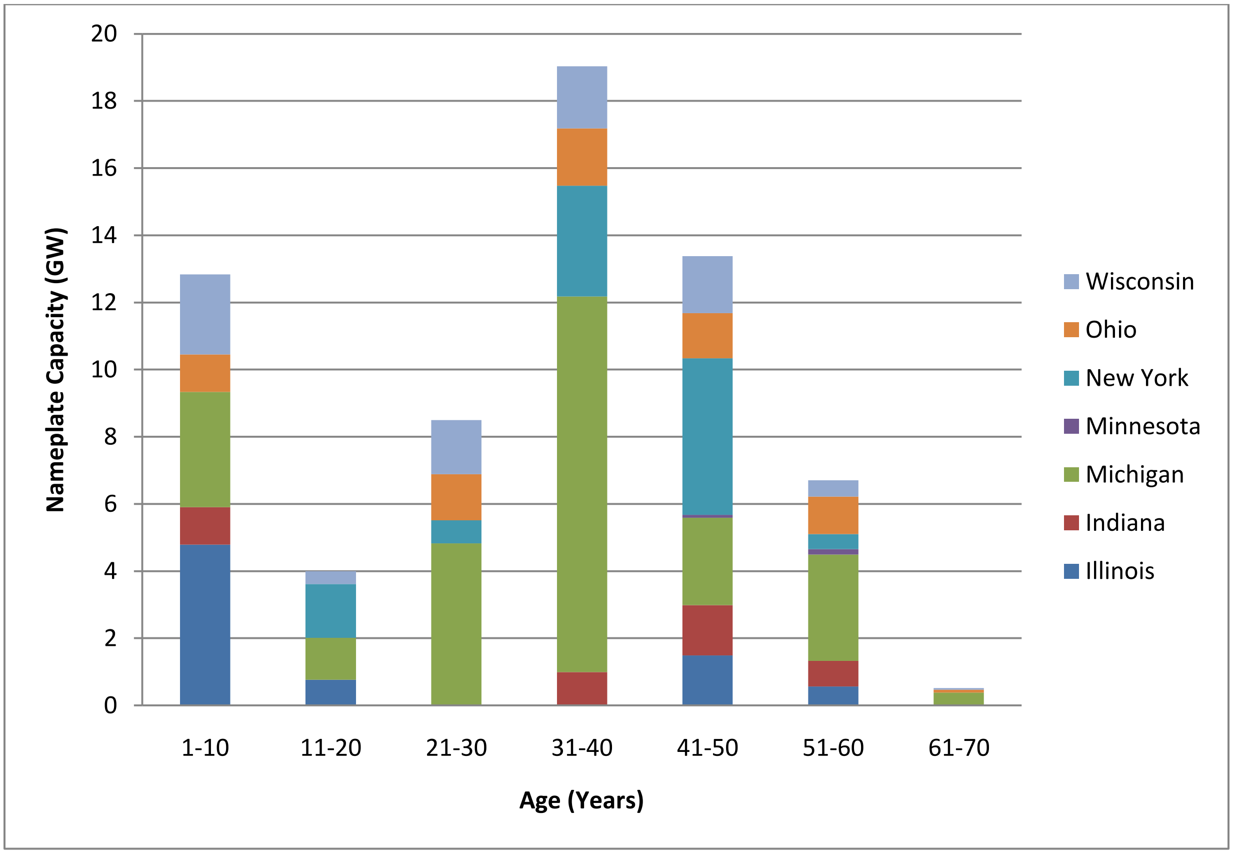

Figure 25: Nameplate Capacity versus Age of Near-Shore Conventional Generation Facilities in Great Lakes States. This figure shows the age and the nameplate capacity of all power plants above 200 MW in the Great Lakes region, in aggregate and by state. Further this figure shows the amount of generation that will be replaced in the next couple of decades.[270][xxi]

[xx] Coal, nuclear, natural gas, oil and hydro powered generation units within 20 miles of the shoreline.

[xxi] There are no generation facilities with a nameplate capacity of 200 MW or more in Pennsylvania within 20 miles from the shores of Lake Erie.

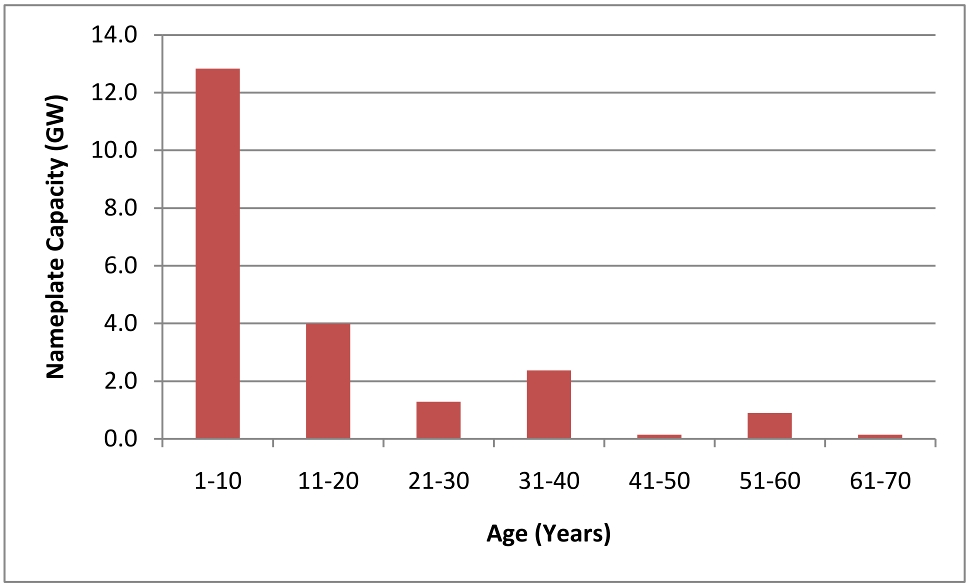

Figure 26: Nameplate Capacity versus Age of Near-Shore Natural Gas Generation Facilities in the Great Lakes States. This figure shows that the majority of natural gas generation units in the basin are relatively new and therefore natural gas may not pose a substantial opportunity for replacement.[271]

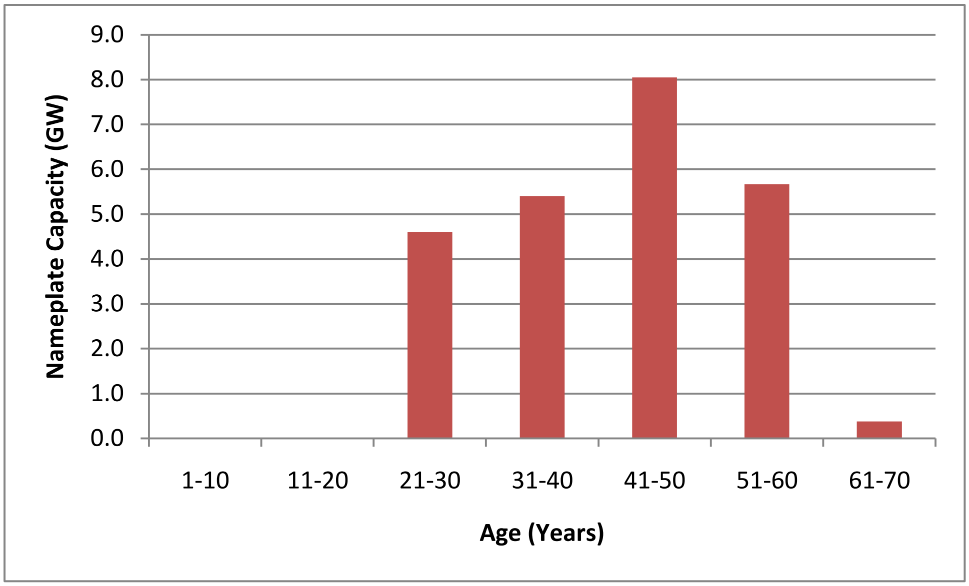

Figure 27: Nameplate Capacity versus Age of Near-Shore Coal-Fueled Generation Facilities in the Great Lakes States. This figure shows that the majority of coal generation units in the basin will need to be replaced in 1-2 decades, thus representing a substantial opportunity for transmission capacity availability for offshore wind.[272]

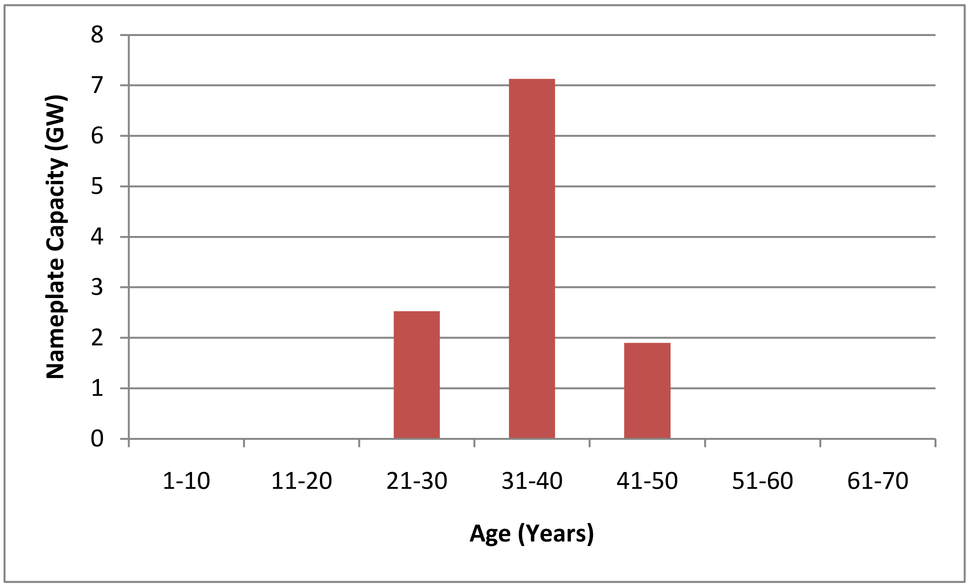

Figure 28: Nameplate Capacity versus Age of Near-Shore Nuclear Generation Facilities in the Great Lake States. This figure shows that the majority of nuclear generation facilities in the basin are aging and will need to be replaced in 1-2 decades, thus representing a low constraint transmission capacity opportunity.[273]

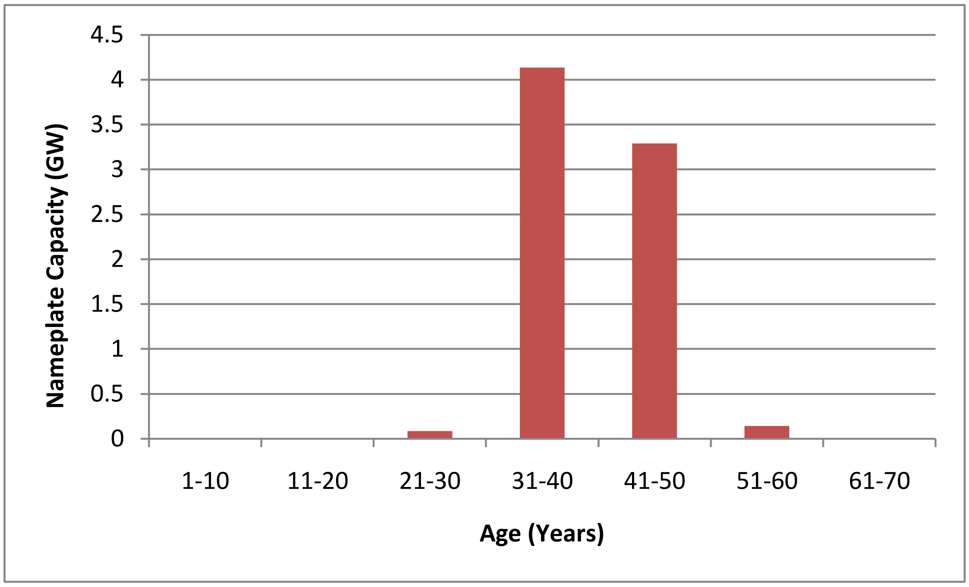

Figure 29: Nameplate Capacity versus Age of Other[xxii] **Near-Shore Generation Facilities in the Great Lakes States. This figure shows that majority of other types of generation in the basin are aging and will need to be replaced in 1-2 decades, however the transmission capacity opportunity is much less than for natural gas, coal, and nuclear.**[274]

[xxii] Other generation facilities includes: Disillate Fuel Oil (all Diesel, and No. 1, No. 2, and No. 4 Fuel Oils); Residual Fuel Oil (Include No. 5, and No. 6 Fuel Oil, and Bunker C Fuel Oil); Water, Conventional or Pumped Storage; Kerosene; and Petroleum Coke.

Considerations for Coupling or Replacement of Existing Generation Facilities

Two major concerns associated with dedicating unused grid reservations to new wind projects are intermittency and congestion. Replacing conventional base-load generation with wind generation can have negative implications for grid reliability. Most conventional fuel sources are able to be stored and dispatched in a controlled manner in order to generate an appropriate amount of electricity to match varying demand. However, wind speeds are naturally intermittent and non-uniform. Therefore, replacing a consistent base-load generation facility with a wind facility can create reliability concerns. Reliability can be managed with advanced balancing of the grid system, flexible dispatching of natural gas generation, demand control practices or energy storage technology. See Appendix H: Intermittency and Intermittency Coping Strategies) for further discussion of intermittency and intermittency-coping strategies.

Congestion relief is another consideration for this strategy. Over time, siting decisions for generation facilities throughout the basin have been made based on a wide range of factors, such as access to water for cooling and rail for shipping fuel, tax and other economic incentives, and community receptiveness. Consequently, the existing layout of generation facilities on the grid may not be ideal from a regional transmission perspective, resulting in costly congestion. If the region is to integrate additional electricity, those new generators can be sited strategically to reduce existing congestion. While the coupling or replacement strategy offers low-transmission-constraint opportunities for offshore wind integration, siting new offshore wind facilities to take advantage of those opportunities—rather than based on optimal layout of the regional grid—may result in missed opportunity to relieve congestion.[275] See Appendix B for a detailed description of transmission congestion. Thus, one potential trade-off when integrating offshore wind into the grid is coupling conventional generation facilities versus connecting directly to load. In such a case, the benefits of either option can be reviewed in order to maximize the benefit of the wind project.

Opportunity with Coal

Coal-fired generation facilities typically provide consistent base-load power and often operate at low capacity factors (see following section for regional coal power plant data). Additionally, coal plants tend to be large in generation capacity (200 to 1000+ MW) and located near the shoreline for fuel shipping and cooling purposes. Some coal-fired generation facilities are associated with relatively high environmental impacts and low efficiencies. The opportunity to couple or replace coal plants with offshore wind is ripe and the benefits are attractive. However, the challenge of transitioning base-load generation to intermittent wind poses a barrier. A detailed analysis of the opportunity for coupling or replacement of coal in the Great Lakes region is presented later in this section.

Opportunity with Nuclear

Nuclear generation is similar to coal, from the perspective of wind "coupling," in that facilities are large and provide consistent base-load power. However, some of the additional benefits of emissions reduction are not realized with nuclear under a replacement strategy, since it is not a source of carbon or other chemicals like NOx and SOx. However, nuclear generation, like other steam-turbine-based generation facilities, is a source of thermal pollution in aquatic habitats and of water vapor emissions—a debated GHG. Additionally, the domestic fleet of nuclear power plants is aging and the construction of new nuclear is currently under great scrutiny due to concerns about radioactive materials. Building a nuclear generation facility is a particularly lengthy and expensive process, relative to other conventionally fueled generation facilities. Consequently, such large sunken investments in nuclear power plants may pose a barrier to transitioning away from this technology.

Opportunity with Natural Gas

Integrating offshore wind via existing natural gas-fueled generation facilities is notably different than via base-load facilities such as coal and nuclear. Natural gas fueled generation facilities commonly serve as peaking plants where generation ramps up and down quickly. Therefore, natural gas fueled generation facilities often exhibit inconsistent capacity factors and corresponding unused grid reservations. This ability to change generation quickly is favorable for coupling with wind since the natural intermittency of wind could be "dampened" by the controlled peaking of natural gas fueled facilities. However, the concept of transferring unused grid reservations from conventional generation facilities to offshore wind projects may require more integrated agreements between facilities. Rather than completely selling or transferring grid reservations, a coupling arrangement with natural gas-fueled facilities would likely function more like a partnership with continuous monitoring of and communication about real-time generation. It should be noted that certain natural gas technologies, like combined heat and power (CHP), do function more like base-load generation facilities and have thus have the opportunity to participate in more direct grid reservation transfers as with coal and nuclear.

Opportunity with Petroleum

Petroleum represents less than 1% of fuel sources in all eight states and two Canadian provinces in the Great Lakes region (see Appendix E for more details on energy portfolios in the region). However, petroleum exhibits many of the same peaking capabilities and concerns as natural gas discussed above.

Opportunity with Hydro

Hydropower exists in various forms, serving both as base-load and peaking depending upon location and application. Hydropower is sometimes able to store energy via damming, enabling consistent base-load generation despite environmental variations. In certain circumstances, hydropower is able to ramp up and down quickly via connecting and disconnecting turbines. Existing hydropower also ranges greatly in capacity, from run-of-the-river turbines to large dams. There is a dearth of opportunity and public support for constructing new hydropower in the Great Lakes region. The opportunity for coupling hydropower with offshore wind must be analyzed on an individual basis as hydropower is such a diverse generation type. There are only three hydropower facilities on the U.S. side of the Lakes that have a nameplate capacity of least 200 MW and that are within 20 miles of the shoreline (Ludington and two at Niagara).[276]

Great Lake Basin Coal Generation Facilities Grid Reservation Opportunities

This section of our report specifically investigates the opportunity for coupling or replacing coal generation facilities with offshore wind power. Coal, a significant fuel source for much of the Great Lakes region, is the object of focus here because it offers opportunities for regional environmental and public health improvements (See Appendix E for detailed fuel mix data). Coal plants also provide good opportunities to couple with offshore wind because coal plants are typically located near large bodies of water for cooling purposes and often run below full capacity. A transition away from existing coal generation could contribute substantially to RPS goals and efficiency standards. While the general coupling and replacement strategies discussed in this part of the report can be utilized with any type of existing generation facility, including nuclear, natural gas, and petroleum, coal presents both the largest opportunity for integrating wind using existing grid reservations and also unique opportunities given the wide-ranging benefits of offsetting coal with offshore wind.

Existing lakeside coal-fired plants within one mile of the Great Lakes shoreline have an average capacity factor of 57% (see Table 8). The unused reserved transmission capacity from these coal plants total 12.3 GW.

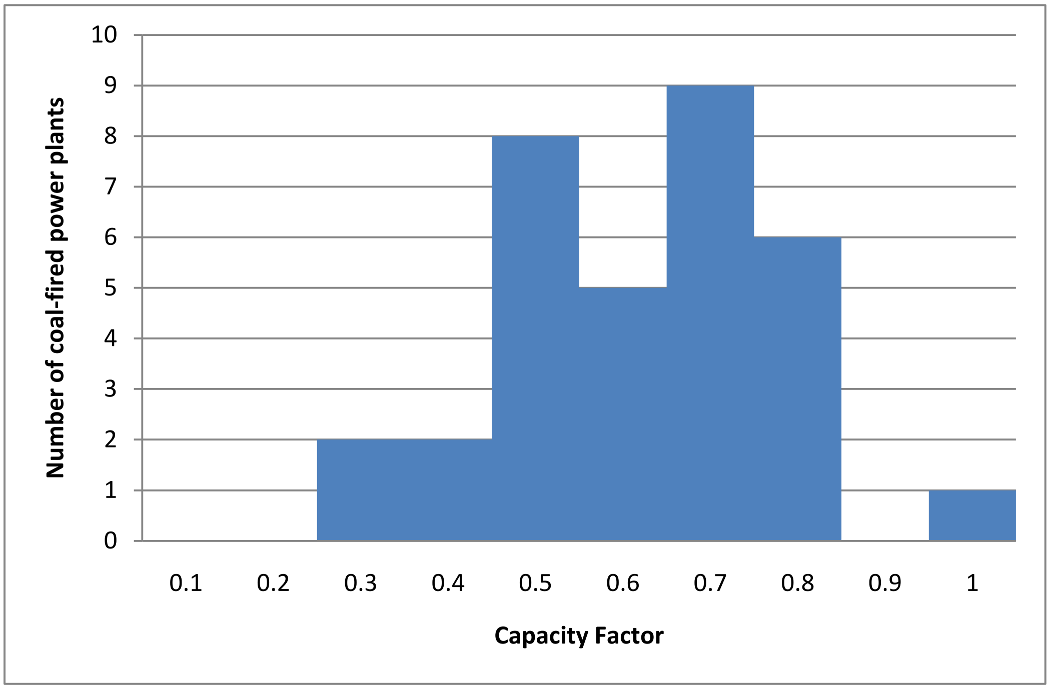

Figure 30: Distribution of Capacity Factors Of Near Shore Coal-Fired Generation Units In The Great Lakes Basin. This distribution shows how large portion of generation units use a fraction of their grid reservation.[277]

Ontario Phasing Out Coal Plants - Grid reservation transfers are not a novel concept for the province of Ontario. Pursuant to the Green Energy Act of 2009, Ontario is on track to eliminate all coal-fired generation in the province by 2014. Anticipating this shift in electric generation infrastructure and as part of its feed-in-tariff (FIT) program, the Ontario Power Authority awarded 3,000 MW of renewable energy contracts in 2010. These contracts were awarded in part based on unused grid reservations on the existing grid, taking into account the anticipated removal of the coal-fired power from the lines. With contracts awarded, Ontario has exhausted its spare grid capacity and, consequently, the "coupling or replacement" development strategy outlined above is not applicable in Ontario. On another note, Ontario is waiting for operational knowledge from freshwater pilot projects in Ohio and Sweden before approving offshore wind FITs.

Source: Ontario Power Authority Staff. Personal Interview. 2010.

Data from EIA[278] and the EPA eGrid database[279] for coal plants with nameplate capacities of 200 MW or higher located within 20 miles (32 kilometers) of the shoreline were used to conduct this analysis. The data do not include coal plants in the Canadian provinces of Quebec and Ontario because Quebec does not lie on the shore of any of the Great Lakes, and Ontario is actively phasing out coal plants by 2014. Similarly, no data from Pennsylvania is presented as the state does not operate any power plants over a 200 MW nameplate capacity within 20 miles of the Lake Erie shore. Ontario has reportedly reallocated the transmission reservations of its coal plants through FIT contracts (see accompanying text box).[280] Coal generation facilities in the basin that satisfy conditions above have a total nameplate capacity of over 28 GW. Taking into account each facility's annual capacity factor, these coal facilities provide a coupling potential of over 12 GW of transmission capacity via unused grid reservations. As seen in Table 8 below, almost all of the coupling potential lies right on the shoreline (<1 mile inland from shore). This is particularly beneficial since additional onshore transmission lines would not be required to connect an offshore wind project to the power plant. Table 9 shows aggregated nameplate capacity and unused grid reservation broken down by state.

Table 8: Existing Lakeside Coal Generation Facilities in the US Great Lakes Region. This table shows the substantial amount of unused transmission capacity at coal plants throughout the basin.[281]

	Distance Inland from Shore (mi)	Total Nameplate Capacity (GW)	Average Capacity Factor	Total Unused Grid Reservation (GW)
	< 1	25.26	0.55	11.26
	1-5	2.90	0.66	0.99
Totals		**28.16**	**0.57**	**12.25**

Table 9: Existing Near-Shore Coal Plants in the Great Lakes States Grid Reservations Over 200 MW. This table shows total nameplate capacity, capacity factor, and unused grid reservations of power plants with at least 200 MW of nameplate capacity by state and distance from shore.[282]

State	Distance Inland from Shore (mi)	Aggregated Plant Nameplate Capacity (GW)	Average Plant Capacity Factor	Aggregated Unused Grid Reservation (GW)
IL	< 1	2.38	0.44	1.33
IN	< 1	2.69	0.53	1.28
MI	< 1	11.93	0.55	5.38
	1-5	1.66	0.57	0.72
MN	< 1	0.25	0.64	0.09
NY	< 1	1.92	0.57	0.84
OH	< 1	3.33	0.63	1.23
WI	< 1	2.75	0.60	1.12
	1-5	1.24	0.78	0.27

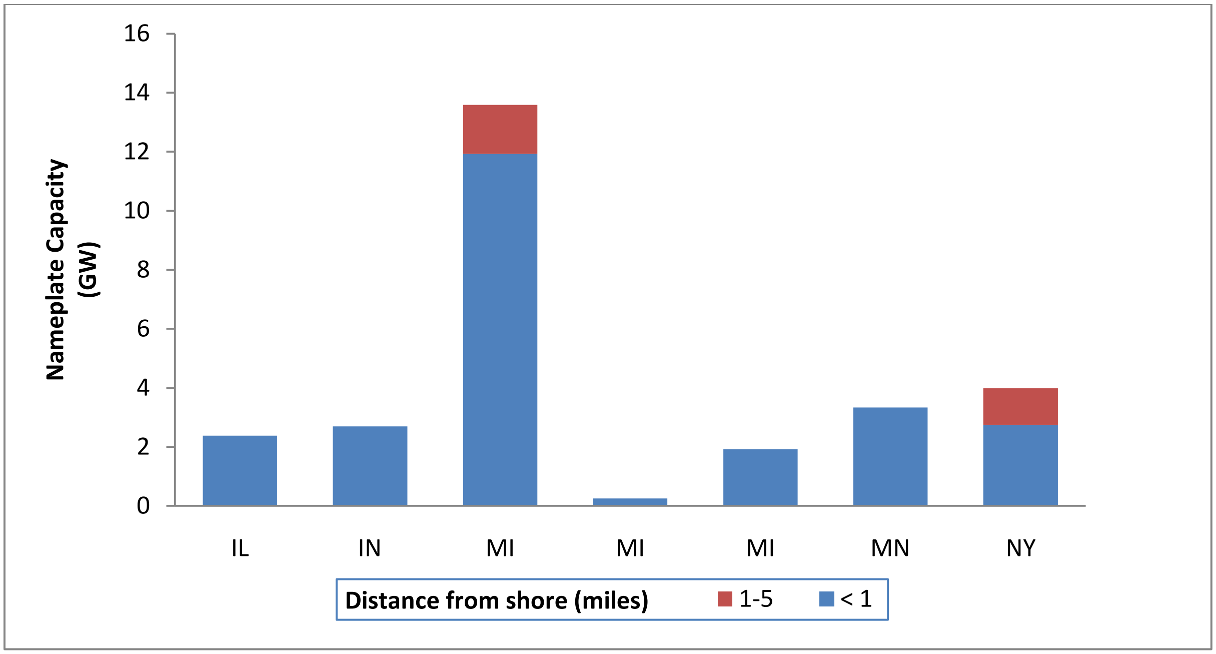

Figure 31: **Aggregated Nameplate Capacity of Existing Lakeside Coal Generation Facilities in the Great Lakes States. This figure offers a visual comparison of the data in the above table, specifically total nameplate capacity of power plants with at least 200 MW of nameplate capacity by state at various distances from shore.**[283]

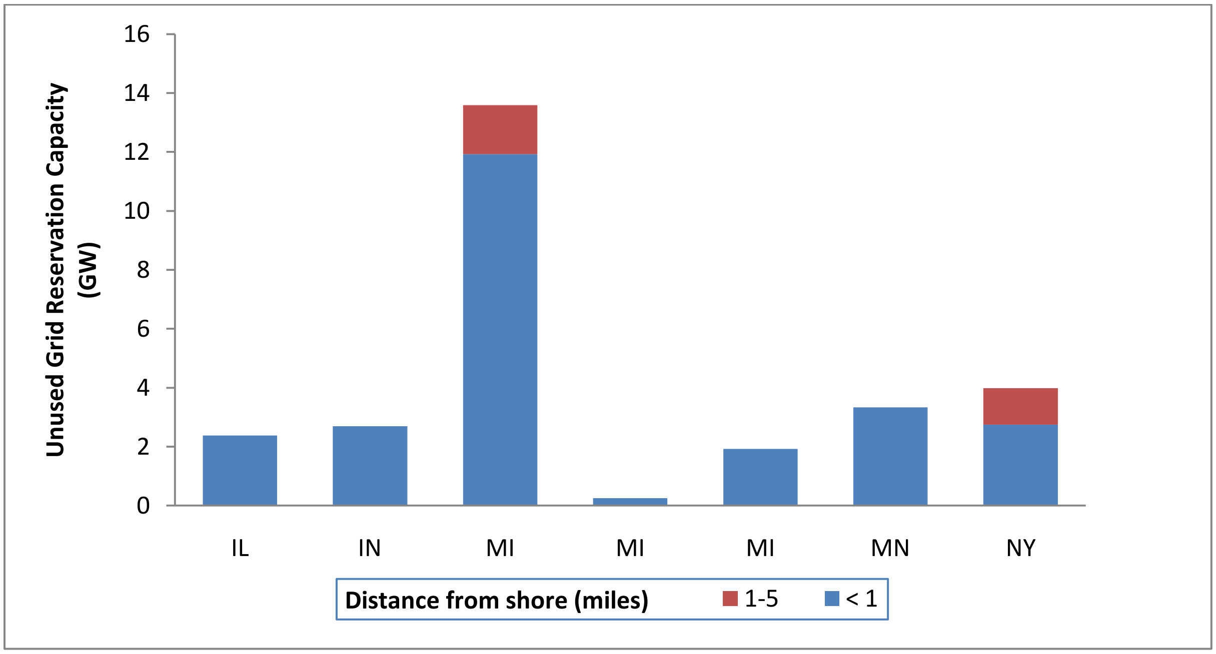

Figure 32: **Aggregated Unused Grid Reservation of Existing Lakeside Coal Generation Facilities in the Great Lake States. This figure offers a visual representation of the above table, specifically comparing total unused grid reservations at power plants with at least 200 MW of nameplate capacity by state at various distances from shore.**[284]

Offshore Wind Potential near Existing Generation Facilities

In order for offshore wind projects to take advantage of excess transmission capacity at existing generation facilities, there must be sufficient offshore wind speeds and lake area with developable depth to construct economical wind facilities within close proximity. Using GIS software, the potential for wind facilities located near existing lakeside generation facilities with suitable replacement characteristics was calculated. Assuming a 10 MW per square mile wind turbine density in waters less than 30 meters deep, an aggregated 64 GW are developable within 25 miles of power plants in the Great Lakes region with nameplate capacity greater than 200 MW. After imposing a 6-mile shoreline exclusion buffer, developable power potential within the 25-mile radius is 20 GW. Figure 33 below shows how this developable power potential varies with the radius from the power plants and the shoreline exclusion buffer imposed. It should be noted that local wind speed data were not considered in this exercise. Insufficient wind speed may rule out development in some of the areas included in the calculations presented below. The following figures (Figure 34, Figure 35, Figure 36 and Figure 37) break the data down by state.

