VERMONT ELECTRIC POWER IN TRANSITION

by
The Coalition For Energy Solutions

"We Do The Numbers"

**A professional group dedicated to providing
the public, governments, and industry with evaluated information
about the availability, environmental impact and cost
of energy choices.**

http://www.coalitionforenergysolutions.org/

Abstract

- This Evaluation considers the engineering and costs of the alternative energy proposals made in the Report, *Repowering Vermont*, published by VPIRG/ VPIREF.

- The Evaluation considers only the electricity sources proposed in the Report: wind, solar, biomass, hydro, and market purchases. Vermont Yankee is not evaluated and Vermont Yankee issues may be addressed in a separate document.

- We conclude that the sources proposed in the Report can be built, but the Report does not give capital costs. The Evaluation estimates $8.23 billion to implement the Report's recommendations for the Strong Case, and $4.01 billion for the moderate case.

- While we believe renewable sources should be pursued, full implementation of the Report recommendations cannot happen within a time frame of three to five years (frequently stated by the author in public meetings). Issues of cost and permitting problems will limit or delay applications.

- The Report does not mention or discuss many environmental impacts and effects potentially requiring mitigation.

- Wind power maps show that only the central ridge of Vermont has enough wind for commercial operation of turbines. Many of these locations are remote from transmission lines. More turbines will be required than the Report estimates.

- Variability and intermittency of wind and solar power are significant technical hurdles that limit their addition to the New England grid. Cost (solar) and local opposition (wind) have already slowed deployment of these resources.

- It is unclear whether the wood-fired power supply proposed in the Report is possible. The amount of wood that can be harvested on a sustainable basis is an open question. The Legislature has chartered a Biomass Development Working Group (2009-2012) to answer questions about biomass use.

- Farm methane and landfill methane power burn this gas, which is a far more potent greenhouse gas than carbon dioxide. We favor their use, but were unable to estimate their costs. These power sources (as well as expansion of in-state hydro) will only supply small amounts of electricity.

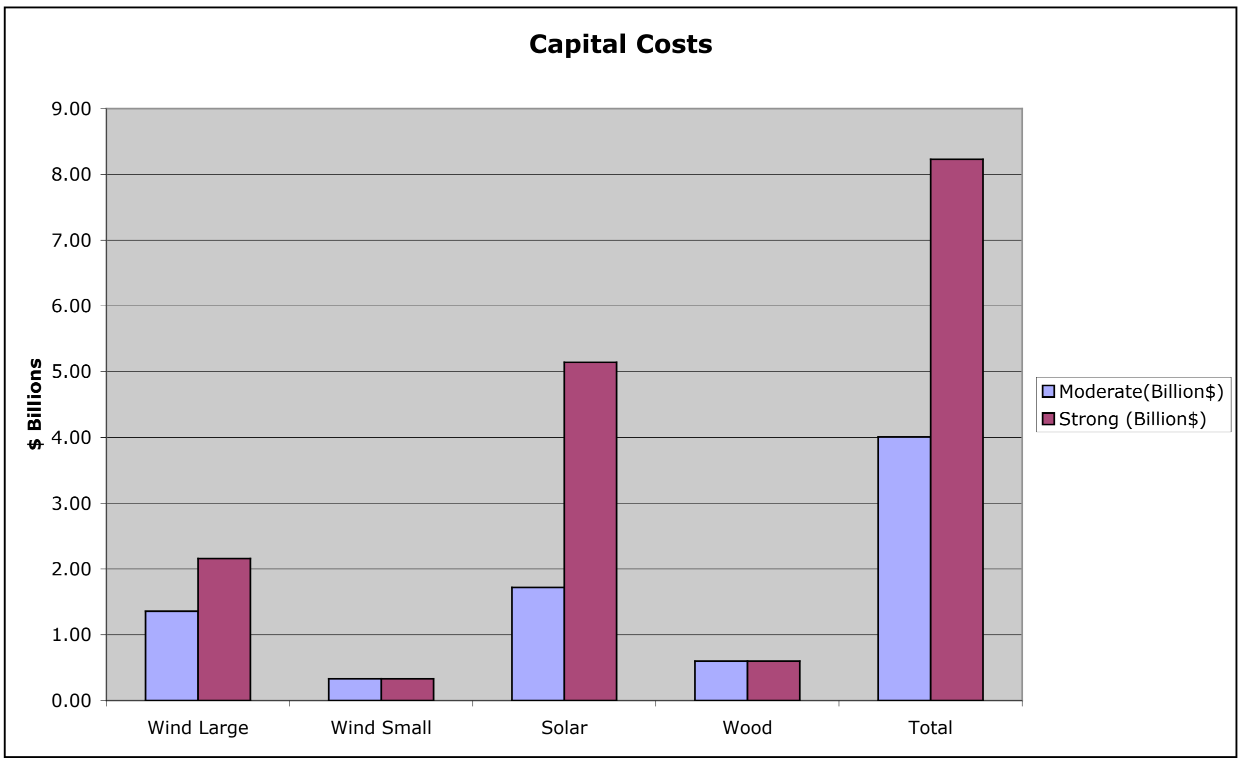
- Vermont will be forced to buy natural gas, coal, and nuclear power from the grid for many years while the new sources are built.

This Evaluation focuses on engineering feasibility and cost. Ultimately, our political process must make choices about energy supply and these choices will include social policy as well as technical considerations. We include some policy considerations in a brief Afterword to the Evaluation.

Capital Cost Summary

Note that costs for farm methane (cow power), landfill methane, and small hydro could not be estimated accurately, so they are not listed, however they are expected to be expensive.

Technology	**Moderate (Billion$)**	**Strong (Billion$)**
Wind Large	1.36	2.16
Wind Small	0.33	0.33
Solar	1.72	5.14
Wood	0.60	0.60
hydro, cow, landfill	0	0
Total	**4.01**	**8.23**



Estimating costs per kWh for renewables is difficult and beyond the scope of this evaluation. We note that Vermont set feed-in tariffs for large wind at 14 cents per kWh, small wind at 20 cents, solar 30 cents, and landfill, biogas, and wood vary between 12 and 16 cents. In contrast, Vermont Yankee offered at 6.1 cents and Hydro Québec is currently at 6.5 cents.

About the Coalition

About the Coalition and the Evaluation. The Coalition for Energy Solutions is a loosely-associated group of energy professionals who study and evaluate energy options. We all have Masters degrees, some are (or were) registered Professional Engineers, and we all live in Vermont or New Hampshire. Some of us teach energy courses at ILEAD.

We did this report on our own time, and have funded printing with our own money. We have accepted no money from outside sources for research or printing our report.

