Final Technical Report DE-EE0006911 Vermont Solar Pathways
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Recipient:	Vermont Energy Investment Corporation
Address:	128 Lakeside Avenue, Suite 401
	Burlington, VT 05401
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Project Team:	Vermont Energy Investment Corporation
	Regulatory Assistance Project
	Vermont Public Service Department

Contacts:	David Hill, Ph.D. (Principal Investigator)
	Director, Distributed Resources / Policy Fellow
	Phone: 802-540-7734
	Fax: 802-658-1648
	E-mail: Dhill@veic.org
	Damon Lane (Project Manager)
	Lead Analyst
	Phone: 802-540-7722
	Fax: 802-658-1648
	E-mail: Dlane@veic.org

Executive Summary

When this project was proposed in 2014, solar was growing in Vermont, but not as quickly as in Hawai'i, California, New Jersey, or Massachusetts. Only the first two grey dots in **Figure 1** were known.

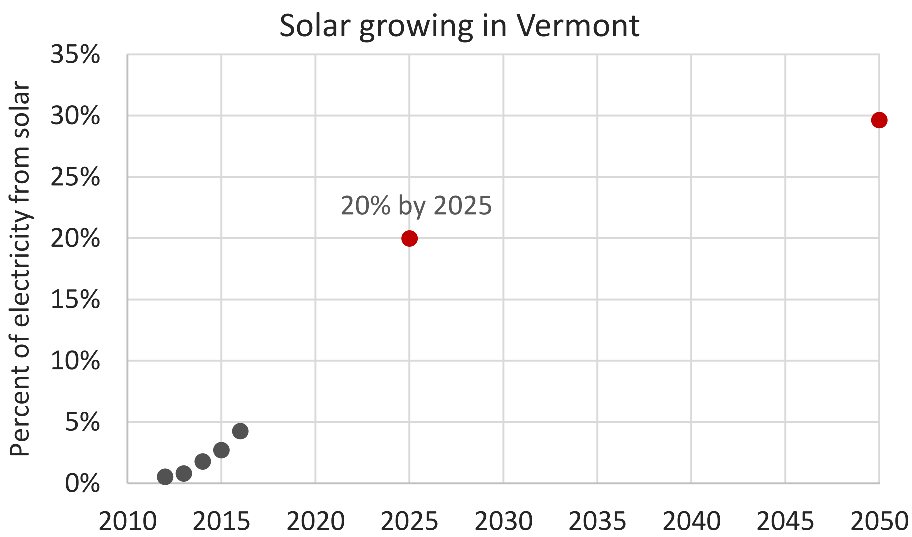

Figure 1. Share of electricity used in Vermont supplied by solar

Solar may not have been seen as worthy of much attention or planning at those levels, and 20 percent by 2025, the goal of this project, seemed optimistic to say the least. Over the course of the project, the stakeholder discussions gained attention, importance, and urgency as installations accelerated. The next three grey dots showed more of an exponential curve that, if extrapolated, could actually land above 20 percent in 2025. The sudden growth in Vermont solar and the effect on the stakeholder discussions show that this project was the right time and scale for Vermont.

Approach

Stakeholder engagement and scenario modeling with the two major methods used in this study. Participants included utilities, regulators, researchers, solar companies, advocates, and citizens and provided input on assumptions and sources, suggested additional scenarios and results formats, and reviewed draft results and text.

Scenario modeling allows for the comparison of different possible futures to a reference scenario and to each other. Rather than the linear process used to estimate cost effective potential, scenario analysis recognizes that society may value a scenario that requires high investment or provides benefits outside the scope of the economic analysis. It also can answer what-if questions that come up throughout the process. The analysis benefited from stakeholder input, while the draft results and graphs were very useful to spur and focus stakeholder discussion.

Findings

Generating 20 percent of the projected electricity consumption in Vermont by 2025 will require an estimated 1,000 MW (1 gigawatt) of installed solar capacity. This represents an increase of over 10 times the capacity installed at the start of this research in 2014. This requires about one tenth of one percent of Vermont's land area. While there is certainly enough room to reach this target, careful siting is important and will be influenced by land use, existing structures and other development, aesthetics, natural and cultural resources, location of energy demand, and proximity and capacity of existing electricity infrastructure.

The planning scenarios presented in this study assume significant in-state investments in solar, energy efficiency, and electrification of transportation and space heating. Compared to the business-as-usual (or "Reference") scenario, the advanced solar scenario that meets the 20 percent target invests $850 million more in efficiency and electrification across 15 years, and an additional $500 million in solar and other renewable generation, and grid infrastructure upgrades. These investments come largely from private entities such as businesses and homeowners installing their own solar systems, as well as rate-based investment through the efficiency utility and electric utilities. These investments help Vermont avoid significant imports of fossil fuels and electricity, saving the state's residents and businesses more than $1.2 billion over 15 years.

The net investments in efficiency and solar in the advanced solar scenarios are only a small fraction of the state's annual energy expenditures. In fact, through 2025, total expenditures in the Reference scenario and in the advanced solar scenario are within 1 percent of each other. Given variability in energy prices, and the minimal cost difference between the two scenarios, the results indicate that it is economically viable – and prudent – for Vermont to invest in a cleaner and a more diverse energy portfolio, highly efficient end uses, and a de-carbonized electric supply.

The research results indicated investments supporting high amounts of solar energy generation in Vermont promise significant future economic return. Extending the analysis through 2050, the investments in solar and efficiency result in almost $8 billion of net savings to Vermont consumers. The advanced solar scenario also reduces greenhouse gas and other emissions, while securing energy resources with less volatile prices, resulting in a more robust and reliable energy system.

Solar is a variable resource, but the electricity grid must meet the demand for power 24 hours a day, under all conditions. Issues such as voltage violations and backflow arise in both the distribution system, which delivers electricity to customers, and at the bulk power system level, which interconnects Vermont to the larger regional power markets. Integrating 1 GW of solar capacity into Vermont's electric grid, which peaks at 1 GW, will require ongoing investment and upgrades to operations and planning systems. Today's technologies and strategies can safely and reliably meet these challenges.

Vermont Solar Market Pathways: Key Findings

SOLAR IS WIDELY AVAILABLE TO HELP MEET VERMONT'S ENERGY NEEDS.
Vermont has sufficient solar resources well-dispersed across the state to meet 20 percent of electricity needs with solar by 2025. Careful planning and siting are important for lower cost and impact. To host enough solar to meet the 2025 target requires about 0.1 percent of Vermont's land area.

MEETING THE VERMONT SOLAR MARKET PATHWAYS TARGET CREATES SIGNIFICANT ECONOMIC BENEFITS.
Through 2025, the total investments and energy expenditures for the Reference (business as usual) scenario and the advanced solar scenario (the solar needed to achieve the advanced solar economy target) vary by less than 1 percent. The advanced solar scenario has higher investments in energy efficiency, solar, and new electric end uses. It also has much lower imports of electricity and fossil fuels. By 2050, the advanced solar scenario is estimated to create $8 billion in net benefits to Vermont compared to outcomes of the Reference scenario.

THE ELECTRIC GRID CAN HANDLE THE INTEGRATION OF HIGHER AMOUNTS OF SOLAR GENERATION.
To meet the target, Vermont must integrate 1 GW of solar capacity into Vermont's electric grid (which currently peaks at 1 GW). This will require more planning, investment, and upgrades to hardware and operations systems. Technologies and strategies available today can safely and reliably meet these challenges. Many initiatives, collaborations, and new business approaches in Vermont and elsewhere will help the state meet these challenges.

SOLAR CAN HELP LOW- AND MODERATE-INCOME HOUSEHOLDS AFFORD ENERGY.
Great opportunity exists for projects that combine solar and efficiency in increasing energy affordability for low- and moderate-income households. Applying social and energy justice in every project is critical for VEIC. Vermont already has business models, financial strategies, and philanthropic initiatives to support this segment of market growth.

SOLAR INTERACTS WELL WITH OTHER ENERGY TECHNOLOGIES AND EMERGING MARKETS.
Solar and energy efficiency are the most common examples of distributed energy resources (DERs). DERs can also be energy storage, electric load shaping, and demand response. DERs are reshaping energy markets and delivery infrastructure in Vermont and elsewhere. Technical and market advances in Vermont are making electrification of vehicles and space conditioning more attractive. As they accelerate, they will help drive the growth of solar energy, and be driven by it.

