

# Industrial Wind Energy: Ridgeline Footprint and Related Issues

Vermont wind farms can provide 20% of our state's electricity needs by 2015.....  
on just a small fraction of the state's 500+ miles of ridgeline.  
*Vermont Public Interest Research Group (VPIRG): Summer 2006 (1)*

*Hugh T. Kemper, Londonderry, Vermont- December, 2006 (2)*

## Introduction:

This paper examines Vermont Public Interest Research Group's (VPIRG) assertion that by 2015 industrial wind turbines on 8.8% (or 46 miles) of Vermont's ridgelines above 2500 feet could provide 20% of Vermont's electricity needs. (1) The examination compares VPIRG's proposal- which is predicated on Vermont's *average* electricity consumption- with the utility industry's standard for measuring wind energy's contribution to system *reliability* and *peak* demand. i.e. its *capacity credit*. **This measurement concludes that for wind energy to provide the reliable generating capacity to meet 20% of Vermont's peak demand industrial wind turbines would require 44% - 88% (or 226-451 miles) of Vermont's ridgeline above 2500'.**

This conclusion is derived from available Searsburg data and wind energy's apparent *capacity credit* in California, Texas, Ontario and Germany.

To provide perspective, a brief review of how electricity grids work precedes this comparative analysis.

This paper concludes with an overview of three related issues- emissions, transmission and governmental incentives. It argues that (1) emissions *may* or *may not* be reduced depending on wind energy's grid specific impact, (2) wind energy poses significant problems to transmission related operations and costs when installed wind capacity reaches 10%-20% of peak demand capacity and (3) incentives promoting renewable energy alternatives should, *in the interest of optimizing investment returns and minimizing ratepayers' costs*, reflect their respective *verifiable* contributions to on-peak/on-season energy generation, system stability and reliability as well as net emissions reduction.

## Electricity Grids: How They Work

An electric power grid's primary responsibility is to provide electricity *on demand* 24/7/365. This means the grid must match aggregate production and consumption instantaneously, continuously and *reliably*.

Following policies developed and enforced by the North American Electric Reliability Council (NERC) (3), each grid must have sufficient generating sources that will:

(1) ensure ‘adequacy’ - the ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers *at all times*, taking into account scheduled and reasonably expected unscheduled outages and

(2) accommodate ‘contingencies’ - the unexpected failure or outage of a system component such as a generator, transmission line, circuit breaker, switch or other electrical element.

This means, in addition to having ‘contingency reserves’, the grid must routinely have generating sources that not only meet *base load demand* (the minimum amount of electric power delivered or required over a given period at a constant rate) but also meet *peak demand* (the highest *hourly load* within a given period-day, month, season or year) as well as the operating flexibility to respond to everything in between.

Since cost is a critical component in source selection, large reliable power plants with low fuel costs are generally dedicated to providing base load power, e.g. coal, nuclear power and (at least seasonally) conventional hydro power (the variable/fuel cost of hydro and nuclear power is essentially zero). Additional capacity is brought on-line on a daily/seasonal basis to meet routine increases in demand and peak demand. Routine, fairly predictable increases in demand can be accommodated by coal, biomass, and hydro (if available). Natural gas and oil are also used but, in recent years, they have become less attractive cost alternatives. To meet short duration peak demand, the key requirements are fast startup and low investment cost, i.e. generally fossil fuel generating units, particularly natural gas units.

Conceptually, the grid’s need to match reliably aggregate production and consumption instantaneously and continuously can be met by controlling generation, demand, or both. In practice, grid operators historically have preferred to control generation almost exclusively.

Consistent with their primary responsibility to provide electricity on demand 24/7/365, grid managers focus intently on each generating source’s *capacity credit* which is a measure tied to peak demand and reflects a generating source’s contribution to system reliability.

### **Comparative Analysis: Average Capacity vs. Capacity Credit**

As detailed in Exhibit A, VPIRG contends that by 2015 20% of Vermont’s annual electricity needs could be provided by industrial wind energy (1) operating, *on average*, at 32% of installed capacity (450MW), (2) consisting of 274, 1.65MW turbines and (3) occupying 46 miles of ridgeline or 8.8% of Vermont’s 517 miles of ridgeline above 2500 feet.

VPIRG’s proposal is predicated on projected Vermont annual electricity consumption of 6,200,000MWh which equates to an *average* daily and hourly consumption of 16,986MWh and 708MW respectively.

The standard measurement, however, employed by the utility industry to determine a generating unit's contribution to meeting electricity needs is *capacity credit*, i.e. its *reliable* contribution to *peak* demand (Vermont's = 1,100MW). **This measurement, applied to VPIRG's scenario, concludes that for wind energy to provide the reliable generating capacity to meet 20% of Vermont's peak demand industrial wind turbines would require 44% - 88% (or 226-451 miles) of Vermont's ridgeline above 2500'**. VPIRG's 46 miles of ridgeline would contribute 2.1%-4.1% of the electricity generating capacity required to meet Vermont's peak demand.

A generating unit's *capacity credit* is derived from its reliable contribution over time to meeting peak demand in the *hour* in which annual peak demand occurs. Although Green Mountain Power (GMP) does not provide Searsburg's contribution to peak demand during the *hour* it occurred, its data does show Searsburg's capacity during the *month* in which peak demand occurred—a range of 8% (August 2001, 2002 & 2003) to 16% (December 2004 and July 2005). (Exhibit B) Of note is that Vermont and New England appear to have set a new peak demand record last August when winds were light. (4)

As *capacity credit* is a measure of a generating unit's reliability in meeting peak demand, it can only be established with confidence based on actual experience over time. In the absence of empirical evidence, this comparative analysis assigns a *capacity credit* to Vermont wind energy of between 5% and 10% based on the aforementioned GMP data and, as addressed below, wind energy's apparent *capacity credit* in California, Texas, Ontario and Germany.

