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# Kibby Wind Power Project: Emissions Displacement Analysis

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TransCanada Maine Wind Development, Inc.

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## Introduction

By harnessing the power of the wind, wind turbines generate electricity without producing air emissions. When added to a region's power grid, wind power reduces the need for other forms of electrical generation that do produce air emissions, thus reducing overall air pollution. The resulting emissions "displacement" is a clear environmental benefit that can be directly attributed to additions of wind generation.

TransCanada Maine Wind Development Inc. (TransCanada) asked Farr Consulting to examine the impact of the Kibby Wind Power Project on emissions of sulfur dioxide ($SO_2$), nitrogen oxides ($NO_X$), and carbon dioxide ($CO_2$) from the power industry in the New England region. When completed, the Kibby Wind Power Project will be electrically interconnected to the New England Power Pool (NEPOOL), the regional power grid that serves all of New England except a small fraction of Maine's electrical load located in the northernmost portion of the state. While it is clear that the Kibby Wind Power Project will displace power from other generation sources, determining which sources and their associated emissions characteristics can be a complicated undertaking. As explained below, this analysis utilizes an annual report[1] produced by New England's Independent System Operator (ISO-NE) to estimate emission reductions that will be attributable to the Kibby Wind Power Project.

## Operation of Centrally Dispatched Power Systems

The NEPOOL system is centrally operated by an Independent System Operator, ISO-New England (ISO-NE). ISO-NE has overall responsibility for the safe and reliable operation of New England's power grid. In carrying out this responsibility, ISO-NE schedules electrical generation capacity to provide sufficient electrical power to meet the region's electrical demand. A defining characteristic of electricity is the fact that it cannot be stored in large quantities. Thus, in scheduling and dispatching the electric system, ISO-NE must closely match supply and demand so that the system balances and voltage is maintained at all times.

Described at a very high level, ISO-NE makes use of two types of resources in ensuring sufficient electrical supply to meet demand: dispatchable resources and non-dispatchable resources.[2] Non-dispatchable resources are resources that produce energy when they are available and generally do so under any conditions in the system. ISO-NE closely monitors the performance of such resources and keeps close track of the amount of generation it expects such sources to produce, but does not alter their level of output. Nuclear, certain types of hydropower, wind, and other generation sources with fixed schedules and/or low costs of production fall into this category. As the name implies, non-dispatchable generation tends to operate whenever it is available and meets electrical load that is always present in the grid.

ISO-NE schedules dispatchable resources, in contrast, so as to balance supply with the variable portion of demand that comes and goes over the course of each day and over high

[1] *2004 New England Marginal Emission Rate Analysis*. ISO-NE, Inc.(2006). This report is publicly available at http://www.ISO-NE.com.

[2] ISO-NE also coordinates imports and exports over interties with neighboring regions. While important, such transactions make up a relatively modest portion of overall power in the pool and are not discussed in any detail here.

demand periods such as the summer cooling season. The ISO estimates the level of generation needed from such resources and schedules sufficient resources to reliably serve load. In real time intervals (typically every five minutes), the ISO sends operating instructions to dispatchable resources so that supply and demand balance in real-time. Oil, and gas-fired resources as well as some hydro resources and even coal plants that can vary their output based on a dispatch signal are dispatchable resources. These resources provide bids to the ISO-NE each hour at the price at which they are willing to provide energy. The ISO then schedules and dispatches resources sufficient to meet demand with the goal of minimizing the total as-bid costs of resources used to serve demand.

The key to estimating the amount of emissions displaced by additions of generation capacity is knowing the emissions characteristics of the dispatchable resources that are on the margin in the system and will be the first to be turned off should load decrease or more non-dispatchable generation come online. Generally, the ISO-NE dispatches resources with lower bid offers first. Available dispatchable resources can be thought of as a supply "stack." The higher the demand, the more resources that are dispatched in the stack and the higher the cost of the marginal resource. For example, in any given interval, a ten megawatt increase in demand will lead the ISO to schedule and dispatch ten more megawatts of dispatchable resources. The exact resource (or combination of resources) that is dispatched to provide those ten megawatts depends on where in the dispatch "stack" the ISO is during the interval in question. Similarly, ten megawatts more generation from non-dispatchable resources will lead the ISO to dispatch ten megawatts fewer dispatchable resources and slide ten megawatts down the dispatch "stack."