THE VERMONT SOLAR PATHWAYS TARGET WILL HELP THE STATE MEET ENERGY, ENVIRONMENTAL, AND OTHER POLICY GOALS.
Vermont has policy targets for meeting 90 percent of the state's total energy needs with renewable resources by 2050 ("90 x 2050"). Vermont Solar Pathways indicates solar is an important contributor for meeting this target in economically and socially equitable ways. Moreover, installing solar energy in Vermont keeps energy expenditures in the state, and reduces dependence on imported fuels. These economic benefits are consistent with Vermont's policy objectives and public opinion. Meeting these targets offers opportunities for Vermont's utilities and businesses to continuously improve and to innovate—and positions them to influence energy markets outside the state.

Contents

1. Background

1.1 SunShot Objectives.

This project was one of 15 receiving U.S. Department of Energy (DOE) Solar Market Pathways Program support, within DOE's Solar Energy Technologies Office. The SunShot goal was to reduce the levelized cost of solar energy systems to $.06 per kWh by 2020. As of the halfway point in the timeline for achieving this goal, SunShot officials estimated that approximately 70 percent of this goal had been met. Since SunShot's launch in 2011, the average price per kWh of energy from a utility-scale photovoltaic (PV) project dropped from about $0.21 to $0.11.

A major goal of the Solar Market Pathways Program was to make solar deployment faster, easier, and less expensive than it was in 2011, across the United States. The case studies and lessons learned from the 15 awarded Solar Market Pathways projects provides examples that can be replicated in other jurisdictions—in support of this goal.

1.2 Vermont Solar Market Pathways Objectives

The essential objective of this Vermont Solar Market Pathways project was to examine what is required to attain 20 percent solar generation by 2025, and what the effects of a transition to such an advanced solar economy would be.

Comprehensive solar planning can contribute to lower solar costs through specific mechanisms. By taking a long-term planning perspective and integrating the growth of the solar market into the state's overall energy economy, Vermont Solar Market Pathways helped policy makers, local planning commissions, and the market understand both the potential and the potential barriers to an advanced solar market. This understanding will improve the chances for sustained market growth and investment.

Comprehensive solar strategies and plans can provide greater certainty to businesses, institutions, and utilities investing in solar. This certainty is expected to help lower the soft costs associated with solar energy. By sharing experience and approaches to identifying and addressing barriers to achieving high levels of solar, plans such as this one will also help lower the costs of addressing these barriers.

Moreover, Vermont Solar Market Pathways supported regional planning, public discourse, and decision making on increasing the use of solar energy by individuals and businesses.

1.3 Vermont Background

Strong Policy Supports an Advanced Solar Economy

The Vermont Department of Public Service undertook its *Total Energy Study* (TES) in 2014, publishing the results in December of that year. Its primary conclusion was that "Vermont can achieve its greenhouse gas emission reduction goals and its renewable energy goals; to do so will require significant changes in energy policy, fuel supply, infrastructure, and technology." [1]

In 2015, the Vermont General Assembly passed the state's first renewable portfolio standard, known as the Renewable Energy Standard (Act 56), which encouraged increases in renewable energy supply as a way to reduce total energy use and costs.[2] The Renewable Energy Standard does not contain a carve-out for solar credit. Because of this, the Standard did not create solar renewable energy certificates (SRECs), a common mechanism for advancing accompanying renewable portfolio standards. Nevertheless, the Standard requires 10 percent of electricity to come from distributed generation; we expect solar to provide most of that requirement. Vermont's Renewable Energy Standard was unique in compelling distribution utilities to support the reduction of fossil fuel consumption through actions like weatherization, thermal efficiency measures, and electrification of energy uses traditionally powered by fossil fuels such as heat pumps and electric vehicles.

Vermont's Demographics

Vermont has a small population (626,000 inhabitants), occupying 326,000 housing units, most of which (71 percent) are owner-occupied housing units—primarily single-family houses.[3] Excepting Burlington area, the U.S. Department of Agriculture considers the state's population to be rural. Winters are relatively long, and energy burden is a challenge for many Vermont households. The median Vermont household income is $54,000, only slightly higher than the national average of $53,000.[4] Nevertheless, with a state goal of meeting 90 percent of total energy needs from renewable sources by 2050 (90 x 2050), Vermont policy makers have an advanced vision for achieving energy security and environmental benefits for its inhabitants.

Over 130 MW of net metered solar supplies energy to homes, farms, businesses, and communities.[5] Further, the presence of renewable energy in the supply mix has kept electricity costs at or below the rate of inflation.[6]

The Vermont Department of Public Service estimates that nearly 5 percent of Vermont's workforce (16,000 jobs) is in the clean energy sector.[7]

A Recent History of Energy Supply and Use in Vermont

Vermont has a single transmission system operated by the Vermont Electric Power Company (VELCO). Seventeen local distribution utilities (municipalities, rural electric cooperatives, and an investor-owned utility) provide retail service.

Prior to 2000, all of Vermont's electric utilities (at the time there were 22) delivered energy efficiency programs to their customers. This well-intended policy had consequences, because investor-owned utilities were caught in a conundrum: To ensure good returns for their shareholders, they needed to sell more electricity; but to ensure compliance with regulators, they needed to promote investments that would reduce electricity sales. Further, energy efficiency program administration was difficult to accomplish effectively for the customers of each of the 22 utilities. Accurate accounting for each utility's contribution to saving energy via retail sales of energy-efficient products in their service territories was also elusive. That is, a store in one utility's location could easily have customers from other utilities buying and installing products—giving the other utilities no information to support a claim to regulators for energy savings.

The Vermont General Assembly created a new entity in 2000, a statewide energy efficiency utility (EEU) for all territory outside the City of Burlington (which maintains its own EEU through the Burlington Electric Department (BED)). The Vermont Energy Investment Corporation (VEIC) has operated the statewide entity, known as Efficiency Vermont, ever since. A 12-year Order of Appointment began in 2010, replacing the earlier 3-year contract cycles, and allows for better planning, greater stability in program offerings, and more strategies for achieving more clean-energy potential than was possible under the shorter cycles.

Throughout Efficiency Vermont's tenure as the statewide EEU, avoided costs of energy supply have been an essential metric in demonstrating the efficacy of energy efficiency. Helping customers use less electricity—through efficient products and appliances, air-sealing and insulation of houses and other buildings, improvements in commercial building energy performance, and many other measures—has a lower average levelized cost than all other new power supply options.[8]

Sustainable energy advisors frequently refer to "efficiency first, then renewables" as a smart path for customers who want to lower their energy costs and carbon footprints. With such a strong and lengthy background in statewide electrical energy efficiency, Vermont has been well positioned to advance its renewable energy economy.

The growth of renewable energy is accelerating: As of late July 2016, 412 MW of wind and solar capacity were online or permitted—of which 70 percent is from solar. Net metering of solar energy to local utilities and the grid has seen a 25 percent increase. It accounts for 167 MW of solar, compared to 134 MW at the end of 2015.[9] These data signal not only a net increase in renewably supplied energy, but also a disproportionately large jump in energy supply from solar sources.

Figure 2 illustrates the rapid growth of solar and under the different funding sources. This market expansion has been propelled by liberal policy toward group net metering; simple permitting; and strong financial performance from a regulated, solar credit on utility bills for net metered generation; and the feed-in tariff.

