FINAL Technical Report

Project Title: 20% Wind by 2030: Overcoming the Challenges in West Virginia

Award Number: DE-EE0000520

Project Period: December 2009 to November 2011
Date of Report: October 13, 2011

Working Partners (Principal Investigators):
Patrick C. Mann, Professor Emeritus of Economics,
West Virginia University (WVU)
(304) 599-2641
pmann@wvu.edu

Dr. Calvin Kent
Marshall University (MU) CBER
(304) 696-3998
Calvin.kent@marshall.edu

Ms. Christine Risch
Marshall University (MU) CBER
(304) 696-6251
Christine.risch@marshall.edu

Recipient Organization:
Jeff Herholdt, Director
WV Division of Energy
State Capitol Complex – Building 6, Room 620
1900 Kanawha Blvd., E
Charleston, WV 25305

DOE Project Team: DOE HQ Program Manager – Jacques Beaudry-Losique
DOE Field Contract Officer – Pam Brodie

Date of Report: **January 23, 2012**

Acknowledgment: "This report is based upon work supported by the U. S. Department of Energy under Award No.EE0000520"

Disclaimer: "Any findings, opinions, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the Department of Energy"

TABLE OF CONTENTS

LIST OF ACRONYMS

CBER - Center for Business and Economic Research

CEGAS - Center for Environmental, Geotechnical and Applied Sciences

FERC – Federal Energy Regulatory Commission

MU – Marshall University

PJM – Pennsylvania New Jersey Maryland Interconnection

RTO – Regional Transmission Operator

SODAR - SOnic Detection And Ranging

USDOE – U. S. Department of Energy

WVDOE - WV Division of Energy

WVU – West Virginia University

WVPSC - West Virginia Public Service Commission

WWG – Wind Working Group

EXECUTIVE SUMMARY

For WVU:

The objective of this project was to examine the obstacles and constraints to the development of wind energy in West Virginia as well as the obstacles and constraints to the achievement of the national goal of 20% Wind by 2030.

For the portion contracted with WVU, there were four tasks in this examination of obstacles and constraints:

Task 1 involved the establishment of a Wind Resource Council. This task was completed in May 2010. The Principal Investigator was involved in regular communication with the members of the Wind Resource Council. This communication regarded outreach activities, technical assistance activities, and the planning of Wind Working Group meetings in 2010 and in 2011.

Task 2 involved conducting limited research activities. These activities involved an ongoing review of wind energy documents including documents regarding the potential for wind farms being located on reclaimed surface mining sites as well as other brownfield sites. The Principal Investigator also examined the results of the Marshall University SODAR assessment of the potential for placing wind farms on reclaimed surface mining sites.

Task 3 involved the conducting of outreach activities. These activities involved working with the members of the Wind Resource Council, the staff of the Regional Wind Energy Institute, and the staff of Penn Future. This task also involved the examination of the importance of transmission for wind energy development. The Principal Investigator kept informed as to transmission developments in Eastern United States. The Principal Investigator coordinated outreach activities with the activities at the Center for Business and Economic Research at Marshall University.

Task 4 involved providing technical assistance. This task involved the provision of information to various parties interested in wind energy development. The Principal Investigator was available to answer requests from interested parties regarding information regarding both utility scale as well as small wind development in West Virginia. Most of the information requested regarded either the permitting process for wind facilities of various sizes in the state or information regarding the wind potential in various parts of the state.

For MU:

This report describes four sub-categories of work done by the Center for Business and Economic Research (CBER) at Marshall University under this contract. The four sub-projects are: 1) research on the impacts of wind turbines on residential property values; 2) research on the integration of wind energy in regional transmission systems; 3) review of state-based wind legislation in consideration of model new policy options for West Virginia; and, 4) promotion of wind facilities on former surface mine sites through development of a database of potential sites.

The report titled "FINDINGS ON THE IMPACT OF WIND TURBINES ON RESIDENTIAL PROPERTY VALUES: A Reference Guide as of 2011" provides a summary of information gleaned from seven studies conducted over the last five years that have attempted to quantify the effect of wind facilities on property values. Two of the studies included were contracted by a wind developer, two produced by real estate appraisers, one by a US Department of Energy laboratory, one from an American university and one from a British university. Impacts to individual properties were found to be neutral by the wind developer and the laboratory, negative by the appraisers and the American university, and uncertain by the British university. This report was provided to the WV Association of Counties and the County Commissioners' Association of WV.

The report titled "Integration of Wind and Electricity Supply: A Review of Recommendations" summarizes the fundamental issues surrounding the topic of wind integration, and describes what electricity delivery experts say are ways to address these issues. This effort focused on PJM, a large regional transmission operator with many interconnection points, making it an important participant in the supply of electricity in much of the eastern U.S. The study concluded that current recommendations to integrate wind focus largely on methods of operating the system to ensure reliability and to cover the costs of balancing the electricity delivery system to accommodate variability. This report was provided to the WVPSC.

The report titled "Wind Siting Issues and Policies in PJM States" attempted to address the debate over whether states should actively promote wind siting by assuming centralized control over the process. The study concluded that due to significant differences in geography, demographics, wind resources and access to electricity markets that State policy is only one of several influencing factors and pre-empting local decisions is not recommended. It was also made clear from this research that wind developers are choosing to utilize local siting processes when given an option to use a pre-empting state process in states such as Washington.

The fourth sub-project was conducted jointly with Marshall's Center for Environmental, Geotechnical and Applied Sciences (CEGAS). Using estimated wind speed data purchased from TrueWind overlaid with GIS data for surface mines in West Virginia CEGAS produced a database of sites with wind speeds exceeding six m/s. This analysis resulted in a list of 123 surface mining permits considered to have development potential and to be worthy of assessment. Of those sites, 29 are estimated to have wind speeds of seven m/s or greater. This data was presented at the West Virginia Wind Working Group Meeting in September 2011 and was supplied to the WV Division of Energy. As a result of this work, a SODAR assessment is currently being performed on a surface mine in Fayette County, WV.

INTRODUCTION & BACKGROUND

For WVU:

The objective of this project was to examine the obstacles and constraints to the development of wind energy in West Virginia as well as the obstacles and constraints to the achievement of the national goal of 20% Wind by 2030. The four tasks in achieving this objective were the establishing of a Wind Resource Council, conducting research activities, conducting outreach activities, and providing technical assistance to all interested parties.

For MU:

The four categories of research under this project all relate to energy efficiency of electricity generation by discussing select issues related to wind power development. If wind energy is able to displace fossil-fueled electricity this would reduce the amount of fossil fuel required to provide electricity to the U.S. The series of reports produced under this project discuss issues that could potentially affect the ability to develop wind projects, by making it easier or harder to site facilities, and the availability of evidence to support a decision.

The impact of wind facilities on property values is a consistently raised as a community concern. This is a legitimate concern as homes are the primary asset of many households. Some wind proponents advocate streamlined siting, a component of which is the economic impact on residential properties and such evaluation must be done to get a permit. In some parts of the U.S., such as the eastern and Midwestern regions, wind turbines are sited fairly close to homes due when communities exist in windy areas. The objective of this research was to provide a definitive assessment as to the quantitative results of relevant valuation studies and the expectation of impact. Unfortunately, the results highlight the difficulties with conducting such analyses and defining a set of expectations for a homeowner. The studies done to date do provide some very useful analysis for an approach to siting that would minimize any negative impact by paying attention to the proximity of homes and turbines, e.g. viewshed and orientation.

The objective of the integration paper was to summarize the fundamental issues surrounding the topic of wind integration, and describe what electricity delivery experts say are ways to address these issues. This subject is important because if wind can't be integrated efficiently its generation will not offset the avoided environmental effects from the mining, drilling, and hazardous waste storage associated with using fossil fuels at a level worthy of subsidizing the resource. The research presents evidence, based on experts currently studying the issue that efficient integration of wind will be challenging.

State wind siting policy is sometimes looked to as a means to expand wind development faster than what occurs in the absence of specific State laws with that intent. Faster wind development is seen by some to be important because wind may be the resource most likely to meet the objectives of renewable portfolio standards. Some also contend that having a State position on wind development is important due to the unique space-occupying characteristics of wind facilities. Although State portfolio standards do not require that wind resources be used to comply, a future need to use renewable energy could make wind development more of a public necessity. This report is a qualitative review of state siting policy and other reports that describe the siting process. The objective of the review was to formulate an opinion on whether policies that allow for centralized siting decision-making is superior to policies that leave siting decisions to localities. If centralized siting is more efficient and can allow more projects to be sited sooner, than such methods should be promoted nationwide. This study concluded that while siting policy could be streamlined and made more efficient, there is little benefit to removing the role of local decision-makers.

Surface-mined lands are nearly ubiquitous in West Virginia. Many of these properties are remote and have few developments opportunities once mining is complete. Some of these sites possess commercial-scale wind resources that if developed would bring additional income to landowners and make the land productive. Desktop analysis of the location of surface mines and estimated wind speeds has produced a set of properties that are candidates for future wind assessment and one site is currently being assessed.

The principal investigator for this project was Christine Risch. Dr. Calvin Kent served as a reviewer and advisor. Christine has more than 12 years of energy-related work experience and has worked on wind subjects for six years, including the property values issue. Dr. Kent has more than 25 years of experience in energy work and also has extensive experience with Federal, state and local policy-making through his work with the U.S. Department of Energy and the West Virginia and South Dakota legislatures. Additional CBER researchers who contributed were Emily Hagan and Elizabeth Eastham.

The reports produced under this project were also reviewed by Dr. Alan Collins of West Virginia University, George Carico of Marshall University's Center for Environmental, Geotechnical and Applied Sciences and Jeff Herholdt of the WV Division of Energy.

RESULTS AND DISCUSSION

For WVU:

The results for the WVU portion have been previously addressed within the Executive Summary. The results include the establishment of a Wind Resource Council, the conducting of outreach activities, and the provision of technical assistance.

For MU:

This section describes the work done to support the conclusions reached for each sub-piece of the project. Initial project objectives were somewhat different than final outcomes due to the availability of information in other research projects. The analytical processes used for the project are summarized below.

Property Values

This work comments on the state of analysis, which is based on limited available data. The objective of the research was to identity a quantitative methodology that could explain likely impacts in a way that is transferable to other locations. By reviewing information presented by other researchers this report was able to conclude that data collected to date is too dissimilar to apply to homes near any particular wind facility. The report provides a concise set of information on study results that can be used as a reference guide.

Primary concluding points are:

- Defined area is very important for this topic, as being five miles from a wind turbine is very different than being half a mile away.
- Aggregate findings are not useful for properties located very near a wind turbine.
- Relatively few property transactions have occurred very near (less than one mile) turbines and the dispersion of those transactions combined with the complexity of property features makes it difficult to accurately observe trends or correlations.
- Many characteristics of a property create value in combination; without observing all characteristics across comparable properties in similar geographic areas the contribution of wind turbines to value can't be measured.
- Properties in poor condition may be more negatively impacted by turbines than properties in good condition. Evaluating wind facility impacts near groups of homes that are below-average is more complex due to a likely tendency for turbines to be located on lower value land in an area.
- The impact to an individual property is a function of site-specific variables including existing property features, topography, geographic features between a property and a turbine and orientation in relation to turbines and prevailing winds.
- Although they do not move, analysis of high-voltage transmission lines could provide some indicators of where and when impact may be negative.
- To better understand the impact of wind turbines on property values more transactions data must be collected and evaluated according to industry standards.

System Integration

This work provides a review of broad recommendations made to successfully integrate wind into the electricity transmission system. An original goal of the project was to provide quantified information on the efficiency of wind that has been integrated to date, to be able to report on whether fossil plants have been forced to operate less efficiency because of wind. Through this research it was discovered that such an evaluation has not yet been done for the PJM region, although considerable research has been done on reliability issues. Another objective of the study was to provide a review of technologies being recommended to be deployed to address the issue. However, it was discovered that while technology solutions do exist, few on-turbine components or other specific technologies are actually being recommended for immediate deployment.

The report was able to provide a summary of recommendations necessary to maintain reliability, which are very similar to what would be needed for efficient integration. Most recommendations to integrate wind regard modifying and expanding the existing operating system and the protocols that govern how and which plants are dispatched and re-dispatched throughout the daily electricity demand cycle in response to price signals, transmission constraints and load patterns. The challenges of wind integration exist in multiple time periods, with second-to-second stability affects that could be resolved with modifications to on-turbine technology, minute-to-minute balancing affects that could be resolved with a combination of on-turbine technology and very fast-acting reserves, hour-to-hour load-following affects that could be resolved with ample supply of flexible generation and responsive load, and longer-term unit commitment affects that can be reduced through incorporation of reliable wind forecasting data.

The report also describes market-based integration recommendations such as FERC-proposed changes in tariffs paid to owners of transmission and PJM's lost opportunity cost protocols for calculation of payments made to generators that are curtailed due for reliability reasons. To develop an understanding of such recommendations as they emerged, the project PI participated in the PJM Intermittent Resources Task Force teleconference calls.

The report describes the characteristics of wind that cause the efficiency and potential reliability issues. An example of data presented to illustrate the nature of wind include Table 2 from the report, which shows how aggregate wind output can sometimes be negative during high load times of day. Figures 3 and 4 shows how wind output and electricity load often follow different patterns.

Based on this review the report concludes that reliability has not been compromised due to the integration of wind, however it can't be concluded that efficiency has not been compromised.

<u>Wind Siting Policy</u>
This work reviewed wind-specific power plant siting policy in regional states plus the states of Washington and Oregon, which are considered by some to have imitable models of effective siting policy. States with total local autonomy over wind siting can have high levels of installed wind (Texas) or none (North Carolina). The report concludes that due to significant differences in geography, demographics, wind resources and access to electricity markets it appears that State policy is only one of several factors influencing levels of installed wind. The research also concludes that imposition of centralized state wind siting authority that can override local decisions, particularly when local preferences are already in force or localities already have experience working with wind developers, is likely to encounter opposition and be unproductive.

These conclusions were reached after comparing data on state-level wind installations with population density figures and estimates of resource potential. In spite of the conclusion that states should not assume centralized siting authority, this report highlights several issues with facility siting that could improve the process. These highlights are not unique to this report but were gleaned from other studies of the subject and based on interviews with industry. These highlights are summarized below.

Many elements of an application to acquire a permit are not well-defined. The report concludes that reducing uncertainty for developers and for potential investors is a positive goal. Improving the permitting process through clarification of requirements, including mitigation and whether mitigation is sufficient, is a superior strategy to encourage investment compared to imposing centralized siting. For some impacts, the ability to produce clarity is dependent on other decisions that may be outside the realm of local government, e.g. whether wind turbines threaten bat populations.

Most wind facilities are already sited using local permitting rather than state permitting. The report concludes that even in States such as such as Washington, Oregon and West Virginia where State authorities officially override local decisions, local input is just as important for development. Siting requirements are also not the only factor influencing the rate of facility construction at the state level; proximity to demand centers and transmission, relative installation costs and topography are also very important factors. In spite of having relatively small amounts of developable wind, several PJM states have relatively high shares of that wind developed. This result is supported by Table 1 of the report presented as Appendix A. Table 1 compares state-by-state levels of installed wind capacity with estimates of potential capacity based on available windy land area for states that are at least partially within the PJM service territory. The data shows that Pennsylvania, where siting decisions are made entirely by localities and West Virginia, where siting decisions are made entirely by central authorities, had similar portions of their estimated potential wind developed at the end of 2010.

The report also provides a matrix of regional state siting policy specific to wind compared to model states with centralized siting policy. This is Table 2 of the report, titled "Comparison of Wind-Specific Siting Guidelines by State (PJM States + WA & OR)" and is presented as Appendix B.

The permitting process can be improved by developing tools to evaluate aesthetic impacts. A primary recommendation of the National Research Council and re-stated in the report is that policy-makers develop a better understanding of wind projects that have relatively widespread aesthetic acceptance relative to those that are less accepted. This is a potential follow-up research project.

Wind Resource Opportunities on Surface-Mined Lands

This work was conducted jointly with CEGAS, who provided GIS services for the project. CEGAS collected estimates of potential wind speed from TruePower and overlaid that data with locational data for current and former surface mines in West Virginia. CBER collected information to translate wind speeds to capacity factors, which was then used to rank the sites that are potentially developable. Sites with estimated annual average wind speeds of at least six meters per second were included, which resulted in a set of 122 eligible permits located throughout the state. The database of sites was supplied to the WV Division of Energy.

A complimentary co-project is also currently assessing wind on an active surface mine using CEGAS's SODAR (SOnic Detection And Ranging) equipment. This site was identified using the GIS data overlays from this project combined with industry contacts maintained by CEGAS and the WVDOE. Assessment began in March 2011.

ACCOMPLISHMENTS

The following accomplishments were made by WVU:

Attended the Wind Powering America Summit in Dallas, Texas in May 2010. At that meeting, the Principal Investigator reported on wind energy development in West Virginia.

Attended the Star Symposium [sponsored by the West Virginia Higher Education Commission] at Marshall University in September 2010. At that meeting, the Principal Investigator served on a panel on the Future of Energy.