### **Wind Energy's Capacity Credit**

As an intermittent, uncontrollable and largely unpredictable (except in the very short term) generating source, wind is inherently unreliable. When the wind does blow within required parameters, wind turbines do generate energy. However, because wind is often 'off-peak and off-season', its *capacity credit*, and thus its capacity value for meeting peak demand, is limited.

A recent study determined that it is difficult to generalize the capacity credit for wind as 'it is a highly site-specific quantity determined by the correlation between wind resource and load'...with values ranging "from 26 % to 0% of rated capacity". (5)

This conclusion is based, in part, on a 2003 study by the California Energy Commission that estimated that three wind farm aggregates- Altamont, San Geronio and Tehachpi, which collectively represented 75% of California's deployed wind capacity- had relative *capacity credits* of 26.0%, 23.9% and 22.0% respectively. While we do not know how these three facilities performed during California's summer '06 energy crunch, we do know how California's aggregate wind power portfolio performed. As has been widely publicized in the press, California wind power produced at 254.6 MW (10.2% of wind's rated capacity of 2,500MW) at the time of peak demand (on July 24th, 2006) and over the preceding seven days (July 17-23) the facilities produced at 4% of rated capacity. (6)

Addressing wind energy's performance in California during the July 06 'heat storm', American Wind Energy Association (AWEA) spokesperson, Christine Real de Azua, explained- **"You really don't count on wind energy as capacity. It is different from other technologies because it can't be dispatched."** *(emphasis added)* (7)

The following excerpt from the Electricity Reliability Council of Texas' (ERCOT) 2005 study suggests a more conservative assessment of wind energy's *capacity credit*. (8)

**In addition to meeting the state's energy needs (MWh), the electric system must also meet expected peak demand (MW). Generation resources other than wind will be needed to meet most of the projected growth in peak demand, as maximum output from wind resources does not correspond to system peak demand.** *(emphasis added)* ERCOT currently assigns 10% of the installed capacity of wind turbines to its calculation of the ERCOT peak capacity reserve margin. Based on a review of historical data of actual wind turbine generation during ERCOT system peaks (from 4 p.m. to 6 p.m. in July and August), the average output for wind turbines was 16.8% of capacity. However, the data also showed that for any hour during these months, the output of the wind turbines could range from 0% of installed capacity to 49% of installed capacity. Stakeholders comprising the ERCOT Generation Adequacy Task Group have expressed concern that use of an average number (i.e., 16.8%) was too optimistic because it fails to adequately recognize the intermittency of wind generation. **Accordingly, the group is working to assign a peak capacity value for wind using an appropriate "confidence factor." While the group has not yet formally made a recommendation to the ERCOT Technical Advisory Committee, it is currently considering recommending a wind capacity value of 2%. In summary, in order to reliably meet system peak demand, dispatchable resources (such as gas, coal, biomass) would be required to replace the wind resources when wind is not blowing.** *(emphasis added)*

ERCOT's more conservative assessment is shared by Energy Probe's recent study of Ontario wind plants: (9)

In Ontario, the IESO assumes that 10% of the installed capacity should be considered as firm capacity for meeting peak demands. A Pembina Institute study has commented on this assumption, "Given that the capacity factor for modern land-based wind turbines is accepted to range from 25%–40%, and that wind generating capacity in Ontario will be relatively geographically distributed, this may be an excessively conservative assumption."

**Both the GE Study conclusion and the IESO's forecast about firm summer peak reliability are inconsistent with Ontario's actual experience.** *(emphasis added)*

During July and August 2006, the actual average frequency of hours when there was little or no wind output in Ontario – output less than 2% – was 18.6%. These very low production hours were about as likely to occur during the daily peak

period as any other time during the day. Ontario's experience in 2006 shows that the conclusion of the GE Study that wind can reliably supply power in summer equal to 17% of its rated capacity significantly over-estimated the actual results. **The actual results for the summer of 2006 also suggest that the IESO should review its forecast that even 10% of the installed wind capacity should be considered as firm capacity for meeting peak demands. During the summer of 2006, wind power provided no firm generation capacity during the peak months.** (*emphasis added*)

The German grid operator, Eon Netz, - one of the world's largest managers of wind energy addresses wind's *capacity credit* in its 2005 Annual Report as follows: (10)

**Wind energy is only able to replace traditional power stations to a limited extent.** (*emphasis added*) Their dependence on the prevailing wind conditions means that wind power has a limited load factor even when technically available. It is not possible to guarantee its use for the continual cover of electricity consumption. **Consequently, traditional power stations with capacities equal to 90% of the installed wind power capacity must be permanently online in order to guarantee power supply at all times.** [*emphasis added*]

While capacity factors for U.S. industrial wind plants are known, (11) *capacity credits* for these facilities do not appear to be available. Even if available, it would be inappropriate, as noted above, to extrapolate a given wind plant's *capacity credit* to other sites as it is highly site-specific. That said, the above experiences suggest that, in the absence of hard evidence to the contrary, caution should prevail when projecting wind energy's *capacity credit*. Experience belied the presumed *capacity credit* for wind energy in Texas and Ontario. In California, the previously referenced reports (6) described wind energy's performance during summer 2006 as disappointing. (12)

## Related Issues

### A. CO2 Emissions: (13)

A primary reason for considering wind as 'part of our energy mix' is that it is emissions free; and that every MWh produced by wind energy displaces one MWh produced by other electricity generating sources. While theoretically true for electricity *generation*- given the grid's matching of production and consumption instantaneously and continuously- it is not true for *emissions* because wind is intermittent and often 'off-peak'.

Because wind is intermittent, grids must have 'fast responsive' backup generating sources available at all times to ensure grid stability and reliability.