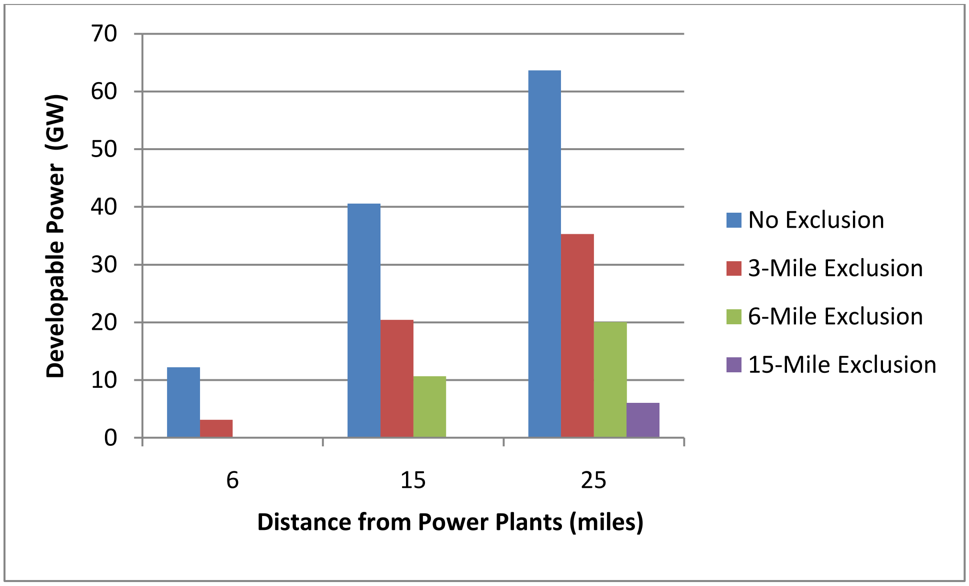

Figure 33: Offshore wind development potential at various distances from all power plants with 200 MW or more capacity throughout the Great Lakes region and with various shoreline buffers. Assuming 10 MW/sq mi nameplate capacity and feasible depths are <30 meters.[285]

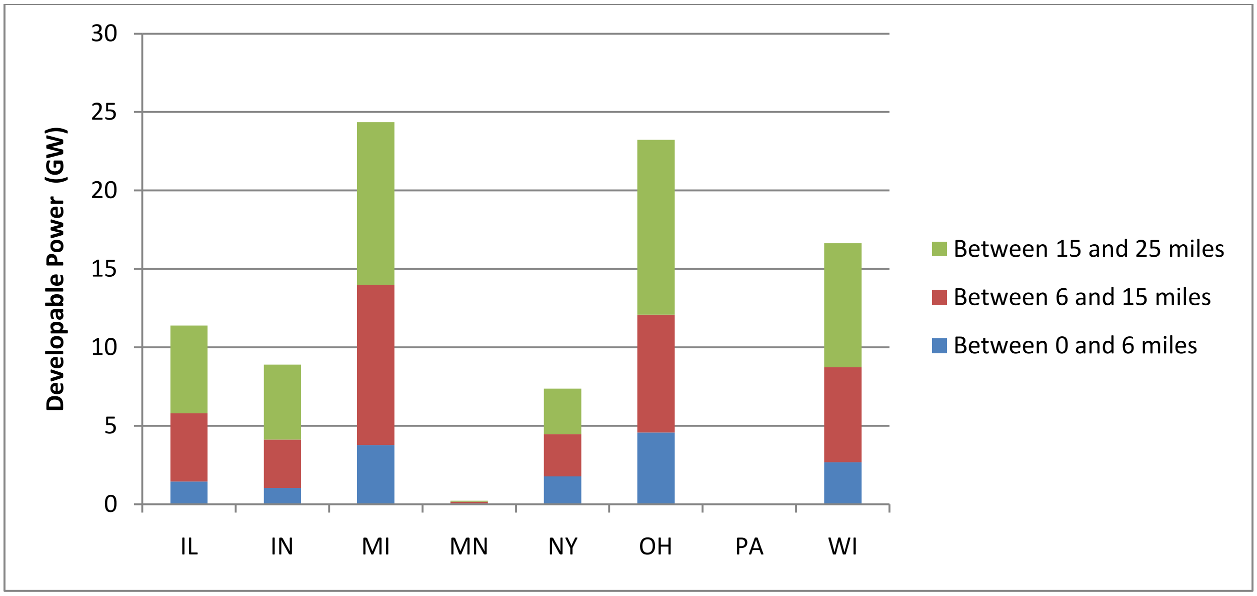

Figure 34: Total Developable Power Capacity by Various Radii from Shore with No Shoreline Exclusion Buffer Using Depths Less Than 30 Meters for Each State in the Great Lakes Region. [286]

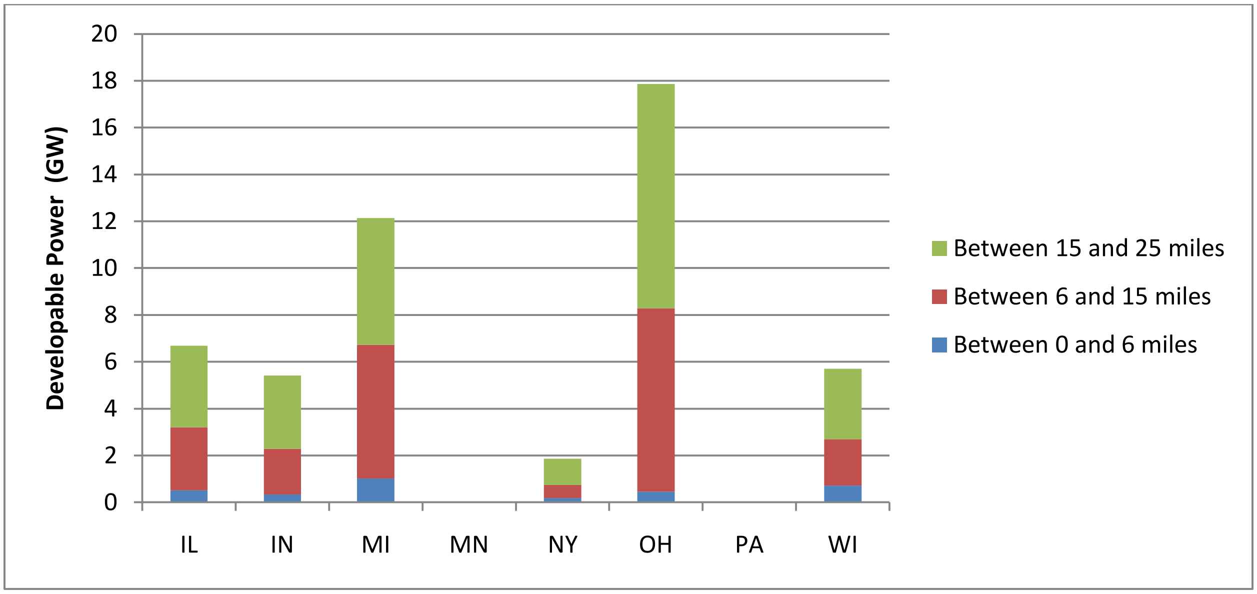

Figure 35: Total Developable Power Capacity by Various Radii From Shore With Using a 3 Mile Shoreline Exclusion Buffer Using Depths Less Than 30 Meters for Each State in the Great Lakes Region [287]

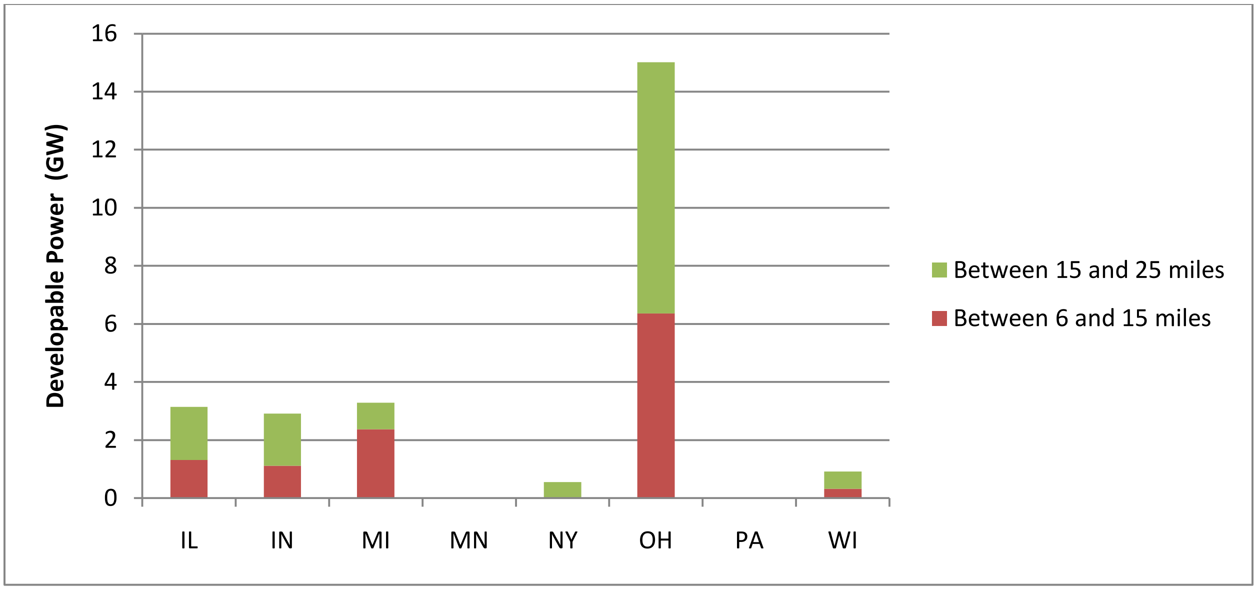

Figure 36: Total Developable Power Capacity by Various Radii From Shore With Using a 6 Mile Shoreline Exclusion Buffer Using Depths Less Than 30 Meters for Each State in the Great Lakes Region[288]

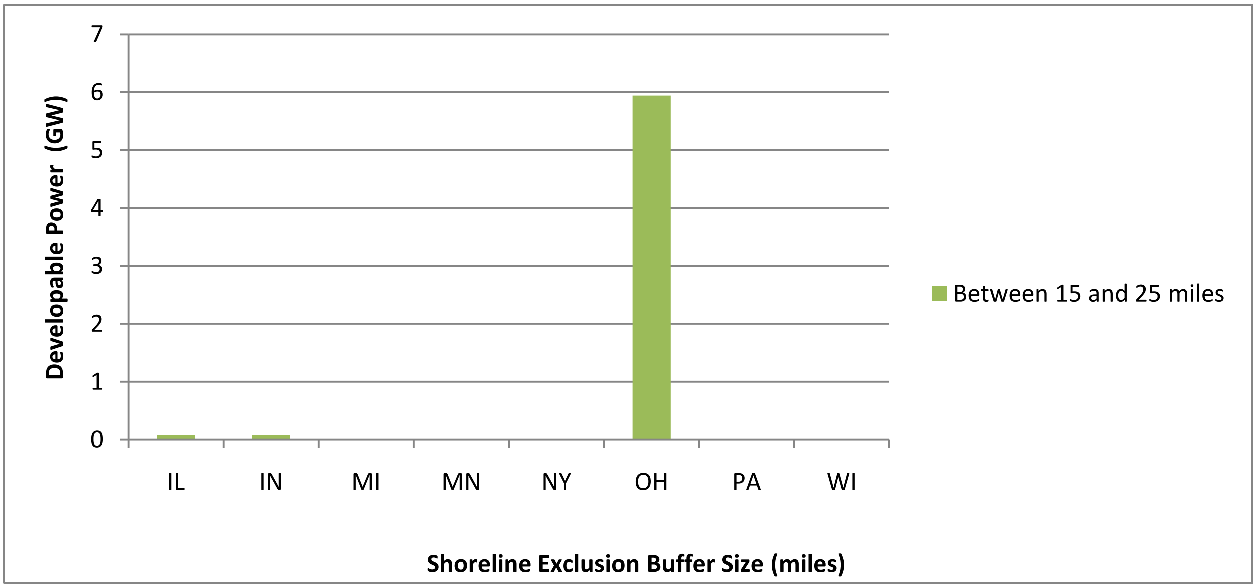

Figure 37: Total Developable Power Capacity by Various Radii From Shore With a 15 Mile Shoreline Exclusion Buffer Using Depths Less Than 30 Meters for Each State in the Great Lakes Region.[289]

To illustrate how these results were calculated, the figures below show a 25-mile radius drawn from the Ludington Pumped Storage facility in Michigan. The color gradient in Lake Michigan represents depth intervals 0-30m, 30-60m, 60-90m, and >90m. Note that the radius appears distorted due to a GIS projection that maintains accurate *area* while distorting shapes (equal-area conic).

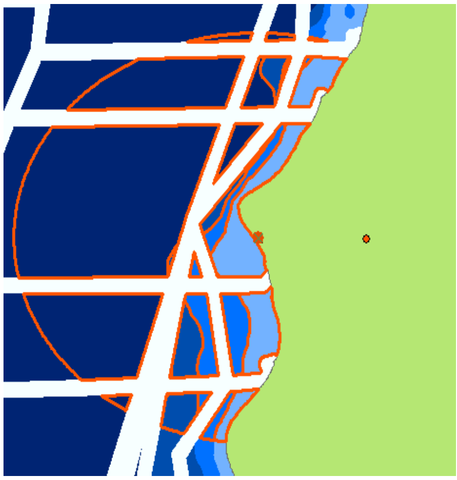

Figure 39: Example of GIS analysis to determine developable power potential for a single location using a 25-mile radius and no shoreline exclusion buffer and shipping routes excluded.

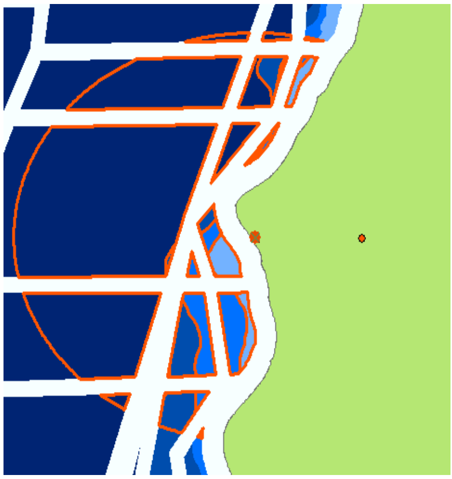

Figure 38: Example of GIS analysis to determine developable power potential for a single location using a 25-mile radius and a 3 mile shoreline exclusion buffer and shipping routes excluded.

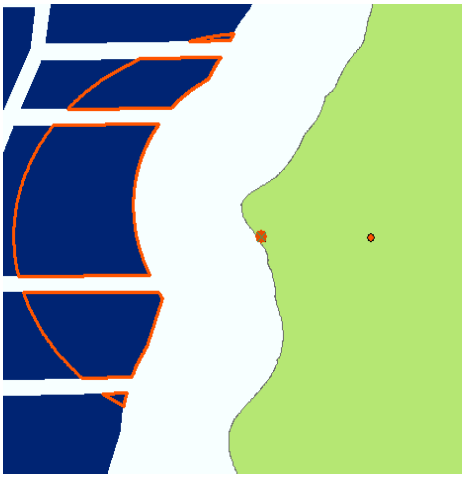

Figure 41: Example of GIS analysis to determine developable power potential for a single location using a 25-mile radius and a 15 mile shoreline exclusion buffer and shipping routes excluded.

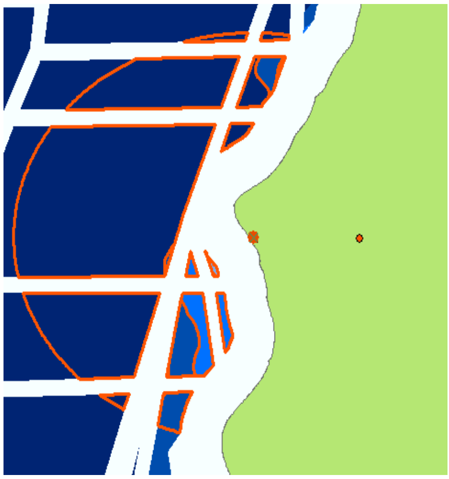

Figure 40: Example of GIS analysis to determine developable power potential for a single location using a 25-mile radius and a 6 mile shoreline exclusion buffer and shipping routes excluded.

Benefits of a Coupling or Replacement Strategy

Economies of Scale

Large, unused grid reservations held by existing generation facilities provide a gateway for large-scale wind power injection, enabling developers to attain the economies of scale necessary to make offshore wind competitive. For example, one coal plant in Michigan has a nameplate capacity of 1.9 GW, a capacity factor of 25%, and sits less than a mile inland from shore. Hypothetically, a maximum of 1.4 GW (the unused 75% of the grid reservation of the coal plant) of offshore wind power could be coupled with this power plant.

Cost Savings

The identified generation facilities have existing substations directly on or near the shore. Offshore wind projects that replace existing generation facilities can reduce upfront capital costs and avoid social and environmental impacts by utilizing existing infrastructure. An integral benefit of replacing existing generation facilities is the potential for increased social and political receptiveness. If an offshore wind project can replace a fossil fuel or nuclear plant, potential transaction costs associated with siting and permitting the offshore wind project may be reduced if local residents and regulators perceive offshore wind as an improvement over the existing facility.

Transmission infrastructure cost savings would vary on a case-by-case basis. Depending on the extent of transmission expansion avoided, these savings can represent only a small fraction of overall capital costs for a typical, large-scale offshore wind farm.[290] However, for smaller offshore wind facilities, these costs can comprise up to 20% of the cost of generated energy. For example, a project that avoids construction of an onshore substation (estimated for this hypothetical example at $5.6 million) and 20 miles of onshore transmission cable (estimated at $1.5 million per mile)[291] would save approximately $35 million in upfront transmission system costs. For a 100MW wind project with a 40% capacity factor and a 15% capital recovery factor, the reduction in the cost of generated electricity could be up to 1.5 cents/kWh, without considering upgrades to the existing substation to allow for wind facility connection (see text box below).

Capital Cost of Onshore Transmission = $35 million
Capital Recovery Factor = 15%
Annualized Capital Cost for Transmission= $5.25 million/year

Nameplate Capacity of Wind Facility = 100 MW
Capacity Factor = 40%
Annual Generation = 100,000 kW * 40% * 8766 hours/year =350 million kWh/year

Contribution of transmission infrastructure to cost of generated electricity
= $5.25 million per year / 350 million kWh per year
= 1.5 cents/kWh

Streamlined Approval Process

A coupling or replacement development strategy also benefits from a partially streamlined regulatory process. New wind projects require approval from the regional ISO, which could be expedited if existing transmission systems were utilized. MISO's ideal transmission service request time line is shown below in Figure 43. The approval process under a coupling or replacement strategy could exempt the transmission system impact study since no new transmission lines would be needed (See Figure 42 and Figure 43 below).[292] Note that the impact study phase ranges from day 45 to day 105, accounting for about 25% of the ideal service request time span. Additionally, building new transmission typically takes 10 years, and thus if existing transmission were used, this time and related cost would be eliminated.

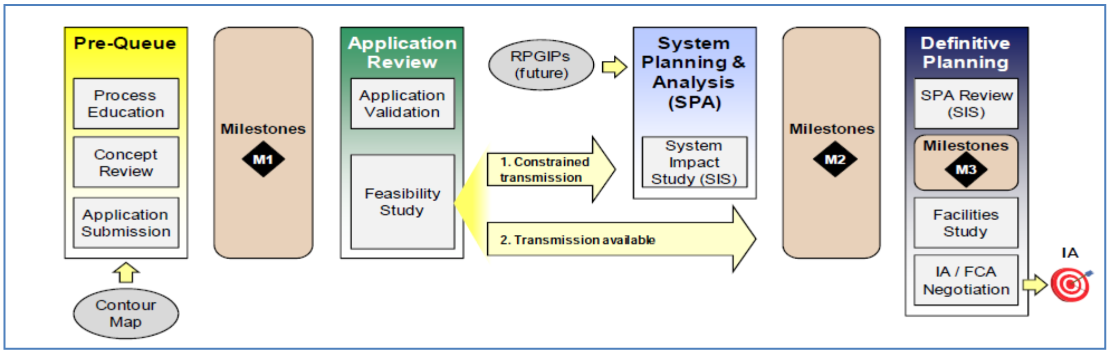

Figure 42: MISO Grid Connection Application Process. This figure shows how if transmission is available, system planning and analysis is unnecessary.[293]

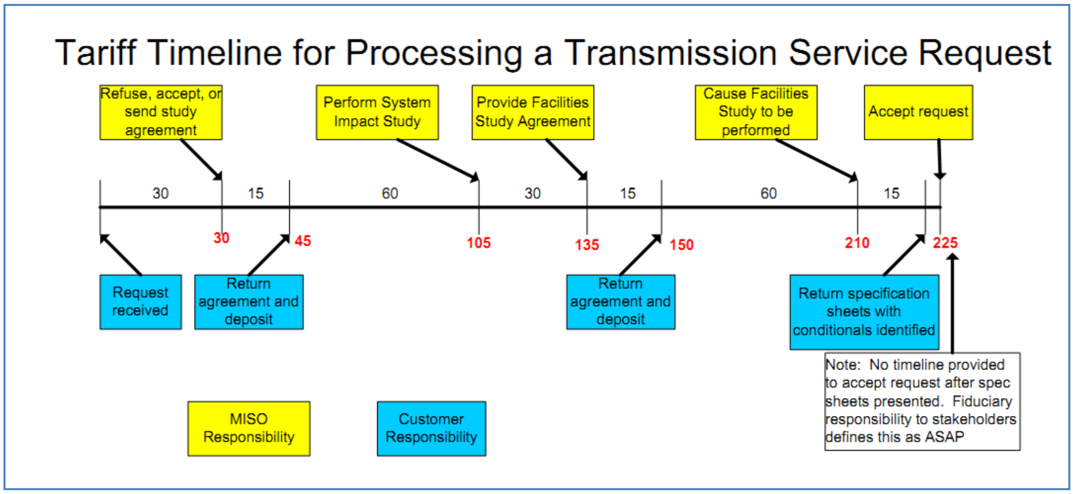

Figure 43: MISO Transmission Service Request Timeline (in days) shows that grid transfers could reduce the interconnection permitting process by 60 days.[294]

In MISO, this streamlined approval process has worked for Harbor Beach, where DTE is pursuing a coupling strategy for an onshore wind project and its Harbor Beach coal generation facility in the Saginaw Bay area of Michigan. [295, 296]

Environmental and Social Benefits

In addition to the direct cost and regulatory benefits, coupling or replacing existing lakeside generation facilities with offshore wind projects can have a number of broader benefits for the region. These benefits include improving air and water quality, minimizing viewshed impacts, and avoiding onshore transmission development.

Replacing older, less efficient generation facilities with offshore wind facilities would reduce regional emissions. Such a transition would play a role in helping the region to meet National Ambient Air Quality Standards (NAAQS) and state greenhouse gas (GHG) reduction goals. Also, conventional generation facilities often use an abundance of water in a consumptive and non-consumptive manner (one of the reasons why they are sited near lakes and rivers). A transition from conventional generation sources to wind power would improve both water availability and quality, which is particularly important in the Great Lakes—the largest group of freshwater lakes in the world. Meeting NAAQS standards, reducing GHG emissions, and improving water quality would boost public health. These are important benefits of a coupling or replacement strategy.

A coupling or replacement strategy can also help to maintain the scenic beauty of the Great Lakes Basin over the long-term. Clustering wind development into larger projects would have the effect of preserving the viewshed of a greater proportion of the lakes for a given amount of offshore wind power. Furthermore, by siting these larger projects adjacent to existing generation facilities, the viewshed will be affected in areas already characterized by major industrial development, thereby minimizing potential marginal impacts of offshore wind on scenic beauty.

Coupling or replacement would also avoid onshore development impacts. If grid capacity can remain constant, no onshore transmission infrastructure would need to be built. This would avoid such environmental impacts as habitat fragmentation, sedimentation of water ways, and wildlife takings, to name a few.

Implications for Policymakers

A major benefit of this strategy is that it can be employed by developers without explicit policy action, although policymakers can provide integral support to coupling or replacement strategies. Developers may selectively adopt this strategy where it makes sense to do so economically. The regulatory structure is currently in place in MISO and the incentives for wind developers are inherent—particularly in areas where interconnecting new power is likely to require transmission system upgrades. However, as discussed previously, more study is needed to determine whether there is a need for policy intervention to facilitate transfer of unused grid reservations. Current holders of unused grid reservations may not have sufficient incentive to release those reservations to wind developers. The ability of wind developers to obtain currently unused grid reservations is critical for the success of this strategy.

Part 3.1 Conclusions

This section described the opportunity to use existing transmission capacity reservations to integrate offshore wind via near-shore conventional generation facilities. Unused grid reservations can be transferred to new offshore wind projects, enabling grid interconnection with minimal transmission barriers. The coupling strategy is targeted at facilities operating at low capacity factors and the replacement strategy is targeted at retiring facilities. Depending on the type of fuel source being replaced, the type of arrangement made for grid reservation transfer will vary. There is a potential to develop up to 64 GW of offshore wind power within a 25-mile radius of these power plants, while over 12 GW of reserved grid capacity remain unused by coal plants, 1.5 GW by nuclear facilities and possibly more by peaking power plants (See Table 9 to give context to this power potential)[xxiii]. The potential benefits of utilizing existing transmission capacity reservations include minimal transmission upgrades, streamlined approval process, maintenance of viewshed integrity and improved public health. The potential barriers include lost opportunity to reduce congestion if not directly connected to load, intermittency issues when replacing base-load generation, complex grid reservation agreements for peaking facilities, and potential issues related to the transfer of grid reservations generally. A major strength of integrating offshore wind via existing conventional generation facilities is that wind developers are able to utilize this strategy without direct action by policymakers.

[xxiii] While the capacity factor was used as a proxy for grid utilization by base-load generating facilities, such an assumption was not made for peaking plants as they generate at or close to nameplate capacity during peak load durations.

Coupling and Replacement of Existing Generation at a Glance…

Potential Benefits:

- Minimal transmission grid upgrades
- Streamlined regulatory approval process
- Opportunity for large-scale offshore wind projects
- Maintain viewshed integrity
- Improve air quality, water quality/availability and emissions

Potential Barriers:

- Lost opportunity to reduce congestion, if not directly connected to congested load
- Reliability concerns due to wind intermittency
- Complex grid reservation partnerships for coupling with peaking fuel sources

PART 3.2: PROMOTE INVESTMENT IN OFFSHORE TRANSMISSION GRIDS; DEVELOP MECHANISMS FOR COST-SHARING AND INTER-JURISDICTIONAL PERMITTING

Overview

As discussed in Part 2 of this report, the substantial transmission components needed for offshore wind development include offshore substations and the cable connection to the onshore grid. Since developers typically bear the entire cost of connecting to the onshore grid, transmission costs for the connection to shore could present a major hurdle to offshore wind development, particularly as developers look far-offshore to access higher wind speeds and avoid many social and environmental impacts associated with near shore sites. Under some circumstances, sharing shore-connection transmission infrastructure can reduce the costs borne by a single developer, thereby improving the economic feasibility of far-offshore projects. Offshore transmission grids can promote infrastructure sharing and, if well planned, also enable new opportunities for energy trading and enhance grid reliability. The following section discusses offshore transmission grids, their benefits and challenges, policy actions to promote their construction, and examples of existing or proposed offshore grids.

