Memorandum
for NESCOE

Raymond Coxe, Ph.D.
President, Mosaic Energy Insights, Inc.
10 Technology Drive, Suite 40, #391
Hudson, MA 01749
Voice: +1 (978) 405-0119
Fax: +1 (978) 776-2313
E-mail: *Ray.Coxe@MosaicEnergyInsights.com*

To: NESCOE **Date:** 11 November 2011
Subject: NESCOE Technical Appendix

This Technical Appendix is a complement to the report entitled *Renewable Resource Supply Curve – New England States Committee on Electricity – November 2011* (the "Supply Curve Report"). That report summarized the results and implications of various analyses regarding:

- the potential for additional wind energy production in New England and New York;
- the range of potential generation costs for such energy;
- the need for, and cost of, network upgrades that might be required to integrate wind generation in northern New Hampshire and western Maine; and
- how the cost of such network upgrades (and the constraints to the pace of transmission development) could affect the mix of wind resources that would meet the region's renewable energy goals at the lowest total cost.

The analyses summarized in the Supply Curve Report included analyses completed by:

- Sustainable Energy Advantages, LLC ("SEA") regarding potential wind resources in New England and New York, and the generation-related costs thereof;
- RLC Engineering ("RLC") regarding the ability of the existing transmission system to support new wind generation in northern New Hampshire and western Maine, the transmission upgrades that might be required to incorporate large amounts of new wind generation in those regions, and the costs for doing so; and
- NESCOE regarding the mix of resources that would meet the region's renewable energy goals under different assumptions.

Detailed discussions of the scope, methodology, assumptions and conclusions of the studies by SEA and RLC can be found in the written reports produced by those organizations; this memorandum does not repeat information from those reports, except where necessary. Similarly, results and conclusions presented in the Supply Curve Report are not repeated here. Instead, the purpose of this Technical Appendix is to describe how the raw data from SEA and RLC were used to develop the tables and figures shown in the Supply Curve Report. To that end, this Technical Appendix includes six sections that discuss how:

1) SEA's estimates of the regional resource potential for on-shore and off-shore wind generation in New England (expressed in the form of "supply blocks"[1] for wind resources) were incorporated into the Supply Curve Report;

---

[1] A *supply block* is a single block of potential wind generation that was separately identified by SEA. Each supply block has a specified (i) project type ('small', 'medium' or 'large' for on-shore wind projects, and

2) SEA's estimates of the potential on-shore wind generation in New York were incorporated into the Supply Curve Report;
3) New England's incremental renewable energy needs for 2016 and 2020 were determined;
4) SEA's estimates of the *Levelized cost of electricity ("LCOE")* [2] for various wind resources were used to develop the regional wind energy supply curves and tables shown in the Supply Curve Report;
5) The transmission upgrades identified by RLC's transmission analyses were aggregated and how the costs of those upgrades were allocated to wind generation benefiting from those upgrades; and
6) The allocated costs of the upgrades identified by RLC and limits to the pace at which transmission in northern NH and western ME could be developed affect the mix of wind resources that would meet the region's renewable energy needs at the lowest overall costs.

In each section of this Technical Appendix, the key assumptions and methodologies used to develop the Supply Curve Report are discussed.

Regional wind resource potential – New England

SEA delivered data on potential wind resources in New England and New York. That data included detailed information on the individual wind supply blocks in New England, including, for each supply block, the following data used in the Supply Curve Report:

- The geographic region (state) within which the supply block is located;
- The generic type of the supply block (on-shore vs. off-shore);
- The specific type of wind projects that could be developed in the supply block (for on-shore blocks: small, medium or large projects; for off-shore blocks: shallow water or deep water projects);
- The maximum number of MWs and GWh/year that could be produced from the supply block by 2016, regardless of cost;
- The maximum number of MWs and GWh/year that could be produced from the supply block by 2020, regardless of cost; and

'shallow' or 'deepwater' for off-shore wind project), (ii) wind speed regime, (iii) generation costs and transmission interconnection costs and (iv) other attributes of that resource block (*e.g.,* ultimate wind generation capacity and maximum buildout rates). SEA identified 141 supply blocks in New England.

