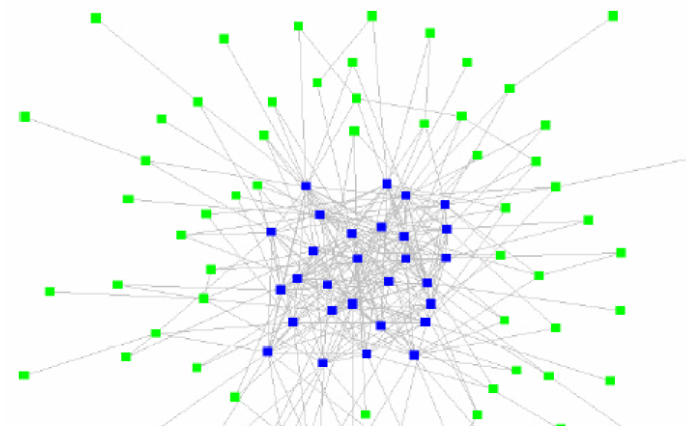

90% Renewable by 2050:

Exploring Vermont's Efficiency & Renewable Energy Pathways

Prepared for:

Vermont Energy Investment Corporation

and Energy Action Network

December 2013

By:

Leigh W. Seddon

L.W. SEDDON, LLC

RENEWABLE ENERGY SERVICES

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The author would also like to acknowledge the assistance that the Vermont Energy Investment Corporation (VEIC) has provided. VEIC staff, with expertise in transportation, thermal efficiency, biomass fuels, and electrical efficiency, have provided input and peer review for this report. The findings of the report and any errors and omissions, however, are the sole responsibility of the author.

About Energy Action Network

In 2009, a diverse group of Vermonters came together to think about how to advance a transition to a sustainable energy future. The result of this discussion and two years of work to understand and document Vermont's energy economy as a system lead to the founding of Energy Action Network (EAN). EAN is now a powerful multi-stakeholder network that provides a forum for diverse organizations to align goals, develop collaborative strategies, and facilitate collective learning. EAN's goal is to end Vermont's reliance on fossil fuels and to create clean, affordable and secure electric, heating, and transportation systems for the 21st Century.

EAN Energy Analysis Introduction

In 2011, Energy Action Network (EAN) developed a detailed energy accounting model to document Vermont's 2010 energy use and then develop a scenario where 80% of Vermont's 2030 energy needs could be met through aggressive efficiency and renewable energy investments. The model looked at energy use broken out into three energy sectors - transportation, thermal heating and cooling, and electricity use. These three sectors were further broken into 3 classes - residential, commercial, and industrial end use.

The EAN scenario was intended to explore possible technology pathways that could lead Vermont to a predominantly renewable energy economy. The purpose of creating a scenario was to identify key barriers and opportunities inherent in the 80% renewable energy goal, offer a framework for discussion about energy choices, and support and stimulate discussion of the 2011 Comprehensive Energy Plan (CEP) recommendations. The EAN goal of "80% renewable by 2030" was adopted in 2010 before the CEP was written or released. In 2011, the CEP was released and established the goal of sourcing 90 percent of the state's total energy from renewable resources by 2050. The CEP's goal of meeting 90% of Vermont's 2050 energy needs through renewable sources is now the current framework for EAN's energy modeling.

EAN's model and scenario was specifically not intended to serve as a proscriptive or rigid "roadmap" but rather, to frame core questions, examine critical assumptions and support public dialogue about Vermont's future energy mix. The model was developed with input and partnership from Vermont Energy Investment Corporation (VEIC), Green Mountain Power (GMP), Biomass Energy Resource Center (BERC), Renewable Energy Vermont (REV), Vermont Public Interest Research Group (VPIRG), and others.

In 2013, EAN launched a collaborative effort with University of Vermont's Gund Institute for Ecological Economics and state agencies partners to develop a dynamic energy simulation model for VT that built on previous modeling efforts. This dynamic energy simulation model would be used to support implementation of the CEP and its goal of meeting 90% of the state's 2050 energy needs with renewable energy sources. The new dynamic model will aid decision-makers in weighing energy choices and options, modeling costs and economic implications, and providing a platform to track state-wide energy metrics over time.

With financial support from the High Meadows Fund and technical support from the Vermont Energy Investment Corporation, EAN undertook to update its energy analysis and analyze key technology and policy pathways that could lead to attaining the CEP's goal of 90% renewable by 2050. This work was designed to assist in the development and preparation of the more complex dynamic energy model. This report summarizes the further development of the EAN model, discusses the key technology drivers that emerged as the essential pathways toward a renewable energy economy, and gives an example of actions required to meet a first interim milestone of 20% renewable by 2020.

For those interested in how energy statistics were gathered, what metrics were used to make comparisons across different sectors and fuel types, and how the EAN energy model was constructed, a technical appendix is included that covers these topics. This appendix also includes sector specific energy projections for EAN's 2020, 2030, 2040, and 2050 milestones.

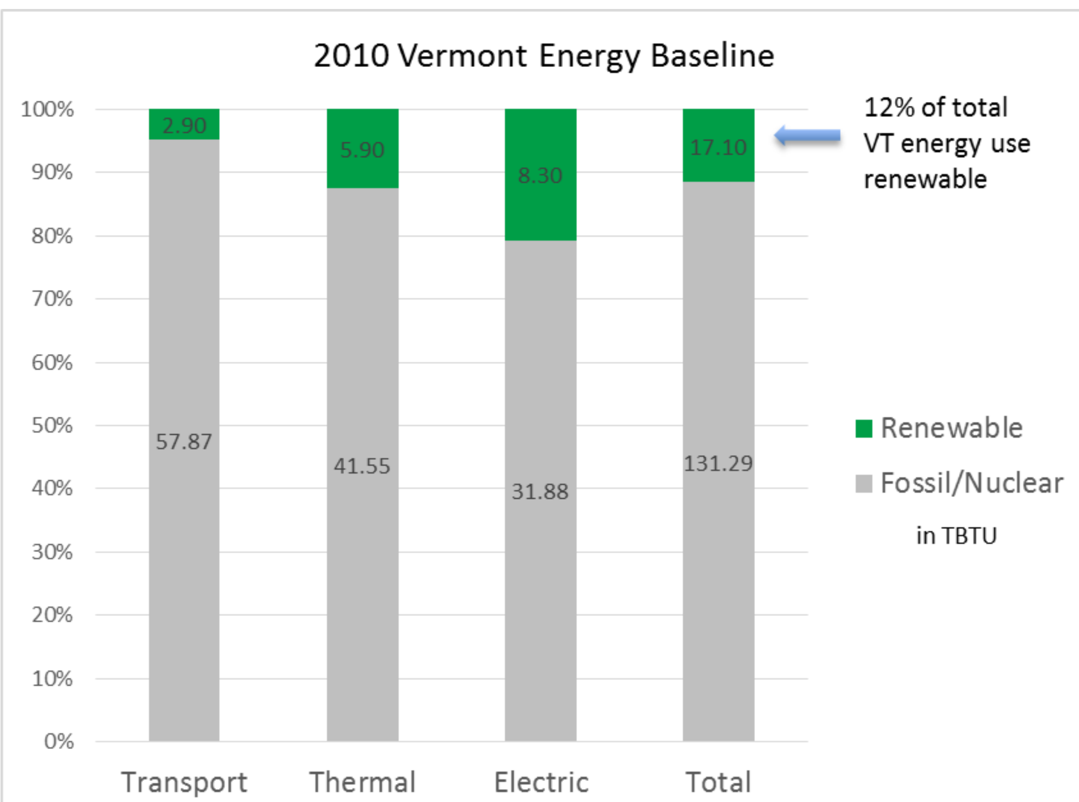
Vermont's Renewable Energy Goal: 90% by 2050

Vermont's 2011 Comprehensive Energy Plan (CEP) established the goal of sourcing 90 percent of the state's total energy from renewable resources by 2050. This goal was set in response to both economic and environmental needs, as well as legislative directives. Act 168 (2006) set the goal of achieving a 50 percent reduction in carbon levels from a 1990 baseline by 2028 and a 75 percent reduction by 2050. Act 92 (2008) set the goal of producing 25% of total energy from *in-state renewables* by 2025, and providing 20% of total statewide electric retail sales with SPEED Program (renewable) resources by 2017.

In 2012, the Legislature passed Act 170, The Vermont Energy Act of 2012. This Act requires the Public Service Department (PSD) to start work on a Total Energy Study that explores the ramifications and pathways to getting to the CEP goal of 90% renewable energy across all sectors by 2050. It also sets a 55% renewable electricity target by 2017 and a 75% renewable electricity target by 2032.

EAN has been analyzing the CEP's 90% by 2050 goal for several years and exploring technology pathways and energy policies that would allow Vermont to achieve this goal. The first requirement was to understand where Vermont stands currently in its renewable energy use across all sectors – transport, thermal heating and cooling, and electrical demand.

A 2010 energy "baseline" was developed to document Vermont's actual energy use and supply sources. At a high-level aggregated view, the chart below shows energy use in each sector in TBTUs (1 trillion British Thermal Units). In addition, it shows the 2010 amount that came from renewable resources (green) and the amount that came from fossil or nuclear energy sources (grey). Hydro Quebec system power (HQ), which provides a significant percentage of our electrical supply (32%), is included as a renewable resource.



