New England Wind Integration Study

November 2010

Summary

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Purpose

The primary goal of ISO New England's New England Wind Integration Study (NEWIS) is to evaluate the operational impacts of a range of hypothetical large-scale wind-integration scenarios. To achieve this goal, the study identified a New England-specific wind climate regime and modeled the effects of this wind regime on the different scenarios. The need to forecast wind energy and the need for flexible resources to balance the variability that increased wind generation adds to the system were also analyzed.

ISO New England commissioned GE Energy Applications and Systems Engineering (GE Energy) in 2009 to conduct the study for New England and to provide ISO New England with information on operational tools and wholesale electricity market design issues associated with the integration and operation of increasing amounts of wind generation.[1] This information could also provide policymakers and other stakeholders with information to assist them in evaluating wind-energy studies and initiatives at the regional, interregional, and national level, notably the scenarios under development within the Eastern Interconnection Planning Collaborative.

This summary provides an overview of the wind penetration scenarios, highlights the major study results, outlines issues that are beyond the scope of the study, and identifies next steps. The complete results will be described in a full report that will be issued shortly.

Introduction

Emerging public policy initiatives to increase renewable sources of electric energy and reduce carbon and other emissions from the electric generation sector are driving consideration of large-scale wind generation development. In New England, these policy drivers include state renewable portfolio standards (RPSs) and other goals for developing renewable energy, tightening of rules governing power-plant emissions of sulfur dioxide (SO_2) and nitrogen oxide (NO_x), and regional carbon dioxide (CO_2) reduction efforts such as the Regional Greenhouse Gas Initiative. Federal legislation and regulations related to addressing climate change and pursuing large-scale transmission are anticipated to be key drivers of the rate of progress toward developing clean energy resources, although the outlook, at present, is uncertain.

[1] The GE Energy project team included GE Energy Applications and Systems Engineering, EnerNex and AWS Truepower.

Wind Potential

Recent studies and proposals indicate significant potential for wind energy nationally and in New England. The North American Electric Reliability Corporation (NERC) has identified more than 200,000 megawatts (MW) of wind proposals in the U.S., including New England, and the U.S. Department of Energy projects that wind power could meet 20% of U.S. demand for electricity if wind development reaches 300,000 MW over the next 20 years. While the potential for wind-power development appears widespread across the country, wind climate regimes, resource characteristics (including supply- and demand-side and transmission resources), load patterns, and market rules in New England differ substantially from other parts of the country, which is why a New England-specific wind integration study is essential to evaluate potential wind scenarios.

Wind is a very small portion of the current resource mix in New England, but the region has a distinct advantage over other regions in that it has an abundance of wind energy potential—in the northern parts of the region and offshore. In New England, developers have proposed more than 3,000 MW of wind projects, which amounts to 30% of the proposed new generating capacity in the ISO's interconnection queue. NEWIS evaluated a range of wind penetration scenarios—up to 12,000 MW; although the wind regime in New England offers the theoretical potential for more than 200,000 MW of wind resources. See Figure 1.