[2] The LCOE in a single, fixed (non-varying) levelized price (in dollars per MWh) 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 in the specific supply block, over the specified term of the contract. The LCOE is calculated to meet the minimum investment criteria of the project's debt and equity investors, and represents the lowest contract price at which wind projects within the supply block are economically feasible.

- The LCOE for energy from that supply block, for two different years of initial commercial operation (2016 and 2020), and three different contract terms (10, 15 and 20 years), thus generating six LCOEs for each supply block.

While a large amount of additional information was also included in the data provided by SEA, the wind resource supply curves and tables in the Supply Curve Report relied upon the data described above.

Regional wind resource potential – New York on-shore resources

The data from SEA also contained information regarding on-shore supply blocks that could be developed in New York. The data for NY supply blocks that was used in developing the Supply Curve Report included the following:

- The geographic location (either Zone 1 or Zone 2 within NY[3]) within which the supply block is located;
- The specific type of the supply block (since all NY supply blocks were on-shore, only three specific types were identified: small, medium or large);
- The maximum number of MWs and GWh/year that could be produced from the supply block by 2020, regardless of cost;
- The LCOE for energy from that supply block, based upon initial commercial operation in 2020 and a 15 year contract term,[4] and assuming that a buyer in New York would purchase the energy from that supply block;
- The LCOE for energy from that supply block (assuming a 2020 start date and a 15 year contract term), but now assuming that the energy would be purchased by a buyer in New England and further assuming that exports from the supply block to New England would incur "low" congestion cost "adders" to reach the New England transmission system; and
- The LCOE for energy from that supply block (assuming a 2020 start date and a 15 year contract term), but now assuming that the energy would be purchased by a buyer in New England and further assuming that exports from the supply block to New England would incur "high" congestion cost adders to reach the New England transmission system.

Table TA-1[5] below summarizes the congestion cost adders that were provided by SEA:

---

3 Zone 1 includes NYISO's load zones A through E, while Zone 2 includes NYISO's load zones F through I.

4 NESCOE requested that for NY wind resources, SEA concentrate on a single year of initial commercial operation (2020) and a single contract term.

5 Tables in this Technical Appendices are labeled as "Table TA-__", to clearly distinguish them from the tables in the Supply Curve Report.

Table TA-1 – congestion cost adders applied to the "no adder" LCOE

Zone in NY:	High adder case	Low adder case
Zone 1	$15.00	$10.00
Zone 2	$7.00	$2.00

Thus, for instance, a supply block located in Zone 1 with an LCOE of $200 / MWh for energy purchased at the "fenceline" of the project would require an LCOE of $210 / MWh if the energy were exported to New England under the "low adder" case, and an LCOE of $215 / MWh if the energy were exported to New England under the "high adder" case.

Again, while a large amount of additional information was also either directly included in the spreadsheet, or could be extracted from the data therein, the wind resource supply curves and tables in the Supply Curve Report relied upon the data described above, with the modifications and assumptions noted below.

Assumptions and modifications regarding NY wind resources

- The total on-shore wind potential developable in NY by 2020 is very large (over 40 GW, corresponding to nearly 100 TWh/yr). This potential greatly exceeds both (a) New York's projected need for the additional renewable energy that will be required to comply with NY's own renewable energy goals and (b) the maximum potential imports into New England, given the finite transmission capacity between these two control areas.
- Hence, several adjustments were made identify the *specific* supply blocks that could be available to supply wind energy to New England. The methodologies for those adjustments, and the adjustments themselves, are summarized below.
    - NY's incremental renewable energy need in 2016 was established at 5452 GWh/year, per information from SEA.
    - The same incremental renewable energy need was used for 2020.
    - SEA directly estimated the amount of NY wind resources that could be developed by 2020. To provide a proxy for the amount of wind resources that could be developed by 2016, the MWs and GWh/year available by 2020 from each NY supply block[6] was multiplied by 35%[7] to roughly estimate the NY wind resources that could be developed by 2016.
    - SEA provided LCOEs for projects commencing commercial operation in 2020 under a 15 year contract. This analysis assumed the same LCOEs for projects

6 SEA's analysis identified a total of 41 supply blocks in New York.

7 For comparison, the lowest ratio of 2016 capacity to 2020 capacity for on-shore wind resources in New England was 36%.

commencing commercial operation in 2016 (*e.g.,* the cost of imported wind energy would be the same in 2016 as in 2020, for a given supply block).