## Methodology for Estimating Emissions Displacement

In order to accurately estimate the amount of emissions displaced by new resources, it is necessary to either conduct detailed modeling or to obtain extensive data on the dispatch of the system. Such detailed data is required in order to examine which resources are marginal and will therefore be offset when new sources of power are added to the system. By examining the marginal resource over intervals when new sources are likely to run and calculating an average emission rate for these resources, it is possible to estimate the total amount of emissions that new generation sources will displace. For wind power, which produces no emissions, all emissions that are displaced are net reductions in emissions from the power grid.

Such dispatch modeling and analysis can be a complicated undertaking. Fortunately, ISO-NE produces an annual report providing the marginal emissions rate for $NO_X$, $SO_2$, and $CO_2$ emissions. This report, the annual *New England Marginal Emissions Rate Analysis,* provides separate rates for peak[3], off-peak, ozone season[4], and non-ozone season periods. In the most recent report, emission rates presented in the report are calculated based on actual generation data and therefore provide an extremely accurate estimate of actual marginal emission rates.

Additional complications in calculating marginal emission rates result from transmission congestion. In most hours, NEPOOL operates with very little or no transmission congestion. In these hours, the marginal resources could be located anywhere on the NEPOOL system.

[3] Peak hours are defined as non-holiday weekday hours between 7am and 11pm. All other hours are off-peak.
[4] The ozone season runs from the beginning of May to the end of September.

In some hours, however, significant congestion prevents the free flow of electricity between subareas of the NEPOOL system. For example, in about ten percent of hours, significant congestion limits the flow of electricity from Maine to the rest of the NEPOOL region. In such hours, Maine effectively has a different marginal emissions rate than the rest of New England. Fortunately, ISO-NE's annual report provides marginal rates for both the entire pool and individual states within NEPOOL that can be used to account for the impacts of transmission congestion.

Once an appropriate marginal emission rate is known for all hours of the year, estimation of the total emissions that will be displaced by the Kibby Wind Power Project is a straightforward calculation. By simply multiplying an estimate of the total generation from the project during each period by the appropriate emissions rate, we calculate an estimate of the total emissions likely to be offset. In addition, this analysis includes a small adjustment to account for transmission losses.

## Analysis and Results – Base Year

Tables 1 through 3 list the marginal emissions rates for $SO_2$, $NO_X$, and $CO_2$ found in the ISO-NE report that are used in this analysis. Table 4 combines the rates for Maine and New England based on the assumption that (as described above) in ten percent of hours congestion between Maine and the rest of New England prevents power produced in Maine from displacing generation outside of the state.[5]

Table 5 presents estimated power generation from the Kibby Wind Power Project for each season studied.[6] When multiplied by the rates in Table 4, the generation values in Table 5 are translated into an estimate of the emissions offset attributable to the project.[7] One final adjustment is made to account for transmission losses. Results are reduced by 2 percent to account for the fact that a small fraction of the energy produced by the Kibby Project does not offset generation in other facilities because of transmission losses. Table 6 presents the resulting emission reductions.

Because the project itself produces no emissions, the Kibby Wind Power Project results in sizeable reductions in air pollution. As shown in Table 6, the project results in about 336 tons of $SO_2$ reductions in the base year, 91 tons of $NO_X$ reductions (25 in the ozone season), and 191,000 tons of $CO_2$ reduction.

## Five Year Projection of Emissions Displaced

The results presented above are calculated using marginal emission rates in the region for 2004, the most recent rates available from ISO-NE. Some changes in marginal emission rates should be expected from these numbers as the Kibby Wind Power Project goes online in 2009 and over the first several years of its operation.

To estimate changes in marginal emission rates in years following the ISO-NE report, it is helpful to examine how marginal emission rates changed in years leading up to 1994. The

[5] Such congested hours are further assumed to occur more frequently in peak hours.
[6] For 132 MW facility. Data on estimated generation provided by TransCanada Maine Wind Development Inc..
[7] This product is divided by 2000 to translate from pounds to tons.

