New England States
Committee on Electricity

EXECUTIVE SUMMARY
RENEWABLE SUPPLY CURVE ANALYSIS

January 2012

In the summer of 2011, the New England Governors expressed interest in continuing to explore the potential for coordinated competitive renewable power procurement.[1] To provide policy-makers additional information about New England's renewable resources, the New England States Committee on Electricity ("NESCOE") completed directionally indicative analysis of the availability of, and potential cost for, new wind resources that could be developed in New England or New York to meet New England's renewable energy goals.[2]

The analysis[3] demonstrates that the regional potential for additional wind energy greatly exceeds the forecasted regional need through 2020. Over 50% of the total wind energy developable by 2016 would come from on-shore projects in Maine, while very large off-shore wind resources could be available by 2020. The costs for off-shore wind energy are higher than the costs of wind energy from many of the on-shore projects, and thus, the actual development of off-shore wind will likely be constrained by cost considerations. When considering generation-only, on-shore wind generation located in Maine would provide the majority of wind energy with the lowest costs. In 2016, 72% of the lowest-cost energy required to meet regional renewable energy goals would come from on-shore generation in Maine. When transmission is considered, a larger percentage of regional needs might be supplied from off-shore wind & imports. For instance, in 2016, imports & off-shore wind would provide 44% of total regional needs. Such resources would provide 45% of regional needs in 2020.

However, the numerous wind resources - both on-shore and off-shore - that could be developed have a wide range of potential costs in both absolute and relative terms. In particular, the specific mix of wind resources that could meet regional renewable energy goals at the lowest *total* cost to consumers depends on the relative costs of new wind resources. In turn, those relative costs are driven by several key parameters, including:

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[1] New England Governors Resolution: http://www.nescoe.com/uploads/NEGC_Coord_Procure_Res._.pdf

[2] This analysis follows related work including: the 2009 *New England Governors' Renewable Energy Blueprint*, the 2010 *Report to the New England Governors on Coordinated Procurement*; and the 2011 *Request for Information* about renewable resources. Information about each is at www.nescoe.com.

[3] In addition to this Executive Summary, the following materials are included in these analyses and are available at www.nescoe.com: 1) NESCOE Renewable Supply Curve Analysis Report; 2) NESCOE Presentation; 3) NESCOE Technical Appendix; 4) New England Wind Generation Report - Sustainable Energy Advantage, LLC; 5) New York Wind Generation Report - Sustainable Energy Advantage, LLC; 6) Wind Generation Presentation - Sustainable Energy Advantage, LLC; and, 7) Transmission Report - RLC Engineering

- The region's preferred standard for integrating new wind resources into the regional power supply mix, since that standard would determine, for each specific wind resource, the amount and cost of additional transmission required to achieve the integration standard;
- The allocation of the costs for such additional transmission; and,
- The relative changes in technology and costs for different wind resources (*e.g.,* the cost reductions from forecasted decreases in the capital cost of off-shore wind generation may, or may not, be matched by cost reductions achieved from higher capacity factors that may be accomplished with taller towers for on-shore generation).

A key implication for a regional coordinated renewables procurement process is that such a process requires a defined standard for integrating the output of new renewable energy resources. A "REC Only" standard – in which the energy output of new renewable generators only needs to displace non-renewable generation and thus increase the supply of Renewable Energy Credits ("RECs") within the region – would tend to reduce the amount of new transmission required to achieve that integration standard. However, such a standard may not maximize the market benefits (*e.g.,* displacement of the highest cost regional generation) that could be provided by new wind resources, given enough additional transmission. A more stringent "REC Plus" integration standard could capture more of those market benefits, but at the cost of requiring additional transmission investment.

An important near-term consideration is the appropriate "energy integration" standard that would be applicable in any joint or separate but coordinated competitive power procurement process. While the current process used by the Independent System Operator-NE ("ISO-NE") to interconnect new generators may be able to support an efficient coordinated procurement process if a "REC Only" standard is used, an efficient coordinated procurement process using a "REC Plus" standard may only be possible with modifications to ISO-NE's interconnection process.

Study Scope

NESCOE sponsored analyses to provide directionally indicative resource and cost information regarding potential new wind resources in New England (both on-shore and off-shore) and New York (on-shore only), and the transmission that might be required to integrate the output of some of those resources. To develop baseline data, NESCOE sponsored studies by Sustainable Energy Advantages, LLC ("SEA") to assess the potential amounts of, and estimate the generation costs for, wind resources in New England and New York. NESCOE also retained RLC Engineering ("RLC") to provide indicative transmission 'buildouts', and the estimated costs of such buildouts, that may be required to integrate energy from new wind resources in northern New England.