- For 2016 and 2020, the NY supply blocks were stacked in order of increasing LCOE, where the "no adder" LCOE was used as the stacking metric. The resources that could meet NY's incremental renewable energy needs (5452 GWh/yr in both 2016 and 2020) at the lowest "no adder" LCOE were then removed from the supply resource base to satisfy NY's needs (the final block was partially derated to reflect any energy from that block that could be available for export to New England).
- The remaining supply blocks were then resorted by LCOE, but now using the LCOEs based on the "low adder" scenario. These restacked supply blocks comprised the *Available NY Wind Supply Curve*.
- The analysis assumed that due to transmission constraints between NY and New England, and the likely infeasibility of exclusively using the transmission ties for wind imports, the maximum feasible wind imports from NY was 2488 GWh/yr (corresponding to approximately 1000 MWs, if a typical NY wind capacity factor of 28.4% is used).
- Finally, the supply blocks in the *Available NY Wind Supply Curve* were examined to identify the supply blocks with the lowest "low adder" LCOE that could be imported into New England while respecting the import constraint of 2488 GWh/year. All supply blocks with a "low adder" LCOE above the cost of the most expensive supply block that could be imported were then removed from further analysis.

In essence, this approach first reserves the least expensive wind resources for NY's internal needs, and then identifies the least expensive *remaining* supply blocks that could be imported into New England, while respecting the import constraint. Only those supply blocks which (i) were not required to meet NY's internal needs, (ii) had the lowest remaining LCOEs, and (iii) could all be fully imported, should they be economically competitive with New England wind resources were then made available to meet New England's renewable energy needs. The available energy from all other supply blocks (*i.e.,* the supply blocks reserved for NY's own needs and the supply blocks that would not be imported due to the availability of lower-cost NY supply blocks that would fill the available transmission capacity) was set to zero.

Determining New England's incremental renewable energy needs for 2016 and 2020
New England's incremental renewable energy needs for 2016 and 2020 were determined from the spreadsheet entitled *2011 Renewable Portfolio Standards Spreadsheet* developed by ISO-NE,

and available at www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/usr_sprdshts/2011_rps_worksheet.xlsx.

This spreadsheet calculates New England's renewable energy needs via two methods:

- Method 1 assumes that the long-term energy efficiency goals of the New England states are fully achieved, thus reducing the total amount of load subject to RPS requirements.
- Method 2 assumes that the long-term state energy efficiency goals are not fully achieved, resulting in greater load subject to RPS requirements.

This analysis used the renewable energy targets calculated using Method 1. Additional discussion of the specific assumptions behind Method 1 is found in ISO-NE's spreadsheet.

For each of the two study years (2016 and 2020), the value of *Incremental Growth in new RPS above 2010 New RPS Value* for that year was taken from the *M1 Results Tab* (this value is found in row 18 of that tab). That number, representing ISO-NE's estimate of the new RPS-qualifying energy needed to meet the RPS requirements for CT, MA, ME, NH and RI in that year was then added to the *Total VT Renewables Goal (GWh)* shown in row 22 of that tab. Table TA-2 below summarizes these calculations.

Table TA-2 – calculation of New England's incremental renewable energy needs

All figures are in GWh/year	**2016**	**2020**
Incremental Growth in new RPS above 2010 New RPS Value (from row 18 of the *M1 Results* tab)	6,495	10,987
Total VT Renewables Goal (from row 22 of the *M1 Results* tab)	1,066	1,276
Grand total for New England (calculated)	7,561	12,263
Grand total for New England (rounded to nearest 250 GWh/yr)	7,500	12,250

The final values used for New England renewable energy needs were thus set to 7,500 GWh/year in 2016, and 12,250 GWh/year in 2020.