Offshore Wind Transmission Configurations: Radial and Network

Radial Configurations

In the current model of grid integration of offshore wind facilities, each wind facility typically has an individual connection to shore. The wind facility and the injection point are the only transmission terminals in this configuration. The images below demonstrate several possible configurations for offshore wind projects. In Figure 44, depicting the business as usual scenario, each wind facility has a separate connection directly to the onshore injection point. In Figure 45, a group of wind facilities has a radial connection to shore. These wind facilities could be built in the same time-frame or, if the initial installed cable has enough additional capacity to accommodate subsequent wind facilities, those additional facilities could be brought online in stages (see Figure 46) by simply connecting to the nearest existing offshore substation.

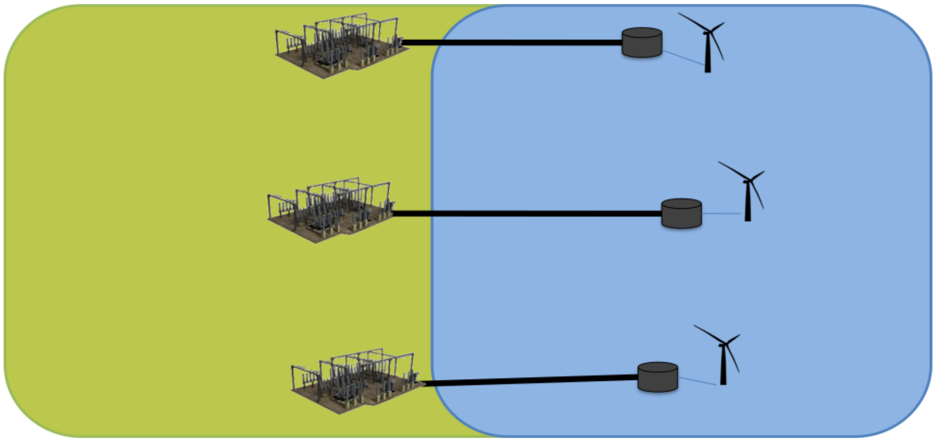

Figure 44: Wind facilities with individual connections to shore (Business-As-Usual)

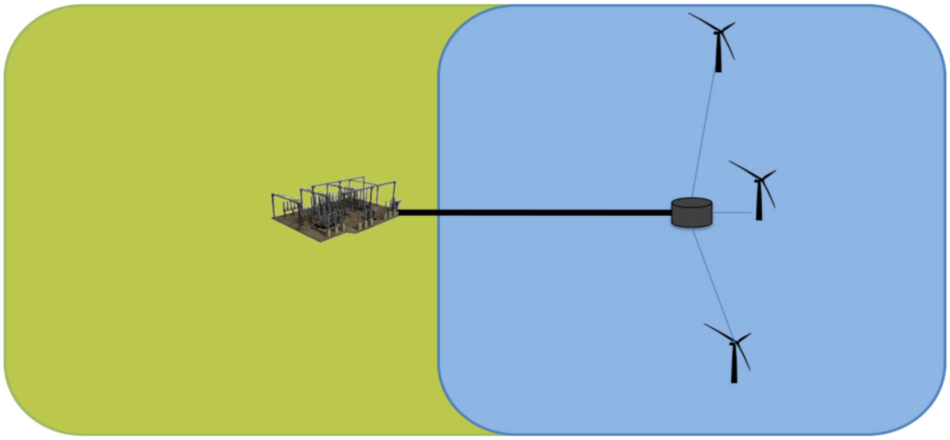

Figure 45: Wind facilities connected to shore in a radial configuration. Wind farms can connect to the offshore substation at different times or in stages. This type of configuration require cooperation by multiple developers and pre-planning and might require nuanced cost recovery schemes.

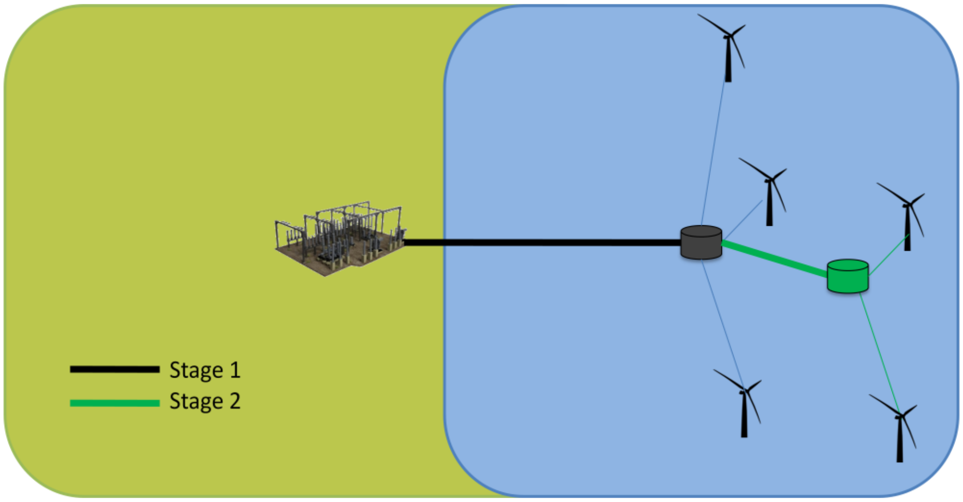

Figure 46: Multistage transmission of radial connection of wind facilities to shore. This type of configuration requires cooperation by multiple developers and pre-planning and might require nuanced cost recovery schemes.

The optimal configuration for a particular offshore wind project will vary. While the transmission cost per unit energy delivered generally decreases as cable capacity increases,[xxiv,297] bundling several offshore projects into a single connection to shore may not always decrease the cost per unit energy delivered for those projects. Depending on the distance between offshore wind facilities relative to the distance to shore, the added cable and offshore substation cost to link offshore wind facilities may surpass the savings generated by sharing a shore connection cable.

Reliability may also be a concern. Hypothetically, failure of the offshore substation or cable link to shore depicted in Figure 45 above would disrupt delivery of wind energy from all the other projects. This would represent an economic loss for the wind facilities, and also for the rate payers, because to balance the loss of a large amount of energy to meet demand would require dispatching costly peaking plants of equal capacity. In such a hypothetical scenario, separate shore connection cables as shown in Figure 44 would minimize the risk that cable failure would eliminate the entire generating capacity of the

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[xxiv] For example, the transmission costs per unit energy delivered on a 200 MW cable are cheaper than two separate 100 MW cables.

region’s wind farms.

Network Configurations

Network transmission system configurations connect one or more offshore wind projects to *multiple* onshore injection points. The presence of more than one injection point makes this system a loop. As with the multi-stage radial system, the capacity of the initial loop could be designed to accommodate future projects. The configuration shown in Figure 47 is a hypothetical example of a network transmission system for offshore wind projects with two onshore injection points. An extension of this concept would be to have a configuration that connects injection points with greater geographic and energy pricing diversity.

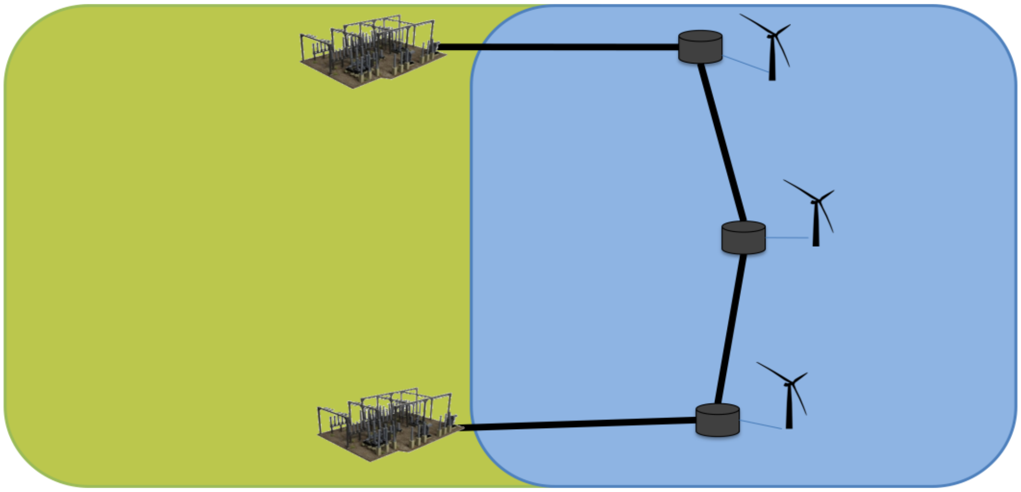

Figure 47: Multiple wind facilities connected to shore using a network configuration. There are multiple onshore connection points, and thus offers potential for multiple forms of economic value. This type of configuration require cooperation by multiple developers and pre-planning and might require nuanced cost recovery schemes as well as harmonized permitting if inter-jurisdictional.

Similar to multi-project radial configurations discussed above, network configurations have environmental and social benefits related to far-offshore development and fewer onshore connections points. Additionally, network configurations could potentially resolve economic and reliability problems found with complex, large-scale radial configurations. While complex radial configurations may not reduce transmission costs substantially and may have reliability concerns, *network* configurations can potentially reduce net transmission costs.

Potential Benefits of Offshore Transmission Grids

Offshore transmission grids, as described above, that connect several wind facilities to shore through a single backbone line offer several advantages. Offshore transmission grids facilitate transmission infrastructure sharing, enable energy trading and congestion relief, promote targeted wind energy development, and reduce environmental impacts. These benefits are discussed here in more detail.

Transmission Infrastructure Sharing

Developers typically pay to connect to the existing grid. An offshore transmission grid would enable multiple wind facilities to share transmission infrastructure for grid connection, thereby potentially reducing costs for each developer, as well as the overall onshore and offshore transmission "footprint." Additionally, wind facilities that are located in close proximity to this offshore grid could share the cost of connecting to that grid, similar to the radial connection configurations.[298]

Bundling multiple offshore wind facilities into shared transmission infrastructure like offshore substations along an offshore grid may reduce costs. Submarine cables are characterized by economies of scale.[299] Cost per unit energy transmitted decreases as the capacity of the transmission line increases.[300] Thus, an area with several projects producing hundreds of megawatts transmitting over a single line could significantly reduce the total expenditure for transmission infrastructure necessary to deliver wind energy to load.

However, the economic benefits of infrastructure sharing are not realized in every situation. A study for the Crown Estate (UK) offshore wind development program found no economic benefit to developers from shared transmission infrastructure.[301] This finding may be a result of the location of the offshore wind projects. If offshore wind projects are not close enough together, the extra cable required to connect the projects may negate savings from the shared connection to shore.[302] Also, bundling requires an extra substation to ramp up the power from each facility. The U.K. zones may not be far enough from shore to justify the costs of an extra substation. However, the Crown Estate study recommended minimizing total submarine cable installations for economic purposes.[303]

Energy Trading and Congestion Relief

An offshore transmission grid with more than one onshore injection point (a network configuration) and spare capacity on the line(s) can potentially provide the opportunity to trade energy within or between states, provinces, or countries.[304] If a section of the onshore grid is congested, the offshore grid may provide an alternative path for delivering the lowest cost power to load. Bypassing the congested onshore grid in this way would provide the additional benefit of congestion relief. A modeling analysis presented during the 7th International Workshop on Large Scale Integration of Wind Power and on Transmission Networks for Offshore Wind Farms predicted that 48 GW of offshore wind capacity by 2020 in Northern Europe would reduce congestion costs 25% when compared to a no-wind scenario, and that a dedicated offshore grid would result in “much lower” congestion costs, with only 0.5-9% of the congestion costs caused by wind variability.[305] This example shows that offshore transmission networks could have economic value while facilitating offshore wind transmission.

Figure 46 above shows an example of a radial configuration that can be built in stages, where the first stage has transmission capacity that exceeds initial generation capacity, allowing additional projects to connect later. Depending on the specifics of the project, the initial stage may not be cost-effective unless the total capacity of the cable is utilized in the near term. In cases where a network configuration such as that pictured in Figure 47 above is built, early stages can be designed to be cost-effective because initial excess capacity on the backbone line could be used for energy trading between connection nodes. Improved grid reliability, congestion relief, energy trading, and reduced grid operation costs can offset the cost of the initial line if planned in a location where these benefits outweigh the expense of the line. Thus, building lines that enable energy trading and congestion relief could allow future offshore wind facilities to connect into offshore lines in later stages without causing economic losses in earlier stages.

Offshore lines/grids could be built in a modular way where each stage adds value, if the initial plan allows for easy additions as new opportunities become economically feasible. If each stage or addition is economically feasible on its own (but also takes a long-term view on offshore wind development) the line can be built with “no financial regrets” in a modular manner, and open up future wind generation opportunities at the same time. In short, offshore grids can be built in a modular way where each stage adds value even if the ultimate vision for the offshore grid project is never realized.

Improved Grid Reliability and Reduced Grid Operation Costs

Offshore grids can improve grid reliability, which reduces grid operation costs. Several offshore transmission lines have been built in Europe with the primary purpose of improving grid reliability.[306] TradeWind conducted a study that modeled an offshore grid and an offshore wind expansion plan for 2020 in Europe. The study found that the offshore wind and grid would result in 1.5 billion Euros (about 2.1 billion USD) per year in grid operation savings after 42 transmission upgrades at 490 million Euros each (about 680 million USD).[307] The upgrades would thus have a net present value of 6.8 billion Euros (about 9.4 billion USD).[xxv] While similar economic potential may exist in the Great Lakes region—especially since transmission bottlenecks exist near the lakes, such as the Chicago area—detailed transmission system studies are required to make such determinations.

Targeted Wind Facility Location

By facilitating grid connection, an offshore transmission grid can promote offshore wind development along a specific corridor where the net benefits of offshore wind are

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[xxv] This calculation uses a discount rate of 5% and a project life-time of 50 years.

maximized not just economically, but also environmentally and socially. Essentially, an offshore grid could function like an offshore wind zone (whether or not the corridor is officially designated as a "wind development zone"). As discussed later in Part 3.3, offshore wind zones could be planned where wind speeds are attractive, transmission barriers are not prohibitive, and public acceptance of the wind projects is high. Because wind speeds tend to increase with distance from shore, offshore grids would likely be attractive connection points for far-offshore wind facilities, if located in feasible depths. Far-offshore development enabled by infrastructure sharing may also be preferable socially because it reduces or eliminates viewshed and noise impacts of near shore turbines. Fewer near shore/onshore development and fewer connections to shore also avoid the social impacts related to construction and land-use conversion of shoreline property.

Reduced Environmental Impact

Offshore transmission grids have the potential to reduce environmental impacts in several ways. First, fewer connections would disrupt less coastal habitat, which is generally considered more sensitive than offshore habitats. If transmission infrastructure sharing allows for wind developers to site projects farther from shore, those projects may also avoid migratory bird flyways and/or other wildlife habitat that is typically located close to shore. Fewer connections would result in less area of bottomland sediment disturbed by cable entrenchment, which means fewer impacts to fish spawning areas and other benthic communities. See Part 2 of this report for more details about environmental impacts from offshore and onshore transmission.

Technological Requirements of Offshore Grids

A transmission grid that enables far-offshore wind facilities has several technological and logistical requirements. Apart from the technology required for deepwater wind turbines (needed in all but Lake Erie), the main technological and logistical requirements for an offshore transmission grid include submarine transmission lines, offshore **nodes** for wind project connection and energy trading, onshore nodes for connection to the onshore grid, and access to specialized construction vessels.[308]

If the grid cable length is less than approximately 60 miles, AC technology can be used. Beyond 60-70 mile range, the power loss due to resistance makes DC technology more cost-effective than AC.[309] High Voltage Alternating Current (HVAC) technology could be used for distances over 50 miles, but in an AC loop, power flow cannot be controlled. Thus, for long-distance cables, High Voltage Direct Current (HVDC) technology is most suitable as it provides the ability to control power flow and makes it easy to supply power to zones operating at different frequencies.[310]

For nodes in offshore grids, EWEA suggests that HVDC-VSC (Voltage Source Converter)[xxvi] is more suited for offshore grids than conventional HVDC. HVDC-VSC allows for modular construction since it has standardized sizes for converter stations, while conventional HVDC is usually customized for each project.[311] It facilitates multi-terminal applications, which makes it suitable for networked grids; its compactness reduces environmental impact; and it may be terminated in an existing onshore AC grid thereby reducing upgrades to the injection point.[312]

Policy Mechanisms

Develop Methods for Inter-Jurisdictional Permitting

Offshore transmission grids face potentially serious political challenges related not only to cost allocation and social and environmental impacts, but also to inter-jurisdictional siting issues. Surmounting these challenges requires a robust regulatory framework for building offshore grids in the Great Lakes. The primary regulatory need for an offshore grid is a streamlined permitting process for interstate, inter-RTO, and even international

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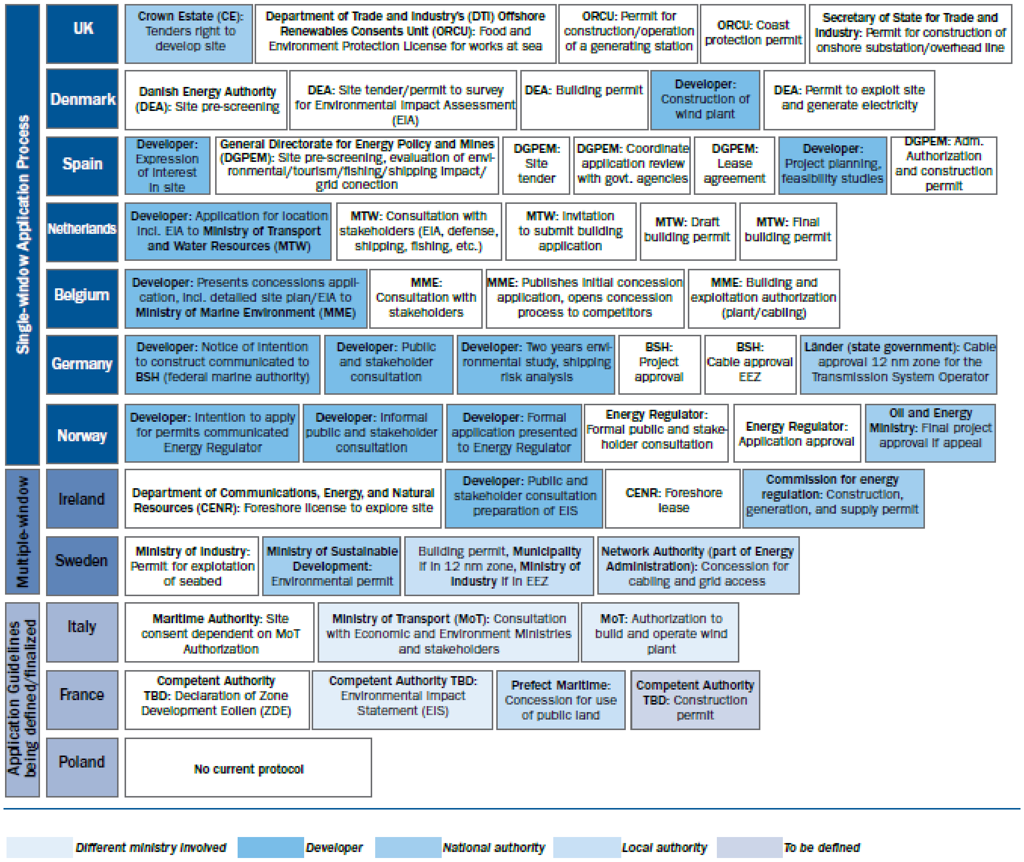
[xxvi] Two companies, ABB and Siemens have both developed separate HVDC-VSC products, HVDC Light and HVDC Plus respectively. These two technologies are not identical and hence efforts are needed to make compatible.

submarine transmission connections. Currently Europe does not have a harmonized planning process (see Figure 48). As discussed in Part 2 of this report, there is a different regulatory framework for each state in the U.S. and each province in Canada. Typically this regulatory guidance is applicable to all types of structures proposed to be located in the lakes, and not transmission specifically. Different regulatory regimes in the Great Lakes states and provinces could potentially act as barriers to offshore grids that cross jurisdictional boundaries.



Single-window Application Process	**UK**	**Crown Estate (CE):** Tenders right to develop site	**Department of Trade and Industry's (DTI) Offshore Renewables Consents Unit (ORCU):** Food and Environment Protection License for works at sea	**ORCU:** Permit for construction/operation of a generating station	**ORCU:** Coast protection permit	**Secretary of State for Trade and Industry:** Permit for construction of onshore substation/overhead line		
	Denmark	**Danish Energy Authority (DEA):** Site pre-screening	**DEA:** Site tender/permit to survey for Environmental Impact Assessment (EIA)	**DEA:** Building permit	**Developer:** Construction of wind plant	**DEA:** Permit to exploit site and generate electricity		
	Spain	**Developer:** Expression of interest in site	**General Directorate for Energy Policy and Mines (DGPEM):** Site pre-screening, evaluation of environmental/tourism/fishing/shipping impact/grid conection	**DGPEM:** Site tender	**DGPEM:** Coordinate application review with govt. agencies	**DGPEM:** Lease agreement	**Developer:** Project planning, feasibility studies	**DGPEM:** Adm. Authorization and construction permit
	Netherlands	**Developer:** Application for location incl. EIA to **Ministry of Transport and Water Resources (MTW)**	**MTW:** Consultation with stakeholders (EIA, defense, shipping, fishing, etc.)	**MTW:** Invitation to submit building application	**MTW:** Draft building permit	**MTW:** Final building permit		
	Belgium	**Developer:** Presents concessions application, incl. detailed site plan/EIA to **Ministry of Marine Environment (MME)**	**MME:** Consultation with stakeholders	**MME:** Publishes initial concession application, opens concession process to competitors	**MME:** Building and exploitation authorization (plant/cabling)			
	Germany	**Developer:** Notice of intention to construct communicated to **BSH** (federal marine authority)	**Developer:** Public and stakeholder consultation	**Developer:** Two years environmental study, shipping risk analysis	**BSH:** Project approval	**BSH:** Cable approval EEZ	**Länder (state government):** Cable approval 12 nm zone for the Transmission System Operator	
	Norway	**Developer:** Intention to apply for permits communicated Energy Regulator	**Developer:** Informal public and stakeholder consultation	**Developer:** Formal application presented to Energy Regulator	**Energy Regulator:** Formal public and stakeholder consultation	**Energy Regulator:** Application approval	**Oil and Energy Ministry:** Final project approval if appeal	
Multiple-window	**Ireland**	**Department of Communications, Energy, and Natural Resources (CENR):** Foreshore license to explore site	**Developer:** Public and stakeholder consultation preparation of EIS	**CENR:** Foreshore lease	**Commission for energy regulation:** Construction, generation, and supply permit			
	Sweden	**Ministry of Industry:** Permit for explotation of seabed	**Ministry of Sustainable Development:** Environmental permit	Building permit, **Municipality** if in 12 nm zone, **Ministry of Industry** if in EEZ	**Network Authority (part of Energy Administration):** Concession for cabling and grid access			
Application Guidelines being defined/finalized	**Italy**	**Maritime Authority:** Site consent dependent on MoT Authorization	**Ministry of Transport (MoT):** Consultation with Economic and Environment Ministries and stakeholders	**MoT:** Authorization to build and operate wind plant				
	France	**Competent Authority TBD:** Declaration of Zone Development Eolien (ZDE)	**Competent Authority TBD:** Environmental Impact Statement (EIS)	**Prefect Maritime:** Concession for use of public land	**Competent Authority TBD:** Construction permit			
	Poland	**No current protocol**						

Different ministry involved *Developer* *National authority* *Local authority* *To be defined*

Figure 48: Permitting requirements for offshore wind in Europe. This figure shows how permitting requirements differ substantially by country in Europe.[313]

Clear and effective regulatory guidance is an issue globally as it relates to building transmission offshore. In the UK offshore wind has been in place for nearly a decade, but its regulatory framework for offshore transmission networks has changed as recently as 2009. New regulations were developed with the goal of ensuring that new offshore renewable energy projects are connected to electricity grid both economically and efficiently.[314] The UK governmental entity, the Department of Energy and Climate Change (DECC), and the industry-funded independent regulator, the Office of the Gas and Electricity Markets (OFGEM) worked together to create the new regulation. The UK is the world leader in offshore wind, with the largest number of projects installed, under construction and in planning, and yet the UK regulatory framework is still being improved.[315]

In order to develop a framework conducive to expanding the Great Lakes regional grid offshore, states and provinces will need to work together to develop harmonized permitting and siting criteria and processes. Looking to the UK and other regulatory processes in Europe that have supported the successful approval of international offshore transmission lines would provide insight for the U.S. and Canadian regulators as rules are developed.

Develop Cost-Sharing Rules for Offshore Grids

Under the current standard, where developers typically pay to connect to the existing onshore grid, costs for an offshore grid would presumably left to developers to share. In cases where the offshore grid has additional benefits such as energy trading and reliability, the offshore grid backbone may qualify for broader cost allocation. However, there is no cost-sharing precedent for offshore grids in the basin. Given the large upfront cost of an offshore grid and the potential financial risk of modular development, establishing a mechanism to share costs equitably among initial and subsequent users and beneficiaries of the grid is prerequisite for their development.

One way to extract economic value from a transmission grid is to provide a means for energy trading, where the electricity price differential between the two locations would compensate for the cost of the line. In the case of offshore grids that enable interstate or international energy trading, the differential in the electricity prices in the two states or countries could provide a basis for justifying the cost of the offshore grid.[316] Cheaper sources of power could be provided to the connected point, thus reducing generation costs by an amount that would offset the cost of the new transmission line. But with the construction of such a grid, the electricity prices at the load are likely to drop, thereby reducing the price differentials. This would greatly increase the payback period of such projects.[317,318] If the new transmission grid enables interstate power trading, the recipient state might disadvantage its local generators by bringing in cheaper electricity from another state.[319] This might reduce local power generation and result in lower revenues for the local utility through reduced electricity prices. Also, if the two states trading power have different Renewable Portfolio Standards (RPS), where definitions of renewable energy vary, situations could arise where ratepayers could be harmed by such inconsistencies.

Cross-lake transmission projects may also qualify in MISO as Multi-Value Projects (MVPs) if they provide congestion relief, increased reliability, and support of policy objectives like renewable energy requirements. This would allow the cost of these projects to be spread across all the rate-payers in the MISO region, an attractive cost sharing method.[320] Regardless of whether an offshore line is considered an MVP project, paid for through interstate/country price differentials, or allocated via another method, cost-sharing mechanisms that allocate costs broadly for offshore transmission will be extremely important for offshore developers.