ISO-NE marginal emissions rate report provides rate estimates going back more than a decade. Since the late 1990's, marginal emission rates in New England have dropped steadily.[8] The single largest factor explaining these reductions is the addition nearly 10,000 MW of natural gas-fired generation in the region.[9] Such natural gas-fired facilities produce very little $SO_2$, and significantly reduced levels of both $NO_X$ and $CO_2$.The last such facility was completed in early 2004, and no such large projects are currently under construction.

Thus, the past several years represent a period of rapid change in the resource mix in New England. By 2004, natural gas had emerged as the primary fuel used by resources operating at the margin, resulting in a significant drop in marginal emission rates. With the end of the string of large gas-fired capacity additions, marginal emission rates are unlikely to have changed greatly since 2004, and are unlikely to change rapidly for several years to come.

Many additional factors have an impact on marginal emission rates. These include changes in emissions regulations, changes in the relative cost of fuels, unit retirements, changes in the transmission system as well as load growth and other factors. The most compelling reason to believe that marginal emission rates are changing is based in the shrinking reserve margins in the NEPOOL region. From 1999 to 2004, New England added significantly more generating capacity than was needed based on load growth. As a result, reserve margins (i.e., the amount of generating capacity available to the pool above and beyond expected peak loads) became unusually high. In order to serve load, ISO-NE rarely had to dispatch the pool's "peaking units." Because they run less often than other capacity, peaking units -- typically natural gas or oil fuel-fired units similar to aircraft or internal combustion engines -- tend to have higher emission rates and lower efficiencies than other dispatchable resources. As a result, when they are utilized more often to serve peak loads, they tend to drive up marginal emission rates. The utilization rates of such peaking units have increased since 2004 and are likely to increase further if reserve margins in the pool continue to shrink slightly as predicted for the next few years.

Figure 1 estimates how marginal emission factors are likely to have changed since the values reported for 2004 and over the early years of the Kibby Wind Power Project. As discussed above, marginal emission rates are likely to increase from 2004 through 2009. The impact is likely to be small as increases due to higher utilization rates among peaking units (as discussed above) will be somewhat offset by tightening emission regulations.[10] Marginal emission rates are predicted again to decrease with the addition of new generation resources in the 2010-2013 period. While these numbers are relatively simple estimates based on an overall assessment of conditions in the pool, little reason exists to expect that marginal emission rates will change rapidly for the next several years, particularly if natural gas remains the marginal fuel as expected. Thus, the estimates presented in Figure 1 are reasonably accurate.

As in the Base Year, these emission factors are multiplied by expected power generation from the Kibby Wind Power Project and adjusted for transmission losses to calculate expected reductions in emissions. Table 7 presents these result for the period 2009 through 2013, the first five years of operation of the Kibby Wind Power Project. Based on the

[8] ISO-NE (2006). See, for example, Figures 5.2 through 5.4.
[9] For reference, the peak load experienced in NEPOOL in 2006 was about 28,000 MW.
[10] 310 CMR 7.29, Emission Standards for Power Plants, May 2004, and Connecticut Executive Order 19, implemented in Regulations of Connecticut State Agencies (RCSA) 22a-174-19a and 22a-174-22 (May 17, 2000).

marginal emissions rates shown in Figure 1, pollution reductions attributable to the project are highest in 2009 and 2010, the first two years of operations. Even as marginal emission rates drop somewhat, reductions in pollution are considerable. The Kibby Wind Power Project is estimated to reduce $SO_2$ emissions by well over 300 tons during each year studied and by more than 1,700 tons over the five year study period. $NO_X$ emissions will drop by more than 80 tons each year and more than 460 tons over five years (more than 120 tons in the ozone season). $CO_2$ emissions drop by about 200,000 tons per year or nearly one million tons when all five years are taken into account.