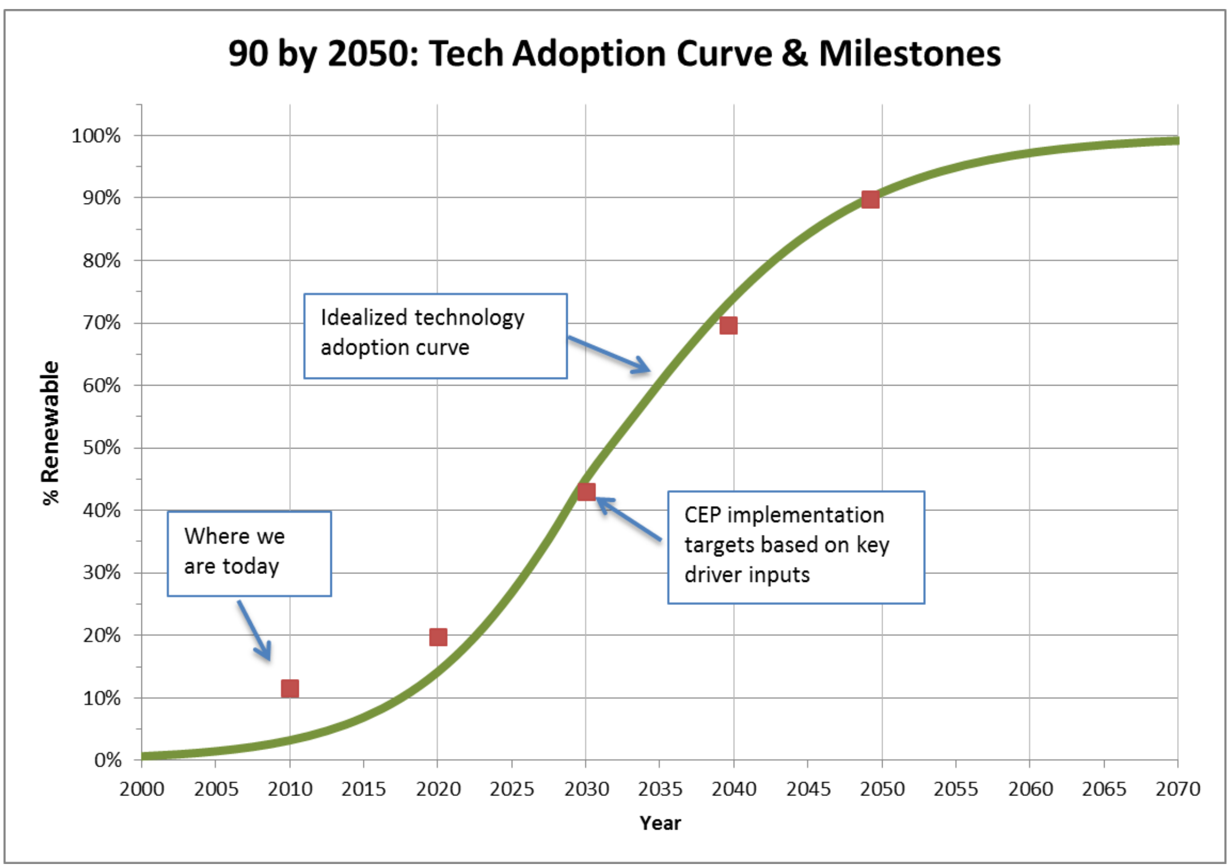
Technology Adoption & Energy Milestones

If Vermont's renewable energy portion is just 12% today, can we reach the goal of 90% by 2050, and if so, what might that look like? Vermont's progress toward 90% renewable energy will likely follow a "sigmoid" or S-curve that is typical of technological and social change in a society.

Adoption curves start off rising rapidly as new technology or ways of behaving (which exist but have been overlooked by the marketplace) are quickly adopted by consumers for both economic and social reasons. Halfway through a transition, adoption is still growing rapidly but the rate of change is starting to slow as fundamental structural barriers (economic, technical, and social) present themselves and take time to resolve. Finally, at the end stages of a transition, growth slows dramatically due to diminishing economic returns and social benefits of achieving the last few percent of the transition.

To further define what the adoption curve for 90% by 2050 might look like, EAN devised a series of decade milestones that could illustrate a snap shot of where we might be in 2020, 2030, and 2040 as we approach 90% renewable in 2050. These milestones are not meant to be a "roadmap", but rather to identify the known technology pathways, key policy drivers, and most important questions for policy makers to consider.

A very important insight gained during the creation of these decade milestones was the importance of balancing the transition across the three sectors of transportation, thermal heating and cooling, and electrical generation. For example, additional renewable electricity does not have much impact until it can be used to power electric vehicles or thermal heat pumps. The rate of adoption of certain technologies, such as electric vehicles, will really be the "gatekeepers" as Vermont moves towards a renewable energy future.



Analysis of Key Pathways

To identify and quantify the energy changes necessary to reach these milestones, EAN analyzed a series of potential technology pathways and policy options that could change Vermont's renewable energy percentage. These relate either to conservation and efficiency efforts or to the development of specific renewable energy sources. From this analysis, policies or resources emerged that are clearly the most important elements of a renewable energy transition. While Vermont should not discount any potential pathway or policy to implement the goals of the CEP, focusing initial attention on "key pathways" makes sense to kick-start implementation and do so in a highly leveraged way.

The tables below list technology or policy pathways for each sector that were considered by EAN. They are classified as either low (< 3%), medium (4-10%), or high (>10%) impact based on their relative effect on increasing Vermont's total renewable energy percentage over the 2010 baseline.

Table 1. Transportation Sector

Pathway	Impact
1. Electric Vehicles/Plug-in Hybrid Vehicles (EV/PHEV) EV/PHEVs currently account for less than 1/10 of 1% of VT's vehicle fleet. But EV adoption is growing at about 50% per year. The EAN scenario assumes that 70% of VT's Light Vehicle Fleet are EVs or PHEVs by 2050 and powered by renewable electricity and biofuels.	High
2. Corporate Average Fuel Economy (CAFE) Standards 2025 national fuel economy standards set an increase of fleet-wide average efficiency (for that year's models) to 54.5 mpg, a doubling of 2010 efficiency standards. This will have an impact on VT's fleet efficiency that is dependent on the rate of new car purchases. The EAN scenario assumes these standards will result in a 20% fuel reduction for VT's entire Light Vehicle Fleet by 2030 and a 40% reduction by 2050.	Med
3. Light Vehicle Biofuel Access to liquid biofuels (other than ethanol) for the light vehicle fleet will be important to achieving the CEP's goals. While pilot efforts to produce biodiesel on VT farms have been successful, limited available agricultural land area may keep in-state production of biofuels under 10M gal/year versus the 50M gals/year needed for hybrids and internal combustion engine (ICE) vehicles in 2050.	Med
4. Vehicle Miles Traveled (VMT) Reduction Vermonters traveled approximately 7,250 million miles in 2010. While VMT increased 10% from 2000 to 2010, for the last few years it has remained constant. Promotion of telecommuting, downtown development, and smart growth settlement patterns in the next few decades could result in VMT reduction for first time in VT's history. The EAN scenario assumes that a 10% reduction in VMT is possible by 2050.	Low
5. Light Vehicle Fleet (LVF) Reduction In 2010, there were approximately 550,000 light vehicles registered in VT. Increased public transport and carpooling options could result in fewer vehicles. EAN assumes that LVF numbers will remain largely unchanged from 2010 to 2050 as additional vehicles needed to support VT's population growth (0.5% per year) and economic growth are offset by alternative transport modes.	Low
6. Heavy Duty Fleet (HDF) Fuel Standards Current HD truck fuel efficiency standards will decrease 2017 model year fuel consumption by up to 20% over 2010 standards. In 2010, there were approximately 22,000 heavy duty trucks (diesel) registered in VT. Since energy consumption of trucks accounted for less than 10% of VT's 2010 transportation energy use, these fuel efficiency improvements will have limited overall impact on the CEP's 2050 goal, but will help eliminate 25% or more of this sub-sector's energy use over time.	Low
7. Heavy Duty Vehicle Biofuel While energy consumption of trucks accounts for less than 10% of VT's transportation energy use, introduction and use of biofuels in this sub-sector is important because a significant portion of the HD fleet will continue to use internal combustion engines rather than electric power. The EAN scenario assumes that 80% of the HD fleet is run on biofuels by 2050, and that biofuels will be less expensive than petro fuels.	Med
8. Aviation Biofuel Aviation fuel accounts for 2.5% of energy use in VT's transportation sector. Aviation bio-fuels are already being tested under FAA approval. While EAN assumes biofuel penetration will reach 50% by 2050, the overall impact on CEP goals is negligible due to the small energy footprint of this sub-sector.	Low

Table 2. Thermal Sector

Pathway	Impact
1. Building Energy Efficiency VT has approximately 300,000 residential buildings and 50,000 commercial ones. The thermal heating and cooling load from these buildings accounts for over 25% of VT's total energy demand (all sectors). Experts at Efficiency Vermont estimate that 30% of this energy could be saved by comprehensive retrofits of 300,000 of these buildings. EAN's scenario assumes efficiency efforts are ramped up quickly in the near term resulting in 15% sector reduction by 2030 and then reaching 30% reduction by 2050.	High
2. Building Heat Pumps In 2010, 70% of the heating energy for VT buildings was supplied by fuel oil and propane. Ground source and cold-weather air source heat pumps can offset the majority of this energy with customer savings of 30-40% over today's price of these fossil fuels. EAN's scenario assumes heat pumps powered by renewable electricity will supply 25% of the thermal energy demand in VT buildings by 2050.	Med
3. Building Biomass Heat In 2010, wood biomass supplied about 12% of residential and commercial heat loads. Given the relatively low and stable price of biomass fuels, its local availability, and its use as a backup fuel, the EAN scenario assumes that building energy supplied by biomass (cord wood and pellets) will more than double (135%) over 2010 levels by 2050.	Med
4. Industrial/District Biomass Heat In 2010, BERC's *Fuel Wood Supply Model* analysis indicated a harvesting potential in VT for an additional 900,000 tons of low-grade fuel wood per year above what is currently used under its "moderate" scenario. If the 10 surrounding counties in MA, NH, and NY are also included, this figure grows to over 3M tons per year. This limited resource base and the complex relationship of biomass combustion to the State's GHG emission targets, leads EAN to conclude that only a limited number of highly efficient thermal biomass plants (including ORC combined heat & power plants) should be built to reserve forest resources for thermal heating. EAN's scenario assumes that commercial building and industrial process heat supplied by large scale biomass plants will more than double by 2050 over 2010 levels, supplying approximately 40% of commercial building and industrial process heat.	Med
5. Liquid Biofuels for Heating As noted above, while VT's potential to make biofuels is limited both by land availability and short growing season, availability of biofuels nationally made from both cellulosic and algal feed stocks is growing rapidly. U.S. renewable fuel standards currently call for a production capacity of 36 billion gallons per year by 2022. These same transportation fuels can be used to replace #2 fuel oil. The EAN scenario assumes that 30% of the heat demand in the thermal sector is meet by liquid biofuels in 2050.	Med
6. Solar Thermal Systems (Heat & AC) Active solar thermal systems are cost-effective today for supplying domestic hot water, radiant heating systems, and low-temperature process heat for industrial applications. By 2030, high temperature solar thermal systems should be available to power air conditioning. EAN's scenario assumes 12% of the thermal sector's energy demand will be met by solar thermal in 2050. This assumption may be conservative given technology improvements that are on the horizon and the potential volatility of fossil fuel prices.	Low