The 'fast responsive' generating units of choice for most grids to backup wind's intermittency are conventional hydro power (if available) and natural gas. Hydro is emissions free while natural gas is relatively emissions benign. (14)

Because wind is often ‘off-peak’, e.g. it blows more at night when demand is low and less during the day when demand is high, grids aren’t always able to ‘ramp down’ base-load generating units that are economically and operationally designed to generate electricity continuously.

The base-load generating units of choice for most grids are coal, nuclear power and/or conventional hydropower (if available). Nuclear power and hydropower are emissions free. Large ‘slow responsive’ coal generating units designed to provide base-load capacity are not suited- economically or operationally- for providing ‘standby’ generating capacity. **Where wind generation displaces coal generation the emissions emanating from ‘standby’ coal units- operating inefficiently- may offset assumed emissions savings.** (15)

In sum, the emissions displaced - *if any*- by wind energy is grid specific, i.e. emissions displacement is a function of which and how specific generating units are impacted by wind generation. **Perhaps more importantly, given wind energy’s limited capacity credit, future emissions levels will be determined largely by the reliable generating sources we choose to meet growing electricity demand.**

### *Vermont Specific*

Vermont CO2 emissions are generated by transportation (56.4%), followed by residential (24.5%), commercial (10.7%), industrial (7.9%) and electric power (0.47%). (16)

**Vermont’s share of NEPOOL CO2 emissions from electricity generation is statistically insignificant-** in 2005, Vermont generated 13,582 metric tons of CO2 or 0.02% of total NEPOOL CO2 emissions. NEPOOL, in turn, accounts for 2.24% of total US CO2 emissions from electricity generation. (17) This performance is attributable to Vermont’s emissions benign electric generation portfolio. (18)

**These figures suggest that Vermont environmental initiatives should focus on reducing automobile/truck emissions and on expanding current programs designed to improve residential efficiency and conservation.**

## **B. Transmission**

Recent studies (19) suggest that the impact of wind’s intermittency on a grid’s operations and associated costs can become significant when installed wind capacity reaches 10%-20% of peak demand based upon capacity. Wind energy’s impact on a specific grid will depend on its ‘robustness’, specifically whether transmission constraints exist or not between the location of wind generation and demand areas. At Vermont’s current peak demand of 1,100MW and assuming Vermont’s transmission capacity is adequately robust, this suggests that Vermont could accommodate 110MW- 220MW of installed wind capacity before encountering significant operating and cost issues. This range of installed capacity would mean 67-133 turbines on 11-22 miles of ridgeline providing between 0.5% and 2.0% of Vermont’s peak demand. (20)

### C. Incentives

Legislation promoting renewable energy (e.g. Production tax credits <sup>(21)</sup>, Renewable Portfolio Standards, Renewable Energy Credits, etc) should reflect the *value* of their respective contributions to (1) ‘on-peak and on-season’ energy generation, (2) system stability and reliability and (3) net emissions reduction as well as *require* each and every facility to provide *verifiable* and transparent evidence of these benefits. **For example, current incentives generally do not differentiate between the value of biomass, a source of base-load generation, and wind energy which contributes little to meeting peak demand and does not obviate the need to build additional reliable capacity as peak demand grows.**

Differentiation among the various alternatives available based on their *value* is consistent with optimizing investment returns and minimizing ratepayers’ costs which, after ensuring system stability and reliability, is a grid’s primary objective. For example, the cost of Renewable Energy Credits (RECs) is passed on to *all ratepayers* and is, as such, equivalent to a *regressive* energy tax. **Differentiation would minimize the impact of this energy tax on consumers by favoring energy sources that provide more value towards meeting the capacity required to meet peak demand.**

In sum, and from a somewhat broader perspective, we should be encouraging energy sources that (1) are reliable and add capacity to meet peak demand, (2) meet or exceed relevant environmental laws, and (3) are low cost and built close to demand areas to minimize transmission costs. The comparative cost analysis should include all costs, i.e. fixed costs, variable costs and the costs of incentive programs. ERCOT’s comparative analysis of the costs, characteristics, benefits and drawbacks by alternative electricity generating sources provides a helpful framework though this analysis does not include conventional hydropower. (Exhibit C)

## Endnotes:

(1) Vermont Public Interest Research Group (VPIRG), “A Decade of Change: A Vision for Vermont’s Renewable Energy Future” (Summer 2006); <http://www.vpirg.org/documents/decadeofchange.pdf>

(2) Hugh Kemper is retired and resides in Londonderry, Vermont. He is editor of Industrial Wind Action Group’s (IWA) web page, [www.windaction.org](http://www.windaction.org). IWA is dedicated to providing the public with facts relating to industrial wind energy so that the cost-benefit evaluation of wind energy vs. alternative energy sources can be conducted in an informed manner. The web site contains over 6,800 items comprised of news articles, opinion pieces, research, photos and quotes pertinent to industrial wind energy. [hughkemper@adelphia.net](mailto:hughkemper@adelphia.net), 802-824-4287.

(3) North American Electric Reliability Council: <https://standards.nerc.net/>

(4) Gordon Fraser, ‘Power usage expected to break records, but supply adequate’, Eagle Tribune 2 August 2006; [http://www.eagletribune.com/nhnews/local\\_story\\_214163204?page=1](http://www.eagletribune.com/nhnews/local_story_214163204?page=1)

CVPS spokesperson Stephen Costello-“Everything is coming together: heat, humidity, relatively low wind at this point.”

Bruce Edwards, “Vermont Energy Demands Near Record”, Rutland Herald 3 August 2006;

<http://www.timesargus.com/apps/pbcs.dll/article?AID=/20060802/NEWS/608020359/1002/NEWS01&template=printart>

Other quotes of interest pertaining to Vermont

GMP’s spokeswoman on one of the hottest days in August ’02- “I called our dispatch to ask how much power we were getting from Searsburg and he said ‘zero’. The blades were not turning.”\*

Sue Robinson, “Energy Change is in the wind”, Burlington Free Press 24 November 2002

<http://www.BurlingtonFreePress.com>

GMP’s CEO to reporter- “On the hottest days when there’s peak demand for energy, the wind generally doesn’t blow.”

