STATE OF MAINE
LAND USE REGULATION COMMISSION

CHAMPLAIN WIND, LLC
BOWERS WIND PROJECT
DEVELOPMENT PERMIT DP 4889

PRE-FILED DIRECT TESTIMONY OF

Abigail Krich

ON BEHALF OF

CONSERVATION LAW FOUNDATION

Introduction

My name is Abigail Krich. I am President of Boreas Renewables, a consulting company that provides technical assistance and advice regarding renewable energy and the electric power infrastructure. As indicated on my Curriculum Vitae, attached to this testimony, I hold a Master's of Engineering Degree in Electrical and Computer Engineering with a focus on power systems from Cornell University as well as a B.S. in Biological and Environmental Engineering, Environmental Option, from Cornell University. I have worked in the renewable energy industry in varying capacities since 2003. Since 2006 I have managed the technical aspects of various renewable generation project developments, including handling interconnection and electricity market issues with independent system operators such as ISO-New England. I also perform regional transmission planning and energy market design advocacy for a regional renewable energy trade group.

Summary

The purpose of my testimony is to highlight the positive economic and environmental impacts that wind energy has in Maine. Electrical generation and consumer demand for electricity must be balanced at all times as there is very little electrical storage available. Therefore, when wind energy is produced, it must displace energy that would have been produced by another source. Wind has almost no marginal cost for producing electricity once it is built so it typically acts as a price-taker in the wholesale electricity markets. Price-taking energy, like wind, displaces more expensive energy in the markets, keeping power prices low. Fossil fuels produce the majority of electricity in New England and represent over 70% of the electrical generating capacity in the region. Wind primarily

displaces natural gas and oil and will displace increasing amounts of coal electricity as more wind is installed.

The New England Wind Integration Study (NEWIS), performed by ISO New England, found that no additional power plants would be needed to balance the additional variations expected from up to 12,000 MW of wind energy in New England. This is equivalent to approximately 24% of the annual regional demand for electricity being met by wind energy. For comparison, wind energy produced 1% of New England's electricity in February 2011. NEWIS found that up to 12,000 MW of wind could be integrated without the need for additional electrical storage. NEWIS also found that if 20% of New England's electricity were supplied by wind it would reduce the region's electricity-related CO_2 emissions by 25%, SO_x emissions by 6%, and NO_x emissions by 26%.

Generation, Load, and the Grid

Electrical generators produce power that is fed into the transmission system, also known as the grid. Consumers of electricity, known as load, take power from the grid. The grid is composed of transmission and distribution lines that connect and transmit electricity between all of the generators and load on the system.

With the exception of northern Maine which is electrically connected to New Brunswick rather than southern Maine, all of the generators and load in New England are tied together electrically by the grid. This means that the electrical performance in one part of the system affects all areas of the system. The New England electrical system serves approximately 14 million people with over 300 generators and is connected by over 8,000 miles of high voltage transmission lines.[1]

Load Must Equal Generation

The high voltage backbones of the New England grid are managed by the Independent System Operator of New England (ISO-NE). To operate reliably, the amount of power being put into the grid by generators and the amount of power being taken from the grid by load must be balanced at all times.

Because the load in New England is constantly fluctuating, the fleet of generators must match their production to the load fluctuation in order to produce exactly the amount of power that is being consumed at any point in time. The process of telling generators to turn on or off and how much electricity to produce at what time is managed by ISO-NE. They manage the system and determine which generators are needed and when they are needed based on a load forecast.

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[1] ISO New England Regional System Plan 2010 (RSP10) at page 15-16. Regional System Plans are released annually and are available at http://iso-ne.com/trans/rsp/index.html.

Variations in Load

There are annual variations in load which mean that some generators are only used during certain parts of the year, typically in the summer when New England load is at its highest. There are daily variations in load that must be matched by turning some generators on and off during the day (called unit commitment) and having other generators ramp their output up or down over the course of the day to match the trends in load (called load following). There are also second-to-second and minute-to-minute variations in load that cannot be predicted but must be matched by generation. A select number of generators receive automated signals from ISO-NE to balance those very quick variations (called regulation).