To put some perspective on these large numbers, an average car with typical use emits somewhere in the range of five to six tons of $CO_2$ each year.[11] Thus, the 200,000 of $CO_2$ offset by the Kibby Wind Power Project is equivalent to removing about 35,000 cars from the road. Similarly, the approximately 90 tons of $NO_X$ offset per year by the Kibby Wind Power Project is equivalent to the $NO_X$ produced in New England to serve the electric needs of roughly 25,000 households.[12] Finally, it is important to note that the emission reduction benefits of the Kibby Wind Power Project will extend well beyond the five-year study period. Although there is inherent uncertainty in any long-range forecast of marginal emission rates, assuming that these rates remain near current values, the project would displace about five million tons of $CO_2$ over its 25-year life.

[11] Assumes typical usage of 12,000 miles driven per year at 23 miles to the gallon.
[12] Assumes annual electric use of just over 10,000 kwh per household and average $NO_X$ emission rates for 2005 (EPA data).

**Table 1: 2004 $SO_2$ Marginal Emission Rates (Lbs/MWh)**

| State | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|
| Maine | 0.36 | 0.19 | 1.08 | 0.69 | 0.64 |
| New England | 1.77 | 1.43 | 2.45 | 2.24 | 2.03 |

*Note: Data from Table 5.7 in 2004 New England Marginal Emission Rate Analysis. ISO-NE, Inc.(2006).*

**Table 2: 2004 $NO_X$ Marginal Emission Rates (Lbs/MWh)**

| State | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|
| Maine | 0.17 | 0.16 | 0.33 | 0.26 | 0.24 |
| New England | 0.48 | 0.38 | 0.66 | 0.59 | 0.54 |

*Note: Data from Table 5.8 in 2004 New England Marginal Emission Rate Analysis. ISO-NE, Inc.(2006).*

**Table 3: 2004 $CO_2$ Marginal Emission Rates (Lbs/MWh)**

| State | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|
| Maine | 983 | 1,002 | 1,056 | 1,045 | 1,027 |
| New England | 1,072 | 1,040 | 1,147 | 1,124 | 1,102 |

*Note: Data from Table 5.9 in 2004 New England Marginal Emission Rate Analysis. ISO-NE, Inc.(2006).*

**Table 4: Base Year Marginal Emission Rates Used in Offset Analysis (Lbs/MWh)**

| State | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|
| $SO_2$ | 1.52 | 1.37 | 2.23 | 2.18 | 1.89 |
| $NO_X$ | 0.43 | 0.37 | 0.61 | 0.58 | 0.51 |
| $CO_2$ | 1,056 | 1,038 | 1,132 | 1,121 | 1,095 |

*Note: Composite rate taking into account transmission congestion*

**Table 5: Base Year Generation by Season Estimated for Kibby Wind Power Project (MWH)**

| | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Total |
|---|---|---|---|---|---|
| Generation | 59,589 | 71,430 | 102,778 | 123,203 | 357,000 |
| % of Total | 16.7% | 20.0% | 28.8% | 34.5% | 100.0% |

**Table 6: Base Year Emissions Reductions Resulting from Kibby Wind Power Project (Tons)**

| | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|
| $SO_2$ | 44.5 | 47.9 | 112.3 | 131.5 | 336.2 |
| $NO_X$ | 12.4 | 12.9 | 30.6 | 34.8 | 90.7 |
| $CO_2$ | 30,846 | 36,334 | 57,031 | 67,665 | 191,876 |