VERMONT ELECTRIC POWER IN TRANSITION

An Evaluation of the Report *Repowering Vermont*, issued by VPIREF

THE COALITION FOR ENERGY SOLUTIONS

"Real Numbers for the Public Good"

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The authors wish to thank these members of the Coalition for their excellent comments and advice. The contents of the report and any errors therein, are solely the responsibility of the authors.

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This report is available on the Coalition's website. The website also contains member's resumes, detailed information, and spreadsheets on issues in this report, and other documents by members.
http://www.coalitionforenergysolutions.org/

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Evaluation Purpose and Methodologies

Vermont's energy situation continues to be a matter of public concern and public policy debate. The effect of energy choices on the economy and the environment are widely debated, with national and international attention. For example, Greenpeace, an international organization opposed to nuclear weapons and nuclear power, opened an office in Burlington.

In the summer of 2009, The Vermont Public Interest Research and Education Fund (VPIREF) issued a report, *Repowering Vermont*, proposing renewable energy supplies to replace the electric power currently generated by Vermont Yankee nuclear plant. (This VPIREF document will be referred to as the Report.)

Shortly after the Report was issued, Coalition for Energy Solutions began an analysis of the energy supplies proposed in the Report in terms of availability, feasibility, cost, and environmental effect. This Evaluation, *Vermont Electric Power In Transition,* describes the results of that analysis. It will be referred to as the Evaluation.

Often proposals are presented that do not have a complete analysis – "set of numbers"- included. To the Coalition, "complete" means all costs, environmental impacts, health impacts including accidents, schedule, and contingencies. Contingencies include what to do while a plan is being implemented, and what to do if the plan doesn't work, or takes longer. Clearly, this is difficult to do, but an attempt must be made, with all assumptions carefully spelled out, not hidden. Conclusions without analysis are merely expressions of wishful thinking.

Purpose of this Evaluation

The Coalition for Energy Solutions strives to provide factual numerical analysis – not just words – on our vital energy choices. We believe that the Report has not provided all the impacts, numbers, and assumptions on which its conclusions are based. There is no way to understand how its results were obtained. Therefore, there is no way to judge whether the results are realistic.

As citizens, members of the Coalition for Energy Solutions participate in the political process, and have opinions on value judgments about energy. However, we will avoid social policy value judgments in the Engineering section of this Evaluation document. Policy considerations are only considered in the Afterword.

Methodology

The Report uses two case studies. The Moderate Case, assumes no growth in electrical use in the next twenty years, with Vermont in 2032 using 6300 GWh per year (Gigawatt Hours per year) as the state does today. The Strong Case assumes that Vermont in 2032 will use 8400 GWh per year, mostly from growth in renewables, and mostly used to power the transportation sector. Wind, solar, biomass, and hydro power are analyzed under both cases.

This Evaluation lists the Report's findings followed by our findings for each type of power, for each case. Our analysis and discussion of environmental effects, economics, and conclusions follow.

The Report makes many other assumptions. It is worth noting, however, that in the Moderate and Strong case, VPIRG assumes that Vermont buys a large part of its power form out of state, as it does now (36% moderate case, 29% strong case).

We have provided numerical results where possible.

In depth studies and spreadsheets are available on the Research and Reports page of our website: www.coalitionforenergysolutions.org

Costs and Environmental Effects

The Report does not show costs for building the proposed supplies, and does not show the cost per kWh (which is what we see on our electric bill) for the new supplies. Studies on these subjects are mentioned in a section called "Economic Analysis Methodology" but there are no links to these studies within the document. Page 15 of the Report asserts that their calculations show 7.3 or 7.8 cents per kWh for the renewable mix. The Report does not describe these calculations. The Report does not calculate the cost per kilowatt-hour for any of the individual technologies, making it impossible to understand the basis for the cost of the entire mix.

In this Evaluation, we have attempted to calculate costs and physical impacts wherever feasible. In addition, with the occasional exception such as logging truck mileage, the Report **assumes** that all proposed renewable sources are environmentally sound and do not require any mitigation to protect the environment. We cannot assess environmental mitigations for so many technologies over such a widespread area, but we do point out some obvious concerns, where warranted, particularly on land use intensity.

Calculating Energy Economics

In many cases, energy economics is difficult to assess, and therefore it is easy to make the numbers come out looking good (for your technology). For example, baseload power plants (fossil and nuclear) run 80-95% of the time, going off-line for maintenance or refueling. They also are described as costing a certain number of dollars "per MW installed capacity."

Renewables are often described as "costing the same or less per MW" as traditional plants. However, the same or less per megawatt *installed* may still mean costing more per kilowatt *delivered*. To understand renewable economics, we must consider capacity factors.

Most renewables, including hydro, solar, and wind are not available 80% of the time. Most hydro plants can make power 30-40% of the time. Wind capacity factors vary from below 20% to 35%. Solar in Vermont has a capacity factor of around 14%. These issues will be discussed more fully in the sections on the various types of energy. However, leaving other factors aside, if a wind turbine can only run 30% of the time, and a fossil plant runs 90% of the time, we would have to install three times as many MW of wind turbines to generate the same number of MWhrs as the fossil plant. This has an effect on the cost and environmental impact of renewables.

In this Evaluation, we show all our assumptions about capacity factors, and justify them. The Report neither shows nor justifies its calculations.

Supply, Backup, and Grid Stability

The current supply system, "the grid" operated by the Independent System Operator, ISO New England, and all a-c grids, have no instantaneous storage. There is nothing on the grid similar to a car battery. Instead, there must always be enough generators running to make up for anything that instantly shuts down.

In addition, the managers (dispatchers) must plan for and have enough generation running to supply forecast needs, on an hourly, daily, yearly and multi year basis. Every type of supply will have some down time, requiring that backup replacement be available. When considering supply options and their costs, the amount of backup needed must be included. A large source of "clean" power that only runs part of the time, in reality is only as "clean" as the backup that runs when it does not. Out of state backup is part of the state's carbon footprint.

If a grid does not have enough backup for sources that shut down, then "instability" will occur. Instability takes the form of frequency swings, and voltage drops that result in brownouts and blackouts. For sources that start and stop frequently where the starting and stopping are not under the Dispatcher's control, backup power that can pick up load rapidly is needed. This backup power must be available or built as intermittent sources are added to the grid. This will eventually limit the amount of wind power that can be connected to the New England grid, but probably won't limit the amount that can be built in Vermont.

Energy Technologies

Wind

Overview of Proposed Wind

By 2032: using **large turbines**

- **Moderate Case**: 145 Turbines of 3 MW average capacity, using 24 miles of mountain ridgeline, to provide one quarter of the electric energy for a year.

  Our Analysis: 181 turbines, 31 miles of ridgeline, for $1.36 billion.

- **Strong Case:** 235 Turbines of 3 MW average capacity using 39 miles of mountain ridgeline, to provide a little more than one quarter (28%) of the electric energy for a year.