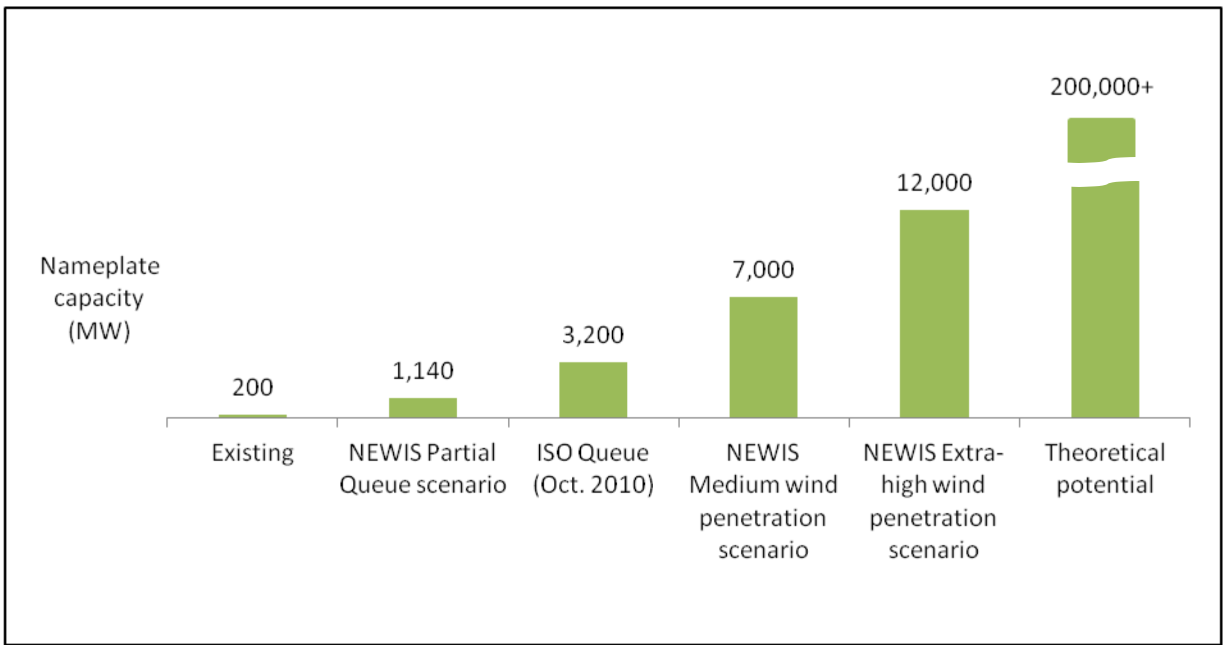

Figure 1: Range of Evaluated New England Wind Potential

Complement to the Governors' Study

NEWIS is intended to complement the results of a 2009 economic study ISO New England developed for the New England Governors.[2] The economic study evaluated scenarios for up to 12,000 MW[3] of wind generation in New England and conceptual transmission to deliver wind energy to the region's load centers; it did not evaluate operational impacts. The New England States Committee on Electricity (NESCOE) used the technical analysis in the ISO's economic study as a basis for developing the New England Governors' Renewable Energy Blueprint, which, in turn, has led the states to explore options for regional coordinated procurement of cost-effective renewable resources. The NEWIS builds on earlier recommendations to establish technical requirements for wind generation interconnection and integration.[4]

Overview of the study

NEWIS began by identifying a New England-specific wind regime based on historical weather data (for 2004–2006) that show when and how strong the wind blows throughout the region. The study team then time-synchronized the wind data to a load profile projected for the year 2020 to model the effect of the wind regime on multiple wind-plant build-out scenarios. The results show the potential wind energy that might be used to serve load and the amount of flexible resources required to serve the remaining "net load" reliably. Figure 2 provides a high-level overview of the study process.

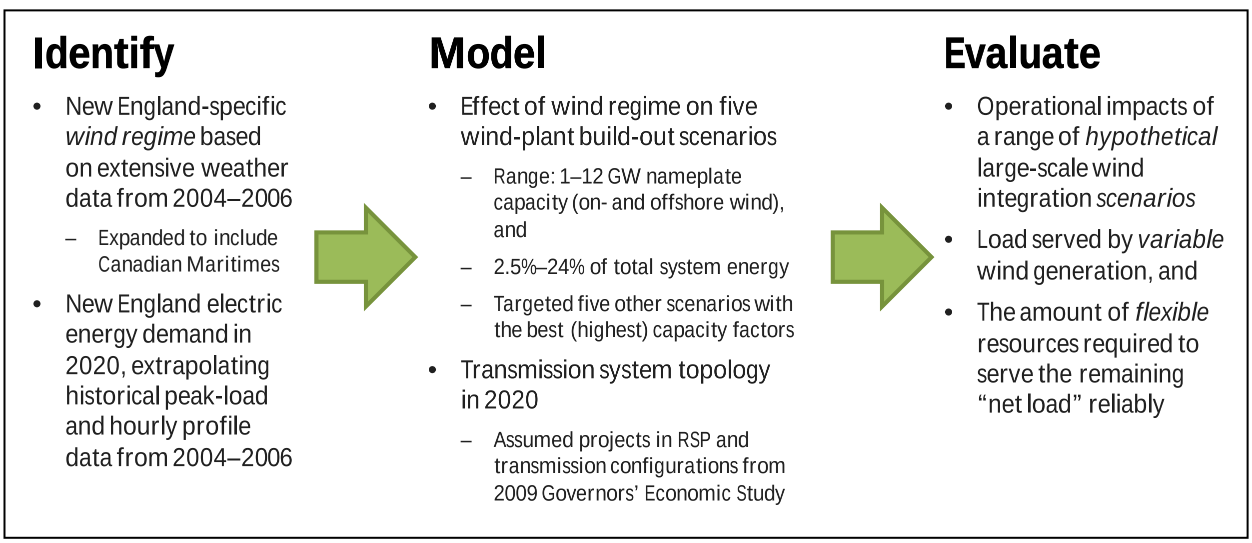

Figure 2: Overview of the study process

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[2] *2030 Power System Study: Scenario Analysis of Renewable Resource Development, Report to the New England Governors*, ISO New England, February 2010.