*Note: Includes two percent reduction to account for transmission losses*

**Figure 1: Changes in Marginal Emission Rates Assumed over Study Period**

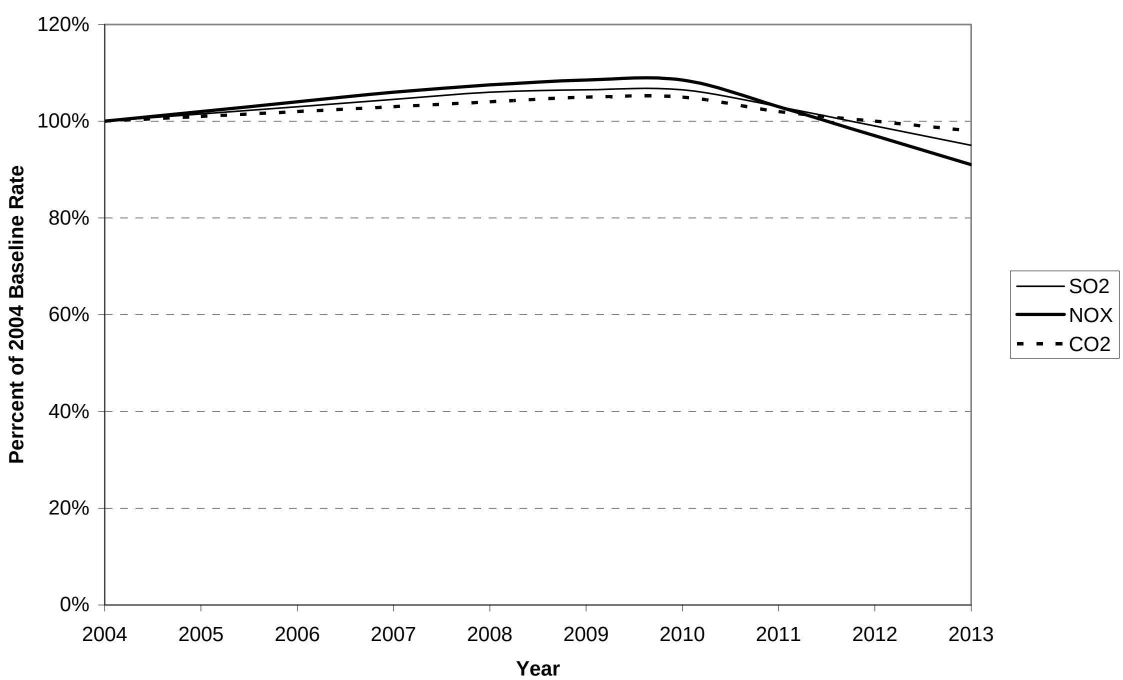

**Table 7: Emissions Reductions Resulting from Kibby Wind Power Project (Tons, Years 2009-2013)**

| | Year | On-Peak Ozone Season | Off-Peak Ozone Season | On-Peak Non-Ozone Season | Off-Peak Non-Ozone Season | Annual Average (All Hours) |
|---|---|---|---|---|---|---|
| $SO_2$ | | | | | | |
| | 2009 | 47.4 | 51.0 | 119.6 | 140.0 | 358.0 |
| | 2010 | 47.4 | 51.0 | 119.6 | 140.0 | 358.0 |
| | 2011 | 45.8 | 49.3 | 115.7 | 135.4 | 346.3 |
| | 2012 | 44.0 | 47.4 | 111.2 | 130.2 | 332.8 |
| | 2013 | 42.3 | 45.5 | 106.7 | 124.9 | 319.4 |
| | Total | 226.8 | 244.2 | 573.0 | 670.6 | 1,714.6 |
| $NO_X$ | | | | | | |
| | 2009 | 13.5 | 14.0 | 33.2 | 37.8 | 98.5 |
| | 2010 | 13.5 | 14.0 | 33.2 | 37.8 | 98.5 |
| | 2011 | 12.8 | 13.3 | 31.5 | 35.9 | 93.5 |
| | 2012 | 12.1 | 12.5 | 29.7 | 33.8 | 88.0 |
| | 2013 | 11.3 | 11.8 | 27.8 | 31.7 | 82.6 |
| | Total | 63.2 | 65.6 | 155.3 | 176.9 | 461.0 |
| $CO_2$ | | | | | | |
| | 2009 | 32,388 | 38,151 | 59,883 | 71,048 | 201,470 |
| | 2010 | 32,388 | 38,151 | 59,883 | 71,048 | 201,470 |
| | 2011 | 31,463 | 37,061 | 58,172 | 69,018 | 195,713 |
| | 2012 | 30,846 | 36,334 | 57,031 | 67,665 | 191,876 |
| | 2013 | 30,229 | 35,608 | 55,890 | 66,311 | 188,038 |
| | Total | 157,314 | 185,306 | 290,858 | 345,089 | 978,567 |