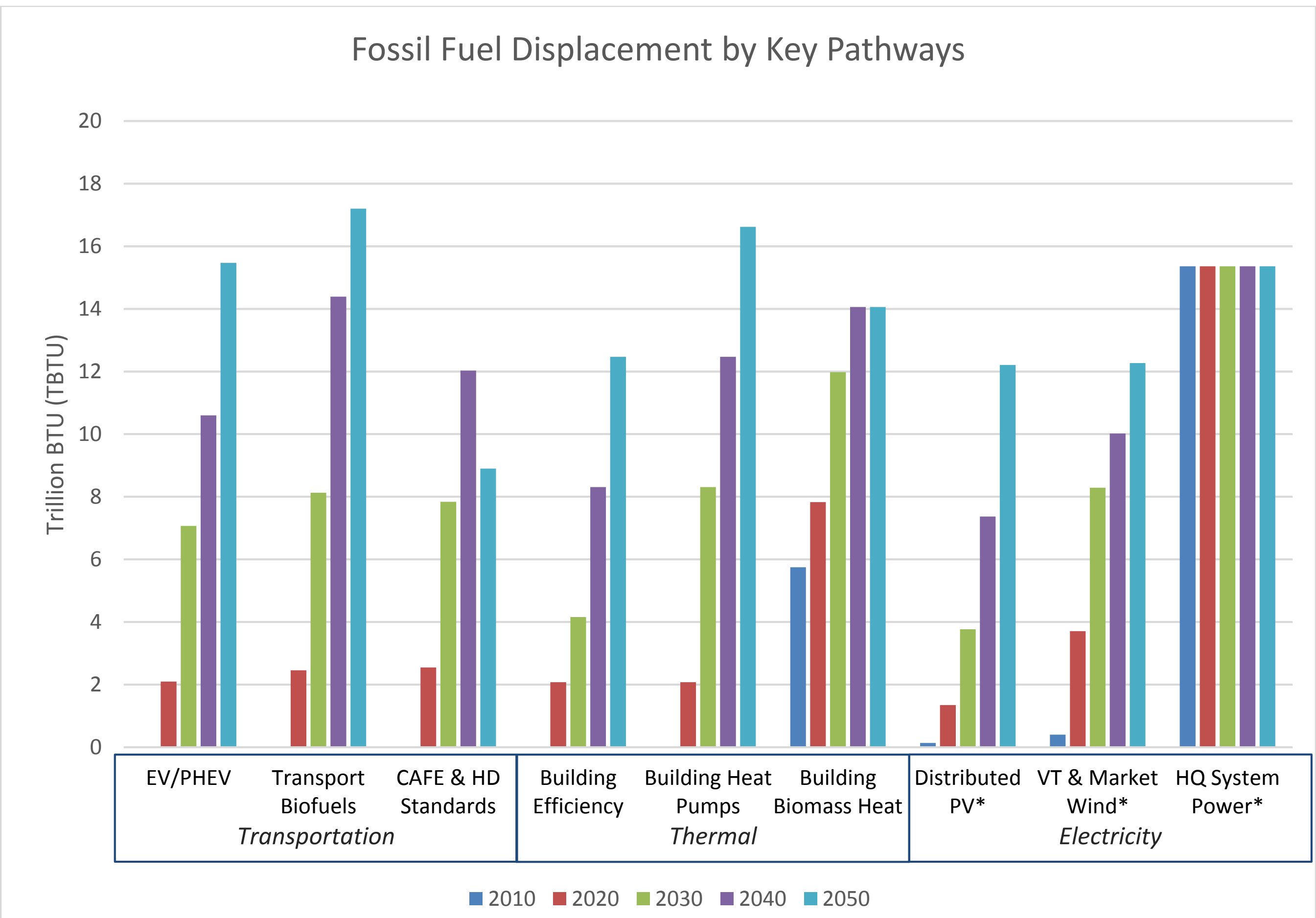
Table 3. Electrical Sector

Pathway	Impact
1. VT Photovoltaic (PV) Generation In 2013, PV generation in VT accounted for approximately 1% of electrical end-use GWH load (32 MW installed capacity). However, its growth is outpacing all other renewable technologies and this will likely continue and accelerate due to rapidly declining costs, ease of permitting, and minimal resource constraints. The EAN scenario assumes that in-state PV generation will grow to 1,000 MW by 2050. At a capacity factor of 15%, this will produce 18% of VT's end-use electricity in 2050.	High
2. VT Wind Generation VT currently has 120 MW of installed wind capacity (2013). 98% of this wind capacity is located four utility-scale projects that account for over 99% of wind energy produced in state on a GWH basis. Utility-scale wind plants currently have the lowest levelized life-cycle energy cost (about $.09/kwh in 2012 dollars) of non-combustion renewable generators, but face considerable permitting barriers. The EAN scenario assumes that an additional 200 MW of wind will be built by 2050, supplying 12% of our end-use electricity.	Med
3. VT Biomass Generation VT currently has two conventional steam-cycle biomass plants (72 MW total capacity), which consume 750,000 tons of wood and sawmill residues annually. Biomass generation potential is constrained in VT, both by limited forest resources that can be sustainable harvested and also by the emerging recognition that biomass fuels should be used primarily for thermal heating. New combined heat and power (CHP) technologies using Organic Rankine Cycle (ORC) technology have the promise to efficiently supply industrial or municipal-scale heat with ancillary electrical generation. Typically constructed in the 1 to 4 MW range, these plants can operate at 70% to 80% combined thermal and electrical efficiency. The EAN scenario assumes that 150 MW of ORC CHP will be built by 2050, supplying 30 MW of electricity or 6% of our total electrical demand.	Low
4. VT Small Hydro Generation Small-scale hydro also has limited growth potential in VT as documented in the PSD 2007 study *The Undeveloped Hydro Potential of Vermont*. The report identified over 93 MW of undeveloped hydroelectric capacity at 332 existing dams. Given the requirements of the Clean Water Act and the difficult and lengthy FERC permitting process, it is likely only a fraction of this potential will ever be developed. The EAN scenario assumes that an additional 30 MW of run of the river hydro will be developed (capacity factor = 40%), bringing VT's total capacity to 173 MW in 2050, supplying 7% of VT's end-use electricity.	Low
5. HQ Power Imports Hydro Quebec power imports currently supply approximately 35% of VT's electrical energy on a GHW basis (2011). HQ generation consists predominantly (98%) of large hydro and wind facilities and is classified as renewable by the State of Vermont. HQ imports are also "firm" system power, providing VT with a "dispatchable" renewable base load resource to supplement intermittent generation from wind and solar farms. The EAN scenario assumes our current contract for 400 MW remains in place and is extended under a new contract to 2050. Under this scenario, assuming HQ's current capacity factor of 50%, HQ imports will supply 22% of our end-use electricity in 2050.	High
6. Regional RE Market Imports In 2011, VT utilities relied on New England market power for about 12% of our electricity. The majority of this power comes from natural gas generators. The EAN scenario sees an important role for purchases of renewable regional market power, and phasing out purchases on non-renewable market power. In the six New England states, wind power is growing rapidly. In 2013, there was approximately 700 MW of installed capacity, up from 2 MW in 2005. 2,000 MW of additional wind capacity were in ISO-NE interconnection queue as of April 2013. The EAN scenario assumes that 200 MW of regional wind (at a capacity factor of 32%) is added by 2050. This will account for 8% of VT's end-use electricity.	Med
7. Electrical Efficiency For the period 2010-2012, Efficiency Vermont was able to save 1.8% of VT's total electrical energy annually through investments in end-use appliance efficiency. The EAN scenario assumes this level of annual efficiency improvement will continue, using a nominal 1.5% annual efficiency savings factor. By 2050, this will have resulted in 25% electrical energy savings over the 2010 baseline use.	Med
8. Transmission & Distribution Efficiency Given the increase in in-state distributed generation, the EAN analysis assumes there will be a 15% decrease in transmission and distribution losses by 2050, lowering the current T&D loss factor of 6.7% to 5.7% of end use. Smart Grid improvements could lower loss factors further, but were not considered in the EAN analysis.	Low

Based on this key pathway analysis and consideration of commercialization “roadmap” projections (DOE, NREL, USDA) for technologies such as solar, wind, and biofuels, EAN developed a series of renewable energy and efficiency implementation curves that would eventually move VT to 90% renewable by 2050. This analysis was based on decade milestones, starting in 2020, that set targets for the introduction and adoption of key policies and resources.

EAN’s pathway analysis was not guided by an econometric model or dynamic energy model, but relies on current knowledge about the potential for efficiency, new electric technologies, and renewable energy resources to enter the marketplace over time and displace non-renewable fossil and nuclear fuels. EAN has launched a collaborative effort with the University of Vermont’s Gund Institute for Ecological Economics and state partners to develop a dynamic energy simulation model for VT. When this model becomes operational in 2014, it will be used to test out the assumptions and effects in the current EAN non-dynamic “accounting” model.

EAN’s initial analysis, however, clearly shows that there are certain key technologies and pathways to achieving the CEP’s 2050 goal. These are shown in the graph below which documents the relative impact of each on reducing fossil fuel use.