Finally, the *Total New England energy demand (net of energy efficiency and passive demand resources)* values shown in Table 3 of the Supply Curve Report were computed by subtracting the applicable values for *Total Energy Reductions due to EE – including passive DR* values (row 56 of the *M1 Regional Targets* tab) from the applicable values for the *Regional Net Energy for Load* (row 59 of the *M1 Regional Targets* tab). Table TA-3 below summarizes these calculations.

Table TA-3 – calculation of New England's total energy demand, net of EE and DR

All figures are in GWh/year	**2016**	**2020**
Regional Net Energy for Load (from row 59 of the *M1 Regional Targets* tab)	143,585	149,145
Total Energy Reductions due to EE – including passive DR (from row 56 of the *M1 Regional Targets* tab)	14,141	22,047
Total New England energy demand (net of energy efficiency and passive demand resources)	129,444	127,098

Developing the regional wind supply curves and tables in the Supply Curve Report

Total regional wind potential – Tables 1 and 2, plus Figures 1 and 2, of the Supply Curve Report

- All of the values in Table 1 and Table 2 of the Supply Curve Report were developed by categorizing the New England wind supply blocks provided by SEA according to state and generic project type (on-shore vs. off-shore)
- Figures 1 and 2 were developed by:
  - stacking the New England wind supply blocks in order of increasing LCOE;
  - determining, for various levels of cumulative annual wind production, the LCOE of the last supply block required to achieve that level of energy production; and
  - plotting the LCOE of that marginal supply block as a function of the cumulative annual wind energy production.

  For each study year, this exercise was repeated for each of the three contract terms (10, 15 and 20 years).

As noted in the Supply Curve Report, Tables 1 and 2 and Figures 1 and 2 of the Supply Curve Report do not consider potential imports from NY.

Regional supply curves – Figures 3 and 4 plus Table 6 of the Supply Curve Report

- Figures 3 and 4 show supply curves for wind resources in New England, categorized by specific project type. These supply curves were based on the LCOEs under a 15 year contract[8] and were produced in the same manner as Figures 1 and 2, except that the contributions of each specific project type were separately tracked and shown in a stacked line chart. As noted in the Supply Curve Report, the values shown in Figures 3 and 4 do not consider potential imports from NY.

[8] All LCOEs used in subsequent analyses were based on 15 year contract terms.

- Table 6 was developed by categorizing the supply blocks with the lowest LCOEs that could cumulative provide enough incremental wind energy to meet regional renewable energy goals in the subject year, now reflecting potential imports from NY.

  For example, the LCOE of the most expensive supply block needed in 2016 was $165.5 per MWh.[9] All supply blocks with an LCOE below $165.5 / MWh were included in the selected wind resource mix. Supply blocks with an LCOE of exactly $165.5 / MWh were prorated down in size to supply exactly enough additional energy to meet the region's renewable energy needs. Supply blocks with an LCOE greater than $165.5 / MWh were not included in the selected resource mix.

RLC's transmission analyses

Based on existing transmission constraints on the New England transmission system, RLC believes that any significant expansion of wind generation in western Maine or northern New Hampshire[10] would require significant new transmission facilities to deliver that energy to either the coastal Maine region (for wind generation in western Maine) or to southern New Hampshire (for wind generation in northern New Hampshire).

To meet those potential transmission needs, RLC developed seven sets of notional transmission upgrades that could integrate the amounts of wind generation indicated below in Table TA-4 (for northern New Hampshire) and Table TA-5 (for western Maine):

Table TA-4 – Information on notional transmission upgrades for Coos region of NH

ID # for notional upgrade	NH1	NH2
State	NH	NH
Region	Coos	Coos
MWs increase	300	700
Capital cost (M of $)	216	1467
Unit cost ($/kW)	720	2096
Levelized rev req (M $ / yr)	35	235
GWh/year @ 30.5% CF	788	1,840
Cumulative GWh/yr	788	2,628
Suggested in-service year	2016	2021

9 For 2020, the LCOE of the most expensive supply block required to meet New England's renewable energy needs was $170.5 / MWh.