The Principal Investigator planned and coordinated the Wind Working Group meeting at the Canaan Valley Resort and Conference Center in October 2010. There were 55 attendees at the Wind Working Group meeting.

Attended the Wind Powering America Summit in Anaheim, California in in May 2011. At that meeting, the Principal Investigator reported on wind energy development in West Virginia.

Attended the West Virginia Brownfields conference in Morgantown, West Virginia on September 2011.

The Principal Investigator planned and coordinated the Wind Working Group meeting at the Canaan Valley Resort and Conference Center in September 2011. There were 50 attendees at the Wind Working Group meeting.

Attended the the Regional Wind Energy Institute meeting in Washington, DC in October 2011. The Principal Investigator made a report on the status of wind energy in West Virginia.

The following accomplishments were made by MU:

The primary objectives of this project were to define and present the facts of the debate surrounding the efficiency of wind generation in the electric grid and the technical recommendations made to optimize that integration and disseminate that information to beneficial parties. Other objectives were to maintain current knowledge of permitting requirements and events related to residential property values near wind facilities in the Eastern U.S. and to share that information with concerned parties. These objectives were accomplished. The PI has completed three reports discussing the current state of these issues. The reports have been posted to the CBER website and have been shared with potentially interested organizations.

A database of surface mines that could have wind resources that are strong enough for development was created and supplied to the WVDOE, thus taking the first step necessary to promote this resource on what is otherwise largely idle lands. The wind assessment work, while not directly tied to this project, was a significant complimentary effort that benefited from work under this project.

During the course of this project the CBER also made three presentations on the research topics. Two presentations were given at the WV Wind Working Group meeting and one at the Southern Alliance for Clean Energy/Appalachian Regional Commission fall meeting in Washington, DC. The project PI was also interviewed for two State Journal articles on the integration topic and one West Virginia Executive article on general wind issues.

All research reports and presentations are available on CBER's website: http://www.marshall.edu/cber/research/index.htm

CONCLUSIONS

For WVU:

There still exist barriers to the development of wind energy in West Virginia. However, these barriers seem to be lessening based on the fact that the total MW in wind energy capacity increased from 330 MW to approximately 600 MW during the life of this research project.

It is reasonable to presume that West Virginia will attain 1,000 MW of wind energy capacity by 2015. However, given the recent [2010] estimate of available wind capacity of 1,880 MW, it is also reasonable to presume that it will take another decade [2025] for West Virginia to attain 1,500 MW of wind energy capacity.

Despite the existence of barriers [e.g., the relatively high cost of constructing wind farms in mountainous terrain], West Virginia has several advantages:

- The existence of a specific protocol for acquiring a siting permit. This protocol is under the jurisdiction of the Public Service Commission.
- Counties and local jurisdictions do not have the power to enact elevation ordinances.
- The nuisance litigation which was prevalent in the first three wind farm projects virtually disappeared in the last two wind farm projects.

For MU:

Below are summary sentences from each sub-project that the PI has determined best reflect the overall conclusions for each issue studied.

The impact of wind turbines on property values: Many characteristics of a property create value in combination; without observing all characteristics across comparable properties in similar geographic areas the contribution of wind turbines to value can't be measured. Relatively few property transactions have occurred less than one mile from turbines, and the dispersion of those transactions combined with the complexity of property features makes it difficult to accurately observe trends or correlations.

The ability to efficiently integrate wind energy into the regional transmission system: Current recommendations to integrate wind focus largely on methods of operating the system to ensure reliability and to cover the costs of balancing the electricity delivery system to accommodate variability. The challenges of wind integration exist in multiple time periods, with second-to-second stability affects that could be resolved with modifications to on-turbine technology, minute-to-minute balancing affects that could be resolved with a combination of on-turbine technology and very fast-acting reserves, hour-to-hour load-following affects that could be resolved with ample supply of flexible generation and responsive load, and longer-term unit commitment affects that can be reduced through incorporation of reliable wind forecasting data.

Review of state-based wind legislation in consideration of model new policy options: Significant differences in geography, demographics, wind resources and access to electricity markets makes it clear that State policy is only one of several factors influencing levels of installed wind. Imposition of centralized state wind siting authority that can override local decisions, particularly when local preferences are already in force or localities already have experience working with wind developers, is likely to encounter opposition and be unproductive. The large majority of wind permits are sought utilizing local input even when given a centralized choice.

RECOMMENDATIONS

For WVU:
None

For MU:

The impact of wind turbines on property values: Because not enough quantitative research has been conducted to date to provide definitive answers to homeowners regarding potential impacts of wind turbines to property values, no statements regarding the direction of expected impacts should be presented to homeowners that reside near a turbine. Additional data on property transactions near turbines should be collected and analyzed in order to provide better information.

The ability to efficiency integrate wind energy into the regional transmission system: As much work on the topic is ongoing, staying current on information as it is released and the decisions made by system operators and FERC is necessary to provide future commentary and advice. The project PI intends to devote at much time as possible to this issue over the next year.

Review of state-based wind legislation in consideration of model new policy options: Efforts focused on increasing clarity for developers in terms of permit requirements and land use options would be a better use of resources than imposing centralized siting. Providing policy-makers with information on which wind projects have relatively widespread aesthetic acceptance relative to those that are less accepted is a potential follow-up research project that would promote best practices for siting.

Wind Resource Opportunities on Surface-Mined Lands: The results of the assessment work on surface mines should be publically released.

REFERENCES

Property Values:

Appraisal One Group. *Wind Turbine Impact Study - Dodge & Fond Du Lac Counties Wisconsin.* Oshkosh: Appraisal Group One, 2009.

BBC News. *Wind farm blights farmhouse.* July 2008.

Goldman Associates. "A Study on the Impact of Windmills on Property Values in Tucker County, West Virginia for the Proposed Beech Ridge Energy, LLC Project in Greenbrier County, West Virginia." 2006.

Hamilton, S and Schwann. "Do high voltage electric transmission lines affect property value?" *Land Economics*, 1995: 436-444.

Heintzelman, Martin D., and Carrie M. Tuttle. *Values in the Wind: A Hedonic Analysis of Wind Power Facilities.* Potsdam, NY: Clarkson University School of Business, 2011.

Hoen, Wiser, Capper, Thayer and Sethi. *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis.* US Department of Energy, Lawrence Berkeley National Laboratory, 2009.

Kinnard, W. and Dickey. "A primer on proximity impact research: Residential property values near high-voltage transmission lines." *Real Estate Issues*, 1995: 23-29.

McCann Appraisal. "Written testimony to Mike McLaughlin, Chairman of the Adams County, IL Board." 2010.

Pitts, J and Jackson. "Power Lines and Property Value Revisited." *Appraisal Journal*, 2007.

Poletti & Associates. "A REAL ESTATE STUDY OF THE PROPOSED WHITE OAK WIND ENERGY CENTER MCLEAN AND WOODFORD COUNTIES, ILLINOIS." 2007.

Sims, S and Dent. "Property Stigma: wind farms are just the latest fashion." *Journal of Property Investment & Finance*, 2007.

The Telegraph. *Giant blades are slicing prices.* October 2004.

Wind Integration:

Bayless, Charles E. "The Case for Baseload." *Electric Perspectives*, September/October 2010: 72-83.

Bentek Energy. "How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market." April 16, 2010.

Botterud, Audun. "Wind Power Forecasting in U.S. Electricity Markets." *The Electricity Journal*, 2011: 71-91.

Campbell, Ric. "Grid Integration of Renewable Energy Generation: US Experience." 2009.

DeCesaro, Jennifer, Kevin Porter, and Michael Milligan. "Wind Energy and Power System Operations: A Review of Wind Integration Studies to Date." *The Electricity Journal* 22, no. 10 (October 2009).

Electric Reliability Council of Texas. "ERCOT Wind Impact/Integration Analysis." February 27, 2008. http://www.ercot.com/meetings/ros/keydocs/2008/0227/ERCOT_final_pres_d1_w-o_backup.pdf (accessed August 2011).

Exeter Associates. *Central Wind Power Forecasting Programs in North America by Regional Transmission Organizations and Electric Utilities.* Exeter Associates, 2009.

Federal Energy Regulatory Commission. *Docket # RM10-11.* 2011. http://elibrary.ferc.gov/idmws/docket_search.asp (accessed March 2011).

Forbes, Kevin, Marco Stampini, and Ernest Zampbelli. "Do Higher Wind Power Penetration Levels Pose a Challenge to Electric Power Reliability?: Evidence from the 50Hertz Transmission System in Germany." *ENERDAY.* Dresden: Dresden University of Technology, 2010.

GE Energy. *New England Wind Integration Study.* ISO New England, 2010.

Glotfelty, Jimmy. "Clean Line Energy Partners." *Plains & Eastern Clean Line.* August 18, 2011.

Hines, Paul. "Estimating Regulating Reserves Requirements as Wind Generation Increases: A Problem Definition." University of Vermont, 2010.

Inhaber, Herbert. "Why Wind Power Does not Deliver the Expected Emissions Reductions." Renewable and Sustainable Energy Review, December 2010.

Kahn, Edward. "Wind Integration Studies: Optimization vs. Simulation." *The Electricity Journal*, November 2010: 51-64.

McCalley, James D. "Frequency control (MW-Hz) with wind." Iowa State University, February 2010.

Milligan, Michael. *Cost-Causation and Integration Cost Analysis for Variable Generation.* Golden: National Renewable Energy Laboratory, 2011.

Monitoring Analytics. "Marginal fuel displacement by wind generation in PJM, 2009." *Energy Market, Part 2.* 2010.

Morgan Lewis. "FERC NOPR on Integrating Renewable Energy Resources into the Transmission Grid." Morgan Lewis, February 2011.

Moser, Bob. *US Transmission: FERC reforms usher new era for renewablse.* August 22, 2011. http://social.windenergyupdate.com/.

National Renewable Energy Laboratory . "Eastern Wind Integration and Transmission Study PJM Stakeholder Meeting." NREL , March 2010.

National Renewable Energy Laboratory. "EASTERN WIND INTEGRATION AND TRANSMISSION STUDY." NREL, January 2010.

—. "Impact of Electric Industry Structure on High Wind Penetration Potential." NREL, July 2009.

New York Independent System Operator. "Growing Wind: Final Report of the NYISO 2010 Wind Generation Study." September 2010.

North American Electric Reliability Corporation. "Flexibility Requirements and Potential Metrics for Variable Generation: Implications for System Planning Studies." August 2010.

—. "NERC IVGTF Task 2.4 Report: Operating Practices, Procedures and Tools." NERC, March 2011.

—. "Potential Reliability Impacts of Emerging Flexible Resources." NERC, November 2010.

—. "Special Report: Ancillary Service and Balancing Authority Area Solutions to Integrate Variable Generation." NERC, March 2011.

PacifiCorp. "2010 Wind Integration Study." PacifiCorp, August 2010.

Piwko, Richard, and et al. "A Whirl of Activity." *IEEE Power & Energy Magazine*, November/December 2009: 26-35.

PJM. "Dispatchable Wind Resource LOC." *Intermittent Resource Task Force.* September 19, 2011.

PJM Interconnection, LLC. "Interconnection for Wind Energy and Other Alternative Technologies." *Docket No. RM05-4-000.* FEDERAL ENERGY REGULATORY COMMISSION, September 19, 2005.

PJM. "Light Load Operational Performance Criteria." January 24, 2011.

—. "PJM Intermittent Resources Task Force Meeting Minutes." May 9, 2011.

—. "PJM Intermittent Resources Working Group Meeting." September 13, 2010.

—. "PJM Resource Adequacy Analysis." *PJM Manual 20.* 2011.

—. "PJM Wind Power Statistics." *PJM.org.* July 25, 2011. http://www.pjm.com/~/media/committees-groups/task-forces/irtf/20110725/20110725-item-03-wind-report.ashx.

—. "Reserves Scheduling, Reporting, and Loading." *Operations 101.* 2010.

Prager, Frank. "Setting the record straight on wind energy." *VP, Environmental Policy - Xcel Energy.* Denver Post, May 28, 2010.

Puga, J. Nicolas. "The Importance of Combined Cycle Generating Plants in Integrating Large Levels of Wind Power Generation." *The Electricity Journal,* August/September 2010: 33-44.

Smith, Charles, and Brian Parsons. "What Does 20% Look Like?" *Developments in wind technology and systems.* IEEE, 2007.

Stoel Rives, LLP. "The Law of Wind - Regulatory and Transmission-Related Issues." 2009.

USDOE: EERE. "20% Wind Energy by 2030." July 2008.

Vittal, Vijay. "Impact of Increased Penetration of DFIG based Wind Turbine Generators on Transient and Small Signal Stability of Power Systems." Arizona State University, February 2, 2010.

Xcel Energy. "Characterizing the Impacts of Significant Wind Generation Facilities on Bulk Power System Operations Planning ." Electrotek Concepts, May 2003.

Wind Siting:

Bohn, Christiane, and Christopher Lant. "Welcoming the Wind? Determinants of Wind Power Development Among U.S. States." *The Professional Geographer,* 2009: 87-100.

Environmental Law Institute. *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role.* Washington: Environmental Law Institute, 2011.

Great Lakes Commission. "Siting and Permitting Wind Farms in Ohio." 2009.

Great Lakes Wind Collaborative. "State and Provincial Land-Based Wind Farm Siting Policy in the Great Lakes Region: Summary and Analysis." 2010.

Hoen, Ben, Ryan Wiser, Peter Cappers, Mark Thayer, and Gautam Sethi. *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis.* Lawrence Berkely National Laboratory, 2009.

Kimrey, Erin. "Regulatory Context for Wind Facility Development in North Carolina and Five Other States." 2008.

National Research Council of the National Academies. *Environmental Impacts of Wind-Energy Projects.* Washington: The National Academies Press, 2007.

NC State University. *Database of State Incentives for Renewable Energy (DSIRE).* 2011. http://www.dsireusa.org/ (accessed October 2011).

OLR Research Report. *Standards in Other States for Siting Wind Projects.* February 16, 2011. http://www.cga.ct.gov/2011/rpt/2011-R-0023.htm.

Oregon Department of Energy, Energy Facility Siting Council. "General Standards for Siting Facilities." *345-022-0080 Scenic and Aesthetic Values.* n.d.

Pennsylvania Department of Conservation and Natural Resources. "Land Use Controls in Pennsylvania as They Relate to Wind Farm Development." n.d.

Planning & Zoning Commission of Allegany County. "The Regulation and Management of Wind-Energy Devices." 2009.

Public Service Commission of Maryland. "Annual Report on the Status of Wind-Powered Generating Stations in the State of Maryland." 2008.

Reilly, Susan. "President & CEO, Renewable Energy Systems." *Testimony before the House Natural Resources Committee.* June 2011.

TeleNomic Research, LLC. *Progress Denied:A Study on the Potential Economic Impact of Permitting Challenges Facing Proposed Energy Projects.* U.S. Chamber of Commerce, 2011.

U.S. Fish & Wildlife Service; Association of Fish & Wildlife Agencies. "Wind Power Siting Regulations and Wildlife Guidelines in the United States." 2007.

USDOE: EERE. "20% Wind Energy by 2030." July 2008.

Virginia General Assembly. "Small Renewable Energy Projects Legislation." *HB 2175 & SB 1347*. April 8, 2009.

Wampler, Carol. "DEQ's Wind Permit by Rule." *Virginia Department of Environmental Quality*. April 2011.

West Virginia Public Service Commission. "Rules Governing Siting Certificates for Exempt Wholesale Generators." *Title 150, Legislative Rule, Public Service Commission*. n.d.

LIST OF APPENDICES

Appendix A

Table 1: Comparison of Installed Wind Capacity and Potential via Available Land Area, Selected States

State	Population (2009)	Installed MW (2010)	Potential MW	Windy Land Area (km2)	% Windy Area Available	Ratio Installed/ Potential	Installed KW per Capita	Installed KW/ sq mi	KW/km2 windy area
West Virginia	1,819,777	431	1,883	1,495	25.2%	22.9%	0.24	17.90	288.26
Pennsylvania	12,604,767	748	3,307	2,124	31.1%	22.6%	0.06	16.70	352.36
Delaware	897,934	2	10	37	5.1%	20.0%	0.00	1.02	54.05
Washington	6,664,195	2,206	18,479	11,933	31.0%	11.9%	0.33	33.15	184.87
Tennessee	6,296,254	29	310	360	17.2%	9.4%	0.00	0.70	80.52
Oregon	3,825,657	2,104	27,100	17,110	31.7%	7.8%	0.55	21.92	122.97
New Jersey	8,791,894	8	132	281	9.4%	6.1%	0.00	1.08	28.47
Maryland	5,773,552	70	1,483	568	52.2%	4.7%	0.01	7.16	123.24
Illinois	12,830,632	2,047	249,882	70,764	70.6%	0.8%	0.16	36.83	28.93
Indiana	6,483,802	1,339	148,228	46,255	64.1%	0.9%	0.21	37.33	28.95
Michigan	9,883,640	164	59,042	19,761	59.8%	0.3%	0.02	2.89	8.30
Ohio	11,542,645	11	54,920	17,190	63.9%	0.0%	0.00	0.27	0.64
Virginia	7,882,590	0	1,793	1,567	22.9%	0.0%	0.00	0.00	0.00
North Carolina	9,380,884	0	808	1,156	14.0%	0.0%	0.00	0.00	0.00
Kentucky	4,314,113	0	61	49	24.9%	0.0%	0.00	0.00	0.00

SOURCE: AWS TruePower and NREL estimates of windy land area and wind energy potential for areas with >= 30% capacity factor at 80m.