  Our Analysis: 288 Turbines, 48 miles of ridgeline for $ 2.16 billion.

By 2032: using **small turbines**

- **Moderate and Strong Cases:** 66 MW capacity, no percentage of the annual energy, number of turbines or locations given.

  Our Analysis: This is possible but there is not enough wind to make these worthwhile, except in special locations. A reported new development of a low speed small turbine could alter this finding.

Analysis

The Report says that it is "astonishing" that a study found that Vermont has 6,000 MW of potential wind energy. The referenced study does use this number, but states that these sites have not been evaluated for technical feasibility, economics, or public acceptance. The Report also states a tiny percentage of ridgelines would be used, without saying how this was determined. Where the turbines can be is all-important. The Report estimates that only 24 to 39 miles of ridgeline will be used for large turbines, and that there are almost 800 miles of suitable ridgeline available in Vermont.

The DOE/NREL map[i] (Department of Energy, National Renewable Energy Laboratory) shows that the level of wind needed to install large turbines (wind level 6 or 7) is only present down the central ridgeline of Vermont, near the Long Trail. This is where national and state forests and hiking trails are located. The Searsburg wind project and proposed Lowell projects are on this ridge, but in low population areas. Much of this central ridge will be needed. At this time, high voltage lines serve only the southern part of ridge area.

The Report assumes that turbines of an **average** capacity 3 MW will be used on the ridgelines. Turbines of 3 MW each are generally used at sea, with consistent sea winds. Turbines of 1.5 to 2.5 MW are used on land, though larger turbines are also used in areas of excellent wind. The Report assumes that these large turbines will be suitable for Vermont's ridges. Using this average capacity permits the Report to claim a shorter ridgeline exposure than might exist with a mix of sizes.

Large Turbines

Wind turbines don't produce power when there is too little or too much wind. Capacity factor is all-important because it determines how many turbines are needed to provide the energy proposed over a year's time. It also determines the miles of ridgeline used and the cost to build, operate, and maintain the extended complex.

The Report does not say what capacity factor is used to get their results. Calculating backwards, the Report appears to use a capacity factor of 34.4%. This is unrealistic. New wind farms on the flat windy plains of Texas and the Dakotas have such high capacity factors. A more likely capacity factor in Vermont is about 0.30[ii]. The entire country of Denmark, for example, has a capacity factor of 0.26, and that is mostly sea wind. On the other hand, some of the Danish turbines are older and would have a lower capacity factor, since wind turbine design has improved.

Since so many turbines are proposed, assuming the capacity factor for all these turbines will be the same as that of one excellent offshore wind farm, or one ridge wind farm in Maine[iii] is not appropriate. Instead, it may be appropriate to compare the capacity factors for entire countries, as stated in a current article on wind power.[iv] Denmark, with much steady offshore wind, has an overall capacity factor of 0.26. Germany, with more inland winds, has a capacity factor of 0.20. By assigning a capacity factor of 0.30 for Vermont, the Coalition believes we are making a favorable but believable assessment of the wind on the ridges.

The other item determining how much ridgeline is used is the turbine power. The Report assumes 3 MW average power units, but goes on to say its estimate is based on turbines smaller and larger than this. They do not say why they plan to use a mix of turbines, but they are probably acknowledging that not all parts of the ridge are equally windy, and that not all parts of the ridge will support a large turbine. They propose 3 MW average turbines. 1.5 and 2.5 MW turbines are more common, with 3.5 MW turbines used mostly at sea. Assuming that all ridges will have the wind and the geography to support 3 MW turbines is unrealistic. The mixture of turbines they propose will use more ridgeline than units sized at the average.

Standard designs are good for -4 to 104 degrees F so special designs will be needed for Vermont's very cold high ridges to deal with ice buildup and gusty winds that can suddenly exceed 50 mph. Manufacturers supply deicing capability, which uses grid power.[v] In addition, the steepness and narrowness of ridges may mean that the very large 3 MW turbines may not be able to be used. If so, more ridgeline will be needed. Not all the ridgeline may be able to be used, because the soil and rock may not support the weight and stress from high winds on the turbines, without excessive foundation work, which adds considerable cost to the installation.

Environmental Effects

There is no mention of the environmental effects of large-scale wind turbine installations. Some people have objected to the effect on the scenic view of these 400 ft tall structures on high ridgelines. In addition, to build and maintain the wind turbines on high ridgelines, land will have to be cleared and roads and power lines built and maintained. The wind turbines need to be located on the highest ridges, which are exposed to the weather, so that winter maintenance of roads and the turbines will be difficult and expensive.

Deaths of birds and bats are a problem in some locations,[vi] although this is not likely to be a problem on the high ridges. This concern should be formally analyzed before any commitment is made to two hundred or more turbines on the mountain ridges.

Accidents and failures of equipment are expected, as is normal in all large industrial scale complexes. The accidents unique to wind turbines are collapse, thrown blades and ice slung from blades. Because of the isolated location of the turbines and towers, these accidents would not likely be harmful to people.

Fires in the electrical equipment could spread to the surrounding vegetation and cause a forest fire. This is probably no more of a problem than the existence of high-voltage lines present. However, it must be noted that high voltage lines are not usually sited in the windiest locations.

Only one country in the world (Denmark) has wind turbines supplying 20% of its power, and it buys and sells to the European grid because the wind does not track its internal demand. Denmark sells half of its wind power to Norway. Many have noted the de-stabilizing effects on the grid of a large use of wind.[vii] This should not be a problem if only Vermont uses wind power, but other states on the grid have plans to use it.

When the wind is insufficiently strong and the turbines stop, the grid must quickly start other supplies. These can be hydro, including pumped storage, and gas turbines. Recently the Bonneville Power Authority wrote about its study to build pumped storage and gas turbine supplies, because the amount of wind power installed is reaching the capacity of the existing hydro plants to make up for low wind periods.[viii]

Economics

The installed capital cost per kW is not mentioned in the Report. Using data from other recent wind farms, such as in Maine, the installed cost is about $2,500 per kW. This includes the entire infrastructure – roads, power lines, maintenance shops, garages, and office buildings.

Our analysis of the Report's Strong Case is 288 turbines, 3 MW each, 48 miles of ridgeline and a capital cost of $2.16 billion. The Report proposed 235 turbines, 3 MW units, 39 miles of ridgeline, no cost given. Using our "all-in" value they cost $1.76 billion. For the moderate case, we calculate 181 turbines, 31 miles of ridgeline, for $1.36 billion, instead of the Report's proposed 145, 3 MW units, 24 miles of ridgeline, no cost given, at $1.09 billion[ix] using our data.

There will be jobs created to build, operate, and maintain the wind turbines. After construction, the number of jobs will of course decrease to the Operating and Maintenance level.