10 More specifically, RLC considered new wind generation that would be located in (i) the Wyman Hydro and the Rumford regions of Maine, and (ii) the Coos region of New Hampshire.

The second NH upgrade has a much higher unit cost (in terms of $/kW of incremental capacity) than the first upgrade.[11] Additionally, SEA's analysis indicates that the maximum amount of wind energy that would likely be required from NH resources is less than 700 GWh per year. Hence, the second NH upgrade (NH2) was not further considered.

By dividing the annual levelized revenue requirements for the NH1 upgrade ($35 million per year) by the notional amount of wind energy that could be integrated through those upgrades (788 GWh/year), a notional "transmission adder" of $44 / MWh was calculated for wind generation in the Coos region.[12] This figure was used to estimate the impact of a transmission cost adder applied to wind energy from New Hampshire.

Table TA-5 below show similar information for the upgrades identified by RLC as appropriate for integrating wind generation located in western Maine.

Table TA-5 – Information on notional transmission upgrades for Maine

ID # for notional upgrade	**ME1**	**ME2**	**ME3**	**ME4**	**ME5**
State	ME	ME	ME	ME	ME
Region	Wyman	Wyman	Rumford	Rumford	Wyman
MWs increase	296	827	250	250	500
Capital cost (M of $)	315	326	105	302	187
Unit cost ($/kW)	1064	394	420	1208	374
Levelized rev req (M $ / yr)	50	52	17	48	30
GWh/year @ 30% CF	778	2,173	657	657	1,314
Cumulative GWh/yr	778	2,951	3,608	4,265	5,579
Suggested in-service year	2016	2018	2019	2021	2022

The Maine upgrades are more complex, with five distinct project stages, and two separate regions considered (the Wyman Hydro region and the Rumford area). As a first step in considering the potential transmission-related constraints on wind development in Maine, the five upgrades above were grouped into two notional "meta-upgrades":

11 The first upgrade only requires the construction of a 345 kV "gathering system" in the Coos region, with an interconnection to the existing New England grid in the Moore / Comerford region. The second upgrade additionally requires new transmission lines from the Coos region to southern New Hampshire.

12 Note that this adder would be in addition to the transmission costs already reflected in the LCOE values calculated by SEA. While it may be possible to estimate the degree of "double counting" (if any) of transmission costs by comparing the total transmission investment inherent in the SEA costs with the costs estimated by RLC, such a comparison would require additional review and analysis.

- Meta-upgrade 1 included upgrades ME1 and ME2, and would enable to the energy from up to 1123 MW of wind generation in the Wyman Hydro region to be delivered to the coastal Maine region. The associated annual energy would be approximately 2750 GWh/year. For the purpose of this analysis, this meta-upgrade was assumed to be fully in-service by 2016.[13] Assuming that the total annual revenue requirement for meta-upgrade 1 ($102 million per year) is allocated across 2951 GWh/year of energy, the unit cost is approximately $35 / MWh.

- Meta-upgrade 2 would complete all five upgrades, allowing the energy from up to 2123 MW of wind generation in the Wyman Hydro and Rumford regions to be delivered to the coastal Maine region. The associated annual energy would be 5579 GWh/year. For the purpose of this analysis, this meta-upgrade was assumed to be in-service by 2020.[14] Assuming that the total annual revenue requirement for all five upgrades ($197 million per year) is allocated across 5579 GWh/year of energy, the unit cost is approximately $35 / MWh.

Thus, the fully allocated transmission costs arising from the network upgrades identified by RLC were distilled to a cost of $44 / MWh for on-shore wind generation in New Hampshire,[15] and a cost of $35 / MWh for on-shore wind generation in Maine. This compilation and analysis of the transmission upgrades identified by RLC led to the transmission limits and costs shown in Table 7 of the Supply Curve Report.