[3] The economic study screened out potential wind development in certain geographic locations (e.g., in areas with high elevation or slope or in proximity to urban areas) where development was considered infeasible for technical or other reasons. For example, the study assumes a five mile buffer around the Appalachian Trail (in each of the affected states) and around the Long Trail (in Vermont), which precludes potential inland wind development in areas with some of the best wind regimes (i.e., higher wind speeds).

[4] *Technical Requirements for Wind Generation Interconnection and Integration, NEWIS Task II Report*, 2009.

Transmission

The study used a base-case transmission system for the 2020 timeframe that assumed completion of the transmission projects in ISO New England's Regional System Plan. The study used three conceptual transmission overlays that were based on the 2 GW, 4 GW and 8 GW configurations developed for the Governors' Study and assumed that wind resources would connect to these transmission configurations. The system as a whole, with these transmission overlays, was observed to be essentially free of congestion.

Net Load

The weather patterns that drive the generation characteristics for windpower vary across many timescales and are loosely correlated with load. For example, ISO-NE experiences its peak loads during the summer months, while, as observed in this study, wind generation produces higher quantities of its energy during the winter months. This loose correlation requires the use of a new metric, "net load," to study the impact of large-scale wind generation. When managing the power system, the output of variable resources such as windpower can be directly subtracted from the amount of load to be served. Flexible (i.e., dispatchable) resources on the system are then used to serve this remaining (i.e., "net") load in order to maintain the power system balance. The net load is then the true variability that must be managed with dispatchable resources and, therefore, it is the "net load" that must be studied when determining operational effects.

Overview of the Scenarios

NEWIS identified five wind-integration scenarios ranging in size from one gigawatt (GW) to 12 GW of nameplate generating capacity.[5] These scenarios produced wind energy ranging from 2.5% to 24% of total New England projected electricity demand in 2020. As a starting point, the scenarios are based on wind resources proposed in the ISO Generator Interconnection Queue (ISO queue). The higher wind-penetration scenarios build on the lower-penetration scenarios. For example, resources assumed in a partial ISO queue build-out scenario are included in the full ISO queue scenario and in each of the other scenarios. The study targeted medium and high wind penetration scenarios for further analysis by identifying the resources with the best (highest) capacity factors for five different types of locations: onshore and offshore, a combination of on- and offshore, by state, and in the Maritimes. Figure 3 identifies the primary scenarios in NEWIS, the nameplate capacity ratings assumed as inputs to the study, and the resulting wind energy production for each scenario based on the applied wind regime.

Offshore and onshore wind generation have different cost structures that should be evaluated when comparing scenarios. Offshore resources generally require less transmission because of their close proximity to the load centers along the coast, but the capital costs of the turbines are higher. In comparison, onshore wind resources require more transmission if they are remote from load centers, but the capital costs of the turbines are lower. The study results show that offshore wind resources tend to better correlate with New England's electric system load.

[5] Nameplate refers to the manufacturer's estimate of the maximum output of a generator, typically in MW.

