

Vermont Solar Market Pathways



Volume 2

Net Metering Brief and Focus Area Briefs

December 2016



Preface

The growth of solar markets will create economic expansion in other segments of Vermont's energy market. In turn, it will also be driven growing consumer interest in electric vehicles and heating systems. These changes in Vermont's energy economy mean that this report and the research that has been undertaken for it have not considered the potential for solar growth in isolation, but as an interconnected feature of the larger energy economy.

Volume 2 of the Vermont Solar Market Pathways Report presents six briefs, each of which addresses a focus area that offers a significant feature of a higher-penetration solar economy. By describing current market conditions, emerging technologies, costs, performance, and other related topics, the focus area briefs in **Volume 2** look closely at topics and market segments expected to be closely inter-related to solar market developments. **Volume 1** (Summary Report) provides an overview of the project and recent results. **Volume 3** (Barriers and Integration) documents potential problems with high solar generation. The discussions and research in the project were supported by scenario analysis. The team built a model of Vermont's total energy system with scenarios that vary the levels of efficiency, fuel switching, and renewables. The model quantifies demand, supply options, costs, and emissions. **Volume 4** (Methods) provides sources for inputs and more comprehensive results than provided elsewhere in the report.

It is consistent with VEIC's mission (reducing the economic, environmental, and social costs of energy use), and important for the SunShot Initiative objectives, that the focus areas directly consider social equity and low-income implications of solar market growth. Over time, supported by appropriate policy, rates, regulation, and oversight, it is possible for solar to help improve energy affordability and performance for consumers at all income levels. Solar is not a do-good gimmick, or a nifty new technology for the wealthy. It is an imperative for making the benefits of a growing clean-energy economy available to those who are economically advantaged. Because of its distributed nature and scalability, solar is positioned, along with efficiency, to directly benefit many people. **Figure 1** illustrates the subjects covered by the focus areas briefs. **Volume 2** combines the discussion of energy storage and smart grid / demand management.

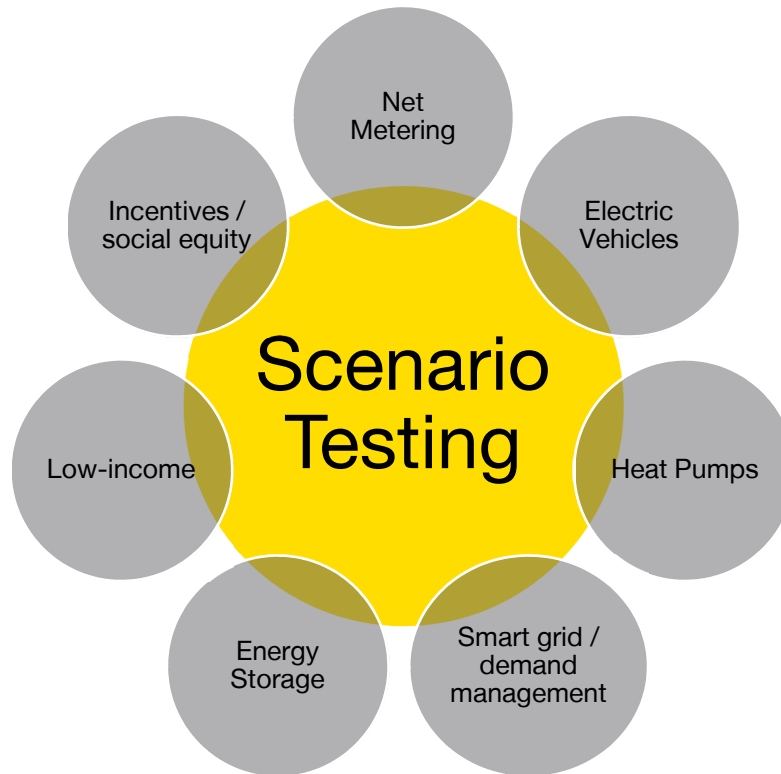


Figure 1. Vermont Solar Market Pathways focus areas involved in the scenario modeling.

Other key points from **Volume 2**:

- Vermont has **updated net metering rules and tariffs** that will go into effect on January 1, 2017. The Team drafted the brief on net metering just as Vermont's net metering rule-making process was starting. The brief identified several possible options for the evolution of net metering. Important elements in the final rule¹ are as follows:
 - Compensation at the retail level for behind-the-meter solar production, with potential positive or negative adjusters linked to siting, system size, and retention or transfer of renewable energy credits. By moving to five categories of net metered systems, the rules will encourage siting on rooftops, previously disturbed lands, and sites that are directly adjacent to electricity consumers.
 - Continuation of group net metering / community solar, providing a potential mechanism for offering solar to households that rent or which do not have rooftops well suited for hosting solar.
 - Removal of capacity caps for how much net metered solar a utility can host. Costs for required upgrades for new net metering system interconnections will generally be borne by applicants.

¹ Vermont Public Service Board, *5.100 Proposed Rule Pertaining to Construction and Operation of Net-Metering Systems*, 2017, <http://psb.vermont.gov/about-us/statutes-and-rules/proposed-changes-rule-5100>.

- Recognition that the impact of the revised net metering rules on market growth will be determined only with time. Generally, the new rules favor certain project categories based on siting and size. In all cases, the compensation from net metering will be lower than it has been. The Public Service Board will update the category criteria and adjustors every two years.
- **Electric vehicles** are a key element in scenarios that meet the State's 90 x 2050 targets. Electric vehicles (EVs) are an emerging technology, and ownership of both all-electric and plug-in hybrid vehicles (PHEVs) still represent a small fraction of the total market.
 - The operating and maintenance costs for electric vehicles are already lower than conventional vehicles. However, the cost of batteries still pushes the purchase cost of EVs above those of comparable internal combustion vehicles. EV battery prices have fallen from around \$1,000 per kWh in 2010 to about \$350 per kWh by the end of 2015.² Current estimates of Tesla EV battery costs for the upcoming Model 3 launch in late 2017 are "less than \$190 per kWh."³ As the EV market grows, battery costs and ultimately EV costs are expected to continue declining.
 - A combination of lower prices, larger battery capacity and range, greater selection of electric vehicle models, and lower total costs of ownership and operation are expected to create a market-driven shift toward EVs.
 - As the EV fleet expands, opportunities to enhance grid efficiency through smart charging, renewable load following, and vehicle-to-grid integration will grow.
 - In addition to light duty passenger vehicles, heavy-duty electric vehicles such as school buses, transit buses, and commercial vehicles are expected to become more prevalent in Vermont.
 - Complementary business models and infrastructure that combine solar and EV charging (for example, carports, solar parking lots, or shared EVs as part of a community solar project), present opportunities for new ventures and entrepreneurial growth.
- **Heat pumps** and high-performance biomass heating systems also make important contributions to 90 x 2050 goals. Using electricity to provide space heating with high-efficiency heat pumps will increase electricity use and displace fossil fuels.
 - The use of heat pumps for residential and commercial space conditioning is increasing, because the performance and economics of heat pumps are making them superior to other options in more situations.

² Angus McCrone et al., "Global Trends in Renewable Energy Investment 2016" (Frankfurt School of Finance & Management; UNEP Collaborating Centre for Climate & Sustainable Energy Finance, 2016), http://fs-unep-centre.org/sites/default/files/publications/globaltrendsrenewableenergyinvestment2016lowres_0.pdf.

³ Fred Lambert, "Tesla Confirms Base Model 3 Will Have Less than 60 kWh Battery Pack Option, Cost Is below \$190/kWh and Falling," *Electrek*, April 26, 2016, <http://electrek.co/2016/04/26/tesla-model-3-battery-pack-cost-kwh/>.

- Improving the building shell, through measures like sealing air leaks, insulating, and installing high-performance windows, is usually very cost effective, and helps to reduce the need for heating and cooling. It is therefore a very good idea to combine a building shell upgrade at the time a heat pump is installed, or when doing new construction and renovations. Improving the building shell often means that a smaller and less expensive heat pump unit can be installed.
- **Smart grid and demand management** technologies help match the output of solar generation to the demand for energy at any given point in time or space.
 - Solar generation varies because of clouds and the apparent movement of the sun. Photovoltaics produce their maximum output when they have direct sunlight on them and when they are cool; shading or angled sunlight produces less electricity. **Smart grid equipment and strategies** use sensors, communications, controls, that help to integrate more solar into the electric generation mix through coordination, forecasting, and dispatch.
 - **Demand management** means that electricity use can be scheduled and managed to match output on the system. For example, smart charging of an electric vehicle can modulate the charge rate according to solar output. Another example is increasing the demand for a single (or group of) water heater(s) when solar output is high. The hot water can be used later when the sun is not shining.
- **Energy storage** further expands the potential to use solar generation to meet loads where and when the sun is not shining. There are several ways to store thermal and electric energy.
 - The use of stationary and mobile batteries is likely to increase as solar markets grow. Electric vehicles depend on battery storage, and significant research and investment in battery technologies and manufacturing are well under way—and are leading to global markets and declining prices.
 - Thermal storage systems using ice, water, or building materials also provide opportunities to capture energy output—for example, when it is windy in the middle of the night, or sunny in the middle of the day—and make that energy available when it is required. This concept is already widely deployed in residential water heaters and commercial cooling with ice making and storage systems.
 - The ability to export electric power into a broader regional market via transmission lines, and to import electric power at other times, is also a form of storage and load management. At the individual household level, exporting power to the grid when the sun is shining and then importing power when the sun is not out (via net metering) is similar. The analysis for Vermont Solar Market Pathways indicates that in a high solar future, there will be times when Vermont will have excess solar power that could be sold on the regional market, though the price at those times may not be attractive because of similar situations in neighboring states.
- High-performance modular housing illustrates how **low- and moderate-income** households can participate in, and significantly benefit from, advanced building techniques and solar energy.

- Through careful design and manufacturing, it is possible for affordable modular housing to offer lower total costs (for energy and mortgage payments) than those for conventional housing. With enough support through financing and electric rates, it is possible for solar to contribute to more affordable, more healthful, and more durable housing for individuals and families facing economic challenges. This has multiple social benefits that go beyond energy savings.
- Offering solar benefits to support low- and moderate-income consumers will expand the markets and create new and innovative approaches to finance, bundling of services, marketing, and business models.
- Well-designed **incentives** and rules are aligned with policy objectives and help markets emerge and mature. Incentives are not intended to be permanent supports. Over time, as market conditions change, it is natural to expect the need for incentives to change. Incentives can also be an important factor supporting market growth for potentially underserved markets, thus contributing to socially equitable outcomes.
 - As the market grows, there will continue to be opportunities for strategic market supports and incentives to catalyze markets and support equitable growth.

The next pages contain the briefs for each of the focus areas, essentially as they appeared in their initial release in June 2015. They demonstrate their functions in an advanced solar economy that supports achievement of Vermont's 90 x 2050 energy goals and of the U.S. Department of Energy's SunShot Initiative objectives, described in **Volume 1**.

One of the essential activities in creating the *Vermont Solar Pathways* report is the statewide articulation of key policy, regulatory, and market issues, by broad energy topic area. The Net Metering Topic Brief and the five Focus Area Briefs explore those issues in depth, and are the product of three stakeholder engagement meetings held in Vermont in early 2015.

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Topic Brief: Toward 20 Percent Solar by 2025 in Vermont

Net Metering and Alternatives

Originally released June 30, 2015

Background

The Vermont Solar Market Pathways Project goal is to set the necessary conditions for solar energy's ability to meet 20 percent of Vermont electricity demand by 2025. Meeting that 20 percent threshold will require planning, tariffs, and procurement mechanisms that do not exist in Vermont today. Although individual and group net metering tariffs, the solar adder (utility incentive credits), and the Standard Offer program (feed-in tariff) have attracted and are expected to continue to attract solar investment to Vermont, current trends do not suggest that current mechanisms will lead to 20 percent solar by 2025.

Vermont has introduced novel renewable energy procurement mechanisms in the past, like group net metering, so it is not only possible, but probable, that Vermont will introduce new and innovative ways of tapping more solar potential. However, with the mechanisms in place today, it is unlikely that Vermont will reach 20 percent solar by 2025.

It is important to note that 20 percent of energy from solar translates into approximately 1,000 MW (1 GW) of solar capacity. Net-metered solar capacity is approximately 65 MW and the ISO-NE Solar PV working group estimates that total installed capacity at the end of 2014 in Vermont was 81.85 MW. Net-metered solar installations are growing: the Standard Offer program has a 2022 cap of 127.5 MW of small, distributed generation, much of which is expected to be solar PV; it is likely that other distributed generation will involve utility power purchase agreement (PPA) projects. The ISO-NE Solar PV Forecast working group has determined that trends like these indicate an estimated 235 MW of solar PV in Vermont by 2024. Recent experience and current trends reflect significant growth in solar opportunity relative to just a few years ago, but these numbers do not imply Vermont is on a glide path to 1,000 MW by 2025.

This topic brief explores the current and future mechanisms that will be required to facilitate the aggressive expansion in solar deployment over the next 10 years to meet the 20 percent target.

Solar Resources in Vermont Today

Solar resources in Vermont can be grouped into five basic parts: (1) residential rooftop; (2) commercial behind the meter; (3) group net metering, (4) ground-mounted projects in front of the meter, but less than 500 kW; and (5) ground-mounted projects greater than 500 kW. Projects greater than 500 kW are variously referred to as *grid scale*, *utility scale*, or *large-scale* projects. Of these projects, those less than 2.2 MW might qualify for the Standard Offer program. Projects greater than 2.2 MW must sell into the market, be procured by a Vermont utility, or be built and used by a utility. Meeting the 20 percent goal for solar by 2025 will likely require contributions

from each of these solar resource “buckets.” This topic brief summarizes the buckets that exist today and describes briefly how resources in each bucket are compensated.

Net Metering

Solar resources less than 500 kW qualify for net energy metering. Vermont has favorable tariffs and payments, as shown by the increasing amounts of solar built in Vermont since 1999. The Vermont Department of Public Service staff produced **Figure 1** in late 2014.

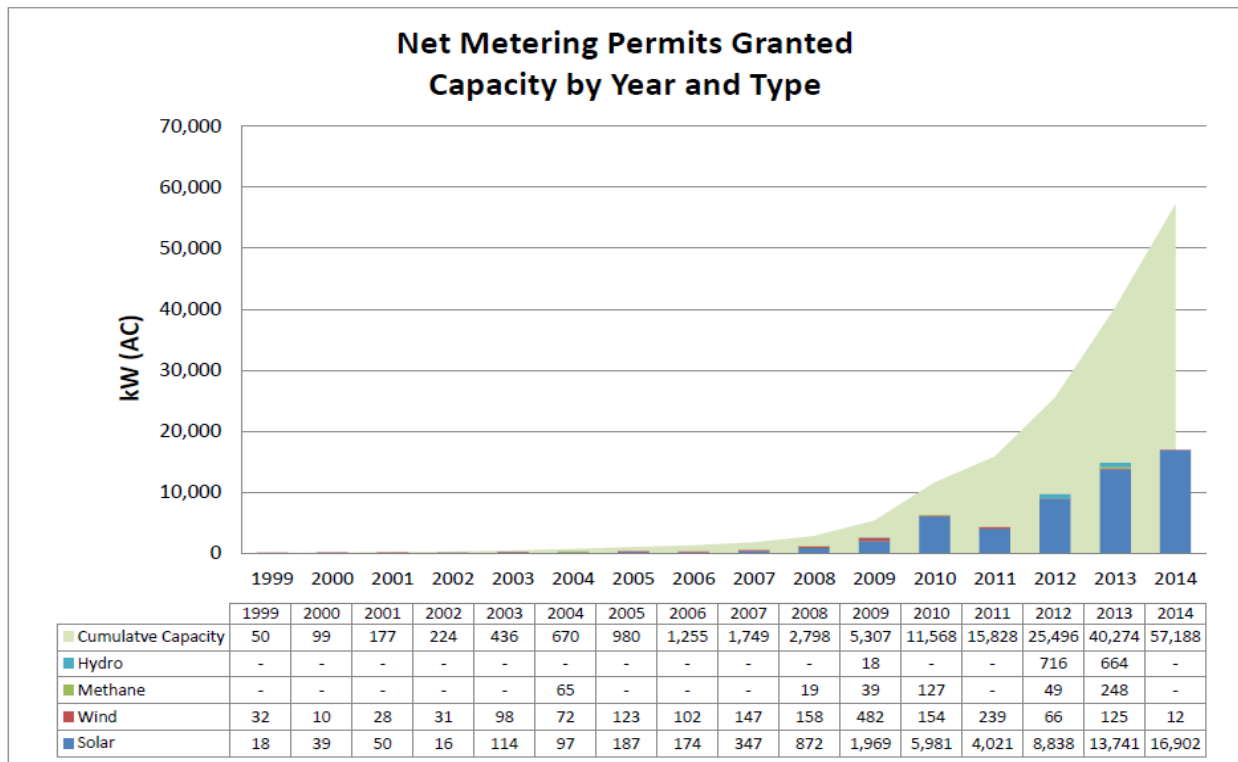


Exhibit 3. Capacity of net metering permits granted by type and cumulative capacity. (Data as of 9/26/14.)