ISO-NE also needs to maintain a specified level of reserve generation at all times to be able to respond to errors inherent in the load forecast. If the load is higher than expected, these reserves are dispatched (instructed to produce power) to make up the difference. If load is lower than expected, ISO-NE tells generators to reduce their output or even turn off.

ISO-NE is not concerned with the precise amount of power each individual load is consuming. They do not dispatch individual generators to follow the patterns of individual loads. The load patterns of an individual house would look very erratic with huge shifts from one moment to the next as lights and appliances are switched on and off. ISO-NE only needs to pay attention to the system load and make sure the generation fleet as a whole balances the system load. Because the 14 million people being served by ISO-NE do not turn their lights and appliances on and off in synch with each other, the total system load appears much more smooth than the load of an individual house. Wind energy, as described later on, is very similar in this respect.

Wind Operates as a Price-Taker in Wholesale Markets

ISO-NE operates competitive energy markets to meet the electric demand. This is done through an auction process in which ISO-NE selects the electricity suppliers that can meet the demand most cost effectively. By bidding in their variable cost of energy (fuel cost, variable operations and maintenance, start-up cost, and emissions cost), ISO can select the generators that will produce the needed electricity at the lowest cost. Capital costs are not considered in these bids. Typical variable costs by generator type are:[2]

- Wind: less than $0.01/kWh
- Hydro: less than $0.01/kWh
- Nuclear: $0.01/kWh

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[2] Final Report: New England Wind Integration Study, Prepared for ISO New England, Prepared by GE Energy Applications and Systems Engineering, EnerNex Corporation, and AWS Truepower. December 5, 2010. Available at http://iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2010/newis_report.pdf (NEWIS) page 259.

- Coal: $0.03 - $0.06/kWh
- Combined cycle natural gas: $0.05 - $0.07/kWh
- Gas turbine: $0.07 - $0.15/kWh
- Oil/Gas steam turbine: $0.15 - $0.23/kWh
- Oil combustion turbine: $0.23 - $0.37/kWh

These costs assume relatively low natural gas fuel prices, but can vary widely as fuel costs fluctuate. Regional gas prices are extremely volatile. They averaged $5.00/MMBTU in the summer of 2010 but were as high as $15.00/MMBTU in the summer of 2008 (pushing up average Maine real time energy prices to $0.103/kWh). Because natural gas is so often the fuel that sets the clearing price in New England, the price of electricity in this region closely tracks natural gas prices.

Since wind energy does not have a fuel cost and has minimal operations and maintenance costs,[3] its variable cost of providing energy is lower than that of any electrical power plant that must purchase fuel to produce electricity. For this reason, wind typically operates as a "price-taker" in the wholesale energy markets, bidding in the equivalent of $0/MWh to produce energy.

The highest price bid that is selected by ISO-NE sets the price that all generators are paid for their electricity. When demand for electricity is low, ISO is generally able to meet the demand with all low-cost generators. When demand is high or many of the low cost generators are not available, ISO has to reach higher up the list to meet the demand resulting in higher electricity prices. For context, in April 2011 the average Maine real time energy price was $0.042/kWh because April is generally a low-demand month. However, on April 13th at 1 p.m. the real time energy price topped out at $0.313/kWh.[4]

Price-taking energy like wind will always clear in the market and displaces the need to purchase energy from the most expensive generators. It has the same effect as reducing the demand for electricity and helps keeps energy market clearing prices low.

Not all energy is purchased in wholesale markets. Much of it is purchased through bilateral contracts or power purchase agreements that may or may not be below market rates. Because wind energy projects are capital intensive, they typically look for long-term energy contracts to guarantee energy payment levels.