The Report mentions a company in Vermont that is manufacturing wind turbines in the state, but does not say anything about using them in Vermont. The company is planning to have a 2.2 MW wind turbine in 2010. It would be prudent to have this company accumulate some years of operating experience with the new unit in various locations before allowing it on Vermont's ridgelines, which have severe weather conditions.

The Report does not discuss financing for the proposed wind farms. Will the wind farms be owned by utilities with their methods of financing? Will they be built and owned by companies, such as Iberdrola, which began commercial operation of a wind farm with 12, 2.0 MW units in Lempster, New Hampshire in 2008?[x] Unfortunately, as noted in the Valley News in November of 2009, Iberdola will not share its capacity factors or results, making analysis of this project rather difficult[xi].

The Report says that the towns with the turbines will get taxes from them. Under the present system, taxes go only to the town with the facility, as is true of any facility, such as a factory. Some people believe that other towns should share the tax money if they have to live with the visual effects. The Legislature can address this as needed. For example, taxes could be divided among the towns that have visual and other impacts of a wind farm. The tax money could be a great boost to rural areas of Vermont. However, tax breaks and incentives for the wind farms could easily cut into this effect.

Grid Stability

Most European countries have less than 10% of their electricity from wind. Denmark has close to 20%, much of which is offshore wind, known to be more stable than most inland winds. There are plans to add much wind power to our NE grid. Stability concerns will eventually limit how much can be added without building more backup, which will probably be gas turbines. Pumped Storage is a longer-term possibility, but environmental concerns have slowed development of it elsewhere. Just the amount of wind power proposed for Vermont should not be a stability problem because the state is such a small part of the grid.

Schedule

The only mention of schedule is that the proposal will be complete by 2032. During the years until then, the proposal suggests dependence on "market generators." This means buying a great deal of power from the New England grid at possibly higher prices than those likely to be in effect under new long term contracts. The present low price of natural gas may not last, and the effect of greenhouse gas charges (RGGI) is likely to increase.

Small Turbines

The Report briefly discusses energy from small wind turbines. As with any source, the capacity factor is key. If the wind does not blow enough, the power becomes very expensive, as shown by the homeowner who installed a 10 kW turbine. Because of the poor location, the capacity factor was low. It cost $40,500 to build. Even with 61% of the cost covered by grants and tax incentives, the cost of power almost equaled what power from the grid would have cost, without even considering operating and maintenance costs.[xii] In this case, a $40,000 wind system produced 6300 kWh of electricity. Electricity can be purchased from the grid for about 15 cents per kWh in Vermont. Therefore, the electricity produced by the wind turbine was worth $950, or a forty-year payback. This assumes no operating costs or repairs over forty years. [xiii]

The Report does not suggest where these small turbines might be located, but it will likely be in areas where the wind conditions will be less than ideal and the capacity factors will be low.

If thousands of people build small wind turbines Vermont may not have enough money for the subsidies. If 10,000 homeowners decided to build home turbines, subsidy levels would be $125,000,000.

We have heard verbal reports of a company in Vermont that is designing a small wind turbine for low speed winds. When and if available this could change the economics of small wind installations, but they still face the problem of storage or using the grid as backup.

Conclusions

Wind power can be used in Vermont to provide electric power. There are many environmental impacts to be considered. People judge these impacts on forests, ridgelines, views, and lifestyle to be significant. The Report does wind power no service by overestimating available wind energy that is feasible to use.

Solar

Overview of Proposed Solar

By 2032:

- **Moderate Case:** Photovoltaic (PV) on 1 in 15 homes, plus business and large commercial installations, no number given, providing 7% of 6300 GWh. Installed capacity: 245 MW.

  Our Analysis: 13,300 houses, 2,790 businesses for $1.72 billion

- **Strong Case**: PV on 1 in 5 homes, plus businesses and large commercial installations, no number given, providing 15% of 8400 GWh. Installed capacity: 734 MW.

  Our Analysis: 40,000 houses, 7,250 businesses for $5.14 billion.

Analysis

The number of homes and business needed is important when it comes to installation, maintenance, and financing. Using an estimate of about 200,000 houses in Vermont, the moderate case requires 13,000 houses to have solar electric panels, totaling 40 MW by 2032. It also requires 205 MW as large commercial installations with a panel area of 0.98 sq miles, equivalent to 2,790 100x100 large building roofs. We give these projects the benefit of the doubt. Right now, capital costs for solar PV are $6500 but we have estimated capital costs as $5,000 kW. Total capital cost will about $1.72 billion, assuming $5,000/kW versus the current $6,500/kW. [xiv]

The strong case requires 40,000 houses to have solar panels, totaling 120 MW by 2032. It also requires 614 MW as large commercial installations no number given.

Total panel area for the strong case is 3.70 sq miles, equivalent to 7,250 large buildings with 100x100 roofs at a cost of $5.14 billion.

In Vermont,[xv] 1 kW of panels can produce = 1 kW x 4.3 avg. peak sun hours/d x 365 d/yr x 0.8 avg. system efficiency = 1,256 kWh/yr/kW. In other areas of the US with more sunshine, that value may be as high as 1,700 kWh/yr/kW.

Environmental Effects

The local environmental effects of solar panel installations are quite modest. There are no emissions from panels in operation. Panels require cleaning and dusting to maintain their efficiency, as is the case for large desert installations.

Accidents will be the normal construction and homeowner ones, such as falling from roofs.

Economics

For an average home with a 3 kW installation, at $6,500 per kW, the homeowner needs $19,500 to install the system. This system will provide about 3,768 kWh per year. This covers about 50% of the average use of a Vermont household. The 25-year levelized cost buying from the utility is about $0.255/kWh. Without subsidies, the cost to of PV power to the homeowner will be $0.445 per kilowatt-hour. However, there are federal and state cash incentives for solar, and tax savings from deducting interest. The 25-year levelized cost of generating solar power, with federal and state cash incentives, plus tax savings from deducting interest from taxable income, is about $0.247/kWh. The amount of tax savings, of course, depend on the tax bracket of the homeowner.

Conclusions

The amount of energy delivered by solar electric panels is quite modest compared to the investment, under current economics.[xvi] The Report states that the efficiency of panels will continue to improve, costs will come down, and new PV technologies will emerge. These are reasonable judgments, based on past performance. How long this will take cannot be predicted.

The up front installed capital cost and the lack of savings relative to buying from the utility appear to be restraining the rapid adoption of solar electric power.

Biomass

The Report suggests three sources of biomass: Wood, Farm Biomass known as "Cow Power," and Landfill Methane.

Wood

Overview of Proposed Wood Use

By 2032:

- **Moderate Case/Strong Case**: 170 MW installed capacity, providing 22% of 6300 GWh/16% of 8400 GWh. Since 70 MW is installed now, the Report claims 100 MW will need to be installed.