“GMP Head Seeks Energy Diversity”, Montpelier Bridge, p. 3, 9 September 2003

(5) Pitt, L et al, Utility-scale Wind Power: Impacts of Increased Penetration, Resource and Environmental economics and Policy Analysis (REPA) Research Group, Department of Economics, Victoria University (2005-02); <http://repa.econ.uvic.ca/publications.htm>

(6) David Dixon, “Wind Generation’s Performance during the July 2006 California Heat Storm”, Energy Pulse 9 September 2006; [http://www.energypulse.net/centers/article/article\\_print.cfm?a\\_id=1332](http://www.energypulse.net/centers/article/article_print.cfm?a_id=1332).

Please note the text of the article refers to peak demand occurring in August. The heat storm actually occurred in July as the supporting data in the article attests.

(7) Esther Whieldon, “CAL-ISO Offers Sobering Wind Assessment: It’s Growing but can’t be Relied On as Capacity”, Platts Power Markets Week 21 August 2006;

[http://construction.ecnext.com/coms2/summary\\_0249-190132\\_ITM\\_platts](http://construction.ecnext.com/coms2/summary_0249-190132_ITM_platts)

Dispatched refers to generating units that can be turned off/on and ramped up/down in response to changes in demand for electricity.

(8) Electricity Reliability Council of Texas, “Transmission Issues Associated with Renewable Energy in Texas”, An Informal White Paper for the Texas Legislature 2005;

<http://www.ercot.com/news/presentations/2006/RenewablesTransmissi.pdf>

(9) Tom Adams, “Review of Wind Power Results in Ontario: May to October 2006”, Energy Probe 16 November 2006; <http://www.energyprobe.org/energyprobe/articles/EPReviewofwindpowerresults.pdf>

(10) E.ON Netz, "E.ON Netz Wind Report 2005";  
[http://www.viewsofscotland.org/library/docs/EON\\_Netz.report.2005\\_e\\_eng.pdf](http://www.viewsofscotland.org/library/docs/EON_Netz.report.2005_e_eng.pdf)

(11) State of Maine-Land Use Regulation Commission, Pre-Filed Direct Testimony of Thomas A. Hewson Jr. On Behalf of The Friends of Western Mountains, August 2006; pages 19-21;  
<http://www.windaction.org/documents/4591>

Capacity Factor is the ratio of the actual energy produced in a given period to the hypothetical maximum possible, i.e. running full time at rated power. For example, a wind turbine with a power rating of 2000 kW that runs (hypothetically) at full power for an entire year would generate 17, 520,000 kWh per the following calculation- [(2000 kW)\*(365 days)\*(24 hours) = 17, 520,000 kWh. However, if it generated 4,380, 000 kWh for the entire year it operated at a 25% capacity factor (4,380,000/17,520,000 = 25%).

The U.S. national average capacity factor was 29% in 2005 for industrial wind plants. As a rule, eastern U.S. wind plants do not perform as well as western wind plants. VPIRG's analysis assumes a 32% capacity factor. Searsburg's 2005 capacity factor was 21.5%

**Reported Wind Project Performance From EIA Form 906 Data: 2005**

8 Reporting Wind Projects in Appalachian Mountains/Eastern States

Operator/Utility	Pitname	State	Capacity	Generation	Capacity
			MW	MWh	Factor
Fenner Wind Project	Fenner Wind	NY	30	51,849	26.2%
NWP Indian Mesa Wind Farm LP	Madison Windpower	NY	11	19,381	19.8%
FPL E Waymart Wind LLC	Waymart Wind	PA	65	142,044	24.9%
FPL Energy Meyersdale Windpower LLC	Meyersdale Windpower	PA	33	28,827	29.6%
Mill Run Windpower LLC	Mill Run Windpower	PA	15	14,059	32.0%
Tennessee Valley Authority	Buffalo Mountain	TN	2	3,339	18.2%
Green Mountain Power Corp.	Searsburg Wind Turb	VT	6	11,466	21.5%
GH Drilling Inc.	Backbone Mountain Wind	WV	66	59,657	30.9%
Total U.S.			5,840	12,913,127	29.0%

A wind plant's projected capacity factor is often used to estimate the number of 'households served'. According to the Energy Information Agency, the average US household uses 888 kWh per month or 10,656 kWh per year. Thus, for example, the estimated number of households served annually by a 2.0MW wind turbine operating at a capacity factor of 29% for a full year would equal 476.8 households:

$$\text{(Rated MW capacity} \times \text{Conversion to kW} \times \text{Capacity Factor} \times \text{Days} \times \text{Hours}) / 10,656 = \# \text{ Households} \dots$$

$$(2.0 \times 1,000 \times 29\% \times 365 \times 24) / 10656 = 476.8 \text{ Households}$$

This is the *average* number of homes served throughout the year. The actual number of homes served at any given time is a function of wind velocity. As the electricity produced is in the ratio of the cube of the wind velocity, there is a dramatic difference in the number of homes served at low vs. high wind speeds.

