AVOIDED EMISSIONS ANALYSIS FOR THE PROPOSED EAST HAVEN WIND FARM

Prepared For:

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1.0 INTRODUCTION

This report was prepared for the Conservation Law Foundation to determine if the proposed 6 MW East Haven Wind Farm in northeastern Vermont will have air emissions benefits. East Haven will be connected into the New England ISO (Independent System Operator) power grid system. The project will initially have four 1.5 MW wind turbines and 50 turbines (75MW) are proposed at full development. This report provides an estimate of avoided air emissions that could be realized from the generation and sale of wind power from the initial 6 MW East Haven Wind Farm Project.

2.0 METHODOLOGY

The method used to estimate avoided emissions from East Haven Wind Farm has two components:

1.) Identification of a group of power plants in New England that have the potential for being displaced by the East Haven Wind Farm.

2.) Estimation of air emissions displaced at those identified power plants.

2.1 IDENTIFICATION OF POSSIBLE DISPLACED POWER FACILITIES

Increasing wind generation capacity on a grid generally displaces other generation that is more expensive to produce. Wind is a must-run source of power (i.e. when the wind is blowing, the power must be utilized). Wind power does not offer the flexibility to respond quickly to peak-demand loads like other facilities (i.e. the releasing of water at a hydro facility or start-up of a gas turbine), nor can it be relied upon to provide consistent base-load power as a nuclear or coal plant provides. However, when wind is available, other power sources will be backed down based on system economics or contract considerations. Nuclear power and hydro-electric units are not displaced because they have low operating costs. The generation units most commonly displaced are powered by fossil fuels. These include natural gas, oil and coal. It is possible to identify the back-down schedule with knowledge of the generation costs or through the use of an economic dispatch model, combined with a wind generation schedule. However this is beyond the scope of this report.

The purpose of this report is to provide an estimate of the avoided emissions from the development of wind at the East Haven site. It does not provide a definitive list of which facilities will be displaced. That would require the application of a dispatch model or equivalent economic dispatch analysis. Instead, we have included generation capacity in New England with the potential for being offset by wind. These facilities are identified in Table A1 in the Appendix with their home state, primary sources of fuel, and nameplate capacity (amount of power the plant could generate at 100% load). We have excluded facilities that are known co-generators (provide both heat and power) because the generation schedule of these facilities are often dictated by the needs of the heat user rather than system demand.

To meet increasing demand, power capacity has been expanded in the New England power pool in the past few years. This new capacity has been overwhelmingly dominated by combined-cycle gas turbine facilities[1]. Combined-cycle generation utilizes a technology that reuses waste heat from the combustion turbine to generate additional power through a heat recovery steam turbine. This process allows the facility to produce less air emissions for the same power output.

[1] AES Granite Ridge, Milford Power Project, and Fore River are examples.

Based on a study conducted by ISO New England Inc. in 2003 entitled "2003 NEPOOL Marginal Emission Rate Analysis", we conclude that oil and gas-fired facilities would be the most likely power plants to be displaced due to the relative prices of oil and natural gas fuels. Coal burning facilities are often base load facilities but have the capacity to be displaced because they occasionally have additional capacity that can be variably dispatched. Because of this, we estimated emissions by using a generation-weighted average for two scenarios:

1) Oil and gas units displaced
2) Oil, gas and coal units displaced

A generation-weighted average analysis is a way of estimating avoided emissions when the back-down order is not known. The total offset emission rate is weighted by each facility's contribution to the power pool.

2.2 ESTIMATION OF EMISSIONS FROM DISPLACED GENERATION

The emissions estimates for displaced generation are taken from EPIndex™. EPIndex is a database describing the Environmental Performance of US Electric Power Plants. This database, created by Resource Systems Group, includes emissions and generation data for all major power plants in the nation.