Source: Vermont Public Service Department

Figure 1. Net metering permits granted as of September 2014.

Until recently, Vermont law had limited solar expansion to 4 percent of peak capacity. As some utilities reached their 4 percent cap, the Vermont General Assembly voted in 2014 to increase the cap to 15 percent of capacity. Individual customers may participate in net metering and groups of customers may participate in group net metering; the size of installed facilities range from a few kW to systems up to 500 kW. **Figure 2** shows the distribution of system size in Vermont. The figure indicates small residential systems between 4 and 6 kW predominate.

The terms of the net-metering tariff determine the extent to which resources in the net-metering “bucket” are compensated. Whether the terms of the tariff are “fair” today is an active topic of discussion, and there are differences of opinion among stakeholders. The Vermont Public Service Board Act 99 Study (November 2014) posited methods for evaluating the fairness of the net-metering tariff. It looked at fairness from the perspective of society and from the perspective of ratepayers as a whole. The study found that current compensation is “fair” from the

perspective of society, where net social benefits are consistently positive. The tariffs are also approximately “fair” from the perspective of all ratepayers, where the net benefits for ratepayers range from small and positive, to small and negative depending on the technology and size of system. Some utilities have questioned whether the revenue collected from net-metered customers constitutes a “fair” contribution to the costs of maintaining the electric system.

It is clear that individual and group net metering are successful today as a mechanism for effectively inducing increased investment and establishing compensation that is considered at least “approximately fair” to all ratepayers and society.

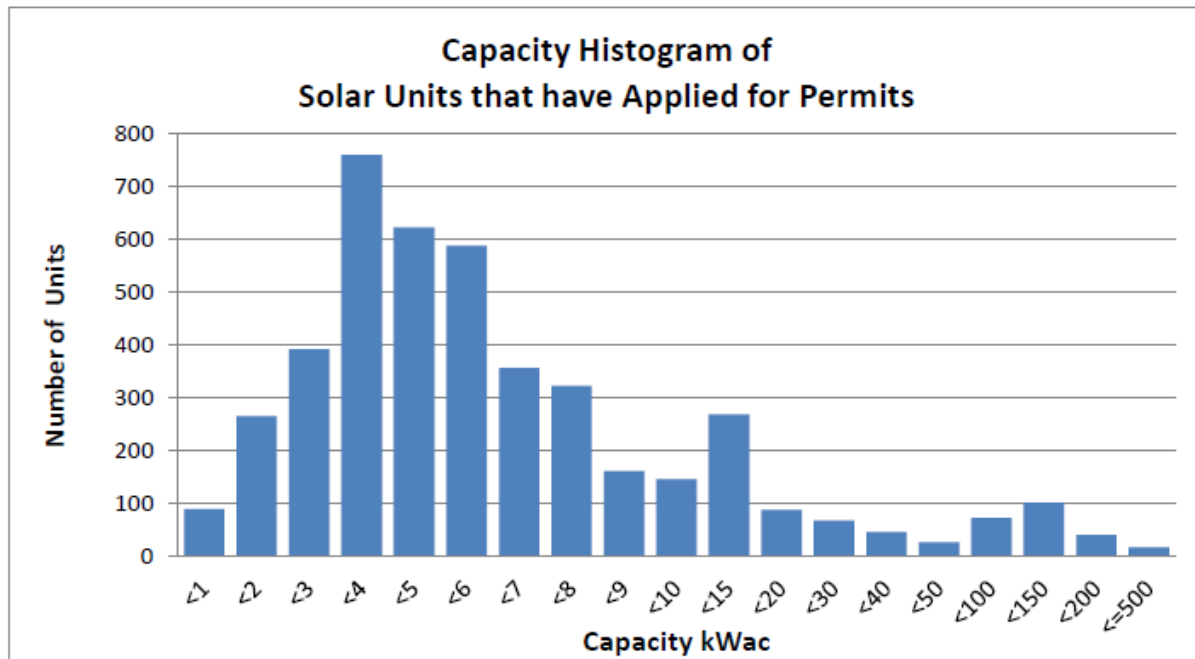


Exhibit 4. Histogram by Capacity (in kW AC) of all net metered solar PV system permit applications (as of 9/26/14)

Figure 2. Trends of distributed generation systems by kW size of system.

Within the net-metering category, projects of different sizes have different costs to the adopter. One stakeholder reported that a survey of recent bid prices for projects put the bid price for 5kW rooftop systems at about \$3 / W, for 150 kW ground-mounted systems at \$2 / W, and for 500 kW ground-mounted systems at about \$1.80 / W.

As increasing amounts of energy come from solar installations and as the Vermont electric system modernizes with more advanced real-time information, communications, and control capabilities, it is worth asking whether the existing net energy metering tariff terms are relevant terms for the low-carbon grid of the future. Increasing amounts of resource coming from solar generation are likely to present integration challenges in some locations that require adaptation in system operations. Location and temporal production patterns matter, and the introduction of advanced real time system capabilities mean that locational and temporal differences will be seen more clearly. Thus, net-metering innovation that compensates according to location and

time might become possible and desirable. These issues will be taken up in a subsequent section.

Standard Offer Projects

Projects greater than 500 kW and less than 2.2 MW are eligible to compete for the Standard Offer Feed-in Tariff (FIT) program. Solar PV is one of six technologies eligible for being bid as a contract based on avoided costs. About 34 MW of standard offer solar PV was installed by the end of 2014. The Vermont Public Service Department has projected that about 110 MW of standard offer solar will be installed by 2024.

One stakeholder reported that a recent survey of installed cost bids for 2 MW ground-mounted systems came in at approximately \$1.60 / W (without site costs).

Power Purchase Agreements, Utility Projects, and Market-based Projects

Utility-built projects and non-utility projects that do not qualify for the Net Metering or Standard Offer programs can market energy to retail customers through a power purchase agreement or utility self-build option, or they can sell into the regional wholesale markets. About 4 MW in PPA solar PV projects are in service today in Vermont and an additional 6 MW is expected by the end of 2016.

Solar Portfolios to Reach 1 GW

Reaching 1 GW of solar generation in Vermont will come from a portfolio of sources comprising rooftop net-metered solar, group net-metered solar, community virtually net-metered solar, commercial solar, and procured solar. The respective amounts of solar coming from these sources is uncertain, but it is clear that the amount that can come from small systems is going to be modest. Stakeholder discussions to date have produced a strong predisposition toward meeting the 1 GW goal with smaller distributed systems to the maximum extent possible. Stakeholders are skeptical that many systems larger than 5 MW can be sited in Vermont. Taking this perspective as a starting point, it is worth thinking through how much solar can come from smaller systems, and what will need to happen to tariffs and procurement mechanisms to maximize the small-system build-out.

According to the National Renewable Energy Laboratory (NREL), 22 to 27 percent of all rooftops are candidates for solar installation.⁴ The remaining approximately 75 percent are not good candidates because (1) they are not south or west facing, (2) they are shaded, or (3) the structure is not sound enough to safely carry a solar installation.

If we can assume that all of Vermont's approximately 310,000 residential metered buildings had rooftops are candidates, then one can estimate that a little more than 75,000 are suitable for solar. If an average installation is about 5 kW, then about 375 MW could potentially sit on residential rooftops. The proportion of these 75,000 customers with a suitable rooftop who want

⁴ Denholm, P.; Margolis, R. (2008). Supply Curves for Rooftop Solar PV-Generated Electricity for the United States. NREL/TP-6A0-44073. Golden, CO: National Renewable Energy Laboratory, <http://www.nrel.gov/docs/fy09osti/44073.pdf>.

a rooftop PV system is not known. Further, the cost per kWh of rooftop systems relative to larger-scale, ground-mounted systems is likely to lead some of these customers to participate in a shared renewable project, rather than install a roof-mounted system.

Therefore, although one could say that a 375 MW technical potential exists, the economic potential is far less. The 375 MW technical potential indicates that more than 625 MW will need to be on something other than a residential rooftops.

Reaching the economic potential of rooftop systems in Vermont will require a favorable tariff that compensates incremental participants at or above their marginal opportunity cost of participating. The marginal cost of attracting customers will grow as the number of solar-friendly customers increases from the smaller initial group of those who are enthusiastic to those who are indifferent or even reluctant to install solar units. The net-metering tariff available today is attracting enthusiastic and willing customers, but the tariff will need to evolve to attract indifferent and reluctant residential customers who have a good solar resource on their property.

One would expect that at some point, the marginal cost of attracting individual residential customers with viable rooftops will exceed the marginal benefit produced. However, it is uncertain at what quantity of residential rooftop this will occur. Making a decision on maximizing the amount of the resource coming from residential rooftop systems in Vermont is a policy decision. Therefore, policy goals will drive the tariff terms needed to reach the residential rooftop goal.

Designing the individual residential tariff to match participation with policy goals is the first critical question the Vermont Solar Pathway Plan participants need to explore further.

Large commercial rooftops, multifamily housing rooftops, parking lots, ground-mounted residential systems, and over-sized residential rooftop systems (net exporting systems) will also make a significant incremental contribution toward the 1 GW goal. The State will need an estimate of the technical potential that these resources can offer. This estimate will help inform a policy decision on how much of the 1 GW would come from these systems. It is safe to assume that the technical potential of these systems will fall well below 625 MW (the amount needed to complement the 375 MW from the residential goal to equal 1 GW).

A second critical question is how owners of these systems will need to be compensated to obtain their participation, consistent with the policy goal for behind the meter systems.

Residential and commercial systems sited behind the meter, to serve the customers and provide some net export to the electric system, will be a portion of the 1 GW goal. Nevertheless, given the economics of larger ground-mounted systems, it is likely that systems to serve multiple customers will play an important role. These systems could be group net-metered systems, community solar systems, or large-scale systems that sell into the regional market.

Additional critical questions therefore are:

- **How should group net metering be expanded?**
- **What should community solar tariffs look like?**

- **How much of the 1 GW will be met with grid scale systems that are owned by Vermont utilities, that are sold by purchased power agreement to Vermont utilities, or that sell into a regional market?**

The Evolution of Net Energy Metering for Residential Customers

Net metering is the current mechanism for interconnecting residential DG. Stakeholders were quick to point out that the first step toward approaching the technical potential of residential rooftops will involve raising the 15% of peak limitation on net metering. Vermont's peak electricity consumption is about 1 GW today and is projected to grow to no more than 1,200 MW by 2025. Limiting net metered DG to 15% of 1,200 MW would limit the contribution from this portion of the solar generation fleet to 180 MW, far below the technical potential of the residential sector and possibly below the economic potential. It is possible that policy makers will decide that going beyond 180 MW of residential behind the meter systems is desirable and so addressing the current 15% limit may be necessary.

In addition to considering raising the cap on net metering as it exists today, policy makers will want to consider evolving the structure of the net metering tariff. As distributed solar grows the value that solar provides and the costs it imposes will change and net metering will likely need to evolve as well. Options include:

- Modifying the existing tariff to keep the terms aligned with the changing value and cost
- Adopting a two way distribution tariff
- Implementing a value of solar tariff by way of net metering or a buy-all, sell-all approach

Aligning the customer value proposition presented by net metering or any alternative to net metering proposed for residential behind the meter systems will improve as information, communications and electric system control technologies mature. While the net metering tariff as it exists today has been found to be approximately fair in Vermont Public Service Board (PSB) studies, improved information on electric system costs and benefits will reveal more accurate estimates over time. Net energy metering is a crude tool that has worked well but improved information will allow more refined assessments and fine tuning of tariffs terms. Estimates of the value of electricity in specific places on the electric system will become better, estimates of the relative value of producing electricity at different times of the day will be better and the ability of distributed generation to provide ancillary services to the system will improve.

Option 1: Keep net energy metering, but evolve all tariffs toward time-of-use and locational pricing

As the necessary information becomes available it will be possible to design tariffs with time of use and locational pricing elements that reflect the relative value of producing and consuming electricity and will thus communicate pricing signals to all customers whether they happen to be consumers or prosumers (producing consumers). It is possible that simply evolving the tariffs that all customers pay will promote fairness. Determining whether this is the case will require valuation studies like the ones already done by Vermont PSB staff. The benefits of staying with a net energy metering structure while evolving the tariff that all customers pay include

administrative simplicity, consistency in price signals provided to customers for conserving and producing, and financial certainty for solar investors.

Option 2: Adopt a two-way distribution tariff

If concerns arise that producing customers are not paying adequately to support maintenance and improvement of the distribution system infrastructure, utilities could introduce a two-way distribution tariff where all customers pay for every kWh of distribution service they receive to purchase from the grid as well as paying for every kWh of distribution service they receive to sell into the grid. A two-way tariff is not an alternative to time of use and locational pricing, it is an additional element to tariff pricing. The adoption of such a tariff should be driven by valuation studies that find that producing customers are systematically contributing too little toward distribution system maintenance and improvement and that non-producing consumers are systematically paying too much toward distribution system maintenance and improvement. If an inequity in distribution system support is found, this approach could directly address the inequity. This approach also has the virtue of maintaining consistency in valuation between conservation of energy and production of energy and maintaining the financial certainty associated with the net energy metering approach. The tariff is more complicated than option 1 and thus does not make sense unless an equity issue is demonstrated. A potential complication associated with implementing a two way distribution tariff is ensuring consistency in valuation between customer side of the meter energy production and grid side of the meter generation. Some adjustment in how grid connected generators pay to use the transmission and distribution system might be necessary to ensure fairness among generation resources.

Option 3: Implement a “value of solar” approach by way of net energy metering or a buy-all, sell-all approach

The valuation studies of net energy metering performed by the Vermont PSB could be said to already reflect a “value of solar” approach. A value of solar approach is simply taking account of the sources of benefit and cost considered in establishing a fair rate for energy produced from behind the meter solar generation. If net energy metering is found to reflect a fair valuation of solar relative to the sources of cost and benefit that policy implies, then net energy metering reflects a fair value of solar. If value components change as solar adoption grows or if policy changes and the elements to be included in assessing the fair value of solar change then the “fairness” of net energy metering is likely to change as well. Vermont PSB studies already attempt to track changes in the value of solar over time and to assess the fairness of the net energy metering tariff relative to those changes. In this sense, Vermont is already implementing a “value of solar” approach. Keeping tariffs consistent with the value of solar seems already implicit in the Vermont approach. Thus, one approach to implementing a value of solar approach is simply to commit to continuing to adapt net energy metering tariffs as the value of elements and the policy values evolve. This approach maintains simplicity and consistency over time, and has the virtue of managing any financial uncertainty introduced by leaving net energy metering. The disadvantage of seeking to implement value of solar through net energy metering is that at some point, the deviation between the marginal value of energy produced from solar and the

marginal value of energy saved by conservation may deviate and economic inefficiency may result.

A buy all, sell all value of solar tariff can address persistent differences between the marginal value of customer generation and the marginal value of customer conservation appear, if those differences are not captured by locational and temporal pricing. A buy all, sell all tariff specifies that producing customers buy all of their energy at retail rates and sell all of their energy at a separate rate. A “buy all-sell all” implementation of a value of solar approach deviates from net energy metering but introduces the advantage of incorporating an explicit and separate valuation of energy production in tariffs. If policy dictates elements of cost and benefit beyond time of use and locational value elements should be incorporated explicitly into the compensation for solar energy production, a value of solar buy all, sell all tariff can incorporate those values.