> *Given the very conservative base case assumptions, actual costs that would emerge from a competitive procurement process would likely be meaningfully lower than the base costs considered here.*
>
> The magnitude of such reductions could range from \$33 to \$68 MWh, with the largest reductions occurring at on-shore wind resources that could most greatly benefit from the use of taller towers. The upper bound on the potential cost reduction of \$68 per MWh consists of three components: \$10 (lower interest rates) + \$23 (continuation of federal incentives) + \$35 (use of higher hub heights from some on-shore supply blocks).

NESCOE synthesized the results of these studies into regional "supply curves" showing the marginal cost of new wind resources in the region as a function of total new wind energy developed. From those supply curves, NESCOE identified and categorized those wind resources that could potentially meet the region's incremental renewable energy needs for the selected study years - 2016 and 2020 - at the lowest total cost.

What the Supply Curve Analysis is *Not*

The supply curve analysis provides high-level indicative cost information to policy makers about various wind resources. As such, the analysis does *not* provide cost data that could support decisions with respect to specific wind projects, for several reasons. First, the analysis only considered two study years – 2016 and 2020 – in order to illustrate the range and mix of wind resources that may be available in the relative near-term and over the next decade. Second, the analysis only considered wind resources that could be developed in New England or New York; this focus on wind was driven by the dominance of wind energy in the renewable projects under development in the region. Third, the analyses did not estimate the capacity or energy market benefits of any specific project. Fourth, the analyses are based on estimates of wind generation and transmission costs, not on specific cost information about actual projects. Finally, the conservative generation assumptions used in the base case analysis (*e.g.,* the assumed unavailability of federal financial incentives) means that actual costs for actual projects will likely be lower than the base case costs.

In sum, this analysis is:

- **Not** an expression of interest in certain types or locations of renewable resources relative to others;
- **Not** a regional resource or transmission plan or recommendation;
- **Not** a projection regarding the actual costs of specific resources or projects;
- **Not** a recommendation or suggestion to develop any specific resource, group of resources, or transmission upgrades; and,
- **Not** an estimate of the benefits of any specific resources or projects.

Regional Supply Potential

The results of SEA's resource analysis show that New England's total potential for wind energy production is sufficient to readily meet regional renewable energy goals. Potential imports from New York could increase the regional supply even further. These findings are consistent with the results of NESCOE's 2011 Request for Information from renewable energy developers. Table ES-1 below shows (i) the total energy (in GWh/year) that could be obtained from on-shore and off-shore wind resources located in New England, (ii) total potential wind energy imports from New York, and (iii) the total regional renewable energy needs, for the two study years (2016 and 2020):

Table ES-1 – comparison of regional wind energy potential to anticipated renewable energy needs (All figures are in GWh/year)

	2016			2020		
	On-shore	Off-shore	Total	On-shore	Off-shore	Total
CT	9	426	435	15	1,144	1,159
MA	366	3,500	3,866	1,208	44,354	45,562
ME	11,000	3,490	14,490	20,165	38,404	58,569
NH	758	0	758	1,459	0	1,459
RI	0	644	644	0	5,998	5,998
VT	1,053	0	1,053	2,993	0	2,993
New England (total)	13,186	8,060	**21,246**	25,840	89,900	**115,740**
Imports from New York (not considered in 2016)	0	0	0	2,488	0	2,488
Grand total	13,186	8,060	**21,246**	28,328	89,900	**118,228**
Comparison: total incremental renewable energy need in region			7,500			12,250

Over 50% of the total wind energy developable by 2016 would come from on-shore projects in Maine, while very large off-shore wind resources could be available by 2020. However, the costs for off-shore wind energy are higher than the costs of wind energy from many of the on-shore projects, and thus, the actual development of off-shore wind will likely be constrained by cost considerations.

Key Sensitivities for Generation Costs

The wind resources considered in Table ES-1 have a very wide range of capital and operating costs. For each wind resource, SEA estimated the *Levelized Cost of Electricity* ("LCOE")[4] for that resource. In doing so, SEA examined the sensitivity of the LCOE to various assumptions, and input parameters, including:

- Contact term (terms of 10, 15 and 20 years);
- Whether debt rates for a project reflect the interest rates that would be expected under normal economic conditions, or the lower interest rates available in the economic climate;
- Whether or not the current federal financial incentives expire as currently scheduled, or are extended indefinitely; and
- The potential benefits from the use of taller towers for on-shore projects that could allow higher capacity factors, and thus lower LCOEs, for projects in certain locations.