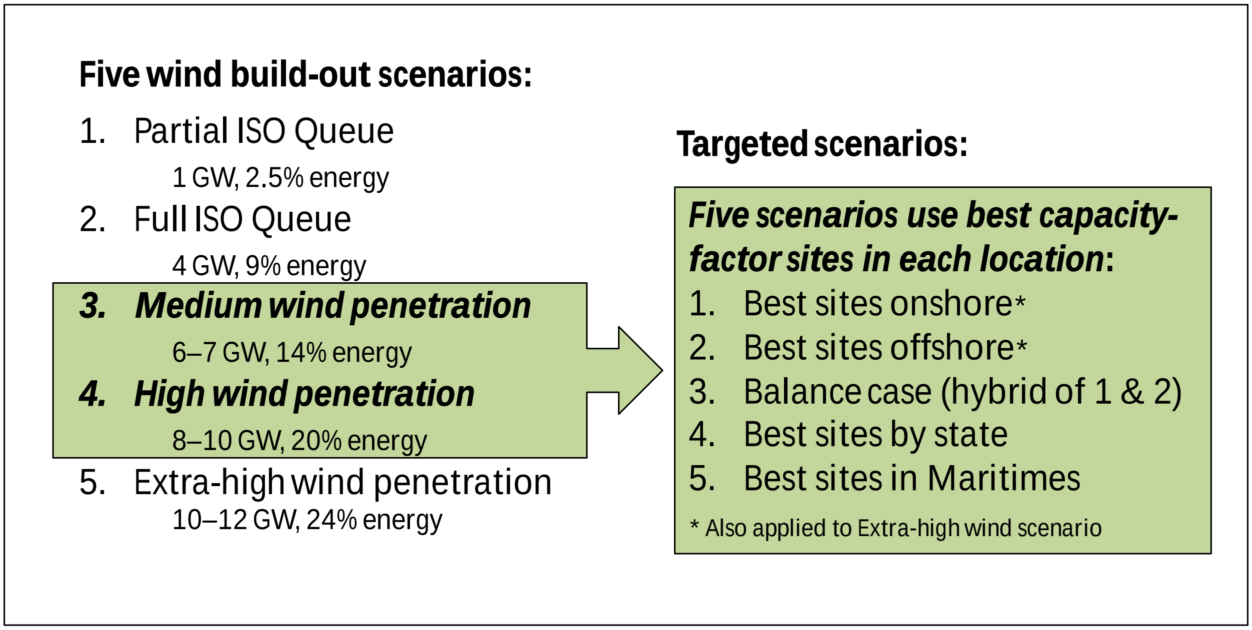

Figure 3: NEWIS Wind-integration Scenarios

The feasibility of obtaining siting approval for hypothetical wind resources identified in these scenarios is beyond the scope of this study.

The magnitude of wind integration contemplated in NEWIS is feasible under the hypothetical future scenario analyses developed for the study; however, real-world operating conditions can vary significantly from these types of idealized scenarios. NEWIS results are intended for comparisons of scenarios, not to predict future system conditions or market outcomes.

Regulation and Operating Reserves

The ISO is required to maintain adequate Automatic Generation Control (AGC) resources to provide regulation service and adequate operating reserves to protect for contingency events.[6] Operating Reserve requirements include Ten Minute Spinning Reserve (TMSR), Ten Minute Non-spinning Reserve (TMNSR), and Thirty Minute Operating Reserve (TMOR). For purposes of this study Total Operating Reserve (TOR) is the sum of TMSR, TMNSR, and TMOR. The study identified regulation and operating reserve requirements for each wind integration scenario. The results show that the TOR requirement increases in all wind energy scenarios due to the increases in TMSR and TMNSR; however, the increase in the regulation requirement would help meet some of the TMSR and TOR requirements.

The average regulation requirement for the load only (i.e., no wind) case was 82 MW. This requirement increases to 161 MW in the 9% wind energy scenario—and to as high as 313 MW in the 20% scenario. The average TOR requirement for the load-only case was 2,250 MW. This requirement increases to

[6] ISO New England Operating Procedure No. 8, Operating Reserve and Regulation; http://www.iso-ne.com/rules_proceds/operating/isone/op8/index.html.

2,270 MW in the 2.5% wind energy scenario, approximately 2,600 MW in the 14% wind energy scenario, and about 2,780 MW with 20% penetration.

Capacity Factors

Offshore wind resources tend to have higher capacity factors, i.e., generate more electricity overall, than onshore resources. From an operational perspective, it is important to understand how changes in the resource mix, such as adding wind generation, would affect the dispatch of the power system across all hours. The capacity factor of wind power is different from traditional generators and capacity factors differ among types of wind resources.

The study identified capacity factors for each wind-integration scenario. The capacity factors for the targeted scenarios ranged from 30%–44% in the medium wind penetration scenario (14% wind energy) to 30%–45% in the high penetration scenario (20% wind energy).[7]

Table 1 identifies the capacity factors for on- and offshore wind scenarios and the overall capacity factor for each scenario.