Such a tariff could be implemented as a “feed-in tariff” or as a buy all, sell all tariff with no set long term value for sales. Implementing a buy all, sell all value of solar tariff as a feed-in tariff would make the “standard offer” to the producing customer a credit for all solar produced at the value of solar with the standard offer terms guaranteed for a term of 5, 10 or 20 years. A value of solar feed in tariff approach provides the financial stability of a long term contract while explicitly aligning compensation to a long term value of solar.

A buy all, sell all value of solar tariff without a long term “standard offer” for the value of solar would introduce significant financial uncertainty relative to a feed in tariff approach and relative to continuing with an evolved form of net energy metering. Immediately moving to such a tariff would be disruptive to further residential solar development. However, there may be some residual value of solar that is not adequately reflected in the options mentioned above that after time of use and locational pricing is implemented and reflected in tariffs.

Shared Renewable Programs

Shared renewable programs are larger scale projects where residential, public, and commercial customers may own or lease a portion of a project. Shared renewable programs are targeted at the development of solar and other renewable energy installations in the 50 kW to 5 MW range where electricity users have the opportunity to buy or subscribe to a share of the project to meet some or all of their electricity needs. Vermont has a head start on many states in developing shared renewable programs for solar. Vermont’s Group Net Metering program is cited by U.S. Department of Energy (DOE) and solar advocates as one example of a “shared renewable program.” Solar shared renewable programs are sometimes called “community solar programs” or “community solar gardens.” We will refer to the whole range of these programs as “shared solar programs.” A shared solar programs may be developed, owned and maintained by a utility, by a third party provider or by a group of customers in a community. It is most often proximate to the customers who subscribe or buy shares.

Shared solar projects have many benefits. The most important benefit for the purpose of this policy brief is that it greatly expands the pool of Vermonters who can own or lease a share of a project. Shared solar projects offer a solar option to residential consumers who do not have a viable space for PV. Shared solar projects can also offer an option to commercial, public and

non-profit owners who do not have or who cannot afford a behind the meter installation. Some shared solar projects have also been developed to serve under-served communities. These projects even extend participation beyond the segment of the population who have an interest and are financially able to invest to those who are willing but may not have the discretionary income to invest. Shared solar projects can also be mixed ownership projects where owners come from residential, low income, commercial, public, and non-profit sectors. In some places, a portion of each shared solar project is reserved for low income participation.

The technical potential for shared solar projects will be driven by land and access limitations. Ground mounted solar PV requires about 7 acres per MW, so the amount of land required for shared solar installations in the 50 kW to 5 MW range require between 1/3 of an acre up to 35 acres (or more, depending on terrain and exposure). Shared solar projects are also usually near subscribers so proximity to subscribers and electric infrastructure affect the technical potential for shared solar. The electric systems of Vermont's many utilities vary and viable project size will be affected by characteristics of the host system. A physical assessment of potential sites needs to be performed to produce a technical potential estimate.

The tariff, ownership, and contracting terms of shared renewable programs vary widely. The most common approaches for shared solar programs are virtual net metering and buy-all, sell-all arrangements. With virtual net metering approaches, a subscriber buys or leases a portion of a solar PV project and receives credit for the energy produced by the project as if the project was located behind their meter. Virtual net metering approaches provide consistency in valuation between behind the meter solar PV and local solar PV projects so the economics of the respective projects can drive installations. Implementing virtual net metering well requires that any substantive differences in electricity system costs (for example, required distribution system upgrade differences) or benefits (for example, ability to control a project to maximize system benefits or line loss prevention benefits) be captured. In a buy-all, sell-all arrangement, the subscriber to a project sells all of the energy produced at a price (value of solar, standard offer, etc.) and buys all of their energy from the utility, and receives a credit against purchases for all sales. Special shared solar projects like community solar projects built specifically to serve low incoming housing may fall under the same tariffs as other shared solar projects or there may be tariffs constructed to match the public purpose goals of those projects.

Ownership of shared solar projects can take various forms. Individuals in a community can co-invest in a project for their mutual benefit, a third party may build a project and sell or lease shares to participants, or a utility may build a project and sell or lease shares.

It is our opinion that shared solar projects will play a very important role in meeting any future solar generation targets. The best shared solar program structures for Vermont should be informed by the wide array of efforts underway nationally, and other work being conducted under the DOE Solar Market Pathways project should be consulted as programs are developed in Vermont.

Agricultural, Commercial, Industrial, and Public Sector Projects

Shared renewable projects are one avenue for engaging the non-residential sector, but other options exist as well. The sites available for non-residential projects larger than 50 kW and smaller than 5 MW will overlap with sites available for shared solar projects. The vehicle used at present in Vermont is the Standard Offer program described in the opening section of the brief. The Standard Offer program currently includes sites up to 2.2 MW but it could be expanded to larger systems in the future. Stakeholders believe that 5 MW is a likely cap for most projects in Vermont in this category or in the shared renewable category.

Grid Scale Solar

The final section will discuss the possibility that grid scale solar installations between 5 and 20 MW may be needed to meet an aggressive goal like 1 GW by 2025. Solar requires 6 to 10 acres per MW, so a 20 MW installation would require 120 to 200 acres. Stakeholders have said that siting a project in this range in Vermont will be extremely difficult and the focus of the scenarios should be on maximizing the contribution of the smaller sized systems discussed above. To the extent that any systems get built in the 5 to 20 MW range in Vermont, they will likely be utility built projects or 3rd party PPA projects built to serve utility retail customers or to be sold into the regional market. Further consideration of these larger projects will happen in a subsequent version of this policy brief as the solar scenarios develop.

Conclusion

The purpose of this policy brief is to provide a context for considering how 1 GW of solar might be achieved in Vermont. A diverse portfolio of solar will be necessary. Residential rooftop, shared solar, and non-residential solar will be the primary contributors toward the 1 GW goal. Structuring tariffs, markets, and procurement for each of these three segments will be important. Net energy metering tariffs will need to evolve as the information, communications, and control technologies advance to the point that locational and temporal pricing become a reality and as the value of solar responds to changes in the grid and policy directions. At the same time, shared solar programs and non-residential contracting mechanisms will need to evolve to match value with compensation. It is important to consider the relative cost and value of projects among these segments (rooftop, shared renewable and non-residential) so that economically efficient choices are made by consumers.

To the extent that projects less than 5 MW do not sum to the 1 GW goal, some larger projects will need to be considered. The stakeholders as a group seem to strongly favor smaller projects, while stakeholders have different opinions on how much the rooftop segment will ultimately contribute. As technical potential estimates of the segments are constructed and scenarios are built, there will be a need to revisit the topic of tariffs and procurement mechanisms. As shared solar program research continues, it will be important to bring information from those efforts to inform this one. In addition, we have not considered the contribution and need for grid scale projects completely here. As the scenarios develop, we will likely need to revisit grid scale potential and mechanisms.

Focus Area Brief: Electric Vehicles

Introduction

Electric vehicles (EVs). Three essential synergies exist between plug-in vehicle and solar PV consumers:

- Overlapping consumer purchase preferences for both technologies
- Use of solar PV power for vehicle charging
- Use of plug-in vehicles for distributed storage and grid reliability assets to respond to fluctuating renewable energy production.

EVs in the Vermont Comprehensive Energy Plan

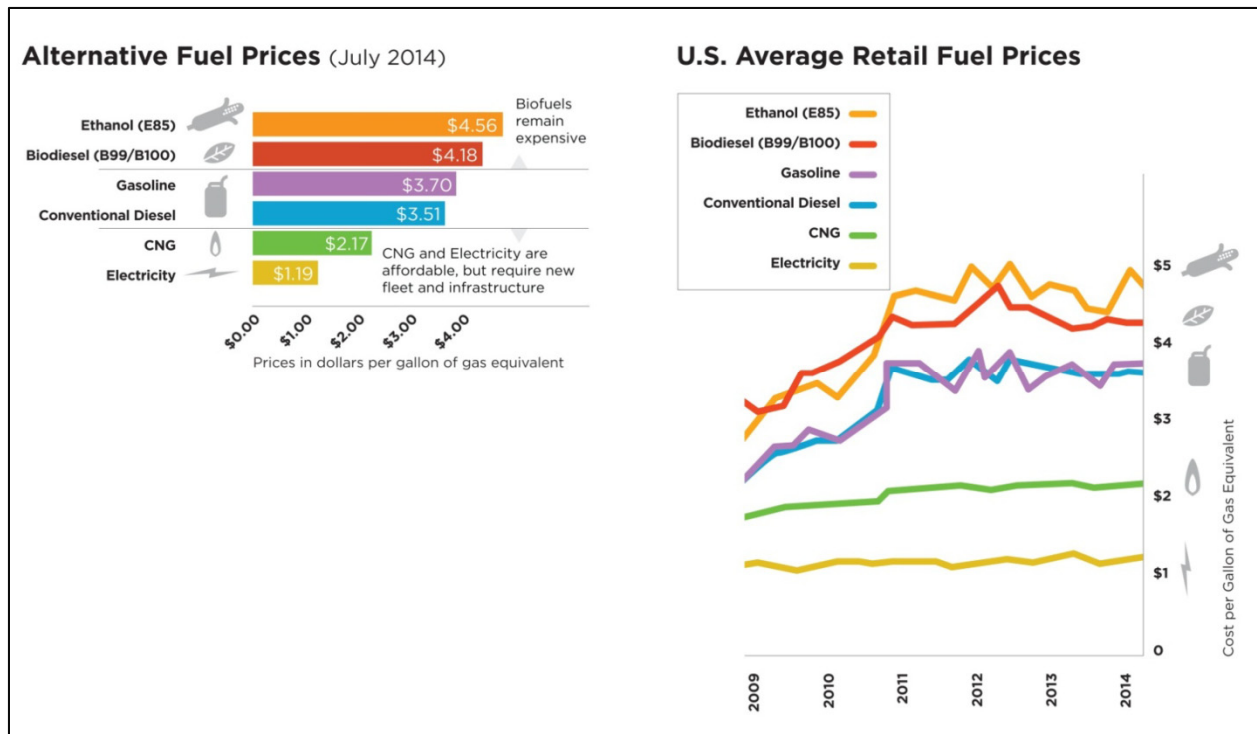
Vermont's transportation sector is currently fueled 95 percent by petroleum. To reduce the reliance on that fossil fuel and thus transform the transportation sector, the 2011 *Vermont Comprehensive Energy Plan* (CEP) identified two primary strategies:

1. Reduce petroleum consumption (Vol. 2, 9.6.2, p. 280)
2. Reduce energy use in the transportation sector (Vol, 2, 9.6.3, p. 284)

Because transportation accounts for the highest share of energy use in Vermont, policies that address this sector have a proportionately large impact on the state's overall energy consumption. Most transportation sector consumption involves gasoline and diesel fuels, both petroleum-based sources of energy. The shift to renewable energy sources for the transportation sector will likely occur at a slower pace than in other sectors, largely because of the limited control the state has over vehicle technology and regulations. For example, the federal government, not the states, set fuel economy standards. Higher upfront costs for plug-in vehicles and shifting technology are also sources of hesitation among consumers considering a switch.

To make significant progress toward the State's target of 90 percent renewable energy by 2050, the Vermont Agency of Transportation has set a goal that 25 percent of all vehicles registered in Vermont be powered by renewable energy sources by 2030. Business-as-usual projections for the number of plug-in EVs are modest. However, there are several reasons to believe that the next 20 years will be different from business as usual. Technological innovation in vehicle engineering, particularly as it relates to batteries, is occurring quickly.

The CEP contains an interim 2030 goal of 25 percent of the vehicle fleet to be powered by renewable energy. This will mean that more than 140,000 more EVs or other renewably powered vehicles will be registered in Vermont, relative to 2015. Biofuels already significantly contribute to renewably powered transportation in Vermont through the U.S. Environmental Protection Agency's (EPA) Renewable Fuel Standard (RFS). The RFS creates a requirement for ethanol blends. However, as **Figure 3** indicates, travel powered by electricity is much more cost effective than travel powered by gasoline or even other alternative fuels. Although these savings offset the relatively high initial cost of EVs for their owners, the savings can be significant today and will provide additional benefits as the technology matures.



Source: U.S. Department of Transportation, [Beyond Traffic](#), 2015.

Figure 3. Prices for alternative fuels, compared to gasoline and conventional diesel.

The Vermont Public Service Department's 2014 Total Energy Study identified technology and policy pathways for achieving the CEP goal of 90 percent of Vermont's energy needs supplied by renewable sources by 2050. The Study also cited the importance of the State's continued recognition of electric vehicle technology as a critical strategy to meet its energy goals.

Survey responses from current and potential EV owners suggest a strong societal correlation between EVs and solar PV consumers. For example, the California EV rebate program has queried more than 16,000 rebate recipients and found that nearly 30 percent of them already have solar PV or are planning to install it. A total of 63 percent indicated they were considering future PV installation.⁵

The development of an advanced solar market in Vermont will provide significant opportunities for increasing the number of renewably powered vehicles in the state. The primary benefits of renewably powered transportation are reduced emissions of greenhouse gases and other harmful pollutants, reduced cost and volatility in transportation energy expenditures, and support for economic development by shifting the monetary savings from saved fuel expenditures to capital for investment. Further, EVs can support the electric grid, by boosting demand-side management (DSM) through controlled charging and distributed energy storage using EV batteries. Both controlled charging and the storage capability can be used to respond to short-

⁵ Center for Sustainable Energy (2015). California Air Resources Board Clean Vehicle Rebate Project, EV Consumer Survey Dashboard. Retrieved 5 May 2015 from <http://energycenter.org/clean-vehicle-rebate-project/survey-dashboard>.

term fluctuations in power generation that might occur if more solar PV generation is brought on line.

Technology and Market Description

There are two basic types of plug-in EVs:

- **All-electric vehicles (AEVs)**, powered solely by electricity with a range of 60 to 100 miles for vehicles under \$40,000. AEVs manufactured by Tesla (purchase price of \$70,000) can travel up to 270 miles without a charge. AEVs account for 25 percent of registered EVs in Vermont (2015).
- **Plug-in hybrid Vehicles (PHEVs)** offer 10 to 75 miles of electric range on a battery, and then the vehicles switch without interruption to gasoline for extended-range operation. PHEVs account for 75 percent of the registered EVs in Vermont (2015).

Most EVs in Vermont are passenger vehicles and travel about 3vmiles per kWh of energy. Given the census of EVs in Vermont, this means an annual consumption of about 2 MWh for the average Vermont vehicle. Energy is delivered to the vehicles through electric vehicle supply equipment (EVSE), commonly referred to as *charging stations*. **Figure 4** presents three basic types of EVSE.

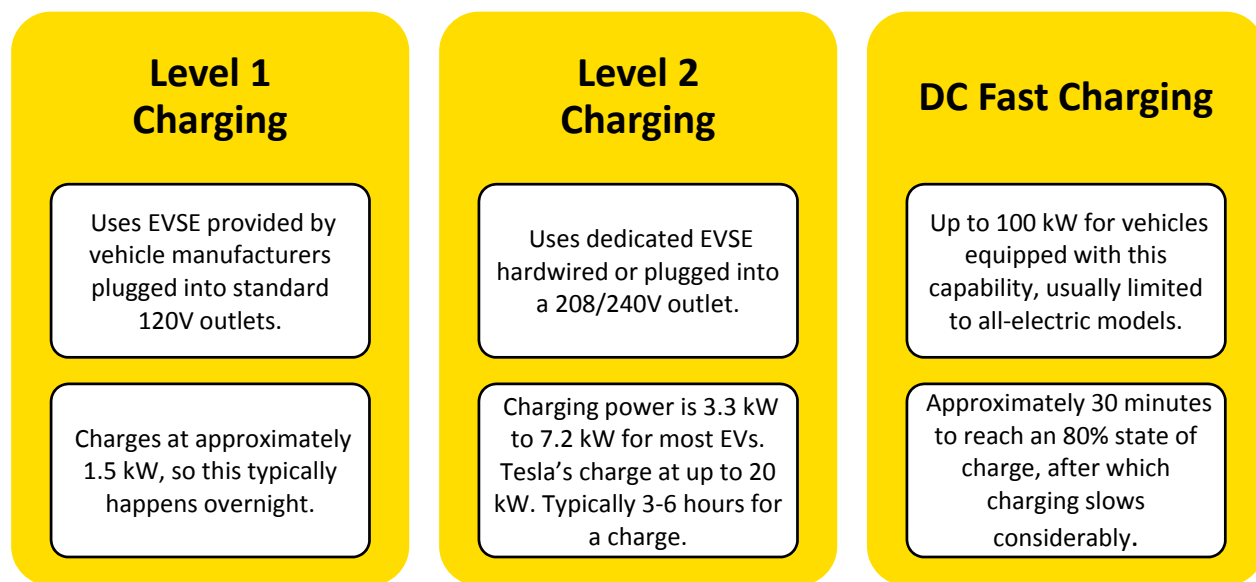


Figure 4. EV charging levels and their respective features.