In the subsequently "Transmission Constrained Supply Mix" analysis, the LCOEs for on-shore wind generation in New Hampshire and Vermont were increased by 50%[16] of $44/MWh (or

---

[13] While this assumption may be liberal (in the sense that RLC indicated that the appropriate in-service date for the second Wyman upgrade would be 2018, instead of 2016), the existing transmission system may be able to accommodate some amounts of incremental wind generation in Maine with no additional upgrades. Hence, the assumption that up to 2754 GWh / year of incremental wind generation from Maine could be integrated into the New England supply mix by 2016 was made.

[14] Again, this assumption may be liberal, in that RLC suggested the full buildout of all five upgrades may require until 2022 to be completed. As with meta-upgrade 1, available capacity on the existing transmission system (and the possibility that some wind generation in Maine could be located in regions that require less transmission investment) suggest that adding up to 5200 GWh / year of incremental wind generation from Maine to the New England supply mix by 2020 may be achievable.

[15] Although no transmission analyses were performed regarding the need for and cost of transmission upgrades required to integrate on-shore wind generation in VT, the subsequent sensitivity analysis also increased the cost of on-shore generation in VT by the same amount as the increase in the cost of on-shore generation in NH, on the assumption that significant wind generation in VT would also require network upgrades with similar costs.

[16] The value of 50% was selected to illustrate the effect of allocating some costs of network upgrades to the generation projects benefitting from those upgrades. Other allocations (*e.g.,* 0% or 100% of the upgrades) costs may be more appropriate. Higher allocations would tend to accelerate the cost-competitiveness of off-shore

$22/MWh), while the LCOEs for on-shore wind generation in Maine were increased by 50% of $35/MWh (or $17.5/MWh).[17]

Transmission out of Maine

The transmission upgrades identified by RLC for western Maine would deliver wind energy produced in the Wyman / Rumford regions to the coastal Maine region. RLC also noted that given transmission constraints between coastal Maine and New England's major load centers south of Maine, an additional transmission upgrade between coastal Maine and southern New England may be appropriate. Consequently, RLC estimated the cost of a notional high-voltage direct current ("HVDC") submarine cable system between coastal Maine and the Boston area, to provide a representative estimate of the cost of a "deep" network upgrade. Table TA-6 below shows the estimated capital and annual costs for the two project sizes considered by RLC (600 MW and 800 MW), along with the allocated unit costs (in $/MWh) for two capacity factors: a maximum capacity factor of 100% and a capacity factor of 30% (representing a typical capacity factor for on-shore wind generation in Maine).

Table TA-6 – Information on notional HVDC cable between coastal Maine and the Boston area

Project size	600 MW	800 MW
Total capital cost (M of 2016 $)	1,600	1,900
Levelized revenue requirements (M of 2016 $ / yr)	256	304
Energy at 100% CF	5,256	7,008
Wind energy delivered (GWh/yr) @ 30% CF	1,577	2,102
Transmission adder if allocated @ 100% CF ($/MWh)	49	43
Transmission adder if allocated solely to wind ($/MWh)	162	145

Caveats and conclusions:

- While an HVDC cable project between coastal Maine and the Boston area (or a similar "deep" network upgrade) may be ultimately be necessary to move significant amounts of wind energy out of Maine, the economic benefits of doing so were not estimated in these analyses. Assuming that new wind energy production in Maine could (a) displace non-renewable generation in southern New England during off-peak periods, when the

wind (again, assuming that off-shore wind projects would have lower network upgrade costs), while lower allocations would tend to favor remote on-shore generation.

17 As noted in later sections, RLC's transmission analyses identified constraints to the pace at which transmission in western Maine could be constructed, which in turn could limit the amount of on-shore wind generation that could be developed in Maine over the next several years. While applying the transmission adders noted above reduced the amount of economically competitive on-shore wind generation in Maine, the economically-induced reduction was not sufficient to comply with the transmission-based limits identified by RLC. Thus, on-shore generation in Maine was exogenously constrained in the "Transmission Constrained Supply Mix" analysis.

existing transmission system may have available capacity or (b) displace non-renewable generation in Maine during periods in which the existing transmission lines from Maine to southern New England are fully loaded, the economic benefits of an HVDC cable system may be less than the costs of such a system, while the incremental wind energy production could still contribute towards the region's renewable energy goals.