Examples of Existing and Proposed Offshore Grids

Several offshore wind connection grids have been proposed or are in the planning process in Europe. While several interstate and international submarine transmission cables already exist in the US and Europe, they were built primarily for reliability and power trading purposes rather than for offshore wind integration. There are already eleven submarine transmission lines connecting northern European nations (see Figure 49). For example, the Scandinavian states meet the majority of their base load with hydropower because it is less expensive to produce than fossil fuel or nuclear power. When Scandinavian countries produce excess hydropower, sale of this inexpensive power can be exported to northern continental Europe through submarine connections, economically benefiting both regions. For the purpose of both increasing the potential for energy trading and for integrating offshore wind, more connections throughout the area are in the planning process or have been proposed by the European Wind Energy Association (EWEA) (see Figure 49). EWEA identified 100 GW of proposed wind projects (in construction, in permitting and approval processes, or proposed by a developer or government).[321] EWEA's proposed offshore infrastructure is based on the expectation of 40 GW of additional offshore wind power by 2020 and 150 GW by 2030.[322] EWEA applied the Kriegers Flak example, described later in this section, to the rest of the area for their suggested offshore grid projects as seen in Figure 49.[323] Such an offshore grid is expected to allow offshore wind farms to transmit power; in addition it will 'smooth' the variability of wind energy and improve the ability of European nations to trade electricity.[324]

EWEA suggests that a transnational offshore grid will have many benefits including:

- smoothed variability by geographically diverse locations of offshore wind farms,
- ability of wind farms to sell wind energy to more than one region,
- increase in power trading possibilities between regions (nations),
- minimization of the need to strengthen onshore high-voltage grid infrastructure,
- connections for other marine based renewable energy technologies,
- economical and shared use of offshore transmission,
- and improved European energy security due to increased interconnection.[325]

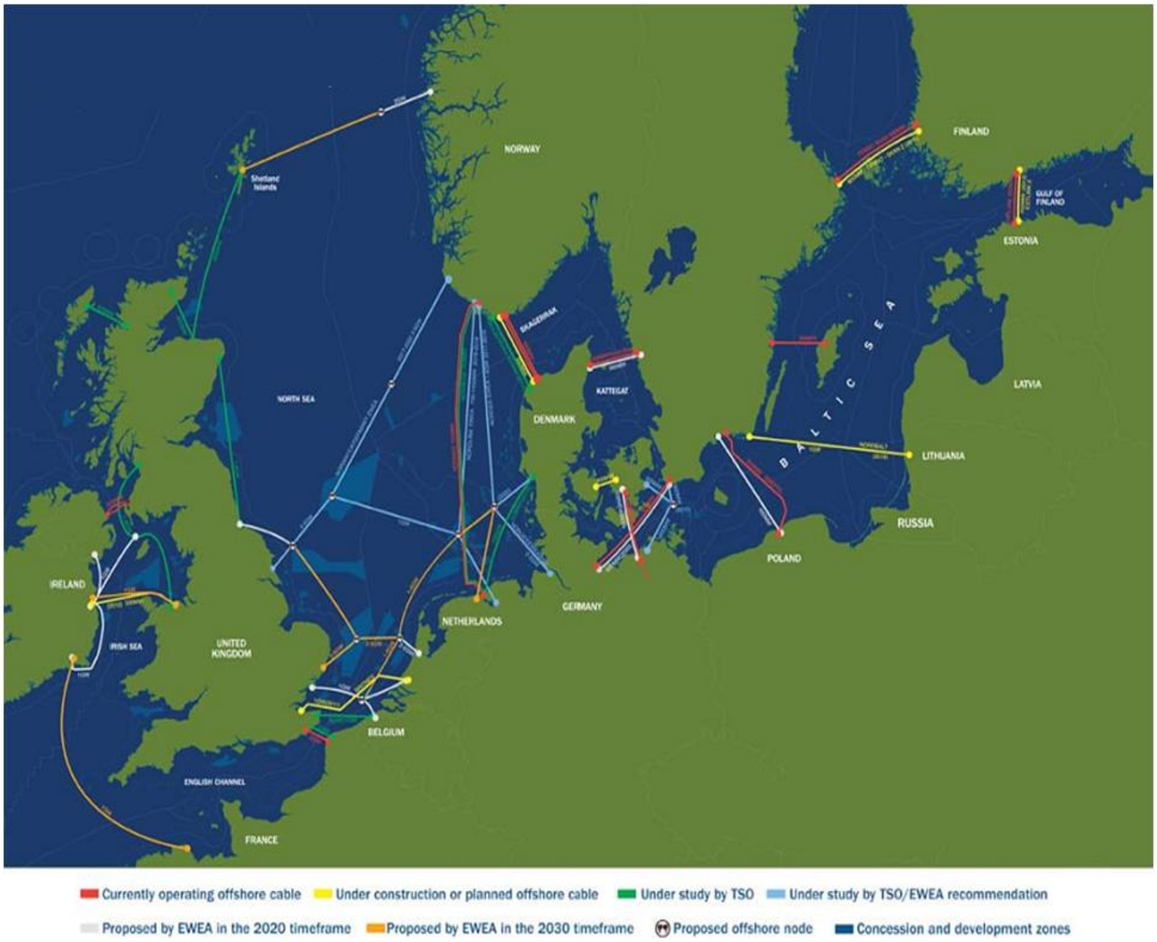


Figure 49: Existent, Under Construction, Planned, and Proposed Offshore Transmission Infrastructure in Europe. This figure shows how Europe has advanced offshore grid infrastructure which suggests that there might be similar economic opportunities in the Great Lakes.[326]

Kriegers Flak

In the Kriegers Flak, off the coast of Denmark, three wind farms are planned totaling 1600 MW of nameplate capacity. BAU would have the projects connect radially to their nations of ownership, Sweden, Denmark, and Germany. Planners believe the additional expense to build a backbone of transmission that would allow both transmission of wind power and energy trading between the three nations would have increased economic benefits. A preliminary cost-benefit analysis showed that the offshore grid would have additional construction costs ranging from 130-300 million Euros and benefits ranging from 36-103 million Euros per year, with the larger capacity infrastructure incurring more benefits (i.e. more energy trading). The additional construction costs for the offshore grid would then pay for themselves in four years and would have a net present value of 1.6 billion Euros.[xxvii] The planners noted that regulatory differences between the three nations may complicate energy trading and differences in onshore infrastructure upgrades may pose a challenge to cost sharing.[327]

A Critical First Step in the Offshore Development Process

The North Sea's Countries (Belgium, Denmark, France, German, Ireland, Luxembourg, the U.K., Sweden and Norway), along with ENTSOE (European Network of Transmission System Operators for Electricity) and ACER (Agency for the Co-operation of Energy Regulators) launched the North Sea's Countries Offshore Grid Initiative in 2009. They signed a memorandum of understanding for the initiative declaring that they:

- share a common goal of reaching a low-carbon economy while maintaining energy security cost-effectively,
- recognize a substantial renewable energy potential in the North Seas,
- will ambitiously pursue offshore wind development recognizing it will require offshore grid infrastructure and onshore grid upgrades,
- understand the significant investment this requires,
- will work in a coordinated fashion to develop the grid to ensure its cost-effectiveness, and
- will identify and resolve barriers to such grid development at all regulatory levels.[328]

[xxvii] This financial estimate uses a 5% discount rate, the high range of costs and benefits, and a project life of 50 years.

Google: Atlantic Wind Connection Grid

Figure 50: Proposed Phase 1 of the Atlantic Wind Connection (NY Times 2010).

Several companies, including Google, have taken an equity stake in a transmission grid off the coast of the eastern United States, entitled the Atlantic Wind Connection.[329] Phase one of the offshore grid would extend from northern New Jersey to Norfolk, Virginia with connections to shore in Delaware and southern New Jersey. The transmission grid would consist of a single submarine transmission pathway with a capacity to transmit 6 GW of power. The transmission would travel along the coast 15-20 miles from shore where offshore wind farms could interconnect to the line while being hardly visible from shore.[330]

The transmission is expected to have economic benefits before wind farms are built to make use of the line by taking advantage of price differentials where it connects to shore.[331] For example, the price of electricity is cheaper in Virginia than it is in New Jersey, but, at present, due to grid constraints generators in Virginia cannot sell power to New Jersey. The project is expected to enable such a trade. Further, the connection is expected to improve grid reliability, which has other economic benefits.[332] A similar transmission project onshore in the same region would see potentially insurmountable permitting hurdles and ROW easements. By going offshore far fewer ROWs and permits are needed.[333]

Cross-Lake Lines in the Great Lakes

The opportunity to build a line that offers energy trading and congestion relief, while integrating offshore wind, exists in Lake Michigan from Milwaukee, WI to Ludington/Muskegon, MI. Unfortunately, a similar line that is currently proposed solely for energy trading and congestion relief does not plan to integrate offshore wind.[334]

Currently, power from Wisconsin cannot be transmitted to Michigan due to the presence of Chicago and Gary, IN, major power sinks and congestion points in the transmission corridor between Wisconsin and Michigan.[335,336] Electricity prices at the Michigan Hub are higher than those at Minnesota or Illinois, west of the Chicago/Gary area. A cross lake transmission line would enable the delivery of cheaper power from Wisconsin to Michigan, bypassing Chicago and Gary.

The cross-lake line could also be used to integrate offshore wind. Between Milwaukee and Ludington a mid-lake plateau exists with depths lower than 90 meters, and a minimum depth of 40 meters.[337] A cross-lake line that passes through this region could access the wind resources in this high wind-speed region without requiring deep-water wind turbine technology, technology necessary at similar distances from shore in all the other Great Lakes besides Lake Erie. Additionally, the line could allow developers to access the wind resources closer to shore. The mid-lake plateau is expected to be attractive to developers because it accesses more robust wind resources than those near shore and the turbines sited there would be invisible to coastal communities.

The injection points on either side of the lake (Milwaukee, Muskegon, and Ludington) all possess transmission infrastructure onshore that could be utilized to connect the cross-lake line to the onshore grid. Ludington has a pumped storage plant[338] that can be used to store electricity, a particularly attractive feature that could store the variable wind energy produced offshore. Coal-fired power plants are located near both Muskegon and Milwaukee, which likely have substations that could act as injection points as well.

The cost of building a cross-lake line capable of integrating future offshore wind could the most significant barrier to its approval. The cost would vary based on the technology used, the number of offshore nodes and the transmission upgrades required at the onshore injection points. If a 1200 MW HVDC system is used to connect Muskegon and Milwaukee, which are approximately 90 miles apart, the submarine cable itself could cost $450 million at $5 million a mile. The converter stations at both ends would cost $200 million each. Thus, the equipment costs alone would total $850 million.[339,340] This cost would increase with the addition of every offshore connection node.

After studying the cross-lake line transmission planners may find that the cost-differential between Wisconsin and Michigan is not large enough or that the congestion relief benefits do not justify the costs of the line. But, if similar lines throughout the basin are proven to be cost-effective, they may also be cost-effective for integrating offshore wind. In addition there may be environmental concerns as this mid-lake plateau is thought to be important to recovering lake trout populations.[341]

Part 3.2 Conclusions

Offshore grid development could improve the economics of offshore wind development in the Great Lakes by serving multiple purposes including offshore wind integration, energy trading, and congestion relief. Offshore grids could also guide developers to build wind projects where the transmission footprint will be least damaging to the environment and most socially acceptable to near-shore communities. Offshore grids will require efficient, flexible, and equitable cost sharing mechanisms and a clear regulatory framework that enables inter-jurisdictional permitting. In Europe and the U.S., projects of this nature have been studied, proposed, or built because of the multiple forms of value they offer relative to simple radial connections.

Offshore Grids at a Glance…

Potential Benefits:

- Enable modular development by offering economic value at every stage of development via energy trading, congestion relief, and/or offshore wind integration.
- Potentially offer environmental and social benefits by reducing the net transmission footprint, targeting the location of offshore wind facilities, thus enabling far-offshore locations that reduce viewshed impacts and impacts to wildlife.

Potential Barriers:

- Inter-regional transmission connections in the Great Lakes basin which allow for future offshore wind interconnection (like cross-lake lines) may not justify their costs through savings related to congestion relief or energy trading alone.
- Inter-jurisdictional permitting may require unprecedented inter-jurisdictional regulatory cooperation.

PART 3.3: PROMOTE OFFSHORE WIND ZONE PLANNING

Overview

This section presents wind zone-based transmission planning as one method for facilitating transmission development to support offshore wind development in the Great Lakes while maximizing net economic, social, and environmental benefits. This section discusses the benefits and potential drawback of wind zone-based planning for offshore wind, experience to date with renewable energy zones for transmission integration, and a potential organizational process for offshore wind resource zones designation.

Offshore Wind Zones for the Great Lakes Region

Where grid capacity is constrained and offshore locations have robust wind resources and are otherwise economical, transmission planning is a powerful leverage point to guide offshore wind developments. “Energy resource zone” planning is one model for such strategic transmission planning that has been used to support offshore wind in Europe and onshore wind and other renewables in several U.S. states. Under this model, regulators designate “zones” for targeted transmission expansion. Zones are selected based on a number of criteria, including wind resource quality and transmission needs, but also social and environmental criteria. These zones serve to strategically focus transmission development where it is needed to support renewable energy. In this way, offshore wind zones are an attempt to resolve the “chicken and egg dilemma” discussed in Part 2, while identifying economically, socially, and environmentally optimal locations for offshore wind development.

In some iterations of resource zone planning, transmission projects designed to service a designated zone may qualify for an expedited permitting process and/or socialized cost-allocation. Additionally, regulators can take the next step and “pre-approve” designated wind zones for offshore wind development. Because transmission planning can serve as a leverage point for directing future offshore wind siting decisions, establishing a multi-stakeholder collaborative planning process to designate offshore wind zones can ensure that diverse interests are represented in these critical decisions. Having transmission planners, offshore wind developers, environmental specialists, and representatives of public concerns working together on the best locations for offshore wind in the Great Lakes could be an effective way to meet such a goal.

Aspects of Preapproval

If the offshore wind zone designation process thoroughly vetted zones based on social and environmental criteria, regulators at the state and federal levels may be able to "pre-approve" these zones for at least some elements of the offshore wind permitting process, thereby streamlining development. While it is likely that project-specific elements of a proposal would still need to be vetted by state permitting agencies, location-specific elements may not. For example, the designation process may consider the presence of contaminated sediments; proximity to breeding grounds, spawning grounds, migratory bird flyways, and bat colonies; and viewshed impacts and local community acceptance. If offshore wind zone designation criteria were harmonized with permitting criteria, much of the work could be done in advance. This would reduce risk for developers that would otherwise have to navigate uncertain permitting processes with an already-developed proposal that might not pass muster.

Costs for the studies required during the offshore wind zone designation phase could be recouped from developers that subsequently site within an offshore wind zone. To ensure optimal designations, the offshore wind zone process must also consider wind resource quality, cost of required transmission upgrades, and possible co-benefits from those upgrades. Ultimately, offshore wind zone must be locations where developers want to build offshore wind projects and can build them efficiently, with minimal impact to the environment and society.[xxviii]

[xxviii] Geo-spatial mapping tools, similar to the Great Lakes Commission's Wind Atlas, may be effective tools for finding efficient wind zone locations. However, such mapping tools should be able to perform algorithmic optimizations that are informed by parameters laid-out by the stakeholders.

Benefits from Offshore Wind Zones

Offshore wind zones can serve to crack the chicken-egg dilemma for transmission planning. By giving a proactive role to a diverse set of stakeholder interests and optimizing offshore wind zone designations based on a wide range of criteria, the process can also maximize the net economic, environmental, and social benefits of offshore wind energy in the Great Lakes region.

Targeted Transmission Upgrades: Onshore and Regional Transmission Benefits from Offshore Wind Zones

By clustering offshore wind projects into select zones in the Great Lakes, offshore wind zones would provide regional transmission planners a focus for onshore transmission upgrades. The onshore grid adjacent to offshore wind zones would need to be upgraded to accommodate expected power input from the zones. Targeting transmission upgrades can reduce the transmission component of cost increases to ratepayers in the region associated with offshore wind development; for the same number of offshore wind facilities, a few major transmission upgrades to service clusters of offshore facilities may be more advantageous than a patchwork of individual upgrades for individual offshore wind facilities. Cost savings could be realized by having higher capacity transmission infrastructure and by minimizing the costly acquisition of ROWs. More power over one line could reduce the number of new ROWs needed, which are expensive and sometimes have to be acquired by means of eminent domain.

High capacity onshore transmission upgrades may also have other economic value in the form of congestion relief, while patchwork upgrades may not. For example, the Regional Generation Outlet Study by MISO found that onshore wind zones could be harmonized with other transmission needs to maximize economic benefits.[342] By including transmission planners in the collaborative process, offshore wind zones could integrate wind while minimizing transmission

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and distribution costs and improving the onshore grid. Transmission planners may also find that offshore wind zones are strategic places for cross-lake or cross-region lines and/or offshore grids, as discussed in Part 3.2. There may be superb wind resources and minimal environmental and social concerns between two injection points that would benefit from energy trading and/or congestion relief. Offshore grids and offshore interregional transmission lines may also allow wind facilities in offshore wind zones to be located at a greater distance from shore. As discussed earlier in Part 3.2, greater distances from shore can improve project economics by accessing stronger wind resources, reduce environmental impacts, and reduce viewshed and noise impacts.

Environmental Benefits from Offshore Wind Zones

Targeting onshore transmission upgrades can reduce environmental impacts by reducing the number of new ROWs needed to integrate offshore wind energy (impacts from new ROWs are discussed in Part 2). Offshore wind zones could also reduce offshore environmental impacts by reducing the number of distinct locations in the Great Lakes where offshore wind projects are developed. This would reduce the number of locations that are impacted by offshore wind construction, as discussed in Part 2. Further, the locations that are developed would be optimal based on environmental criteria employed in offshore wind zone designation, under the direction of environmental specialists in the collaborative planning process. In the best-case scenario, experts suggest that with thoughtful planning, offshore wind facilities may actually improve aquatic ecosystems by acting as artificial reefs to support more aquatic life including fish populations.[343,344] At the very least, offshore wind zones would be planned to avoid sensitive habitat disruption, wildlife impacts, re-suspension of contaminated sediments, and unnecessary transmission footprint.

Benefits to Coastal and Regional Communities from Offshore Wind Zones

Offshore wind zones could reduce both net and direct impacts to coastal communities. By clustering offshore wind facilities in the Great Lakes, fewer coastal communities, including coastal residents and those in the tourism industry, will be impacted by offshore wind development, reducing net impacts to coastal residents and the tourism industry from offshore wind development. Although clusters of offshore facilities could result in concentrated, and thus more severe, impacts to the viewshed where offshore wind zones are located, careful planning of offshore wind zones could potentially minimize these impacts. For instance, transmission planning during the offshore wind zone collaborative planning process could locate offshore facilities at greater distances from shore by improving the economics of offshore transmission. Transmission planning could also minimize the number of onshore grid connections (substations and onshore transmission lines), which affect coastal communities as well and are typically ill-received. Further, the offshore wind zone planning process could specifically seek input from environmental justice specialists who could help further reduce net impacts to society from the siting of infrastructure that could potentially impact nearby residents.

For the Great Lakes regional community, the benefits from offshore wind zones are mostly a result of targeted transmission upgrades and improved economics of offshore wind development. As discussed earlier, transmission planning for offshore wind zones could realize multiple forms of economic value with offshore wind development, which would reduce overall transmission costs. Offshore wind zones could also reduce the price per unit electricity generated by offshore wind facilities, which would be a benefit to rate payers. Such price reduction would be a result of reduced developer transaction costs (discussed below), and the potential for access to high-quality wind resources.

Benefits to Developers from Offshore Wind Zones

Developers could benefit from offshore wind zones in several ways, including reduced transaction costs and improved project economics. The “preapproval” element of offshore wind zones would reduce transaction costs and investment risks by expediting the permitting process and increasing the predictability of project costs, while decreasing litigation vulnerability. Hypothetically, developers may be less susceptible to legal challenge based on the Public Trust Doctrine, given that a comprehensive group of stakeholders designated wind zones—and, by extension, both the wind development within those zones and the transmission development to integrate those zones. An expedited permitting process would reduce investment risk by allowing developers to take advantage of current government incentives. For example, the length of the permitting process for the Cape Wind project (almost 9 years) has reduced predictability of the project’s capital costs, as both offshore wind technology and government incentives have changed over the time period. If stakeholders—developers included—design the preapproval process to require robust wind resources, then wind resource studies, usually a necessary transaction cost, may be completed before the developer begins the permitting process.

Additionally, grid interconnection system impact analyses may be avoided for developers in offshore wind zones, because each offshore wind zone would be planned to accommodate a predetermined amount of wind power. Transmission planners would know the extent to which the predetermined amount of wind power has been met by existing or approved offshore wind facilities in each zone. For example, if an offshore wind zone was designed to support 1,000 MW and existing and approved projects currently account for 500 MW, a developer could seek approval to build a new facility of 500 MW or less.

Potential drawbacks from Offshore Wind Zones

Potentially Suboptimal Development Pattern

If offshore wind zone policy *restricts* development outside of designated zones, offshore wind zones could disrupt development of offshore wind projects where they are cost-effective without targeted transmission upgrades. Developers are expected to be opposed to offshore wind zones if they restrict offshore wind development outside of those areas.[345] If offshore wind zones are properly designated, opposition from developers would not be expected.

However, even if offshore wind zone policy does not restrict offshore wind development outside of designated zones, offshore wind zones may distort developer incentives and result in a suboptimal development pattern. Particularly with preapproval and full transmission support, wind zones are the “Cadillac” for offshore wind development. As such, developers may lose incentive for site development in the most cost-effective areas outside of offshore wind zones — in particular, areas that would not need offshore wind zone designation because wind power could be integrated *without* targeted transmission upgrades. Consequently, it may be prudent to wait to designate offshore wind zones until these lowest cost areas have been developed.

Offshore Wind Zones May Deter Geographically Diverse Development

Without careful planning, offshore wind zones may also result in a suboptimal geographic distribution of wind facilities. Wind, transmission, and grid management experts acknowledge the benefits of siting wind facilities in as many geographically diverse locations as possible.[346] While wind does not blow consistently in any single location, there is wind blowing somewhere within a broader geographic region at all times. Therefore, by distributing wind facilities over a diverse geographic range, there is greater potential for wind intermittency to overlap or balance out, producing more continuous net energy generation. Offshore wind zones may conflict with this geographic diversity objective by clustering wind facilities as opposed to spreading them out. However, a network of offshore wind zones could be planned throughout the Great Lakes region to maximize geographic diversity of wind projects.

Examples of Renewable Energy Zone and Transmission Planning

This section reviews several renewable energy zone and transmission planning studies and programs conducted to integrate renewable energy in many regions including examples at the state, utility, RTO-ISO, and national levels. The examples predominately illustrate that transmission upgrades are necessary to integrate renewable energy; that such upgrades are costly; and that transmission upgrades to integrate renewable energy can have co-benefits in terms of grid reliability and congestion improvements. Components of the following case studies could be used as a template for an offshore wind zone process in the Great Lakes.

Introduction to Transmission Investments: Focus on the U.S.

In the U.S., the average national transmission investment in the 1970's was $5.5 billion per year, while in the 1990's it was less than $3.0 billion per year. However, average national transmission investments have increased recently: in 2008 the U.S. spent $9.5 billion on transmission projects; in 2009, $10.3 billion; and in 2010, $11.0 billion. Despite the recent increase in transmission investments, the North American Electric Reliability Corporation (NERC) states that transmission miles will need to increase 9.5% over the next decade to achieve sufficient levels of reliability in the U.S. Additionally, many states have passed RPSs, which will require more new and upgraded transmission to deliver renewable energy to load, particularly since high quality renewable resources are often located at a distance from load and existing transmission infrastructure.[347]

Texas Competitive Renewable Energy Zones

Texas' RPS is considered to be the most successful in the country, largely because Texas has the most installed wind capacity of any state. However, delivering wind power to load is an issue. Texas wind projects are located in the west, while load centers are in the east, with limited transmission capacity to send wind energy east. [348] Consequently, in 2005 Texas legislators, in consultation with the Texas reliability council and the regional transmission operator (ERCOT), passed a bill directing state regulators to designate Competitive Renewable Energy Zones (CREZ) and to create a transmission plan to deliver the energy from these zones to load.[349,350]

The main criterion for Texas CREZ designation was financial commitment by wind developers, but wind speeds were also a key consideration. The Texas Public Utility Commission ultimately chose many CREZs requiring upgraded and new transmission lines, all located in western Texas, with a total wind power potential of 18.5 GW. After choosing CREZs, Texas state regulators proposed transmission projects including new ROWs for over 2300 miles of mostly 345 kV transmission lines. The regulators then invited all interested entities to submit construction proposals, with a goal of making the process as competitive as possible. More than ten proposals were accepted, including three proposals from new transmission companies.[351]

To spread costs to consumers over time, Texas regulators are staggering construction. Projects will be built in order of priority based on convenience and necessity of projects. The first projects are expected to begin in 2011. However, litigation over whether transmission company bid selections by Texas regulators were least-cost to ratepayers may slow completion of the proposed transmission.[352]

The Texas CREZ example illustrates that if regulators propose transmission projects to integrate renewable energy, a competitive bidding process is one way to get the projects built. However, clearly demonstrating the steps regulators take to minimize costs to the rate base can help to avoid litigation.

Colorado Renewable Energy Resource Zones

In 2007, the Colorado Legislature passed a bill that established a task force to identify renewable energy development areas with a minimum potential of 1 GW of renewable energy. The legislature then passed a bill requiring utilities to submit plans to develop in these areas, including transmission. The bill allowed the utilities to recover transmission construction costs at the cost of capital plus a return on equity. The bill also required the utilities to submit reports every other year starting in 2007, recommending new renewable energy resource zones, to which the Public Utility Commission is required to respond within 180 days. In May 2009 applications were filed with the Colorado PUC to access the renewable energy resource zones.[353] These bills force regulators and utilities to continually think about increasing renewable energy generation and transmission planning to deliver the generated electricity to load. In 2008, Xcel (the local utility and transmission owner and developer) agreed to conduct stakeholder-driven transmission study groups to aid planning for the zones.[354]

California

California has enacted several policies to facilitate renewable energy generation and the transmission necessary to deliver it to load. These policies create innovative ways to pay for transmission before the total capacity of the line is accounted for. They also promote cooperation by stakeholders and regulators to meet California's RPS, and guarantee cost recovery for transmission projects geared to service renewable energy generation.

Foundation, Delivery, and Collector Lines as Defined by CA's RETI

Foundation: commonly known as transmission lines, the lines increase CA's transmission capacity as a whole.

Delivery: commonly known as distribution lines, the lines deliver energy from transmission lines to load.

Collector: commonly known as collector lines, these lines deliver energy from generating units to transmission lines.

California's Location Constrained Resource Interconnection (LCRI) policy is a direct attempt at resolving the “chicken-egg dilemma.” The goal of the policy is to build transmission to areas where developers have expressed interest in harnessing the available renewable energy resource. Under LCRI policy, the California Independent System Operator (CAISO) is allowed to recover new transmission costs through its transmission access fee, which is charged to the rate base. In order for new LCRI transmission to be approved, there must be a demonstrated interest in 60% or more of the transmission capacity, 25% of which must come from interconnection agreements, while the remaining 35% can come from contracts that are 5 years or longer. Once the transmission is built, generators pay a pro-rata charge for use of the transmission infrastructure as they come on-line, thus reducing the amount charged to the rate base. The policy limits LCRI projects to 15% of total transmission investments in CAISO. The first LCRI, approved in May 2009, was a project consisting of 10 miles of new transmission and a substation to access the Tehachapi renewable energy development area.[355] Under most cost-allocation policies found in the U.S. the generator is required to pay for grid-interconnection infrastructure, which can be prohibitive if the location of the generation project is far from the grid. The LCRI cost-allocation mechanism seen in Tehaphapi is an innovative way to deal with this problem.

The California Legislature also commissioned the Renewable Energy Transmission Initiative (RETI). RETI is a stakeholder collaborative tasked with developing broad support for the transmission needed to meet California’s RPS of 33% by 2020. RETI is a joint effort of the CA Energy Commission, CAISO, CPUC, independently owned utilities, and publicly owned utilities. A conceptual transmission plan created by RETI included transmission lines to access 9.5 GW from 11 designated zones. RETI categorized transmission infrastructure as “foundation,” “delivery,” and “collector” lines. The majority of the proposed transmission lines are “foundation” lines. RETI estimated the total cost of the plan to be $6.5 billion.[356] Note that CPUC guarantees cost recovery for utilities through retail rates for transmission projects deemed necessary to meet California’s RPS if FERC does not approve the projects.[357]

Michigan Wind Energy Resource Zones

The Wind Energy Resource Zone Board was commissioned by the Michigan State Legislature in 2008. The board was charged with determining the regions of the state with the highest wind energy potential and conducting “related studies.”[358] The 11-member board included representatives from cities and villages, townships, the state attorney general's office, the Michigan Public Service Commission (MPSC), the renewable energy industry, the electric utility industry, independent transmission companies, environmental organizations, alternative energy suppliers, and members of the public.[359] The board identified four regions with the highest wind energy potential given land availability and wind resources, mapped their locations, and estimated the maximum development capacity for those regions—a total of 6.1 GW.[360] A study by Michigan transmission owners estimated the cost of transmission upgrades necessary to integrate the four regions could be as much as $900 million.[361] This process was successful in that it involved stakeholders outside of industry and regulatory bodies, thereby providing planners insight into social and environmental concerns with wind development and associated transmission development. MISO integrated the Michigan wind zones into its own wind zone planning process. Projects in MISO’s wind zones that require transmission upgrades can qualify for socialized cost allocation.[362]

New York ISO Wind Generation Study

The New York Independent System Operator (NYISO) co-founded a study with the New York State Energy Research and Development Association (NYSERDA) to evaluate the impacts of large-scale wind integration, as needed to meet New York’s RPS of 25% by 2013.[363] The study found that the onshore wind projects required to meet the RPS would necessitate transmission upgrades to deliver the wind energy to load, and that 8% of the wind energy generated would be undeliverable. NYISO determined that new high voltage transmission would be necessary deliver the wind energy produced in Upstate New York, where the majority of the wind resource and developable land are located, to Southeast New York where the majority of load is located. However, they found that the majority of grid upgrades would need to be lower voltage (115 kV) distribution lines near wind generation, rather than the higher voltage lines that transport the power to load. The necessary grid upgrades were estimated to cost $75-325 million, however many of the transmission facilities studied were approaching the end of their operational lives and would need to be replaced regardless of the RPS. More importantly, no transmission or distribution upgrades were found to be necessary for offshore wind because the major ocean offshore resource is located near load in Southeast New York; thus wind energy generated offshore can feed directly into load where transmission capacity is already sufficient.[364] It also was found that integrating offshore wind was cheaper than onshore wind because of higher capacity factors and more coincidental outputs with peak demand.[365] This project was successful in modeling the difference between offshore and onshore wind energy in terms of transmission requirements and grid management concerns and in pointing out the fact that the majority of transmission infrastructure in the U.S. is approaching the end of its operational life. However, the study did not consider New York's offshore wind resource in the Great Lakes.