* Offsets NG generation at a 2.69 source energy factor

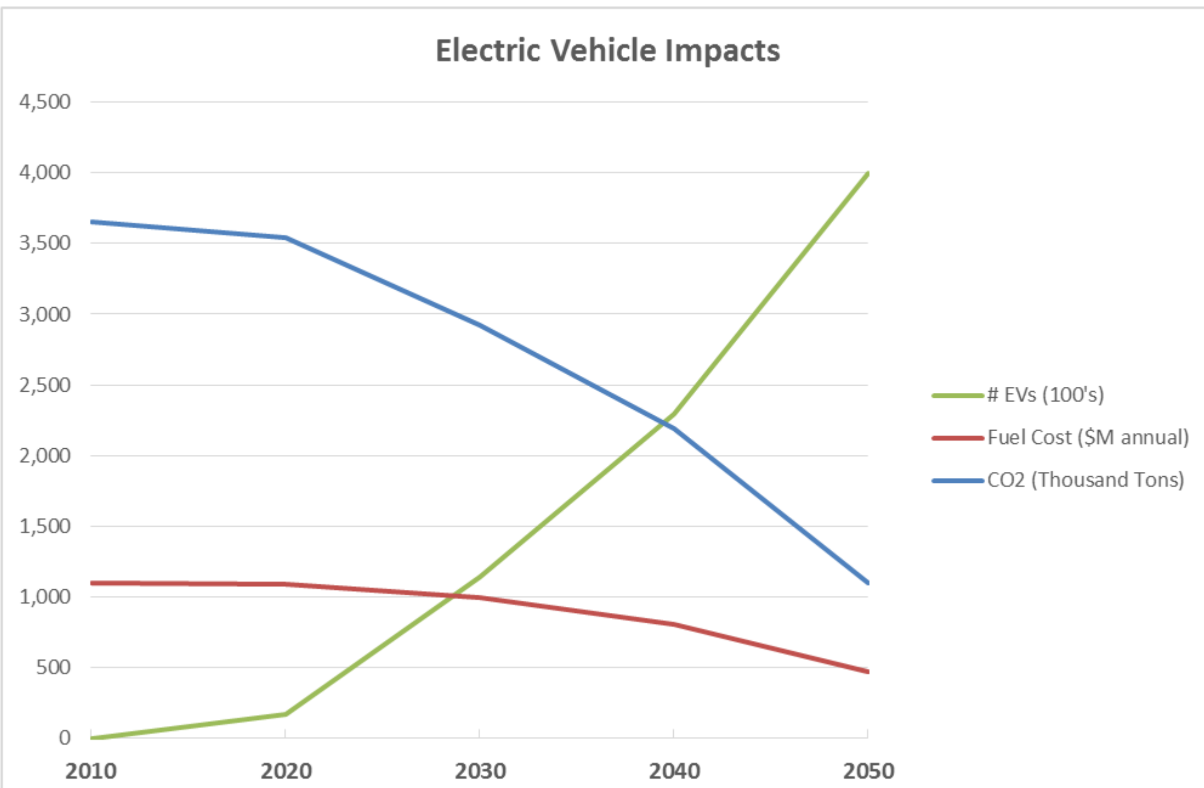
Transformative Effects of Combining Efficiency with Renewables

Investments in transportation, thermal, and electrical efficiency have been and will remain our lowest cost resource for meeting the goals of the CEP. Efficiency investments deliver a triple "bottom line" return of reduced energy use, reduced capital investment and operating cost, and reduced environmental impact of energy production and use.

Efficiency needs to be considered in a much broader context than the traditional focus on more efficient appliances and thermal insulation for our buildings. When the synergistic effects of increased electrification through renewables and efficiency improvements are considered together, each sector will experience profound transformation in terms of the efficiency of energy use, the cost of energy services, and the impact of energy production and consumption on natural resources. Below are three examples from EAN's energy model.

Transportation: Electric Vehicles

Electric (EV) and plug-in hybrid (PHEV) vehicles offer the promise of greatly reduced energy use and operating cost per vehicle mile. This is true today (2013) and will become more so as EV/PHEV vehicle capital costs decline rapidly in the next decade. By transitioning 70% of our automobiles (known as the Light Vehicle Fleet, or LVF) to EV and PHEV vehicles run on renewable fuels, Vermonters could save $500M annually at today's gasoline prices and cut LVF greenhouse gas emissions to less than a third of 2010 levels.



Assumptions:

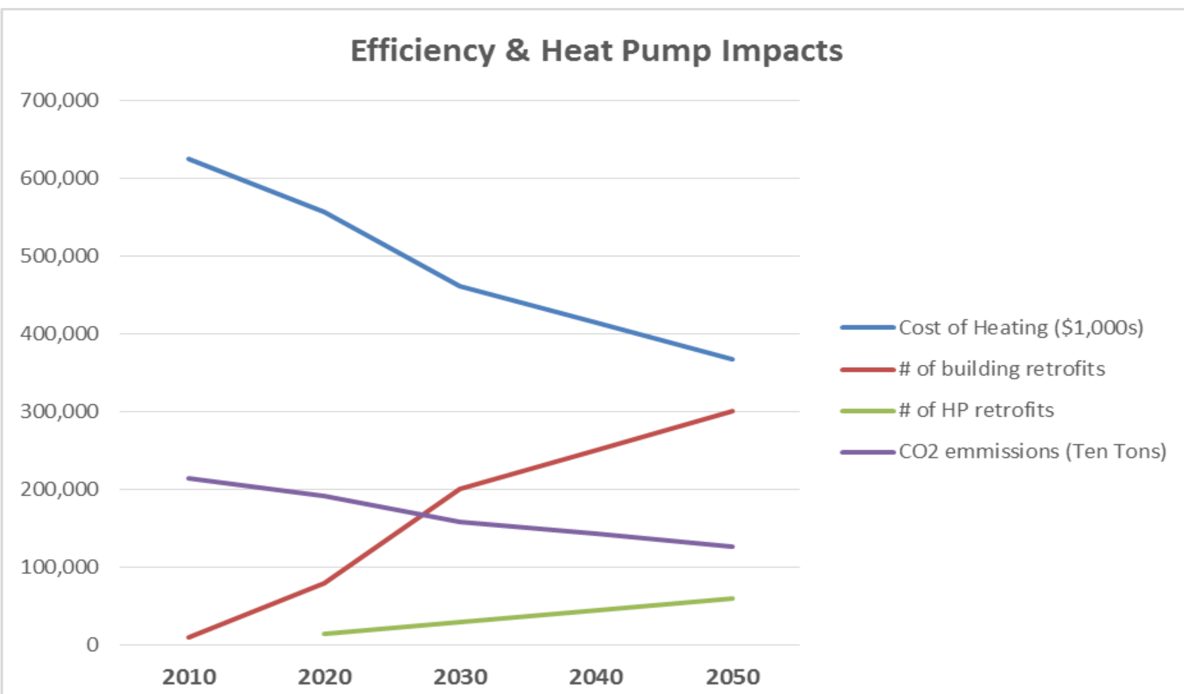
5,500 M vehicle miles driven annually in 2010 (UVM TRC). Remains unchanged to 2050.
Electricity cost = $.15/ kWh (2010 VT average)
All EVs powered with renewable electricity. EVs require 3 kWh/mile (UVM TRC) = $.052/mile in 2010.
VT 2010 fleet fuel cost = $.20/mile (based on $1.1B for 5,500M miles in 2010, UVM TRC)
Fuel costs held constant in 2010 nominal dollars.

Thermal: Efficiency & Heat Pumps

Vermonters spend over $625 M every year on oil, propane, and natural gas to heat residential and commercial buildings. Most of this money leaves the state to pay for extracting, refining, and transporting these fuels to VT and is lost to our state and local economy. Efficiency Vermont estimates it is possible to save at least one-third of this energy if 85% of Vermont's 350,000 homes and businesses receive building audits and cost-effective efficiency retrofits. Achieving an average of 30% heating load reduction in 300,000 buildings would save Vermonters $200 M a year at today's fuel prices, giving Vermont's economy a profound boost.

Electric heat pump (HP) technology has progressed rapidly in the last decade, and cold climate air source heat pumps (ASHP) are now available that can efficiently supply up to 75% of a building's heat load and do so at a 40% savings over the current price of oil. If heat pumps are run with electricity from renewable sources, then 75% of the building's heat has become renewable and greenhouse gas (GHG) emissions have been cut by 75%.

The chart below shows the impact of combining a statewide efficiency program that reaches 300,000 homes by 2050 (with 30% average savings) and heat pump retrofits of 60,000 buildings (20% penetration rate). At today's fuel and electricity cost, this would save Vermonters $260 M per year when fully implemented. It would also cut GHG emissions by over 40% from current levels.



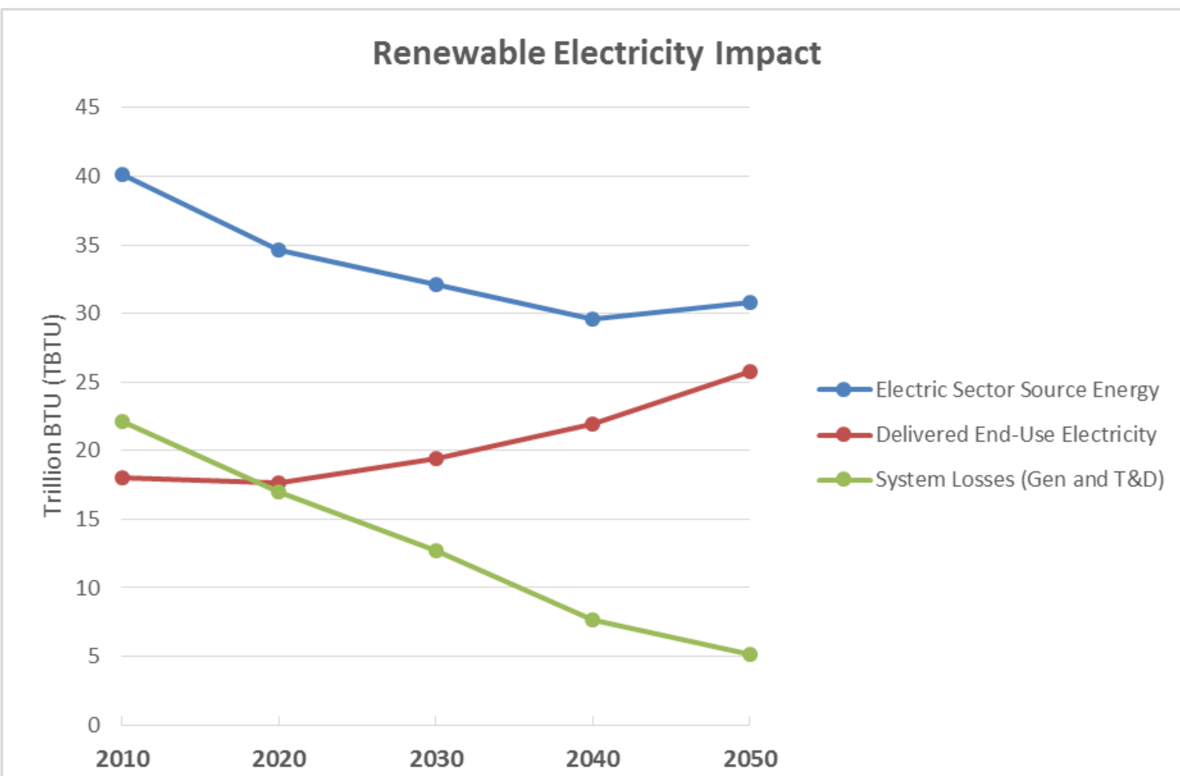
$625 M in heating cost in 2010 for residential & commercial purchases of oil, LPG, and NG (EIA)
Efficiency retrofits have average energy reduction of 30%. Individual building range = 20% to 50%. (VEIC)
Heat pumps are cold climate air-source units that provide 75% of annual building load.
ASHP save 40% of energy cost with electricity at $.146/kWh, oil at $3.99/gal and LPG at $2.99/gal (Letendre)

Electricity: Distributed Renewable Generation

Revamping our existing electric grid through investments in renewable distributed generation (DG) offers the promise of zero-emission electricity, greatly reduced source fuel losses associated with nuclear and fossil fuel generators, and reduced transmission and distribution losses. EAN's analysis of Vermont's 2010 electric sector determined that 49% of the energy consumption in this sector is waste, thermal losses at generating plants (44%) and losses in the transmission system (5%). Renewable generators such as solar, wind, and hydro facilities have no source losses because they do not consume fuel.