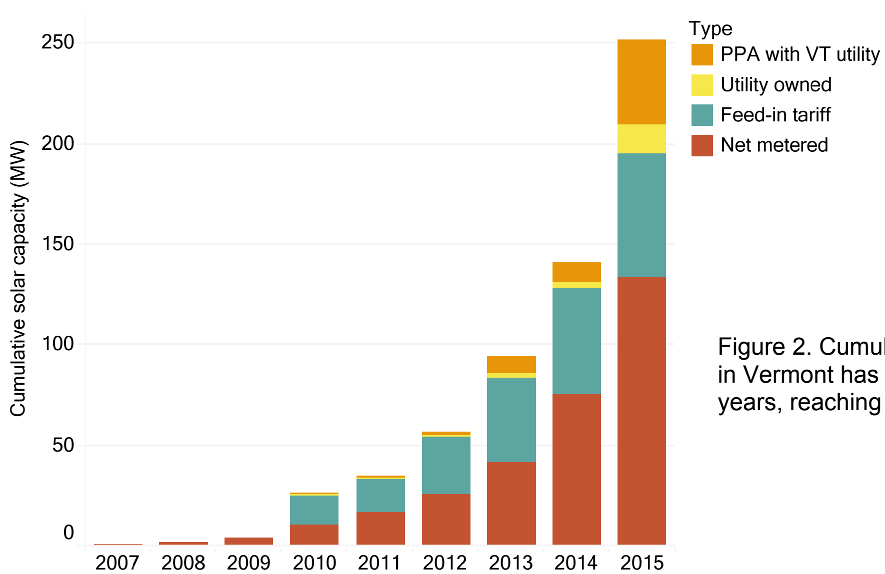

Figure 2. Cumulative permitted solar capacity in Vermont has grown quickly in the last five years, reaching 251 MW by the end of 2015.

Vermont has put a priority on environmental stewardship and energy self-sufficiency for decades. The political decision to quickly transition to an energy mix dominated by renewables is just one of the latest events in a long history of progressive policy decisions on energy. Some highlights of this ongoing effort:

- Land use planning regulation (Act 250, passed in 1970).
- Community-level incentives and technical assistance for revitalization of downtowns (Downtown Designation, administered by the Agency of Commerce and Community Development).
- Statewide EEU concept created via legislation in 1999 (see the beginning of this section).
- Small Scale Renewable Energy Incentive Program (2003) offered upfront rebates for residential, small commercial, and non-profit installations. The administration of this program ceased for most systems at the end of 2014.
- Greenhouse gas reduction goals set in 2005: 25 percent by 2012, 50 percent by 2028, 75 percent by 2050, compared to 1990 baseline (Vermont did not meet the 2012 goal. Actual emissions were very similar to 1990, not 25 percent below).[10]
- Sustainably Priced Energy Enterprise Development (SPEED, 2005) feed-in tariff for new utility scale renewable energy projects.
- Streamlined solar registration provided a permit in 10 days for small systems.
- A solar adder, a credit on electric bills for each kWh a solar installation produces, began to pay 19 to 20 cents per kWh for net-metered solar generation.
- In 2011, the Vermont Department of Public Service set a 90 percent renewable total energy target by 2050.
- Standard Offer annual auctions replaced SPEED for new utility scale renewable energy projects (2012).
- *Total Energy Study* (Department of Public Service, 2014) considered paths and viability of 90 x 2050 target.
- Act 56 (2015) established a renewable portfolio standard: energy supply from renewables must be at least 55 percent by 2017, 75 percent by 2032.

Vermont is capitalizing on this foundation to transition away from the use of imported fossil fuels to locally owned renewable energy for electricity, transportation, and thermal needs. The state's consumption and generation is small compared to its neighbors, consuming 4 percent of the electricity on the New England grid, and using less than 1 percent of Hydro Québec capacity.

Vermont could rely on imported electricity, or use these neighboring resources to balance in-state renewables. However, many Vermonters are unwilling to export the impact of their energy use and want to model local sustainability, with a high penetration of renewables, balanced and managed with the state's own resources.

Fast growth of wind and solar power drew opposition in the early 2010s. The General Assembly responded with a Siting Task Force. The State also funded the Regional Planning Commissions to account for energy in their regional plans. This can help site renewable energy projects where locals want them, because it gives towns a voice in Vermont's permitting process if they create town energy plans that help support the state's renewable energy goals.

The changes that have occurred since the inception of this Solar Market Pathways project in late 2014 show how quickly Vermont is moving toward achieving these targets:

- The General Assembly raised the cap for net-metered renewable capacity from 4 percent to 15 percent of the connected utility's peak load, in 2014.
- Later in 2014, Burlington Electric Department, the state's third-largest utility and operating its own EEU, acquired a 7.4 MW hydropower station to complete its efforts to supply 100 percent of its energy from renewable sources.
- In June 2015, the General Assembly passed a renewable portfolio standard that allows credit for reducing fossil fuel use in building and transportation sectors, and is among the most aggressive policies in the United States.[11] It requires 75 percent of electricity to come from renewable sources by 2032.
- In November 2015, Green Mountain Power (GMP), an investor-owned utility (IOU) serving 71 percent of the state's utility accounts, reached the net metering cap, 15 percent of peak. It decided to continue to allow small systems to interconnect, as well as 7.5 MW of strategically located larger systems. The utility created a map to guide new solar projects to areas of the grid that have ample capacity to accept it.[12]
- By the close of 2015, Vermont Electric Cooperative (VEC; the second-largest utility), Washington Electric Cooperative (WEC; the fourth-largest utility), and three smaller municipal utilities reached, or were approaching the 15 percent net metering cap.
- In August 2016, The Public Service Board issued new net metering rules that removed the program cap, added incentives for preferred siting and REC treatment, and slightly lowered the total incentive most systems would get.[13]

1.4 Implications for Broader Applicability

Vermont is ahead of the curve in becoming an advanced solar economy. Because it is a small state and operates—even at the policy level—on a community scale, issues that arise as solar saturation increases are frequently addressed quickly and with well-informed deliberations. The State and its stakeholders typically seek options for mitigating issues relating to net metering or siting, for example. The state also enjoys good working relationships among the utilities, and has explored many different approaches for modifying rate structures and incentives. For example, regulators, the statewide energy efficiency utility, and distribution utilities, are discussing concepts around distributed energy resources (DERs) and fuel switching under Tier III of the new Renewable Energy Standard.[14]

The approach in this report was to use scenario analyses to help provide a framework for stakeholders to examine options and implications for alternative pathways towards becoming an advanced solar economy. This approach, the structure of the analyses, and the process of stakeholder engagement are all exportable to support solar market growth in other markets and jurisdictions.

1.5 Structure of the Report

The final Vermont Solar Market Pathways document was released in December 2016 (with a condensed version for the public). There are four volumes:

Volume 1: Summary Report. Objectives, background, approach, high-level findings, and strategies for becoming an advanced solar economy. This Final Technical Report is based on the Summary Report.

Volume 2: Net Metering Brief and Focus Area Briefs. Narrative and analysis on key market segments and strategies related to solar market growth: net metering and alternatives; electric vehicles; heat pumps; storage, load shifting, and demand response; high-performance manufactured housing; and incentives. This volume also contains a broad analysis of pathways to an advanced solar economy, submitted as a Phase II Roadmap for the Smart Electric Power Alliance (SEPA) 51st State initiative.[15]

Volume 3: Barriers and Integration Brief. Investigation and analysis of technical, market, and policy barriers and strategies. Analysis of distribution and bulk power system implications for high-saturation solar.

Volume 4: Methods and Detail Tables. Methodology, assumptions, and results from scenario modeling, using the Long Range Energy Alternatives Planning System and other tools.

Several of the projects tasks, as specified in the Statement of Project Objectives, were related to the preparation of the Vermont Solar Pathways Plan. They are listed below with their dates of completion and where their content appears in this report.

Task 2: Conduct Net Metering Analysis & Task 3: Conduct Strategic Focus Area Analysis

These analyses were documented in briefs that became Volume 2, published June 2015. Content from the briefs was included in this report in Sections 3, 4, and 5.

Task 4: Integrate and Identify Barriers

In this task, completed September 2015, the results of the previous tasks were brought to together for a comprehensive consideration of what issues this level of growth in solar and electrification could cause. These potential barriers were documented in Volume 3. Relevant content is included in this report in Section 4.

Task 8: Build Consensus and Articulate Outcomes

In September 2016, the project team held two stakeholder meetings to discuss the draft report and gather feedback for the final report.

2. Introduction

The general approach for this study is the investigation of the implications of becoming an "advanced solar economy" within the context of the total energy system. We began by defining, and then refining, various scenarios where solar could provide 20 percent of electric consumption, our definition of an advanced solar economy. With stakeholder review and feedback, we then used those scenarios to investigate the implications across technical, economic, regulatory sectors, and business models. Undoubtedly, transitioning to an advanced solar economy will require shifts for consumers, utilities, solar companies, and other businesses. Transitioning will create those shifts, too. The transition will also require and create shifts for regulators and policy makers. The point is not to predict or define each of shift, but to use the scenario modeling and the ensuing discussions to encourage dialogue and innovation.