Most EV owners charge at home overnight. Several Vermont electric utilities have optional residential time-of-use (TOU) rate programs that result in lower costs during overnight hours. The variability in rates is shown in **Table 1**. Workplace charging is the second most common option, when available. It also provides a helpful “second showroom” with DOE. That is, employees with access to charging are 20 times more likely to own an EV than those who do not have workplace charging stations—and the visibility of EVs and charging stations encourages EV purchasing. Public charging stations are necessary to increase the confidence of consumers considering an EV purchase, particularly for all-electric vehicles. Vermont currently has 60 public charging

stations, 13 of which offer DC Fast Charging for EVs equipped with this capability. The number of charging stations has more than doubled over the past two years.

Table 1. Selected Vermont utility time-of-use rates, 2015

Utility ⁶	Residential standard rate customer charge	Standard kWh rate	Residential TOU customer charge	TOU rate for on-peak use per kWh	TOU rate for off-peak use per kWh
Green Mountain Power	\$0.43 / day (approximately \$12.90 / month)	\$0.147 / kWh	\$16.26 / month	\$0.257 4 consecutive hours between 7 a.m. and noon, and 3 consecutive hours from 4 to 10 p.m.	\$0.114
Vermont Electric Cooperative	\$17.22 / month	\$0.087 / kWh up to 100 kWh \$0.176 / kWh in excess of 100 kWh	\$17.22 / month	\$0.19789 / kWh 6 a.m. to 10 p.m. M-F	\$0.142
Burlington Electric Department	\$8.21 / month	\$0.1088 / kWh up to 100 kWh \$0.148 per kWh thereafter	\$13.86 / month	\$0.108 / kWh up to 100 kWh \$0.23 / kWh above 100 kWh June 1 - September 30, M-F, 12:01 p.m. - 6 p.m. and December 1 - March 31, M-F, 6:01 a.m. to 10 p.m.	\$0.108

Of the 112 new car dealers in Vermont, 28 offer EVs. There are no state incentives for EVs, but there is a federal tax credit of up to \$7,500 for the first 200,000 EVs sold by manufacturer, nationwide. The exact amount varies depending on the size of the battery. Cumulative sales for the current EV market leaders, GM and Nissan, are approximately 70,000 vehicles each. At this pace, the incentives are expected to remain for several more years. It is possible that they could be renewed in the future.

⁶ Other Vermont utilities, including municipal utilities, offer TOU rates.

Vermont is one of 10 states participating in the California Zero Emission Vehicle (ZEV) program, which requires automakers to sell increasing numbers of plug-ins and hydrogen fuel cell vehicles in the next 10 years. This requirement will result in up to 15 percent of sales by 2025.

EVs are registered in over 60 percent of Vermont communities and comprise about 0.1 percent of the total Vermont fleet of registered vehicles. EV sales over the past year have reached approximately 1 percent of new, light-duty vehicle sales in the state. As **Figure 5** illustrates, significant growth has occurred since 2012, with 891 plug-in vehicles registered in the state as of April 2015. Per-capita rates of EV ownership are highest in Lamoille County, indicating plug-in vehicles do work in rural areas.

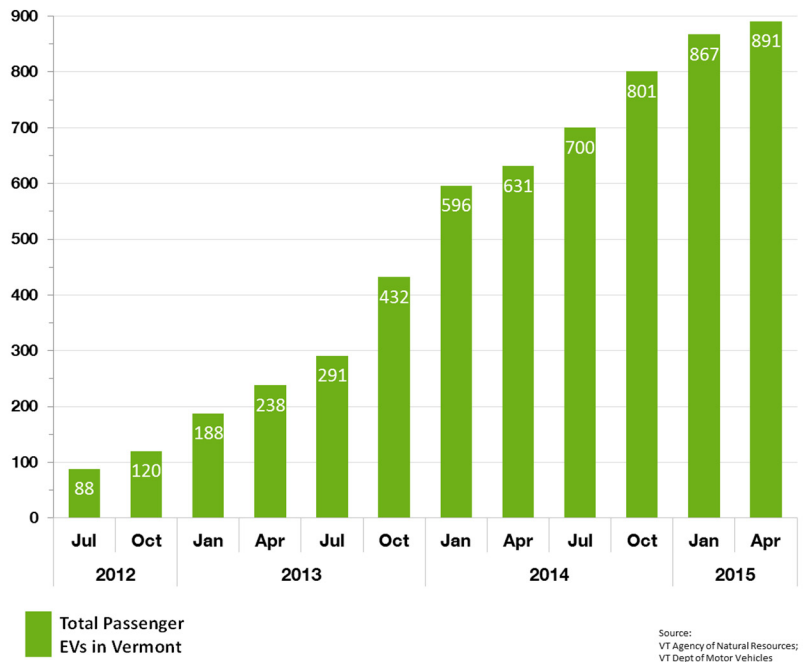


Figure 5. Vermont electric vehicle registrations since 2012.

Table 2 shows annual new EV registrations. The slowdown in new registrations in 2014 was assumed to be due to decreased inventory available at local dealerships and a “bridging” phenomenon that occurs in marketplaces when a new product appears: the enthusiasm of early adopters wanes for a short time and is subsequently supplanted with demand from more mainstream consumers. EV market volatility will likely continue in the near term as new models come into the market, and as generally improving economic conditions affect new vehicle purchases.

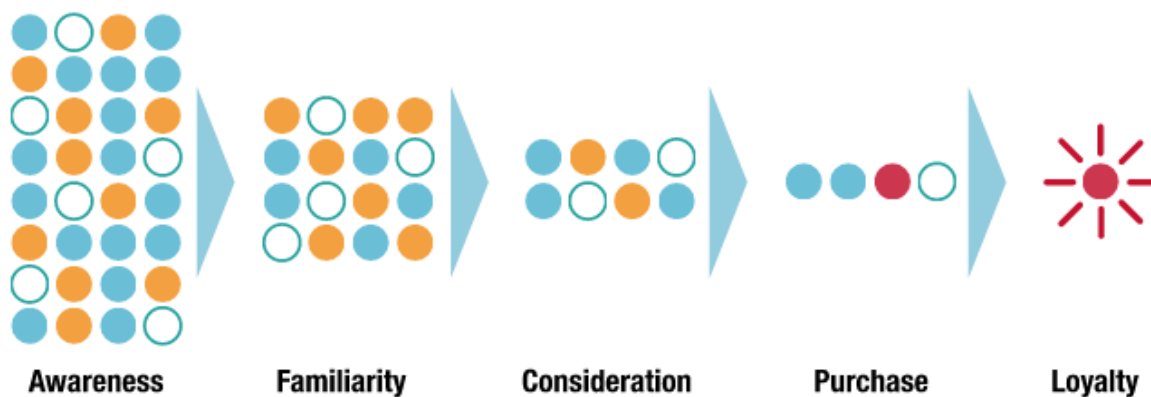
Table 2. Annual Vermont EV sales by type

Year	Plug-in hybrid vehicles	All-electric vehicles	Total
2013	326	82	408
2014	204	67	271

The current estimate of electricity use related to EVs in Vermont is approximately 1,900 MWh annually. This is approximately 0.03 percent of Vermont’s retail electricity sales, so the impacts of EVs on the grid are negligible at this point. However, in some rare cases, local distribution networks must be upgraded because of high power draw (20 kW or more) associated with certain vehicles and charging equipment.

The ongoing growth in EV adoption is encouraging, even though much more work is needed to meet Vermont’s energy transformation goal of having 140,000 renewably powered vehicles on the roads over the next 15 years. **Meeting this goal will require average sales of more than 9,000 additional EVs a year.**

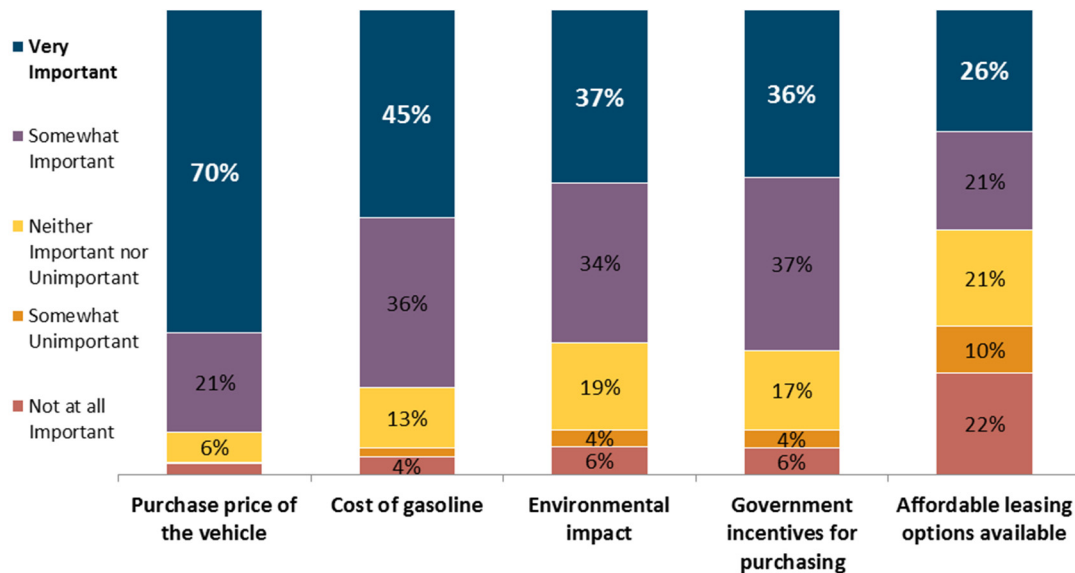
The Drive Electric Vermont program (<http://www.driveelectricvt.com/>) is working on many fronts to support these goals. The consumer decision funnel in **Figure 6** illustrates the process of consumer engagement from initial product awareness to familiarity, consideration, and purchase, and evolving into loyalty. Although social media and other technological changes now give consumers greater ability to skip these discrete stages, the funnel still provides a helpful framework for understanding the typical consumer EV purchase process. Drive Electric Vermont engages with consumers at each stage of this process.



Source: McKinsey & Co., 2009

Figure 6. Classic consumer engagement and decision funnel.

In 2014, VEIC commissioned a statistical survey of 495 Vermont consumers about their awareness and attitudes toward electric vehicles. The survey results have informed priorities for Drive Electric Vermont. The research found general awareness of electric vehicles was present in over 90 percent of the survey respondents, but many potential consumers wanted to know more about the options available to them. Vehicle cost was the most common barrier to considering EV purchases, followed by concerns about limited vehicle range and charging infrastructure. Purchase cost was also cited as the most important issue to motivate consumers to purchase or lease an EV, as shown in **Figure 7**.



Source: MSR Group, 2014

Figure 7. Factors motivating Vermonters in purchasing electric vehicles.

These data demonstrate that electric vehicles are a clear priority for Vermont in meeting its energy and environmental goals. Ongoing research and Drive Electric Vermont program development have highlighted critical areas for speeding market transformation of EV technology. The most urgent areas are increased consumer familiarity, dealer education to better inform customers considering new vehicle purchases, and the availability of consumer incentives to reduce barriers and increase motivation to move forward with an EV lease or purchase.

Market Conditions

Opportunities

Growth

Business-as-Usual Scenario. The Vermont ZEV action plan contains detailed information on activities under way in Vermont to support automakers in complying with ZEV program requirements. **Figure 8** illustrates the anticipated continued growth in the market, particularly in 2017 and beyond after the expiration of the existing travel provision, which allows manufacturers to meet their requirements by only selling EVs in California. The ZEV program requirements have a variety of credits for different vehicle technologies, so actual experience of sales could differ from the scenario presented below. A relatively conservative estimate under existing policies would be approximately 10,000 EVs in Vermont by 2023, or nearing about 2 percent of the fleet of registered vehicles.

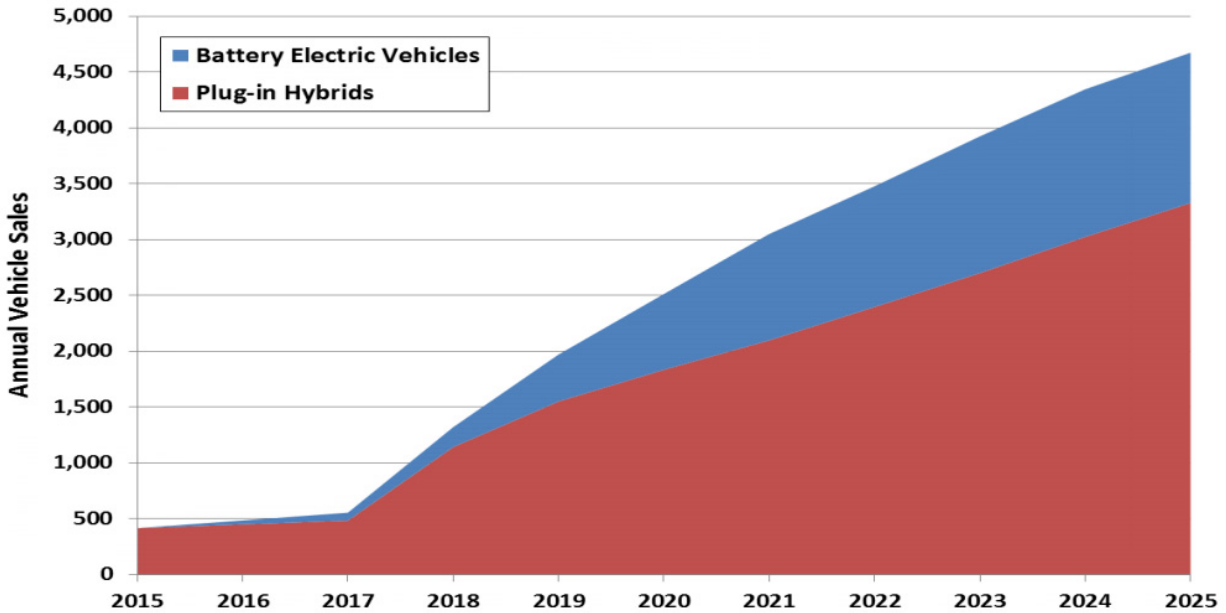


Figure 8. Vermont ZEV Program compliance scenario.⁷

90 x 2050 and Solar Development Pathways Scenario. The Vermont *Comprehensive Energy Plan* includes goals for 25 percent of vehicles to be powered by renewable energy in 2030 and 90 percent by 2050. These values translate to approximately 143,000 EVs in 2030 and 515,000 EVs by 2050. Achieving this rate of growth will depend on vehicle availability at competitive pricing and sustained programs to transform the new and used vehicle markets. VEIC is investigating growth curves that consider current adoption rates and long-term prospects.

Technical Advances

Advancements in EV technology and battery capacity are beginning to make longer ranges possible—at the same or even lower purchase cost of older EV models.

Challenges

Barriers

Although EV sales in Vermont have grown 10-fold in the last three years, they still make up a very small segment of the automobile market. Plug-in vehicles still represent less than 1 percent of new-vehicle sales in Vermont. When aligned with a Rogers’s innovation adoption bell curve, this assigns *innovator* status to plug-in EV purchasers and lessors. Sales of non-plug-in hybrid vehicles has progressed along this continuum to the level in which purchasers fall into the *early adopter* category, as shown in **Figure 9**.