Appendix B

Table 2: Comparison of Wind-Specific Siting Guidelines by State (PJM States + WA & OR)

	State Authority for Siting	Formal Land Use Guidelines at Local Level	Mandatory Wind-Specific State-Imposed Elements of Development Process
Delaware	Delaware Department of Natural Resources and Environmental Control regulates offshore wind development but does not control onshore siting	Local regulation of onshore siting; zoning applies.	Law prohibits unreasonable restrictions on the installation of wind facilities that qualify for support under the state Green Energy Fund the State Energy Office. Law defines a set of restrictions that are permitted to be used including setbacks, noise, and appearance.[12]
Indiana	The Indiana Utility Regulatory Commission approves construction of all power plants.[3]	Local regulation only.	None.
Illinois	None.	Local regulation only. Wind facilities are often considered a "special use" in areas zoned for agriculture.	Law has set maximum setback limits for turbines installed for on-site end users.[4]
Kentucky	The Kentucky State Board on Electric Generation and Transmission Siting and Siting Board for power plants with a capacity of 10 MW or more.	Local regulation for projects smaller than 10 MW.	None.
Maryland	Maryland Public Service Commission for facilities of 70 MW and greater	Onshore wind facilities are permitted locally if smaller than 70 MW. Local zoning includes minimum setback restrictions in at least one county.[5]	Facilities are exempt from the MD PSC process only if public hearings are held.[6]
Michigan	None.	Local regulation only. Various local ordinances apply.	None.

[1] (NC State University 2011)
[2] (U.S. Fish & Wildlife Service; Association of Fish & Wildlife Agencies 2007)
[3] (Great Lakes Wind Collaborative 2010)
[4] (NC State University 2011)
[5] (Planning & Zoning Commission of Allegany County 2009)
[6] (Public Service Commission of Maryland 2008)

New Jersey	New Jersey Department of Environmental Protection	Local regulation of onshore siting.	Law prevents placement of unreasonable limits on small wind energy systems related to height restrictions, setbacks and noise limits and allows wind projects to get variances from local ordinances due to consideration that wind generation is an "inherently beneficial use." [7]
North Carolina	The North Carolina Utilities Commission	Local regulation of onshore siting. Various local ordinances apply.	Law limits ridgeline development of structures taller than 40 feet. Although the law lists "windmills" as being exempt there is disagreement as to whether this applies to modern turbines.8
Ohio	The Ohio Power Siting Board for facilities 5 MW or larger	Local regulation for projects smaller than 5 MW.	State siting law includes mandatory setback requirements. In addition to providing information required of all electricity generators the applicant must provide information on the impacts of: ice throw; blade shear; shadow flicker.9
Oregon	The Oregon Energy Facility Siting Council (EFSC) for projects greater than 105 MW. Developers have the option of seeking local approval or having the Council make the determination.10	Although the Council's decision preempts local authority most projects are permitted locally. Local zoning includes various county-level setback requirements, flicker regulations, and noise standards. Local permitting triggers mandatory State environmental and wildlife impact studies.	Siting standards include requirements to prove the public is protected from turbine blade and electrical hazards, that the need for new access roads has been minimized, that artificial raptor habitat will not be created and that public access is restricted. Facilities up to 300 MW are eligible for expedited review.
Pennsylvania	None. Power plant development is considered a land use decision and siting approval lies primarily with local governments.	Local zoning varies by county and municipality. Some counties have no zoning.	None. State law enables local authorities to regulate development. 11
Virginia	The Virginia State Corporation Commission (SCC). The VA Department of Environmental Quality (DEQ) has authority over PBR applications.	Local zoning applies, including maximum height restrictions in at least one county. Local government certification of compliance with land-use ordinances is a prerequisite for permit by rule coverage.	Projects with capacity of 100 MW or less that apply via permit by rule (PBR) are exempt from SCC authority. PBR applications can receive expedited approval. Law requires submission of the results of year-long raptor migration and bat acoustic

[7] (NC State University 2011)
[8] (Kimrey 2008)
[9] (Great Lakes Commission 2009)
[10] (Oregon Department of Energy, Energy Facility Siting Council n.d.)
[11] (Pennsylvania Department of Conservation and Natural Resources)

			surveys. Local ordinances must be consistent with state energy policy.12
Washington	The Energy Facility Site Evaluation Council (EFSEC) is a centralized siting agency for all power plants over 350 megawatts.	Most wind facilities are permitted locally. Local permitting triggers an automatic state-level environmental review.	Wind projects smaller than 350 MW are exempt from EFSEC jurisdiction unless they opt into the process.13
West Virginia	The West Virginia Public Service Commission approves development of all electricity generation facilities.	None.	Law requires applicant to file copies of the results of Spring and Fall avian migration studies including lighting studies and risk assessments.14

[12] (U.S. Fish & Wildlife Service; Association of Fish & Wildlife Agencies 2007)
[13] (U.S. Fish & Wildlife Service; Association of Fish & Wildlife Agencies 2007)
[14] (West Virginia Public Service Commission)

LIST OF FIGURES

Figure 1 Hour of Daily Peak Wind Output in PJM, 2010 (# of Days at Hour)

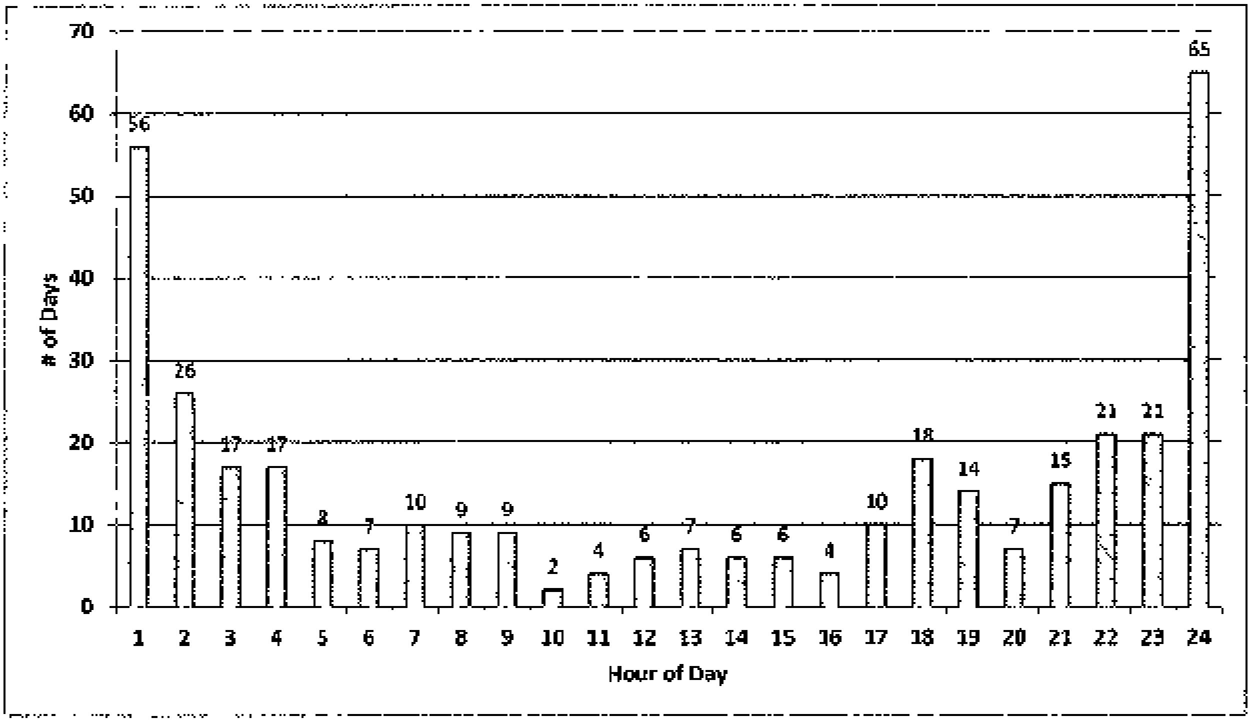
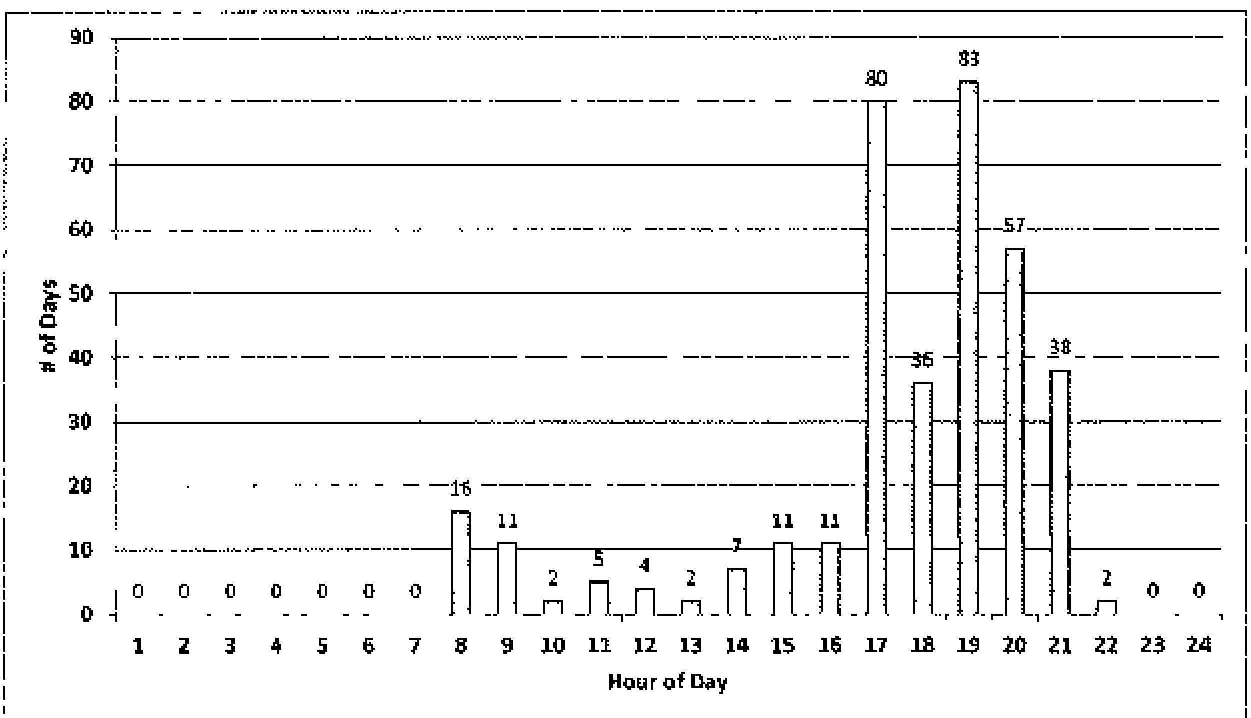


Figure 2 Hour of Daily Peak Load in PJM, 2010 (# of Days at Hour)



LIST OF TABLES

Table 1 Some Recent Key PJM RTO Wind Statistics

	MW	Date of Event	Time of Event	As of Date
Wind Capacity	4,711	-	-	June 2011
Max Hourly Wind (2011)	3,774	February 13, 2011	7-8pm	August 31, 2011
Min Hourly Wind (2011)	-10.0	August 29, 2011	6-7pm	August 31, 2011
Max 2011 RTO Load	157,803	July 21, 2011	4-5pm	July 21, 2011
Min 2011 RTO Load	50,650	April 24, 2011	4-5am	July 21, 2011
Max Hourly Wind (2010)	3,387	October 28, 2010	11am-12pm	
Min Hourly Wind (2010)	-1.0	August 19, 2010	11am-12pm	

Wind Siting Issues and Policies in PJM States

Prepared for:
West Virginia Division of Energy
and
Wind Powering America

November 2011

CBER
MARSHALL UNIVERSITY
CENTER FOR BUSINESS AND ECONOMIC RESEARCH

Wind Siting Issues and Policies in PJM States

Principal Investigator:
Christine Risch

Research Associate:
Emily Hagan

Center for Business and Economic Research
Marshall University
One John Marshall Drive
Huntington, WV 25755

Phone: (304) 696-6251 • Fax: (304) 696-6088

Acknowledgements:

This report was supported by a grant from Wind Powering American via the West Virginia Division of Energy.

Wind Siting Issues and Policies in PJM States

Motivation

The U.S. Department of Energy (USDOE) has stated that increasing the uniformity of regulatory requirements across regions would greatly facilitate the increased deployment of wind projects necessary to reach its national goal of 20 percent wind generation by 2030 (USDOE: EERE 2008). If this goal is to be met, wind development must occur quite rapidly in the next few years. Implementing increased uniformity of facility siting would fall to federal and State entities. The states of Washington and Oregon are considered by some to have induced greater levels of installed wind capacity due to their centralized siting policy compared to states with siting approaches with heavy local decision making (Bohn and Lant 2009). However, due to significant differences in geography, demographics, wind resources and access to electricity markets it appears that State policy is only one of several influencing factors.

State policy may accomplish goals faster than local policy.

State wind siting policy is sometimes looked to as a means to expand wind development faster than what occurs in the absence of specific State laws with that intent. Faster wind development is seen by some to be important because wind may be the resource most likely to meet the objectives of renewable portfolio standards. Although State portfolio standards do not require that wind resources be used to comply, a future need to use renewable energy could make wind development more of a public necessity.

It is not easy to site a wind facility. A recent report completed by TeleNomic Research for the U.S. Chamber of Commerce states that it is just as difficult to site a wind facility as it is to site conventional power plants. The report lists the three primary reasons for siting difficulty as "Not In My Back Yard" (NIMBY) activism, a broken permitting process, and a system that allows limitless challenges by opponents of development (TeleNomic Research, LLC 2011).

Most wind siting decisions are made by the localities where the facilities will be placed. This is logical as it is contended that localities receive a large share of the impacts of a wind facility, both positive and negative, and should have the dominant role in a siting process. However, in some cases states may feel that policy goals may be usurped by communities with wind resources that do not want to host wind. States may then consider using policy that bypasses local decision-making to allow greater and quicker facility siting. Such policy may not produce the most desirable results. For one, it is clear that even in states such as Washington wind developers are choosing to utilize local siting processes when given an option to use a pre-empting state process. One of the primary concerns regarding wind facility siting is aesthetic impacts, which are unique to each project and locality and are frequently inadequately addressed by regulatory review processes (National Research Council of the National Academies 2007).

Few states have an official position on wind siting. Maine is one exception. The State of Maine's wind energy act states that "it is in the public interest to reduce the potential for controversy regarding siting of grid-scale wind energy development by expediting development in places where it is most compatible with existing patterns of development and resource values when considered broadly at the landscape level" (OLR Research Report 2011).

Wind development can be promoted by establishing renewable energy zones where development is "pre-approved," e.g. in parts of the Columbia Gorge, or by disallowing passage of local ordinances that restrict development, e.g. Delaware (NC State University 2011). States and localities can also discourage wind development by passing ordinances that indirectly disallow turbine erection, such as height restrictions or setback distances that remove large quantities of windy land from developer access. Most often, when localities pass wind ordinances it is to discourage wind (Environmental Law Institute 2011).

Several states have developed model siting ordinances that provide voluntary recommendations for wind siting. Such ordinances are typically developed by a collaborative process involving both industry and government. Having an ordinance doesn't necessarily mean any wind development occurs. The North Carolina Wind Working Group created a model ordinance, but the state has not yet developed any commercial wind capacity due to local ordinances that restrict ridge-top development.

A "wind overlay zone" such as the Columbia Gorge Bi-State Renewable Energy Zone (CCBREZ) seeks to attract wind development to a specific area determined to be ideally suited to host turbines. The CCBREZ is a local effort that markets itself to wind developers and wind component manufacturers and offers assistance in identifying potential location incentives.

It is believed by some that having a formal State position on local wind siting authority is important because of the quantity of land that wind facilities occupy compared to conventional power plants (ELI 2011). As stated by the Environmental Law Institute "*in the absence of state legislation defining local government powers and setting standards, wind siting may labor under a handicap as each locality independently works out its own approaches* (ELI 2011)." However, some counties with heavily developed wind have no zoning at all, e.g. Somerset County, PA and Grant County, WV. In West Virginia most counties do not have zoning authority.

<u>Many elements of an application to acquire a permit are not well-defined.</u>

Permitting is an important step in the wind development process that is directly correlated with ability to get project financing. A site permit must be acquired before a project will be financed (Reilly 2011).