- Given the high unit costs associated with an HVDC cable system (especially for low capacity factors), and the costs for the AC system upgrades previously discussed and known to be required, subsequent analyses did not further increase the cost of on-shore generation in Maine to reflect potential costs for an HVDC cable system.

Implications of RLC's analysis

Table TA-7[18] below compares the wind energy (in GWh/year) from on-shore resources located in NH and ME that would be included in the lowest LCOE supply mixes for 2016 and 2020 with the corresponding upper limits suggested by RLC's analysis:

Table TA-7 – Annual wind energy from NH and ME
Desired generation (based on generation-only LCOE) vs. limits suggested by RLC analyses

	Energy by 2016 (GWh/yr)			Energy by 2020 (GWh/yr)		
State	Desired generation: From Table 6 of ES	Maximum feasible per RLC analysis	Need to constrain?	Desired generation: From Table 6 of ES	Maximum feasible per RLC analysis	Need to constrain?
NH	309	788	No	595	788	No
ME	5,391	2,951	**Yes**	5,743	5,579	**Yes**

Table TA-7 suggests that the single NH upgrade (allowing the integration of up to 300 MW of generation in the Coos region) may be sufficient to accommodate all of the wind resources with the lowest LCOE values, for both 2016 and 2020.[19] On the other hand, practical limitations on the pace at which new transmission could be developed in Maine may limit the total wind energy from on-shore resources in Maine that could be obtained by 2016 and 2020.

As previously discussed, in the subsequent Transmission Constrained Supply Mix analysis, the LCOEs for on-shore wind generation from Maine were increased by $17.5 / MWh, while the LCOEs for on-shore generation in New Hampshire and Vermont were increased by $22 / MWh.

18 Table TA-7 repeats the information contained in Table 8 of the Supply Curve Report.

19 Due to the limited geographic detail in the SEA data set, it was not possible to determine if all of the wind generation in NH with the lowest LCOE values would, in fact, be located in the Coos county region. For purposes of this analysis, it is assumed that all of the desired NH generation could be integrated into the New England supply mix via the first NH upgrade identified by RLC.

To the extent that such increases in the LCOE still resulted in suggested wind generation in Maine that exceeded the limits indicated by RLC's analyses, total on-shore generation in Maine was further constrained to comply with those limits.

Development of Table 9 and comparison to Table 6

As with Table 6, the values in Table 9 were developed by categorizing the supply blocks with the lowest LCOEs that could cumulative provide enough incremental wind energy to meet regional renewable energy goals in the subject year, including potential imports from NY. For example, the LCOE of the most expensive supply block needed in 2016 was $183.5 per MWh.[20] All supply blocks with an LCOE below $183.5 / MWh were included in the selected wind resource mix. Supply blocks with an LCOE of exactly $183.5 / MWh were prorated down in size to supply enough additional energy to meet the region's renewable energy needs.

Table 6 of the Supply Curve Report shows the mix of wind resources that could meet New England's renewable energy needs at the lowest cost *if* the existing transmission system had unlimited capacity (or if the transmission system could be rapidly expanded at no cost). Table 9 of the Supply Curve Report shows the mix of wind resources that could meet New England's renewable energy needs at the lowest cost *if* the cost of on-shore wind resources in Maine, New Hampshire and Vermont are increased by certain amounts ($17.5 / MWh for resources in Maine, and $22 / MWh for resources in New Hampshire and Vermont) and if the maximum pace of transmission development in western Maine constrains the development of on-shore generation in that region. Thus, the comparison of Table 6 with Table 9 highlights the effect of (i) allocating some of the costs of network upgrade to the generation projects causing the need for such upgrades and (ii) recognizing the limits on transmission development in western Maine. As such, this comparison illustrates the key questions to be considered by regional policy makers.

[20] For 2020, the LCOE of the most expensive supply block required to meet New England renewable energy needs was $181.5 / MWh.