⁷ “Vermont Zero Emission Vehicle Action Plan” (State of Vermont: Agency of Natural Resources, September 2014), http://anr.vermont.gov/about_us/special-topics/climate-change/initiatives/zev.



Figure 9. Rogers' "diffusion of innovations" bell curve, which is applicable to EV adoption in Vermont and nationwide.

Price is still a major barrier for plug-in EV sales. As is evident in **Figure 7**, 91 percent of Vermonters answering the survey indicated that the purchase price of a vehicle is *somewhat* or *very important*. Even with incentives, EVs typically have significantly higher up-front costs than those of conventional vehicles. Affordable lease options are becoming more common, but these are not always well advertised, and cost is still perceived to be a major barrier.

As a rural, mountainous, northern state, Vermont is known for its challenging driving conditions in winter. Compared to the national average, Vermont has more than 3 times the all-wheel-drive (AWD) auto inventory per capita of the national average.⁸ Although hybrid AWD vehicles are currently on the market, there is only one commercially available plug-in **electric AWD** vehicle available in Vermont. It retails at \$75,000.⁹

Another major barrier to EV adoption in Vermont is **battery range**. Because of Vermont's low population density, commutes tend to be long and development less concentrated than in other states. The limited battery range is definitely problematic. Also EV technology performs at its highest efficiency in stop-and-go traffic (via regenerative braking), and on flat terrain. Most Vermont driving involves neither of these. Exacerbating the barrier of limited battery range is the lack of a comprehensive EV charging network. Vermont currently has 69 public EV charging stations. Expanding this network will facilitate EV adoption in Vermont.

Finally, **auto dealer engagement** is a powerful tool in selling electric vehicles. Many Vermont dealers do not offer electric vehicles at all. Dealers that offer them typically do not promote them.

⁸ Kelsey Mays, "Winter Weather Sends All-Wheel-Drive Inventory Up 20 Percent," *Cars.com*, February 20, 2014, <https://www.cars.com/articles/2014/02/winter-weather-sends-all-wheel-drive-inventory-up-20-percent/>.

⁹ TESLA Model S (now available) and Model X (available in 2016); Toyota RAV4 EV has been discontinued.

Dealer staff is often not well informed about the products and will sometimes actively direct customers away from electric vehicle options.

Overcoming Barriers

As with any new technology, incentives and disincentives are powerful policy tools. Incentives might involve cash offsets, dealer inducements, and tax credits to customers. Several states offer EV incentives: California, Colorado, Georgia, Louisiana, Massachusetts, Utah, and (most recently) Texas. Some states offer registration fee exemptions or travel incentives such as free tolls or access to high occupancy vehicle (HOV) lanes. Incentives could also be offered in the electricity sector. **Electric rate structures for EV charging can provide significant benefits to Vermont's electric grid by encouraging EV owners to charge at night during off-peak hours.** Distribution utilities can charge rates that make EV charging extremely cost effective for EV owners. ConEdison in New York offers on-peak delivery rates of 19.4 cents / kWh and off-peak rates of 1.36 cents / kWh.¹⁰

On the other side of the equation, disincentives can also be a powerful tool. An increase in the State gas tax or the implementation of a carbon tax in Vermont would provide an economic disincentive for drivers to use vehicles that consume fossil fuels; conversely, a carbon tax would be a significant factor in motivating EV sales.

Aside from economic incentives and disincentives, notable other ways to overcome market barriers to EVs are the broader introduction of AWD EVs into the Vermont marketplace, particularly at a price that, when combined with economic incentives, is comparable to the purchase price of a modest conventional gasoline-powered vehicle.

Expanding EV-charging infrastructure is one way in which Vermont regulators can promote the adoption of electric vehicles. Allowing distribution utilities to assign rate base spending on EV charging stations would motivate Vermont's utilities to install charging stations and receive a guaranteed rate of return, while building their sales bases. Alternately, public-private partnerships could promote the retail sale of electricity in places like conventional gas stations if they were to offer DC fast charging, or at highway rest areas to promote tourism and long-distance travel by EV owners.

To address the lack of dealer initiative related to EV sales, additional sales commissions or spiffs (time-of-sale bonuses) could be offered for dealer sales staff. Educational outreach programs directed at dealers and sales staff could build greater familiarity with the vehicles and their benefits.

Innovative marketing strategies such as packaging together an electric vehicle with rooftop solar PV and an attractive financing option could promote vehicle-to-building technology in the future.

Electric vehicle sales continue to grow as EVs are seen as a viable alternative to fossil fuel consumption through conventional vehicles. As the EV markets continue to grow, economies of

¹⁰ "Electric Vehicles - Rate Options for Charging Your Plug-in Electric Vehicle (PEV)," *ConEdison*, accessed December 12, 2016, <http://www.coned.com/electricvehicles/rates.asp>.

scale will contribute to less expensive batteries and better technology options. This combination of declining costs and maturing technologies will be instrumental in overcoming market barriers.

Scenario Inputs

	Current account / historical data	Reference (business as usual)	Long-range target	Revised SDP
Applicable market segments	Light-duty vehicles	Light-duty vehicles	Light-duty vehicles	Light-duty vehicles
Number of units	891	10,000 by 2023	23,000 by 2023 143,000 by 2030 515,000 by 2050	23,000 by 2023 143,000 by 2030 515,000 by 2050
Total annual energy consumption	1,900 MWh	Calculated in LEAP	Calculated in LEAP	Calculated in LEAP
Type of growth	NA	Exponential	Logistic	Logistic
Changes in performance characteristics		2% increase in range annually until vehicles reach 200 miles of range		
Costs		\$35,000 for 200-mile range vehicle in 2020	\$25,000 for 200-mile range vehicle in 2020	\$25,000 for 200-mile range vehicle in 2020

Unmet Needs

Future work on the role of EVs in the Vermont Solar Deployment Plan will need to examine how the projected vehicle fleet storage capacity can be paired with expanding solar to help with system integration and intermittency of generation.

Focus Area Brief: Heat Pumps

Introduction

Electric heating has historically not been a prudent choice for Vermont residents and businesses because electric resistance heat costs more than any other fuel. Early heat pump technology did not function well in cold winter temperatures. New cold-climate heat pumps, however, now address both issues, operating more than twice as efficiently as resistance heat, and capable of working down to extremely low temperatures.

Heat pumps can be an attractive option for buildings that already have a source of heat. They make it possible for that existing source to become a backup to the heat pump technology. If solar PV is available to the building, it can supply the electrical power needed to operate the heat pump.

These improvements mean that solar PV can be converted efficiently and cost effectively to space conditioning, as well as to water heating. This strategy is being used in net-zero-energy new construction as well as in existing home retrofits. Lower solar costs make heat pumps competitive now with equipment that uses fossil fuels and biomass.

Heat pumps also benefit solar by increasing the electric demand on the grid and creating more room for solar generation. They add water heating and space conditioning to the services that solar PV can provide. This additional electric load comes with demand response opportunity. Water heating has long been used for demand response, and heat pump water heaters can continue this tradition while being much more efficient. During the early afternoon in the summer, heat pump space heaters may be dispatched to pre-cool space when solar generation is peaking and demand has not yet risen to the afternoon peak. Heat pumps may also be controlled at other times to balance supply and demand, however, they operate most efficiently when allowed to modulate based on their own programming.

Technology and Market Description

Heat pumps use electricity to move heat. There are many variations of the technology, but the focus here is on air source heat pumps that use energy in outdoor air to provide space heating and cooling. Heat pump water heaters work similarly and are another aspect of growing electrification in Vermont.

The economics are most compelling for homes using one of the non-electricity fuels for heating, highlighted in **Table 3**. For homes with more expensive heating fuels, a heat pump could be paid off in as little as four or five years. Operating costs are nearly even as those for natural gas and wood, so people are not likely to rush to switch, but might consider heat pumps when replacing failed systems.

Table 3. Annual savings for a typical home (75 MMBtu / year), assuming 80 percent fuel offset¹¹

Fuel	Cost of 75 MMBtu / Year
Natural gas	- \$68
Wood	- \$23
Pellets	\$289
Fuel oil	\$590
Kerosene	\$909
Propane	\$1,026
Electricity	\$1,583

Heat pumps are least efficient when outdoor temperatures are very high or low, so they pose a challenge for utilities by possibly contributing to peak problems. Currently in Vermont, winter peak is not a concern, but both peaks are growing, and the summer peak is an issue in some areas. Equipment controls and solar supply can both help lower the summer peak. Winter peak issues can be addressed with controls that shift heating to existing fossil systems during peak conditions.

Market Conditions

Opportunities

Growth

Vermonters generally are enthusiastic about heat pumps for displacing fossil fuel heating, as shown in Efficiency Vermont data:

- The most common search term on www.encyvermont.com is *heat pumps*
- The fourth most common search term on that site is *heat pump* (the singular form)
- In 2014-2015, VEIC's Customer Support group reported 200 customers who have contacted them are waiting for Efficiency Vermont to roll out a heat pump program
- Trade shows indicate that Vermonters associate the Efficiency Vermont brand with heat pumps
- Even roofers have expressed an interest in offering heat pumps

Green Mountain Power's (GMP's) lease program took more than 600 calls in the first few days of its announcement. The utility had to stop taking calls because it could not satisfy the high volume of requests.

As awareness of residential split systems (heat pumps whose technology offers both heating and cooling) continues to grow, so do sales:

- 2012 sales
 - Close to 35 percent growth over 2011
 - Approximately 1,720 units sold

¹¹ An updated version of this table is available in Volume 1.

- 2013 sales
 - Major manufacturers reported growth of 40 percent
 - 2,400 units sold


Technical Advances

Cold-climate heat pumps are advancing quickly. Initially only available as single head units, there are now multi-zone and multi-head systems. These systems come with more installation options for the indoor units that address some of the barriers listed below. Soon, heat pumps designed to connect to conventional duct and water pipe distribution systems will be available, as will be combined space and water heating systems. These improvements increase the number of homes and businesses that can use the technology.

Efficiency is also increasing. Researchers are now designing systems that can use carbon dioxide as a highly efficient and low-impact refrigerant. Solid-state heat pumps are another focus of research. In Vermont, heat from heat pumps currently costs less than all fuels except cord wood and natural gas, as shown in **Table 4**. With increasing efficiency, heat pumps might overtake these two fuel sources, again expanding their potential market.

Table 4. Relative cost-effectiveness of electric heat pumps, compared to other fuel types¹²

Fuel Type	Unit	Btu/Unit	Efficiency	\$/Unit	\$/MMBtu
Natural Gas	Therm	100,000	90%	\$ 1.48	\$ 16.44
Wood	Cord	22,000,000	60%	\$ 227.00	\$ 17.20
Pellets	Ton	16,400,000	80%	\$ 294.00	\$ 22.41
Fuel Oil	Gallon	138,200	85%	\$ 3.22	\$ 27.41
Kerosene	Gallon	136,600	85%	\$ 3.80	\$ 32.73
Propane	Gallon	91,600	90%	\$ 2.86	\$ 34.69
Electricity	kWh	3,412	100%	\$ 0.15	\$ 43.96
Electricity (Heat Pump)	kWh	3,412	250%	\$ 0.15	\$ 17.58



Source: Adapted from Vermont Fuel Price Report, Vermont Public Service Department

Challenges

Barriers

- Perception that heat pumps don't work in Vermont's climate
- High upfront costs mean financing might be required; many customers are debt averse
- Many older homes need weatherization, first

¹² An updated version of this table is available in Volume 1.

- Many older homes also don't have open floor plans, so they cannot be effectively heated from a single source
- The aesthetic effects of visible units in living space are a drawback, compared to traditional heating systems hidden in basements

Overcoming barriers

- Training and good information about heat pumps' capabilities and applications
- Weatherization assistance
- Future heat pumps that connect to ducted and hydronic distribution systems

Costs

- Single-zone ductless: \$4,000
- Multi-zone ductless: \$6,000 to \$20,000
- Ground source: \$20,000+

As contractors become more familiar with the technology, costs will likely come down. There have been some group-buying efforts similar to those for solar. Contractors are combining heat pump and solar projects, gaining customers for both markets and rolling projects into attractive cash-flow-neutral loans.

Scenario Inputs

Data type	Current accounts / historical data
Applicable market segments	<ul style="list-style-type: none"> • Residential market: fossil fuel displacement • Commercial market uncertain • Restaurant application • LIHEAP • 40,000 - 45,000 households • Multifamily; retrofit and new construction
Number of units, and market share by type	<ul style="list-style-type: none"> • Low lease penetration with GMP program • 6,000 CCHPs installed in Maine • Collect information on Efficiency Vermont incentives • GMP goal of 750 heat pumps leased by end of 2015 • Home Performance
Typical load profiles, annual consumption, annual production	<ul style="list-style-type: none"> • Winter peak not a concern right now • Work on reworking load shape via Itron • VELCO estimates that Vermont will not see a net increase in demand from heat pumps for at least 10 years from now
Type of growth	Exponential
Changes in performance characteristics	<ul style="list-style-type: none"> • Higher efficiency units • CO₂ as refrigerant with higher coefficient of performance (COP) • Solid-state heat pumps

Data type	Current accounts / historical data
	<ul style="list-style-type: none"> New brands in the marketplace, offering new technology and other air-to-water heat pumps, with steadily increasing performance each year
Costs	<ul style="list-style-type: none"> Installation cost reduction as Heating, Ventilation, and Air Conditioning (HVAC) technicians become more familiar with the equipment More competition in the marketplace Equipment costs should come down with improved efficiency
Technical or market elements	<ul style="list-style-type: none"> Controlling units remotely to shape loads: Is it the most cost-effective way to reduce peaks? Or are battery banks, for example, better for smoothing out loads?
Top three issues	
Peak load impacts	Forecast the possible negative impacts on peak load
Source of the energy	Movement away from dirty energy
Equipment obsolescence	New equipment outperforming existing equipment, and that equipment is being removed before the end of its useful life
Incentives	Allowing market to transform itself
Manufacturers	Service support: Recall communication

Unmet Needs

More information needed

- Utility plans for controls or rates to manage peak
- Cost projections for equipment and fuels
- Demand response control of heat pumps is likely to be an important strategy to address solar on distribution circuits. This focus group will examine items such as the potential for communications and controls to be integrated with higher solar saturation.

Focus Area Brief: High-Performance Modular Homes & Mobile Home Replacement

Introduction

High-performance modular homes are a relatively new entry in the homeowner marketplace, and they significantly reduce heating and cooling loads through air tightness, high insulation levels, and heat recovery ventilation. By lowering heating and cooling loads with those measures, loads can further be reduced by smaller and less complex HVAC systems such as point source heating and cooling devices. The most efficient and cost-effective point source approach for meeting these demands is ductless cold climate heat pumps. Combined with solar hot water or heat pump hot water heating, these homes can be all-electric with no reliance on fossil fuels. This makes them a very attractive option for people with low to moderate incomes, and those on fixed incomes.

A high saturation of solar power, when combined with the conservation strategies and all-electric approach in high-performance modular homes, can significantly reduce or eliminate energy costs for a homeowner. A solar package can be included in the homes' financing. In effect, homeowners are pre-buying their energy with the home purchase. Solar energy, either site based or available at the community level, can then be part of an affordable housing solution that protects homeowners from future energy cost escalation and reduces their carbon footprint.

Technology and Market Description

For many years, there has been a general conversation about what to do to replace older, energy-inefficient mobile homes with more efficient, durable, and comfortable models. The U.S. Department of Housing and Urban Development (HUD) created standards for mobile homes in 1976 and has updated them several times since. Although the HUD standards have contributed greatly to upgrading the quality of the homes, those standards do not approach the energy efficiency requirements of Vermont's Residential Building Energy Standards (RBES) or ENERGYSTAR® Homes for "stick-built" or modular homes.