Table 1 Capacity Factors for Wind-integration Scenarios Based on Three-year Average Energy Outputs

Scenario	Nameplate Capacity	Onshore (%)	Offshore (%)	Overall (%)
Partial ISO Queue	1.1 GW	35	40	37
Full ISO Queue	4.2 GW	33	41	34
20% Best onshore + Full Queue	9.8 GW	33	41	34
20% Best offshore + Full Queue	8.3 GW	33	**45**	40
20% Balance on/offshore + Full Queue	8.8 GW	33	42	38
20% By state + Full Queue	10.2 GW	30	43	32
20% Maritimes[8] + Full Queue	9 GW	**37**	41	37
14% Best onshore + Full Queue	6.7 GW	34	41	34
14% Best offshore + Full Queue	6.1 GW	33	44	38
14% Balance on/offshore + Full Queue	6.3 GW	33	42	37
14% By state + Full Queue	7.3 GW	30	42	32
14% Maritimes + Full Queue	6.4 GW	36	41	36
24% Best onshore + Full Queue	12 GW	33	41	34
24% Best offshore + Full Queue	9.7 GW	33	45	**41**

[7] The capacity factors are based on the three-year (2004–2006) average energy outputs of each simulated wind plant.

[8] The Maritimes scenario assumes onshore wind resources in the Canadian Maritimes Provinces with a 40% capacity factor; the 14% wind-energy scenario assumes 2.2 GW of wind-generating capacity and the 20% wind-energy scenario assumes almost 5 GW, based on nameplate ratings.

Capacity Values

Offshore wind resources generally produce higher capacity values than onshore resources. The capacity value of wind generation is a calculation of the output of wind power during times of system need (e.g., peak load hours). (This is different from a capacity factor, which is a calculation of overall wind power output.)

From an operational perspective, it is important to understand how changes in the resource mix, such as adding wind generation, would affect the dispatch of the power system at the time of the system peak.

The study identified capacity values for each wind-integration scenario. The average capacity values for the targeted scenarios ranged from 23%–35% in the medium wind penetration scenario (14% wind energy) to 20%–34% in the high penetration scenario (20% wind energy). The capacity values are based on the three-year (2004–2006) average energy outputs of each simulated wind plant.

Major Findings and Recommendations

Large-scale wind integration is achievable under certain conditions

- New England could potentially integrate wind resources to meet up to 24% of the region's total annual electric energy needs in 2020 *if* the system includes transmission upgrades comparable to the configurations identified in the Governors' Study. It is important to note that this study assumes (1) the continued availability of existing supply-side and demand-side resources as cleared through the second FCA (in other words, no significant retirements relative to the capacity cleared through the second FCA), (2) the retention of the additional resources cleared in the second Forward Capacity Auction, and (3) increases in regulation and operating reserves as recommended in this study.

Wind resources would reduce fossil-fueled generation as an energy resource in New England

- When available to provide energy, wind generation would primarily reduce natural-gas-fired generation as an energy resource in New England because natural gas units are most often the marginal (last dispatched) resource operating in the region. However even with wind generation producing 24% of the region's electric energy—natural gas resources would still be called upon to provide more than 25% of the total annual energy. (This compares to 40% of annual energy from natural gas generation in 2009.) Therefore a 24% wind energy scenario would represent a major shift in the fuel mix for the region—resulting in wind and natural gas generation providing approximately the same amount of electric energy to the system.

- The results show that wind generation would almost fully displace generation from oil-fired thermal steam units.

Region needs to maintain a flexible system

- Any conditions that reduce the system flexibility may potentially, negatively impact the ability of New England to integrate large amounts of wind power.

- The balancing of net load—essential for large-scale wind integration—was seen largely being provided by the flexibility of the region's natural-gas-fired generation fleet. If future displacement of natural-gas-fired generation by wind energy is such that there is attrition of these types of flexible resources, the need for supplemental payments for flexible resources and/or energy storage technologies may increase.

- The addition of large-scale wind generation, with its characteristic low operating costs, would reduce wholesale electric energy market revenues for all resources, but would reduce revenues for some more than others. It is unclear, given the large decrease in energy market revenues for natural-gas-fired resources, whether these units would be economically viable, under current market conditions and, therefore, continue to be available to supply system needs under this scenario. As wind penetration increases, the market design may need to evolve to incent resources to provide the flexibility required to balance net load and dispatchable resources.

- Wind provides some capacity to the system, but it is primarily a winter-season energy resource. While wind generation may be able to be a substitute for a portion of the energy provided by other types of resources, the system would need to maintain adequate capacity resources to serve the summer peak demand, which typically coincides with reduced wind generation output.

Regulation and operating reserve requirements would increase

- Significant penetration of wind generation will increase the regulation capacity requirement and will increase the frequency of utilization of these resources. The study identified a need for an increase in the regulation requirement even in the lowest wind penetration scenario (2.5% wind energy), and the requirement would have noticeable increases for higher penetration levels.