  Our Analysis: 247 MW installed capacity will be needed, 171 MW to be installed. Costs between $600 and $900 million for plant construction

In the Strong and Moderate cases, the amount of electricity to be generated by wood is 1379 GWh.

Analysis

If there is three times as much new growth remaining behind each year as is harvested, per the Report, there would appear to be a serious forest fire hazard developing due to overgrowth. This may need to be harvested to minimize the danger. In any case, there is a large potential fuel source for electric power generation.

However, how large a fuel source is a real question, not easy to answer. Vermont's forests are regrowth. How much can be harvested on a sustainable basis each year makes a tremendous difference and estimates vary from 0.5 to 2 cords per acre. Burning the wood dry or green also makes a big difference.

Our analysis shows 1 million tons of wood can generate 784 GWh a year in present design plants.[xvii] Increasing wood-fired electricity output, as proposed, from current levels (400 GWh) to 1379 GWh proposed would require 1,714,000 more tons than are currently harvested. To make 400 GWh of electricity, the McNeil and Ryegate plants use 700,000 tons of wood chips. Making 1379 GWh of electricity from wood would require approximately three times the amount of wood, or 2,100,000 tons of wood chips. A cord of wood is estimated at 2.5 tons, so this would require 840,000 cords, or 560,000 more cords per year to be harvested in the future. For comparison, the total harvest in Vermont varies between 800,000 and 1,000,000 cords per year.

Another way to look at the wood harvest is to look at forest area requirements. At 1/2 a cord per acre, 840,000 cords would require 1.7 million acres. If 2 cords per acre, wood for power plants would require would be 420,000 acres. For comparison, the Green Mountain National Forest is 400,000 acres. [xviii]

It is difficult to tell if this amount of additional harvest is sustainable or not. It may be. However, foresters state that a careful management plan of our woodland resources is needed to insure sustainability, in light of the history of clear cutting for sheep and farm agriculture in the 19th century. This amount of additional wood might well be available, but the situation is not clear.

In personal communications with foresters, we have heard that the forests are doing worse in the first decade of the 21st century than they were in the last decade of the twentieth, and growth rates are somewhat difficult to estimate at this time.

The Vermont Legislature is aware of these issues, and has started a Biomass Development working group. Its report should clarify these issues and provide policy recommendations. However, the group is just beginning its work, and results will not be available for at least a year.

The Report mentions the inefficiency of using wood to generate electricity, which is due to any steam plants second law of thermodynamics limit. The report favors combined heat and power and wood gasification to increase efficiency. This argument could be extended to saying that Vermont's wood resource might be better applied in its traditional use of heating buildings, thereby displacing costly oil and gas. There are other sources of electricity.

Environmental Effects

Burning wood releases particulates and dioxin, a very toxic chemical. Plant's using wood chips must be carefully maintained to control these releases.

Harvested wood must be transported to the locations where it will be used, including chipping. The effects of the harvesting, truck traffic, rural road maintenance, and chipping are well known from present operations. They will increase in scale as use increases.

The Report proposes two conflicting uses.

One, on page 25, it proposes increasing efficiency by using waste heat for building heating and industrial purposes. This requires the plants to be located with buildings and factories, requiring the wood to be trucked to the plant.

Two, it proposes smaller plants located around the state to use "local forests," to minimize trucking, and sizing the plants based on "how much heat can be utilized."

These plants will require transmission lines, roads, and transport of the wood to the plants. Roads into the forests will also be needed to get the wood. The proposed 100 MW requires 68,571 truckloads per year (25 cords per truck).

The long-term sustainability of wood as a fuel must be carefully judged. Wood is a crop that has a long life cycle. In the early 19th century, Vermont had been largely cleared to raise sheep. It took until the 20th century for natural growth and a vigorous replanting program to restore Vermont's forests. Long-term soil depletion must be monitored and management of the forests as a crop adjusted.[xix]

The Vermont Energy Digest[xx] said, "While interest in wood as an energy source is growing, our ability in Vermont to harvest the wood could be a problem. The theory that wood is cheap and plentiful may not be compatible with environmentally sound wood energy use and a livable wage for loggers into the future." [xxi]

Economics

The Report states that 80% of Vermont is forested, with 11 million tons of new growth each year. Only 2.75 million tons is harvested each year, so thickened growth is 9.25 million tons each year. Use of wood and wood chips for heating, and other applications is mentioned, along with the two plants that generate electricity using wood chips; Ryegate, 20.3 MW and McNeil 53 MW. The Report also expects 1380 GWh per year from wood. The capacity factors are not estimated correctly, in our opinion. The McNeil and Ryegate wood-fired plants are 70 MW installed, and make between 350 and 450 GWh a year. Assume that 70 MW of wood installed makes 400 GWh of energy. Then 1380 GWh would require 241 MW installed, of which 70 MW are already installed. Therefore, 171 MW are needed, not 100 MW.

The Vermont Energy Digest shows the plants making 353 GWh in 2005.[xxii]

The DOE shows the plants making 453 GWh in 2007. [xxiii]

We use an average 400 GWh. 1,380 GWh needs 241 MW. With 70 installed 171 MW more will be needed.

A new 28 MW wood-fired power plant in Mingo, West Virginia will be built for 150 million.[xxiv] This would be $5300 per kW. 171 MW new construction could therefore be expected to cost $906 million. This cost seems too high. Another source (which does not want to be quoted) estimates $3500 per kilowatt. This gives $598 million. True costs are likely to be somewhere between these figures.

To make 400 GWh of electricity, the McNeil and Ryegate plants use 700,000 tons of wood chips. Making 1380 GWh of electricity from wood would require 2,415,000 tons.

Costs of power from future plants can be approximated from costs of the present plants. The Rye plant power cost $174 per MWh (2008), Mc Neil $ 52.59 per MWh (2006).[xxv]

Conclusions

Wood as a fuel for electric power generation in Vermont can make a good contribution to the mix as suggested by the Report. It has an environmental impact that is not small, considering the amount of truck traffic and forest roads. Like coal, wood burning produces particulate air emissions. Industrial-scale wood burning facilities will require a certain level of pollution control, which is easily available, but must be considered in terms of the cost. The long-term sustainability of forest wood as a crop must be carefully judged in terms of centuries, and monitored, considering the reported poor conditions of the state's forests. Before undertaking policies that greatly increase the annual forest harvest, it would seem prudent to have a detailed long-term management plan.

Biomass: Farm Biomass and Cow Power

Overview of Proposed Farm Biomass

By 2032:

- **Moderate Case** 20 MW installed capacity, providing 2% of 6300 GWh
- **Strong Case**: 45 MW installed capacity, providing 4% of 8400 GWh. In this case, 15 MW would come from cow manure, and the other 30 MW from crops and residue mixed in.