Task 1: Design Initial Scenarios and Convene a Stakeholder Group

This section of the report describes the stakeholder engagement and scenario modeling approach, which started with Task 1, completed by May 2015.

2.1 Stakeholder Engagement

The project was defined by and benefited greatly from an active, non-binding stakeholder engagement process. This process informed the creation of the Reference scenario, the advanced solar scenario, revisions to those scenarios, and alternative solar scenarios. The Team conducted 11 stakeholder meetings, with participants from Vermont distribution utilities, the transmission operator, public service regulators, state agencies (economic development, transportation, agriculture, and natural resources), the statewide energy efficiency utility, solar vendors, environmental activists, the Vermont Law School, and universities and colleges with active environment and energy programs. (See the **Stakeholder List** at the end of this document).

The original list of invited participants contained more than 100 names, and grew to over 150 through referrals and forwarded invitations. Meeting attendance varied; on average, 18 stakeholders attended each meeting. The Team also invited stakeholders to comment on documents and modeling results as they became available.

Figure 3. Second stakeholder meeting, April 2015 in Rutland.

Over 100 individuals attended a meeting, provided written comments, or otherwise participated in the project. By starting the modeling and stakeholder engagement at that same time, the Project Team involved the stakeholders in each step of the modeling. Providing stakeholders with a model that needs help is better for engagement than providing one that appears to be final. Stakeholders felt like they could influence and help build the model, and dozens of their corrections and suggestions were in it. Participating in building the model and reviewing documents helped the stakeholders feel buy-in to the project. The Project Team showed that it appreciated this input by being open to it at the time it is received, taking a moment in the next meeting to thank a participant for their comment in the previous meeting, and showing how the comment was addressed. The strong stakeholder participation and buy-in appears to result from a combination of their existing relationships and the Project Team's efforts to design and execute an engaging process.

The stakeholder process was successful because of the Project Team's deliberate approach, openness to input, follow through, and two factors somewhat external to the project: First, Many of individual stakeholders already had working relationships through other venues and had specific experience working together on thorny issues without a clear path to solutions or under unclear jurisdictions in the Vermont System Planning Committee (VSPC).16 In 2017, the VSPC celebrated 10 years of being a "statewide collaborative process for addressing electric grid reliability planning."

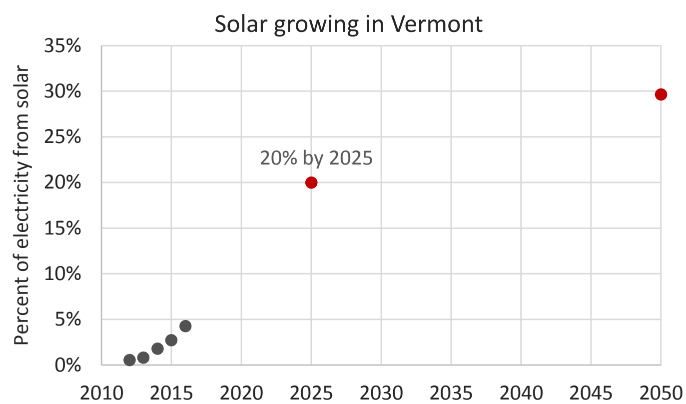

Figure 4. Share of electricity used in Vermont supplied by solar.

The second factor is the quick growth of solar during the study. When the project was proposed in 2014, solar was growing in Vermont, but not as quickly as in Hawai'i, California, New Jersey, or Massachusetts. Only the first two grey dots in **Figure 1** were known.

Solar may not have been seen as worthy of much attention or planning at those levels, and 20 percent by 2025, the goal of this project, seemed optimistic. Over the course of the project, the stakeholder discussions gained attention, importance, and urgency as installations accelerated. The next three grey dots showed more of an exponential curve that, if extrapolated, could actually land above 20 percent in 2025.

The utilities were struggling to keep up with interconnection requests and while they knew they needed to plan for 2025, they did not have the time. The project became a resource for some of that planning, answering specific questions, creating new scenarios, or presenting data in different formats in direct response to their questions and feedback. The sudden growth in Vermont solar and the effect on the stakeholder discussions show that this project was the right time and scale for Vermont.

2.2 Scenario Modeling

LEAP, the Long-range Energy Alternatives Planning System, is energy policy analysis software developed at the Stockholm Environment Institute (SEI). LEAP offers a framework for energy supply and demand accounting, enabling users to work with existing data sets to construct and compare future energy scenarios. Its flexible energy accounting capabilities help create models of different energy systems and scenarios. It is demand driven: The user models energy consumption within the system before adding supply, which is matched to the demand. Users can examine graphic and tabular results on energy flows, costs, and environmental impacts and modify them at multiple levels from end use devices, building types, sectors, to the total area demand by fuel.

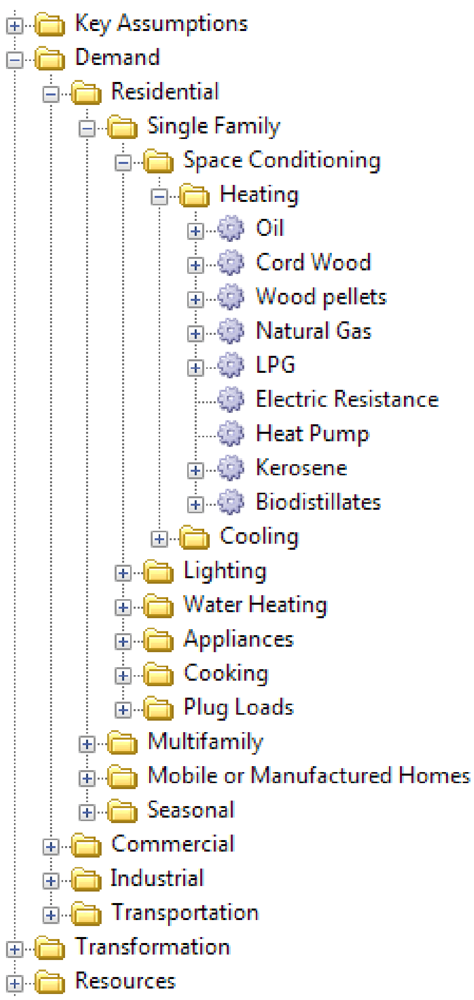

Figure 5. Sample demand tree structure in the LEAP system.

SEI have refined LEAP for more than 20 years. It has been used to conduct integrated energy and environmental planning in more than 190 countries (further LEAP modeling information is in **Volume 4** of the report).[17] LEAP modeling typically begins with the development of a demand tree that represents energy demand across various devices, end uses, subsectors, and sectors. **Figure 5** offers an example of a demand tree structure. The Team used recent data to create "current accounts," which then became the basis for forecast changes in the Reference and alternative solar scenarios.

The Team entered current and projected energy use in the demand tree, across all of its branches, to calculate the energy demand by fuel type and sectors. Examples of the type of embedded and analyzed information within the structure are: projected changes in energy efficiency for end use devices, the demand for specific end uses, and shifts between different devices for a specific end use (for example, greater use of electric or plug-in hybrid vehicles). The structure also reflects fundamental demographic and economic levels as activity drivers; examples are population, household size, commercial building area, and vehicle miles traveled.

Once the demand for various types of energy is determined, LEAP calculates the necessary resources to meet that demand, and including factors such as transmission losses. For electricity, the time of demand and available supply also comes into play. **Figure 6** shows how resources at the left move through one or more transitions to serve end uses at the right. This Sankey diagram shows only the energy that ends up being used. There are losses at each step that add up to more than half of the original resources in most fossil fuel economies.