Table ES-2 below summarizes the estimated change in LCOE for each of these sensitivities:

Table ES-2 – potential impact on LCOE of different assumptions

Assumption	Base case value	Sensitivity cases	Impact on LCOE (relative to base case)
Contract term	15 year term	10 year term	Increase LCOE by approximately 20%
		20 year term	Decrease LCOE by approximately 10%

Assumption	Base case value	Sensitivity case	Potential reduction in LCOE
Interest rates	Interest rates reflecting normal economic conditions	Lower interest rates reflecting current climate	Approximately $10 / MWh
Availability of federal financial incentives	No incentives available	Incentives continue at current levels	Approximately $23 / MWh
Taller towers for on-shore projects	Capacity factors based on detailed wind data for 80 m hub height	All capacity factors increased uniformly to approximate the potential benefits of higher hub heights[5]	Average of $35 / MWh

Thus, longer contract terms result in lower LCOEs, while relaxing *any* of the conservative assumptions regarding interest rates, the availability of federal financial incentives or potential benefits of taller towers would reduce the LCOE. Given the very conservative base case assumptions, actual costs that would emerge from a competitive procurement process would likely be meaningfully lower than the base costs considered here. The magnitude of

[4] The LCOE is a single, fixed levelized price that would be paid under a long-term contract by a purchaser of all of the electrical output and environmental attributes produced from a wind project, and is calculated to meet the minimum investment criteria of the project's debt and equity investors. Thus, the LCOE for a wind project represents the lowest contract price at which that project is economically feasible.

[5] SEA has advised NESCOE that many on-shore projects would *not* be able to use taller towers, and thus, only some on-shore projects would achieve such reductions in the LCOE. A more detailed analysis would be required to quantify the benefits of taller towers for individual wind resources.

such reductions could range from $33 to $68 MWh, with the largest reductions occurring at on-shore wind resources that could most greatly benefit from the use of taller towers.

Determining the Mix of Wind Resources That Meet Regional Needs at the Lowest Cost

NESCOE then synthesized the results of these studies into regional "supply curves" showing the marginal cost of new wind resources in the region as a function of total new wind energy developed. From these supply curves, NESCOE identified and categorized those wind resources that could potentially meet the region's incremental renewable energy needs for the selected study years at the lowest cost. This development of a "least cost" supply mix was performed for two scenarios:

- **"Generation Costs Only"** – the least-cost supply mix was developed assuming that no new transmission would be required to integrate the selected resources – thus, the least-cost mix of wind resources was determined solely from the generation costs estimated by SEA.
- **"Transmission Costs Included"** – new transmission (as identified by RLC) was assumed to be required for certain on-shore wind generation resources in northern New England, and some of the estimated costs of that additional transmission were added to the generation costs estimated by SEA – thus, the least-cost mix of wind resources was affected by the costs of the transmission assumed to be required for various wind resources.

For the "Generation Costs Only" scenario, on-shore wind generation located in Maine would provide the majority of wind energy with the lowest generation-related costs. For example, in 2016, 72% of the lowest-cost energy required to meet regional renewable energy goals would come from on-shore generation in Maine. Such generation in Maine would supply approximately 5400 GWh/year out of total regional need of about 7500 GWh/year in 2016.

When considering generation-only, on-shore wind generation located in Maine would provide the majority of wind energy with the lowest costs. In 2016, 72% of the lowest-cost energy required to meet regional renewable energy goals would come from on-shore generation in Maine. When transmission is considered, a larger percentage of regional needs might be supplied from off-shore wind & imports. For instance, in 2016, imports & off-shore wind would provide 44% of total regional needs. Such resources would provide 45% of regional needs in 2020.

Impacts of Transmission Limits

However, the existing transmission system is not capable of supporting such an increase in wind generation in Maine. Transmission studies by RLC identified potential transmission upgrades in northern New Hampshire and western Maine that could support substantial increases in wind generation in those areas (although those upgrades would not, by themselves, fully deliver the incremental wind energy to major load centers in New England). The cost of those transmission upgrades and their timing could significantly affect the mix of wind resources with the lowest total costs. In the "Transmission Costs Included" scenario, the LCOEs for on-shore generation in northern New England (ME, NH and VT) were increased to reflect a portion of the costs of the minimum transmission identified by RLC as being required to support substantial increases in wind generation in northern New England. Furthermore, on-shore generation in Maine was constrained as necessary to match the maximum generation that could be supported by transmission that could be developed by the selected study years (2016 and 2020).

In this "Transmission Costs Included" scenario, a larger percentage of regional needs might be supplied from off-shore wind and imports. For instance, in 2016, imports and off-shore wind would provide 44% of total regional needs. Such resources would provide 45% of regional needs in 2020.