In 2009 the Maine Public Utilities Commission approved a twenty-year contract between Central Maine Power and Bangor-Hydro-Electric Company and First Wind's Rollins Wind Project. This contract specified that the energy would be sold at a specified discount from the actual market price with a floor price of $0.055 - $0.065/kWh and a cap of $0.110/kWh. NSTAR selected three New England wind projects as part of the

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[3] Average wind O&M costs are equivalent to $0.01/kWh. 2009 Wind Technologies Market Report, U.S. Department of Energy, Energy Efficiency & Renewable Energy. August 2010. Page 54. Available at: http://www1.eere.energy.gov/windandhydro/pdfs/2009_wind_technologies_market_report.pdf&id=4381

[4] http://iso-ne.com/markets/hstdata/znl_info/index.html.

2010 Massachusetts RFP for long-term renewable energy contracts. Pricing details have not been disclosed, but speculations are that the price is below $0.10/kWh.

Whether these long-term contracts end up being above or below market rates depends on fuel prices over time. What they do provide is certainty. Unlike wind, a fossil fuel power plant cannot guarantee its fuel prices five or ten years down the road so it cannot lock in a power sale price. In June of 2008, when natural gas prices were three times what they are today, the Maine real time energy price averaged $0.103/kWh and topped out at $0.400/kWh. In a market like that one, these long-term wind energy contracts would be considered bargain-basement prices.

All energy purchased through these types of bilateral contracts still needs to be accounted for by ISO-NE and is generally entered into the wholesale market as a price-taker. Therefore, regardless of the long-term contract price, wind energy can still suppress market prices for the energy that has not been purchased through contract. In this way, long-term contracts for wind can also reduce regional energy prices indirectly.

Wind Energy Can Reduce Electricity Prices

The experience Texas has had with wind energy serves as a model for what Maine might expect. Wind development in Texas has predominantly occurred in the western part of the state while the major load centers are in the eastern part of the state. Due to transmission constraints for power flows between the western and eastern parts of the state, the western regions have become export constrained. This is not entirely dissimilar from the situation Maine is in with the rest of New England. Maine is also export constrained and holds the potential for the majority of on-shore wind development in New England.

In January 2011, the Public Utilities Commission of Texas released a report to the Texas Legislature on the scope of competition in electric markets in Texas.[5] The report finds from Texas's operational experience that balancing energy market prices "are typically lower in the West zone because the West zone is export constrained and prices within that zone are affected by the large amount of low-cost wind energy."[6]

We have already seen a similar impact of wind energy on pricing in Maine. On May 25, 2011, First Wind announced a Power Purchase Agreement (PPA) with New Brunswick Power to sell the energy from their Mars Hill project for four years. New Brunswick Power had won the opportunity to provide standard offer service to all customer classes in Northern Maine earlier this year by offering a reduction in electricity prices of 10 to 21%. The use of locally-produced wind power as one of the energy sources being used was cited as one reason for the decrease in Northern Maine consumers' energy bills.

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[5] Scope of Competition in Electric Markets in Texas, Report to the 82nd Texas Legislature. Public Utilities Commission of Texas, January 2011. http://www.puc.state.tx.us/electric/reports/scope/index.cfm

[6] Scope of Competition at page 53.

The Need For New Electric Generation Capacity

While New England is currently long on electrical capacity, it will still need additional capacity to be added over the coming years to meet load growth and make up for unit retirements. ISO-NE predicts the New England summer peak load will grow at a compound annual growth rate of 1.4% between 2010 and 2019.[7] Over 2,300 MW of generation capacity in New England is more than fifty years old.[8] Though it is not known when these resources will retire, they will not be able to operate indefinitely. It is also unclear how long the oil-fired generators (representing 12.6% of New England's generation capacity) can continue generating at current levels (less than 1% of New England's electrical energy generation) before they will need to retire.

Fossil Fuels Used for Electricity Production in New England

Fossil fuels produced 55% of the electric energy used in New England in 2009, compared with 69% nationally.[9] While New England's energy mix and emissions are relatively cleaner than the national average, the majority of our power is still being produced by carbon-emitting fossil fuels.