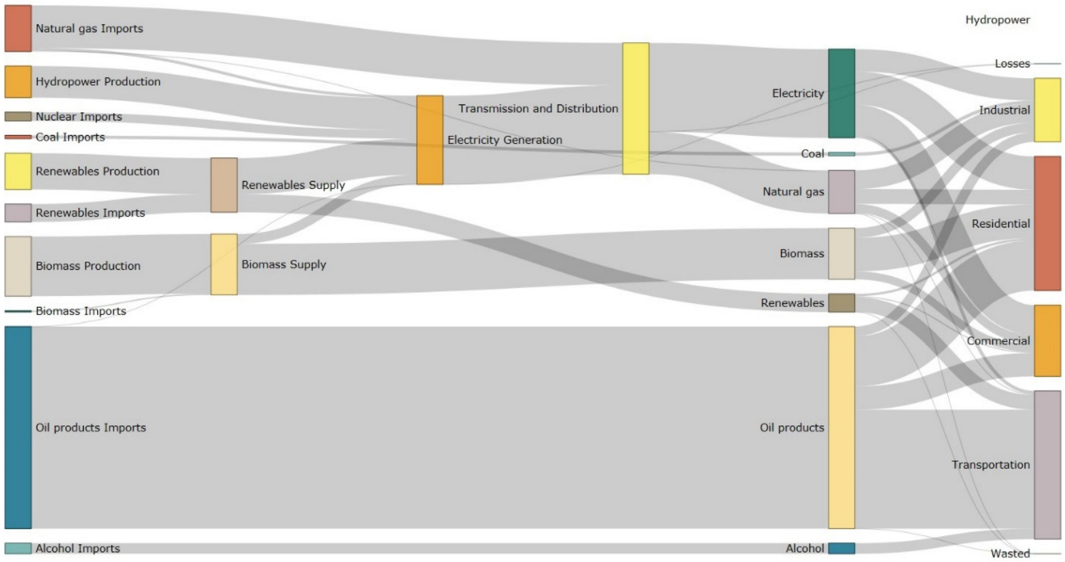

Figure 6. A Sankey diagram representation of how LEAP uses energy resources to meet total energy demand.

The Team drew historic information primarily from the Public Service Department's *Utility Facts 2013* [18] and U.S. Energy Information Administration (EIA) data to fill in the demand tree. The Team used projections from the Department's TES, the utilities' committed supply from their Integrated Resource Plans, and stakeholder input.

Demand Drivers

Each sector has a unit that measures activity in the sector. That unit is the "demand driver." LEAP multiplies it by the energy intensity of the activity to calculate energy demand.

The population is assumed to grow at 0.35 percent per year.[19] The number of people per household is assumed to decrease from 2.4 in 2010 to 2.17 in 2050.[20] These assumptions combine to give the number of households, the model's basic unit for **residential energy consumption.**

The Team based the projected change in the **energy demand from the commercial sector** on data in the TES. The demand driver for the commercial sector is commercial building square feet.

The Team entered total **industrial consumption** by fuel directly from the TES into the model.

Transportation energy use is based on vehicle miles traveled (VMT). This metric has risen throughout most of American history.[21] In Vermont however, VMT peaked in 2006 and has since declined slightly.[22] Given this trend, and Vermont's efforts to concentrate land development and to support alternatives to single-occupancy vehicles, VMT is assumed in the model to remain flat, while population and economic activity grow slightly.

The Team based **electricity supply** on the TES,[23] the utilities' Committed Supply, and other necessary sources to meet the demand projected in the model and the 90 x 2050 goal, and to supply 20 percent of annual electricity from solar. The Department provided the data from selected Integrated Resource Plans filed by Vermont distribution utilities for the "Committed Resources" graph on page E.7 of *Utility Facts 2013.*[24]

2.3 Scenarios

Table 1 summarizes the scenarios definitions and major sources. The Advanced solar is further refined into Low Net Metering and Delayed Deployment versions.

Table 1. Scenarios for the Vermont Solar Market Pathways, with major data sources, and showing the progression from current accounts to the advanced solar scenario

Scenario	Represents	Data sources
Current accounts	Description of current energy supply and demand balance. Historic information is from 2010-2015 depending on available data. Basis for all other scenarios.	*Utility Facts 2013*, EIA, *Vermont Residential Fuel Study,* device-specific data from various sources
Reference	Business as usual. Involves expected baseline levels of energy efficiency such as continued Efficiency Vermont operations and improvements in vehicle efficiency through Federal Standards. Renewable generation and natural gas growth continues.	*Total Energy Study* BAU scenario
90 x 2050_{VEIC}	Meeting the 90 x 2050 target. Based on the economic modeling done for the TES.	Adapted from *Total Energy Study* TREES Local scenarios
Advanced solar[25]	Reaches the 20% of generation target by 2025 and also the 90 x 2050 goals for 2050	Based on 90 x 2050: Demand is the same, supply is shifted toward solar

The **Reference scenario** contains energy use values and assumptions as they are today, but it assumes increases in vehicle efficiency, because of Corporate Average Fuel Economy (CAFE) standards,[26] and some increased use of natural gas—which, although a cleaner fuel to burn, is still a fossil fuel. The Reference scenario is based on the business-as-usual (BAU) scenario of the Vermont TES. The Vermont Solar Pathways Team revised the model to reflect less growth in natural gas use after the cancelation of the planned second phase of a pipeline project.

The **90 x 2050_{VEIC} scenario** has stronger efficiency, quicker fuel switching, and accelerated renewable energy adoption to achieve the State's goal of meeting 90 percent of total energy needs with renewable sources by 2050. This scenario is based on the TES Total Renewable Energy and Efficiency Standard (TREES; local energy) scenario.[27] The TREES Local scenarios consist of two pricing outcomes, one that assumes a high cost of biomass and biofuels, and one that assumes a low cost. These scenarios test policies requiring all Vermont energy distributors to source an escalating percentage of their supply from in state, Vermont renewables or energy efficiency resources. The 90 x 2050_{VEIC} scenario combines the high and low biomass cost versions of TREES Local.

The Team created **advanced solar scenario** for this project to meet the goal to supply 20 percent of annual electric generation from solar by 2025. The demand side is exactly the same as that of the 90 x 2050_{VEIC} scenario, but the supply side shifts more toward solar, and away from imported hydropower and wind.

The initial draft of this scenario was part of Task 1 and was completed May 2015. Presenting the draft inputs and results to various audiences elicited feedback from participants who collectively offered many different perspectives. The stakeholders undertook detailed reviews of the scenarios, which led to many improvements to the model. The Team presented the results and model in the following ways:

- Webinar for the U.S. Department of Energy, SunShot systems integration, June 2015
- Regional Planning Commissions (RPCs) webinar, June 2015
- Bennington RPC, July 2015
- American Solar Energy Society "Solar 2015" conference, July 2015
- Stakeholder meetings, May and October 2015
- Northwest Regional Planning Commission, October 2015

Task 5: Revise Scenarios and Determine Priority Issues and Analysis for Budget Period 2 (calendar year 2016)

Based on feedback on the initial scenario models, and the additional information, context, and focus from tasks 2, 3, and 4, the team revised the scenario models by December 2015. The results did not change radically but the model became more accurate, flexible, and robust:

- Added hourly production data for solar, wind, and hydro to the dispatch model.
- Smoothed forecasted changes in consumption to avoid unrealistic step changes.
- Aligned heat pump efficiency projections with updated, more aggressive estimates.
- Reduced the assumed number of homes using natural gas.
- Made small changes to residential shell and heating equipment efficiency expectations, to more closely align with TES consumption projections.
- Changed the transportation model from top-down to bottom-up, which allowed the team to use stronger and more detailed assumptions.

These changes were the basis for a revised advanced solar scenario, a high solar model that the Team has continually refined. A significant issue came up from using more data with greater temporal detail. The Team used the LEAP model to dispatch electricity to meet the demand in the first version of the model. Although it contains many detailed data, and can concurrently calculate several regions and scenarios, the model cannot handle high levels of temporal detail. The Team sought greater detail about the times of over-generation and unmet need, so that it could investigate load shifting, curtailment, storage, and electricity trading. To address the temporal data limit in the LEAP model, the team created a script that uses simple logic to "dispatch" generation for each hour of the year, giving the Team a chance to model 8,760 (hourly) time slices—365 times more than LEAP was using.

Additional scenarios. The advanced solar scenario is one way to reach 20 percent solar penetration by 2025, just as the 90 x 2050_{VEIC} scenario is one way to meet Vermont's 90 percent total energy from renewables goal by 2050. The Team encouraged stakeholders to suggest alternatives that would be worthy of investigation. Stakeholders suggested the following:

- **Low Net Metering:** assume a higher share of utility scale solar for lower costs
- **Delayed Solar Deployment:** wait for solar to get cheaper to install so much
- **Act 56, the Renewable Energy Standard:** show growth in all types of renewables as required by the new law
- **Poor Siting:** how much more would grid integration cost without good siting?