Tables ES-3 and ES-4 below show the detailed breakdown of the wind resources identified in each scenario

Table ES-3 – Least-cost wind supply mix for "Generation Costs Only" scenario
(totals may not add due to rounding)

	2016			2020		
	On-shore	Off-shore	Total	On-shore	Off-shore	Total
CT	0	0	0	0	0	0
MA	346	0	346	936	0	936
ME	5,391	0	5,391	5,743	0	5,743
NH	309	0	309	595	0	595
RI	0	0	0	0	0	0
VT	883	0	883	2,489	0	2,489
New England total	6,929	0	6,929	9,762	0	9,762
NY	571	0	571	2,488	0	2,488
Grand total	7,500	0	7,500	12,250	0	12,250

Table ES-4 – Least-cost wind supply mix for "Transmission Costs Included" scenario
(totals may not add due to rounding)

	2016			2020		
	On-shore	Off-shore	Total	On-shore	Off-shore	Total
CT	0	0	0	0	0	0
MA	360	720	1,080	986	2,683	3,669
ME	2,711	59	2,770	3,949	206	4,155
NH	280	0	280	396	0	396
RI	0	0	0	0	76	76
VT	883	0	883	1,467	0	1,467
New England total	4,234	779	5,012	6,798	2,964	9,762
NY	2,488	0	2,488	2,488	0	2,488
Grand total	6,722	779	7,500	9,286	2,964	12,250

Implications of Generation & Transmission Cost Scenarios

- Through 2016, on-shore generation will dominate the least-cost wind energy mix, even in the "Transmission Costs Included" scenario. In the short term, the primary impact of including transmission costs in the estimated LCOE is to increase the opportunity for importing wind from New York (note that such imports are assumed to *not* require significant transmission upgrades).
- In the longer-term, off-shore wind energy may become more cost competitive, and comprise a larger percentage of the New England wind supply mix, *if* (a) on-shore generation projects require significant transmission upgrades to be integrated into the regional power supply mix, (b) the cost of such

transmission upgrades would be allocated to the on-shore generators benefiting from those upgrades, (c) the energy from off-shore wind generation can be integrated with relatively few transmission upgrades and (d) the relative costs and performances of on-shore and off-shore resources develop as forecasted.

Caveats regarding Generation & Transmission Cost Scenarios

- The observations above assume that the existing transmission system cannot support meaningful additional wind generation in Maine, New Hampshire and Vermont. If the existing system could support additional on-shore wind generation, the amount of economical on-shore wind generation in these states would be greater than what is shown in Table ES-4.
- Second, the observations assume that the generation cost premium for off-shore wind decreases as forecasted by SEA - such cost decreases may or may not occur.
- Third, the base case LCOEs for on-shore wind projects were developed using historical hub heights. Many wind developers in the region are planning to use taller towers that could achieve higher capacity factors, allowing a corresponding decrease in the cost of on-shore wind energy. If enough on-shore wind projects can employ taller towers that achieve higher capacity factors, then on-shore wind projects may provide almost all of the competitive wind resources.
- Finally, the observations assume that the incremental transmission required to effectively integrate new *off-shore* wind generation (and imports) is significantly less than the incremental transmission required to integrate new *on-shore* wind generation in northern New England. Off-shore wind generation and wind imports may be able to displace fossil generation with relatively few, if any, transmission upgrades (*e.g.,* by directly interconnecting at an existing coastal fossil generating station). However, the market benefits of resources developed under such a "REC Only" integration standard may be limited, as those resources may not be able to displace the highest cost regional generation or contribute towards regional reliability goals.

Conclusion

The analysis demonstrates that the regional potential for additional wind energy greatly exceeds the forecasted regional need through 2020. Over 50% of the total wind energy developable by 2016 would come from on-shore projects in Maine, while very large off-shore wind resources could be available by 2020. However, the costs for off-shore wind energy are higher than the costs of wind energy from many of the on-shore projects, and thus, the actual development of off-shore wind will likely be constrained by cost considerations. Again, given the very conservative base case assumptions, actual costs that would emerge from a competitive procurement process would likely be meaningfully lower than the base costs considered here. It is important that the Supply Curve Analysis be viewed as directionally indicative and not representative of actual costs the states may see following a solicitation to market participants.

NESCOE's supply curve analysis highlights the importance of the applicable standard for integrating incremental wind energy into the New England power supply system. This standard will determine the timing, magnitude and costs of the transmission upgrades required for specific new wind resources. In turn, those transmission costs, and their allocation, will affect the relative cost-competitiveness of different wind resources. In sum, a key decision point regarding the potential structure and benefits of a coordinated competitive renewables procurement process is the energy integration standard that would apply.