The plant, unit and emissions data in EPIndex™ were gathered from the Energy Information Administration (EIA), the Federal Energy Regulatory Commission (FERC), the Environmental Protection Agency (EPA), and state agencies. Sources of emissions data, in priority order, are as follows:

1) Continuous emissions monitors (CEMs), required by EPA under the Clean Air Act. CEMs are reported to EPA by plant and/or individual unit. These data are available for CO_2, NOx and SO_2 for most large fossil fueled power plants.
2) Other emissions data published by the EPA such as the National Emissions Inventory (NEI) and the Emissions & Generation Resource Integrated Database (EGRIDs).
3) Best available engineering estimates (BAEE). Many air pollutant emissions, including most air toxics, are calculated using best available engineering estimates with equipment specific emissions factors at the plant or unit level. BAEE was not used in this analysis because CEM data was available for the plants of interest. However BAEE was used as a check on the CEM data in the EPIndex™ database.

Estimates of displacement emissions are for direct emissions only. Emissions associated with fuel extraction, off-site processing or transportation are not included. Because fossil fuel extraction, processing and transportation create significant air emissions, the displacement emissions estimates reported here are probably underestimates of the total fuel system emissions. Additionally, these estimates include control technologies in place at all of these facilities. For example, Merrimack Station in Bow, N.H. has both selective catalytic reduction (SCR) to control NOx and electrostatic precipitators (ESPs) to control particulates. William Wyman Station in Yarmouth, Maine utilizes low excess air and flue gas recirculation for NOx and mulitcyclones and ESPs for particulates.

3.0 RESULTS & DISCUSSION

Nitrogen oxides or NOx refers to Nitrogen oxide and Nitrogen dioxide which contain nitrogen and oxygen. These gases are highly reactive and contribute to the formation of ozone in the lower atmosphere. NOx is formed in two ways during fuel combustion. The first and most common is 'thermal NOx', which is formed by the thermal fixation of atmospheric nitrogen and oxygen. Secondly, 'fuel NOx' is formed by the oxidation of nitrogen in the fuel during combustion. These gases have substantial impacts on air quality, causing a direct adverse public health effect and contributing to acid rain and ground level ozone.

Under a coal, gas, and oil scenario, we estimate the NOx offset emissions to be almost twice as much as the oil/gas scenario. The emission rates (lbs/MWh) are shown in Table 1 and the overall avoided emissions are shown in Table 2, assuming 19,000 MWh of wind power annually.

Sulfur dioxide (SO_2) gas is a major contributor to acid rain although government regulation has helped to significantly reduce the impact of this pollutant. There are negligible SO_2 avoided emissions associated with natural gas combustion. However, coal and oil both have significant sulfur dioxide emissions. Sulfur dioxide emissions are related to the sulfur content of the fuel and control efficiencies in place for the facility. Effective sulfur control technology has been installed at many facilities or low sulfur fuels have been used as required by the Clean Air Act Amendments of 1990.

Carbon dioxide (CO_2) is the primary greenhouse gas in our environment. The combustion of all three fuels (coal, oil, and gas) converts the fuel's stored carbon into carbon dioxide and to a lesser extent carbon monoxide. To place these emissions reductions in perspective, 19,000 MWh of wind power by East Haven will reduce carbon dioxide emissions (assuming the generation-weighted average coal/oil/gas scenario), which contribute to global warming, by an amount equivalent to taking about 2,200 automobiles off the road [1] each year. At the 75 MW full development phase, the CO_2 reductions would be equivalent to more than 28,000 automobiles removed.

Table 1: Avoided Air Emissions from the East Haven Wind Farm (lbs/MWh)

Scenario	NO x	SO x	CO2
Coal, Oil and Gas	1.16	4.26	1,339
Oil and Gas Only	0.49	1.75	829

Table 2: Avoided Air Emissions from the East Haven Wind Farm (Tons/year) – at 19,000 MWh

Scenario	NO x	SO x	CO2
Coal, Oil and Gas	11	40	12,722
Oil and Gas Only	5	17	7,874

4.0 COMPARISON WITH OTHER METHODS OF ESTIMATION

Several other alternative methods have been used to estimate the avoided air emissions from wind generation. The first method is to use a true marginal dispatch analysis which would employ either detailed recent historical records of economic dispatch at the unit level or a unit dispatch model. A study conducted by ISO New England Inc. in 2003 entitled "2003 NEPOOL Marginal Emission Rate Analysis" provided marginal emission rates based on the Inter Regional Electric Market Model (IREMM) which is an electric power production model for NEPOOL based on system economics. The results of this study for 2003 are shown in Table 3.