While the rest of the nation has long-since almost completely stopped generating electricity from oil, New England is unique. Generators fueled primarily by oil make up 21.5% of New England's summer capacity mix and an additional 17.6% consists of dual-fuel units that can burn natural gas or oil.[10]

Because the price of oil has increased and the price of natural gas has decreased in the last couple of years, oil produced a mere 0.7% of the electricity in New England in 2009.[11] However, the price differential between oil and other fuels has not always been this high. As recently as 2005, oil-fired units were responsible for 4.6% of the electricity produced in New England, and units that burned oil and natural gas (dual-fuel units) were responsible for 12.6%.[12] If the price of natural gas were to rise again to be near or above the price of oil, we would almost certainly see a rapid increase in the percent of our electricity produced with oil.[13]

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[7] RSP10 page 23.
[8] Table 2.1, 2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission, April 2011, ISO-NE. http://iso-ne.com/trans/celt/report/2011/index.html.
[9] RSP10 page 93.
[10] RSP10 page 99.
[11] RSP10 page 92-93.
[12] RSP06 page 52.
[13] The ISO New England Regional System Plan 2005 states: "An increasing energy use and rising natural gas prices relative to oil prices will tend to increase generating plant production by oil units, resulting in higher total air emissions in New England over the 10-year period. Conservation efforts and renewable resources will reduce emissions and encourage greater fuel diversity." (RSP05 page 20).

Wind Energy Displaces Fossil Fuel Energy

As discussed above, generation must always match load and each type of resource is another tool in ISO-NE's toolkit to maintain this balance. Wind energy is not an exception. When wind energy is produced and fed onto the grid it must displace energy that would have been produced by another generator. Because ISO-NE uses economics to determine which plants should produce power, wind energy will displace the most expensive energy that can be backed down without violating reliability standards. The New England Wind Integration Study (NEWIS), discussed later, found that wind in New England would primarily displace energy from natural gas combined cycle generation, as this is typically the most expensive and flexible generation on the system. With increasing quantities of wind installed, NEWIS also showed limited but increasing displacement of coal energy. Although there is very little generation from oil at this time in New England, the wind scenarios in NEWIS all appear to displace the little oil generation that there would have been.[14]

Figure 1 and Figure 2 show the simulated dispatch for one peak-load week with and without wind generation. The lightest blue color represents peaking oil-fired steam turbines. There is a fair amount of energy produced by the oil peakers in the no-wind simulation, but this is almost entirely eliminated in the 20% wind simulation.

[14] NEWIS at pages 221, 262, 294, 297, 302, 303, 304, 306, 307 and Overview of ISO New England and Near Final Results of the New England Wind Integration Study, Bill Henson, ISO-NE. NEWEEP Wind Integration Webinar, October 26, 2010. Slide 27. Available at: http://www.windpoweringamerica.gov/newengland/filter_detail.asp?itemid=2837