(12) Wind energy's performance was also disappointing in the Pacific Northwest during last summer's period of heat induced peak demand. On Aug 21, when afternoon temperatures in Washington soared, Avista Corp's (AVA) utility division asked customers to cut their electricity use while it scoured the region

for power supplies. **Utility operators were frustrated, in part, because the company's supply of wind power was producing nothing, thanks to a lack of wind** (emphasis added)... "Typically in the Northwest, very hot weather means high pressure, and high pressure means no wind", said Steve Silkworth, who is in charge of buying renewable energy for Avista Utilities.\*\*

\*\*Mark Golden, "As heat sizzles, growing wind power fizzles", Market Watch 1 December 2006

<http://www.marketwatch.com/news/story/heat-sizzles-growing-wind-power/story.aspx?guid=%7BDD65E18A-123E-47E1-903F-E4F732038A53%7D>

(13) Petroleum is the principal source (44%) of U.S. CO2 emissions followed by Coal (35.4%), natural gas (20.4%) and other (0.2%). \*

Coal generates 53% of U.S. electricity followed by nuclear power (21.6%), natural gas (13.5%), renewable sources (8.8%- primarily conventional hydropower), and petroleum (3.0%). \*\*

Electricity generation represents 39% of U.S. CO2 emissions. Within the electricity sector, coal accounts for 82.4% of CO2 emissions followed by Natural Gas (12.9%) and petroleum (4.2%). \*

\*United States, Department of Energy, Energy Information Administration, Annual Energy Outlook 2006 with Projections to 2030, Table A18; <http://www.eia.doe.gov/oiaf/aeo/pdf/appendixes.pdf>

\*\*United States, Department of Energy, Energy Information Administration, Annual Energy Outlook 2006 with Projections to 2030, Table A8; <http://www.eia.doe.gov/oiaf/aeo/pdf/appendixes.pdf>

(14) Natural gas generates approximately 1.314 pds/kWh of CO2 vs. Coal (2.117 pds/kWh) and petroleum (1.915 pds/kWh).\*

\*United States, Department of Energy, Environmental Protection Agency, Carbon Dioxide Emissions from the Generation of Electric Power in the United States July 2000, page 2. <http://tonto.eia.doe.gov/FTP/ROOT/environment/co2emiss00.pdf>

The CO2 emissions displaced by wind energy are a function of installed wind energy capacity, its capacity factor and the fossil fuel generating units displaced (if any) by wind generation. According to the American Wind Energy Association there was 9,149 MW of installed wind energy capacity at the end of 2005. Applying the 2005 national average capacity factor of 29% and assuming the displacement of natural gas, wind energy's gross annual CO2 savings approximates 30,540,145,154 pounds:

Installed Capacity x conversion to kW x capacity factor x days x hours x pds/kWh = CO2 pounds saved  
(9,149) x (1000) x (29%) x (365) x (24) x (1.314) = 30,540,145,154

This estimated gross savings represents 0.6% of total CO2 emissions from U.S. electricity generation in 2004 (2,298.6 million metric tons). CO2 emissions from electricity generation are expected to increase 1.4% p.a. thru 2030. \*\*

\*\*United States, Department of Energy, Energy Information Administration, Annual Energy Outlook 2006 with Projections to 2030, Table A18; <http://www.eia.doe.gov/oiaf/aeo/pdf/appendixes.pdf>

The net CO2 emission savings from wind generation is a function of the grid specific impact of wind generation. If, for example, hydro and/or nuclear generation is displaced, there are no emissions savings. If fossil fuel generating units are displaced, the gross estimated savings from wind generation will be reduced by emissions generated by these units serving in a 'standby/reserve' capacity.

(15) O. Liik, R. Oidram & M. Keel; Estimation of Real Emissions Reduction Caused By Wind; Tallinn Technical University, Estonia; 24 July 2003; [http://www.etsap.org/worksh\\_6\\_2003/2003P\\_liik.pdf](http://www.etsap.org/worksh_6_2003/2003P_liik.pdf)

David White, Reduction in Carbon Dioxide Emissions: Estimating the Potential Contribution from Wind Power, Renewable Energy Foundation, UK December 2004  
<http://www.ref.org.uk/images/pdfs/Whiteco2.pdf>

(16) United States, Environmental Protection Agency, CO2 Emissions From Fossil Fuel Consumption;  
[http://www.epa.gov/climatechange/emissions/downloads/CO2FFC\\_2003.pdf](http://www.epa.gov/climatechange/emissions/downloads/CO2FFC_2003.pdf)

(17) United States, Department of Energy, Energy Information Agency, Electric Power Industry Estimated Emissions by State (EIA-767 and EIA-906);  
[http://www.eia.doe.gov/cneaf/electricity/epa/emission\\_state.xls](http://www.eia.doe.gov/cneaf/electricity/epa/emission_state.xls)

<b>2005</b>			
<b>(metric tons)</b>	<b>CO2</b>	<b>SO2</b>	<b>NOX</b>
CT	11,541,609	7,758	10,518
MA	26,821,851	76,346	30,823
ME	7,057,588	22,033	11,629
NH	8,166,077	46,949	11,179
RI	2,601,956	564	2,131
VT	<u>13,582</u>	<u>64</u>	<u>484</u>
NEPOOL	56,202,663	153,714	66,764
VT/NEPOOL	<b>0.02%</b>	<b>0.04%</b>	<b>0.72%</b>
USA	2,513,609,417	10,339,530	3,961,135
NEPOOL/USA	2.24%	1.49%	1.69%
VT/USA	<b>0.00%</b>	<b>0.00%</b>	<b>0.01%</b>

(18) Vermont, Department of Public Service, 2005 Vermont Electric Plan January 2005; page 4-18 and Fig 9-2; <http://publicservice.vermont.gov/pub/state-plans/state-plan-electric2005.pdf>

<b>Vermont Electricity Generating Portfolio</b>	<b>100%</b>	
Percentage Contribution by Source		
Demand Side Management	6.5%	
<u>In-State</u>	<u>47.4%</u>	
Vermont Yankee	33.9%	<i>emissions free</i>
Small Hydro	6.4%	<i>emissions free</i>
Other Renewables	4.6%	
Gas & Oil	2.5%	
<u>Out-of-State</u>	<u>46.1%</u>	
System (Market)	13.5%	
Hydro Quebec	32.6%	<i>emissions free</i>

(19) United States, National Renewable Energy Laboratory, Grid Impacts of Wind Power Variability: Recent Assessments from a Variety of Utilities in the United States 2006;  
<http://www.uwig.org/Ewec06gridpaper.pdf>

Examples of costs incurred (a.k.a. 'ancillary service' costs) to accommodate wind generation and maintain system reliability and security are (1) committing unneeded generation, (2) allocating more load-following capability and (3) allocating more regulation capacity.