Our Conclusions: **All methane-to-carbon dioxide conversion processes are valuable from the point of view of greenhouse gas emissions. Extent of possible use of these technologies is difficult to estimate.**

Analysis

According to its website, CVPS expects to gather 200 watts of electricity per cow.[xxvi] The Report claims Vermont will receive 15 MW from cow power, which would require 75,000 cows, which is about half as many there are in Vermont now.[xxvii] Not mentioned is the fact that the animals must be kept in lots where the manure can be collected. This goal requires use of the waste from half the cows, or expansion of the herd.

Environmental Effects

The Report mentions some positive effects, such as displacing fossil-fueled power and farm run-off improvement. It does not mention that this method also removes methane, which would otherwise act as a greenhouse gas. Burning Cow Power methane turns it into CO_2 and water. Methane is more than 20 times as harmful a greenhouse gas as carbon dioxide. Therefore, burning methane is a net benefit from the use of Cow Power.

Economics

The Report gives no cost for cow power. The State recently passed a bill setting the rates for cow power and other alternatives. The rates are up to seven times higher than current market rates, but the total amount of purchase from the alternatives is capped.

Costs can be understood from the recently completed Westminster Farms project.[xxviii] The investment was $1.5 million for 225 kW, $6667 per kW. In conventional terms, this is hugely excessive, and the amount of electric power is very small. For example, our evaluation shows large wind turbines were $2,500 per kW and solar PV $6,500 per kW. However, as the reference shows, the combined economics are many and complicated: there are also savings in animal bedding and heating oil. The article does not mention the benefit of converting methane to CO_2, which is a significant greenhouse gas reduction.[xxix]

On the other hand, the Report notes that now, 300 cows must be in one area with one manure pit, in order to justify the digester. The Report says that digesters for smaller numbers of cows are under development. Many farms in Vermont have fewer than 300 cows, so smaller digesters would be welcome in the state.

Cow power is expensive, but it will never be a major part of the energy mix, so the expense should not affect the consumer too heavily. It has many positive environmental effects

Conclusions

Cow power is a small source of electric power and will remain that way because it would take an impossible number of animals to produce large amounts of power. It is expensive but should be used just for the environmental benefit of converting methane. The additional savings for the Farmers are another advantage.

Landfill Methane

Overview of Proposed Landfill Methane

By 2032:

- **Moderate Case/Strong Case.** 19 MW installed capacity, providing 150 GWh. 2.3% of 6300 GWh/1.8% of 8400 GWh

The Report states that there will be 11.2 MW installed in the next few years, and there are no other large landfills, but there may be smaller ones.

Our conclusion: All methane-to-carbon dioxide conversion processes are valuable from the point of view of greenhouse gas emissions. The extent of possible use of these technologies is very difficult to estimate. We agree with the Report that they will not be more than a few percent of energy needs.

Analysis

The Report states that 10.2 MW of Landfill Methane is installed now, and will increase to 11.2 MW soon. Further, the Report assumes that another 7.8 MW will be generated from other landfill gas facilities. The Report does not list any locations with specific plans.

No cost is given for Landfill methane power. This source will remain small and will only be sustainable as long as placing waste organic material (kitchen waste, etc.) in landfills is Vermont's method of a "permanent solution."

The smaller landfills are not listed in the Report. It is unclear whether the Report is recommending enough landfills to generate their proposed increase in power generation, or predicting that they will be built. Right now, Washington Electric Cooperative uses extensive landfill methane from the largest landfill in Vermont[xxx].

However, their rates to their consumers are a mixture of the rates from this methane plant and also a small hydro plant. No cost conclusions can be derived from this.

The Report does not list any locations with specific plans.

Unfortunately, the cost of this is impossible to estimate without knowing something more about the sources. It is also very difficult to understand whether these projects are feasible, with so little information.

Like Farm Biomass projects, Landfill Methane projects are ecologically valuable because they convert methane to CO_2. This conversion lowers the effective greenhouse emissions of the landfill.

Environmental Effects

Converting methane to CO_2 is a large Greenhouse Gas improvement. The landfills exist and they leak methane into the atmosphere. So the installation and maintenance of the equipment for gas capture and electric power production is a minimal impact.

Economics

The Report mentions the present Landfill Power projects but gives no costs. Landfill methane will always be a very small source of electric power, and is of great value in converting methane to CO_2. The price paid is not so important since most or all of it can be charged as an environmental protection cost.

Conclusions

This method of electric power production should be used to the fullest extent possible because of the advantage of converting methane that otherwise would leak into the atmosphere.

All methane-to-carbon dioxide conversion processes are valuable from the point of view of greenhouse gas emissions. The extent of possible use of these technologies is very difficult to estimate. We agree with the Report that they will not be more than a few percent of energy needs.

Vermont Hydroelectric Power

Overview of Proposed Vermont Hydroelectric Power

By 2032:

- **Moderate Case/Strong Case** 113 MW installed capacity, providing 8% of 6300 GWh/6% of 8400 GWh

In both cases, the Report expects this technology to provide 493 GWh per year. The report proposes retention of existing in-state hydroelectric power, and the addition of 15 MW.

Our Conclusion: We do not know where these plants would be located and so cannot estimate costs and environmental effects.

Analysis

Hydroelectric power has environmental effects that are well known and accepted because of their long time use. The Report proposes that the 98 MW existing be kept. Costs are well known and inexpensive.

The Report proposes 15 MW[xxxi] more generation, and says this is conservative. Beyond this, the potential for very small units is prohibitively costly.[xxxii] They will be used in streams that were not developed by the power companies because they were too small to be economical. These small units can contribute if they are owned, operated, and maintained as an adjunct to a main business, i.e. Farmers have them in their streams. The Report notes that there are "wildlife issues and permitting hurdles for small scale, low-impact hydropower." (pg 28) All rivers and streams feeding the Connecticut River are controlled by the Corps of Engineers as part of flood control.

Beyond repowering the existing dams, small dams might be used to provide power. Many streams and brooks in the state could be used. Estimating the cost is difficult, and estimating the effect on fish and other wildlife is very difficult.

When thinking about building many small dams, the effects on tourism should be considered. In general, small free-flowing streams are part of the Vermont landscape, and a great tourist draw. It is unclear what the Report plans in this regard, and what effect it would have upon the state as a whole. For example, trout fishing is a tourist draw for Vermont, and excessive low head hydro could threaten that industry.

Conclusions

The existing 98 MW should be able to continue to contribute as planned. Power beyond 15 MW of small hydro that can be restored, will be from "micro" or "pico" sized units, and very cost- inefficient. Permitting issues may delay or prevent many of these units. The Report does not make clear what small hydro really means, where it would be, or what it means for Vermont as a whole. Therefore, we have not drawn conclusions, except that tourism and wildlife effects should be considered before embarking on an extensive program.