The Project Team created the first two and shared results for them; the latter two were discussed at stakeholder meeting, but not modeled.

2.4 Costs

The Project Team added costs to the model to estimate the investment required to transform the energy system and to estimate the resulting change in annual energy spending. Each part of the model has a cost: efficiency in all sectors of the demand side, new generation that is added during the model timeframe, grid upgrades to host high-penetration renewables, and the cost of fuel used directly or in power plants. The sources and assumptions for cost projections are:

- The Team estimated costs from Vermont-specific data if available, and the best regional or federal estimates otherwise.
- Initial solar costs are from the 2016 *Vermont Solar Cost Study* by the Clean Energy States Alliance (CESA).[28]
- Future solar costs use that baseline and decrease according to a profile VEIC previously developed using national trends. These results are shown in **Figure 7**.

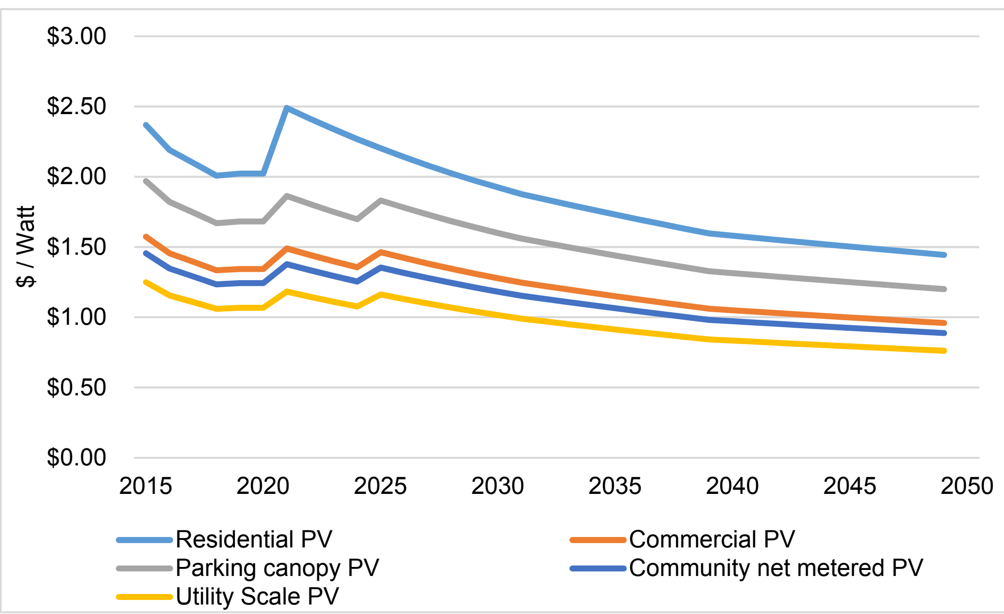

Figure 7. Projected future after-tax installed cost of solar PV in Vermont. Assumes the Investment Tax Credit fully expires in 2025.

- The Team derived efficiency costs from the 2013-2014 Vermont Demand Resources Proceeding, as approved by the Vermont Public Service Board.
- Fuel costs, delivery costs, and capital costs for energy generation and supply reflect costs estimated by Open Energy Information (OpenEI), EIA, CESA, the National Renewable Energy Laboratory (NREL), and the DOE's *Clean Cities Alternative Fuel Price Report.*

Details of cost sources and other assumptions were presented in **Volume 4.**

3. Project Results and Discussion

This section discussed the primary results from the Team's work to date. For greater detail on the input and scenario results, see **Volume 4**.

3.1 Changes in Energy Use and Supply

Energy efficiency is a key resource for meeting the high renewable energy goals. In each of the high renewable scenarios (90 x 2050_{VEIC} and the advanced solar scenarios) consumption declined through 2050. Vermont has mature energy efficiency programs, so the Team assumed baseline energy efficiency in the Reference scenario as well. The Team projected growth in population and commercial space as a base assumption, but total energy consumed declines in all scenarios. This efficiency comes from many places, including home weatherization, national automotive efficiency standards, and—most significantly—electrification of heating and transportation. As explained in Vermont's 2016 Comprehensive Energy Plan, "heat pump and electric vehicle technology is capable of supplying the same level of energy service as its combustion-based counterparts, with a third or less of the site energy requirements." The impacts of electrification and the extent of efficiency improvements are detailed below. These savings reduce total energy consumption by roughly 10 percent by 2025, and 40 percent by 2050, compared to 2010.

Efficiency Is a Key Resource in All Scenarios

Figure 8 shows the results of efficiency across all sectors of the economy. The costs and savings for efficiency improvements in the building sectors are based on historical experience with Vermont's efficiency efforts, and are consistent with projections from the State's forecasting Demand Resources Plan and its Comprehensive Energy Plan targets. The costs for these savings represent a significant investment by Vermont in more efficient buildings, equipment, and vehicles, amounting to approximately 1 percent of annual energy spending.

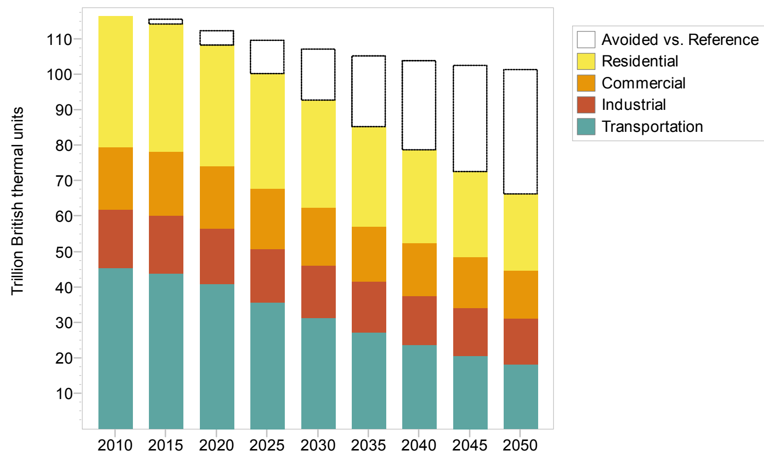

Figure 8. Vermont site energy demand, by 5-year increments, and by market sectors, showing the effect of more aggressive efficiency and fuel switching in the Advanced solar scenario, compared to the Reference scenario.

The benefits include avoided energy resource costs, mostly from imported fuels, with a present value through 2025 of more than $1.2 billion. Across time, the long-lasting investments in efficiency result in significant positive net benefits.

Strategic Electrification – Heat Pumps

Heat pumps use electricity to move heat. There are many variations of the technology, but the attention here is on air source heat pumps that use energy in outdoor air to provide space heating and cooling. Heat pump water heaters work in a similar way and are another product that is contributing to growth in "smart" electrification in Vermont.

Heat pumps are least efficient when outdoor temperatures are very high or low, so they pose a challenge for utilities by potentially increasing demand during peak periods. Currently in Vermont, summer peak typically causes the most concern to utilities. However, there are areas that experience winter peak concerns. With additional solar, utilities are seeing many localized summer peaks shift from afternoon to after sunset. There are also circuits where solar is causing the peak to shift from summer to winter. Both equipment controls and solar supply can help lower the summer peak, though storage or other means are necessary to deal with peak demand after sunset. Winter peak issues can be addressed with controls that pre-heat during time of solar output or shift heating to existing fossil systems during peak conditions.

Heat Pump Market Conditions. Vermonters generally are enthusiastic about heat pumps for displacing fossil fuel heating, as shown in Efficiency Vermont and GMP data:

- The most common search term on www.efficiencyvermont.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 and are waiting for Efficiency Vermont to launch a heat pump program.
- Customer support staff for 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 accepting calls because it could not satisfy the high volume of requests.

Technical Advances. Cold-climate heat pumps are advancing quickly in the marketplace. 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 area of research. In Vermont, heat from heat pumps currently costs less than all fuels except cordwood, fuel oil, and natural gas, as shown in **Table 2**. Fuel oil has a higher historical average, but has recently dropped in price. With increasing efficiency, electric heat pumps might overtake these three fuel sources.