Most of the process of acquiring a permit to site a wind facility is no different than what is required for other types of power plants. Elements of a permit application require the following issues to be addressed in some combination: economic impact, environmental impact, wildlife impacts (may be voluntary), viewshed impacts, cultural impact, noise impact, shadow flicker, historical preservation, construction impacts, public health, e.g. setbacks from roads, homes or property lines (state or local), electromagnetic interference. Some elements such as shadow flicker, setbacks and certain wildlife impact assessments are specific to wind turbines but the majority of requirements apply to all electric generators.

Many application requirements, particularly those related to wildlife and viewshed, do not specify what impacts are acceptable and what will lead to permit denial, and may frustrate permit seekers. Viewshed impact is an evaluation element that can involve subjectivity because it must often be done on a case-by-case basis. Especially for the initial wind facility applications, few states and developers had experience with viewshed evaluation and no standards were in place. The National Academy of Sciences states that many project reviewing boards possess a "lack of understanding of visual methods for landscape analysis and a lack of clear guidelines for decision making (National Research Council of the National Academies 2007)."

In Oregon, a state known for having wind-friendly siting policy, law was created to protect scenic values that local or federal land use plans have identified as important (Oregon Department of Energy, Energy Facility Siting Council n.d.). Because the standard only considers applicable land use plans, such plans must be formally in place to be determined to be affected or not. When plans are not in place, evaluation may become more subjective and difficult to ascertain whether a developer has submitted enough information with which to make a decision.

Some of the most controversial aspects of wind turbine siting are setbacks from houses. Few homeowners would choose to reside within a quarter mile of a turbine if given the choice, but setbacks of more than a quarter-mile often make projects impossible to build due to the greatly restricted land area. This is an especially true in the East and Midwest as rural communities are more prevalent in windy areas, contrary to the Northwest where windy areas are less populated.

In a recent nationwide study of the effects of 1,345 wind turbines on property values, 70 of 125 observed property transactions within one mile of a wind turbine were in PA and NY (Hoen, et al. 2009). The study concluded that there is no evidence of wind facilities causing a negative impact on residential property values. The study illustrates some of the differences in siting conditions between the East and the West as none of the observed transactions within one mile of a turbine were in Washington or Oregon, and only four were in Texas. For transactions between one and three miles from a wind turbine only 20 of 2,019 transactions were in Oregon and Washington. Of the 1,345 turbines evaluated in total, 582 were in Oregon and Washington but very few were actually close enough to homes to be a nuisance. While this study is not a complete picture of geographic diversity and the proximity of turbines and homes, it illustrates the importance of geography in creating different conditions between states, specifically the differences that exist between wind development options in the Eastern vs. Western U.S. and shows that it is not appropriate to compare these areas in terms of the siting process.

Some developers have stated that the biggest obstacle the wind industry is facing when it comes to developing renewable energy projects, specifically on public lands, is uncertainty relating to permitting created by the U.S. Fish & Wildlife Service's 2011 "Eagle Guidance" language (Reilly 2011). Due to the expertise required to accurately evaluate wildlife impacts this is an area of decision-making that determination should be made by State and federal entities that specialize in biology. Until final decisions are made this issue will continue to cause uncertainty for development.

Reducing uncertainty for developers and for potential investors is a positive goal. Developers in general desire clearly specified requirements and waiting periods that define a clear path that if followed will lead to the approvals necessary for development. This is the objective behind laws such as Virginia's Permit by Rule (PBR) (Virginia General Assembly 2009).

The Virginia PBR is an expedited permitting process used by its Department of Environmental Quality (DEQ) originally for certain solid waste facilities that now applies to wind and other renewable power generation facilities up to 100 MW. The rule lists the criteria that an applicant must meet and submit in order for a permit application to be evaluated. Other than the DEQ, no other state agencies need be directly involved, reducing the complexity of the process, although development must still comply with local ordinances (Wampler 2011). As of late 2011, the PBR process had not yet been utilized to site a wind project in Virginia.

A PBR-style "one-stop shopping" application via a central siting entity is a simpler process than many but does not mean a developer can by-pass local approval to get a siting permit. The original intent of many central energy facility siting boards is to serve all power generation facilities, so the need is based on the broader industry. The decision to have central siting is tied to state development histories and the relationships that evolved between state and local governments.

Most wind facilities are sited using local permitting rather than state permitting.

In most states, local authorities approve siting decisions. State permitting decisions officially override local decisions in a few states such as Washington, Oregon and West Virginia. Even in states with central authority local decisions are just as important for development. Ultimately, wind developers must work closely with local jurisdictions in all stages of development and more often than not choose to pursue local siting when given a choice. Local is important because the presence of wind facilities primarily impacts the immediate area, contrasted with fossil plants with emissions and water consumption that impact a much larger area.

States with total local autonomy over wind siting can have high levels of installed wind (Texas) or none (North Carolina). States that want to encourage wind development generally do not allow local autonomy and instead define the scope of local siting decisions (Environmental Law Institute 2011). But even among states such as Washington that have state permitting not all development is approved by the state; in Washington most facilities are approved by county governments rather than via the central siting process (Environmental Law Institute 2011).

Siting requirements are also not the only factor influencing the rate of facility construction at the state level; proximity to demand centers and transmission, relative installation costs and topography are also very important factors. In spite of having relatively small amounts of developable wind, several PJM states have relatively high shares of that wind developed.

Table 1 compares state-by-state levels of installed wind capacity with estimates of potential capacity based on available windy land area for states that are at least partially within the PJM service territory. The data shows that Pennsylvania, where siting decisions are made entirely by localities and West Virginia, where siting decisions are made entirely by central authorities, had similar portions of their estimated potential wind developed at the end of 2010. Federal lands are not included as part of wind potential. This comparison focuses on states in the PJM region because PJM is one of the primary entities charged with implementing integration of wind energy into the regional electricity system. In 2011, additional wind facilities came online in Virginia, West Virginia and several other states. New projects were announced in several states including North Carolina.

Table 1: Comparison of Installed Wind Capacity and Potential via Available Land Area, Selected States

State	Population (2009)	Installed MW (2010)	Potential MW	Windy Land Area (km2)	% Windy Area Available	Ratio Installed/ Potential	Installed KW per Capita	Installed KW/ sq mi	KW/km2 windy area
West Virginia	1,819,777	431	1,883	1,495	25.2%	22.9%	0.24	17.90	288.26
Pennsylvania	12,604,767	748	3,307	2,124	31.1%	22.6%	0.06	16.70	352.36
Delaware	897,934	2	10	37	5.1%	20.0%	0.00	1.02	54.05
Washington	6,664,195	2,206	18,479	11,933	31.0%	11.9%	0.33	33.15	184.87
Tennessee	6,296,254	29	310	360	17.2%	9.4%	0.00	0.70	80.52
Oregon	3,825,657	2,104	27,100	17,110	31.7%	7.8%	0.55	21.92	122.97
New Jersey	8,791,894	8	132	281	9.4%	6.1%	0.00	1.08	28.47
Maryland	5,773,552	70	1,483	568	52.2%	4.7%	0.01	7.16	123.24
Illinois	12,830,632	2,047	249,882	70,764	70.6%	0.8%	0.16	36.83	28.93
Indiana	6,483,802	1,339	148,228	46,255	64.1%	0.9%	0.21	37.33	28.95
Michigan	9,883,640	164	59,042	19,761	59.8%	0.3%	0.02	2.89	8.30
Ohio	11,542,645	11	54,920	17,190	63.9%	0.0%	0.00	0.27	0.64
Virginia	7,882,590	0	1,793	1,567	22.9%	0.0%	0.00	0.00	0.00
North Carolina	9,380,884	0	808	1,156	14.0%	0.0%	0.00	0.00	0.00
Kentucky	4,314,113	0	61	49	24.9%	0.0%	0.00	0.00	0.00

SOURCE: AWS TruePower and NREL estimates of windy land area and wind energy potential for areas with >= 30% capacity factor at 80m.

Table 2 compares wind-specific elements of permitting processes in PJM states with Washington and Oregon and indicates which states utilize local control of the process. These items exclude environmental compliance associated with construction, e.g. storm water runoff, fill placement, etc. and other elements of siting applicable to all power plants required by state public service or utility commissions. Washington and Oregon are included to compare the mandatory state requirements.

<u>The permitting process can be improved by developing tools to evaluate aesthetic impacts.</u>

Compared to even five years ago, wind developers now have good experience with obtaining permits and have successfully received permits in most PJM states. Localities that don't want wind are setting ordinances that effectively prevent development. In Eastern states, much of the undeveloped windy areas are located on Federal lands with uncertain approval processes.

Local is what matters most in wind siting. Counties and towns greatly influence the ability to site facilities. The goal of reducing uncertainty for developers behind the concept of "permit by rule" applies to many states and types of power plants. Assessing the visual impact of wind facilities must be done on a case by case basis, but processes exist that can reduce subjectivity. The National Research Council in a publication chapter titled "Impacts of Wind-Energy Development on Humans" has developed a site of questions that if asked could help evaluate the potential for negative aesthetic impacts. Examples of these questions are: "Are projects at scales appropriate to the landscape context?" and "How great is the offsite visibility of infrastructure?"

It has been recommended that policy-makers develop a better understanding of wind projects that have relatively widespread aesthetic acceptance relative to those that are less accepted. This type of understanding applies to historical and recreational sites as well as landscapes and would require guidance from experts in these areas (National Research Council of the National Academies 2007).

Imposition of centralized state wind siting authority that can override local decisions, particularly when local preferences are already in force or localities already have experience working with wind developers is likely to encounter opposition and be unproductive. Improving the permitting process through clarification of requirements, including mitigation and whether mitigation is sufficient, is a superior strategy to encourage investment. For some impacts, the ability to produce clarity is dependent on other decisions that may be outside the realm of local government, e.g. whether wind turbines threaten bat populations.

Table 2: Comparison of Wind-Specific Siting Guidelines by State (PJM States + WA & OR)			
	State Authority for Siting	**Formal Land Use Guidelines at Local Level**	**Mandatory Wind-Specific State-Imposed Elements of Development Process**
Delaware	Delaware Department of Natural Resources and Environmental Control regulates offshore wind development but does not control onshore siting	Local regulation of onshore siting, zoning applies	Law prohibits unreasonable restrictions on the installation of wind facilities that qualify for support under the state Green Energy Fund the State Energy Office Law defines a set of restrictions that are permitted to be used including setbacks, noise, and appearance [12]
Indiana	The Indiana Utility Regulatory Commission approves construction of all power plants [3]	Local regulation only	None
Illinois	None	Local regulation only Wind facilities are often considered a "special use" in areas zoned for agriculture	Law has set maximum setback limits for turbines installed for on-site end users [4]
Kentucky	The Kentucky State Board on Electric Generation and Transmission Siting and Siting Board for power plants with a capacity of 10 MW or more	Local regulation for projects smaller than 10 MW	None
Maryland	Maryland Public Service Commission for facilities of 70 MW and greater	Onshore wind facilities are permitted locally if smaller than 70 MW Local zoning includes minimum setback restrictions in at least one county [5]	Facilities are exempt from the MD PSC process only if public hearings are held [6]
Michigan	None	Local regulation only Various local ordinances apply	None
New Jersey	New Jersey Department of Environmental Protection	Local regulation of onshore siting	Law prevents placement of unreasonable limits on small wind energy systems related to height restrictions, setbacks and noise limits and allows wind projects to get variances from local ordinances due to consideration that wind generation is an "inherently beneficial use" [7]
North Carolina	The North Carolina Utilities	Local regulation of onshore siting Various	Law limits ridgeline development of structures

[1] (NC State University 2011)
[2] (U S Fish & Wildlife Service, Association of Fish & Wildlife Agencies 2007)
[3] (Great Lakes Wind Collaborative 2010)
[4] (NC State University 2011)
[5] (Planning & Zoning Commission of Allegany County 2009)
[6] (Public Service Commission of Maryland 2008)
[7] (NC State University 2011)

	Commission	local ordinances apply	taller than 40 feet Although the law lists "windmills" as being exempt there is disagreement as to whether this applies to modern turbines [8]
Ohio	The Ohio Power Siting Board for facilities 5 MW or larger	Local regulation for projects smaller than 5 MW	State siting law includes mandatory setback requirements In addition to providing information required of all electricity generators the applicant must provide information on the impacts of ice throw, blade shear, shadow flicker [9]
Oregon	The Oregon Energy Facility Siting Council (EFSC) for projects greater than 105 MW Developers have the option of seeking local approval or having the Council make the determination [10]	Although the Council's decision preempts local authority most projects are permitted locally Local zoning includes various county-level setback requirements, flicker regulations, and noise standards Local permitting triggers mandatory State environmental and wildlife impact studies	Siting standards include requirements to prove the public is protected from turbine blade and electrical hazards, that the need for new access roads has been minimized, that artificial raptor habitat will not be created and that public access is restricted Facilities up to 300 MW are eligible for expedited review
Pennsylvania	None Power plant development is considered a land use decision and siting approval lies primarily with local governments	Local zoning varies by county and municipality Some counties have no zoning	None State law enables local authorities to regulate development [11]
Virginia	The Virginia State Corporation Commission (SCC) The VA Department of Environmental Quality (DEQ) has authority over PBR applications	Local zoning applies, including maximum height restrictions in at least one county Local government certification of compliance with land-use ordinances is a prerequisite for permit by rule coverage	Projects with capacity of 100 MW or less that apply via permit by rule (PBR) are exempt from SCC authority PBR applications can receive expedited approval Law requires submission of the results of year-long raptor migration and bat acoustic surveys Local ordinances must be consistent with state energy policy [12]
Washington	The Energy Facility Site Evaluation Council (EFSEC) is a centralized siting agency for all power plants over 350 megawatts	Most wind facilities are permitted locally Local permitting triggers an automatic state-level environmental review	Wind projects smaller than 350 MW are exempt from EFSEC jurisdiction unless they opt into the process [13]
West Virginia	The West Virginia Public Service Commission approves development of all electricity generation facilities	None	Law requires applicant to file copies of the results of Spring and Fall avian migration studies including lighting studies and risk assessments [14]

[8] (Kimrey 2008)
[9] (Great Lakes Commission 2009)
[10] (Oregon Department of Energy, Energy Facility Siting Council n d)
[11] (Pennsylvania Department of Conservation and Natural Resources)
[12] (U S Fish & Wildlife Service, Association of Fish & Wildlife Agencies 2007)
[13] (U S Fish & Wildlife Service, Association of Fish & Wildlife Agencies 2007)
[14] (West Virginia Public Service Commission)

Works Cited

Bohn, Christiane, and Christopher Lant. "Welcoming the Wind? Determinants of Wind Power Development Among U.S. States." *The Professional Geographer*, 2009: 87-100.

Environmental Law Institute. *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role.* Washington: Environmental Law Institute, 2011.

Great Lakes Commission. "Siting and Permitting Wind Farms in Ohio." 2009.

Great Lakes Wind Collaborative. "State and Provincial Land-Based Wind Farm Siting Policy in the Great Lakes Region: Summary and Analysis." 2010.

Hoen, Ben, Ryan Wiser, Peter Cappers, Mark Thayer, and Gautam Sethi. *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis.* Lawrence Berkely National Laboratory, 2009.

Kimrey, Erin. "Regulatory Context for Wind Facility Development in North Carolina and Five Other States." 2008.

National Research Council of the National Academies. *Environmental Impacts of Wind-Energy Projects.* Washington: The National Academies Press, 2007.

NC State University. *Database of State Incentives for Renewable Energy (DSIRE).* 2011. http://www.dsireusa.org/ (accessed October 2011).

OLR Research Report. *Standards in Other States for Siting Wind Projects.* February 16, 2011. http://www.cga.ct.gov/2011/rpt/2011-R-0023.htm.

Oregon Department of Energy, Energy Facility Siting Council. "General Standards for Siting Facilities." *345-022-0080 Scenic and Aesthetic Values.* n.d.

Pennsylvania Department of Conservation and Natural Resources. "Land Use Controls in Pennsylvania as They Relate to Wind Farm Development." n.d.

Planning & Zoning Commission of Allegany County. "The Regulation and Management of Wind-Energy Devices." 2009.

Public Service Commission of Maryland. "Annual Report on the Status of Wind-Powered Generating Stations in the State of Maryland." 2008.

Reilly, Susan. "President & CEO, Renewable Energy Systems." *Testimony before the House Natural Resources Committee.* June 2011.

TeleNomic Research, LLC. *Progress Denied:A Study on the Potential Economic Impact of Permitting Challenges Facing Proposed Energy Projects.* U.S. Chamber of Commerce, 2011.

U.S. Fish & Wildlife Service; Association of Fish & Wildlife Agencies. "Wind Power Siting Regulations and Wildlife Guidelines in the United States." 2007.

USDOE: EERE. "20% Wind Energy by 2030." July 2008.

Virginia General Assembly. "Small Renewable Energy Projects Legislation." *HB 2175 & SB 1347.* April 8, 2009.