Transitioning our electric system to rely predominantly on these renewable sources of power is *the* foundation of achieving 90% by 2050. Not only will it allow for electrification of transportation and a portion of our heating needs, but it is the single most important element to reduce waste in our overall energy system and reduce GHG emissions. EAN's 90% by 2050 scenario shows that despite increasing our end-use electrical consumption by 45% in 2050 to power transportation and thermal sectors, the electrical sector overall source energy consumption will actually decrease over 20% because of new more efficient renewable generation that has no source energy losses.

The chart below shows the impact of transitioning Vermont's electric system to over 90% renewable generation by 2050. While the state's electric system today is approaching 30% renewable (counting Hydro Quebec), in 2010 Vermont's reliance on nuclear energy (VT Yankee) and natural gas market power contributed to large source energy losses and made the electric sector 80% non-renewable.



Achieving the First Milestone: 20% by 2020

For the 2020 milestone, EAN set a target goal of 20% renewable energy use across all sectors. Given available technology, Vermont's current energy programs, and where the state should be on the transformation S-curve, achieving 20% (roughly a 2/3 increase of our 2010 renewable percentage) appears achievable and cost-effective.

To illustrate the actions that might allow Vermont to reach this goal, EAN has compiled a list of targets from our key pathway analysis.

<u>Transport Sector</u>

- ➢ Electric vehicles: increase to 5% of light vehicle fleet
  - Requires adding 28,000 EVs and PHEVs
- ➢ Biofuels: increase by an additional 3% of liquid fuels for light vehicle fleet
  - Requires an additional 10 M gallons biofuels annually
- ➢ Increase vehicle fleet efficiency by 5%
  - Requires support of CAFE & HD standards by encouraging new efficient vehicle purchases

<u>Thermal Sector</u>

- ➢ Efficiency: Reduce building heat loses by 5%
  - Requires retrofitting 50,000 buildings with 30% average energy savings
- ➢ Biomass: increase by additional 7% of building sector heat load
  - Requires installation of 20,000 new pellet stoves or boilers
- ➢ Provide 2% building heat & hot water through solar thermal systems
  - Requires installation of 3,000 residential-scale (10 sq. m) SHW systems
- ➢ Biomass Combined Heat & Power (CHP)
  - Requires building 60 MW of highest-efficiency combined heat and power plants, providing 50 MW thermal and 10 MW electric generation

<u>Electric Sector</u>

- ➢ Hydro Electric: Build or refurbish 5 MW small-scale hydro capacity at existing dam sites
  - o Requires active support of Agency of Natural Resources to streamline permitting
- ➢ Solar Energy: Build 100 MW new PV capacity (50 "Solar Farms")
  - o Requires setting enhanced goals for the Standard Offer Program
- ➢ Wind Power: Build 30 MW new in-state capacity and contract for 50 MW regional wind capacity
  - o Requires siting guidelines and permit process reform

As the above list indicates, getting from 2010's 12% renewable to a 2020 goal of 20% is a large undertaking. Making headway in the transport sector stands out as the greatest challenge because of the current "immature" state of both the electric vehicle and biofuels industry. That said, national and state studies confirm that electric and hybrid vehicles have a significant cost benefit advantage over ICE vehicles even at today's early stage of development. Removing market barriers including consumer awareness, public charging infrastructure, and availability of the vehicles are the key policies that will kick start EV adoption and bring large benefits to both individual consumers and the state's overall economy. The adoption rate of EV/PHEV automobiles is the primary gate-keeper on how fast Vermont can move toward a renewable economy. It is also important to understand that accelerating early stage adoption plays out for decades in significantly higher penetration rates as we approach 2050. Drive Electric Vermont (DEV) is the statewide entity engaged in promoting the adoption of EVs and eliminating barriers to their rapid adoption (www.driveelectricvermont.com). Support for this stakeholder group, comprised of state agencies, utilities, regional and municipal planners, and NGOs, is critical to increasing EV adoption rates.

In the thermal sector, Vermont is a leader in both efficiency and biomass technologies. It also can boast of having some of the world's leading efficiency and biomass practitioners and businesses. However, without new business models to overcome market barriers and increase annual penetration rates, these low-cost, proven energy resources will continue to be underutilized. Efficiency Vermont, for all its success, is retrofitting less than half the number of housing units annually that are necessary to reach the legislative efficiency goals set in the Vermont Energy Efficiency and Affordability Act of 2008. The recommendations laid out in the 2013 Thermal Efficiency Task Force Report to the Legislature provide a clear set of policy recommendations to get back on track. The report calls for a $27M annual increase in the state's current efficiency program budget. Given that this additional public investment will leverage an additional $38M in private investment and provide an overall return of $6M for every $1M of public funds invested, finding a source of funds for this public investment is the near-term priority for the thermal sector.

The electric sector is currently over 25% renewable, in large part due to our 400 MW system power contract with Hydro Quebec. Solar photovoltaics (PV) is Vermont's fastest growing distributed generation (DG) technology, though its current installed capacity is only 20% of Vermont's installed wind capacity. On an end-use electrical supply basis (GWHs), PV's contribution is only one-tenth of that of wind due to its lower capacity factor (15% versus 32%). Despite this small installed base and lower capacity factor, the rapidly declining technology costs of PV and its minimal resource constraints mean that solar PV is poised to rapidly expand in VT. Two key policies drivers will determine how fast PV generation grows in VT. A third policy issue, the handling of Renewable Energy Credits (RECs) will determine whether distributed generation, such as PV, can contribute to our renewable energy goals:

1. Revised targets need to be set for Vermont's SPEED Program along with an expansion of the Standard Offer Program. The Standard Offer program (offering 25-year levelized price contracts for qualifying PV facilities of 2.2 MW or less) has been instrumental in the development of community-scale solar in VT and reducing the cost per kWh of PV. The current 5 MW annual Legislative cap on the Standard Offer program needs to be revisited in light of market changes and the state's energy, economic, and climate goals.

2. Solar net metering installations are now approaching 20 MW of installed capacity, most of this installed in just the past few years. Several of VT's smaller utilities have now hit the 4% statutory cap on net metering and have ceased to allow new, customer-owned, net metered generation to connect to their distribution systems. A statutory cap on net metering is unnecessary if utility rate structures and billing practices are revised to reflect the true added system benefits and costs associated with each type of net metering generation. The Department of Public Service should update its 2012 study of the benefits and costs of net metering to reflect current research and also initiate a PSB docket to explore alternative rate structures. It is important to note that the federal 30% investment tax credit for solar energy is due to expire at the end of 2016, providing a 3-year window where VT can take advantage of below market cost installations. PSD and PSB efforts to resolve the longer term structural net metering issues should not interfere or substitute for prompt legislative action on the 4% statutory cap.

3. Retirement of Renewable Energy Credits (RECs). RECs, generated by SPEED Program facilities, are currently being sold by Vermont into the New England market. Since RECs embody the renewable energy attributes (such as carbon reduction) of renewable generation, their sale means that technically and legally the entire output of the SPEED program (832 GWH or 15% of retail electric sales in 2012) cannot be counted as renewable. While REC sales have lowered the price of building distributed generation in VT, this practice is incompatible with the state's CEP goals, its climate goals, and furthering renewables in the

region. CT recently closed its market to VT RECs and the remainder of New England states will likely follow suit. Between now and 2020, VT can phase in the retirement of RECs with the goal of having all SPEED program RECs retired and off the market by 2020.

Technical Appendix

EAN Model Methodology

In order to determine the current and future mix of energy resources and the level of achievement in meeting renewable energy targets, an accounting framework was set up to tally the renewable and non-renewable portions of Vermont's energy supply mix. The goal was to provide a consistent and transparent framework, accurately account for all fuel types, and to rely on existing data from published, reliable sources. All energy use data was converted into British Thermal Units (BTU) to allow numerical and percentage comparison between fuels and sectors. The standard model unit is Trillion BTUs (TBTU). This can easily be converted to gigawatt-hours (GWH) for a "metric model" by dividing TBTUs by .003412.

EAN chose to start with a 2010 energy baseline compiled primarily from data published by the U.S. Energy Information Agency (EIA). This data was doubled checked against reports from Vermont's Public Service Department (PSD), Public Service Board (PSB), and UVM's Transportation Research center (TRC). Small differences were noted in the 2010 baseline, especially in the transportation sector. None of these differences were large enough to effect the general conclusions of the scenario analysis.

An "accounting" energy model was then developed using the same matrix of fuel sources and energy sectors, so that the 2010 baseline and future years could be compared side by side. The renewable energy fraction of the model in 2050 was set to 90% to reflect the goals of the state's Comprehensive Energy Plan (CEP). To reach this 90% goal, different technologies pathways, levels of energy efficiency and penetration of renewable resources were iteratively tried and vetted. The model makes no claim to representing an "optimum resource" case, rather it shows how based on existing commercialized technologies, VT could achieve 90% renewable energy supply by 2050.

The CEP goal of "90% renewable" has been interpreted by EAN members to mean that 90% of the total energy use in 2050 will come from renewable resources. Promoting energy conservation and investing in efficiency were included as key elements to achieving this renewable energy goal. While this seems straightforward, several accounting questions arise:

1. What is meant by total energy? Is it just VT's end-use energy, i.e. energy that is used by the residential, commercial, and industrial sectors? Or is it Vermont's total energy "footprint" that would include energy used in the processing, transportation, and transformation of the energy sources used in VT?
2. How should energy efficiency and conservation be accounted for? Is efficiency an "energy source" that should be tallied just like renewable energy resources and count toward the state's renewable energy goals? Or do efficiency and conservation reduce our energy demand, making it easier to meet our energy needs with renewables, but should not be counted as part of the renewable energy goal?