(20)

Miles of Ridgeline >2500'	517				
Vermont Peak Demand		MW	1,100	1,100	1,100
<b>Provided By:</b>					
Installed Wind Plants' Capacity		MW	110	110	220
Turbine Rated Capacity		MW	1.65	1.65	1.65
<b>Capacity Credit</b>			<b>10.0%</b>	<b>5.0%</b>	<b>10.0%</b>
Contribution to Peak Demand		MW	11.0	5.5	22.0
<b>% Peak Demand</b>			<b>1.0%</b>	<b>0.5%</b>	<b>2.0%</b>
Contribution of one industrial wind turbine to peak demand		MW	0.1650	0.0825	0.1650
Number of Turbines Required			67	67	133
Number of Turbines per mile			6	6	6
Miles of Ridgeline Dedicated to wind turbines			11	11	22
<b>% of Ridgeline &gt;2500' dedicated to Industrial wind turbines</b>			<b>2.1%</b>	<b>2.1%</b>	<b>4.3%</b>

The possible cost implications to transmission systems with growing penetration of wind energy caused by its intermittency raise once again the 'footprint' issue. For comparative purposes, the analysis below approximates the ridgeline miles required to displace Vermont Yankee's base-load generation contribution to Vermont's peak demand and to NEPOOL.

Prior to the recent expansion of Vermont Yankee's gross capacity (540MW to 650MW), Vermont's purchases totaled 273MW or approximately 54% of Vermont Yankee's net capacity (506MW).

[http://www.eia.doe.gov/cneaf/nuclear/page/at\\_a\\_glance/reactors/vermontyankee.html](http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/vermontyankee.html)

Vermont Electric Corporation has purchased for four years 10MW of Vermont Yankee's expanded capacity. <http://jeffords.senate.gov/rh030306.pdf> Thus, Vermont's purchases total 283MW representing approximately 46.5% of Vermont Yankee's expanded net capacity and 25.7% of Vermont's peak demand.

The analysis suggests that replacing Vermont's share of Vermont Yankee's electricity generation at a 5% capacity credit for wind energy would require 572 miles of ridgeline (110.6% of available ridgelines =>2500') and at a 10% capacity credit 286 miles of ridgeline (55.3%). To displace Vermont Yankee's entire electricity generation would require between 615 miles (at 10% capacity credit for wind) and 1230 miles (at 5% capacity credit) of New England ridgelines.

Vermont Peak Demand		MW	1100	1100
Miles of Vermont Ridgeline > 2500'	517			
<b>Provided By:</b>				
Installed Wind Plants' Capacity		MW	2830	5660
Turbine Rated Capacity		MW	1.65	1.65
<b>Capacity Credit</b>			<b>10.0%</b>	<b>5.0%</b>
Vermont Yankee (VY) Contribution to Peak Demand		MW	283	283
<b>VY % Contribution to Vermont Peak Demand</b>			<b>25.7%</b>	<b>25.7%</b>
Contribution of one industrial wind turbine to peak demand		MW	0.1650	0.0825
Number of Turbines Required			1715	3430
Number of Turbines per mile			6	6
Miles of Ridgeline Dedicated to industrial wind turbines			286	572
<b>% of Ridgeline &gt;2500' dedicated to Industrial wind turbines</b>			<b>55.3%</b>	<b>110.6%</b>
Estimated Vermont % Share of Vermont Yankee (VY) Capacity			46.5%	46.5%
Estimated Total Vermont Yankee Capacity		MW	609	609
Number of Turbines Required to Displace VY Capacity			3688	7377
<b>Miles of N.E. Ridgeline Required to Displace VY Capacity</b>			<b>615</b>	<b>1229</b>

While there are varying estimates of Vermont Yankee's net capacity, Vermont Yankee provides reliable base-load generation. Its capacity factor varies somewhat depending on whether outages for refueling are required. "In 2003, a year without a refueling outage, it operated at a capacity factor of 99.5%. In 2001 and 2002 (years with refueling outages) it operated at an average capacity factor of 91%" [DPS 2005 Vermont Electric Plan, page 4-7] Given this capacity factor variance, NEPOOL presumably accords Vermont Yankee a capacity credit for meeting peak demand of approximately 91%.

The large discrepancy between the 'footprint' required by Vermont Yankee (approximately 1/3 square mile) and 615 to 1229 miles of ridgeline reflects the spacing required by wind turbines to maximize their operating efficiency. Wind turbines are engineered to rotate at speeds of 5-6 times wind speed up to velocities of approximately 35-40 mph above which they are tethered to avoid structural damage. To optimize performance each turbine's space should have unimpeded exposure to the wind and be free of 'wake turbulence' generated by nearby turbines. While the spacing for each location will be site specific- depending on topography and the directional consistency of wind- there are *general rules* that do apply. When grid configured, a 1.5MW turbine generally requires 40 acres, a 2.0-2.5 MW turbine 70 acres. When configured side-by-side along a ridgeline, 1.5MW turbines can be generally spaced at +/- 8 turbines per mile while 2.0-2.5MW turbines are limited to +/- 5 per mile.

(21) On May 13, 2005 Senator Lamar Alexander (R-TN) had the following comments about Renewable Portfolio Standards and the federal production tax credit (currently 1.9 cents per/kWh) during a press conference to introduce The Environmentally Responsible Wind Power Act of 2005.  
[\[http://www.windaction.org/documents/126\]](http://www.windaction.org/documents/126)

It is important for our colleagues to know that a Renewable Portfolio Standard or RPS is all about wind. There are very few opportunities to build new dams and expand hydro power, which produces 7 of the 9 percent of renewable power we use today. Of the remaining 2 percent of renewal power sources, current subsidies aren't enough to increase solar power by very much. More research and development is needed to make biomass more efficient. And there is limited availability of geothermal power, that is, drawing power from water that is heated underground.