Wampler, Carol. "DEQ's Wind Permit by Rule." *Virginia Department of Environmental Quality.* April 2011.

West Virginia Public Service Commission. "Rules Governing Siting Certificates for Exempt Wholesale Generators." *Title 150, Legislative Rule, Public Service Commission.* n.d.

Integration of Wind and Electricity Supply: A Review of Recommendations

Prepared for:
West Virginia Division of Energy
and
Wind Powering America

10/20/2011

MARSHALL UNIVERSITY
CENTER FOR BUSINESS AND ECONOMIC RESEARCH

Integration of Wind and Electricity Supply: A Review of Recommendations

Principal Investigator:
Christine Risch

Center for Business and Economic Research
Marshall University
One John Marshall Drive
Huntington, WV 25755

Phone: (304) 696-6251 • Fax: (304) 696-6088

Acknowledgements:

This report was supported by a grant from Wind Powering American via the West Virginia Division of Energy.

Disclaimer:

Contents

Table of Figures

Table of Tables

Integration of Wind and Electricity Supply: A Review of Recommendations

Introduction

This paper seeks to summarize the fundamental issues surrounding the topic of wind integration, and describe what electricity delivery experts say are ways to address these issues. This effort focuses on PJM, a large regional transmission operator with many interconnection points, making it an important participant in the supply of electricity in much of the eastern U.S. PJM is currently conducting its first system-wide variable generation integration study.

Delivering electricity that includes wind power is more complicated than delivering it without wind. From an engineering standpoint it is more of a challenge. More resources have to be committed to maintaining stability, which reduces overall efficiency, depending on the type of resource committed. Managing stability has implications for both short and long-term. With variable resources such as wind, the system must prepare for more real-time fluctuation in both supply and demand while without variable resources supply is more controlled. Utilizing wind also complicates planning for future power adequacy as wind patterns vary from year to year.

What is successful wind integration? Successful integration allows electricity consumers to take advantage of wind's most desirable attributes, primary that its marginal production has near-zero costs, emissions or water consumption. Successful integration also does not waste fossil resources to accommodate wind. As the amount of installed wind has increased, it has been observed that the marginal costs of wind to the system are greater than the marginal cost of turbine operation due to the variable nature of wind and the resulting dependence on other generators in the system for balance (FERC 2011). Power plant dispatch decisions are based on marginal cost, which does not include the indirect costs of maintaining system reliability at other plants, a portion of which can at times be attributed to wind. If coal plants, especially older coal plants, are used to balance wind's variability then integration will be more costly (Puga 2010).

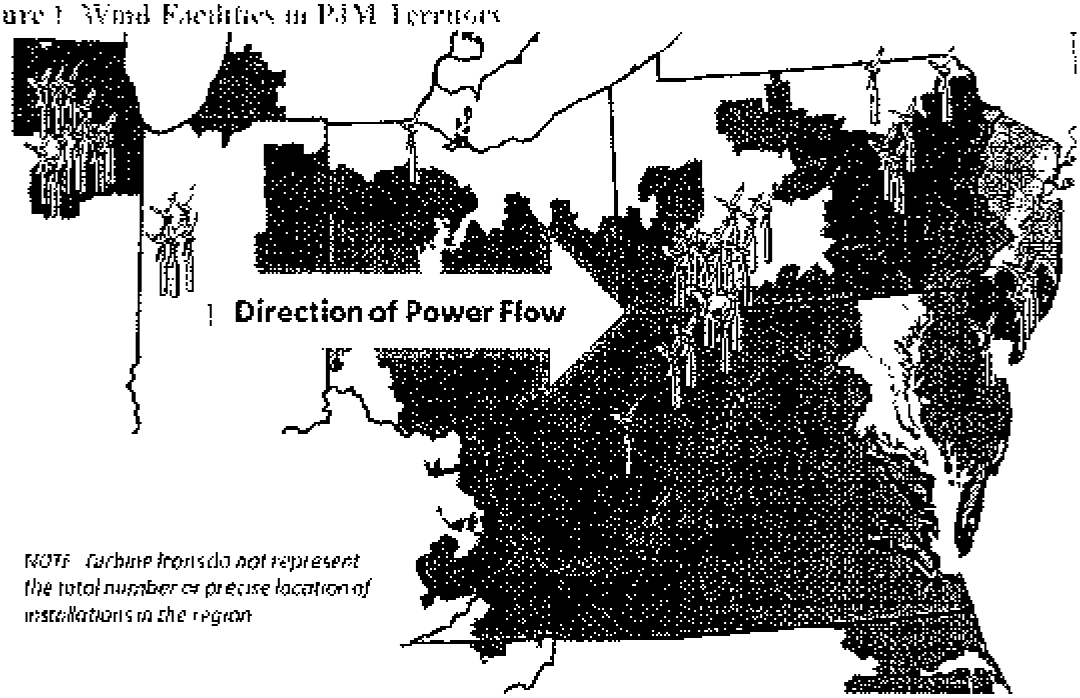
Much of the literature of wind integration studies argues that successful integration is not a question of reliability, but a question of cost and efficiency (DeCesaro, Porter and Milligan 2009). The North American Electricity Reliability Corporation (NERC) has studied balancing authorities with high wind penetration levels and state that variable generation "has not appreciably affected the reliability of the bulk power system" (NERC 2010). Delivery of electricity can be managed with wind, provided that total supply is maintained regardless of what power wind is contributing. Others argue that the overscheduling of non-wind resources required to ensure reliability with higher wind penetration creates a less reliable system because of the increase in dispatch instructions (Forbes, Stampini and Zampbelli 2010).

So why try to integrate wind when using fossil resources is easier? It is easier to engineer a reliable electricity delivery system with stored fuel. But fossil resources are finite, not sustainable and underpriced relative to the externalities that they generate. Fossil and nuclear energy require large quantities of water to operate and fossil fuels release emissions into the atmosphere. Many are concerned that the price of fossil fuels, and thus the price of electricity are not high enough to reflect the externalities created by extraction and emissions and that physical reliance on these resources is excessive relative to the eventual need to replace them with sustainable resources. Given the societal level of these issues, and the benefits of sustaining electricity consumption choices, it is appropriate for government to support alternatives.

Wind energy is available in large quantities and can be converted into electricity with conventional technology. It is thus one of the best prospects for widespread installation of renewable energy production capacity. However, the inflexible nature of much of the incumbent electricity infrastructure and the variable nature of wind tremendously complicate the ability to efficiently utilize wind energy. These features complicate system operations in many time periods: real-time, near-term (hour-to-hour), short-term (day-ahead) and long-term (years).

There are many studies and reports published on wind integration (Campbell 2009) (GE Energy 2010) (NERC 2008) (NREL 2010). This paper focuses on efforts in the PJM Interconnection as West Virginia and its electric utilities are part of the PJM and West Virginia is located centrally in the region as presently defined. As PJM operates a very large system, its success with integrating wind will impact the destiny of the resource. PJM is also closely connected with other large systems focused on integrating wind, including others that also use five minute markets such as the Midwest Independent System Operator (MISO) and the New York ISO (NYISO). Strong connections to other large utilities such as TVA in the south are also maintained. Figure 1 shows the PJM dispatch territory.

Figure 1 Wind Facilities in PJM Territory



How Wind Impacts the System

The variable nature of wind impacts the way electricity is controlled on the system. Increased variability is experienced by the system in multiple time periods and affects system operations at the local level, the balancing area level and the interconnection level. Because it is asynchronous[1] wind decreases the inertia on the system and contributes to imbalance of both voltage and frequency, two key elements of the electricity system that are managed instantaneously with automatic controls (NERC 2010).

The population of studies that assess the impact of wind on systems are typically divided into three time periods: regulation[2] (very short-term; up to 10 minutes), load-following (10 minutes to several hours) and unit commitment (longer than an hour but up to a day or more in the future) (DeCesaro, Porter and Milligan 2009). It is important to acknowledge that wind, and other variable resources, are not the only type of plants that have such system impacts. Some types of fossil plants, including coal plants, may also create a need for regulation due to an inability to respond to an automatic generation control signal (Milligan 2011).

Wind in the system looks like negative load to the system operator (PJM 2011). The quantity of load needed to be served by non-wind resources is referred to as "net load" to illustrate the changed shape of what must be supplied. A system with integrated wind needs the ability to more actively deploy load-following generation or more load-management capability (USDOE: EERE 2008). As a system operator manages available generation on its system to balance load it is optimizing the mix of resources based on both economic and reliability criteria. The process is termed "security-constrained economic dispatch" referring to the dispatch of the generators in merit-cost order as long as reliability is not compromised. The optimization process considers the level of power likely to be available in the near-term from all plants. Coal or natural gas resources are often economically curtailed because of wind but they are curtailed or re-dispatched because of other coal and gas plants as well, depending on relative marginal cost and transmission constraints.

Integration includes the ability to prepare for up and down wind ramping and to control wind generation via dispatch instructions, including the ability to curtail it when availability of other generators may be reduced if they are curtailed to accommodate wind. To achieve reliability most effectively the dispatch process must have the option to curtail wind. Although wind curtailment reduces the effectiveness of renewable mandates, planning for some wind curtailment as opposed to zero is more efficient for the system as a whole (NREL 2010).

Overall, integrating wind means more changes in output by conventional generators to balance the demand and supply of electricity (NREL 2009). This induced cycling by conventional

---

[1] Asynchronous generators often operate with a rotational speed that is slower than the speed of the utility grid to which they are connected, thus reducing system inertia and frequency response.

[2] PJM describes "regulation" as the capability of a specific resource with real-time control and response capability to increase or decrease its output in response to a control signal to control for frequency deviations.

generators causes increased fuel consumption per unit of generation, likened to the difference in fuel economy achieved by automobiles in city stop-and-go driving vs. highway driving (Inhaber 2010). City driving is much less efficient than highway driving and a frequently cycling fossil power plant is less efficient than one producing a stable output. However, it is very difficult to attribute how much system-wide cycling is due to wind when it is the interaction between all types of generators that determines actual dispatch.

For example, a report on the interaction between wind and coal generation in Colorado illustrates that on few days in 2008 wind generation caused coal plants to cycle to the point that they emitted more than they would have if they had not been curtailed (Bentek Energy 2010). That interaction may have been substantially different if natural gas prices had not been high on September 28-29, possibly causing less gas generation to be on-line and thus leaving the cycling to coal plants. Nominal Colorado industrial natural gas prices were $15.93/mcf in September of 2008, the second highest monthly price of the decade; October of 2008 had the highest price of the decade (EIA 2011).

The Colorado incident is a good example of what can happen with wind, but it is a very short-term example and is not representative of daily events (Prager 2010). It illustrates well the importance of the total generation portfolio, the geography of that portfolio, the size of the balancing area, the relative prices of fossil fuels, and the timeframe being evaluated. A comparable incident has not been reported in the PJM region.

Wind is expected to decrease the required capacity of conventional generation for some regions by an amount equivalent to 20 to 25 percent of installed wind (New York Independent System Operator 2010). However, due to wind-induced cycling that already occurs, it will be difficult to displace all the fuel used to produce a MWh of conventional generation for every MWh of wind generation. In PJM, wind has primarily displaced coal-fired generation, with natural gas second, but it has also displaced petroleum-based fuels, land-fill gas, municipal solid waste, hydro, nuclear, system imports and even wind power (Monitoring Analytics 2010).

Much thought has been given to whether wind generation will increase the need for various types of system reserves used to maintain reliability. The answer depends on the type of reserve and the level of wind in a system. Contingency reserves, the spinning reserves in place to make up for the unexpected loss of the largest generator in a system, have been predicted by most to be unchanged because of wind (NERC 2010, NREL 2010, NYISO 2010). However, an increase is expected in at least one ISO, the New England ISO (GE Energy 2010). The required contingency reserve in various systems is in the range of 1,200 to 1,700 MW but the level of installed wind, and the associated potential ramping in a 10 or 15-minute period could create a need for contingency reserves. For this particular set of conclusions the NYISO looked at integration of 8 GW of wind while the NEISO looked at 12 GW. Contingency reserves must be spinning, i.e. they must be online and available within a few minutes, because of the nature of unexpected outages.

NERC recommends that with increasing penetration of renewables balancing authorities should permit contingency reserves to be used more frequently to correct energy imbalances. NERC specifically states that contingency reserves be used more often to balance a loss of wind generation (North American Electric Reliability Corporation 2011).

It is widely stated that wind generation increases need for regulation services (GE Energy 2010, National Renewable Energy Laboratory 2010). Regulation is used to control for frequency deviations on the grid and must be provided by resources with real-time telecommunications that are capable of changing output very quickly in response to a regulating control signal. Regulation service is provided in a very short time frame, i.e. seconds to less than 5 minutes, and must be provided by spinning reserves. Because regulation is the most expensive of the balancing services this is a cost assigned to wind integration (Hines 2010).

NYISO determined that integrating 8 GW of wind would not impact system reliability but would increase need for regulation services by nine percent per GW of wind (NYISO 2010). Table 1 shows the results of the Eastern Wind Integration & Transmission Study, which models the amount by which PJM's regulation reserves might need to increase in four wind expansion scenarios, from 1,055 MW that would be required in the absence of wind power (NREL 2010).

Table 1 Eastern Wind Integration Study – Select Scenario Results

EWITS Scenario	Additional Regulation Needed in PJM	Total Installed Wind in PJM (MW)	Additional Regulation as % of Wind MW	PJM Wind Penetration (% of annual energy D)	US Wind Penetration (% of annual energy D)	Geography of Wind Development
Scenario 1	939 MW	22,669	4.1%	7.8%	20%	high quality on-shore resources, much in Midwest
Scenario 2	1,304 MW	33,192	3.9%	11.1%	20%	fewer Midwest resources plus some off-shore
Scenario 3	3,408 MW	78,736	4.3%	25.6%	20%	more eastern development plus aggressive off-shore
Scenario 4	4,355 MW	93,736	4.6%	30.5%	30%	very aggressive on- and off-shore

As part of its effort to identify the quantity of additional reserves needed due to wind PJM is monitoring wind ramp data for maximum up and down ramping. As of June 2011, the maximum 15-minute downward wind ramp experienced in PJM was 590 MW and the maximum 15-minute upward ramp was 608 MW (PJM 2011). For a 60-minute period the maximum down and up ramps were 1,005 MW and 928 MW respectively. Based on these observations, and with current wind capacity of about 5 GW throughout the system, the need for additional contingency reserves in PJM has not been observed. However, moving to 22 or 33 GW of wind could change this. As the amount of wind capacity grows, the ramping observations are likely to increase.

Individual utilities are also working to integrate wind. Because wind generation can impact individual plants by causing them to cycle their output more or to be curtailed to below their ideal operating level, some utilities have been developing integrated resource plans for wind and fossil assets for several years. Such plans characterize the impact local wind generation may have on system operation and reserve requirements (Xcel Energy 2003). PacifiCorp conducted a wind integration study in 2010 and determined that both regulation and load following reserve services increase with higher wind penetration compared to load only (PacifiCorp 2010).

The Nature of Wind in PJM

Wind turbines are one of only a few asynchronous, or induction, generators on the system, meaning that they can add to or draw power from the grid. They are of variable speed but provide a constant frequency electrical output (Vittal 2010). Wind turbines have no inertia but add power to the system which affects the synchronizing capability of conventional generators, thus affecting both the voltage and frequency of the system, thus increasing the need for regulation reserves in order to maintain stability. Wind turbines also take power from the system at low wind speeds. As shown in Table 2, the minimum hourly aggregate wind output in 2010 was actually negative (PJM 2011).