Table 2. Relative cost-effectiveness of electric heat pumps, compared to other fuel types

Fuel type	Unit	Btu / unit	Efficiency	$ / unit	$ / MMBtu
Natural gas	CCF	100,000	80%	$1.41	$14.88
Fuel oil	Gallon	138,200	80%	$2.10	$15.96
Wood (green)	Cord	22,000,000	60%	$227.00	$17.21
Electricity (heat pump)	kWh	3.412	250%	$0.15	**$18.32**
Pellets	Ton	16,400,000	80%	$278.00	$21.19
Kerosene	Gallon	136,600	80%	$2.67	$24.40
Propane	Gallon	91,600	80%	$2.27	$30.96
Electric resistance	kWh	3.412	100%	$0.15	$43.46

Source: Adapted from Vermont Fuel Price Report[29]

Figure 9 illustrates the growth of heat pumps as a share of space conditioning for single-family homes.

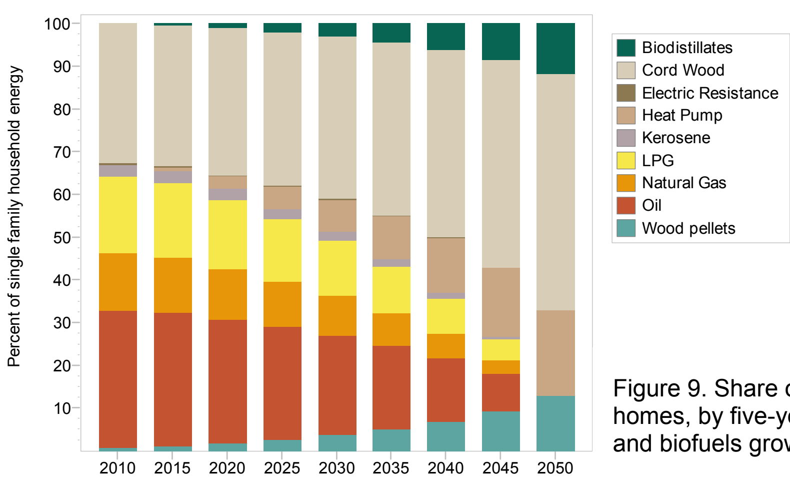

Figure 9. Share of heating energy in single family homes, by five-year increments, and fuel, with electricity and biofuels growing to displace fossil fuels.

Strategic Electrification – Electric Vehicles

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 monies from fuel expenditures to capital for investment or spending. Further, electric vehicles (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 respond to short-term fluctuations in power generation that might occur if more solar PV generation is brought on line. Grid upgrades may be necessary for fast charging stations or if several charging stations are concentrated in a small area, to avoid overloaded transformers, voltage drop, or other distribution grid problems.

Most EVs in Vermont are passenger vehicles and travel about 3 miles 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.

Reference scenario. The *Vermont Zero Emission Vehicle Action Plan* contains detailed information on activities under way in Vermont to support automakers in complying with zero-emission vehicle (ZEV) program requirements. **Figure 10** illustrates the anticipated continued growth in the market. This is particularly the case for 2017 and beyond, after the expiration of the existing travel provision, which allows manufacturers to meet their requirements by selling EVs only in California. The ZEV program requirements have 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.

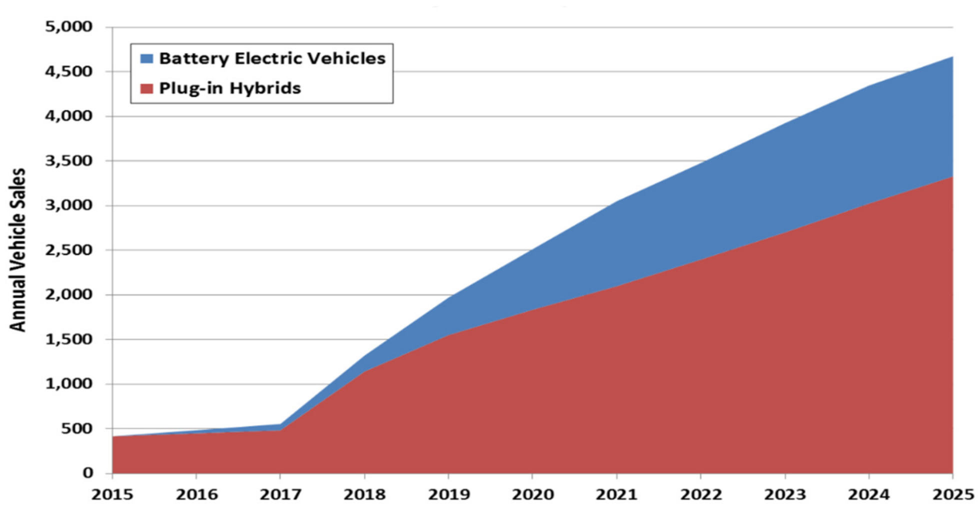

Figure 10. *Vermont ZEV Action Plan* compliance scenario.[30]

90 x 2050 and advanced solar 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.

Technical advances. Advancements in EV technology and battery capacity are beginning to make possible longer ranges for driving at the same or even a lower purchase cost than older EV models. While most cost-competitive all-electric vehicles currently have a range of around 100 miles, rapid technological advances are underway. The Chevy Bolt, an all-electric vehicle with a range of 238 miles and priced just under $30,000 (once the federal tax credit is factored in) is now available for purchase.[31] The lines separating energy generation, storage, and use are also beginning to blur. Shareholders from Tesla and SolarCity, a panel manufacturer, recently approved a merger for the two companies.[32] The new company plans to combine solar generation, battery storage, and transportation.

Figure 11 shows the projected change in fuel supplying light-duty vehicles in the model. Change starts slowly, but electricity powers more than half the demand by 2040 and almost all of it by 2050.

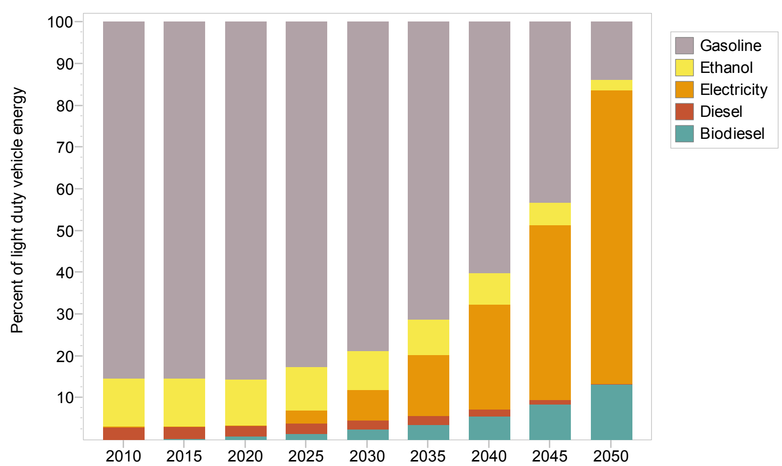

Figure 11. Share of light-duty vehicle energy provided by fuel, with electricity growing later in the period.

Renewable Generation in the Decarbonized Grid

The shift to greater electrification heating systems and transportation provides a benefit if the electricity supply is clean. Vermont already has the lowest carbon intensity electricity generation in the country,[33] but a major change is still required to meet our 2025 and 2050 goals, especially after Vermont Yankee's low-carbon nuclear generation was partially replaced in 2014 with electricity from natural gas power plants.

Figure 12 shows the transition of Vermont's grid in the model. The data were based on utilities contracted supply through 2030. All in-state renewables were expected to continue beyond the contract periods. In-state nuclear generation was replaced by nuclear elsewhere in New England, and then disappears. By that time, solar and new wind have grown to provide more annual generation than Vermont Yankee had in the past.