Experts agree that the bottom line is that a requirement that electric companies produce 10 percent of their electricity from renewable energy, if it could be achieved at all, would mean that about 70 percent of the increase would come from wind. In other words, we would go from producing about 1 percent of our electricity from wind to 7 or 8 percent.

Testimony before our Energy Committee and most other sources suggest that to produce this much wind energy in the United States could require building more than 100,000 of new, massive wind turbines. We have less than 7,000 such windmills in the U.S. today, with the largest number in Texas and California.

Testimony also indicated that, even without the RPS, if Congress continues its sustained generous subsidy for wind production for the next 10 years, it will guarantee that the U.S. has about 100,000 of these windmills by 2025. According to the Treasury Department, this wind subsidy, if renewed each year for the next five years, would reimburse wind investors for 25 percent of the cost of wind production and cost taxpayers \$3.7 billion over those 5 years. General Electric Wind, one of the largest manufacturers of wind turbines, has experienced a 500 percent growth in its wind business this year due to the renewal of the wind production tax credit last year.

I want to make sure that my colleagues know that there are serious questions about how much relying on wind power will raise the cost of electricity, questions about whether there are better ways to spend \$3.7 billion in support of clean energy, questions about whether wind even produces the amount of energy that is claimed. My studies suggest that at a time when American needs large amounts of low-cost reliable power, wind produces puny amounts of high-cost unreliable power. We need lower prices; wind power raises prices.

**EXHIBIT A**

**Vermont Energy/Ridgeline Profile**

		<b>VPIRG 2015</b>		<b>Capacity 2006</b>		<b>Credit 2006</b>		<b>Capacity VPIRG 2006</b>	<b>Credit VPIRG 2006</b>	
Projected Annual Consumption	MWh	6,200,000	(1)	N/A		N/A				
Projected Average Daily Consumption	MWh	16,986		N/A		N/A				
Projected Average Hourly Consumption	MW	708		N/A		N/A				
Peak Demand	MW	N/A		1,100	(3)	Same		1,100	Same	
Miles of Ridgeline >2500'		517		Same		Same				
<b>Provided By:</b>										
Installed Wind Plants' Capacity	MW	450		Same		Same				
Turbine Rated Capacity	MW	1.65		Same		Same				
<b>Capacity Factor</b>		<b>32.0%</b>	(2)	N/A		N/A				
<b>Capacity Credit</b>		N/A		<b>10.0%</b>	(4)	<b>5.0%</b>		<b>10.0%</b>	<b>5.0%</b>	
Annual Production	MWh	1,260,000		N/A		N/A				
Contribution to Peak Demand	MW	N/A		223		Same		45	23	
% of Total Vermont Annual Consumption		<b>20.3%</b>		N/A		N/A				
<b>% of Peak Demand</b>		N/A		<b>20.3%</b>		Same		<b>4.1%</b>	<b>2.1%</b>	
Total Annual Production of Single 1.65MW Turbine	MWh	4599		N/A		N/A				
Contribution of one industrial wind turbine to peak demand	MW	N/A		0.165		0.0825		0.165	0.0825	
Number of Turbines Required		274		1353		2707		274	Same	
Number of Turbines per mile		6		Same		Same		6	Same	
Ridgeline Miles Dedicated to industrial wind turbines		46		226		451		46	Same	
<b>% of Ridgeline &gt;2500' dedicated to ind. wind turbines</b>		<b>8.8%</b>		<b>43.6%</b>		<b>87.3%</b>		<b>8.8%</b>	Same	

(1) VPIRG's analysis assumes conservation and energy efficiency measures can reduce Vermont's annual electricity consumption by 5% vs. 2005 levels. Thus projected 2015 annual consumption of 6,200,000 MWh's is below the 6,500,000 MWh's assumed to have been consumed in 2005. It should be noted that VPIRG's 2005 starting point, i.e. approximately 6,500,000 MWh's, is less than the consumption level reported, i.e. 5,882,483 MWh's (an avg. of 16.116 MWh's per day and 671.5 MWh's per hour) by Vermont DPS in its "Draft Update to the 2005 Vermont Electric Plan"; <http://publicservice.vermont.gov/pub/other/drafteplanupdate.pdf>. It is also noteworthy that this Plan's projected 2015 annual consumption is a relatively flat 5,967,000 MWh's (16,347 MWh's per day/681.2 MWh's per hour) with various Demand Side Management (DSM) initiatives and 6,847,000 MWh's (18759 MWh's per day/781.6 MWh's per hour) without DSM initiatives.

(2) Capacity Factor is addressed in endnote (12); 32% (vs. a national average of 29%) is high for eastern wind plants; Searsburg's capacity factor was 21.5% (2005).

- (3) The capacity implications of the difference between Vermont's peak demand (MW) and average consumption (MWh) are significant. As DPS notes: **"Peak electric demand is a major determinant for setting the capacity of an electric supply system because a reliable electrical system is one that can meet every hour of demand"**. (emphasis added) (DPS' Draft updated 2005 Electric Plan, page 41)

Peak demand (MW)- current and forecast- per the aforementioned DPS plan update is as follows- with (w) and without (wo) DSM initiatives:

2006	2006	2006	2006	2015	2015	2015	2015
Summer	Summer	Winter	Winter	Summer	Summer	Summer	Winter
<u>w/DSM</u>	<u>wo/DSM</u>	<u>w/DSM</u>	<u>wo/DSM</u>	<u>w/DSM</u>	<u>wo/DSM</u>	<u>w/DSM</u>	<u>wo/DSM</u>
1,084	1,094	1,040	1,063	1,163	1,341	927	1,214

August '06 press reports mention a new Vermont peak demand record vs. previous record (December '05). This apparent record peak demand occurred at the same time NEPOOL appears to have recorded a new peak demand record, i.e. 28,030 MW's on 8/2/06 vs. 30,345 MW's in available capacity.