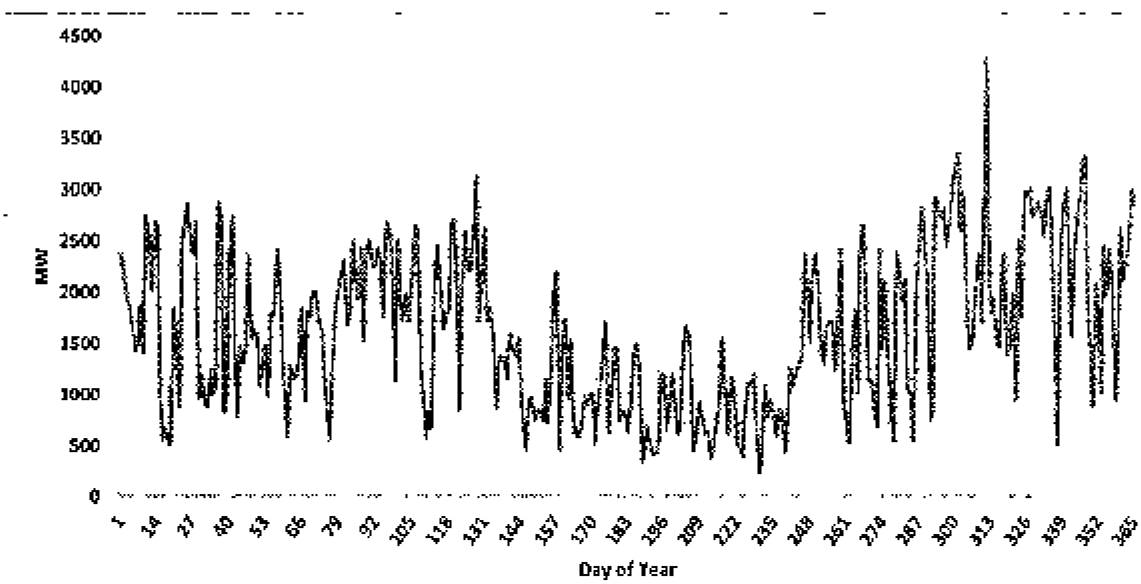
Table 2 Some Recent Key PJM RTO Wind Statistics

	MW	Date of Event	Time of Event	As of Date
Wind Capacity	4,711	-	-	June 2011
Max Hourly Wind (2011)	3,774	February 13, 2011	7-8pm	August 31, 2011
Min Hourly Wind (2011)	-10.0	August 29, 2011	6-7pm	August 31, 2011
Max 2011 RTO Load	157,803	July 21, 2011	4-5pm	July 21, 2011
Min 2011 RTO Load	50,650	April 24, 2011	4-5am	July 21, 2011
Max Hourly Wind (2010)	3,387	October 28, 2010	11am-12pm	
Min Hourly Wind (2010)	-1.0	August 19, 2010	11am-12pm	

Total installed wind capacity in PJM was 4,711 MW as of June 2011 (PJM 2011). As of August 31 the maximum hourly average wind power generated in 2011 was 3,774 MW between 7 and 8pm on February 13 and represented almost 80 percent of total wind capability in the RTO. The minimum wind output for 2011 was -10 MW, occurring between 6 and 7pm on August 29. Output data is net of curtailment, although as of 2010 PJM had rarely curtailed wind, and had done so manually (PJM 2010).

Figure 2 provides a year's worth of maximum daily wind output, illustrating seasonal changes. Because wind is less available in the summer months, and because the peak load in PJM is in the middle of summer, more non-wind resources must be available to meet load during the summer. This data also illustrates the greater range of wind output in many winter, spring and fall months, variability for which the system operator must be prepared for.

Figure 2 Maximum Daily Wind Output in PJM, 2010 (MW)



A longer-term impact of wind's variability is the effect on system planning. Because annual and seasonal capacity factors vary from year to year with weather, deciding what level of capacity credit[3] should apply varies by regional standards. PJM allows the peak season capacity factor of 13 percent to apply for planning purposes, a figure based on actual non-curtailed wind output (PJM 2009). Plants with capacity credit are considered a capacity resource by PJM, have capacity interconnection rights and can receive payments for participating in PJM's Capacity Market (PJM 2009).

The challenges of short-term integration are illustrated with diurnal, hourly peak wind output. Wind does not usually peak when load peaks, i.e. wind and load peaks are not coincident. As shown in Figure 3 wind peaks most often around midnight and is thus out of phase with load during the morning ramp up and the evening ramp down. The frequency of peak load by hour of day in PJM is shown in Figure 4.

[3] Capacity credit is the portion of installed capacity allowed to count toward total system capacity, including installed reserve margins, needed to ensure that enough capacity is available to meet future peak load.

Figure 3 Hour of Daily Peak Wind Output in PJM, 2010 (# of Days at Hour)

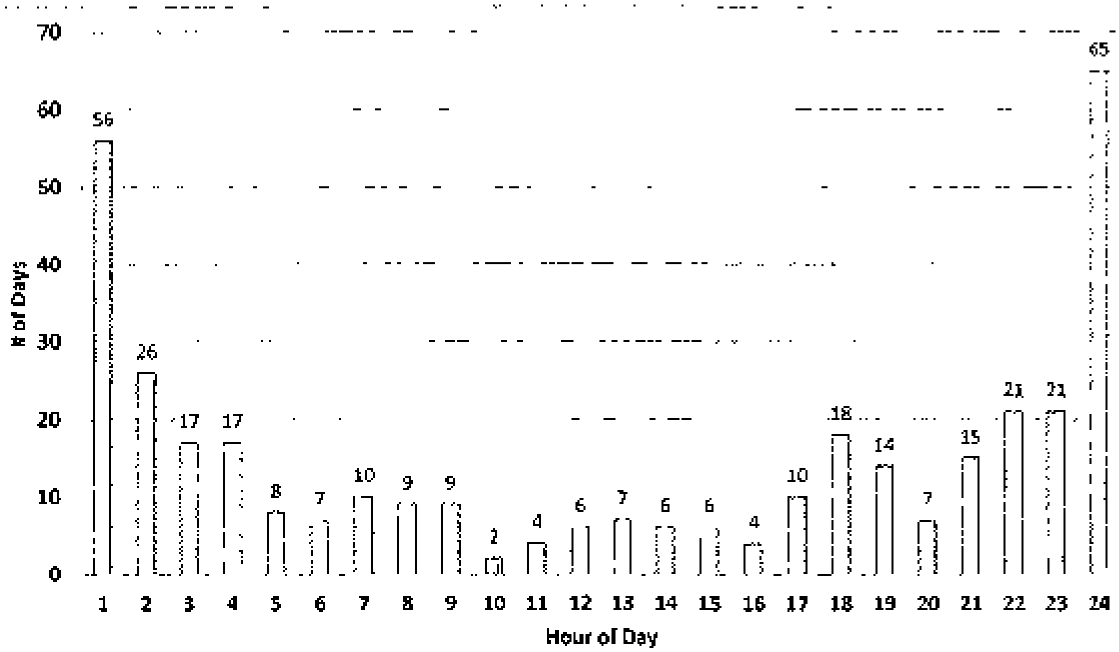
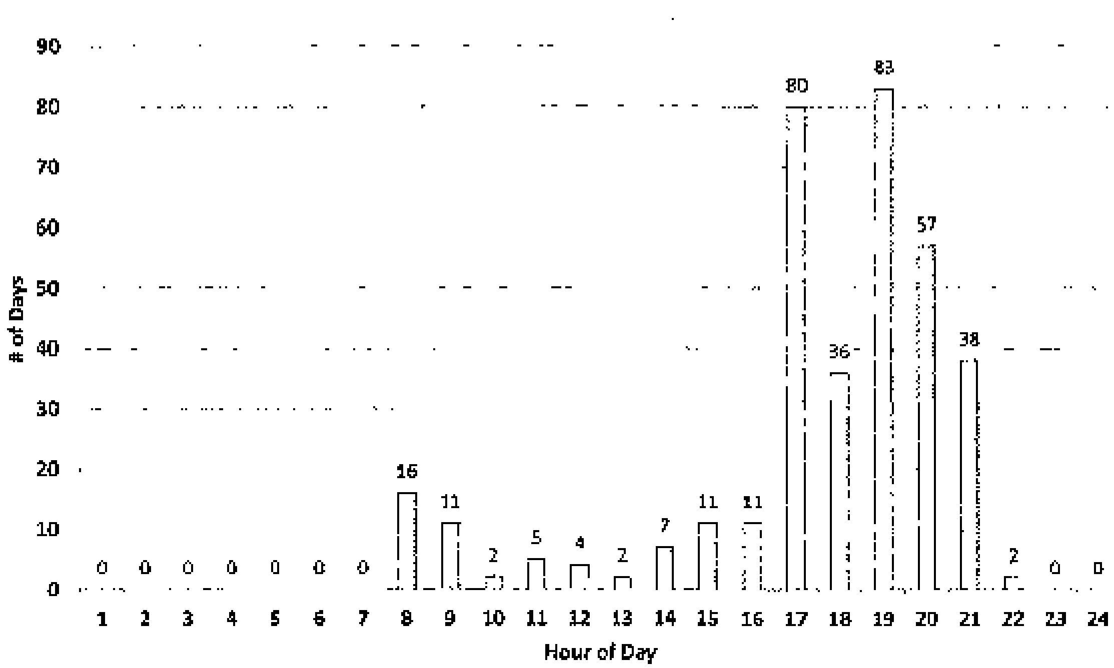
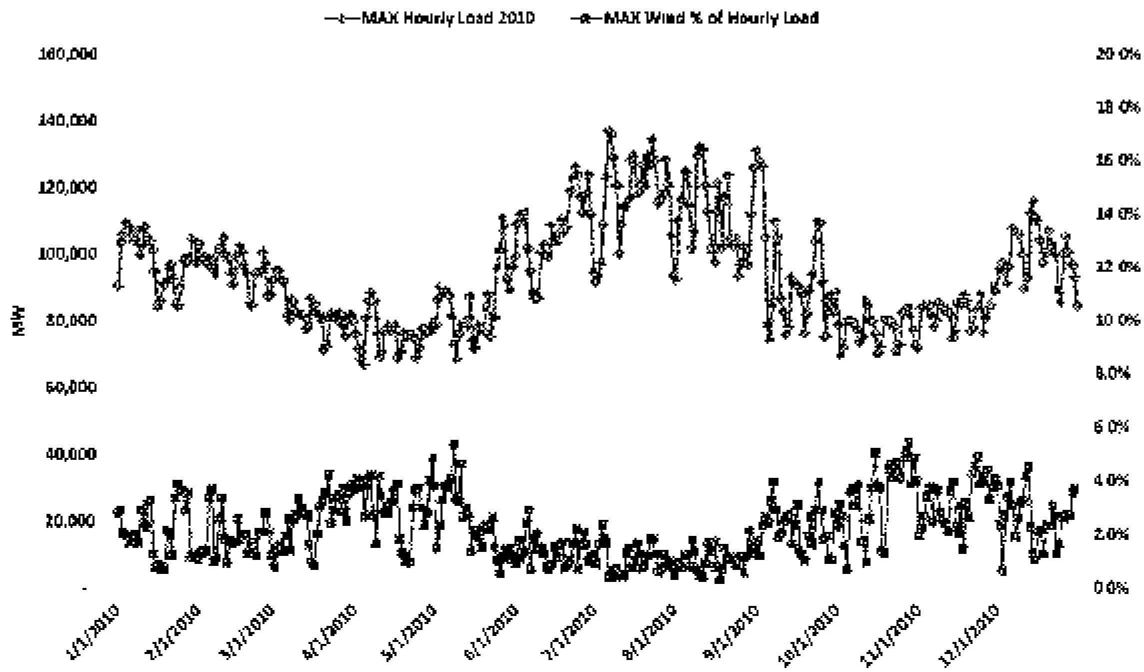


Figure 4 Hour of Daily Peak Load in PJM, 2010 (# of Days at Hour)



Combining information from the graphs above further illustrates the seasonal divergence of wind output and demand for electricity. Maximum electricity load is seen in July and August. In 2010, wind power contributed between zero and 5.4 percent of hourly load in PJM.

Figure 5 Maximum Hourly Load per Day and Wind as Max % of Hourly Load in PJM, 2010



PJM has not yet completed its own wind integration study but has initiated a study via a contract with GE Energy that will be complete in late 2012 (PJM 2011).

The PJM Renewable Integration Study is has two primary goals:

1) Determine for the PJM balancing area, the operational, planning and market effects of large-scale integration of wind power as well as mitigation/facilitation measures available to PJM, and
2) Make recommendations for the implementation of such mitigation/facilitation measures.

Some specific issues the study is expected to address include: entry and exit of supply resources, wind forecasting including output variation in areas with complex terrain, future fossil fuel prices, price response characteristics of demand resources and operating costs for new and existing units (PJM 2010).

Recommendations

Many of the recommended methods to integrate wind, such as combining balancing areas and expanding use of intra-hour markets, are already part of the trend toward greater interconnection in electricity supply. Other proposed solutions, such as energy storage and demand response have also been promoted for decades. Such resources if deployed routinely to reduce peak load would reduce reliance on system reserves provided by fossil resources, thus allowing the benefits of wind energy to be more fully realized. But as these non-traditional resources are slow to develop and physically limited, utilities are obligated to find other ways of serving whatever load is on the system and to do so within the numerous reliability constraints set by NERC.

Most recommendations to integrate wind regard modifying and expanding the existing operating system and the protocols that govern how and which plants are dispatched and re-dispatched throughout the daily electricity demand cycle in response to price signals, transmission constraints and load patterns. Many protocols require technology to be successful, but are not a technology solution, while some technologies such as fast- or slow-ramping energy storage are partial solutions in themselves.

NERC has evaluated the potential impact of variable resource integration extensively. Many of its recommendations focus on the potential effects of using non-conventional resources, such as demand-side response and energy storage, as reserves to balance wind's variation. These include strategies to optimize this contribution such as ensuring that appropriate communication exists between such resources and the system operator, adjusting reliability standards to expand the types of resources that are allowed to provide various reserves and services, and developing the correct price signals for those services (NERC 2010).

Most on-turbine technology options that could be used to reduce wind's short-run contribution to system variability are only partial solutions to integration and are not broadly recommended for immediate implementation. The recommendations closest to being implemented are regulatory, largely to be imposed by the Federal Energy Regulatory Commission (FERC), or market-based and designed to improve the fairness by which variable and fossil resources are compensated in the marketplace. Because FERC's role is to regulate transmission services, which must be scheduled by generators prior to generation, recommendations related to its rules largely involve changes in tariffs paid to owners of transmission.

Technology Recommendations

Incorporating additional electronic controls on wind turbines can partially resolve some of the issues related to its tendency to complicate compliance with real-time grid control performance standards. Wind turbines can be built to operate like synchronous generators providing reactive power (GE 2010). However, there are few firm recommendations or requirements to do this. Costs may be substantial and could significantly alter the wind component supply chain. Most discussion of this type of integration solution seems to be confined to academic and electrical engineering circles. IEEE characterizes many of these technology solutions, such as inertial response and other components that make wind turbines behave as synchronous generators, as the "Wind Plant of the Future" (Piwko and et al 2009). An example of a turbine-level technology is a doubly-fed induction generator controls on turbines providing pitch control for frequency regulation (McCalley 2010).

In spite of a lack of strong recommendations to integrate new components in wind turbines, there is some belief that truly successful, large-scale integration of wind will only be accomplished with turbines that act more like conventional plants. Such plants would be scheduled automatically over short periods of time with a known degree of accuracy, provide ancillary services including spinning reserves in both the up and down direction and frequency regulation, possess inertial response, voltage control and reactive power control with state-of-the-art power electronics. As this technology already exists it is a matter of economics, not ability (Smith and Parsons 2007).

One physical characteristic of modern wind turbines that increases availability and is already deployed is low voltage ride-through (LVRT), a technology that was implemented through operating standards. In 2005 PJM accepted a proposal by NERC and AWEA to require new wind facilities of greater than 20 MW to have LVRT capability for certain levels of voltage loss (PJM Interconnection, LLC 2005). FERC Order 661 requires wind turbines to remain in service during a fault for up to nine cycles at a voltage as low as zero (Stoel Rives, LLP 2009). While this does impose an additional expense on wind generators, this capability allows them to generate more in situations where they would previously have just disconnected from the grid. Such technologies make wind more "grid-friendly."

Solutions to decreased inertia and real-time output variation that can be alleviated by turbine-level technology can also be accomplished by fast-moving energy storage or load control (McCalley 2010). These resources could provide similar benefits as on-turbine technology but would have to be fully dispatchable and controllable by the system operator. These resources exist in small quantities, e.g. industrial demand-response units, grid-connected electric vehicles, pumped storage, but are presently not numerous enough to match the variability of large-scale wind. NERC has identified demand response, electric vehicles and several types of energy storage as technically capable of supporting all ten specific reliability functions it identified in its assessment of the impact of variable resources on system reliability, from the very short-term inertial impacts to unit commitment, although it expects situations with the longest response times and limited duration of response to be most suited to these resources (NERC 2010).

Increase the Flexibility of the System

Wind is a very flexible type of generation, both up and down (especially), but it is variable and not as regularly variable as load. NERC has stated that the electricity supply system must become more flexible in order to successfully integrate wind and that both supply-side and demand-side resources can provide this (NERC 2010). The characteristics of other generation on the system, i.e. the balance of generation, are very important as this determines the source of flexibility and the efficiency of integration.

Proposed flexibility solutions involve a combination of physical attributes and institutional protocols. Recommended sources of flexibility include expanded use of intra-hour markets, consolidation of balancing authorities, expansion of the type of reserves used for various ancillary services, lowering minimum generation levels of base load plants and enhanced communication between wind facilities, utilities and system operators.

NERC states that there are no technical limitations to non-conventional resources such as demand-response, electric vehicles and energy storage providing flexibility-related reliability functions but that economics will be the determining factor in widespread deployment (North American Electric Reliability Corporation 2010).

NERC has proposed a new type of reserve called "Variable Generation Tail Event Reserve" be created to cover the infrequent, but large ramps of variable generation. This type of reserve would be like conventional contingency reserves but would be assigned to cover generation ramping events, such as those created by wind resources. Such as reserve is needed because NERC reliability rules require contingency reserves to be restored within 90 minutes, making wind generation tail events too slow to use conventional contingency reserves. Because a large variable energy resource ramp often takes two hours or longer to reach a maximum level, reserves are needed that can respond for the entire duration of the ramp (NERC 2010).