To resolve the first question, EAN has adopted the methodology of using "source energy" data. Source energy factors for liquid or solid fuels include the pre-combustion effects, which is the energy associated with extracting, processing, and delivering the primary fuels to the point of conversion in an electrical power plants or directly in buildings. For electricity, source energy factors additionally account for the conversion inefficiencies at the power plant and the transmission and distribution losses from the power plant to the building.

While use of source energy factors necessarily includes assumptions and generalizations about the production of fuels and electricity, these factors are now well documented and available based on regional inputs, such as for the Northeast U.S. More importantly, use of a "source" energy framework rather than an "end-use" energy framework is the only accurate and honest way to judge how “renewable” VT’s energy economy is or will become. Even though EAN’s model focuses on energy use within VT’s political borders, the State’s energy footprint is regional and global in extent. As an example, to supply 1 unit of electricity to Vermont from a natural gas power plant in Massachusetts requires the combustion of approximately 3 units of natural gas. We need to count the 3 units of “source” energy if we want to account for all fossil/nuclear fuels required to support VT’s energy demand. Using source energy is also important if we want to be able to understand the impact and full benefit of an energy transition to renewables that includes distributed generation and more localized energy sources.

For EAN’s work, we relied on the publication, *Source Energy and Emission Factors for Energy Use in Buildings*, M. Deru and P. Torcellini, National Renewable Energy Laboratory Report NREL/TP-550-38617, Revised June 2007. These source energy factors were applied to EIA end-use data to provide greater transparency and avoid potential double counting that could occur using EIA’s “primary energy” data. For renewable energy sources that rely on the combustion or transformation of renewable fuels, such as ethanol, biodiesel, and biomass heat and electricity, we relied on information found in specific “energy balance” studies for these fuels. For renewables that do not consume a fuel, such as photovoltaic and wind energy, we assumed a unity source energy factor.

One of the interesting issues that arise when using “source energy” accounting is how to treat source energy losses for renewable fuels. Should these losses (for instance the 70% energy lost when generating electricity from biomass with a conventional steam cycle turbine) be counted as adding to the percentage of renewable energy use in Vermont? The logical disconnect of having wasteful energy transformation processes support our progress toward our renewable energy goals argues for treating these losses as a separate category. For the purposes of the EAN model, renewable source energy inefficiencies are documented and accounted for in total energy use, but are excluded from the calculation of overall state percentage of renewable energy use.

To answer the second question about accounting for efficiency, EAN chose not to treat it as an energy “source” that bolsters the renewable energy fraction. This would have required creating a hypothetical “business as usual” 2050 energy scenario to which increased amounts of efficiency are applied and counted. Rather EAN chose to apply all efficiency and conservation as demand reduction measures that lowered the amount of future energy use. Aggressive building energy retrofits, national vehicle CAFE standards, improved efficiency of the electric grid, etc., were all considered, analyzed, and assigned a demand reduction factor. These demand reduction factors are applied to the 2010 baseline to produce new future energy “baselines” that renewable energy options could then be applied. This framework helps simplify the model complexity and improve transparency, but it does result in a “higher bar” than models that treat efficiency improvements as adding to the percentage “renewable”.

The Energy/Sector Matrix

The model creates a matrix of energy sources and end-use sectors.

The energy source categories are:

Energy Source	Description/ EIA Code	Source Energy Factor
Distillate Fuel Oil	Distillate fuel oil total end-use consumption Transport and Thermal sectors, (DFTXB)	1.158
Gasoline	Transport sector only (MMTCB)	1.187
Jet Fuel	Aviation fuel (JFXTB)	1.205
Other Oils	Residual fuel oil total end-use consumption. (RFTXB), Lubricants (LUTCB)	1.191
Natural Gas	Natural Gas (thermal sector only) (NGCCB, NGICB, NGRCB). NG transport sector from UVM data	1.092
Propane (LPG)	LPG total end-use consumption. (LGTXB)	1.151
Nuclear	Nuclear electricity (PSB/utility data used)	3.075
Non-Renewable Market Power	ISO-NE market power (mostly NG generation)	2.629
Biomass - electric	Wood for electric generation (PSB/utility data)	3.333
Biomass- thermal	Wood for thermal heat (WDCCB, WDCIB, WBCRB)	1.096
Biofuels	Liquid biodiesel and fuel oil, bio-gas (no EIA data)	1.150
Ethanol	Fuel ethanol consumed by transport sector. (EMACB)	1.700
Hydro	Hydro electricity (PSB/utility data used)	1.000
Solar	Photovoltaic electricity and solar thermal heat. (SOTCB) PSB data used to calculate electric portion.	1.000
Wind	Wind electricity (WYTCB)	1.000
Renewable Market Power	ISO-NE market power that is renewable	1.000
RE Losses	Generation losses from renewable combustion generation	n/a
Non-RE Losses	Generation losses from non-renewable generation	n/a

The total energy use from a particular source is equal to the "end-use consumption" multiplied by the source energy factor. Because electric generation losses from combustion or nuclear sources are so large (typically 2.5 to 3x end-use consumption), two separate energy categories were included to track losses for renewable and non-renewable generation. This allows greater transparency about the overall effect on Vermont's energy intensity and energy footprint if a greater portion of our electricity is derived from non-combustion technologies such as photovoltaics, wind, and hydro-power.

To account for population change and its impact on energy use, the model incorporates population estimates based on Vermont and Federal estimates. The analysis assumes VT's population and energy consumption growth is 0.6% per year through 2020, 0.4% per year through 2030. 0.2% per year from 2030 to 2050.

2010 Transport Sector Energy Data

Fuel/end use	Source Energy Factor	Transport			
In TBTU		Residential (light vehicle)	Commercial Aviation/Truck/Rail	Industrial Truck/Rail	Sector Total
Nat Gas (transport & thermal)	1.092		0.003		0.003
Distillate Fuel Oil	1.158		6.05	2.98	9.03
Jet Fuel	1.205		1.52		1.52
LPG	1.151		0.04		0.045
Gasoline	1.187	44.17	0.08	0.67	44.93
Others Oils (residual & lubricants)	1.191		0.21	0.10	0.31
Nuclear	3.075				
Market Non-RE (Nat Gas)	2.629				
Biomass (electric)	3.333				
Biomass (thermal)	1.096				
Biodiesel	1.150	0.001			0.001
Ethanol	1.700	2.89	0.01		2.9
Solar	1.000				
Wind (in-state)	1.000				
Hydro	1.000				
Market RE (out of state wind)	1.000				
Gen losses from biomass generation					
Non-RE Source Energy for biofuels		2.02	0.01		2.03
Gen & TD losses from non-RE sources					
Total Energy		49.09	7.92	3.76	**60.77**
Renewable Energy					**2.90**

Fuel/end use		Transport			
In % of total energy use		Residential (light vehicle)	Commercial Aviation/Truck/Rail	Industrial Truck/Rail	Sector Total
Nat Gas (transport & thermal)			0.002%		0.002%
Distillate Fuel Oil			4.078%	2.01%	6.087%
Jet Fuel			1.024%		1.024%
LPG			0.030%		0.030%
Gasoline		29.77%	0.053%	0.45%	30.275%
Others Oils (residual & lubricants)			0.139%	0.07%	0.208%
Nuclear					
Market Power (Nat Gas)					
Biomass (electric)					
Biomass (thermal)					
Biodiesel		0.00%			0.001%
Ethanol		1.95%	0.007%		1.954%
Solar					
Wind					
Hydro					
Market RE (out of state wind)					
Gen losses from biomass generation					
Non-RE Source Energy for biofuels		1.36%	0.005%		1.368%
Gen & TD losses from non-RE sources					
Total Energy		33.08%	5.34%	2.53%	**40.95%**
% renewable					**4.77%**

2010 Thermal Sector Energy Data

Fuel/end use	**Source Energy Factor**	**Thermal Energy**			
In TBTU		Residential	Commercial	Industrial	Sector Total
Nat Gas (transport & thermal)	1.092	3.39	2.62	3.20	9.21
Distillate Fuel Oil	1.158	11.63	4.63	3.78	20.05
Jet Fuel	1.205				
LPG	1.151	6.82	3.25	0.26	10.33
Gasoline	1.187				
Others Oils (residual & lubricants)	1.191		0.53	0.88	1.41
Nuclear	3.075				
Market Non-RE (Nat Gas)	2.629				
Biomass (electric)	3.333				
Biomass (thermal)	1.096	3.84	0.64	1.27	5.75
Biodiesel	1.150				
Ethanol	1.700				
Solar	1.000	0.15			0.15
Wind (in-state)	1.000				
Hydro	1.000				
Market RE (out of state wind)	1.000				
Gen losses from biomass generation					
Non-RE Source Energy for biofuels		0.37	0.06	0.12	0.55
Gen & TD losses from non-RE sources					
Total Energy		26.19	11.75	9.52	**47.45**
Renewable Energy					**5.90**

Fuel/end use		**Thermal Heat**			
In % of total energy use		Residential	Commercial	Industrial	Sector Total
Nat Gas (transport & thermal)		2.28%	1.77%	2.16%	6.20%
Distillate Fuel Oil		7.84%	3.12%	2.55%	13.51%
Jet Fuel					
LPG		4.59%	2.19%	0.18%	6.96%
Gasoline					
Others Oils (residual & lubricants)			0.36%	0.59%	0.95%
Nuclear					
Market Power (Nat Gas)					
Biomass (electric)					
Biomass (thermal)		2.59%	0.43%	0.86%	3.88%
Biodiesel					
Ethanol					
Solar		0.10%			0.10%
Wind					
Hydro					
Market RE (out of state wind)					
Gen losses from biomass generation					
Non-RE Source Energy for biofuels		0.25%	0.04%	0.08%	0.37%
Gen & TD losses from non-RE sources					
Total Energy		17.65%	7.92%	6.41%	**31.98%**
% renewable					**12.44%**