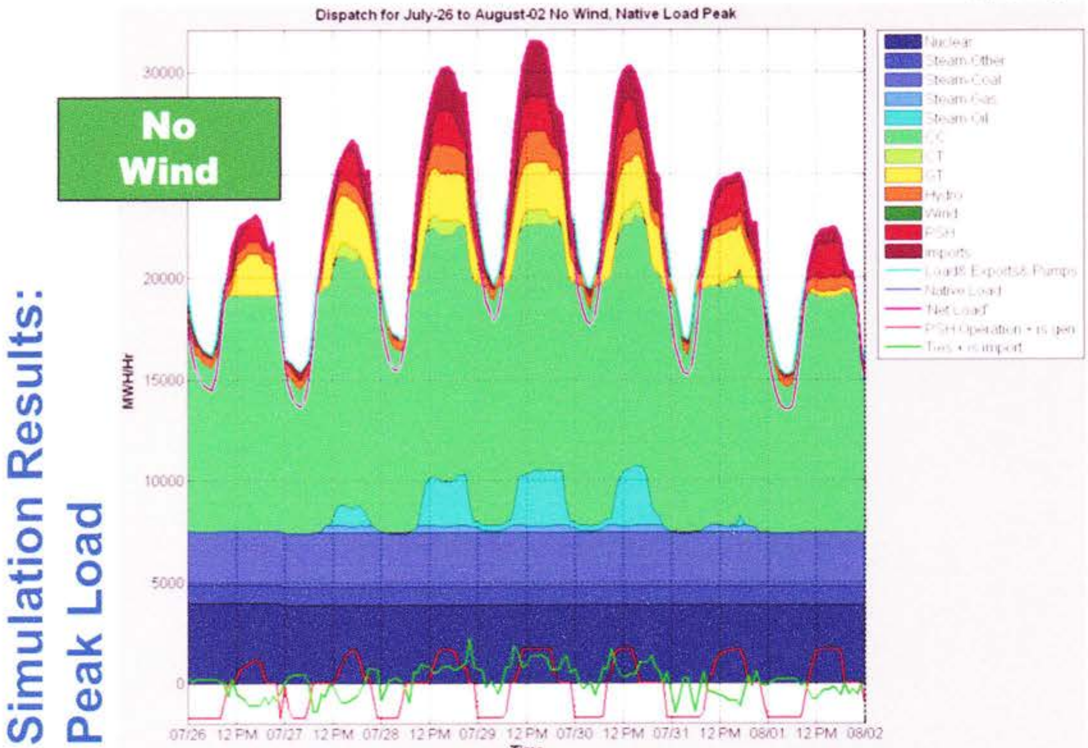

Figure 1 NEWIS dispatch simulation results for a peak load week with no wind[15]

[15] Overview of ISO New England and Near Final Results of the New England Wind Integration Study, Bill Henson, ISO-NE. NEWEEP Wind Integration Webinar, October 26, 2010. Slide 27. Available at: http://www.windpoweringamerica.gov/newengland/filter_detail.asp?itemid=2837 . (NEWEEP) slide 23.

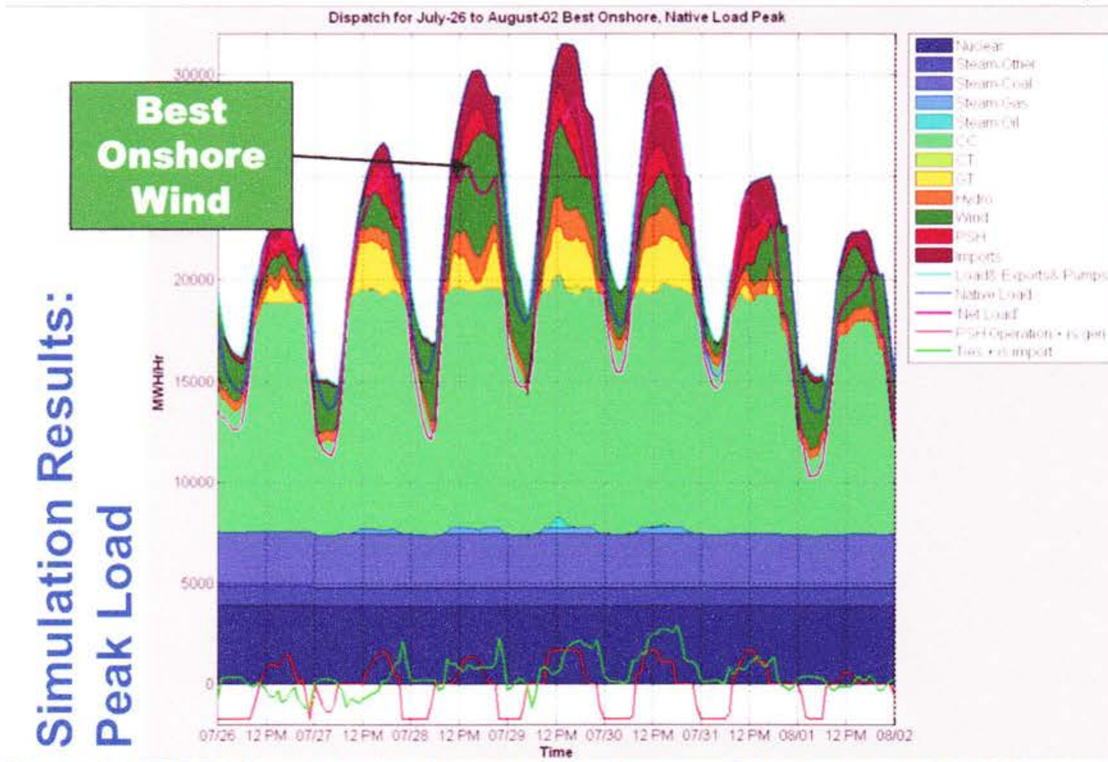

Figure 2 NEWIS dispatch simulation results for a peak load week with 20% wind generation, "Best Onshore Wind" scenario[16]