It is also expected that any load that can supply replacement reserve or supplemental operating reserves will be able to supply Variable Generation Tail Event Reserves. In fact, NERC considers the potential aggregate contribution of demand response, electric vehicles and various types of energy storage to variable generation tail events reserves to be "significant" (NERC 2010). This is because these types of resources match the longer response time-frame of wind ramps with less concern regarding over-deployment that would occur with conventional generation being used as such a reserve.

Another integration recommendation is to expand use of shorter market intervals, such as the five-minute markets already in place at PJM and other ISOs. Such intra-hour markets make adjustment to serve changing load more optimal as plants can incorporate the latest information about their position. With tighter, intra-hour markets these schedules can be adjusted closer to real-time as wind forecasts change.

FERC has also proposed mandating 15-minute transmission scheduling for all utilities and balancing authorities (FERC 2011). According to FERC, intra-hour scheduling is fairer to variable generators because the re-dispatching that occurs optimizes use of available generation and reduces transmission imbalance charges that might be levied on wind generators who have reserved transmission capacity (Morgan Lewis 2011). Markets that only settle once an hour will be based on somewhat old wind and weather data by the time the generation actually occurs. The impact on conventional reserves is also greater with less frequent scheduling because actual generation may not match the associated transmission schedules, causing an unnecessary reliance on a public utility transmission provider's reserves (Morgan Lewis 2011).

To incentivize development of more flexible units it is recommended that the market for ancillary services be expanded to cover more types of faster-ramping units or demand resources (Puga 2010). A somewhat similar recommendation is to incentivize generation services that are bundled with variable renewable output to supply firm capacity and energy (EEI 2011). As NERC is the entity that sets guidelines for what types of resources qualify to provide different types of reserves, such decisions will be reliability based.

One recommended way to incentivize use of more efficient reserves is to change balancing authority rules to allow non-spinning reserve and supplemental operating reserves to be used to compensate for large wind ramps instead of regulation services (Campbell 2009). Expanded use of non-spinning reserves is one way to avoid system efficiency losses associated with idling or cycling spinning reserves to accommodate wind ramps. Spinning reserves can include demand response resources but they must be attained within ten minutes from a request. In addition, current rules allow PJM to implement no more than 10 interruptions in a given delivery year from qualified load management programs (PJM 2011). Some quick-start, non-synchronous resources such as hydro facilities and combustion turbines can provide reserves in 10-minute intervals but these reserves are generally part of the contingency or primary reserve category and held for that purpose (PJM 2010).

Supplemental reserves are not synchronized to the system but they are part of PJM's total operating reserves and are calculated, along with contingency reserves, to address load forecast error and forced outage rates (PJM 2010). Current reliability rules in the United States require non-spinning reserves and supplemental operating reserves to only be in service for a period of time (usually 1 hours to 2 hours) that is shorter than the wind ramps that may occur over a longer period of several hours (DeCesaro, Porter and Milligan 2009). Because net load (load minus wind output) varies more than load alone, incorporating wind forecast errors would increase the time period needed substantially.

Another FERC-proposed rule is to require expanded communication between wind facilities and public utility transmission providers regarding outages and output forecasts, not just between wind facilities and the system operator (Morgan Lewis 2011). This would allow utilities that transmit wind power that they do not control to have more complete information about how much wind is on their systems.

As wind output increases, especially during light load periods, traditional utility base load plants may need to operate below their optimal levels. The concept of increasing "base load turn-down levels" is one that is regularly mentioned in integration literature (NREL 2010). Such base load flexibility comes with an efficiency penalty, illustrated by the analogy of city driving vs.

highway driving. Or, if load is extremely low like in the early morning hours of fall and spring it may be impossible to further reduce base load output. If base load plants are already generating at their stated economic minimums, PJM will not dispatch them down further unless it is for reliability reasons. PJM is currently developing light load criteria to alleviate the growing problem of thermal overloading during the hours of 1 to 5am (PJM 2011). This effort focuses on reliability and ensuring that enough generation is available to respond to the morning load increase.

Due to reliability rules that obligate power delivery, flexible resources must also prove availability. For example, concern is sometimes raised about the availability of natural gas to fill in the gaps created by wind. Gas plants are typically more flexible than coal plants and suffer less efficiency loss when cycled and are thus better suited to back up wind. It has been recommended for reliability reasons that NERC should require gas turbines to keep a two-week supply of some other fuel that could be safely burned in place of gas (Bayless 2010). NERC recommends that gas pipeline flow is made more flexible to ensure deliverability matches reserve needs (North American Electric Reliability Corporation 2010).

Ideally, all this flexibility will be managed automatically. With the right tools, including always-on real-time communication and monitoring capabilities and a fleet of immediately responsive plants, this is possible. It is also very important that flexibility be appropriately valued by the market in order to have sufficient amounts of response capability supplied (National Renewable Energy Laboratory 2009). If plants or demand resources supplying ancillary services, or plants being curtailed to accommodate wind, are not financially motivated to provide those services integration will not be successful.

Develop Financial Mechanisms to Ensure Fairness and Availability

The very low marginal cost of wind is good for consumers in the short run. No resource can compete with wind at this price and are thus outbid in the wholesale market for electricity. But whether marginal prices provide the right signals to provide for a generation portfolio with the required flexibility characteristics is unclear (NREL 2010). There are costs associated with increased flexibility that are at odds with the dispatch of generating units based on marginal cost.

As suggested by FERC and others, the marginal costs of a wind facility may not account for the true marginal cost of providing firm wholesale power due to increased real-time cycling of conventional plants to accommodate wind. Pricing structures may be needed that allow generators providing ancillary services to recover their costs, even though they are operating at lower capacity factors, in order to ensure their availability and keep them economically feasible (Bayless 2010, National Renewable Energy Laboratory 2010).

FERC's interpretation of this issue is described as a "cost recovery gap that presently exists for the recovery of the capacity costs associated with the mitigation of generator imbalances" (Morgan Lewis 2011). Part of this gap shows up in the need for public utility transmission providers to provide regulation services to balance wind output, an issue that FERC proposes to resolve by allowing utilities to charge wind facilities for regulation. Under FERC's proposed Schedule 10 providers can charge a rate specific to variable resources, not the rate associated with load variability, if it is shown they cause a different cost (Morgan Lewis 2011). The Schedule 10 tariff would cover the costs of regulation reserve capacity held to accommodate load fluctuation and generation fluctuation, whereas current tariffs only cover load fluctuation.

FERC Schedule 10 is one of three proposed changes to the current Open Access Transmission Tariff (OATT) and Large Generator Interconnection Agreement (LGIA) listed in a recent FERC Notice of Proposed Rulemaking designed specifically to facilitate the integration of variable resources into the bulk power system. The other two proposed rules are to transition to intra-hour transmission service schedules and to require that public utility transmission providers be given wind facility data that can be used for system power output forecasting (Morgan Lewis 2011). The aim of these changes is to ensure that public utility transmission providers are able to recover all costs associated with accommodating fluctuations in generation associated with variable resources.

PJM supports the three actions in the FERC proposal assuming that choosing to use Schedule 10 is optional. PJM also suggests that FERC should "allow for regional differences" rather than mandating a 15 minute scheduling interval for all utilities and RTOs (Federal Energy Regulatory Commission 2011). The American Wind Energy Association and most wind facility owners are not supportive of Schedule 10 as many fear the costs would not be imposed fairly. As the rule would apply to all generators, natural gas trade associations are also unsupportive. Utilities and utility trade associations are generally supportive of all the recommendations, although some utilities express discomfort with 15-minute scheduling intervals.

In PJM, the issue of "lost opportunity costs" has recently been raised. Lost opportunity costs are allocated to generators that are curtailed for reliability reasons when they would normally have remained on-line due to their economics. PJM is working to equalize the rules under which wind plants receive such payments if they are in compliance with the operating agreement and following dispatch instructions. A recent proposal to increase the level of compensation from a facility's scheduled day-ahead position to the lesser of PJM's forecasted position or the facility's desired output was approved by PJM's Market Implementation Committee and will be filed with FERC at the end of 2011 (PJM 2011). Currently, wind facilities only receive lost opportunity cost payments to their day-ahead position (PJM 2011).

Other operating protocols are currently being designed in an attempt to be fairer to wind. Some recommendations regard the issue of cost causation and a desire to be certain that this is correctly assigned. While wind undoubtedly contributes to fossil cycling and imposes reserve costs wind generators' positive contribution to reserves is often neglected. This blurs the ability to accurately assign cost causation and may excessively penalize wind while ignoring its positive contributions. NREL recommends using a performance-based metric to capture both costs and contributions, e.g. calculation of wind's contribution to reserve levels as well as its own need for reserves (Milligan 2011).

Increase the Ability to Anticipate Wind Output

Accurately predicting day-ahead electricity load is vital to efficient electricity supply. Errors in forecasting cause under- or over-commitment of generating units which increases operating costs. Wind forecasting can never be perfect, but the better the expectation of wind output, the less re-dispatching needed to make way for it or cover for it. Improvements in short-term forecasts would reduce the impact on regulation requirements (National Renewable Energy Laboratory 2010) which is the most inefficient way to balance wind variability.

System operators must be able to measure the variability of the wind within time periods. A large balancing authority has an advantage because wind power forecasting error decreases as geographical area increases (Botterud 2011). Use of intra-hour markets allows the system to take advantage of changing forecasts and to incorporate that information in real-time dispatch decisions.

Wind forecasting is difficult due to the many variables that influence output. A facility may have various levels of output at a same forecasted wind speed depending on the number of turbines in service, the rate of change in wind speed, direction of wind and weather conditions. The key piece of information needed is how much output the wind facility will produce, i.e. where it will be on its power curve. This is another level of uncertainty, in addition to weather uncertainty, that is important when incorporating forecasts. In the ERCOT system, there is a tendency to under-forecast wind (Electric Reliability Council of Texas 2008).

Wind forecast data is one of the items FERC has proposed to require wind generators to provide public utility transmission providers to which they are interconnected. This includes site-specific information on, among other things: temperature, wind speed, wind direction and atmospheric pressure (Morgan Lewis 2011).

PJM's wind forecasting model is designed by Energy & Meteo, and uses a combination of several numerical weather models weighted according to the weather situation, site-specific power curves based on historical data, and a shorter-term model (0-10 hours) based on wind power measurements and numerical weather prediction. Wind turbine deration data is integrated in the forecast (Exeter Associates 2009).

The PJM tool includes four separate forecasts for different time periods. A long-term forecast provides hourly data from 48 hours ahead to 168 hours ahead. A medium-term forecast is updated from 6 hours ahead to 48 hours ahead. A short-term forecast is updated with a frequency of every 10 minutes using a forecast interval of 5 minutes for the next 6 hours. A ramp forecast is updated every 10 minutes at 5 minute intervals for the next 6 hours (Exeter Associates 2009).

The PJM tool includes four separate forecasts for different time periods. A long-term forecast provides hourly data from 48 hours ahead to 168 hours ahead. A medium-term forecast is updated from 6 hours ahead to 48 hours ahead. A short-term forecast is updated with a frequency of every 10 minutes using a forecast interval of 5 minutes for the next 6 hours. A ramp forecast is updated every 10 minutes at 5 minute intervals for the next 6 hours (Exeter Associates 2009).

The cost of PJM's wind forecasting system is passed along via its tariff. This is common among other systems incorporating forecasts, but some RTOs charge the wind facilities themselves, e.g. NYISO (Exeter Associates 2009). As of September 2011, PJM was receiving good meteorological data from 55 percent of wind facilities in its territory and is working to improve that rate (PJM 2011).

Expand transmission

Transmission expansion is a necessity for successful wind integration. Transmission enhances the capacity value and thus capacity credit of wind generation (National Renewable Energy Laboratory 2010). This is because it would allow increased transmission of more high quality Midwestern wind with a higher capacity factor, including a higher peak load factor, to eastern markets. According to NERC "resolving transmission constraints is critical because larger balancing areas lose much of the benefits associated with size if constraints are in play (North American Electric Reliability Corporation 2011)."

More transmission would mean less wind is curtailed because there will be fewer constraints throughout the system. Without expanded transmission, wind facilities are also more likely to compete with each other to get on the system, defeating the intent of a renewable portfolio standard. Some believe that transmission expansion will comprise the largest cost component of wind integration (Kahn 2010).

FERC Order 1000 may encourage transmission development by expanding the traditional right to develop from public utility domain to include independent developers. As part of this order, FERC has required regional transmission operators to come up with a way to allocate the costs of new transmission to beneficiaries (Moser 2011). This means that PJM will be making such decisions for its region, which can be expected to be closely tied to the same decisions in the MISO. This is expected due to the fact that MISO wind is imported into the PJM system (PJM 2011).

The size of a transmission facility built to integrate wind should not be built to handle all the target wind generation at its maximum coincident output. Some wind can at times be curtailed more economically than building transmission that would be loaded only for a few coincident hours. Planning for some curtailment is thus likely to be more cost effective than designing a transmission system for the peak coincident output of all wind facilities (National Renewable Energy Laboratory 2010). Enhanced transmission will also facilitate the sharing of flexible supply and demand resources that can be used to accommodate wind energy (NERC 2010).

An example of a non-conventional transmission expansion plan is high-voltage DC lines (HVDC). An HVDC line would behave like a generator as it would have no load and would thus be fed into a receiving utility system like a merchant power plant. Current efforts to build HVDC lines are focused on delivering high-quality wind from Kansas and Oklahoma into the TVA system. To provide firm power an HVDC line would purchase ancillary services at an amount of about 10 percent of wind capacity (Glotfelty 2011).

The role of the FERC in deciding how integration costs are assigned is very important. Some of its recent recommendations for integrating variable generation are summarized below.

- Mandatory 15-minute transmission scheduling for all utilities and balancing authorities
- Expanded communication between wind facilities and transmission providers regarding facility output; this includes requiring wind facilities to provide wind forecasting data to utilities
- Allow utilities to charge wind facilities a wind-specific rate for regulation reserve capacity shown to be required because of wind
- Require RTOs (such as PJM) to come up with a way to allocate the costs of new transmission to beneficiaries

Conclusions

Current recommendations to integrate wind focus on methods of operating the system to ensure reliability and covering the costs of balancing the electricity delivery system to accommodate its variability. Integrating wind reliably is said to be a surmountable engineering challenge, but integrating wind efficiently has many more uncertainties.

The challenges of wind integration exist in multiple time periods, with second-to-second stability affects that could be resolved with modifications to on-turbine technology, minute-to-minute balancing affects that could be resolved with a combination of on-turbine technology and very fast-acting reserves, hour-to-hour load-following affects that could be resolved with ample supply of flexible generation and responsive load, and longer-term unit commitment affects that can be reduced through incorporation of reliable wind forecasting data.

Many of the recommendations to improve the efficiency of integration support the type of generating equipment and non-traditional resources that many have been advocating for decades, such as energy storage, modern transmission and demand-side management. Few strong recommendations are currently being made to alter the components in wind turbines in a way that would allow them to participate in the market like conventional generators.

There are ubiquitous recommendations to incentivize non-traditional electricity resources such as demand-side management and expand use of non-spinning resources as operating reserves, but there is much uncertainty regarding how extensively such resources could be utilized. NERC and RTO standards limit the frequency with which demand-side resources can be called upon and reliability standards govern use of non-spinning resources. Such standards may need to be changed to allow use of these resources in quantities large enough to support wind. NERC supports changing standards and has also proposed a new category of reserves called "tail event reserves" that could be used specifically to support wind and other variable resources.

Allocating to wind facilities the costs of operating reserves used to balance wind variability will make integration costs more transparent. However, due to the high level of interconnectedness in the system and the large number of generators already cycling in response to intra-hour market signals and to system imbalances caused by other fossil generators, and in spite of wind, there are issues of fairness when system costs are allocated specifically to wind.

In the near-term, the current non-wind generating mix is a very important determinant in how efficiently wind is utilized from day to day. Fossil fuel prices matter quite a bit because when natural gas prices are high coal plants have to cycle more to accommodate wind, especially in off-peak hours.

As wind penetration increases, the existing fleet of base load plants is likely to be forced to operate below their preferred levels of output more frequently than before. Wind is expected to displace conventional generation, but not at a megawatt per megawatt basis. As wind expands more generation capacity, or responsive load, will be needed to respond to more potential output fluctuation.

The process of moving toward better integration includes ongoing studies by all major ISOs, many other balancing authorities, utilities and NERC. This includes development of flexibility metrics that can be used to assess the adequacy of various flexible resources responding to real-time demand and supply conditions. It is recommended that balancing authorities coordinate their integration efforts, but most utilities and ISOs are pushing for the ability to develop unique solutions. ISOs such as PJM that have access to a wide range of services and are highly connected to other systems are in a good position to test response to various incentives and protocols.

Works Cited

Bayless, Charles E. "The Case for Baseload." *Electric Perspectives*, September/October 2010: 72-83.