2010 Electric Sector Energy Data

Fuel/end use	Source Energy Factor	Electricity			
In TBTU		Residential	Commercial	Industrial	Sector Total
Nat Gas (transport & thermal)	1.092				
Distillate Fuel Oil	1.158				
Jet Fuel	1.205				
LPG	1.151				
Gasoline	1.187				
Others Oils (residual & lubricants)	1.191	0.20	0.19	0.13	0.52
Nuclear	3.075	2.76	2.61	1.80	7.17
Market Non-RE (Nat Gas)	2.629	0.79	0.75	0.51	2.05
Biomass (electric)	3.333	0.41	0.39	0.27	1.06
Biomass (thermal)	1.096				
Biodiesel	1.150				
Ethanol	1.700				
Solar	1.000	0.05			0.05
Wind (in-state)	1.000	0.02	0.02	0.01	0.04
Hydro	1.000	2.72	2.57	1.77	7.05
Market RE (out of state wind)	1.000	0.04	0.03	0.02	0.095
Gen losses from biomass generation		0.95	0.90	0.62	2.48
Non-RE Source Energy for biofuels					
Gen & TD losses from non-RE sources		7.57	7.16	4.94	19.66
Total Energy		15.50	14.61	10.07	**40.18**
Renewable Energy					**8.30**

Fuel/end use		Electricity			
In % of total energy use		Residential	Commercial	Industrial	Sector Total
Nat Gas (transport & thermal)					
Distillate Fuel Oil					
Jet Fuel					
LPG					
Gasoline					
Others Oils (residual & lubricants)		0.14%	0.13%	0.09%	0.35%
Nuclear		1.86%	1.76%	1.21%	4.83%
Market Power (Nat Gas)		0.53%	0.50%	0.35%	1.38%
Biomass (electric)		0.28%	0.26%	0.18%	0.72%
Biomass (thermal)					
Biodiesel					
Ethanol					
Solar		0.03%			0.03%
Wind		0.01%	0.01%	0.01%	0.03%
Hydro		1.83%	1.73%	1.19%	4.75%
Market RE (out of state wind)		0.02%	0.02%	0.02%	0.06%
Gen losses from biomass generation		0.64%	0.61%	0.42%	1.67%
Non-RE Source Energy for biofuels					
Gen & TD losses from non-RE sources		5.10%	4.82%	3.33%	13.25%
Total Energy		10.44%	9.84%	6.79%	**27.08%**
% renewable					**20.66%**

2010 Total Energy Data

Fuel/end use	**Source Energy Factor**		**Total**		**Total Energy**
In TBTU		Residential	Commercial	Industrial	Total TBTU
Nat Gas (transport & thermal)	1.092	3.39	2.62	3.20	9.21
Distillate Fuel Oil	1.158	11.63	10.69	6.76	29.08
Jet Fuel	1.205		1.52		1.52
LPG	1.151	6.82	3.30	0.26	10.38
Gasoline	1.187	44.17	0.08	0.67	44.93
Others Oils (residual & lubricants)	1.191	0.20	0.93	1.11	2.24
Nuclear	3.075	2.76	2.61	1.80	7.17
Market Non-RE (Nat Gas)	2.629	0.79	0.75	0.51	2.05
Biomass (electric)	3.333	0.41	0.39	0.27	1.06
Biomass (thermal)	1.096	3.84	0.64	1.27	5.75
Biodiesel	1.150	0.00			0.00
Ethanol	1.700	2.89	0.01		2.90
Solar	1.000	0.20			0.20
Wind (in-state)	1.000	0.02	0.02	0.01	0.04
Hydro	1.000	2.72	2.57	1.77	7.05
Market RE (out of state wind)	1.000	0.04	0.03	0.02	0.09
Gen losses from biomass generation		0.95	0.90	0.62	2.48
Non-RE Source Energy for biofuels		2.39	0.07	0.12	2.58
Gen & TD losses from non-RE sources		7.57	7.16	4.94	19.66
Total Energy		90.78	34.27	23.35	**148.40**
Renewable Energy					13.76

Fuel/end use		**Total**		**Total Energy**
In % of total energy use	Residential	Commercial	Industrial	Total %
Nat Gas (transport & thermal)	2.28%	1.77%	2.16%	6.20%
Distillate Fuel Oil	7.84%	7.20%	4.56%	19.60%
Jet Fuel		1.02%		1.02%
LPG	4.59%	2.22%	0.18%	6.99%
Gasoline	29.77%	0.05%	0.45%	30.28%
Others Oils (residual & lubricants)	0.14%	0.63%	0.75%	1.51%
Nuclear	1.86%	1.76%	1.21%	4.83%
Market Power (Nat Gas)	0.53%	0.50%	0.35%	1.38%
Biomass (electric)	0.28%	0.26%	0.18%	0.72%
Biomass (thermal)	2.59%	0.43%	0.86%	3.88%
Biodiesel	0.00%			0.00%
Ethanol	1.95%	0.01%		1.95%
Solar	0.13%			0.13%
Wind	0.01%	0.01%	0.01%	0.03%
Hydro	1.83%	1.73%	1.19%	4.75%
Market RE (out of state wind)	0.02%	0.02%	0.02%	0.06%
Gen losses from biomass generation	0.64%	0.61%	0.42%	1.67%
Non-RE Source Energy for biofuels	1.61%	0.05%	0.08%	1.74%
Gen & TD losses from non-RE sources	5.10%	4.82%	3.33%	13.25%
Total Energy	61.17%	23.10%	15.73%	100.00%
% renewable				**11.53%**

Renewable Electric Technologies

In 2010, VT's electrical sector was approximately 20% renewable when analyzed on the basis of utility power contracts and with source energy losses included. The majority of this renewable power (68%) is from Hydro-Quebec. The remainder comes from in-state hydro (16%), biomass (13%), wind (2%), solar PV (1%), and farm/landfill methane (1%).

EAN's analysis assumes that by 2050, the electrical sector will have to be over 90% renewable and that end-use consumption in VT will have to increase by approximately 45% to achieve the renewable electrification goals necessary in the transport and thermal sectors. Based on current energy price forecasts and research reports about renewable technologies and their projected cost curves, the EAN analysis identifies the following generation technologies and sources as having the greatest likelihood of supplying this increased energy:

A. Photovoltaics

Rapidly declining equipment costs have resulted in installed PV capacity in the U.S. growing by about 35% each year since 2010 (see GTM chart below). In VT, PV capacity (while still only 1% of total generation) has been growing even more rapidly due to favorable net metering polices and the Standard Offer under the SPEED Program. The spring 2013 RFP for VT's Standard Offer, showed the current 25-year levelized cost of energy (LCOE) for a 2MW "community-scale" PV plant ranged from $134 to $175 per MWH for the ten lowest bids. While approximately twice as expensive as the current levelized cost of combined-cycle natural gas plants ($69-$97/MWH) that provide the majority of ISO-NE system power, the declining costs of PV, its zero emission footprint, modularity from residential rooftop to utility-scale plants, and its ease of siting and permitting, mean that PV will continue to be the fastest growing generation technology. By 2050, the EAN analysis assumes VT will have contracts for approximately 1,000 MW of PV, generating 1,300 GWH assuming a 15% capacity factor.

More than two-thirds of America's distributed PV (everything except for utility-scale projects) has been installed since January 2011. And by 2015, the country's distributed PV market is expected to jump by more than 200%.

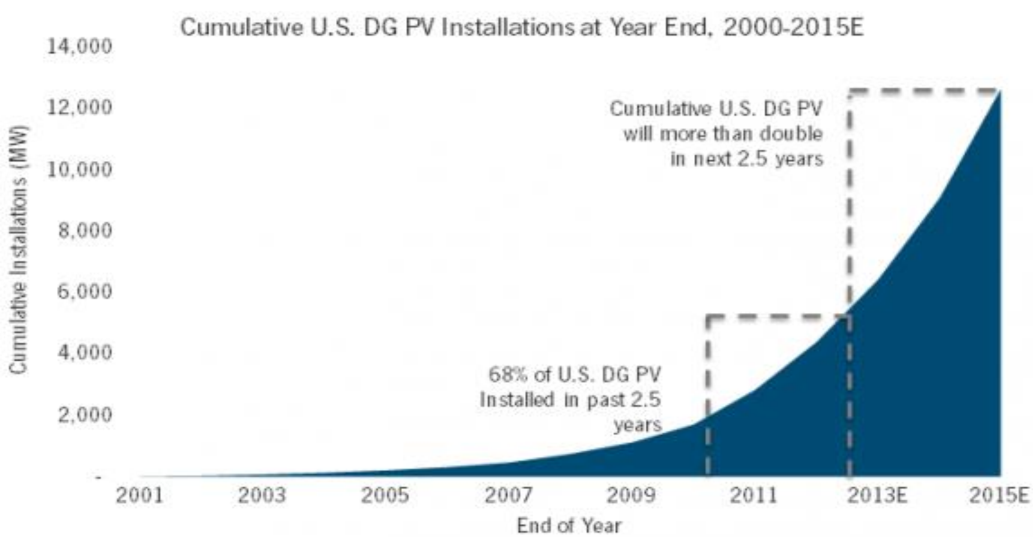


Chart: GTM Research/SEIA U.S. Solar Market Insight

B. Wind

Aside from traditional hydro-electric generation, utility-scale wind is currently the lowest cost renewable generation source in New England. Currently, VT has 4 utility-scale operating wind farms – Kingdom Community Wind (Lowell, 63 MW), Sheffield (40 MW), Georgia Mountain (10MW), and Searsburg (6 MW). In addition, VT utilities have contracts with other New England wind farms. In total, wind supplies approximately 550 GWH or about 9% of VT's end-use electrical demand.

The current 25-year levelized cost for wind plants in the 100 MW range is approximately $85/MWH. Smaller plants, such as Kingdom Community Wind, have a LCOE in the $95/MWh range. Given that the LCOE of a 100 MW wind farm is currently just about 10% higher than a combined cycle NG plant, and that wind is on a declining cost curve as opposed to an escalating one for NG, it is expected that the majority of new renewable market power in New England for at least the next decade will come from wind.

While small-scale wind systems (<100 kW) continue to be installed in VT, declining net metered installations and zero installation in the Standard Offer program are evidence of the market and regulatory hurdles facing this technology. In the absence of a declining cost curve for small-scale wind technology (as is the case with PV), it is likely that small wind will play an insignificant role in renewable electrification.

The EAN analysis assumes that by 2050 VT will have 520 MW of wind power capacity, or an additional 400 MW over 2013 levels. 200 MW might come from in-state wind farms and 200 MW from larger regional farms that VT utilities contract with. At a capacity factor of 33%, this 520 MW will supply approximately 1,500 GWH or about 20% of VT's 2050 projected total electrical end-use energy.