Bonneville Power Association (BPA) Network Open Season

BPA, located in the Pacific Northwest, took requests for transmission upgrades to integrate new generation. It required each developer who submitted a request to deposit one year's worth of transmission charges to show commitment to their project(s). BPA then conducted studies to determine which projects could be built while keeping transmission costs to the rate base constant.[366] It was determined that five of the 153 requests, accommodating 3,400 MW of new generation, 2,600 MW of which will come from wind, could be built without rate increases and granted those requests. Total costs for the five projects are expected to be $800 million, and construction began in 2009.[367] This example shows that renewable energy can be integrated without increasing costs to rate payers.

Southwest Power Pool (SPP) Balanced Portfolio Approach

SPP formed a cost allocation working group (CAWG) to determine a better way to plan and build transmission regionally, which formulated the Balanced Portfolio Approach. Similar to Bonneville Power Authority's network open season, SPP's CAWG reviews portfolios of transmission upgrades (many transmission upgrades at the same time) under the balanced portfolio approach. The benefits of a portfolio of transmission projects must exceed the costs over a 10 year period. The portfolios are mostly made up of high voltage transmission projects, but can include low voltage projects as long as total expenditures on those projects do not exceed high voltage projects.[368] Priority is given to the former because high voltage transmission projects expand overall capacity and reliability for the region. California's RETI conceptual transmission plan recommended a larger portion of high voltage transmission projects as well. In

2008, FERC approved **postage stamp** cost recovery (an extra transmission fee) for the balanced portfolio approach to be allocated to the entire SPP rate base. In 2009, SPP approved the first balanced portfolio, which includes five new transmission lines, a new transformer, and a connection between two transmission lines at a total cost of $700 million.[369] Although SPP's focus here was not on renewable energy integration, this newfound process was successful in planning and approving transmission projects.

Midwest-ISO Regional Generation Outlet Study

Assisted by state regulators and industry stakeholders, MISO conducted a regional transmission study with a focus on wind power integration and reliability, entitled the Regional Generation Outlet Study (RGOS). The study was conducted with the motivation of identifying transmission upgrades that would both allow states in the region to meet RPS and also improve the grid as a whole, thus reducing reliability and congestion costs. The RGOS identified a number of wind zones using methods approved by the Midwest Governors Association and the Upper Midwest Transmission Development Initiative, discussed below.[370]

MISO's Multi Value Projects (MVP)

Projects that meet the following criterion are socialized to MISO's entire load and exports:

Criterion 1: the transmission project helps meet policy mandates while improving grid reliability and economics.

Criterion 2: the transmission project provides multiple types of economic value across multiple pricing zones with a benefit-to-cost ratio equal to or greater than 1.

Criterion 3: project addresses at least one reliability concerns and at least one economic concern and has a benefit-to-cost ratio equal to or greater than 1.

Source: FERC, 2010. *Staff Presentation*.

RGOS determined that the best fit for the region would be a region-wide transmission overlay premised on a distributed set of wind zones of various sizes. RGOS found that locating wind zones in geographically distributed areas, as opposed to exclusively either in locations near load or in prime wind resource areas, would result in the least-cost per unit of energy delivered. The study found that the wind zones combined with the transmission overlay would reduce the load-weighted **location marginal pricing** (LMP, the cost of managing transmission congestion) by $0.0043-0.0049/kWh. This finding identified a set of MVP projects (see textbox) for both the MISO and the PJM footprints, with respective investment costs of $5.4bln and $4.4bln. These MVP projects will be given priority in the planning and approval process. Also, RGOS studied scenarios using no new transmission technology, using 745 kV lines, and using DC lines, but found none of these options to be clearly advantageous. The three scenarios ranged in investment estimates of $16bln to $22bln, and consisted of between 6,400-8,000 miles of new transmission miles.[371]

RGOS was successful in determining a regional wind integration and transmission plan. In the process it identified cost effective transmission projects that will be fast-tracked for approval. RGOS also found that new high voltage transmission technology was not necessarily advantageous.

UK Offshore Wind Zone Planning

The UK began planning and developing offshore wind in 2000 through a three stage process. Round 1 was a testing and knowledge building exercise. Regulators took submissions from developers and limited construction per developer to 10 km^2 with a minimum installed capacity of 20 MW. Regulators let developers determine locations based on depth, transmission availability, and environmental sensitivity. As a result all projects were sited in depths less than 20 meters and within 12 km from shore. A total of 962 MW (nameplate) were installed at 11 sites (multiple developers per site).[372]

In 2003, the UK began Round 2 of its offshore wind development program and commissioned strategic environmental assessments (SEA, similar to a USACE PEIS) for three coastal areas with the purpose of siting more offshore wind development. The three coastal areas chosen for the SEA were the Greater Wash, the Thames Estuary, and Liverpool Bay. The SEA created a precautionary exclusion zone between 8 and 13 km from shore for environmental reasons and set a limit on installed capacity for the three areas at 7.5 GW each. The Crown Estate then announced a competitive bid process from July-October 2003, and accepted 15 of 41 bids. Of the projects accepted 11 are fully operational to date.[373]

In 2007, the UK began round 3 of offshore wind development. Regulators commissioned another round of SEAs to facilitate 25 GW of additional offshore wind power.[374] For this round the UK regulators are taking a more involved role to guarantee goals are met, but also in part due to the increased onshore transmission infrastructure needs.[375] For Round 3, nine new offshore wind zones were identified by the U.K. Department of Energy and Climate Change with potential nameplate capacities ranging from 665 MW to 9000 MW.[376] These zones were identified with the SEA process, created by the Department of Energy and Climate Change, with a goal of "opening up the waters" to as much as 33 GW of offshore wind power.[377] Realizing the magnitude of offshore wind power planned in round 3, UK regulators commission a study to assess the onshore transmission needs necessary to integrate 25 GW of additional offshore wind energy. The study found that the optimal ratio of offshore wind nameplate capacity to transmission capacity was determined to be 1.12:1. The total estimated transmission costs of integrating the 25 GW of additional offshore wind energy were estimated to be $16.5 billion. The study found that minimizing the offshore transmission network is important for economic reasons and that significant onshore transmission upgrades are necessary.[378]

The UK's offshore wind development program has been very successful; as of 2009 the UK led the world in installed offshore wind capacity.[379] Of the many factors leading to its success, the SEA stands out. The SEA made project approval certain for developers, given bids were won, because the development areas were pre-approved for offshore wind development.

Renewable Energy Zone and Transmission Planning Conclusions

The innovations in aforementioned transmission planning include identifying a need for transmission upgrades in order to meet renewable energy goals, creating innovative cost-allocation schemes, finding transmission synergies between new renewable energy development and congestion relief, creating renewable energy zones to target transmission upgrades, creating collaborative planning processes to support transmission upgrades, and conducting environmental studies before developers seek project approval.[380] In particular, planning of zones with the regional grid in mind, as done by MISO, SPP, and CAISO, was successful in identifying the most beneficial transmission upgrades that increased transmission capacity to deliver renewable energy to load, but also reduced congestion, increased reliability, and/or improved grid economics. Further, the NERC, MISO, CAISO, and SPP studies together confirm that regional transmission upgrades are necessary and have economic value. Much of the extensive offshore wind development in the U.K. may be fairly attributed to their SEA, which gave clear directives for developers to site offshore wind projects. While there are certainly other reasons why the U.K. is a leader in offshore wind development, similar collaborative leadership would help development efforts in the U.S. and Canada. Cape Wind may be a salient example for why renewable energy zone planning is necessary for offshore wind development in the Great Lakes. If qualified experts and dedicated stakeholders are included in the planning process, offshore wind zones would avoid locations where the public is likely to prevent development.

It is important to note that there are other current or completed transmission planning processes whose details are not discussed in this report. For example, similar studies are being conducted, in various stages, by Southwestern Area Transmission (a collaboration of transmission owners, operators, and users; state regulators, and environmental entities), and the Western Governors Association in conjunction with the DOE.[381]

Envisioning the Offshore Wind Zone Process for the Great Lakes Region

A collaborative wind resource planning process has proven to be successful for onshore wind resources in the state of Michigan. The process gave a proactive role to stakeholders, including regulators and interest groups, and resulted in the designation of four wind zones. The wind zones enabled expedited permitting processes for transmission developers, thus focusing transmission upgrades, but also incorporated environmental and social concerns. This process ultimately advanced wind development in Michigan. The designation of offshore wind zones for the Great Lakes region could follow a similar process (see Figure 51), benefiting from lessons learned from the Michigan example and other renewable energy zone planning processes. The following is a discussion of each of the five steps proposed for offshore wind zones in the Great Lakes region:

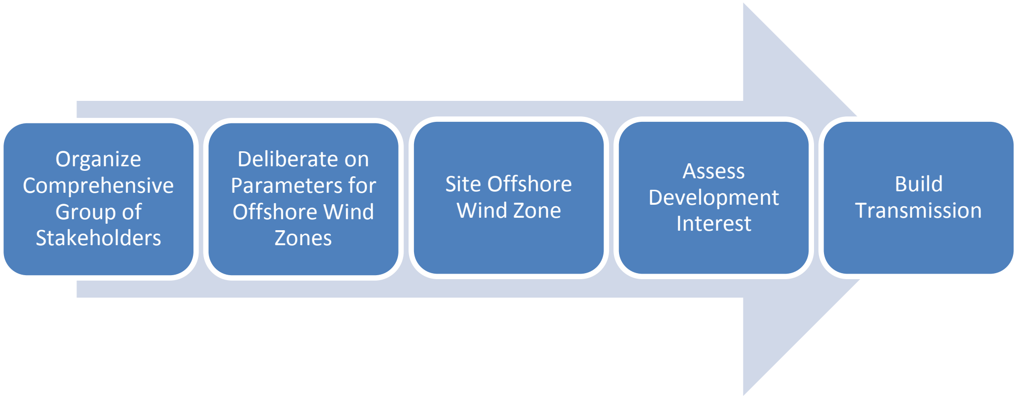

Figure 51: Flow chart of High-Level Steps for the Offshore Wind Zone Collaborative Process

Convene a Comprehensive Group of Stakeholders

A board of stakeholders representing a diverse set of interests from across the region must be organized. The Great Lakes Wind Collaborative and the Great Lakes Commission currently maintain promising connections to potential participants. Full representation ensures that decision-making will account for the full range of affected interests in the Basin. Stakeholders include:

- state/provincial public service commissions (or equivalent),
- state/provincial public utility commissions (or equivalent),
- utilities,
- transmission companies,
- grid management organizations (ISOs/RTOs or equivalent),
- environmental groups,
- community groups,
- the general public, and
- offshore wind developers.

While direct representation can be designed to include key actors/decision makers and stakeholders, leaving the process open to all affected by wind projects can add to the transparency and credibility of the process. Consistent commitment from participants is paramount for ensuring accountability and investment in the collaborative process. A key element of successful collaboration is a neutral, universally trusted mediator. The initial efforts of the board include comprehensively highlighting concerns, issues, and interests. Then, common goals and objectives can be prioritized through consensus building. A transparent framework to guide the collaborative process, developed by the group itself, is a vital component to achieve success.

Deliberate on Parameters of Offshore Wind Zones

Second, the board of stakeholders would have to deliberate on which social, environmental, and economic selection criteria are relevant and how to prioritize those criteria in zone designation decisions. For example, the Michigan Wind Energy Resource Zone group decided that wind resources were the first concern, found the places with the best wind resources, and then conducted transmission studies to determine which zones would be most cost-effectively developed. The offshore wind zone board would have to develop criteria for screening zones. For example, the Great Lakes region can be first narrowed based upon wind resources, depth, distance from shore, or migratory bird pathways, etc. In order to screen areas of the Lakes based on established criteria, studies could be conducted to gather the relevant information.

Table 10: Studies that may be necessary to aid a Great Lakes offshore wind zone collaborative process (many are already available)

Environmental	Location of contaminated soils, sediments, fish spawning grounds, bird and bat populations, migratory bird flyways, habitat fragmentation sensitivity, bird ascent and descent angles
Social	Location of tourism dependent areas; effects of offshore wind on tourism
Wind Project Economics	High-grade wind resource assessment, lake depth, lake substrate, construction equipment and staging area availability
Transmission Economics	Location of onshore grid locations with minimal upgrades necessary to integrate substantial amounts of offshore wind energy, grid locations between which energy trading would add economic value. Grid locations between which congestion relief would add economic value

Site Offshore Wind Zones

With necessary studies in hand, the board can make final designations and regulators can designate certain zones for preapproval. “Pre-approval” at the Federal level may require a programmatic environmental impact statement (PEIS) for the designated zones, similar to the U.K.’s systematic environmental assessments (SEAs) discussed earlier, which gave developers clear directions as to where to build projects. Several organizations and companies, including the GLC, have asked USACE to do a PEIS for offshore wind in the Great Lakes to no avail. A PEIS or equivalent may require an act of Congress.

Additionally, it may be difficult to coordinate pre-approval across state and international boundaries. MISO’s MVP and SPP’s Balanced Portfolio Approach are the only policies discussed in this report that bridge political boundaries. SPP has approved several inter-state projects under the Balanced Portfolio Approach.[382] MISO has approved one MVP project, to date.[383]

Assess Development Interest

Before building transmission upgrades, development interest will need to be assessed for the offshore wind zones. Ideally, developer interest would be incorporated as a criterion in the designation process. However, a critical mass of offshore wind project proposals/applications may be necessary to justify cost recovery for transmission upgrades. A guarantee from utilities to purchase electricity from the offshore wind zones is one way to justify transmission cost recovery, but a long queue for offshore wind project permits in an offshore wind zone may suffice.

Infrastructure Sharing In Offshore Wind Zones

Depending on the specifics of the wind zone, offshore infrastructure sharing may be optimal based on social and environmental criteria, if not also economic criteria. In cases like this, it may be necessary to develop a mechanism to aid developers in sharing that infrastructure. Developers building offshore wind projects in the same area are currently not explicitly incentivized to collaborate when building substations and connections to shore. Despite the potential benefits, as discussed in Part 3.2, developers in Europe and the U.S. have struggled to cooperate on joint projects. In Europe, "discussions tend to be mired in commercial and regulatory issues. There is a lack of true strategic planning or legal provisions to impose planning of offshore transmission infrastructures in the different countries."[384]

The Wash – An example of mandated sharing of transmission infrastructure

During Round 2 of the UK offshore wind development program, several projects were being built in the Wash, a bay on the eastern, central coast of Great Britain. The projects were being constructed by different companies. Although the projects were connecting to shore at the same point the companies did not choose to coordinate and share costs for a single offshore transformer, or a single onshore substation, or a single submarine transmission line to transport the power from the offshore transformer to an onshore substation. UK regulators took note of this lack of coordination and forced the companies to share as much infrastructure as possible.

Source: Clibbon, Peter. 2010. *Offshore Wind Farms: The First Decade*. Presentation at the 2010

Build Transmission

The final step is to build transmission, if the benefit to cost ratio of the wind zones' transmission upgrade is agreeable, or if offshore development interest is sufficient. Cost recovery and allocation may be an issue for offshore wind zones. Cost recovery and allocation may take many forms depending on ISO territory. Offshore wind zones may fit into previously established cost recovery mechanisms like postage stamps or MVPs, but could also take on new cost recovery schemes (subject to FERC approval) like California CREZ where developers take-on transmission upgrade costs as they come online, thus relieving the burden to rate payers.

Part 3.3 Conclusions

Region-wide consensus-based planning for offshore wind in the Great Lakes can encourage the development of offshore transmission infrastructure with optimal environmental, social and economic benefits. Strategic upgrades to the existing grid can allow for limited investment that results in large opportunities for offshore wind development. Offshore wind zones can provide benefits to developers, such as clear regional guidance and streamlined approval processes. Benefits to the public include among others, lower cost of renewable generation and fewer new ROWs. Some of the challenges encountered with this policy option are organizing and mediating diverse groups of stakeholders, planning for consistent net wind generation, and allowing for development outside of offshore wind zones. Case studies of similar efforts included in this section serve as templates for offshore wind zones in the Great Lakes Region.

Offshore Wind Zones at a Glance…

Potential Benefits:

- Formulation of strong consensus from collaborative consisting of diverse regional stakeholders
- Large scale coordination of environmentally, socially and economically optimal locations for offshore wind development
- Targeting of vital onshore transmission upgrades to support offshore wind development
- Onshore co-benefits, such as provision of congestion relief and reduction of new ROWs

Potential Barriers:

- Limitation of the number of developed locations due to concentrated offshore wind development
- Lack of geographical diversity in wind generation (resulting in intermittent generation)
- Reduced motivation to develop offshore wind in viable locations outside of offshore wind zones
- Coordination and management of a diverse and dedicated group of stakeholders

SUMMARY AND CONCLUSIONS

To formulate policy options to facilitate offshore wind transmission in the Great Lakes, this report examines both the transmission problem—how transmission might constrain offshore wind development and major barriers to new transmission development—and a range of solutions that could maximize net economic, environmental, and social benefits. This report draws on a year and a half of research by an inter-disciplinary graduate student project team. The research included a literature review, an expert interview process, and quantitative and spatial analyses.

This report begins by determining how transmission has constrained offshore wind development in Europe and whether it might play a similarly constraining role in the Great Lakes. To anticipate transmission constraints in the Great Lakes, this report offers a preliminary, broad-stroke analysis that compares existing "minimal constraint" integration opportunities to a high-growth scenario for offshore wind in the Great Lakes region. This report then examines barriers to new transmission development including cost, regulations, the environment, and social concerns.

To offer solutions—policy options and strategies to facilitate transmission to deliver offshore wind power—this report examines ways to avoid major transmission upgrades and, where transmission limits development, how transmission can be built while meeting other policy objectives related to environmental, social, and economic costs. The analysis determined that spare transmission capacity exists in the Great Lakes region, originally built to deliver energy from near-shore generation units that are now operated at less than maximum capacity. This report suggests that regulators and industry consider ways to incentivize grid reservation transfers or sharing to utilize existing spare transmission capacity. Where transmission is limiting, this report suggests that offshore wind zone planning and offshore grids could facilitate offshore wind power integration while meeting concurrent objectives of minimizing economic, environmental, and social impacts of offshore wind transmission.

In conclusion, the Great Lakes region has a salient opportunity to transition to this clean, local, renewable, and abundant electricity generation source. This offshore wind resource is on the brink of development. This report finds that offshore wind will be constrained by limited transmission in mid- to high-growth scenarios and that such constraints will likely force suboptimal offshore wind siting decisions.

Careful collaborative transmission and wind site planning can address this problem before it arises. Policy to support grid upgrades that optimize economic, environmental, and social benefits can play a pivotal role in the expansion of the offshore wind industry in the basin. Specifically, to minimize costly onshore transmission upgrades, policy makers can work to incentivize grid reservation transfers and sharing. Offshore grids can facilitate large-scale wind integration while reducing environmental and social impacts and by enabling multiple forms of economic value. Offshore wind zones can promote strategic development of offshore wind while targeting transmission upgrades to support that development.

The three policy options analyzed in detail in this report can contribute to the advancement of offshore wind in the Great Lakes and the transmission needed to deliver it, while minimizing costs and environmental and social impacts. Because transmission constraints can have a real impact on offshore wind siting decisions, transmission planning can serve as a powerful leverage point to incorporate multiple objectives in future offshore wind development decisions.

Project Team Perspectives

Despite its potential, offshore wind may not play a substantial role in the basin’s energy portfolio until either costs come down or a broader regulatory framework like a Federal renewable energy standard or carbon tax motivates a move to more expensive renewable energy. Even then, public opposition rooted in viewshed concerns may seriously inhibit the ability of developers to site large-scale projects in shallow waters near shore. For this reason, investment in deep-water foundations and floating turbine technology is essential given the bathymetry of four of the five Great Lakes. The attractiveness of far-offshore development also makes the offshore component of transmission central to the success of development in the lakes; finding ways to make offshore transmission cheaper (i.e., with multiple forms of economic value) will enable far-offshore wind facilities, which can relieve the industry of viewshed concerns while improving project economics. Two of the strategies presented in detail in this report—offshore grids and offshore wind zones—have potential to play a meaningful role on this front, particularly if offshore transmission can be planned to capitalize on multiple forms of value like energy trading, congestion relief, and improved grid reliability.

Areas of Further Research

Throughout the literature and case reviews, interviews, and analyses that comprised this research, specific topics were identified as requiring further research. These topics represent current knowledge gaps that would likely influence the development of transmission to support offshore wind development in the Great Lakes region. The following list includes key offshore transmission research opportunities:

- Existing transmission capacity evaluation for the Great Lakes region using detailed transmission data is needed to determine where spare capacity could be utilized to deliver offshore wind power.
- Technological solutions addressing the challenges of coupling intermittent offshore wind with existing baseload generation units is needed to enable wind to be a viable source for a large portion of the basin's energy portfolio.
- Incentives and legal mechanisms available to current holders of unused grid reservations need to be identified in order to encourage transfer or sharing of such reservation between offshore wind developers and current holders.
- A publically available offshore wind resource study for the Great Lakes region, emphasizing both speed and intermittency, needs to be completed for use in sitting wind zones, quantifying wind development potential, etc.
- A comprehensive review of public perception of offshore wind in the Great Lakes region is needed to characterize viewshed and other local concerns related to offshore wind. (Note: the Great Lakes Commission is undertaking this study).

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GLOSSARY

Alternating Current (AC) – Alternating Current is the electric current that reverses direction of flow at regular intervals.

Capacity Factor – Capacity factor is the ratio of the electrical energy generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same time period expressed either as a fraction or a percentage. Offshore wind turbines have higher capacity factor than their onshore counterparts because of higher speed and more consistent wind.

Congestion – Electrical transmission congestion occurs when constraints in the transmission system prevent the electricity demand of a node from being met by the cheapest power being generated.

Direct Current (DC) – Direct Current is the electric current that flows in one direction in a circuit.

Headroom – Headroom is the unused capacity in transmission infrastructure.

Heat Dissipation – Heat dissipation is the phenomenon of transmission cables giving off heat when transmitting energy due to the resistance offered by the cable to the flow of current.

Injection Points – An injection point, for the purposes of this report, is a location where offshore wind power can be connected to the onshore grid.

Intermittency Coping – Renewable energy resources have an intermittent nature, where they are essentially volatile. To cope with the volatility of renewable energy resources grid managers need to track power produced from renewable energy generating units and have dispatchable power (usually natural gas peaking plants) ready to generate power to smooth out the changes in renewable power output.

Levelized Cost – The levelized cost of electricity is the Net Present Value (NPV) of the capital, operation and maintenance cost of a power plant over its generating life, converted to an equalized annual cost.

Location Marginal Pricing (LMP) – The LMP of a particular area is the marginal cost of generating electricity usually measured in $/1 MWh. It reflects the costs of transmission congestion in an area, the higher the LMP, the more congested that region is.

MVP (Multi-Value Projects) – Midwest-ISO's (FERC approved) cost allocation policy includes a category of projects called MVPs. These transmission projects meet more than a single transmission need. For example, a project could improve reliability and connect renewable energy to load. If approved, the cost of an MVP is distributed over the entire Midwest-ISO rate-base including exports of energy to Midwest-ISOs surrounding regions.

Near Shore – "Near-shore" is defined for the purposes of this report in terms of cost, rather than distance. A number of factors affect the cost of submarine cable—most notably length, but also type of cable used, voltage, depth, ambient water temperature, cost of installation and maintenance, and others (which will be discussed in a later section of this report). "Near shore" is defined as within a short enough distance to shore that, given the other factors affecting cost, the capital costs for the transmission connection to shore do not represent more than 10 percent of total project costs. Depending on the project size and the other factors mentioned above, "near-shore" could be as close as 3 miles for small projects, or as far as 15 miles for larger projects.

Negative Loads – A negative load is a generating unit that offsets power demanded from a central power plant. Often renewable energy generating units are considered negative loads in practice because when they are producing power the central power plant can produce less, or the power demand from the central power plant decreases. Essentially, a "negative load" is a grid management accounting term.

Nameplate – Power generation units, like an offshore wind turbine or a combustion turbine, have a nameplate capacity. The nameplate capacity of a generating unit is the maximum amount of power the unit can generate when operated continuously at full-power. So an offshore wind turbine with a nameplate capacity of 5 MW can produce energy at the rate of 5MW in ideal design conditions. Note, **capacity factors** give a better idea of the amount of power one can expect from a generation unit. For example, a wind turbine with a nameplate capacity of 5 MW may have a capacity factor of 0.35; so on average one can expect 1.75 MW (5 * 0.35) of power from the turbine.

Ohmic Losses – Ohmic losses are the power losses in transmission due to the resistance that the line provides to the flow of current.

Postage-Stamp – A postage-stamp cost allocation method is a type of transmission project cost recovery, where transmission companies are allowed to charge a fee to users of said transmission project to recover the costs of the project.

Radial Connection – A radial connection is a transmission configuration where multiple wind facilities are connected to a single point on the shore.

Reliability – The criteria for a reliable grid are 1) *adequacy*, defined as a continuous ample supply to consumers, and 2) *security*, measured by the ability to withstand various forms of disturbances. Reliability of the grid is measured in term of *risk* of unacceptable events, where risk consists of 1) the likelihood that an event will occur, and 2) the consequences of that event. Since the late 1960’s, the North American Electric Reliability Corporation (NERC) has been tasked with reducing the risk associated with the power grid. NERC manages the risk via activities such as reliability standards development, compliance enforcement and assessment of future system events. NERC’s primary expectations are to 1) maintain real-time integrity, thus avoiding brief cascading blackouts and 2) protect the generation and transmission equipment from catastrophic damage, thus avoiding long term outages spanning weeks or months. In order to more accurately regulate and report the electric industry's status, NERC operates with eight regional entities, each which contain numerous balancing authorities. In the Great Lakes Region, there are there regional entities: Northeast Power Coordinating Council (NPCC), Reliability*First* Corporation (RFC) and Midwest Reliability Organization (MRO).

The development of reliable transmission can both reduce environmental impact and reduce overall cost. A reliable transmission system can be achieved through thoughtful sub-station and protection system design that can isolate a failure event so as not to affect the larger grid's reliability. Future offshore wind projects in the Great Lakes can create additional quantifiable benefit if their respective transmission systems increase the reliability in the larger surrounding existing grid

ROW (Right of Way) – In order to build transmission or expand existing transmission developers need to obtain ROWs. These are usually easements from property owners and can be obtained via eminent domain.

Scour – Fluctuating water bounces off solid structures and scours the bottom of the body of water. For example, when trees fall into a stream the flowing water scours the sediment around the tree creating a hole or a deeper section of the river.

APPENDIX

List of Appendices:

Appendix A: Renewable Portfolio Standards (RPS) - Descriptions by State[385]

Minnesota: "30% by 2025"

Minnesota has one of the oldest and most aggressive renewable electricity standards. In 1994, Xcel Energy, which supplies about half of the electricity in the state, was mandated to build 425MW of wind energy and 125 MW of biomass energy capacity by 2002. In 2001, an additional 400MW of wind energy by 2006 was added to Xcel's requirements along with a state-wide Renewable Energy Objective (REO) that mandated all utilities produce 10% renewable electricity by 2015. In 2003, Xcel's requirements were augmented again with and additional 300MW of wind by 2010. Finally in 2007, Minnesota legislators passed "SF 4", which set targets at 15% renewable electricity for Xcel Energy and 7% renewable electricity for all other electricity providers by 2010. The targets ramp up over time to 30% renewable electricity for Xcel Energy and 25% renewable electricity for all other electricity providers by 2025. "SF 4" is relevant to 100% of electricity sales and it heavily supports wind by specifying that 25% of Xcel's electricity must come from wind in 2025. Any renewable electricity sources must be located in the Midwest Renewable Energy Tracking System (M-RETS) region, which includes Illinois, Iowa, Manitoba, Minnesota, Montana, North Dakota, Ohio, South Dakota, and Wisconsin.[386] Eligible resources include wind, biomass, solar, hydroelectric (<100 MW), hydrogen from renewable resources, landfill gas. The REO is under the jurisdiction of the Minnesota Public Utilities Commission (PUC) and is tracked by M-RETS. Compliance is achieved throughout the procurement of Renewable Electricity Credits (RECs), where 1 REC is equivalent to 1 MWh of renewable electricity. Renewable electricity purchased in the consumer green pricing program is excluded from the REO, however the cost of RECs can be recovered via consumer's rates. There is formally no cost cap, but the PUC maintains authority to limit cost of RECs. The PUC regularly investigates electricity providers and the penalty for noncompliance can include forced construction of renewable facilities, purchasing of RECs or lump sum fees (however the cost of the penalty cannot exceed the cheapest option as determined by the PUC). The PUC has authority to delay requirements for various reasons related to feasibility and impact of new renewable resources. In addition to Xcel's accelerated mandates, it also has to annually contribute considerable funds to Prairie Island nuclear generation for the purpose of moving nuclear waste out of state. Every two years, utilities report to the PUC, and in turn, the PUC and Minnesota Department of Commerce report to the Minnesota House of Representative and Senate.