Members of Vermont's energy efficiency community have been particularly vocal in asserting that it does not make sense to replace an older, inefficient home with something that cannot meet a high level of energy efficiency, given the price of fuel and the State's legislated commitment to reducing carbon emissions. Tropical Storm Irene added urgency to this conversation because 15 percent of the homes damaged or destroyed by Irene were mobile or manufactured homes. Replacing poor-quality, but very inexpensive, homes with homes of better quality that cost more must be considered in the context of the fact that nationally 41 percent of mobile home dwellers have incomes below 50 percent of area median. A University of Vermont survey of nine sizable mobile home parks has found similar demographics in Vermont.¹³

¹³ Daniel Baker, Kelly Hamshaw, and Corey Beach, "A Window Into Park Life: Findings From a Resident Survey of Nine Mobile Home Park Communities in Vermont," *Journal of Rural and Community Development* 6, no. 2 (December 29, 2011), <http://journals.brandonu.ca/jrcd/article/view/415>.

Currently, there are more than 22,000 manufactured and mobile homes in Vermont. One-third of these homes are located in mobile home parks on leased land, whereas the remaining homes are on privately owned land. Nearly 70 percent of the homes were built more than 20 years ago, and approximately 25 percent of the homes were built prior to 1976 and the HUD Code. Data from the U.S. Energy Information Administration (EIA) in 2009 showed Northeast mobile homes had average energy consumption of 79.2 MMBTUs per year.¹⁴ By comparison, a high-performance modular home will use around 22 MMBTUs per year in energy; a PV rooftop array of 6 kW would allow the home to produce as much energy as it consumes. These comparisons are shown in **Figure 10**.

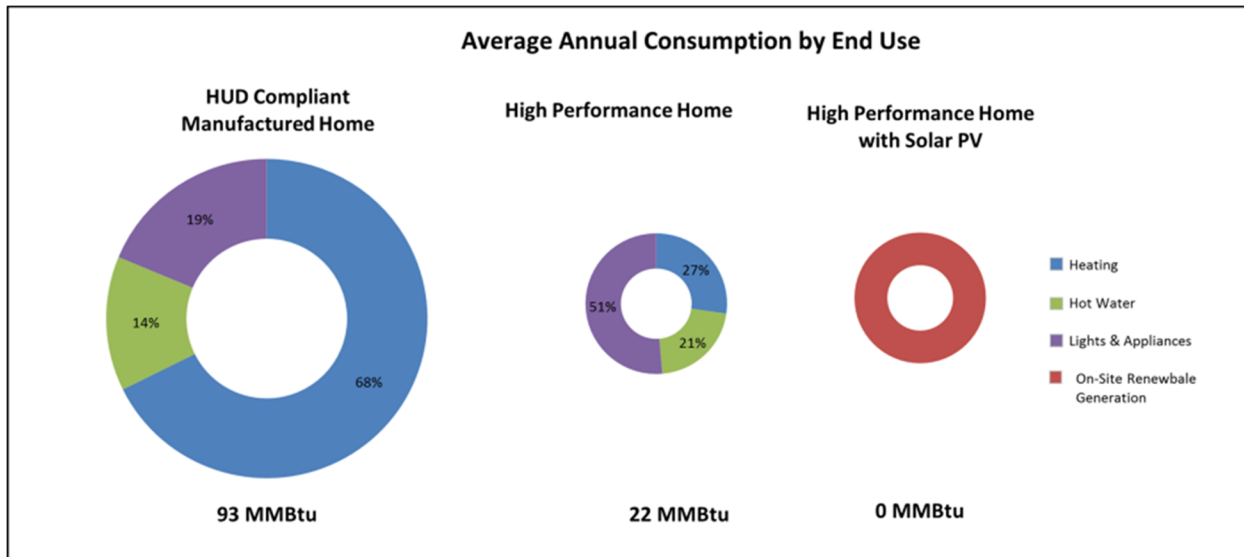


Figure 10. Modeled average annual consumption by end use in Vermont, comparing new HUD-compliant manufactured home standards with a home that meets Efficiency Vermont's High-Performance Home (HPH) tier, assuming the HPH has solar power.

The 2011 *Vermont Comprehensive Energy Plan* calls for a broader market penetration of net-zero-energy buildings, with a goal of having 30 percent built to net-zero design standards by 2020 as an interim target, on the way to 100 percent net-zero buildings by 2030. With this goal in mind, policy makers and decision makers could make net-zero-energy modular housing a priority for Vermont.

Currently, Efficiency Vermont offers a Mobile Home Replacement program and provides incentives for the purchase of high-performance modular units at \$8,500 for buyers with incomes less than or equal to percent of area median income and \$2,000 for those whose income is above 80 percent of area median income. Several cost breakouts are shown in **Figure 11**. The State also offers a \$35,000 tax credit through its HomeOwnership Center Network, which amounts to a 0 percent interest loan with payment deferred until the home, on leased land, is sold. Partners supporting this effort have also created statewide financing terms for these homes on private and leased land, with local lenders and a USDA Rural Development program. These options are as good as or better than typical home financing packages. Currently, low-income homebuyers

¹⁴ U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey 2009*, Table CE4.7

of one manufacturer's buildings ([Vermod](#)) can access financing terms that are as low as 30 years at 1 percent, with a small down payment.

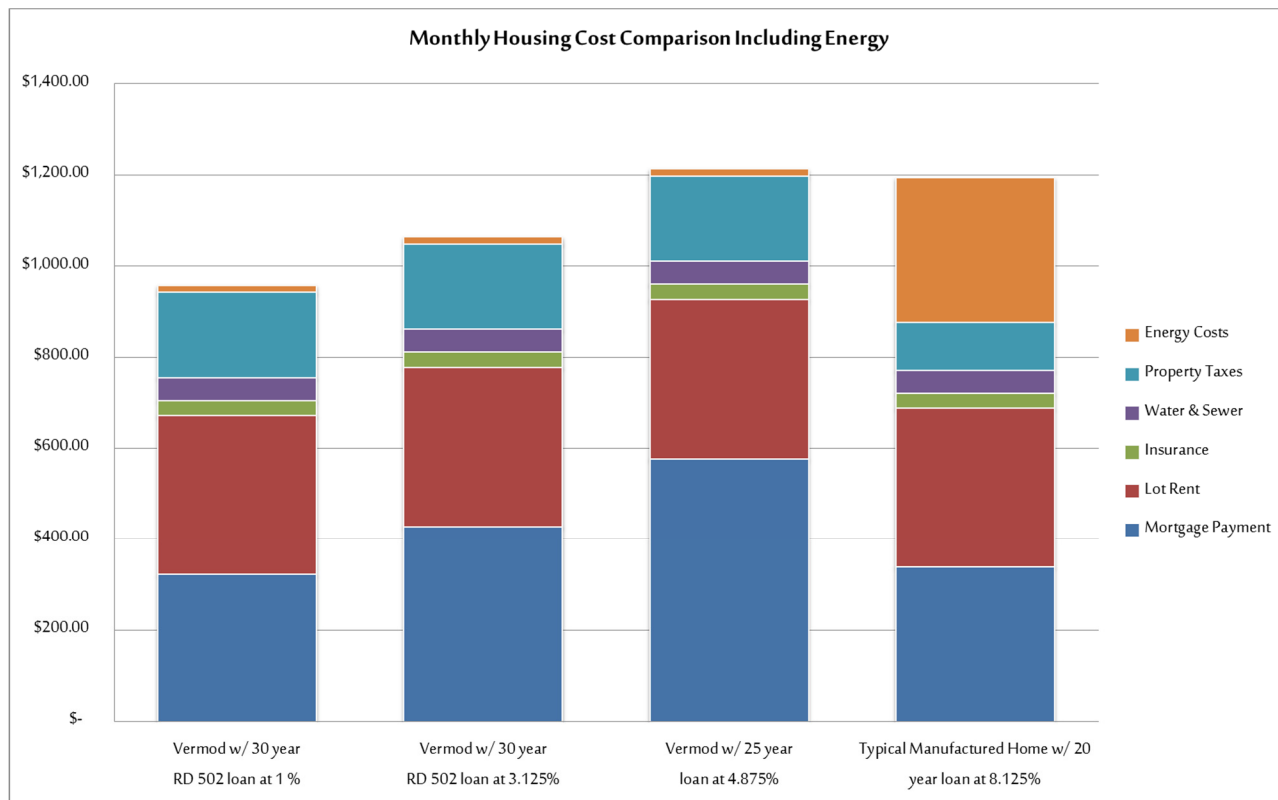


Figure 11. Housing types at available loan terms, highlighting the benefit of USDA Rural Development 502 financing in the two leftmost bars.

Figure 11 assumes a Vermont Housing Finance Agency loan and Efficiency Vermont incentives, where applicable. Note that the monthly payment for a high-performance modular home (denoted in the figure by one manufacturer's name, *Vermod*) would increase by \$15 if energy costs doubled; under the same conditions, the owner of a typical manufactured home would have to pay more than \$300.

Market Conditions – Opportunities and Challenges

Initial conditions:

- \$145,000 for a 980-square-foot, 2-bedroom, 2-bathroom unit without incentives or subsidies
- Three factories in Vermont can construct these mobile home replacement units
- Estimated pace of replacements in 2015: 20 mobile homes
 - Anticipate more than doubling the number of units in 2016, and continuing that trend over the next five years

Opportunities

Growth

High growth for this market would be the achievement of 1 percent replacement of the mobile and manufactured housing stock per year in five years. This would represent around 200 replacement units per year by 2020. The strategies for achieving this goal are outlined below.

Low growth would be the achievement of approximately 50 units per year in five years; that pace would represent approximately 0.25 percent of Vermont's current housing stock.

This initiative and approach to affordable housing began in 2014 in Vermont and across the United States. VEIC is introducing this concept and specific product to the low-income sector for the first time. There are no data on prior mobile home replacement efforts of this type to evaluate. To inform the next phase of developing high-performance homes of modest scale, VEIC, under a grant from High Meadows Fund, conducted market research about the demographics of the potential market and psychographic characteristics of potential buyers. That high-performance home market research is available on the High Meadows Fund website.¹⁵

The main conclusions were:

- There is no ready-and-waiting market to be served. The market needs to be created.
- Land costs are a significant factor. Finding sites in clustered developments or parks could alleviate this challenge. Southern Vermont and Central Vermont might offer opportunities because land prices in those regions are relatively moderate.
- Even with a financing package, low-income Vermonters will not be able to afford these homes unless they can have access to significant subsidies. Such subsidies could be less than the per-home subsidy for other new affordable-housing options.
- People who are comfortable with change and taking risks are more likely to be early adopters.
- Visiting a home makes a big difference in purchase decision making. People can see and feel the difference in a way that is hard to convey with printed material.
- The terms *High-Performance Home* and *Net-Zero Home* are very weak, and are not understood in the marketplace. Most people do not associate the terms with comfort and affordability of a home.
- Early adopters valued having a “trusted advisor” to guide them in the home-buying process—someone they knew personally or to whom they had been introduced by a trusted source.

¹⁵ Energy Futures Group et al., *Market Potential for High Performance Homes in Vermont*, <https://static1.squarespace.com/static/51b0ce25e4b0e8d244de368b/t/547f1163e4b002e3c07d92c1/1417613667602/HPH+Market+Research+Report+11-12-14A.pdf>.

Next Phase

Having learned to build a great home and receiving impressive results in terms of energy efficiency, the next phase of this effort will seek to fully fund and implement an overall strategy for moving the project beyond the pilot phase. The strategy for this phase will be to create a path to a sustainable business model for the small, modestly priced high-performance home industry. Specifically, VEIC will:

1. Implement a marketing plan for the high-performance home products in Vermont, identifying obstacles to sales and what appeals to potential buyers. This will involve working with other team members to overcome barriers identified both through the market research and in conversations with potential buyers.
2. Pull together a reasonable financing package for a highly energy-efficient small home. The package might contain on-bill financing or other mechanisms to convert energy savings into a long-term financing opportunity.
3. Test whether mobile home parks can be re-developed in a manner that improves overall quality of life by using the high-performance home model—either as individually owned homes or rental housing. The test would also seek information on whether the high-performance home model enhances the potential of residents to own an asset that appreciates in value.
4. Test whether there is a broader market that can be penetrated with the high-performance home in many locations inside and outside Vermont for early adopters, downsizing elders, and other buyers who meet the profile outlined in the marketing research.

Technical Advances

Efforts are under way to improve the initial cost and financing which will make this type of housing more accessible to low-income Vermonters:

- Minimal down payment
- Low fixed interest rates (less than 4 percent and down to 1 percent for homebuyers at 50 percent of area median income)
- Long terms (30 years)
- Second mortgages at 0 percent interest, with payment deferred until the home is sold
- On-bill financing, using energy savings to cover a portion of the mortgage payment through the homeowner's electric utility
- Higher incentive through Efficiency Vermont for low-income homebuyers, to support early adoption and market transformation
- Increasing the volume of high-performance home production, which should lead to a 10 percent reduction in initial cost of homes

Building science and technologies change very quickly. Further, the industry continues to introduce approaches for effectively achieving high-performance characteristics in new and more cost-effective ways. The High-performance Modular Team at VEIC regularly evaluates the new science and technologies, and incorporates new approaches that can improve the home and reduce either initial cost or life-cycle costs.

Challenges

Barriers

Broadly speaking, the goal of this effort is to transform the market to the point at which high-performance modular homes (HPMH) are affordable and accessible, and can be purchased with conventional sources of financing. Two primary challenges exist:

1. The purchase price is significantly higher than a new manufactured ENERGY STAR home of the same size. Although the ENERGY STAR standard for manufactured homes still fails to meet the Vermont residential energy code, homebuyers consider the product efficient.
2. The concept of this kind of home is very unfamiliar to most people

Overcoming Barriers

The HPMH Team seeks support in continuing to develop tools to overcome these three challenges. What is needed:

1. A financing package that overcomes initial first-cost barriers for moderate-income Vermonters who want to purchase these homes
2. Supplemental financing and funding that enables low-income residents of mobile home parks to own or rent a high-performance home
3. A marketing approach—including graphics, a name, and the necessary hand-holding—that makes the home an attractive purchase option
4. Business planning and support for a company (or companies) willing to serve this market

These elements will allow Vermont to begin to see traditional mobile home parks transformed into communities that provide higher-quality and higher-efficiency options for residents, and to see a substantial increase in market-based sales of high-performance, modest homes.

Costs

- \$145,000 today for a 980 square-foot, 2-bedroom, 2-bathroom home, net-zero energy
 - A 10 percent reduction in cost is possible if the volume of sales and production increase (eventually, these should be compared to baseline to meet Code or ENERGY STAR standard, to determine the incremental cost difference).

Scenario Inputs

	Current accounts / historical data	Reference (business as usual)	Long-range target	Revised SDP
Applicable market segments	22,000 existing mobile and manufactured homes in Vermont			

	Current accounts / historical data	Reference (business as usual)	Long-range target	Revised SDP
Number of units (and identify the units)	~ 20 replacement units anticipated in 2015	~ 200 HPMH replacements per year by 2020	23,000 or 100% replacement of MH housing stock by 2050	23,000+ or 100% replacement of MH housing stock by 2050
Total capacity				
Total annual energy consumption	Savings estimated at ~ 70MMBTUs / unit / year			
Type of growth	NA	Linear	Interpolate	Exponential
Changes in performance characteristics	Transforming housing from below RBES to exceed Code by 75%			
Costs	High-performance unit costs twice that of a typical new manufactured home of the same size (\$70,000 vs. \$145,000)	Anticipate a 10% reduction in cost as demand and volume of production increases		

Unmet Needs

More information needed:

Looking forward, the economics and possible controlled integration of community scale solar versus individual unit solar might be topics for this group to consider.

Focus Area Brief: Incentives

Introduction

Tax credits and other direct incentives have been essential to the growth of solar PV markets. With declining costs and the possibility that future federal tax credits will decline, it is essential to examine whether incentives are still necessary for promoting market development. As the market continues to grow, it is also important to consider if particular market segments (for example, low-income or low-wealth segments) require ongoing incentive support.

Historically, direct incentives have provided statewide oversight of solar electric installations; they have also enabled close communication between the end user and the installer. Without the benefit of a comprehensive direct incentives program, policy makers and decision makers must consider innovative approaches for continued oversight and communication. Incentives can also affect the type of solar installation (rooftop versus ground mounted) and the technical operations (for example, western versus southern exposure) of systems that are deployed. Targeted incentives encouraging well-sited and right-sized systems should be encouraged for maximum efficiency.