[1] Based on 555 gal/yr/auto and 20.2 lb CO2/gal

Table 3: 2003 NEPOOL Marginal Emissions Rates (lbs/MWh)[1]

Scenario	NO x	SO x	CO2
Oil and Gas (Annual Average)	0.73	1.98	1,179

Source: ISO New England Inc.

In comparing emission rates in Table 3 with this report (Table 1) it can be seen that in general the annual emission rates in the NEPOOL study are intermediate between the oil and gas only scenario and the coal, oil and gas scenario.

Another alternative that has been suggested is to consider that new wind generation be considered as a replacement for the next new unit of generation that is capable of being dispatched on a demand basis. This approach is sometimes referred to as the 'proxy plant' analysis. In New England this new unit is likely to be a new combined-cycle gas turbine that can meet the current Best Available Control Technology / Lowest Achievable Emission Rate (BACT/LAER) Standards for emission controls. Combined cycle gas turbines are currently the least expensive generation that can meet variable power demand and environmental regulations in New England. This may not always be so. The emissions from a typical modern combined-cycle generation unit are given in Table 4. The emission rates shown here could be considered a "floor" for potential avoided emissions.

Table 4: Emissions from a Combined-Cycle Gas Turbine (lbs/MWh)

Plant Name	NO x	SO x	CO2
Fore River Station (Weymouth, MA)	0.07	0.005	913

Source: US EPA Continuous Emission Monitoring and US Dept. of Energy

One final method that has been conducted by both public and private sector organizations considers calculating offset emissions using a full system mix emission rate. This method takes the entire mix of power facilities in a grid and calculates the overall generation-weighted average emission rates. This is similar to our method but includes all power plants in the system. However, we reject this method as a reliable option because it assumes all power pool contributors will be displaced. We have already discussed that certain types of power producers (e.g. nuclear and hydro-power) do not adjust their power output due to their low operating costs. Additionally, co-generating facilities may not have the flexibility to reduce power production due to heating demands.

5.0 CONCLUSIONS

This report discusses several methods to assess avoided emissions from wind energy production at East Haven. These reductions are caused by the displacement of fossil-fueled generation in the New England power pool. They are independent of any reductions which may be achieved through demand side management programs or efficiency improvements by power consumers. They are also in addition to any emission reductions which have been achieved by the electric power generators. Substantial additional emissions reduction benefits will exist at full phase operation of the wind farm.

[1] ISO New England Inc., NEPOOL Marginal Emission Rate Analysis, Prepared for the NEPOOL Environmental Planning Committee December 2004. Table 5.3

At this point, it is not clear what the precise mix of the displaced power will be from East Haven. We have provided two estimates of avoided emissions; one with coal, oil and gas displaced and the other just assuming oil and gas. We also discuss other alternative approaches for avoided emissions analysis. The application of a system dispatch model, however, was beyond the scope of this report.

Although we believe that the realized avoided emissions from the wind project will be somewhat different than what we have estimated, the results of our analysis provide an adequate and robust assessment of the likely effect of the facility on emissions displacement. Based on this analysis, it is clear that East Haven Wind will have significant air quality benefits to the New England region and Vermont. In addition to the pollutants presented here, there would be significant reductions in particulates, volatile organic compounds (VOCs) and toxic air emissions from the operation of the East Haven Wind Farm. On the very conservative side, we could expect emission savings to be at least those presented in Table 4. This assumes that highly efficient natural gas could be dispatched. However, it is our opinion that the savings will be greater. Additionally, the displacement of fossil-fueled power by wind will reduce water consumption, water pollution, and the production of solid waste.