\*Bruce Edwards, 'Vermont energy demands near record', Times Argus 3 August 2006

<http://www.timesargus.com/apps/pbcs.dll/article?AID=/20060802/NEWS/608020359/1002/NEWS01&template=printart>

Gordon Fraser, 'Power usage expected to break records, but supply adequate', Eagle Tribune 2 August '06

[http://www.eagletribune.com/nhnews/local\\_story\\_214163204?page=1](http://www.eagletribune.com/nhnews/local_story_214163204?page=1)

- (4) Capacity credit is a measure of a generating source's contribution to system reliability and is tied to meeting peak demand. The rationale for a range of 5%-10% is discussed in detail in the body of this report.

**EXHIBIT B**

**Green Mountain Power Corporation: Searsburg**

Rated Capacity MW 6.0  
 Est. Annual Production @ 100% Capacity Factor MWh 52,560

(rated capacity x 100% x 365 days x 24 hours) = MWh's per annum operating at a 100% capacity factor

	Year	2005	2004	2003	2002	2001	2000
<b>ANNUAL PRODUCTION</b>							
MWh Annual Wind Production	(2)	(endnote #11)	11,023	10,828	11,458	12,135	12,246
Estimated Annual Capacity Factor			21.0%	20.6%	21.8%	23.1%	23.3%
<i>MWh Annual Production net of Renewable Energy Credits Sold</i>	(1)	1,484	0	8,568	9,577	12,135	
<b>PEAK DEMAND</b>							
Month During Which Peak Demand Occurred		July	Dec	(3) Aug	(4) Aug	(5) Aug	(6) Jan
Capacity In Month of Peak Demand	MW	0.960	0.960	0.480	0.480	0.480	0.850
Est. Capacity Factor in Month of Peak Demand		16.0%	16.0%	8.0%	8.0%	8.0%	14.2%
Day of Maximum One-Hour Peak Demand		July 19	Dec 21	Aug 5	Aug 15	Aug 9	Jan 17
Maximum One-Hour Peak Demand	MW	351.9	326.7	330.2	342.0	341.2	323.5
<b>Capacity At Maximum One-Hour of Peak Demand</b>	MW	????	????	????	????	????	????
<b>Contribution to Maximum One-Hour Peak Demand</b>		????	????	????	????	????	????

Green Mountain Power Corporation, SEC Form 10-K for years FY 2005-2000

- (1) <http://www.sec.gov/Archives/edgar/data/43704/000004370406000023/gmpform10k2005.htm>
- (2) <http://www.sec.gov/Archives/edgar/data/43704/000004370405000021/annualreporton10k.txt>
- (3) <http://www.sec.gov/Archives/edgar/data/43704/000004370404000026/doc1.txt>
- (4) <http://www.sec.gov/Archives/edgar/data/43704/000004370403000002/gmpcorp200210k.txt>
- (5) <http://www.sec.gov/Archives/edgar/data/43704/000004370402000005/secform10k2001.txt>
- (6) <http://www.sec.gov/Archives/edgar/data/43704/000004370401000017/0000043704-01-000017.txt>

## Exhibit C

### ERCOT CHART OF COST, CHARACTERISTICS, BENEFITS AND DRAWBACKS BY ELECTRICITY SOURCE

[endnote #7, page 8]

The following chart, developed by ERCOT staff with stakeholder input, is intended as a point of reference only and does not represent a comprehensive survey or analysis.

Resource	Cost/MWh	(1)	Characteristic	Benefits	Drawbacks
Coal	\$36-40		Base load	Stable fuel cost Stable Cost Slow Responsive	Emissions Long Lead Time High up-front Cost
Natural Gas C.C	(2) \$52-69		Base load	Short lead time Responsive	Volatile fuel cost
Natural Gas C.T.	(3) \$74-115		Base load	Short lead time Quick start Very responsive	Volatile fuel cost
Nuclear	\$36-42		Base load	Stable fuel cost No Emissions Slow Responsive	Permitting/lead time Security Spent fuel disposal
Landfill Gas	\$40		Base load	Low fuel cost	Limited # landfills Small facilities
Biomass	\$48		Base load	Low fuel cost Reduce solid waste	Small facilities
Wind	\$39- \$53	(4) (5)	Intermittent	No emissions No fuel costs Stable cost Low operating cost	Not dispatchable Not responsive Transmission needs Low peak value
Solar Photovoltaic	\$314		Intermittent	No emissions No fuel costs Offsets summer peak load	High upfront cost Not responsive
Solar Thermal	\$169		Intermittent	No emissions No fuel costs Offsets summer peak load	High upfront cost Not responsive

- (1) Approximate generation cost averages with many variables including capital costs, life expectancy, O&M, capacity factor and fuel costs. Excludes ancillary service costs and transmission impacts.
- (2) Combined-cycle plants convert combustion heat into steam to generate additional electricity.
- (3) Single-cycle combustion turbines
- (4) Based on 40% capacity factor
- (5) Based on 30% capacity factor. The cost of wind energy is also subject to other variables including the federal production tax credit and the state Renewable Energy Credit requirement.

**Author's Note:** Wind energy's intermittency and limited capacity credit precludes it from being considered as an electricity source in isolation. *The full cost of wind energy to the grid should include its costs as well as the cost implications of the reliable generating units dedicated to backup wind generation.* This link provides insight into Hydro-Quebec's methodology for backstopping wind energy:

<http://www.hydroquebec.com/learning/eolienne/complementarite.html>