Traditional Energy Supplies From Outside of Vermont

The report assumes that two types of power from outside Vermont will stay in use. These supplies are "Regional Hydroelectric Power" which generally means buying from Hydro Quebec, and "Market Purchases" from other suppliers on the ISO New England grid.

Regional Hydroelectric Power

Overview of Proposed Regional Hydroelectric Power

By 2032:

- Moderate Case 31% of 6300 GWh, 1,930 GWh
- Strong Case 24% of 8400 GWh, 2,030 GWh

Analysis

Hydro Quebec's performance, cost and environmental effects are known from its years as a supplier. Performance and environmental effects should continue to be acceptable. The cost will be known when the consumer prices are finally announced. Since Hydro Quebec is now widely sought-after as a seller of low-carbon power, there will be likely many competitors for this power, and Vermont will almost certainly have to pay more for HQ power in the future.

Market Purchases

The Report proposes: In 2013 from the graph**, no text**, 32% Market Purchases. To some extent, this fact is *hidden in the graph.* If VY is shut down, the following year its power will have to be purchased elsewhere: the Market. However, the report assumes that this market purchase will fall back to 5% by 2032, for both moderate and strong cases.

The Report says that having the market able to "fill in when local resources are not able to meet our needs is **valuable** to Vermont utilities." Valuable means avoiding brownouts and rolling blackouts! Vermont utilities access 15 dispatchable units totaling 150 MW, mostly old diesel generators whose use should be minimized.

It is not clear how much higher the price would be in 2013 for that 32% of electricity which would be purchased. The Report does not acknowledge this situation except in **one graph**, and it is beyond the scope of this Evaluation to attempt to determine the price.

Market purchases are expected to become increasingly costly, even though the current price is low. The price will be increased by the need for fossil fuel generators to purchase Regional Greenhouse Gas Initiative allowances. Regional price swings are expected, and usually due to the relatively volatile price of natural gas.

The Report admits that the "region" (that is, the grid and the power supplied by New England ISO) is "dominated by fossil fuels and nuclear power." Therefore, the "Market Purchases" they propose will be similarly dominated.

During the first years of the proposed plan Vermont citizens will be heavily dependent on market purchases, and would have to pay the price.

Conclusions

Market purchases are expected to be available, but the price can be expected to be high, on the average.

Conclusions of the Overall Evaluation

Transition Considerations

The Report proposes a transition to a different electric power economy, with heavy emphasis on efficiency of use and sustainable supplies. The transition plan requires very heavy use of market purchases up front. This will continue for seven years until purchases decreases to the present level. The proposal then suggests decreasing purchases to 5% of the supply. These purchases will add to Vermont's carbon footprint, and may be expensive. The purchases are made up of nuclear and fossil power, with a large component generated by natural gas. Vermont currently obtains several million dollars a year in greenhouse gas credits from the Regional Greenhouse Gas Initiative of the New England States.[xxxiii] This source of funding would certainly be diminished, and Vermont might even be paying for credits for several years.

The Report assumes a decrease in the present types of electric power use, and an increase in generation capacity that is enough to supply electric cars.

It is good and prudent planning to ask what will happen if the Report's projections do not come true. What if building wind turbines on the ridges is stalled by intervenors? What if Vermont runs out of money and stops subsidizing home solar and home wind turbines? What if nearly doubling the output of Vermont's forests is analyzed and found to be a poor forest-management choice for sustainability? We are not saying that all these things will happen, but assuming that none of them happen is optimistic.

A worst case would appear to be an increase in the present types of use, due to a slower deployment of efficiency measures, and perhaps more population and business than expected, coupled with a greater use of electric cars. Drawing conclusions from the Report, Vermont would have to expand the proposed wind, wood and solar generation, coupled with purchases from Hydro Quebec and the New England grid beyond the estimated amounts. The environmental effects of these sources would also increase. If this additional expansion does not work however, and many aspects of it are uncertain, the most likely solution would be even more purchases from the grid and installation of gas turbines in Vermont.

Vermont's Energy Future

The State's electric power decisions have a large effect on the environment, and will figure significantly in its economy and the well-being of its citizens.

Efficiency and Conservation are the most important areas for improvement, no matter what is done about supplies. This is true because of society's history of inefficient use of inexpensive energy believed to be unlimited, coupled with unlimited exploitation of the environment.

Fortunately, there are many options for electric power supplies. All of the supplies have environmental effects, monetary costs, and generation characteristics. Weighing these differences is a process of making value judgments about the effects on

Vermont and its people. Science and engineering can only tell us how things work, the possible effects and the odds of accidents.

The costs and impacts detailed in this Evaluation should be considered in the debate over the power supply choices that are going to be made.

The investment proposed for the large supplies is $ 8.23 billion, strong case, and $4.01 billion, moderate case. Additional investment will be required for small supplies. The Report assumes that purchases from Hydro Quebec will remain the same, and grid purchases will be somewhat lower than now. Of note is that grid purchases will increase to nearly 25% of supply at the start of the Report's plan.

We have listed many important impacts and potential problems not in the Report, on forests, roads, views, and air quality, with the resulting economic effects.

Deciding what is acceptable among the various impacts of the different supply choices is a matter of judgment, not science, or engineering, and will be done by our political process.

The Coalition for Energy Solutions hopes that this Evaluation contributes to the public debate.

Afterword

In this Afterword, we discuss some policy considerations that were not covered in the main evaluation.

Policy Considerations

Wind

We recommend a phased approach to adoption of wind power. The proposed turbines are much larger than the present turbines installed at Searsburg. Installation of the first few of these large turbines will provide the information needed to decide on the future scope of the plan. Only after installing and operating a few of the new, larger turbines, building roads to them, and gathering costs and capacity factors, should such a gigantic project be undertaken.

Solar

We believe the state should encourage solar photovoltaic on state and municipal buildings, and perhaps require some solar panels for new home construction. Now, however, solar is most attractive to households for which the tax savings are generous, that is, high-income households. Underwriting household solar for Vermont's top-earning families does not appear to be a good economical choice for the state of Vermont at the present time. More resources and incentives for efficiency and conservation than is presently the case seem a better immediate objective. Solar power can be added later.

Wood

We believe that wood can provide more energy that it does now, but it appears that a forest management plan has not been created to allow harvesting on a long-term sustainable basis. A careful study of present and future expectations for wood use as direct building heat and other needs appears in order, before a commitment to use a large amount of this resource for electric power generation is made. The Legislature's Biomass Development working Group report should be received before major decisions are made.