Wisconsin: "10% by 2015"

Wisconsin has a substantial history of legislating renewable electricity generation. The RPS originated with a mandate in 1998 of 50MW in eastern Wisconsin by 2000 and then in 1999, it expanded to 2.2% renewable electricity by 2011 statewide. The current RES mandates 10% renewable electricity by 2015. The current RPS is applicable to 100% of electricity sales in the state. Both existing and new renewable generation are included, but only generation post-January 2004 can receive tradable Renewable Resource Credits (RRC). A RRC is defined as 1 MWh of renewable energy delivered to a customer's meter. Eligible sources include fuel cells fuelled with renewable energy, tidal/wave, solar thermal, solar PV, wind, geothermal, hydroelectric (<60MW), and biomass (wood/plant residue, biological waste, crops and landfill gases). Sources must be located in Wisconsin or outside the state as long as the electricity is used to meet Wisconsin load. The RPS is under the jurisdiction of the Wisconsin Public Service Commission (PSC) and relies on M-RETS to track the RRCs. The Center for Resource Solutions' Green-e Standards does not permit green pricing programs to contribute to RPS requirements. Wisconsin's RPS includes a clause for a retailer cost cap, though it remains as an undefined "excessive increase in ratepayers' rates," determined by the PSC. Wisconsin also has a special public benefits fund which mandates electric and natural gas utilities to spend 1.2% of annual gross revenue on renewable energy and energy efficiency programs (in addition to the RPS). Penalties for not meeting the RPS can range between \$5,000 and \$500,000; however an electricity provider can request a delay in compliance if "good faith effort" is demonstrated. Electric utilities must report annually on progress towards RPS requirements and every other year the PSC provides a progress report to the Governor.

Illinois: “25% by 2025”

In 2001, Illinois enacted a voluntary Renewable Portfolio Standard (RPS), applicable to investor owned utilities serving at 100,000+ customers (consisting of about 73% of electricity sales). The target begins at 2.0% renewable electricity in 2008 and ramps up annually to 25% in 2025. New and existing facilities are eligible under the RPS. Through June 2011, generation sources should be located in Illinois and thereafter RPS boundaries will be expanded to adjoining states, as long as resources exist. Eligible resources include, but are not limited to, wind, solar thermal, solar PV, biodiesel, organic waste biomass, existing hydropower and landfill gas. An effort to achieve 75% of renewable electricity from wind is included in the RPS. The Illinois Commerce Commission maintains jurisdiction, however the RPS is administered by the newly created Illinois Power Agency. Compliance is achieved by procuring RECs, which are tracked by both M-RETS and PJM’s Generation Attributes Tracking System. There is a cost cap that ranges from 0.5% to 2.0% of the previous year’s cost to consumers, depending upon the phase of RPS ramping (though this limit shall be reviewed in 2011). The penalty for noncompliance is yet undefined, but is the responsibility of the Illinois Power Agency. The Illinois Power Authority reports annually to Governor and General Assembly.

Indiana: No RPS to Date

Michigan: “10.0% by 2015,” plus 500MW and 600MW

Michigan’s RES, enacted October 2008, is relevant to 100% of electric sales and includes special requirements for two large utilities, Consumer’s Energy and Detroit Electric. The RES mandated 2% renewable electricity in 2012 and ramps up to 10% renewable electricity by 2015, with an additional 500MW and 600MW renewable capacity for Consumer’s Energy and Detroit Edison, respectively. New and existing facilities are included, with a stipulation that certain existing facilities require efficiency and/or maintenance upgrades. Sources must be in located in

Michigan or in the retail service territory. Up to 10% of obligation can be met by energy efficiency and advanced clean energy resources, with some additional stipulations. Eligible resources include biomass (defined as non-fossil fuel organic matter that replenishes within a human time frame), solar PV, solar thermal, upgraded hydroelectric, geothermal, municipal solid waste and landfill gas. Preferential incentives exist for solar power, peak demand generation, advanced storage capacity and systems constructed with equipment/labor from Michigan. The RES is under the jurisdiction of the Michigan Public Service Commission (PSC) and is tracked by RECs accounted by M-RETS. There is a cost cap which utilities are not required to meet standards based on a limit of increased cost of $3.00 per month per residential customer, $16.58 per month per commercial customer and $187.50 per month per industrial customer. Compliance penalties will include purchasing additional RECs, of which the cost must not be passed on to the consumer. Additionally, RECs will not be granted for power purchased as green pricing electricity from the consumer. Each electric provider must submit reports providing information about action taken to achieve RES and the PSC has ability to grant extensions to the 2015 deadline. Michigan's RES is part of a legislation that also describes an Energy Efficiency Resources Standard (EERS), net metering and wind resource zones.

Ohio: "12.5% by 2024"

Ohio's Renewable Electricity Standard (RES), enacted on May 1st, 2008, is relevant to approximately 89% of the total electric sales. The RES mandates 0.25% renewable electricity in 2009 and ramps up annually to an end goal of 12.5% renewable electricity in 2024. The requirement specifies that 0.50% of the 12.5% must be electricity from solar PV facilities. Any source constructed on January 1st 1998 is included and at least ½ of the sources must be physically located in Ohio. Eligible resources include solar PV, solar thermal, wind (onshore and offshore), geothermal, biomass (methane by-product of pulping and wood manufacture), low-impact hydroelectric, fuel from non-combusted solid wastes, fuel cells and storage that promotes renewable energy. The RES is under the jurisdiction of the Public Utilities Commission of Ohio (PUCO) and RECs are tracked by M-RETS of the PJM Generation Attributes Tracking System. There is a cost cap for retailers in which utilities do not required to meet standards if costs are greater than 3% conventional generation, as determined by the PUCO. Compliance penalties are currently set at $45/REC for electricity from non-solar sources and $450/MWh for electricity from solar. A reasonable flexibility mechanism is included to allow for interim monitoring, review and alternations of the RES. Ohio's RES is part of a legislation that also prescribes an Energy Efficiency Resources Standard (EERS) and greenhouse gas (GHG) reporting.

Pennsylvania: "10% by 2020"

Pennsylvania began a relatively unstructured initiative in 1996 that required utilities to establish funds for renewable energy and clean energy technologies. More recently in 2004, an Alternative Energy Portfolio Standard (AEPS) was enacted that is relevant to approximately 97% of the state's electricity sales. The AEPS consists of two tiers of targets. Tier 1 includes most "traditional" renewable resources and starts at 1.5% renewable electricity in 2006, then ramps up in multiple segments to 8.0% renewable electricity in 2020 (which includes a special clause for 0.5% of solar PV in 2020). Tier 2, which addresses other renewable and management options, begins at 4.2% in 2006 and ramps up to 10% on 2020. The majority of the renewable resources must be within the PJM region, while certain categories of eligible resources can be located within the larger MISO region. Eligible resources within Tier 1 include solar PV, solar thermal, wind, low-impact hydropower, geothermal, biological derived methane, fuel cells, select organic biomass and coal mine methane. Tier 2 includes waste coal, small-scale distributed generation systems, demand-side management, large scale hydropower, municipal solid waste, industry by-products and combined coal gasification technology. Compliance is achieved by the procurement of RECs and alternative energy credit purchased by consumer cannot be attributed to AEPS requirements. The AEPS is under the jurisdiction of the Pennsylvania Public Utility Commission (PUC) and Department of Environmental Protection (DEP) and RECs are tracked by PJM's Generation Attributes Tracking System (GATS). There is a cost cap contained within an alternative compliance mechanism and the PUC can modify requirements if renewable resources are not available within the respective regions. A noncompliance penalty is currently set at $45 per non-solar PV REC and 200% of average market value for solar PV REC (though the PUC maintains authority to adjust REC prices). The PUC and DEP report annually to the

Environmental Resources and Energy Committees in both the House and Senate, with year 2011 identified as the time frame to make any major adjustments to legislation to maintain appropriate progress toward the 2020 goals.

New York: "25% by 2013," *including 1% from voluntary green power markets*

In September 2004, New York enacted a Renewable Portfolio Standard (RPS), which utilizes a central management and procurement mechanism developed by the New York Public Service Commission (PSC) and facilitated by the New York State Energy Research and Development Authority (NYSERDA). The RPS is relevant to approximately 82% of the electric sales in the state. New York's existing renewable electricity (mostly from large hydroelectric facilities) is expected to contribute 17.25% of total electricity generation in 2013. The RPS outlines an annually incrementing target that increases to 6.56% new renewable electricity by 2013 and 0.19% renewable electricity state purchase requirement. A goal of 1% voluntary green power purchased by consumers by 2013 is also included in the RPS. The aggregated RPS goal is 25% total renewable electricity consumption by 2013. The renewable electricity facilities must be located in New York or the outside New York if electricity is explicitly delivered to New York consumers. New York's RPS is segmented into three tiers. Eligible resources included in the main tier are wind, solar PV, ocean thermal, tidal/wave, upgrades to low-impact hydroelectric (< 30 MW), biogas (including, but not limited to, landfill/sewage/manure methane), qualifying biomass and qualifying liquid biofuels. Tier two focuses on customer-sited renewable resources and includes fuel cell, solar PV, wind and organic biogas (which is supported by mandatory net-metering). Tier three concerns maintenance resources and includes low-impact hydroelectric (<5MW), wind and direct combustion biomass. New York's RPS is tracked by New York Independent System Operator (NYISO) and supported with funding and planning resources by NYSERDA. RPS implementation costs are capped by a rate payer surcharge a determined by the PSC and administered by NYSERDA. Penalties for non-compliance are not explicit in the RPS, but are the responsibility of NYSERDA. New York's RPS will be extensively reviewed in 2009.

Ontario: “FIT Program”

The main motivating mechanism in the Canadian province of Ontario is the Feed-In-Tariff (FIT) Program. The program, enacted in 2009 under the *Green Energy and Green Economy Act*, guarantees a structured and stable pricing scheme for renewable electricity generation.[387] The program is under the jurisdiction of the Ontario Power Authority. Eligible resources include biomass, biogas, landfill gas, on-shore and off-shore wind, solar PV and hydropower. In its initial year, Ontario’s FIT program has received much successful interest and, as of April 13, 2010, the program is not able to take any further applications for 10kW+ generators—in part due to limited capacity of the electric grid.[388] In addition to boosting economy and technology, the FIT program maintains the goal to phase out coal-fired electricity by 2014.

Appendix B: What is congestion?

Electrical transmission congestion occurs when constraints in the transmission system prevent the delivery of cheap available power to any load. These constraints can be in the form of physical limitations to the transfer of electricity or in the form of operational restrictions that exist to ensure reliability of the grid. When this cheap power cannot be delivered, more expensive units are used to generate and dispatch power to the load. [389] This causes electricity prices to be higher in the transmission constrained area. The cost of congestion is then the price differential between the expensive and cheap sources of power.

If there were no congestion, electricity could flow freely from the cheapest source to the load and there would be uniform prices across grid.

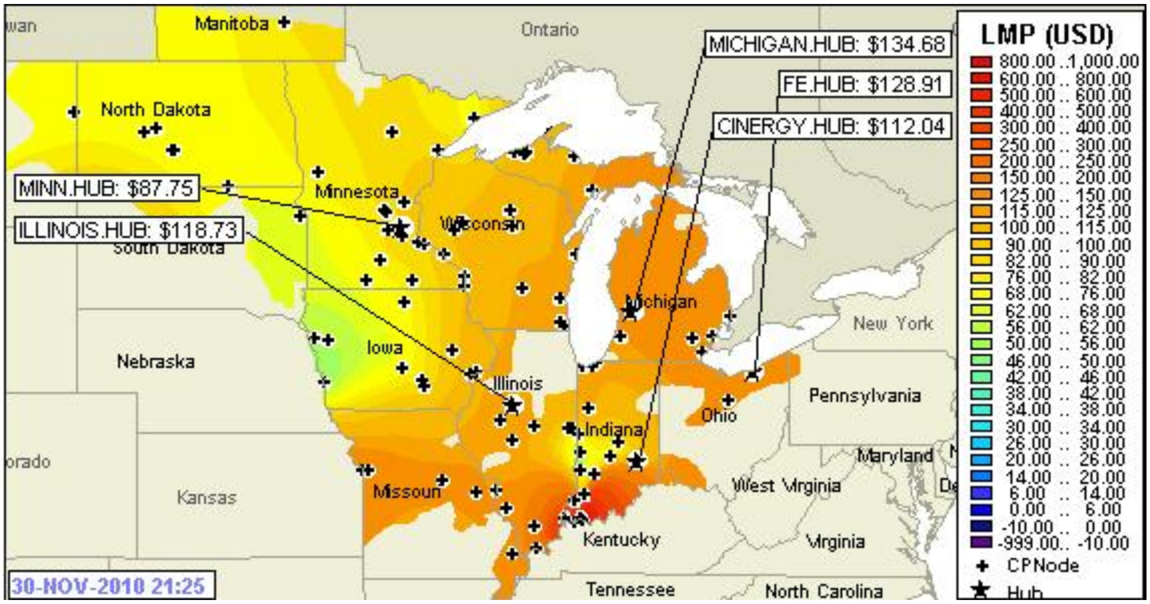


Figure 52: Locational Marginal Prices (LMP) in the MISO region[390]

This map shows the Locational Marginal Price (LMP) of electricity at nodes across the Midwest ISO region. The different colors indicate different LMP values. The points of color change are nodes where cheaper is energy is unable to flow through due to congestion.

Congestion is an important factor to consider in transmission planning because of the economic costs that it imposes on the energy market as a result of a mismatch between demand and supply of energy. In fact, congestion costs for PJM were as high as $2.1 billion in 2008[391]. In extreme cases, transmission congestion can compromise the reliability of the grid. If there is congestion between a low-cost generator and a load, power has to be dispatched from a high-cost generator on the load side of the congestion point. If this high-cost generator cannot meet the entire demand of the load, then the system's overall reliability is threatened.[392]

Quantifying Congestion

1. Economic costs due to congestion
2. Levels of transmission usage
3. Reliability consequences.[393]

Economic Cost of Congestion:

A simple way to look at it would be to consider a simple two node model. The transmission capacity between Node A which has a low-cost generation unit and Node B, which has a higher cost generation unit is 200 MW (see Figure 53).

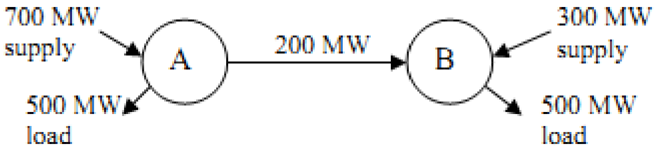


Figure 53: A two-node network[394]

The intersection of the marginal cost curves of the two generators gives the dispatch numbers: 700 MW from A and 300 MW from B (see Figure 54).

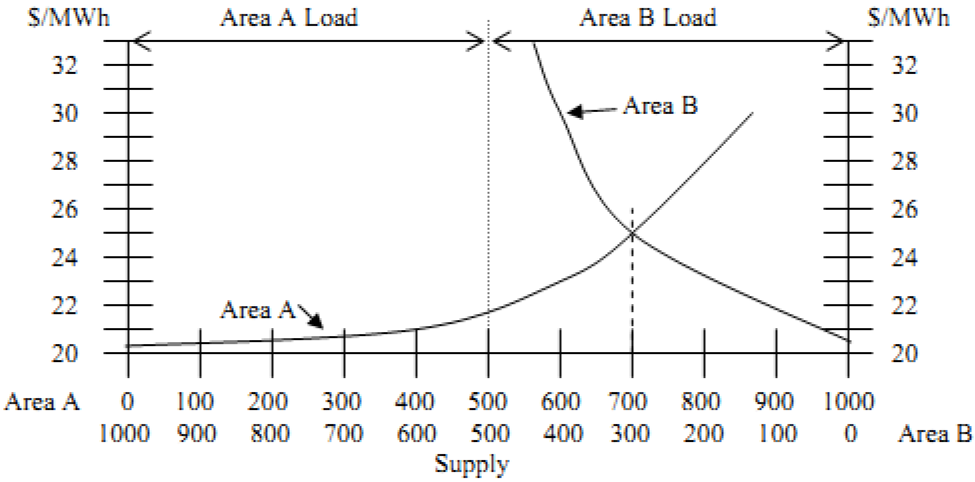
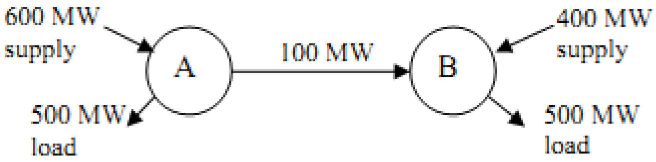


Figure 54: Marginal cost of supply from the two generators.[395]

If the transmission capacity between the two areas is constrained to only 100 MW, Area A can supply only 100 MW of power to Area B. This forces Area B to rely on more expensive generation units in Area B. The cost of congestion is the difference between the production costs in the constrained and unconstrained cases.[396]



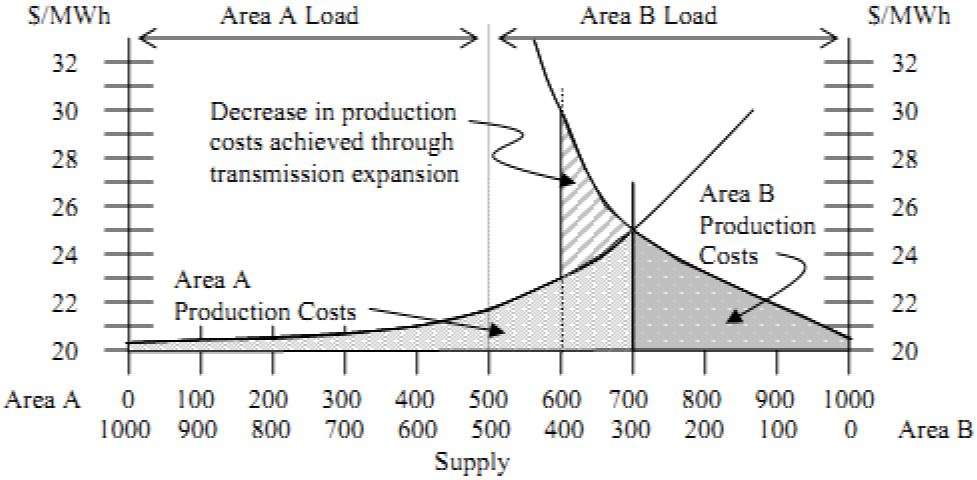


Figure 55: The cost of congestion.

This is a simple model merely for illustrating the concept of economic cost of transmission congestion. The electrical grid in reality is far more complex with several generation points and several loads forming several power flow loops.

From January through September of 2010, PJM faced congestion costs of $1.14 billion[397]. The congestion costs for ISO New England was $121 million in 2008 and $25 million in 2009. [398]

Relieving Congestion

Relieving transmission congestion is not merely a matter of adding transmission capacity to the constrained line. Since the electrical grid is a network, relieving congestion at one point may shift the congestion to some other point[399]. Some other ways of providing inexpensive energy to the constrained load center are[400]:

1. Installing new generation capacity near the load that provides inexpensive energy

2. Reducing the demand at the load center through demand response or energy efficiency measures

3. Installing energy storage devices

Energy storage options are still not commercially viable while demand response and energy efficiency measures require the involvement of both utilities and consumers.

In some cases, reinforcing existing transmission lines or adding new transmission lines may be the only option, where as in other cases adding new local generation may be the only way to relieve congestion. In other cases, either option may be feasible, in which case the least expensive option is chosen. The cheapest option may even be to not relieve the congestion at all.[401]

Relevance to Offshore Wind

As mentioned in Part 1, in the Great Lakes region, several load centers are located on the shore close to developable offshore wind resources. Where feasible, the offshore wind farms can relieve congestion by acting as a local energy generation resource.

When offshore wind technology matures to enable floating turbines to be set up, offshore wind farms can be situated even in the deepest parts of the Great Lakes. In this case, congestion relieving transmission lines can be laid across lakes. The wind farms located along these congestion relief lines can be tied into these lines if they have collector stations installed.

Also, new offshore wind farm development may be constrained by transmission congestion at the onshore grid injection points. The map below shows the renewable energy resources that are or will be constrained by congestion issues in the grid. Type II Conditional Congestion areas are those areas with renewable resources like offshore wind that are not technologically mature, but when mature will be limited by transmission availability[402].

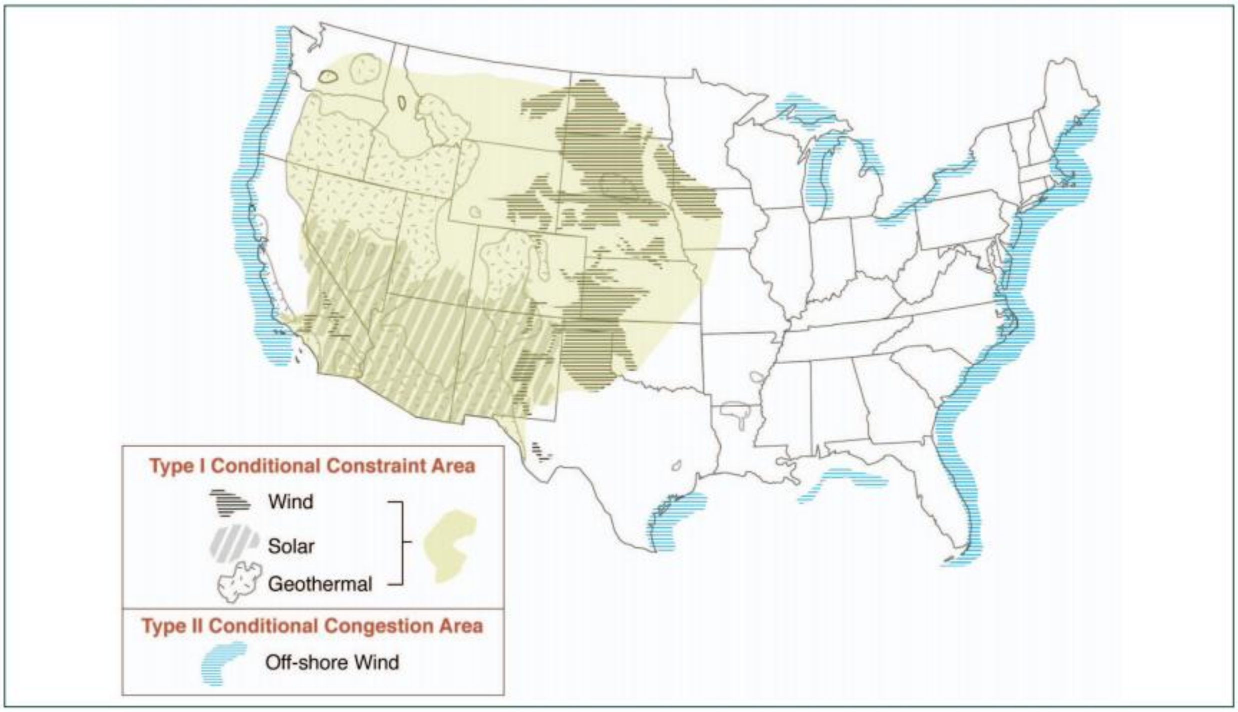


Figure 56 Renewable Energy Resource Development could be constrained by congestion issues.[403]

The feasibility of such resources then depends on whether the transmission capacity will ever be available in the future. Delays and uncertainty in this may prevent the projects from taking off.

Case Studies

In the US and Europe transmission congestion has been relieved by adding transmission lines and by adding new generation.

Adding new transmission:

The Mid-Atlantic region and the New England area were identified as critical congestions areas by the 2006 NETCS. To relieve the congestion in this region, several new transmission lines were built since 2000.

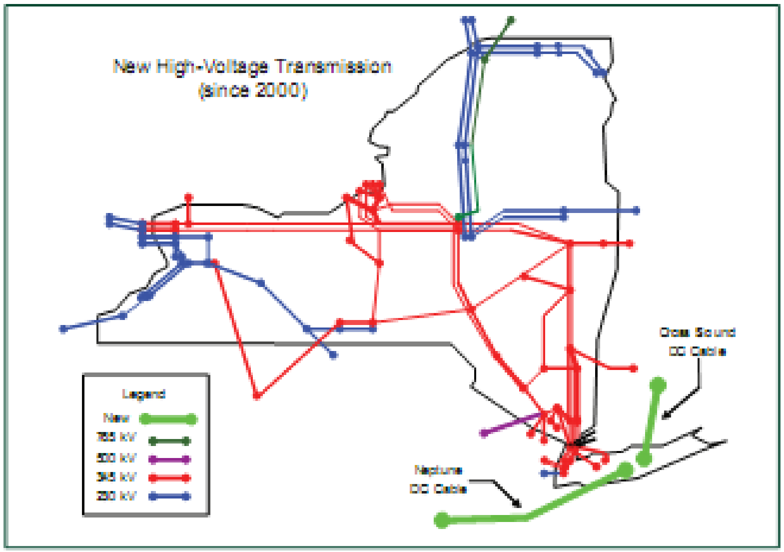


Figure 57 New Transmission Built in the New York Area[404]

The following figure shows why these new transmission lines were needed.

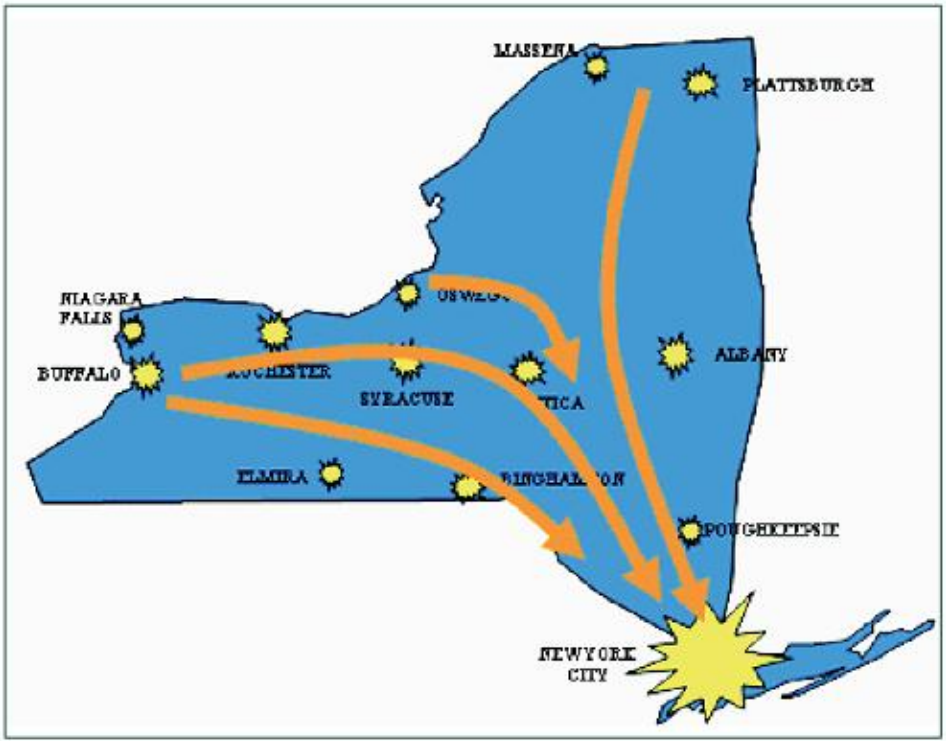


Figure 58 Bulk Power Flows in New York State[405]

The majority of the power flow is towards New York City from upstate NY. Thus New York City is a centre of congestion and electricity prices here are much higher than those in the rest of the state.[406] To relieve this congestion, two new projects were proposed, one in 2002 and another in 2008.

1. Cross Sound Cable

The Cross Sound Cable, developed by TransEnergieUS is a 330 MW HVDC transmission cable running between Shoreham, New York (Long Island) and New Haven, Connecticut. Though it was completed in 2002, it did not begin commercial operation until 2004 due to opposition from the State of Connecticut. After the blackout in 2003, DOE issued an emergency order to operate this cable.[407]

This cable uses the HVDC Light technology developed by ABB. Two DC lines one 150kV above ground potential and another 150kV below function effectively as a 300 kV line. Running 6 feet below the sea floor, over a length of 42 km (84 km because there are two lines), this cable helps to reduce congestion on the interface between New York City and upstate NY.