Technical and Market Description

State Incentive

The Vermont Small Scale Renewable Energy Incentive Program (SSREIP) discontinued its residential solar electric incentive on December 31, 2014. An incentive structure for “special category” customers (municipalities, public schools, and low-income nonprofit housing) remains, although no funds are available for such projects. The Special Category incentive structure is based on module capacity at \$1.00 / Watt, up to 10 kW, with system capacity of up to 25 kW. The incentive requires a reservation and an approved application prior to installation. Afterward, the installer must submit paperwork documenting the system and verifying completion. The program issues the payment directly to the installer, who then transfers it to the customer either through (1) a discount on the final invoice or (2) a rebate from the installer to the customer, once payment has been received from the program.

The Vermont SSREIP does not allow self-installations, and requires that customers use pre-approved Reserving Partners to access the program. The Reserving Partner must oversee system design and installation, and identify—by name and title—the person who installs each project. These Partners apply to Renewable Energy Vermont for acceptance into the program. Businesses with experienced installers committed to high-quality, safe installations may have several “open” reservations at a time. Businesses new to the solar industry are considered “Provisional Partners,” and may have only one open reservation at a time. All Partner installations are subject to inspection by Vermont SSREIP staff, to ensure the installation was completed with homeowner safety and program compliance in mind.

Other basic requirements for the State Incentive are (1) system warranties to ensure that installations remain functional for at least five years; (2) interconnection to the electric utility grid; and (3) a Certificate of Public Good pursuant to 30 V.S.A. § 248 from the Vermont Public Service Board.¹⁶

Federal Tax Credits

The Business Energy Investment Tax Credit offsets 30 percent of solar PV system expenditures, with no maximum credit. The credit is available for eligible systems placed in service on or before December 31, 2016. After December 31, 2016, the credit will decrease to 10 percent.¹⁷

The Residential Renewable Energy Tax Credit allows taxpayers to claim 30 percent of qualified expenditures for a system that serves a dwelling unit located in the United States and is owned and used as the taxpayer's residence. It does not have to be the taxpayer's principal residence. There is no maximum credit for systems placed in service after 2008. Systems must be placed in service on or before December 31, 2016.¹⁸

Corporate Depreciation

Businesses may use the federal Modified Accelerated Cost-Recovery System (MACRS) to recover investment in solar. Solar photovoltaic systems are classified as five-year property, which refers to the Business Energy Investment Tax Credit to define eligible property.¹⁹

Standard Offer Contracts

Vermont retail electricity providers are required to purchase electricity generated by eligible renewable energy facilities through the State's Sustainably Priced Energy Enterprise Development (SPEED) Program—now known as the Vermont Standard Offer. The Standard Offer uses long-term (10 to 25 years for PV technology) contracts, with fixed standard offer rates. The program provides a reasonable return on investment (ROI) to renewable energy facility developers. In turn, the existence of this reasonable ROI is intended to increase renewable energy production by facility developers. These systems may be up to 2.2 MW. Competitive RFPs are released annually on April 1; contracts are issued according to the proposed \$ / kWh structure.²⁰

¹⁶ The Public Service Board offers an expedited Certificate of Public Good process for solar electric systems 15 kW and less.

¹⁷ NC Clean Energy Technology Center, "Business Energy Investment Tax Credit (ITC)," *DSIRE*, December 21, 2015, <http://programs.dsireusa.org/system/program/detail/658>.

¹⁸ NC Clean Energy Technology Center, "Residential Renewable Energy Tax Credit," *DSIRE*, January 14, 2016, <http://programs.dsireusa.org/system/program/detail/1235>.

¹⁹ NC Clean Energy Technology Center, "Modified Accelerated Cost-Recovery System (MACRS)," *DSIRE*, January 11, 2016, <http://programs.dsireusa.org/system/program/detail/676>.

²⁰ NC Clean Energy Technology Center, "Standard Offer Program," *DSIRE*, accessed December 13, 2016, <http://programs.dsireusa.org/system/program/detail/5680>.

Historical Trends

State Incentive

The Vermont PV market has sustained tremendous growth over the past several years. Between 2006 and 2009, solar electric installations receiving state incentives funded through the Clean Energy Development Fund (CEDF) via the SSREIP increased at approximately 40 percent per year (56 installations in 2006; 75 in 2007; 109 in 2008; and 153 in 2009). The market stagnated from 2009 to 2010, due to confusion about compliance with conditions for receiving American Recovery and Reinvestment Act incentives through the SSREIP. The market, however, quickly rebounded, increasing 183 percent in 2011 (442 PV installations).²¹ The 2011 rate of installation kept pace throughout 2012, even with the sun-setting of the ARRA-funded program and declining incentive rates (\$1.75 / W at the height of the period down to \$0.75 / W at the close). In 2013, incentive rates continued to decline (to \$0.45 / W for residential installations and \$0.40 / W for commercial ones).

The PV market quickly responded with the emergence of large-scale leasing options to the public. This market force precipitated another large increase in PV installations, up another 106 percent (404 installations in 2012 to 833 in 2013²²). By the end of 2013, customer economics for commercial PV were such that the SSREIP no longer was necessary to support that market sector, and the program retired the incentive structure for commercial PV. Under the 2014 SSREIP PV incentive structure (\$0.25 / W for residential customers), 1,023 PV installations were completed. This number represented 36 percent of total PV systems receiving an incentive through the SSREIP; another 339 systems were still under reservation. The Vermont PV market remained robust in spite of a continually decreasing incentive. This trend provided strong support for ending the PV incentive altogether from the SSREIP. The CEDF subsequently removed it from the SSREIP on December 31, 2014.

Over the course of the SSREIP PV program, 3,685 PV installations were completed, representing 25.1 MW and 29.5 MWh; an additional 2.3 MW are now under reservation. These and other data are shown in **Table 5**. The trends in incentive rates as installations have increased are shown in **Figure 12**. **Figure 13** shows the comparative value of SSREIP dollars between 2004 and mid-year 2015.

Table 5. Vermont SSREIP summary of solar installations and reservations awaiting installation and incentives, January 2003 through May 7, 2015

Solar PV: For all funding sources	
Number installed	3,685
Total cost of installed systems	\$125,176,209
Incentives paid for installed systems	\$15,068,349

²¹ SSREIP database. May 2015.

²² Ibid.

Solar PV: For all funding sources	
Total installed capacity (W)	25,117,566
Estimated annual kWh / year	29,507,823
Leveraged economic development: \$1 SSREIP investment ²³ equals	\$7.31
Number under reservation	339
Value of current reservations - not yet installed	\$625,982
Total proposed capacity (W)	2,361,475

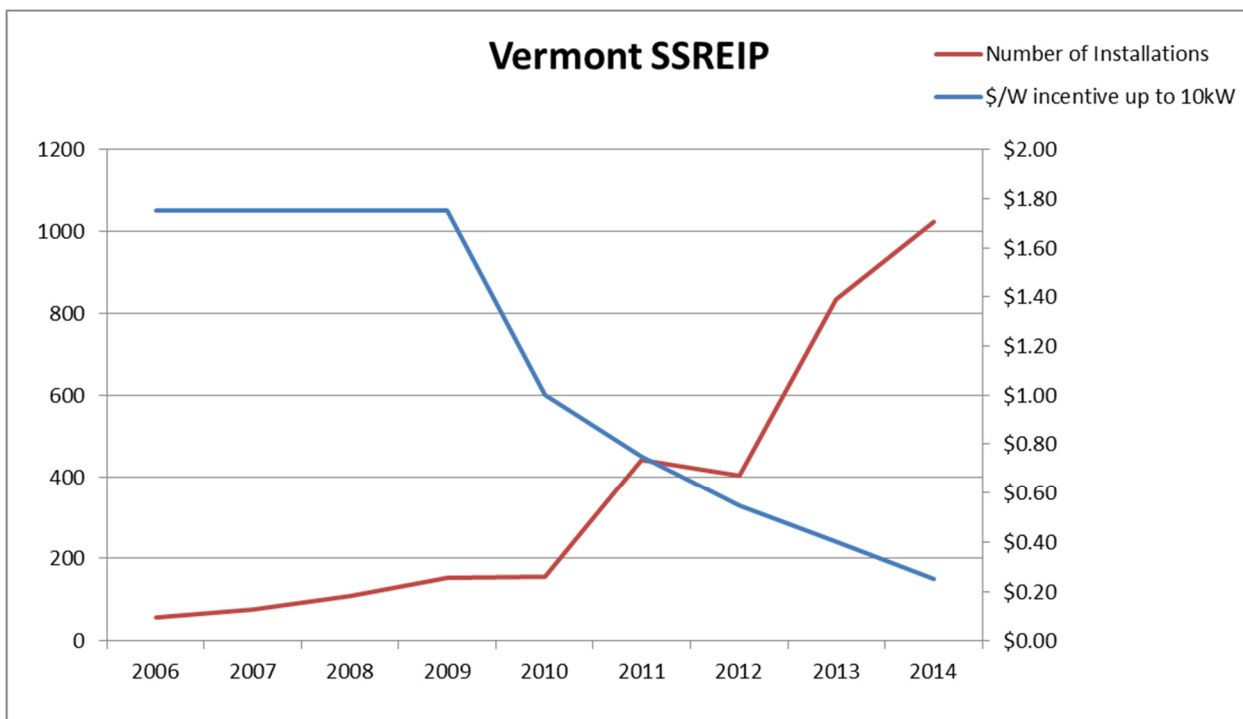


Figure 12. Vermont SSREIP incentive rate, compared to the number of program installations, 2006 – 2014.

²³ Based on reported costs of installed systems and awarded incentives.

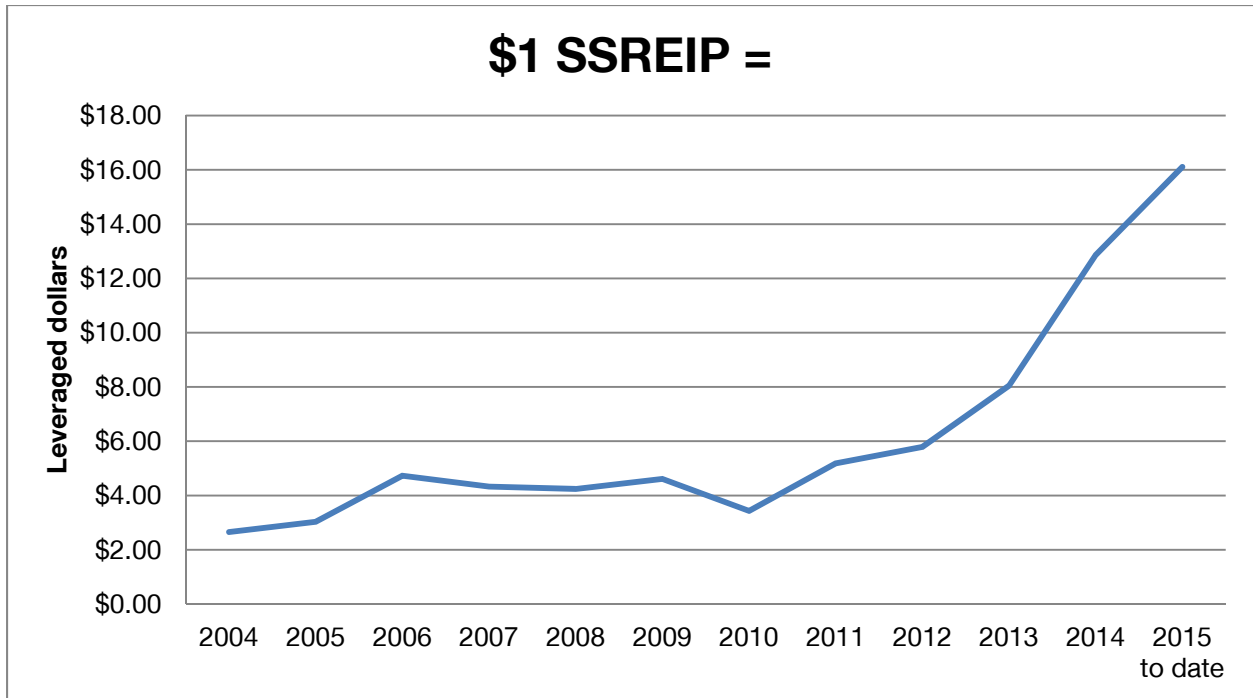


Figure 13. Trend line showing the value of leveraged SSREIP dollars.

Market Conditions

State Incentive

Between January 1, 2003, and the first quarter of 2015 (January 1 through March 30, 2015), the Vermont SSREIP has paid incentives on 3,685 solar photovoltaic systems, resulting in a total estimated annual production of over 25 MWh / year. The program expects to pay incentives on an additional 339 solar photovoltaic systems in 2015, resulting in an additional production of over 2 MWh / year. The average size of a solar photovoltaic system installed in the first quarter of 2015 is approximately 7.5 kW and costs slightly less than \$32,000, before incentives (including tax credits). These systems cost an average of \$4.26 / Watt before incentives. The state incentive has decreased this average cost to \$4.02 / Watt.

There is continued interest in the Special Category, particularly because of the High Performance Mobile Home Replacement pilot (see **Focus Area Brief: High-Performance Modular Homes and Mobile Home Replacement**). That program has allowed end users to access the increased Special Category PV incentive rates directly. Schools, municipalities, and nonprofit low-income housing organizations continue to be interested in solar energy. However, they are now turning to alternate ownership models and to federal grant programs to provide financial opportunities, now that the SSREIP no longer provides incentives for them.

Standard Offer Contracts

Standard offer rates have remained under \$0.15 / kWh, with the 2014 rate fixed at less than \$0.13 / kWh.²⁴ As a result of standard offer contracts, Vermont has acquired an additional 5 MW of solar-produced electricity per year. This is expected to increase over the coming years due to Vermont Act 170,²⁵ which expanded the Standard Offer Program up to 127.5 MW for in-state renewable energy projects (including other technologies) over the next ten years.²⁶ Even if all of the expected increase in production and purchases takes place, Vermont will not achieve its goal of meeting 20 percent of its electricity needs through the Standard Offer program by 2017. Much of the Standard Offer capacity is solar. Facility developers argue that such projects require a lot of work, and often do not see adequate financial returns. However, with the decreasing cost of installing solar electric systems, the impact of changing rates is less traumatizing to the market.

Renewable Portfolio Standard - RESET Bill

Vermont is currently considering a Renewable Portfolio Standard (RPS) that would generate revenue to support new incentive models. The Vermont General Assembly has not yet determined the solar portion of the standard (*solar carve-out*).²⁷ That determination will influence the market and how it will react to the proposed incentives under the RPS. The scenario modeling for this project will need to make assumptions to address the uncertainty.

Opportunities

Currently, some tax credits will be decreasing and all direct Vermont state incentives will be expiring. National trends indicate that direct incentives are falling out of favor, not necessarily because they have ceased to be useful, but because they compete with other, more critical budgetary priorities. Taken together with lowered installation costs direct PV incentives will be increasingly less attractive to state and utility budgets.

To maintain the current momentum in the marketplace, other incentive structures must quickly and seamlessly replace reduced tax benefits and direct incentives. Different market sectors have different financial needs and abilities to take advantage of advanced incentive structures. Corporate and commercial markets will likely remain on track with tax benefits such as depreciation, the Investment Tax Credit, and third-party ownership models. Residential markets, particularly low- to-moderate income, will likely rely on innovative financing programs that offer interest rate buy-downs and on-bill financing. Credit enhancements should allow low-income

²⁴ *Standard offer rates* refer to the rates an alternative energy supplier—chosen by a customer’s utility—charges. In some jurisdictions, utility customers can choose their own alternative energy supplier and pay the supplier’s rates, which are typically lower than the utility’s chosen standard offer supplier.

²⁵ General Assembly of the State of Vermont, *An Act Relating to the Vermont Energy Act of 2012*, 2012, <http://legislature.vermont.gov/bill/status/2012/S.214> (see act/resolve text).

²⁶ VEPP Inc., “Standard Offer Program,” *Vermont Standard Offer*, accessed December 13, 2016, <http://www.vermontstandardoffer.com/standard-offer-program-summary/>.