APPENDIX

Table A1[1]: Power Plants in New England Considered in RSG Analysis

State	Plant Name	Primary Fuel	Nameplate Capacity (MW)
MA	ANP Bellingham Energy	Natural Gas	580
MA	ANP Blackstone Energy II	Natural Gas	510
MA	Anderson Power	Oil	1
MA	Berkshire Power	Natural Gas	272
MA	Brayton Point	Coal	1611
MA	Canal Plant	Oil	1164
MA	Cherry Street	Oil	20
MA	Cleary Flood	Natural Gas	146
MA	Commercial Street	Oil	1
MA	Dartmouth Power Associates	Natural Gas	77
MA	Dighton Power Associates	Natural Gas	200
MA	Doreen	Oil	21
MA	Fore River Station	Natural Gas	870
MA	Framingham LLC	Oil	43
MA	High St Station	Oil	13
MA	M Street Jet	Oil	69
MA	Medway LLC	Oil	135
MA	Milford Power LP	Natural Gas	178
MA	Millennium Power	Natural Gas	360
MA	Mount Tom	Coal	136
MA	Mystic LLC	Oil	1100
MA	Nantucket	Oil	20
MA	New Boston LLC	Natural Gas	736
MA	Oak Bluffs Generating Facility	Oil	8
MA	Potter Station 2	Natural Gas	106
MA	Salem Harbor	Coal	805
MA	Shrewsbury	Oil	14
MA	Sithe Edgar LLC	Oil	284
MA	Somerset Station	Coal	150
MA	Stony Brook	Oil	530
MA	Waters River	Natural Gas	65
MA	West Springfield	Oil	129
MA	West Tisbury Generating Facility	Oil	6
MA	Wilkins Station	Oil	6
MA	Woodland Road	Oil	20
ME	Cape Gas Turbine	Oil	18
ME	Flos Inn Diesel	Oil	6
ME	Maine Independence Station	Natural Gas	548
ME	Mason Steam	Oil	104
ME	Rumford Power Associates	Natural Gas	273
ME	Westbrook Energy Center	Natural Gas	369
ME	William F Wyman	Oil	846

[1] Coal burning plants appear in gray. These were only included in one of the two RSG scenarios (Coal/Oil/Gas). The rest of the plants were considered in both scenarios.

Table A1 (continued): Power Plants in New England Considered in Analysis

State	Plant Name	Primary Fuel	Nameplate Capacity (MW)
CT	Branford	Oil	19
CT	Bridgeport Energy	Natural Gas	520
CT	Bridgeport Station	Coal	546
CT	Cos Cob	Oil	64
CT	Franklin Drive	Oil	19
CT	Montville Station	Oil	495
CT	Lake Road Generating	Natural Gas	840
CT	Milford Power Project	Natural Gas	540
CT	New Haven Harbor	Oil	422
CT	North Main Street	Oil	17
CT	Devon Station	Oil	398
CT	Norwalk Harbor Generating Station	Oil	343
CT	South Norwalk	Oil	17
CT	Torrington Terminal	Oil	19
CT	Wallingford Energy	Natural Gas	243
NH	AES Granite Ridge	Natural Gas	900
NH	Durgin & Crowell Lumber Co Inc	Oil	6
NH	Lost Nation	Oil	18
NH	Merrimack	Coal	496
NH	Newington Power Faci	Natural Gas	370
NH	Newington	Oil	414
NH	White Lake	Oil	19
RI	Block Island	Oil	6
RI	Calpine Tiverton Power	Natural Gas	273
RI	Manchester St	Natural Gas	489
RI	Ocean State Power	Natural Gas	254
RI	Ocean State Power II	Natural Gas	254
RI	Rhode Island State Energy Station	Natural Gas	595
VT	Ascutney	Oil	13
VT	Berlin 5	Oil	42
VT	Burlington GT	Oil	28
VT	Colchester 16	Oil	18
VT	Diesel Plant 1	Oil	1
VT	Florence	Oil	9
VT	Newport Diesels	Oil	7
VT	Rutland	Oil	13
VT	St Albans	Oil	3