2. Neptune Regional Transmission System

The Neptune Regional Transmission System links Long Island and low cost energy sources in New Jersey. It is a 100km long and runs between New Cassel, Long Island and Sayreville, New Jersey. The line has a capacity of 660 MW. The project was completed in 2007. The cables were laid 6 feet under the sea floor (80km) and 3 – 4 feet below the ground, on land.[408]

These two projects gave opened up a transmission corridor from Midwest to Long Island and on to New England and Canada.[409] Due to the opening of the corridor, the cables have greatly helped to reduce congestion in New York.[410] The Neptune project alone helped reduce electricity prices in NY by 3%.[411]

Adding generation:

In some cases adding new transmission lines may not ease congestion. A lot of Sweden's electricity is generated by hydropower plants. The large power plants are situated in the North while the load centers are situated in the South. When loads are high and the hydropower generation is high, the transmission lines between the North and the South are operated at close to their maximum capacity of 7 GW causing a bottleneck. This affects the development of wind power in the North and limits the export of power from the South.[412] Currently a 600 MW line runs between Sweden and Poland. This link called the SwePol Link is being underutilized because of the congestion in the Swedish North-South link.

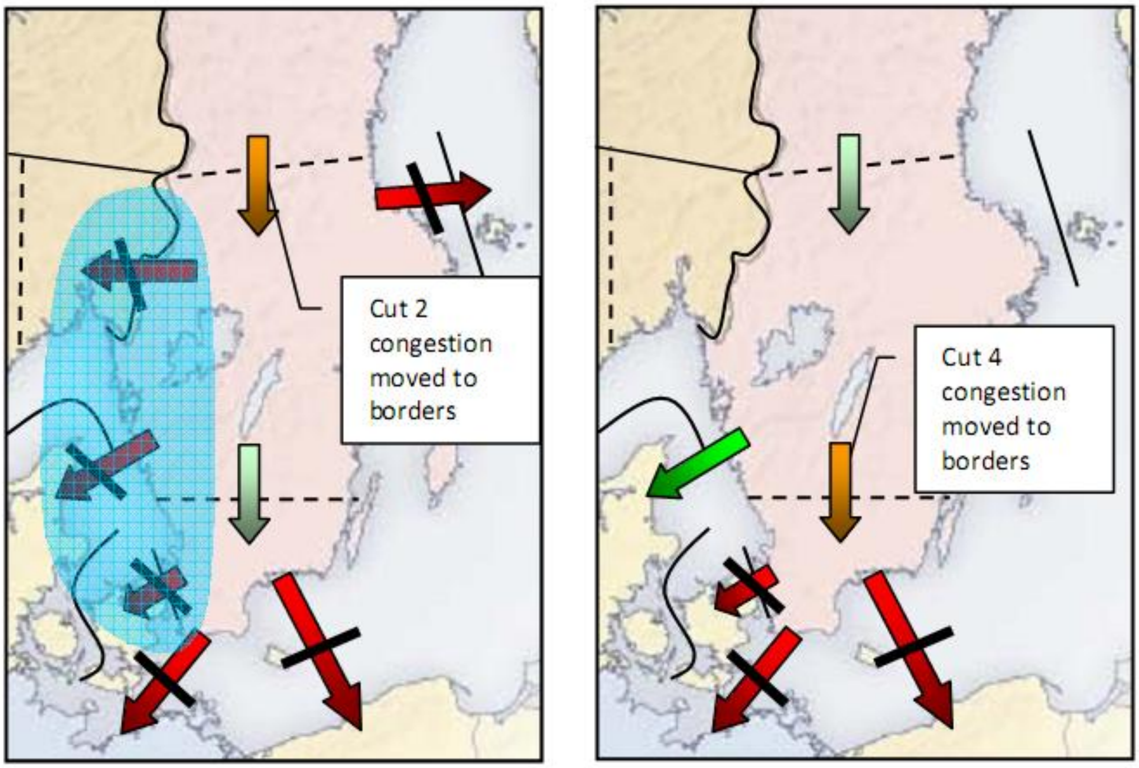


Figure 59. Export capacity reductions to resolve internal Swedish congestion. The congesting flows (orange arrows) are prevented by reducing export capacities along the red arrows.

Adding new sources of power in the south can ease the congestion on the North South link and thus facilitate the use of the SwePol Link. Offshore wind farms in the South can help to mitigate this problem as load centers in the South can be supplied energy from the offshore wind farms instead of transmitting power from the hydropower plants in the North.

Appendix C: Great Lakes Bathymetry Maps

(30 meters and less is developable with commercially proven offshore turbine wind technology)

Key

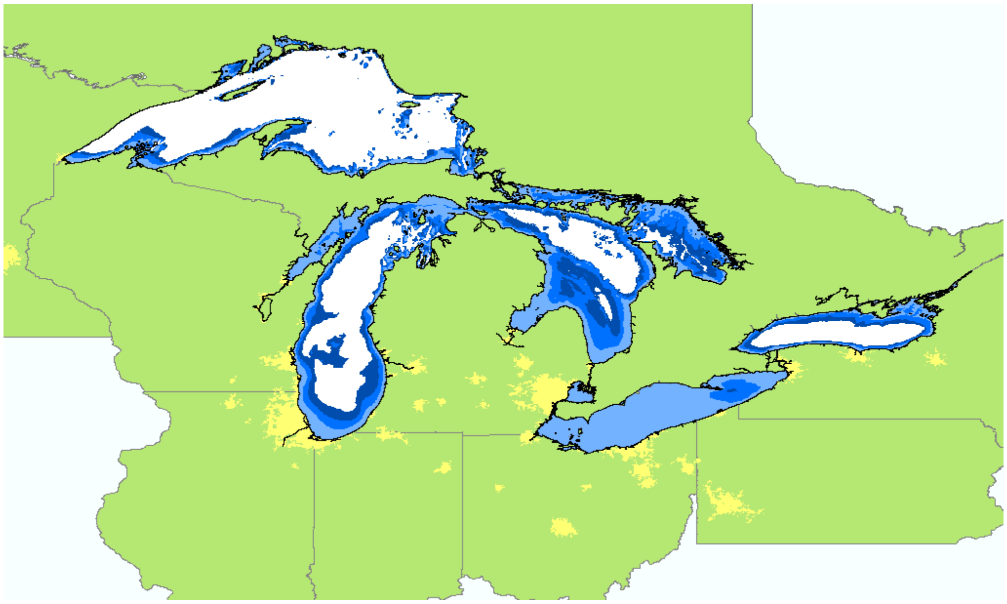
Bathymetry (m)

- 🟦 <30
- 🟦 30 - 60
- 🟦 60 - 90
- ⬜ > 90

US Urban Areas (2000)

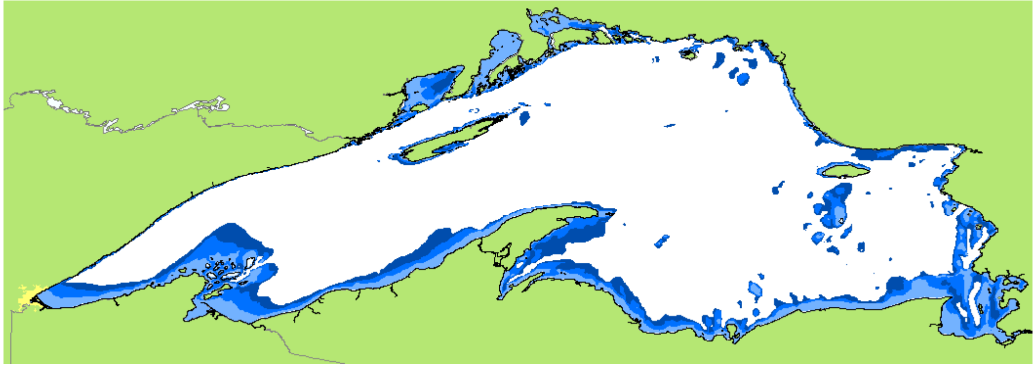
- 🟨

Great Lakes Basin (Scale = 1:7,500,000)

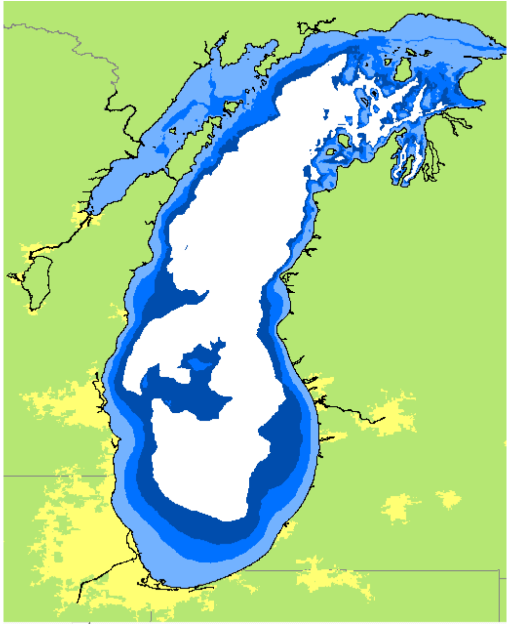


Individual Lake Maps (Scale = 1:3,200,000)

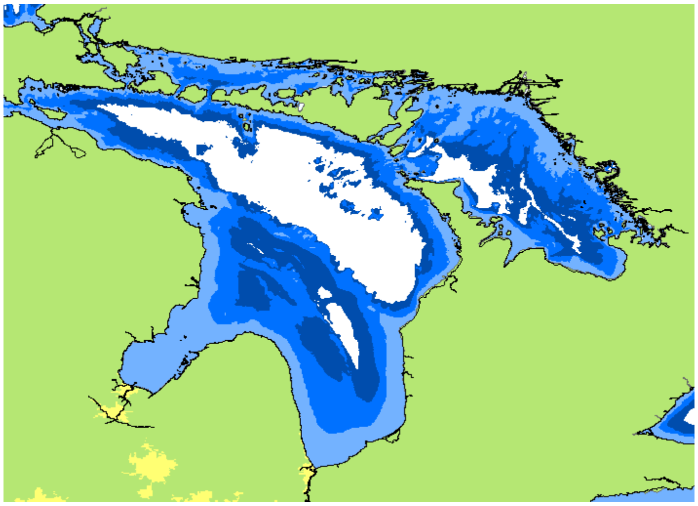
Lake Superior



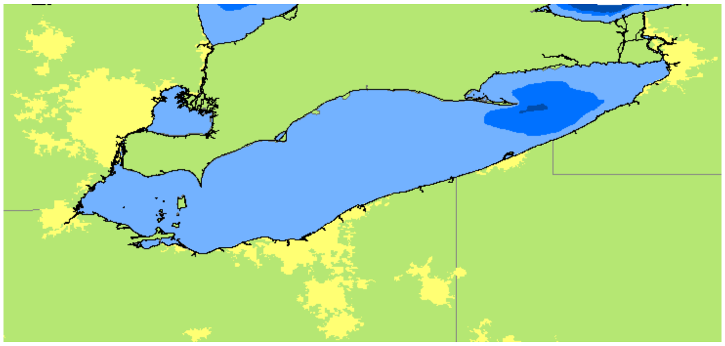
Lake Michigan



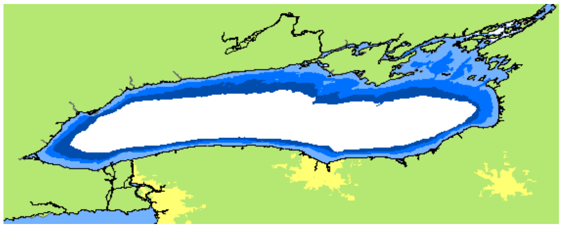
Lake Huron



Lake Erie



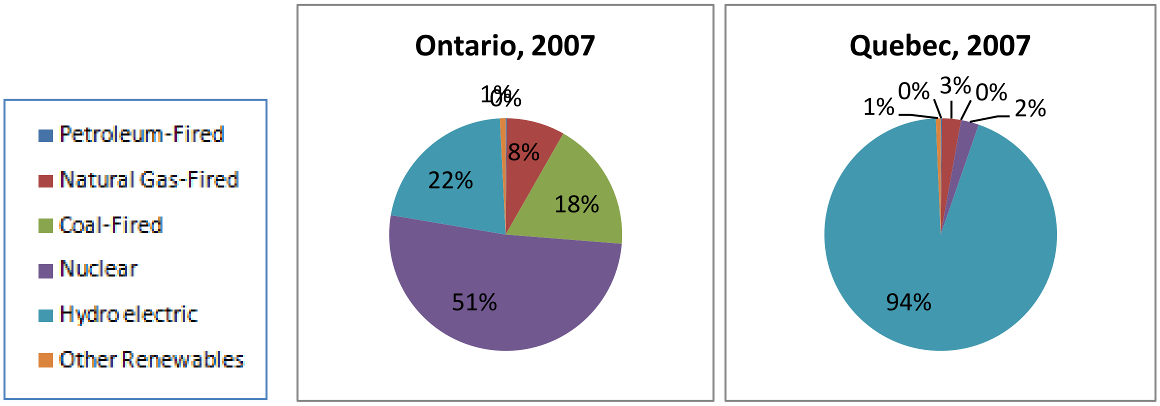
Lake Ontario

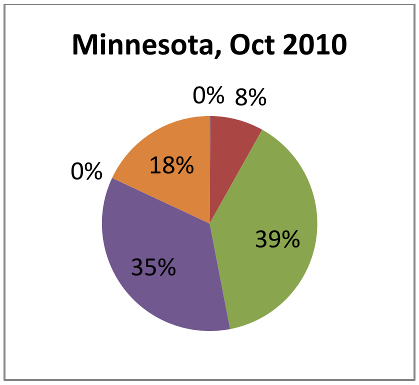


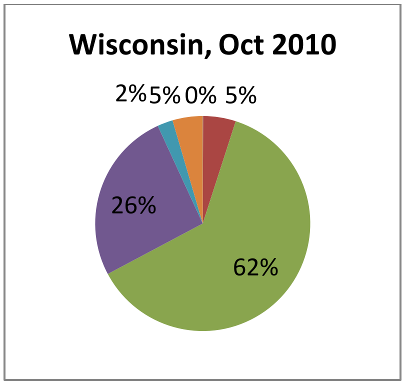
Appendix D: Cost of moving projects offshore

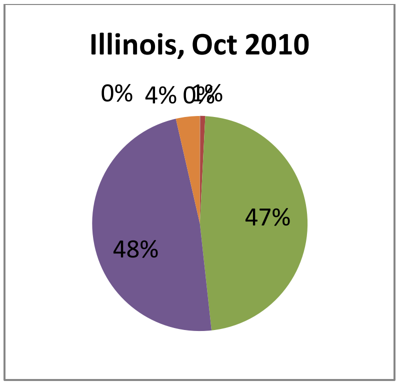
Moving a proposed project further offshore could lead to a substantial increase in the price of electricity delivered from that facility. The factors that add to this cost include the cost of the submarine transmission cable and the additional transmission losses from moving further offshore. For example, if a proposed 100 MW offshore wind facility were to move from 6 miles to 15 miles from the shore, the contribution of transmission infrastructure to the cost of electricity generated could go up from 1.06 cents/kWh to 2.65 cents/kWh. This is under the assumption submarine transmission cables would cost $4 million per mile. These additional 9 miles of transmission would increase the capital cost by $36 million. The additional length of cable would also result in transmission losses (0.65% of the energy is lost every 100 miles).[413] Using a Fixed Charge Rate of 15%, this move further offshore would result in an increase of the cost of electricity by 1.64 cents/kWh.

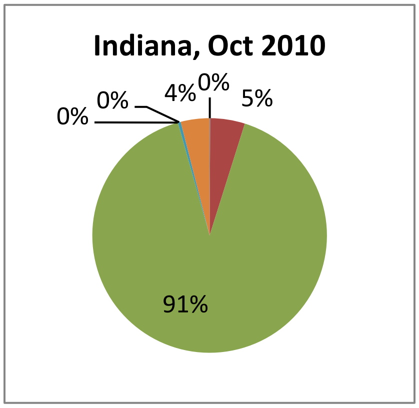
Appendix E: Great Lake Region Electricity Mixes

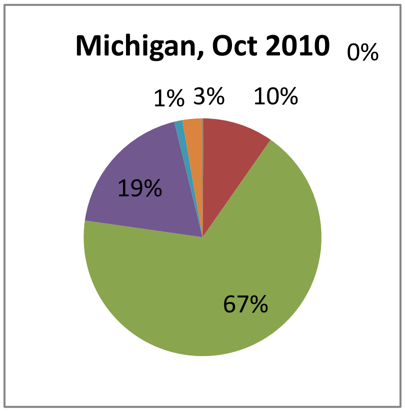


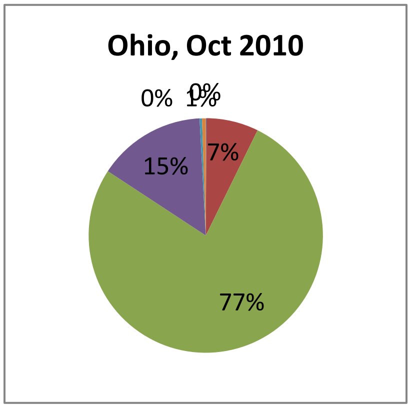

Minnesota, Oct 2010

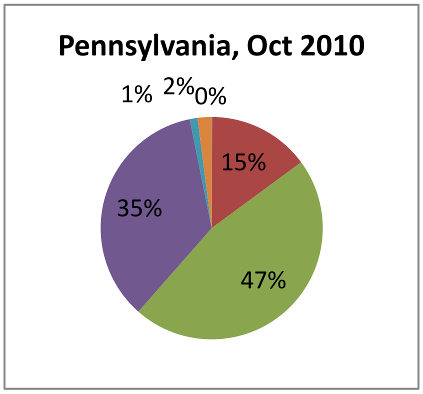

Wisconsin, Oct 2010

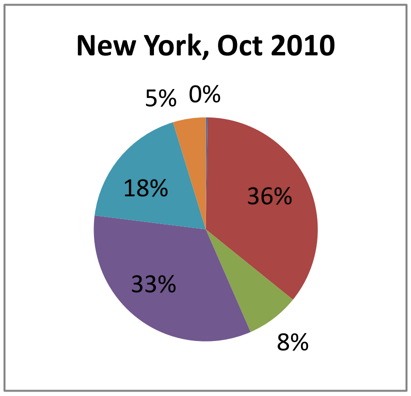

Illinois, Oct 2010


Indiana, Oct 2010


Michigan, Oct 2010


Ohio, Oct 2010


Pennsylvania, Oct 2010


New York, Oct 2010

Appendix F: Why offshore transmission is more expensive?

- Offshore and Shore connection

Specialized equipment would be required to lay the cable when it has to pass through shallow areas to reach the landing location (point of connection on shore) and also to connect it to the offshore wind farm.[414] These equipments increase the cost of offshore cables.

- Transportation and installation

Offshore cable installation require tugs and barges to transport the offshore pieces, heavy lift capable vessels for the actual installation of the offshore structures, vessels for laying and possibly burying the power cable and sub-sea vessels with remotely operated vehicles for inspection, all of which add to the cost. [415]

- Protection

  - Burial

The cables can be protected by burying them under the lake or sea bed which requires specialized equipment. In environmentally sensitive areas where burying is not feasibly, the cables can be protected from fishing activity, anchors and abrasive geology by embedding them in pipes.[416]

  - Extra protection

If needed, additional protection can be provided by laying mattresses or concrete bags over the cable or by dumping rocks over the cable requiring more specialized equipment and resulting in higher costs.[417]

  - Corrosion protection

The cable also needs to be protected from corrosion by water. The additional layer of protection further increases the cost of the project.

- Redundancy

The reliability of the transmission system can be increased by laying additional lines which would enormously increase the cost.[418]

- Cable design
    - Insulation

Another reason for a difference between offshore and onshore transmission comes from the need for insulation in submarine cables as the conductor cannot be exposed to water.

- Voltage

As shown in Section 3 higher voltage lines cost more than lower voltage ones. But at the same time, lower voltage lines have a lower power density (power transmitted per unit cross-sectional area). This necessitates the installing of several cables which again raises the cost[419]. Also a low voltage line has higher transmission losses as the power is transmitted at high current values which results in a higher thermal loss.

- Depth

Increase in depth increases the cost in several ways[420]. Firstly, the cable now has to be designed to operate at higher pressure than on land. Additional insulation adds weight to the cable thus requiring more expensive equipment and larger vessels to handle the additional weight.

- Repair and Maintenance

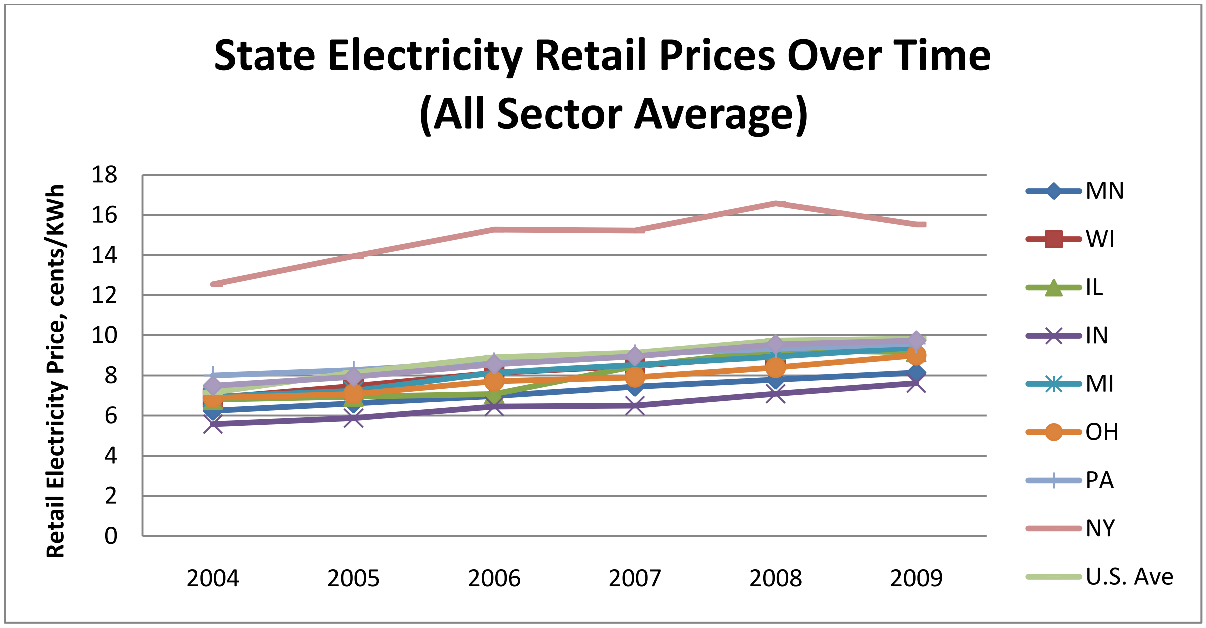
Repair and maintenance of offshore cables require the same sub-sea capable vessels as in the installation phase, which again adds to the overall cost.

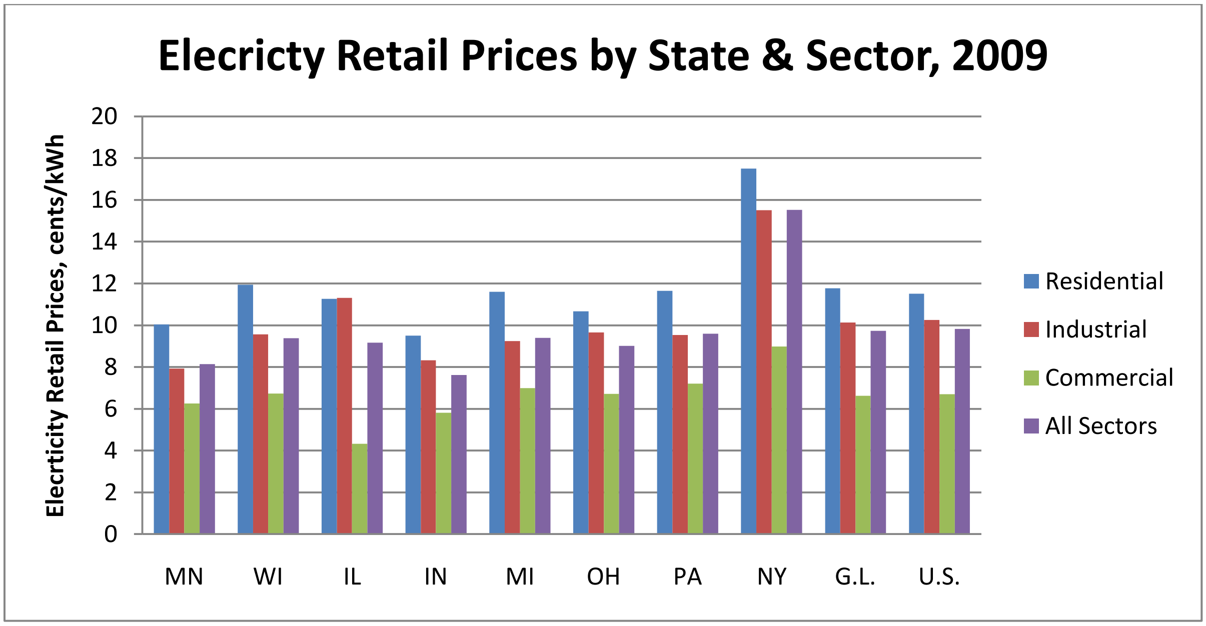
- Substations

Offshore wind farms over 250 MW require a number of offshore substations that further increase the cost.[421]

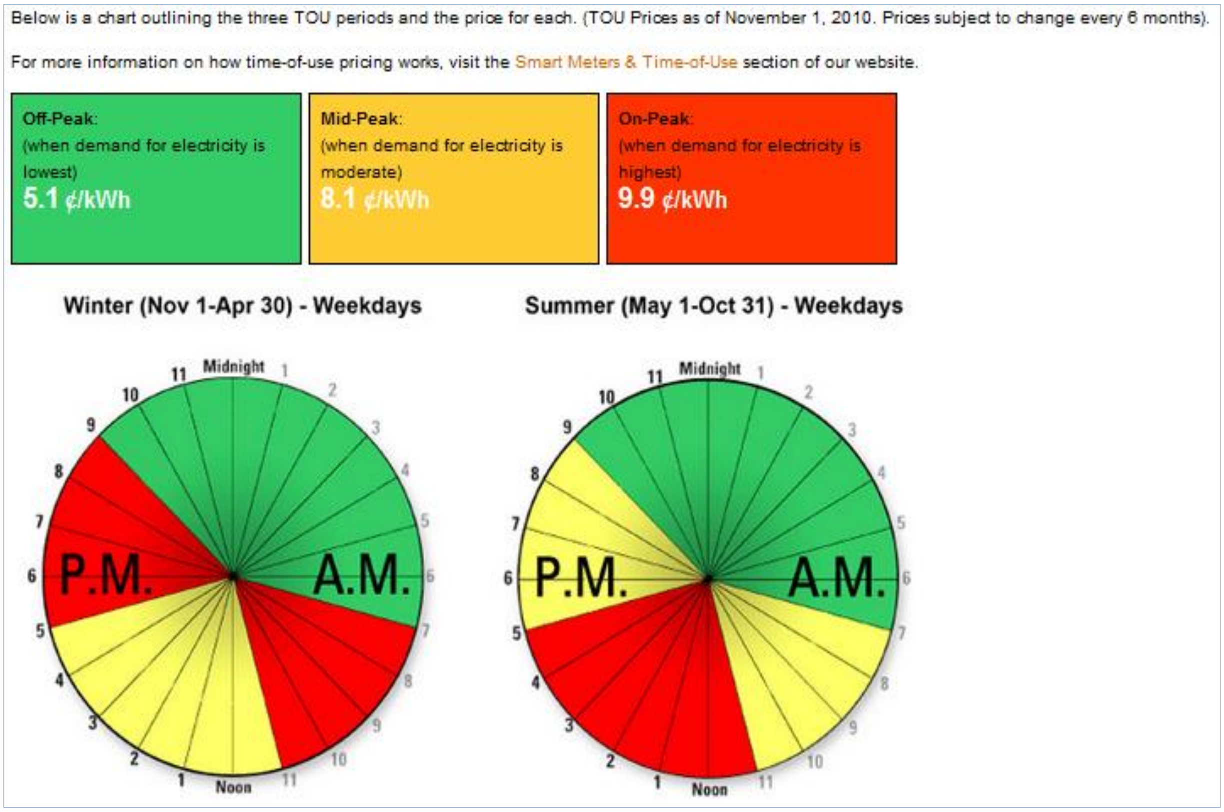
Appendix G: Electricity Prices for Great Lakes States and Provinces

State price information from U.S. Energy Information Administration





Ontario Time of Use Pricing information from Ontario Energy Board



Below is a chart outlining the three TOU periods and the price for each. (TOU Prices as of November 1, 2010. Prices subject to change every 6 months).

For more information on how time-of-use pricing works, visit the Smart Meters & Time-of-Use section of our website.