Excessive Optimism in the Report

Throughout the Report there are many examples of hoping for good things. It speaks of "aggressive goals" "smart energy storage technology" – whatever that is, "optimal charging pattern" and "emerging technologies." All of us want the best for Vermont, our country and the world. It is reasonable to expect that technologies will improve and prices will fall, because that is our experience. However when it comes to planning for the future, it is not prudent to plan on technology improvements and price decreases on a schedule. Plans should include contingencies for "what if it doesn't come true." It is better to be cautious and have a backup plan and be pleasantly surprised than to have a rude awakening. For Vermont's electric power future the "rude awakening" would come in the form of very high prices due to purchasing large amounts of energy from the New England grid.

Vermont Yankee as Vermont's "fair share"

About half of the Report is a negative evaluation of Vermont Yankee. Our Evaluation has only addressed the possible sources of renewable replacement power. However, in this section on policy, we note that Vermont will continue to be part of the New England grid for mutual backup between the states. The grid is a shared responsibility. When Vermont uses the grid as backup, the locations and people outside the state absorb the environmental effects of the backup generation. Having the Vermont Yankee plant located in the state has effects, but the presence of one good-sized plant (like Vermont Yankee) could be considered part of the state's "fair share" of being part of the grid.

End Notes

[i] http://www.windpoweringamerica.gov/images/windmaps/vt_50m_800.jpg
[ii] http://www.aweo.org/ProblemWithWind.html
[iii] http://www.coalitionforenergysolutions.org/maine_wind_farms.pdf
[iv] http://en.wikipedia.org/wiki/Wind_power
[v] http://en.wikipedia.org/wiki/Wind_turbine_design

[vi] http://www.aweo.org/ProblemWithWind.html
[vii] http://en.wikipedia.org/wiki/Wind_power

[viii] http://seattletimes.nwsource.com/html/localnews/2009542434_apwabalancingwind.html, http://www.bpa.gov/corporate/pubs/fact_sheets/09fs/BPA_supports_wind_power_for_the_Pacific_Northwest_-_Mar_2009.pdf
[ix] http://www.coalitionforenergysolutions.org/ and see spreadsheet Repowering 1 by Willem Post
[x] Valley News, October 18, 2009
[xi] Valley News, West Lebanon, NH October 18, 2009. Editorial, "Lempster's Wind Farm."

xii A 10 kW wind turbine, installed cost $40,500, located 400' from a new $500,000 house generated electricity from January 2008 to January 2009. The unit generated 10 kW X 8,760 hrs/yr x 0.0715 capacity factor = 6,286 kWh during that year of which 6,094 kWh was used and 192 kWh was sold to the utility as part of "net-metering." The owner pays the utility $9/mo. for standby power. Note the very low 0.0715 capacity factor.

Simplified analysis of costs and savings:

The owner received a $12,500 grant from Efficiency Vermont (EV) and had to pay state and federal income taxes on it.
The electricity cost savings = 6,286 kWh/yr x $0.13/kWh - $9/mo x 12 mo
= $709.18/yr
Without incentives the interest on $40,500 @ 6%/yr = $2,430/yr
With the $12,500 grant from EV, the interest on ($40,500 - $12,500) @
6%/yr = $1,680/yr
With the recently enacted federal tax credit = $40,500 x 0.30 = $12,150, the interest on
($28,000 - $12,150) @ 6% = $951/yr

So it takes incentives equivalent to about $24,650/$40,500 X 100% = 61%
of the installed capital cost to ALMOST equal buying from the utility.

Operating and Maintenance costs were not considered.

[xiii] http://www.greenbuildingadvisor.com/blogs/dept/musings/resisting-allure-small-wind-turbines
[xiv] Calculation for solar panels
The Report calculates: Strong Case PV capacity = 1,290,000,000 kWh/yr x 1/1,757 kWh/yr/kW = 734 MW. The 1,757 kWh/yr/kW is not possible in Vermont. As a result, the installed MW of PV panels and the installed capital costs are greater than stated in the report. See calculations below.

Moderate Case PV capacity=430,000.000kWh/yrx1/1,256kwhr/yr/kW=342 MW
Capital cost = 342MWx5,000kW-$1.71 billion
Panel area=4.3 10- 8 kWh/yrx1/12.56x1.4kWhr/yr/sqft x _.788 10-7 sqft/mile = .88 sq miles, assuming 49% increase in panel output per sq ft

Strong case PV capacity 1.29 10-8 kWh/yr x 1/ 1,256 kWh/yr/kW =1,027MW
Capital cost = 1,027 MW x $5,000/kW=$5.14 billion
Panel area = 1.29 10-8 kWh/yr x 1/ 12.56 x 1.4kWh/yr/sq ft x 1/ 2.788 108 sqft/sqmile = 2.63 miles

[xv] http://www.solar-estimate.org/index.php?verifycookie=1&page=solar-calculations&subpage=
[xvi] Valley News, West Lebanon, NH. July 7,2009 article Special on Electricity
[xvii] (10-6 tons x 2000 lb/ton x 7000 BTU/lb x 1/3413 BTU/kWh x .3 eff. x .638 cap factor).
[xviii] http://www.fs.fed.us/r9/forests/greenmountain/htm/greenmountain/g_home.htm
[xix] http://www.smartgrowthvermont.org/toolbox/issues/healthyforests/
[xx] http://www.vtrural.org/files/Vermont%20Energy%20Digest%204-071.pdf
[xxi] Vermont Energy Digest, 2007 pg 26
[xxii] http://www.vtrural.org/files/Vermont%20Energy%20Digest%204-071.pdf

[xxiii] http://www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/vermont.html

[xxiv] http://www.allbusiness.com/energy-utilities/utilities-industry-electric-power/13228347-1.html
[xxv] Vermont Comprehensive Energy Plan, Public Review Draft, 2009, p 188,189.
[xxvi] http://www.cvps.com/cowpower/How%20It%20Works.html
[xxvii] http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_011_011.pdf
[xxviii] Douglas Visits Farm's Methane Digester Operation, Brattleboro Reformer, October 20, 2009
[xxix] Vermont Comprehensive Energy Plan 2009, Public Review Draft, pg VII-183 "the greenhouse gas value of methane in the atmosphere is 21 times that of carbon dioxide.
[xxx] http://www.washingtonelectric.coop/pages/about.htm
[xxxi] Vermont Energy Digest, pg 53 "..about 10-15 MW of projects that are environmentally and economically feasible."
[xxxii] Vermont Energy Digest pg 53. A pico-hydro-sized system (less than 5 kW) in Vermont costs around $20,000 installed (including the grid interconnection), without permitting costs. On a project of under 1 MW, permitting costs add about $2,000 per kW to the total cost, bringing the total cost of a 5 kW system up to $30,000, according to Lori Barg of Community Hydro (Barg, 2007).
[xxxiii] Vermont and the Regional Greenhouse Gas Initiative, by Guy Page. August 3, 3009. Vermont Energy Partnership website