Bentek Energy. "How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market." April 16, 2010.

Botterud, Audun. "Wind Power Forecasting in U.S. Electricity Markets." *The Electricity Journal*, 2011: 71-91.

Campbell, Ric. "Grid Integration of Renewable Energy Generation: US Experience." 2009.

DeCesaro, Jennifer, Kevin Porter, and Michael Milligan. "Wind Energy and Power System Operations: A Review of Wind Integration Studies to Date." *The Electricity Journal* 22, no. 10 (October 2009).

Electric Reliability Council of Texas. "ERCOT Wind Impact/Integration Analysis." February 27, 2008. http://www.ercot.com/meetings/ros/keydocs/2008/0227/ERCOT_final_pres_d1_w-o_backup.pdf (accessed August 2011).

Exeter Associates. *Central Wind Power Forecasting Programs in North America by Regional Transmission Organizations and Electric Utilities.* Exeter Associates, 2009.

Federal Energy Regulatory Commission. *Docket # RM10-11.* 2011. http://elibrary.ferc.gov/idmws/docket_search.asp (accessed March 2011).

Forbes, Kevin, Marco Stampini, and Ernest Zampbelli. "Do Higher Wind Power Penetration Levels Pose a Challenge to Electric Power Reliability?: Evidence from the 50Hertz Transmission System in Germany." *ENERDAY.* Dresden: Dresden University of Technology, 2010.

GE Energy. *New England Wind Integration Study.* ISO New England, 2010.

Glotfelty, Jimmy. "Clean Line Energy Partners." *Plains & Eastern Clean Line.* August 18, 2011.

Hines, Paul. "Estimating Regulating Reserves Requirements as Wind Generation Increases: A Problem Definition." University of Vermont, 2010.

Inhaber, Herbert. "Why Wind Power Does not Deliver the Expected Emissions Reductions." Renewable and Sustainable Energy Review, December 2010.

Kahn, Edward. "Wind Integration Studies: Optimization vs. Simulation." *The Electricity Journal*, November 2010: 51-64.

McCalley, James D. "Frequency control (MW-Hz) with wind." Iowa State University, February 2010.

Milligan, Michael. *Cost-Causation and Integration Cost Analysis for Variable Generation.* Golden: National Renewable Energy Laboratory, 2011.

Monitoring Analytics. "Marginal fuel displacement by wind generation in PJM, 2009." *Energy Market, Part 2.* 2010.

Morgan Lewis. "FERC NOPR on Integrating Renewable Energy Resources into the Transmission Grid." Morgan Lewis, February 2011.

Moser, Bob. *US Transmission: FERC reforms usher new era for renewablse.* August 22, 2011. http://social.windenergyupdate.com/.

National Renewable Energy Laboratory . "Eastern Wind Integration and Transmission Study PJM Stakeholder Meeting." NREL , March 2010.

National Renewable Energy Laboratory. "EASTERN WIND INTEGRATION AND TRANSMISSION STUDY." NREL, January 2010.

—. "Impact of Electric Industry Structure on High Wind Penetration Potential." NREL, July 2009.

New York Independent System Operator. "Growing Wind: Final Report of the NYISO 2010 Wind Generation Study." September 2010.

North American Electric Reliability Corporation. "Flexibility Requirements and Potential Metrics for Variable Generation: Implications for System Planning Studies." August 2010.

—. "NERC IVGTF Task 2.4 Report: Operating Practices, Procedures and Tools." NERC, March 2011.

—. "Potential Reliability Impacts of Emerging Flexible Resources." NERC, November 2010.

—. "Special Report: Ancillary Service and Balancing Authority Area Solutions to Integrate Variable Generation." NERC, March 2011.

PacifiCorp. "2010 Wind Integration Study." PacifiCorp, August 2010.

Piwko, Richard, and et al. "A Whirl of Activity." *IEEE Power & Energy Magazine,* November/December 2009: 26-35.

PJM. "Dispatchable Wind Resource LOC." *Intermittent Resource Task Force.* September 19, 2011.

PJM Interconnection, LLC. "Interconnection for Wind Energy and Other Alternative Technologies." *Docket No. RM05-4-000.* FEDERAL ENERGY REGULATORY COMMISSION, September 19, 2005.

PJM. "Light Load Operational Performance Criteria." January 24, 2011.

—. "PJM Intermittent Resources Task Force Meeting Minutes." May 9, 2011.

—. "PJM Intermittent Resources Working Group Meeting." September 13, 2010.

—. "PJM Resource Adequacy Analysis." *PJM Manual 20.* 2011.

—. "PJM Wind Power Statistics." *PJM.org*. July 25, 2011. http://www.pjm.com/~/media/committees-groups/task-forces/irtf/20110725/20110725-item-03-wind-report.ashx.

—. "Reserves Scheduling, Reporting, and Loading." *Operations 101*. 2010.

Prager, Frank. "Setting the record straight on wind energy." *VP, Environmental Policy - Xcel Energy*. Denver Post, May 28, 2010.

Puga, J. Nicolas. "The Importance of Combined Cycle Generating Plants in Integrating Large Levels of Wind Power Generation." *The Electricity Journal*, August/September 2010: 33-44.

Smith, Charles, and Brian Parsons. "What Does 20% Look Like?" *Developments in wind technology and systems*. IEEE, 2007.

Stoel Rives, LLP. "The Law of Wind - Regulatory and Transmission-Related Issues." 2009.

USDOE: EERE. "20% Wind Energy by 2030." July 2008.

Vittal, Vijay. "Impact of Increased Penetration of DFIG based Wind Turbine Generators on Transient and Small Signal Stability of Power Systems." Arizona State University, February 2, 2010.

Xcel Energy. "Characterizing the Impacts of Significant Wind Generation Facilities on Bulk Power System Operations Planning ." Electrotek Concepts, May 2003.

FINDINGS ON THE IMPACT OF WIND TURBINES ON RESIDENTIAL PROPERTY VALUES: A Reference Guide as of 2011

Prepared for:

West Virginia Division of Energy

and

Wind Powering America

April 2011

(Revised September 2011)

CBER

MARSHALL UNIVERSITY

CENTER FOR BUSINESS AND ECONOMIC RESEARCH

FINDINGS ON THE IMPACT OF WIND TURBINES ON RESIDENTIAL PROPERTY VALUES: A Reference Guide as of 2011

This document provides a summary of information gleaned from seven studies conducted over the last five years that have attempted to quantify the effect of wind facilities on property values. Two of the studies included were contracted by a wind developer, two were produced by real estate appraisers, one by a US Department of Energy laboratory, one from an American university and one from a British university. Impacts to individual properties were found to be neutral by the wind developer and the laboratory, negative by the appraisers and uncertain by the British university and negative by the American university.

It is logical for property owners to be concerned that having a good view of a wind turbine may lower the potential resale value of their property. Unfortunately, this guide does not relieve that concern nor does it provide for an expectation of devaluation. This is the state of analysis, based on limited available data. Primary points:

- Defined area is very important for this topic, as being five miles from a wind turbine is very different than being half a mile away.
- Aggregate findings are not useful for properties located very near a wind turbine.
- Relatively few property transactions have occurred very near (less than one mile) turbines and the dispersion of those transactions combined with the complexity of property features makes it difficult to accurately observe trends or correlations.
- Many characteristics of a property create value in combination; without observing all characteristics across comparable properties in similar geographic areas the contribution of wind turbines to value can't be measured.
- Properties in poor condition may be more negatively impacted by turbines than properties in good condition. Evaluating wind facility impacts near groups of homes that are below-average is more complex due to a likely tendency for turbines to be located on lower value land in an area.
- The impact to an individual property is a function of site-specific variables including existing property features, topography, geographic features between a property and a turbine and orientation in relation to turbines and prevailing winds.
- Although they do not move, analysis of high-voltage transmission lines could provide some indicators of where and when impact may be negative.
- To better understand the impact of wind turbines on property values more transactions data must be collected and evaluated according to industry standards.

There is no indication that wind turbines cause a persistent negative impact on property values in the area (5-mile radius) around a wind facility.

One of the larger-scale analyses of this issue is a Lawrence Berkeley National Laboratory (LBNL) study which found that valuation for a collective set of properties sold within five miles of wind turbines was no different than the set of properties sold outside of five miles (Hoen 2009).

These aggregate findings can't be transferred to individual properties and it can't be promised that no impact will occur. Properties located within a mile of a wind facility can't be evaluated the same as those located more than two miles away.

In the literature of impact studies, findings of negative impact are most often found in those based on surveys of homeowners or appraisal experts that were conducted prior to construction of a wind facility.

A series of interviews with participants in the real estate market in Tucker County, WV found no indication of a perceived negative impact from the Mountaineer wind facility. However, due to sparse sales, not enough quantitative data was available to make an absolute statement (Goldman Associates 2006).

Not enough data has been collected on home sales very near wind turbines to establish whether turbines impact these homes differently compared to homes further away.

The LBNL study included only 125 transactions within one mile of 1,345 turbines surveyed at 24 wind projects and analysis was thus based on pooled data from nine different states. A persistent negative sales impact was not observed within these 125 transactions. This study suggests that if an impact does exist at close proximity, it may exist in the time period immediately following project announcement but before construction, and could fade following construction.

The LBNL study observed sales volumes were slightly lower within one mile of wind turbines, less than two years after construction, but not significantly different more than two years after construction. Reduced sales volume is another possible impact.

A study of sales data from homes near six wind facilities in three New York counties, using the date of the draft EIS document as the before and after point, evaluated results by census block-group, census block, and parcel-level fixed effects. The study found consistently more negative impacts the closer a property was to a turbine, with exceptions for properties close enough to receive direct payments from the developer or in some cases from properties in relatively good or very good condition (Heintzelman and Tuttle 2011).

A study by McCann Appraisal found that 15 homes located within two miles of a wind facility were on average valued 25 percent less per square foot than 38 homes located more than two miles away (McCann Appraisal 2010), but the firm did not correlate value with other property characteristics or earlier sale values, and thus does not show causation. A study for Invenergy using the same data notes that the homes located closer to the facility were as a group quite a bit older than the homes located further away, making the two groups not comparable (Poletti & Associates 2007).

A survey of realtors, some of which had sold homes near turbines, conducted by Appraisal One found high expectation for wind turbines to negatively impact improved residential property, with increasing expectation the closer ("bordering," "close" or "near") the home to a turbine (Appraisal One Group 2009). Having a turbine visible from the front of a home was found to be more negative than a view from the back.

The paucity of data negates extrapolation to any specific area, although more turbines are located close to homes in the East and Midwest due to population density and geography.

It is possible to have relatively depreciating home values while living near wind turbines, and some depreciation may be attributed to the turbines.

Without a more thorough sample, it is unknown to what extent any lower observed transaction price is due to close proximity to turbines or if the difference is due to other features of the property or an area.

Both positive and negative impacts found in the New York study show the importance of the state of the underlying property. Homes in poor condition were more likely to be negatively impacted while homes in good condition were less likely to be impacted.

Like with transmission lines differences may be temporary, as perceived impacts may be realized in lower prices after a facility is announced but may recede following actual construction. This finding is consistent with the International Association of Assessing Officers (IAAO) finding of a u-shaped response curve resulting from the presence of industrial facilities, where values drop but then recover over time (Kinnard 1995). The New York study also includes transactions that occurred before actual construction but after facility announcement, using the date of the draft EIS document, because using a later date would have made the statistical results insignificant (Heintzelman and Tuttle 2011).

In the United Kingdom, there have been cases of taxing authorities lowering valuations for properties due to their proximity to wind turbines (BBC News 2008) and of individuals being awarded damages for a reduction in home value due to visual and sound impacts of wind turbines (The Telegraph 2004)

It is possible to have appreciating home values while living near wind turbines, even within one mile of a turbine, but the appreciation can't be attributed to the turbines.

The LBNL study found that sales of homes with an "extreme," "substantial" or "moderate" view of turbines sold at prices that were no different than homes with no views of turbines, although there were only 28, 35 and 106 of these sales respectively, and thus no ability to extrapolate

Properties that are involved in lease arrangements with a wind facility may experience value appreciation relative to properties that are not in such leases In New York, properties within 0 1 miles of a turbine were found to appreciate in value relative to properties at further but varying distances possibly due to this factor (Heintzelman and Tuttle 2011)

Wind development can influence values positively due to direct property purchases

Other home or area features are probably just as important in influencing resale price as are the presence of wind turbines.

The IAAO, the most respected organization for property valuation guidelines, does not include wind turbines as a factor influencing value, but differences in view or proximity to a potential "nuisance" can influence an appraisal Under accepted appraisal standards of both the IAAO and The Appraisal Institute (AI) whether any factor does constitute a nuisance which reduces the value of the property is determined by using market comparables Under this approach properties that are considered "suitable substitutes" of the subject property are collected and their features are compared These suitable substitutes are called comparables There can be many differences between the subject property and the comparables The appraisal must adjust the value of the subject property to the comparables by either adding value or lowering value The presence of a nuisance may appear to reduce the value of the subject property but the only way that can be determined is to compare ALL the differences between the subject and each comparable The mere presence of a potential nuisance and a lower sale price for a property does not mean the nuisance caused the lower valuation if other factors are present which might account for the difference

Appraisal standards indicate that at least the following variables should be compared to the subject property

- Proximity to the subject

- Time of sale
- Location
- Site characteristics (including nuisances)
- Design
- Quality of construction
- Age of structure
- Condition
- Number of rooms (bed and bath)
- Living area
- Functional utility
- HVAC
- Garage
- Porches, patio, pools
- Other (fireplaces, kitchen equipment, date of remodeling, decoration)
- Sales or financing terms

To determine whether a potential nuisance detracts from value all the differences from the comparable property must be valued. This can only be accurately done if there are multiple sales of suitable substitutes. There are methods of regression analysis and appraisal manuals which indicate the value of the variables, but these are of little value in rural areas where there are few sales.

Evidence from high-voltage transmission lines (HVTLs) can provide some insight.

Scenic areas, custom homes and houses next to poorly maintained properties may be more impacted due to their unique or undesirable features (Pitts 2007).

A negative impact is more likely when a property has an encumbered view because of a HVTL (Hamilton 1995).

It is too early to make generalized conclusions about the impact of wind turbines on individual home values.

Applied to the question of the appraisal of properties in the vicinity of wind towers, until there are sufficient sales in an area there can be no defensible conclusion that a wind facility detracts (or possibly adds) value. Any conclusions must be very specific to the site involved. Studies that include a number of sites in different locations are of little value, but they may provide an indication of whether the presence of wind facilities might influence value. A scenic vista is possibly an important feature of a home and may be highly correlated with sale value but it is unlikely to be the only factor in the determination of value.

The universe of properties that are potentially impacted by wind turbines is growing as installed wind capacity increases. As wind increases market share, more transactions will be observable.

Hub heights are getting higher. Most studies have assessed turbines with hubs heights of up to 80 meters, but some firms now install turbines with 100 meter hub heights. The taller and larger turbines could have different impacts.

Evidence from both U.S. and U.K. studies show that it is often difficult to separate effects of existing area stigmas such as other industrial facilities and HVTLs that already affect values (Sims 2007).

Evidence from New York shows it is easy to overestimate the contribution of wind turbines to value declines of marginal property due to a tendency to site wind turbines on properties that already have relatively low values (Heintzelman and Tuttle 2011).

Works Cited

Appraisal One Group. *Wind Turbine Impact Study - Dodge & Fond Du Lac Counties Wisconsin.* Oshkosh: Appraisal Group One, 2009.

BBC News. *Wind farm blights farmhouse.* July 2008.

Goldman Associates. "A Study on the Impact of Windmills on Property Values in Tucker County, West Virginia for the Proposed Beech Ridge Energy, LLC Project in Greenbrier County, West Virginia." 2006.

Hamilton, S and Schwann. "Do high voltage electric transmission lines affect property value?" *Land Economics,* 1995: 436-444.

Heintzelman, Martin D., and Carrie M. Tuttle. *Values in the Wind: A Hedonic Analysis of Wind Power Facilities.* Potsdam, NY: Clarkson University School of Business, 2011.

Hoen, Wiser, Capper, Thayer and Sethi. *The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis.* US Department of Energy, Lawrence Berkeley National Laboratory, 2009.

Kinnard, W. and Dickey. "A primer on proximity impact research: Residential property values near high-voltage transmission lines." *Real Estate Issues,* 1995: 23-29.

McCann Appraisal. "Written testimony to Mike McLaughlin, Chairman of the Adams County, IL Board." 2010.

Pitts, J and Jackson. "Power Lines and Property Value Revisited." *Appraisal Journal,* 2007.

Poletti & Associates. "A REAL ESTATE STUDY OF THE PROPOSED WHITE OAK WIND ENERGY CENTER MCLEAN AND WOODFORD COUNTIES, ILLINOIS." 2007.

Sims, S and Dent. "Property Stigma: wind farms are just the latest fashion." *Journal of Property Investment & Finance,* 2007.

The Telegraph. *Giant blades are slicing prices.* October 2004.