- Additional spinning and non-spinning reserves will be required as wind penetration grows to maintain current levels of contingency response. The overall Total Operating Reserve (TOR) requirement increases in all wind energy scenarios due to the increases in Ten Minute Spinning Reserve (TMSR) and Ten Minute Non-spinning Reserve (TMNSR); however, the increase in the regulation requirement would help meet some of the TMSR and TOR requirements.

ISO should monitor other approaches to calculating capacity values

- The capacity value of wind generation is a function of many factors, including wind generation profiles for specific wind plants, system load profiles, and the penetration level of wind generation on the system. The ISO currently estimates capacity values using an approximate methodology based on the plant capacity factor during peak load hours. This methodology gives a reasonable approximation across the scenarios studied, and the ISO should monitor a comparison of the rigorous LOLE/ELCC[9] method with its method for calculating capacity values as it gains operational experience with wind energy.

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[9] Effective Load Carrying Capability (ELCC) is a data driven metric for capacity value, and represents the amount of additional load that can be served by the addition of a generator while maintaining the existing level of reliability. Loss of Load Expectation (LOLE) is the expected number of hours or days that the load will not be met over a defined time period.

Major transmission expansion would be required

- Major transmission expansion would be required to accommodate the levels of wind integration contemplated in this study and wind resources would need to interconnect into the new bulk transmission facilities in order to avoid having their generation output curtailed. This is particularly true for remote onshore wind scenarios in northern New England and the Maritimes.

ISO will need to develop windpower forecasting capability

- At higher levels of wind penetration, the ISO will need accurate intra-day and day-ahead wind-power forecasts in order to ensure efficient unit commitment and market operation. In addition, as wind penetration increases, the ISO will need tools to forecast wind ramping so that system operators can prepare for volatile wind situations by obtaining additional reserves or making other system adjustments.

Technical requirements for wind interconnections must be implemented

- Large-scale wind integration will be difficult without implementing the recommendations in the 2009 NEWIS Task II report, "Technical Requirements for Wind Generation Interconnection and Integration." These technical recommendations address turbine and plant technology, wind generation forecasting, and grid operations with significant wind generation.

Issues beyond the scope of the study

While NEWIS is a detailed and extensive wind integration study for New England, it is important to emphasize several issues that are beyond the scope of this study.

NEWIS is not a blueprint to achieve any of the wind-integration scenarios described in the report, such as 2.5% or 24% wind energy by 2020. The study does not contain an ISO recommendation for the region to pursue any particular wind-integration scenario and is not intended to identify real or preferred wind-integration scenarios.

NEWIS is not a detailed transmission planning study and further analysis would be required for any actual wind-generation proposals, though it is clear that major transmission expansion would be required to achieve the wind penetration levels contemplated in the study.

NEWIS results that indicate potential reductions in wholesale electricity prices and generator emissions in the 2020 timeframe are based on numerous assumptions and hypothetical scenarios developed for modeling purposes only. Therefore, these results were not intended to predict outcomes of the future electric system or market conditions and should not constitute the primary basis for evaluating the different scenarios. Finally, NEWIS serves to identify potential market implications of wind generation reducing the use of existing resources, however, it does not evaluate these market implications or solve the problem of identifying a financing mechanism to ensure the long-term viability of resources that will be needed for capacity, but would be displaced in the energy market by wind generation.

Suggestions for Future Work

GE Energy identified the following suggestions in the NEWIS report as areas where further work could be of significant value:

1. Evaluate refinement of conceptual transmission overlays developed initially for the Governors' Study
2. Conduct detailed transmission planning studies (e.g., voltage and stability studies) if the levels of wind integration evaluated in this study are to be pursued
3. Incorporate actual wind data into ISO operations analysis to enhance ISO processes for reliable wind forecasting, operations, and system planning as wind generation comes online
4. Evaluate the impacts of cycling and maneuvering thermal generators to balance the variability of wind generation
5. Evaluate the ability to maintain an adequate fleet of flexible resources assuming wind energy will reduce the use of natural-gas-fired generation; and
6. Evaluate the capability of demand resources to add flexibility to manage the variability of wind generation.

ISO New England's Next Steps

ISO New England will consider GE Energy's recommendations and suggestions for future work in the final report.

ISO New England plans to issue the full NEWIS report in December 2010 after presenting the final results to stakeholders at the Planning Advisory Committee on November 16.

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About ISO New England