Wind Power Variability

Wind power output varies primarily with wind speed. Because wind speed is constantly changing, there is inherent variation in the power output from wind plants. Wind speeds are location-specific and wind speeds vary from one location to another. Even within an individual wind plant there will be variations in the wind speeds from one wind turbine to another and some wind turbines may be increasing power productions when other turbines in the same project are decreasing. From one wind plant to another, this spatial variation effect is even stronger and the output from one plant to another correlates more weakly the further apart they are.[17]

An empirical study of long-term high resolution wind speed data performed by the US Department of Energy's National Renewable Energy Laboratory's National Wind Technology Center showed that "despite their close proximity, instantaneous outputs from individual turbines of a large wind farm are not synchronized. Physical separations and differences of local terrains cause wind speeds at each turbine to vary."[18] Further, "as more and more wind generating plants over a wider area are integrated into the grid,

[16] NEWEEP slide 24.

[17] Wan, Y. (2005). Primer on Wind Power for Utility Applications. 45 pp.; NREL Report No. TP-500-36230. http://www.nrel.gov/docs/fy06osti/36230.pdf . (Wan) at page 15.

[18] Wan at page 13.

spatial diversity of the wind resources will make the overall wind power much less volatile than the output from any individual wind farm."[19]

The New England Wind Integration Study (NEWIS)

ISO-NE released the final New England Wind Integration Study (NEWIS) in December 2010.[20] This two-year effort looked into the operational impacts of integrating substantial amounts of wind generation into the New England system. It studied a number of scenarios including approximately 2.5%, 9%, 14%, 20%, and 24% of annual electricity demand being met by wind energy (1,140 MW to 12,000 MW installed wind).[21] These study levels do not represent the amount of wind that is expected or possible within New England, but they are useful for answering a number of hypothetical questions relevant to the long-term system planning process over a range of potential future scenarios.

The NEWIS results showed that, with the current fleet of existing generation and demand response resources, New England could integrate even the highest levels of wind energy studied. Even when looking at 12,000 MW of wind energy on the system, no additional generators would be needed to balance the variations in wind energy output. The study assumed that there would be no major attrition of existing generators or demand-side resources and that these existing resources would remain available to provide system flexibility.[22]

Due to the variable nature of wind, many people expect that electrical storage is needed in order to "smooth out" wind power generation to make it look like the output from many conventional generators. Except in the case of small island systems such as Hawaii, this is generally not the case. In New England we have a number of pumped-storage hydro facilities that are used for electricity market arbitrage. When electricity prices are low, these facilities consume electricity by pumping water uphill to a storage reservoir. When electricity prices are high, these facilities produce electricity by running that same water downhill and through a turbine. This is the only large-scale electricity storage that exists in New England today.

If electricity storage were an essential part of operating a power system with significant amounts of wind energy, one would expect that pumped-storage hydro utilization would increase with increasing amounts of wind energy. Quite the opposite, the NEWIS study showed relatively little increase in the use of existing pumped-storage hydro. NEWIS

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[19] Wan at page 16.

[20] Final Report: New England Wind Integration Study, Prepared for ISO New England, Prepared by GE Energy Applications and Systems Engineering, EnerNex Corporation, and AWS Truepower. December 5, 2010. Available at http://iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2010/newis_report.pdf

[21] In February 2011, wind produced 1% of the total electricity generated in New England. In the state of Maine that figure rises to an impressive 7.9%. *See* U.S. EIA, Electric Power Monthly, May 2011 Edition, Tables 1.6.A and 1.17.A.