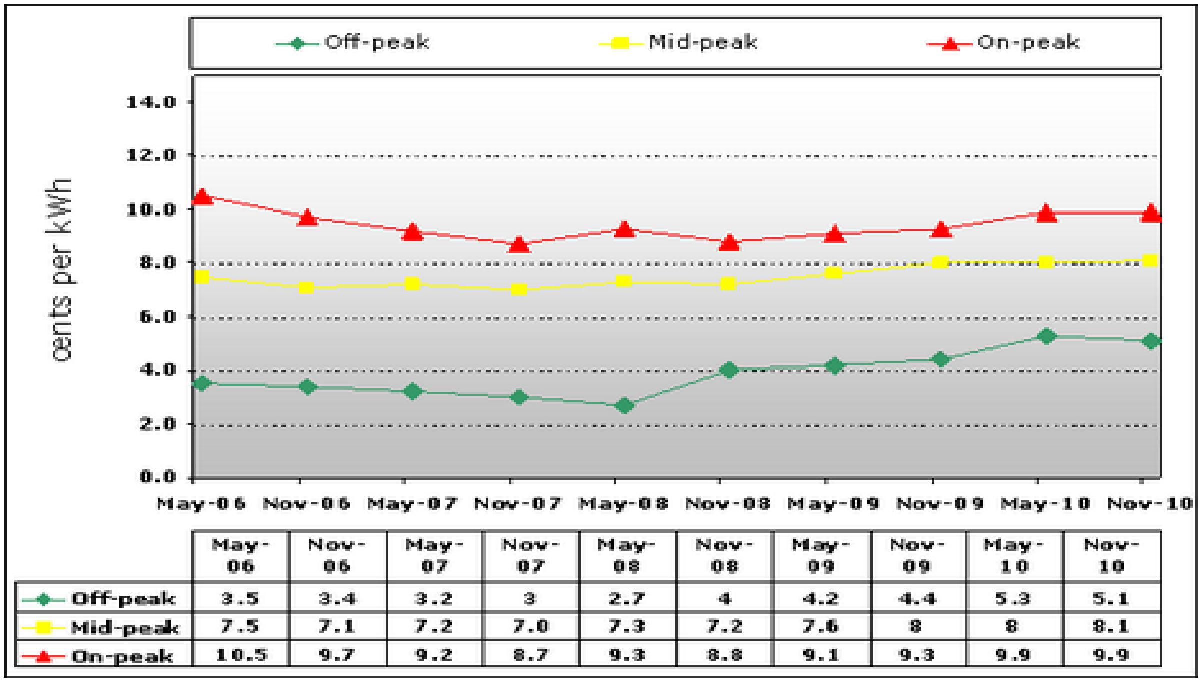
Off-Peak:
(when demand for electricity is lowest)
5.1 ¢/kWh

Mid-Peak:
(when demand for electricity is moderate)
8.1 ¢/kWh

On-Peak:
(when demand for electricity is highest)
9.9 ¢/kWh

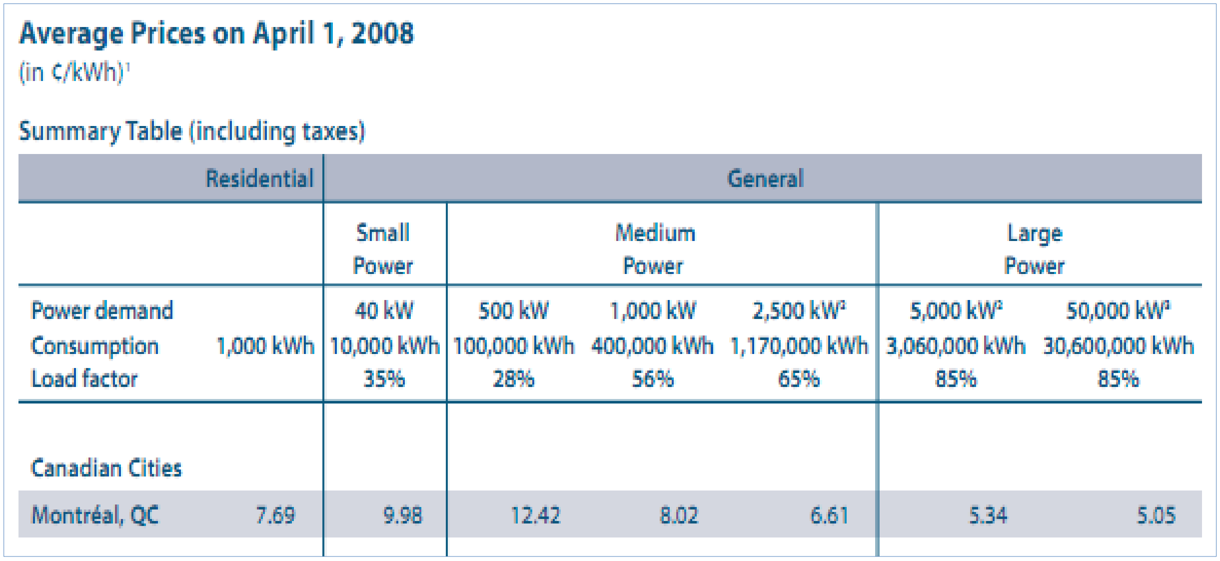
Winter (Nov 1-Apr 30) - Weekdays

Summer (May 1-Oct 31) - Weekdays



	May-06	Nov-06	May-07	Nov-07	May-08	Nov-08	May-09	Nov-09	May-10	Nov-10
Off-peak	3.5	3.4	3.2	3	2.7	4	4.2	4.4	5.3	5.1
Mid-peak	7.5	7.1	7.2	7.0	7.3	7.2	7.6	8	8	8.1
On-peak	10.5	9.7	9.2	8.7	9.3	8.8	9.1	9.3	9.9	9.9

Quebec Price information from “Comparison of Electricity Prices in Major North American Cities, 2008” from Hydro Quebec

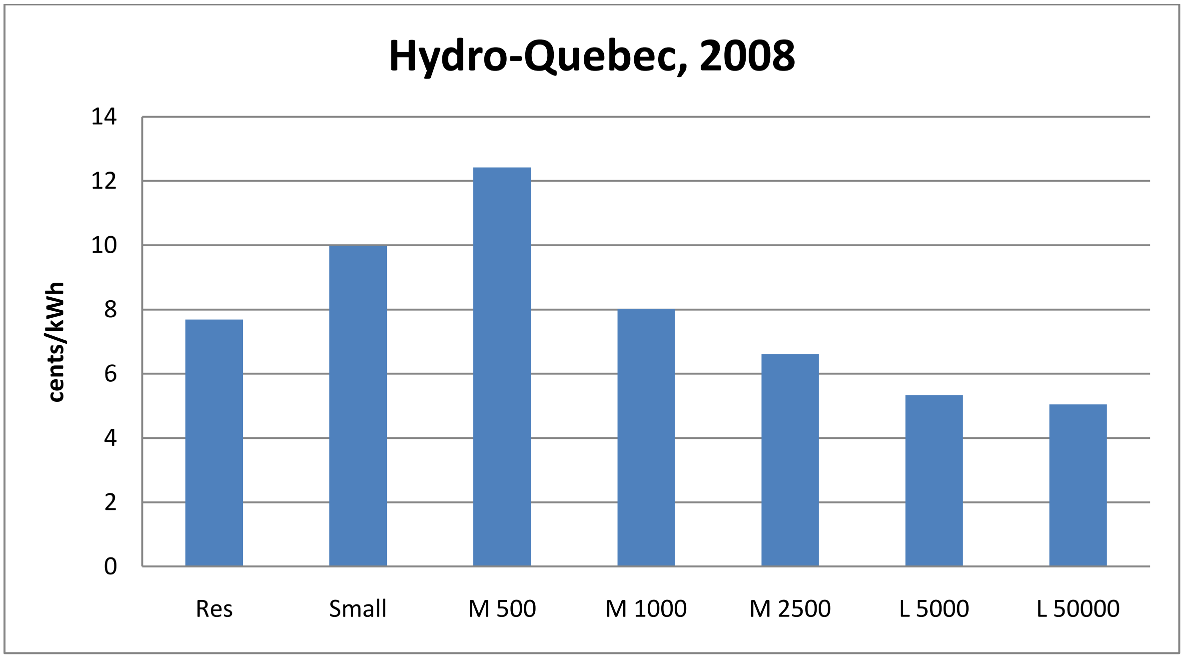


Average Prices on April 1, 2008

(in ¢/kWh)[1]

Summary Table (including taxes)

	Residential	General					
		Small Power	Medium Power			Large Power	
Power demand		40 kW	500 kW	1,000 kW	2,500 kW[2]	5,000 kW[3]	50,000 kW[3]
Consumption	1,000 kWh	10,000 kWh	100,000 kWh	400,000 kWh	1,170,000 kWh	3,060,000 kWh	30,600,000 kWh
Load factor		35%	28%	56%	65%	85%	85%
Canadian Cities							
Montréal, QC	7.69	9.98	12.42	8.02	6.61	5.34	5.05



Appendix H: Intermittency and Intermittency Coping Strategies

Overview of Intermittency:

The wind speed maps included in this report display a single averaged wind speed. However, wind is not constant over time; it exhibits hourly variation and seasonal cycles. Since generation is proportional to the wind speed, any change in wind speed directly affects the quantity of electricity generated. Unlike many conventional fuel sources (like coal, natural gas or nuclear), wind as a resource cannot be stored nor consumed under a controllable schedule. Rather, electricity generated from wind simply depends upon the natural environment, regardless of electricity demand. This poses some challenges for integrating wind into a substantial portion of the electricity portfolio. Measures must be taken to manage this characteristic of wind generation.

Intermittency Illustration:

Figure 60 below displays average monthly wind speed for two locations in the Great Lakes region, Chicago and Cleveland.[422,xxix] Generally, the wind is stronger in the winter than in the summer near both of these locations. Therefore, there will be more electricity generated from wind during the winter than during the summer.

[xxix] Note that these are onshore surface wind speeds recorded for the purposes of general weather monitoring, not for use by the wind power industry.

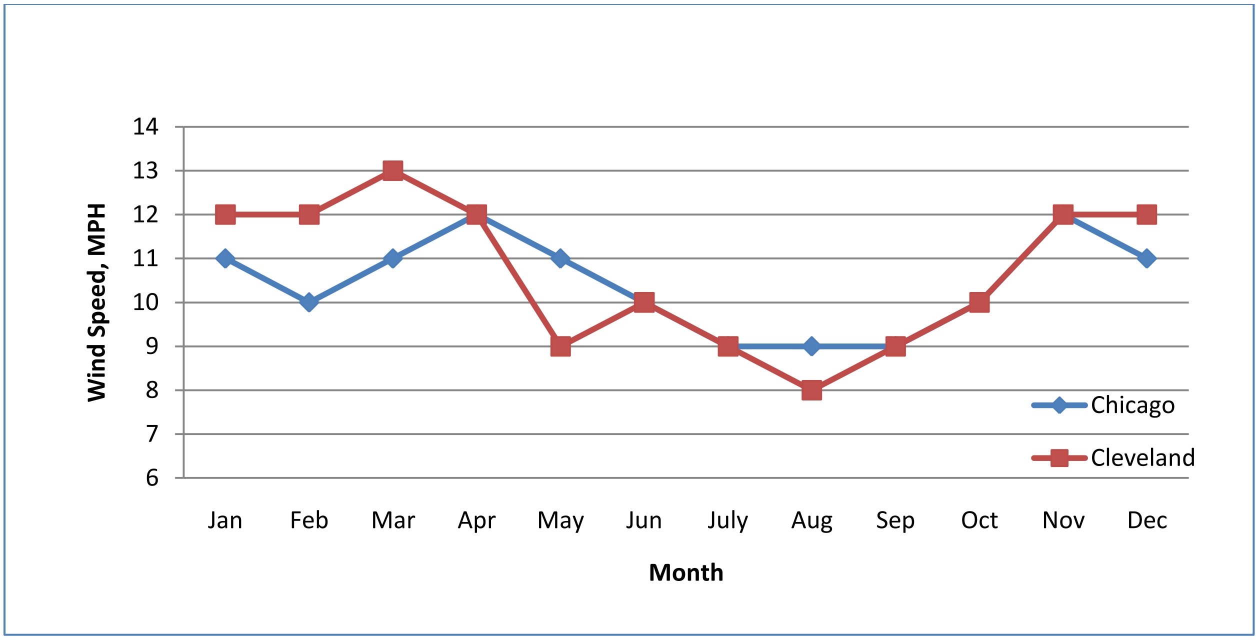


Figure 60: Average Monthly Wind Speed (mph) for Chicago and Cleveland. This shows the seasonal trends in average wind speed, which does not match the seasonal trends in electricity demand.

Matching generation to demand is critical. Figure 61 below shows the total electricity use in Illinois and Ohio during 2009.[423] There is a trend of higher electricity use during the summer and winter and lower use during spring and fall. This pattern does not completely match the seasonal wind resource trend shown above. The main discrepancy occurs during the summer, when the wind resource is lower and electricity use is higher. If wind were a major portion of the electricity portfolio, this mismatch would require additional contribution by dispatchable generation sources in order to meet higher electricity demand in the summer.

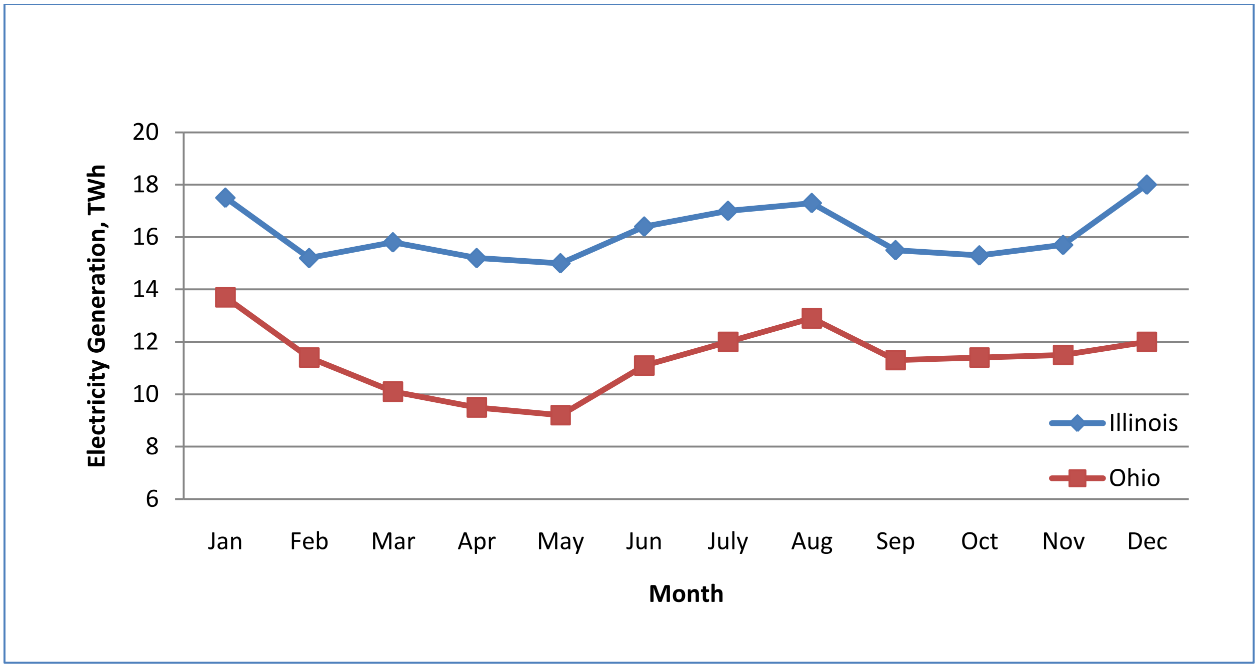


Figure 61: Monthly Electricity Generation in 2009 in Illinois and Ohio. This shows the seasonal trend in electricity demand, does not match the seasonal trends in average wind speed.

In addition to seasonal wind resource trends, wind is variable on a daily and even hourly basis. Figure 62 below illustrates this characteristic over three days, again in Chicago and Cleveland.[424] This characteristics example shows the lack a consistency across days in both locations. While wind exhibits predictable broad trends over the course of the year, hourly wind speeds depend on transient local weather patterns and consequently are less predictable.

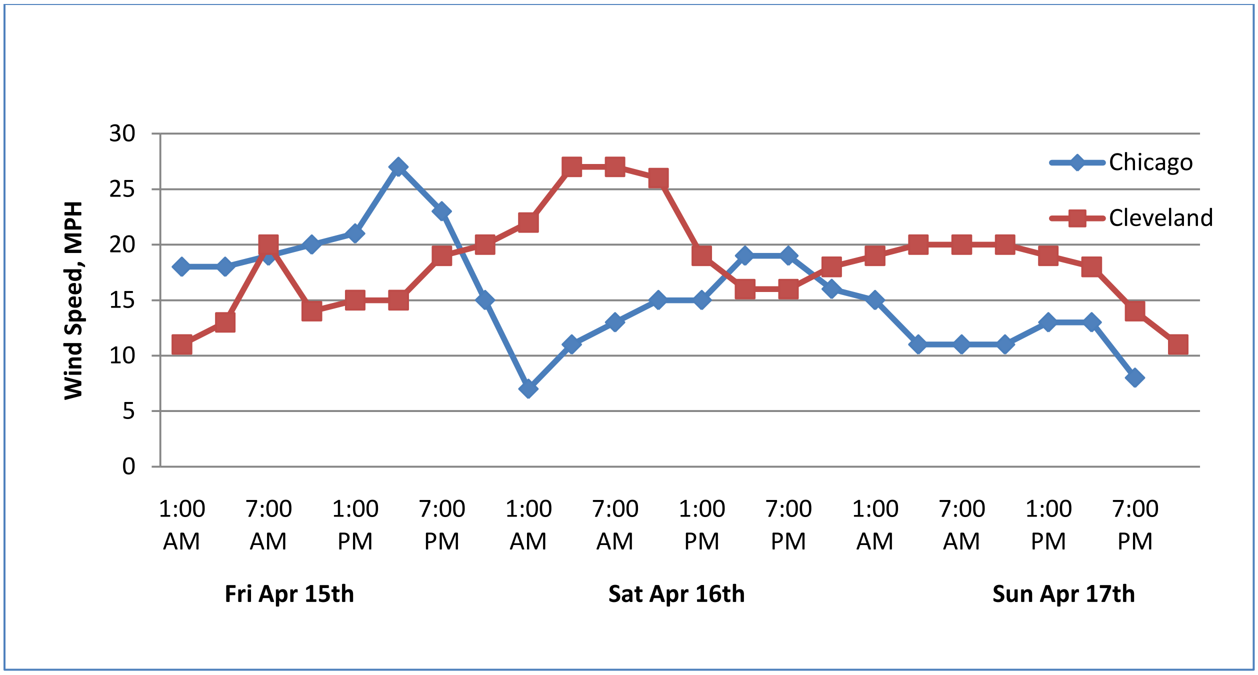


Figure 62: Hourly Wind Speed over a Three Day Period for Chicago and Cleveland. This shows the lack of daily trends in wind speed, which differs from the predictable daily trend of electricity demand.

This variability poses challenges for matching electricity demand with wind generation on an hourly basis. Figure 4 below graphically depicts a typical electricity demand schedule for a 24 hour period. While individual sectors have unique trends, there is a distinguished net demand peak between 2:00 PM and 6:00 PM, which occurs every day, year-round. Since wind speeds do not exhibit a similar daily peak, matching generation to demand could be problematic if wind becomes a substantial portion of the electricity portfolio in the Great Lakes region.

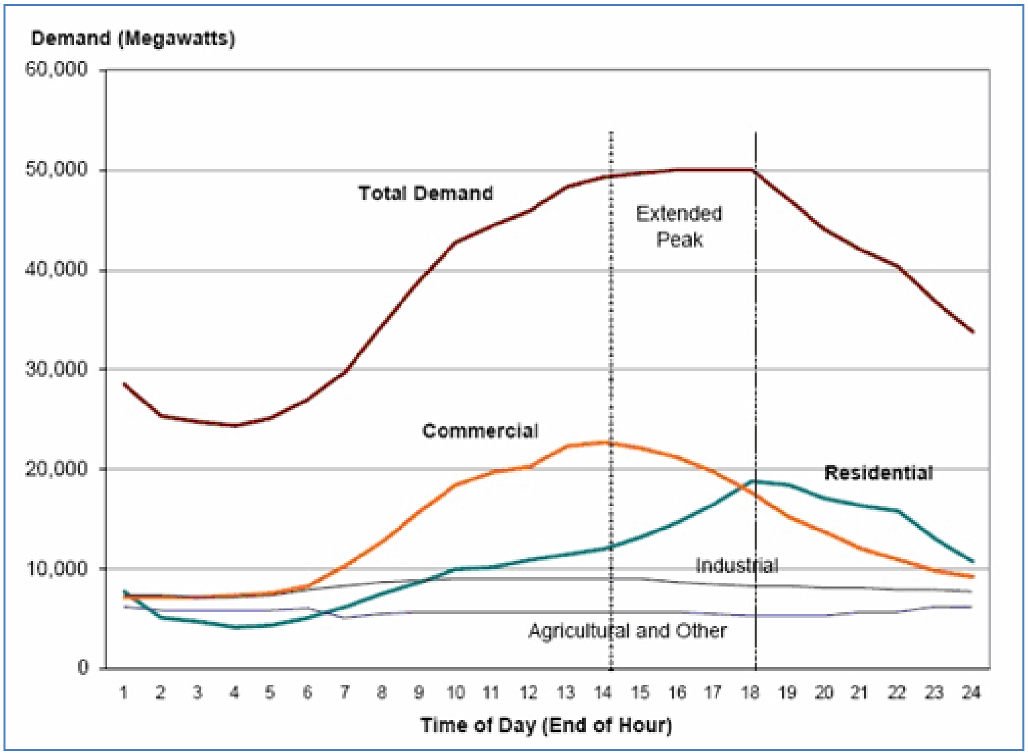


Figure 63: Trends in Daily Demand of Electricity. This shows a daily peak in net demand of electricity between 2:00 pm and 6:00 pm.[425]

Integration of Intermittent Wind Generation

Coupling with Natural Gas: Unlike baseload facilities like coal and nuclear, natural gas-fueled generation facilities have the ability to quickly ramp generation up or down with minimal impact to the facility. This flexibility can be coordinated with the natural variability of the wind resource to produce a more constant level of net electricity generation. Estimates suggest that when coupling a wind facility with a natural gas facility, the natural gas facility needs to have about 15% of the capacity of the wind facility to balance intermittency effects.[426]

Wind Forecasting: Advanced wind forecasting is vital in order to proactively plan the aggregated generation schedule for a diverse portfolio, since dispatchable generation facilities will need to account for the variability of electrical generation from wind facilities. More wind speed data collection locations and more advanced metrological models can increase the accuracy and scope of wind forecasting. This is particularly needed in the Great Lakes region for far offshore wind speeds.

The benefits of advanced wind speed forecasting have been clearly demonstrated. For example, a 100 MW wind project can achieve a 2000 MWh monthly savings through advanced forecasting. Such efficiency savings could result in a monthly savings of $100,000, assuming a wholesale price of $0.05/KWh.[427] Thus, advanced wind forecasting minimizes economic impacts of integrating offshore wind power by reducing the cost of generated electricity to consumers. Additionally, wind forecasting can have co-benefits to many other industries operating within the Great Lakes region, such as shipping, fishing and tourism.

Energy Storage: One method to directly address the discrepancy between wind generation and electricity demand is energy storage. Energy captured by wind turbines can be stored mechanically, chemically, or thermally using technologies such as pumped hydro storage, storage in batteries, hydrogen fuel cell production, or compressed air storage. The appropriate method of energy storage depends upon the intended use of the energy. . Some of these storage technologies allow for energy captured from wind to be used in sectors outside of the electricity industry. Each technology is associated with a level of efficiency and cost. Figure 64 below displays the relative costs associated with various energy storage technologies.

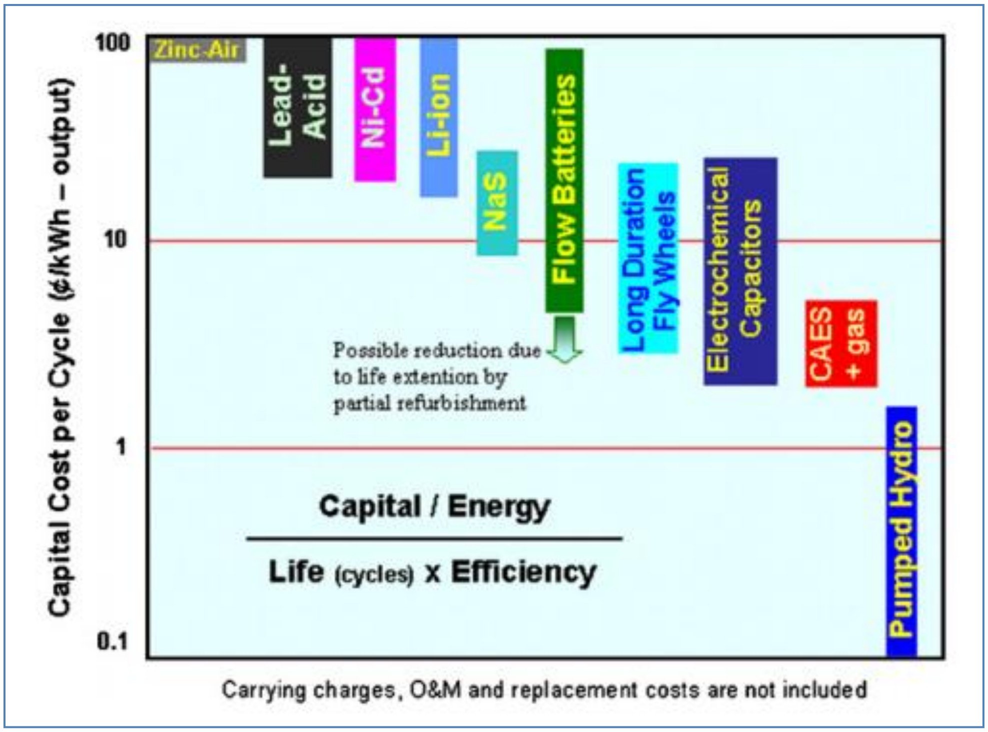


Figure 64: Distribution of Storage Techniques as a Function of Investment Cost Calculated per Charge-discharge Cycle. This shows the potential to integrate a large portion of wind into the electricity portfolio through the use of energy storage. [428]

Demand-Side Management: While aggregated electricity demand is typically treated as perfectly inelastic, certain components of demand have the ability to be flexible. For example, vital operations like refrigeration generally requires electricity under a rigid schedule, while less time-sensitive operations like battery charging could be scheduled during off-peak hours. Demand-side management can be achieved through nighttime load switching, direct-load control, load limiters, commercial/industrial programs, time-of-use pricing, demand bidding, and smart metering appliances. Demand-side management, in combination with advanced wind forecasting, has the opportunity to reschedule non-critical electricity demands for when wind resources are high. This would avoid a portion of the need for energy storage and ramping of dispatchable generation facilities. The economic benefit of demand-side management has been demonstrated and is illustrated in Figure 65 for a 26 GW wind facility supported by a larger generating system with low, medium, and high levels of flexibility. The greatest benefit of implementing demand-side management occurs when the generating system is otherwise inflexible for ramping up or down to meet changing demand. As demand-side management capability increases, marginal decreases in fuel cost are realized.

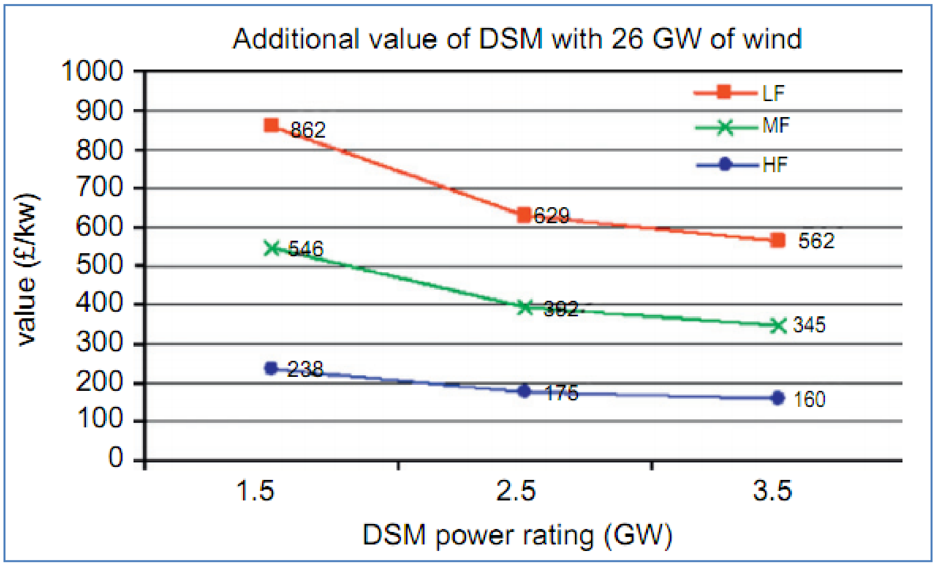


Figure 65: Capitalized Value of Reduction of Fuel Cost with Demand-side Management for a 26 GW Wind Facility. This shows the economic benefit of demand-side management for low, medium and high levels of flexibility of generating systems. [429]

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