²⁷ This information will be supplied in a subsequent draft, once the updated information is confirmed and available on the Vermont.gov website.

consumers and those who are unable to take advantage of the tax credit to purchase solar electric systems or buy into a community / group solar array with a cash-neutral-or-better monthly payment.

Group net metering and community solar opportunities will likely stimulate an uptick in participation from residential markets. Other approaches are:

- State support for a Solarize program²⁸
- Payment for net excess from net metering
- An easy, facilitated process for donating excess net metering credits to nonprofit organizations or low-income consumers, with a charitable donation deduction
- State RPS requirement for distributed generation, or specifically PV (currently part of the State's RESET law)²⁹
- Increasing the Standard Offer program, both in terms of size of systems that can participate and total number of MW. A sliding amount of MW could be put out to bid each year, based on the rate of PV deployed / installed. More MW could be bid if there is a slow rate of deployment.
- Deploy incentives—but not direct subsidies—if they guide customers toward synergistic technologies. Vermont will not reach 90 x 2050 without electric vehicles, for example. How do we create collaborative incentives that support growth in both markets simultaneously?

The Rogers Adoption Curve, shown in **Figure 9** for electric vehicles, pertains to PV, too. If customer acceptance of PV is to move beyond *Innovators*, public awareness and information campaigns will be crucial for overcoming hurdles that relate to general perception and understanding of PV technology. Financially struggling individuals and groups will likely not engage the PV marketplace without a substantial capital or other motivation to do so. Further, with the phase-out of the direct incentives for Vermont, the state lost access to a qualified installer inventory with training verification. Consumer confidence is tied directly to an installer class that is trustworthy and competent.

Highly engaged end users will likely not need further support through direct incentives. However, certain markets could benefit from programs that offer minimal direct incentives. Reducing the need for capital outlay and providing an infrastructure for information and customer support will be essential to addressing barriers for low- to moderate-income individuals and families. Even high-income consumers who can take broad advantage of ever-decreasing tax benefits / credits are in a position to deprioritize renewables in the face of competing interests. In the next 5 to 10 years, Gen Xers and Millennials will have to contend with significant financial burdens and barriers preventing engagement with the solar electric market. Some of these are student loan repayment, decreased rates of home ownership, aging and potentially ailing parents, daycare costs, and high tuition payments for their children. It essential to anticipate consumer needs in

²⁸ Linda Irvine et al., "The Solarize Guidebook: A Community Guide to Collective Purchasing of Residential PV Systems" (National Renewable Energy Laboratory, May 2012), <http://www.nrel.gov/docs/fy12osti/54738.pdf>.

²⁹ General Assembly of the State of Vermont, *H.40*, 2015, 40, <http://legislature.vermont.gov/bill/status/2016/H.40> (see act/resolve text).

order to provide a cost-effective, prescriptive financial product that allows struggling markets engage the solar PV marketplace with ease and assurance of a reasonable return on investment.

Finally, non-traditional incentives such as increased property values for homes with solar PV should also be explored.

Incentive programs have also made it possible to track market data. Supplemental tracking programs will be important to monitor activity toward the achievement of goals, ensuring that forward movement aligns closely to projections, or indicates the need to redirect future resources.

Challenges

Costs

Costs for the programs described above can be difficult to calculate. Target deployment must be initially broken down by sector. Using market data from the SSREIP can develop a direct incentive structure for low- to moderate-income consumers. The expired \$0.25 / W structure, combined with appropriate financing, would support installations for moderate-income customers, whereas broader application of the \$1 / W structure—with additional administrative and financial support from nonprofit, low-income housing organizations—would continue the rise of solar PV ownership by low-income consumers.

Community solar and group net metering offer economies of scale and tax benefits to consumers who would not ordinarily be able to take advantage of financial offsets. However, developers might require further financial incentives to bring the \$ / W down to levels that would engage moderate-income consumers. Direct incentives to this market could cost-effectively raise awareness; further, deployment of this financial structure could be phased out as Vermont moves closer to its targets in five years. Community solar tariffs are more thoroughly explored in the **Topic Brief: Net Metering**.

Scenario Inputs

Incentive inputs are dependent on this project's Phase I modeling of technologies and markets. Incentive inputs will likely be determined in late June or July 2015.

Unmet Needs

The following unmet needs also suggest directions for further work, if Vermont is to achieve its 90 x 2050 goals:

- Further research on costs associated with charitable donations for excess renewable energy credits needs to be conducted. However, too much emphasis on tax credits could negatively affect low- to moderate-income participation, because those taxpayers might not meet the thresholds for taking advantage of such credits.
- Further information and discussion for this group will be how incentives and other market signals' rates might be designed in a way that facilitates system integration of high levels

of solar. It is possible that there will be incentives for systems that are located on target feeders, or which can meet certain performance specifications.

- Expanding the Standard Offer program could be beneficial to commercial installations, particularly if they include community solar projects. Vermont needs further research on costs associated with an expanded program.
- Vermont needs to determine the impact of the proposed RPS.
- To increase solar deployment, the State should consider incentives for PV development within or adjacent to built-up areas that are serviced by a generation facility. This siting suggestion could reduce impacts on natural resources that support and contribute to the continued development of other industries, such as tourism, forestry, and agriculture. They might also contribute ecological services such as maintaining the clean water statewide, providing flood attenuation, and preserving wildlife habitat.

Focus Area Brief: Smart Grid, Demand Management, & Energy Storage

Introduction

The smart grid offers opportunities to integrate improved energy forecasting (with weather, load, and generation factors) with distribution system operations and management. Demand management through distributed customer-level equipment and devices can work with batteries and other forms of storage to enhance the capacity of the grid to support higher saturations of intermittent solar PV generation. The following are attributes of and future considerations for smart grid, demand management, and energy storage:

- The smart grid allows communication and coordination of loads with generation to help manage the localized and system wide variability of PV system supply.
- The smart grid allows standards-based, real-time communication with inverters and generation meters. It also allows communication with responsive loads and storage. (for example, electric vehicles, pre-heating and cooling, peak demand management)
- As battery prices drop, “grid-scale” storage and distributed storage will be part of the smart grid response and capability to coordinate and optimize site and system energy.
- The location of controllable loads and storage, relative to sources of generation, will begin to matter at a certain level of solar penetration. It is important to note that location will not be the driving factor, at first. However, the value of storage and demand response will vary by location, even in the relatively early stages. It is likely the variation in locational value will increase as saturations increase, overall.
- Providing sufficient system status, control, and forecast networks to distributed generation, controllable load, and storage will be challenging. Meeting those challenges will require compromises.
- New rates models and interconnection rules and processes will likely be needed to fully realize the public and private cost savings potential of smart grid and energy storage.
- Smart grid, demand management, and storage can collectively provide insight into costs by location and time of use, to reflect the true cost and value of solar generation.

These items set the context for understanding the current and near-future market responses to the relationship between customer and utility, in scenarios with advanced and refined system integration of solar generation.

Technology and Market Description

The electricity grid is the connections between energy supplies, transmission, and distribution to customer load end uses

- Circuits and transformers have capacity limitations that vary in response to load, supply, weather, and other effects

- Costs are related to the wholesale purchase of power at various time scales, associated investments in system maintenance, and ongoing operation

The smart grid enables communication and automation of the electricity grid

- New sensors and control points are available to utilities
- Networking everything is required
- Standards allow different systems to communicate together, for example:
 - OpenADR for demand response
 - SEP 1.1, SEP 2.0 for consumer connected devices

Sources of data that apply directly to smart grid uses and applications

- ISO-New England, Vermont's regional transmission organization
- Distribution utilities
- Other energy markets
- Weather forecasts
- Equipment and devices directly or through product and service aggregators

Controllable loads / resources

- Energy storage
 - Direct storage in energy “batteries” (electro-chemical batteries)
 - Thermal (ice-making, pre-heating and cooling of space, water, or process fluids and equipment)
 - Pumped hydro – there is little hydropower in Vermont is not run-of-river, what is dispatched is subject to tighter flow regulation, and no new storage hydropower in the state is anticipated
 - Flywheels, compressed air, etc.
- Demand response (DR)
 - Large, traditional DR loads
 - Distributed DR: smart appliances, devices, and equipment
 - Integration: direct to device or through service providers / aggregators
- Electric vehicles
 - Rate and level of charging can be configurable by time, location, and account, to moderate variability and lower costs.
 - Location of charging stations
- PV systems
 - Smart inverters can communicate with the grid to provide diagnostics and support to lower maintenance and operating costs.
 - Smart inverters could provide volt/VAR support and other grid services.
 - “Flicker” due to passing cloud cover drives rapid and significant changes in power production for large systems.

Applications that automate load /resource management

- Utility-driven demand response program management

- Grid-scale storage to manage peak and localized variability
- Customer-driven applications that respond to market prices
- New markets, energy management services that aggregate customer accounts and utility programs, etc.

Incentives / rates that motivate automated controls

- True energy cost information, rate plans, and associated configurable signals between customers and electricity system.

Historical Trends

- Advanced metering infrastructure (AMI)
 - Distribution utilities have been installing AMI networks (smart meters) in Vermont. The state has a 90 percent saturation rate (only small municipal utilities and individual opt-outs use non-AMI)
 - Much of the distribution equipment is also connected
 - Other parts of the country are not as well built out, compared to Vermont.
- Behind the meter
 - Legacy DR load controllers: water heaters, conventional thermostats
 - Smart thermostats and home energy management systems are an area of significant growth
 - Heat pumps need statewide standards, but there is a rapidly growing market for heat pump domestic hot water (DHW) and space conditioning, driven by fuel cost differences, improved equipment performance, and utility incentives and financing (see also **Focus Area Brief: Heat Pumps**)
- Batteries
 - New residential products have seen significant investment and early market traction nationally, but are still at a very low level of penetration
 - Falling cost of generation and storage are at parity with customer utility costs in some locations
 - Note: without rate structures that reflect differences in energy costs over time, the pure economic benefits of storage are negligible or negative for most customers, and market uptake will be driven solely by the benefit of backup during outages
- Section 111(d) of the U.S. Clean Air Act
 - National and regional EPA office support for state compliance with carbon emissions reductions incorporates cost considerations, and flexible approaches to implementation that will likely leverage smart grid, demand management, and other relevant existing policy preferences
 - The state-by-state approach from national leaders in the West and Northeast are likely to exert strong influence on Vermont policy actions, despite the state's relative exemption from current emissions reductions targets; this could drive grid generation and time-of-use impacts associated with supply carbon intensity economics that favor enabling rules for rate structures and storage.

Market Conditions

Opportunities

Growth

The amount of solar PV generation deployed in the high scenario modeled in this study is approximately 1 GW. Assuming a capacity factor of 13 percent, 1 GW of PV would produce approximately 3 GWh / day.³⁰

Key Questions

- Depending on conditions, is it possible to imagine that the full daily capacity must be able to shift, requiring a full 3 GWh of storage?
- Would more than a day be required, to ensure capacity during multiple under-performing days?
- Or is storage required to handle only smaller and more localized fluctuations? In that case, only a fraction of the 3 GWh would be required.

If only 0.3 GWh (or 300 MWh) of storage was required, that would be equivalent to 30,000 of the larger Tesla Powerwall batteries at 10 kWh each. Assuming at-scale installed costs of \$3,500 each, that capacity would cost more than \$100 million. Other sources of storage will have different costs and performance characteristics. So a blended portfolio analysis might be required to consider different battery size and technologies (including electric vehicles). In addition to this analysis, various demand response and thermal storage scenarios might be required. It is possible that existing equipment such as HVAC systems, water treatment systems, and snow-making systems have a considerable amount of storage capacity that requires only advanced controls. This is a significant problem, but it scales well. The scale of demand for storage will depend on saturation levels and percent of solar on feeders. Once suitable communication and management systems are developed, the marginal cost can be quite low in comparison to battery storage.

What additional value propositions do distributed generation and storage provide through enabling smart grid technologies?

Grid power quality and availability can be supported through transactive relationships with individual or aggregated customer equipment directly or through third-party services. In some localized instances, the economic benefit of this grid support role could exceed the marginal value of energy production. These opportunities need to be better understood, and the foundational principles for rates and associated marketplace mechanisms created, to allow for optimal performance of the system as a whole.

³⁰ D. Steward and E. Doris, "The Effect of State Policy Suites on the Development of Solar Markets," Technical Report (Golden, CO: National Renewable Energy Laboratory, November 2014), <http://www.nrel.gov/docs/fy15osti/62506.pdf>.

Technical Advances

Time-of-use rates would significantly help battery technology, since under flat rates for residential and small-business customers there is no incentive to charge and discharge a battery at all, even if the communication and controls existed. The roundtrip efficiency for the Tesla batteries is 92 percent, so ratepayers lose 8 percent on any energy that they provide to the grid, and then replenish their own capacity—whether from renewable energy sources or the grid. Further, there is the amortized cost of the equipment purchase and maintenance, since batteries can withstand only a moderate number of charge cycles in their lifetime. Policy and market advances will enable the technical potential of these technical advances.

Many of the devices and systems that could provide storage and DR capabilities are starting to integrate communication and controls capabilities, as those technologies become more affordable and more mature. Integrating these features into building systems at the time of manufacture allows for both lower cost and more functionality than the add-on solutions available today (such as switching a device to low-power mode, rather than simply cutting power to it entirely).

Challenges

Barriers

Besides the need for dynamic or time-of-use rates, Vermont needs a technology marketplace for the control systems, robust and well-adopted communication standards, and market mechanisms that allow fair prices and efficient transactions. This is potentially a chicken-or-egg challenge, since incentives for the development of both dynamic rates and rate-responsive devices are dependent each on the presence of the other.

Overcoming Barriers

Utilities and regulators can address these in many different ways.

Costs

We will continue to gather estimates for current and future prices of customer sited as well as circuit-level storage and control technologies.

Reducing Costs

Pilots could help determine appropriate models for dynamic rates and could also help build the case with regulators and other stakeholders. Proof-of-concept demonstration projects and incentives might help to build public adoption for storage and DR devices.

Scenario Inputs

	Current accounts / historical data	Reference (business as usual)	Long-range target	Revised SDP
Applicable market segments (add rows as necessary)	Very small (< 1%) of customer behind-the-meter storage and DR controls at residential and commercial scales	Need base case definition for rate models that drive uptake of DR and storage	TBD	TBD
Number of units (and identify the units)				
Total capacity			Economic optima?	
Total annual energy consumption				
Type of growth	NA	Linear		Exponential
Changes in performance characteristics	Not currently cost competitive with very low market presence and grid impact. Existing storage products have become only recently “productized” to enable mass-manufacturing reductions in hard and soft costs.	Coupled to financing packages of residential PV systems, backup and daily-cycle storage systems might grow rapidly; but without changes to rate structure, they will be constrained to backup systems, and to a smaller number of larger commercial customers.		

	Current accounts / historical data	Reference (business as usual)	Long-range target	Revised SDP
Costs	Breakeven capital cost for a reserves-only storage device (\$ / kW) 100 MW mid-ranges between \$1,800 - \$3,000 \$ / kW ³¹	Need projections	Need projections	

Unmet Needs

More Information Needed

Critical:

- Characteristics of existing system costs and constraints related to business-as-usual scenarios.
- Likely range of values for associated grid support services provided by distributed generation, storage, and load management that are enabled by advanced solar deployment.

More information is needed on:

- Grid circuit constraints: Hundreds of distinct parts of the grid have associated costs that could be modeled with a simplified collection of circuit types, possibly reflecting the characteristics of the overall network.
- PV grid interactive effects: Some of the costs and benefits of solar power can be recognized only at spatial and granular scales. To reflect these contributions in the model, these interactions must be better understood through simplifying estimates and analyses.
- Rate structure changes are likely responses to greater system information capabilities and market forces (such as those highlighted by concerns over a “utility death spiral”); ultimately, these rates might drive adoption curves for demand management and energy storage systems at the customer level.

³¹ Denholm et al. Table 5-4, p. 32. “The Value of Energy Storage for Grid Applications” NREL & US DOE Technical Report NREL/TP-6A20-58465, May 2013. <http://www.nrel.gov/docs/fy13osti/58465.pdf>.