C. Biomass Combined Heat & Power (CHP)

Biomass electric generation potential is constrained in VT, both by limited forest resources that can be sustainable harvested and also by the emerging recognition that our biomass fuel resources should be used primarily for thermal heating. EAN assumes that efficiency standards will be set for all new biomass generation, similar to standards currently in place for biomass projects in the Standard Offer program. (See *Biomass Energy Development Working Group Final Report, January 2012).*

VT currently has two conventional steam-cycle biomass plants (McNeil, 50 MW and Ryegate, 22MW) which together consume 750,000 tons of wood annually. These traditional steam-cycle generating plants are less than 30% efficient. Without add-on thermal cogeneration equipment, 70% of the biomass resource used to fuel these plants is wasted. For reasons of resource efficiency, market economics, and environmental impact, EAN believes this type of traditional steam cycle technology will not and should not be built in the future. The EAN analysis assumes both McNeil and Ryegate will continue to operate in the future, but notes that large efficiency gains could be achieved by retrofitting McNeil for thermal cogeneration and supplying Burlington, UVM, or the Fletcher Allen Hospital with heat.

The 2010 *Wood Fuel Supply Update* (BERC, 2010) estimates that under a "moderate" harvesting scenario there are approximately an additional 900,000 green tons of available low-grade wood fuel supply in VT. The EAN scenario assumes that any future biomass generation will be supplied by small combined heat and power (CHP) plants that are primarily thermal plants with ancillary generators that convert up to 20% of the plant's capacity as electrical generation. Organic Rankine Cycle (ORC) plants, operating at over 80% combined thermal and electrical efficiency, have been used in Europe for years and will likely be the technology of choice for small-scale distributed biomass generation in Vermont. While new combined heat and power (CHP) technologies have the promise to efficiently supply industrial or municipal-scale heat with ancillary electrical generation (typically in the less than one MW range), this technology has not entered the U.S. market due to our low thermal and electrical energy costs.

An intriguing idea is that ORC plants could be combined with wood pellet production to produce both pellets and renewable electricity. The chart below is typical of ORC plant size in Europe, though it should be noted that modular ORC units can be ganged together to provide multi-MW scale plants if desired.

ORC MODEL	GROSS ELECTRIC POWER	THERMAL POWER	PELLETS PRODUCTION	
			TON/H	TON/YEAR
CHP-6	619 kW	2689 kW	2,50	18.750
CHP-7	729 kW	3146 kW	2,94	22.058
CHP-10	1000 kW	4095 kW	3,94	29.550
CHP-14	1317 kW	5341 kW	5,14	38.565
CHP-18	1862 kW	7843 kW	7,82	58.650
CHP-22	2319 kW	9598 kW	9,59	71.948

Chart & figures courtesy of PRODESA, Zaragoza, Spain

D. Small Hydro Generation

Small-scale hydro also has limited growth potential in VT as documented in the PSD 2007 study *The Undeveloped Hydro Potential of Vermont* (Barg, L.). The author’s analysis identified over 93 MW of undeveloped hydroelectric capacity at 332 existing dams. Given the requirements of the Clean Water Act and the difficult and lengthy FERC permitting process, it is likely only a fraction of this potential, perhaps 50 MW, will ever be developed. Current installation costs for small (<500 kW) run-of-river hydro retrofits are in the $2,500/kW range, exclusive of permitting. At sites where permitting costs are low, net metered hydro generation using Vermont’s Group Net Metering (GNM) rules is currently cost-effective.

The EAN analysis assumes that 30 MW of additional small hydro capacity will be developed by 2050 at existing dam sites.

Decade Milestone Energy Use

The spreadsheets below indicate energy source by sector at each decade milestone leading to 2050. Far right column indicates change over 2010 baseline.

2020 Energy Matrix

Fuel/end use	**Sector**					
In TBTU	Transport	Thermal	Electric	Total	% Total Energy	% of 2010 Baseline
Nat Gas (transport & thermal)	0.003	9.21		9.21	6.7%	100%
Distillate Fuel Oil	8.43	17.30		25.73	18.8%	88%
Jet Fuel	1.52			1.52	1.1%	100%
LPG	0.04	6.21		6.26	4.6%	60%
Gasoline	39.53			39.53	28.9%	88%
Others Oils (residual & lubricants)	0.31	1.41	0.52	2.24	1.6%	100%
Nuclear			5.54	5.54	4.1%	77%
Market Non-RE (Nat Gas)			1.35	1.35	1.0%	66%
Biomass (electric)			1.21	1.21	0.9%	114%
Biomass (thermal)		8.66		8.66	6.3%	151%
Biofuel (diesel, jet & heating oil)	1.50			1.50	1.1%	>1000%
Ethanol (corn)	2.55			2.55	1.9%	88%
Solar (in-state)		0.59	0.50	1.09	0.8%	544%
Wind (in-state)			1.52	1.52	1.1%	>1000%
Hydro			7.11	7.11	5.2%	101%
Market RE*	0.57	0.57	1.08	2.22	1.6%	>1000%
Gen losses from biomass generation**			2.77	2.77	2.0%	112%
Non-RE Source Energy for biofuels	2.01	0.55		2.56	1.9%	99%
Gen & TD losses from non-RE sources			14.05	14.05	10.3%	71%
Total Energy	56.46	44.50	35.66	136.62	100%	92%
% Renewable	8%	22%	35%	20%		
% non-renewable	92%	78%	65%	80%		
* All EV & HP electrical energy allocated to "market RE"						
**not counted in % renewable formula						

2030 Energy Matrix

Fuel/end use	Sector					
In TBTU	Transport	Thermal	Electric	Total	% Total Energy	% of 2010 Baseline
Nat Gas (transport & thermal)	0.003	9.21		9.21	7.9%	100%
Distillate Fuel Oil	5.98	5.88		11.86	10.2%	41%
Jet Fuel	1.29			1.29	1.1%	85%
LPG	0.04	0.89		0.93	0.8%	9%
Gasoline	23.74			23.74	20.4%	53%
Others Oils (residual & lubricants)	0.31	1.41	0.52	2.24	1.9%	100%
Nuclear			3.75	3.75	3.2%	52%
Market Non-RE (Nat Gas)			0.91	0.91	0.8%	44%
Biomass (electric)			1.60	1.60	1.4%	151%
Biomass (thermal)		12.86		12.86	11.0%	224%
Biofuel (diesel, jet & heating oil)	8.20	3.30		11.50	9.9%	>1000%
Ethanol (corn)	1.53			1.53	1.3%	53%
Solar (in-state)		1.25	1.40	2.65	2.3%	>1000%
Wind (in-state)			2.01	2.01	1.7%	>1000%
Hydro			7.29	7.29	6.3%	103%
Market RE*	1.91	2.28	1.08	5.27	4.5%	>1000%
Gen losses from biomass generation**			3.55	3.55	3.0%	143%
Non-RE Source Energy for biofuels	2.30	1.05		3.35	2.9%	130%
Gen & TD losses from non-RE sources			11.07	11.07	9.5%	56%
Total Energy	45.31	38.12	33.18	116.61	100%	79%
% Renewable	26%	52%	45%	40%		
% non-renewable	74%	48%	55%	60%		
* All EV & HP electrical energy allocated to "market RE"						
**not counted in % renewable formula						

2040 Energy Matrix

Fuel/end use	**Sector**					
In TBTU	Transport	Thermal	Electric	Total	% Total Energy	% of 2010 Baseline
Nat Gas (transport & thermal)	0.003	1.73		1.74	1.9%	19%
Distillate Fuel Oil	0.91	0.24		1.15	1.2%	4%
Jet Fuel	1.06			1.06	1.1%	70%
LPG	0.04	0.99		1.04	1.1%	10%
Gasoline	13.99			13.99	15.0%	31%
Others Oils (residual & lubricants)	0.31	0.66	0.52	1.49	1.6%	67%
Nuclear			0.29	0.29	0.3%	4%
Market Non-RE (Nat Gas)			0.33	0.33	0.3%	16%
Biomass (electric)						
Biomass (thermal)		15.70		15.70	16.8%	273%
Biofuel (diesel, jet & heating oil)	14.61	6.61		21.21	22.7%	>1000%
Ethanol (corn)	0.90			0.90	1.0%	31%
Solar (in-state)		1.91	2.74	4.65	5.0%	>1000%
Wind (in-state)			2.01	2.01	2.2%	>1000%
Hydro			7.41	7.41	7.9%	105%
Market RE*	2.86	3.42	2.07	8.35	9.0%	>1000%
Gen losses from biomass generation**			4.15	4.15	4.4%	168%
Non-RE Source Energy for biofuels	2.82	1.54		4.37	4.7%	169%
Gen & TD losses from non-RE sources			3.47	3.47	3.7%	18%
Total Energy	37.51	32.82	22.99	93.32	100%	63%
% Renewable	49%	84%	76%	68%		
% non-renewable	51%	16%	24%	32%		
* All EV & HP electrical energy allocated to "market RE"						
**not counted in % renewable formula						

2050 Energy Matrix

Fuel/end use	Sector					
	Transport	Thermal	Electric	Total	% Total Energy	% of 2010 Baseline
Nat Gas (transport & thermal)	0.003	0.79		0.79	0.8%	9%
Distillate Fuel Oil	1.00	1.34		2.34	2.5%	8%
Jet Fuel	0.76			0.76	0.8%	50%
LPG	0.04	0.98		1.03	1.1%	10%
Gasoline	2.50			2.50	2.7%	6%
Others Oils (residual & lubricants)	0.31			0.31	0.3%	14%
Nuclear						
Market Non-RE (Nat Gas)			0.10	0.10	0.1%	5%
Biomass (electric)			2.02	2.02	2.1%	190%
Biomass (thermal)		16.18		16.18	17.2%	281%
Biofuel (diesel, jet & heating oil)	25.28	9.91		35.18	37.3%	>1000%
Ethanol (corn)	0.16			0.16	0.2%	6%
Solar (in-state)		2.35	4.53	6.89	7.3%	>1000%
Wind (in-state)			2.01	2.01	2.1%	>1000%
Hydro			7.41	7.41	7.9%	105%
Market RE*	4.17	4.56	2.07	10.81	11.5%	>1000%
Gen losses from biomass generation**			4.39	4.39	4.7%	177%
Non-RE Source Energy for biofuels						
Gen & TD losses from non-RE sources			1.39	1.39	1.5%	7%
Total Energy	34.23	36.12	23.92	94.27	100%	64%
% Renewable	87%	91%	92%	90%		
% non-renewable	13%	9%	8%	10%		
* All EV & HP electrical energy allocated to "market RE"						
**not counted in % renewable formula						

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