[22] NEWIS page 205.

found that the required balancing of net load (load minus wind generation) was provided adequately by the flexibility of the existing generation fleet. Further, the wind generation had the effect of reducing the price differential between on-peak and off-peak pricing, reducing the opportunities for market arbitrage.[23]

With 20% of New England's energy provided by wind power, NEWIS found NO_X emissions would be reduced by approximately 26%, SO_X emissions reduced by 6%, and CO_2 emissions reduced by 25%.[24] As shown in Figure 3, at low levels of wind penetration wind would offset carbon dioxide emissions in proportion with the wind levels. As wind penetration levels rise, the carbon dioxide emission reductions actually grow faster than the wind levels.

Wind Penetration (Energy)	CO2 Reduction
2.5%	2.5%
9%	9%
14%	17%
20%	25%
24%	30%

Figure 3 Carbon dioxide emission reductions found with varying penetrations of wind energy[25]

This is consistent with an independent scientific study performed by the National Academy of Science. This 2007 report estimates that onshore wind energy development will contribute about 1.2% to 4.5% of U.S. electricity generation in 2020. Based on this projection, the study gives a potential range of CO_2 emissions offsets of 3.8% to 7.1% of projected emissions from electricity generation units.[26]

ISO-NE Economic Study 2010

In 2010 ISO-NE elected to perform an economic study looking at eleven different hypothetical future scenarios for the year 2030.[27] A comparison of two base case scenarios, which differ only by the addition of 1,500 MW of new efficient natural gas

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[23] NEWIS page 33.
[24] NEWIS page 26.
[25] NEWEEP slide 28.
[26] Environmental Impacts of Wind-Energy Projects, Committee on Environmental Impacts of Wind Energy Projects, National Research Council of the National Academies, 2007. Pages 64-65. Available at: http://books.nap.edu/catalog.php?record_id=11935
[27] 2010 Economic Study Preliminary Results available in the PAC materials for March 16, 2011 available at http://iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2011/mar162011/index.html

combined cycle units in one and the addition of 4,170 MW of wind in the other, provides some insight into the impacts of additional wind in the New England region.

In the wind case, the average annual energy market clearing price decreased by approximately $2/MWh.[28] The annual New England production cost was found to decrease from about $4.9 billion in the gas case to about $4.2 billion in the wind case.[29] Total annual New England CO_2 emissions resulting from electricity production decreased from about 54 million tons per year in the gas case to about 48 million tons per year in the wind case.[30]

[28] 2010 Economic Study Preliminary Results at slide 38.
[29] 2010 Economic Study Preliminary Results at slide 40.
[30] 2010 Economic Study Preliminary Results at slide 43.

Conclusion

- Wind energy in Maine has positive economic and environmental impacts.
- Electrical generation and load must be balanced at all times. When wind energy is produced, it must displace energy that would have been produced by another source.
- Wind has almost no marginal cost for producing electricity once it is built so it typically acts as a price-taker in the wholesale electricity markets.
- Price-taking energy, like wind, displaces more expensive energy in the markets, keeping power prices low.
- Fossil fuels produce the majority of electricity in New England. Wind would primarily displace natural gas and oil and increasing amounts of coal electricity as more wind is installed.
- The New England Wind Integration Study (NEWIS) found that no additional power plants would be needed to balance the additional variations expected from up to 12,000 MW of wind energy in New England.
- NEWIS found that up to 12,000 MW of wind could be integrated without the need for additional electrical storage.
- NEWIS also found that if 20% of New England's electricity were supplied by wind it would reduce the region's electricity-related CO_2 emissions by 25%, SO_x emissions by 6%, and NO_x emissions by 26%.

Dated: Friday, June 10, 2011

Abigail Krich

STATE OF MASSACHUSETTS
COUNTY OF MIDDLESEX

The above-named Abigail Krich has made oath and personally attested to me that the foregoing is true and accurate to the best of her knowledge and belief.

Dated: Friday, June 10, 2011

Jessica L Nelson
Notary Public
My Commission Expires:

JESSICA L. NELSON
Notary Public, Commonwealth of Massachusetts
My Commission Expires March 16, 2018