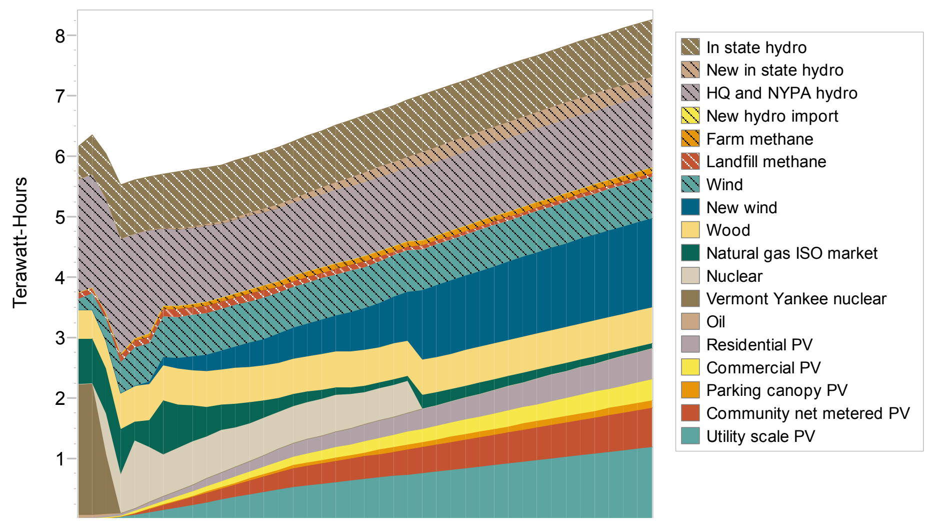

Figure 12. Electricity generation by year and source in the advanced solar.

Figure 13 compares electricity supply in the advanced solar scenario compared to the Reference scenario. Solar ramps up more quickly, but by 2050 wind and solar make roughly the same contribution to electricity demand. A small amount of new in-state hydropower adds to this to offset a large amount of natural gas-fired electricity from the New England grid. The new hydropower capacity is expected to be from upgrades to existing facilities or adding generation equipment to existing dams; no new dams were assumed. In September of 2016, Green Mountain Power purchased fourteen hydropower facilities in New England with a combined capacity of 17 MW.[34] The Team updated the energy model to reflect this new capacity, adjusting for the Vermont dams that were already included.

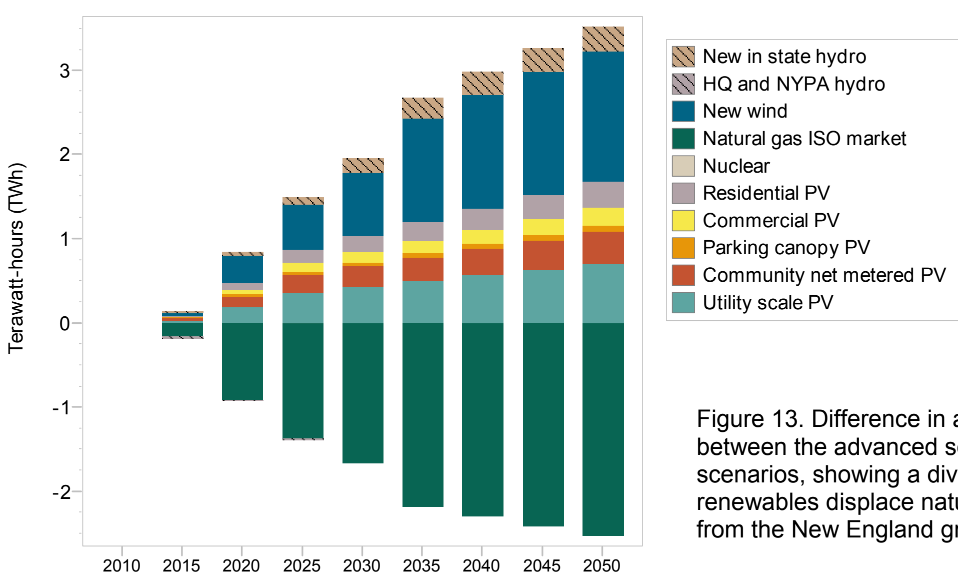

Figure 13. Difference in annual generation between the advanced solar and the Reference scenarios, showing a diverse mix of renewables displace natural gas-fired power from the New England grid.

3.2 Grid Impacts

The California "duck curve"[35] brought the issues of low daytime net load and high evening ramp rates to the attention of the solar industry, utilities, and regulators. Shawn Enterline, at the time the Director of Regulatory Affairs at GMP, and an active stakeholder on this project, used hourly simulations to create the Vermont "Champ Curve" shown in **Figure 14**. "Champ" is a mythical sea creature residing in Lake Champlain, the state's major body of water. Champ's belly goes below zero between 2025 and 2030, as the installed capacity increases beyond 1 GW.

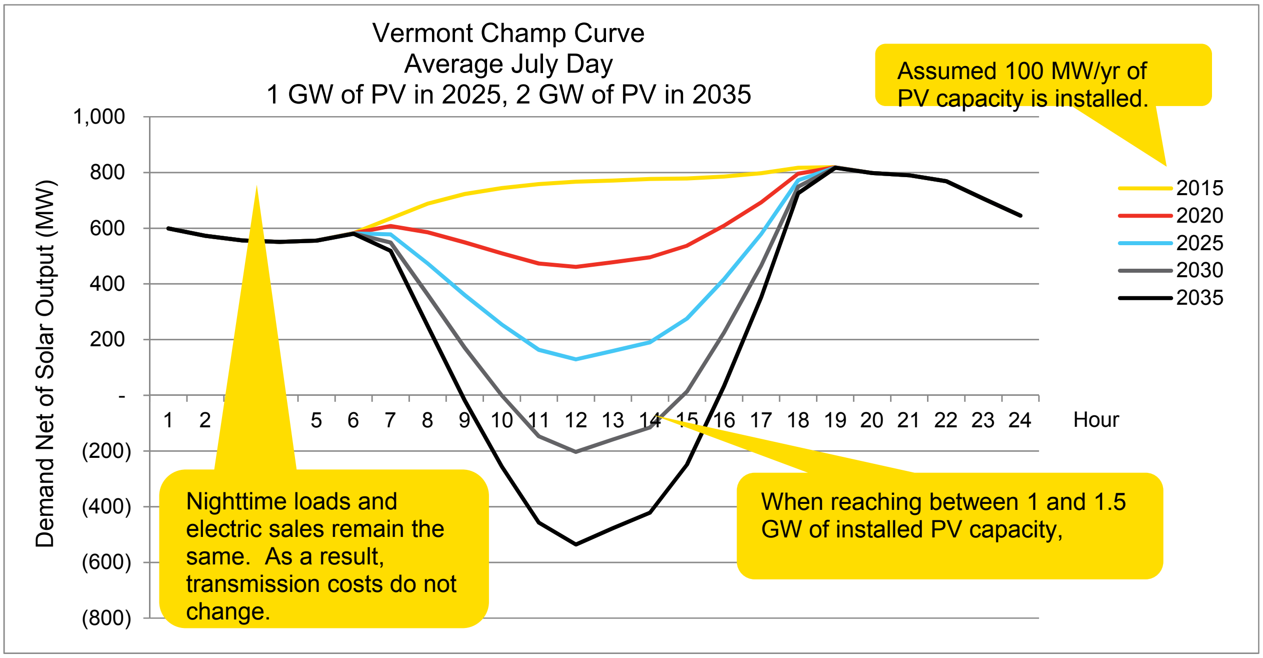

Figure 14. Vermont Champ Curve, showing the net load on an average July day.[36]

The potential for over-generation is a challenge. **Figure 14** considers only solar generation, so other generation would also need to be shut down or curtailed during hours of negative load. Curtailment requires controls and other infrastructure and has economic impacts on projects, so is not a preferred strategy.

See **Figure 22** for a comparison of demand with all generation on three sample days in 2025. Ramping down hydropower generation has ecological impacts from rising water in the reservoirs. Curtailing wind or solar has economic impacts. Must-take contracts would need to be re-negotiated before this situation, or else utilities would have to pay for power they do not use. Demand response / load shifting and storage might mitigate this likely problem. These data raise many issues that can be addressed with several possible strategies, discussed in **Section 4.1 Bulk Power System Integration.**

3.3 Economic Outcomes

The team conducted economic analyses for three advanced solar scenarios. These are the main Advanced solar scenario, Delayed Deployment and Low Net Metering (NM) scenarios. These can be compared to the Reference scenario and to the 90 x 2050_{VEIC} scenario. The Reference scenario does not meet the statewide target of meeting 90 percent of total energy needs with renewables by 2050. The 90 x 2050_{VEIC}, advanced solar, Delayed Deployment and Low NM scenario all meet the 90 x 2050 target. The Advanced solar and Low NM scenario also meet the advanced solar economy target of supplying 20 percent of electric sales from solar by 2025.

In 2015, Vermont's solar industry employed 1,367 workers.[37] This project envisions four times more solar installed in 2025 than in 2015. However, the annual addition of solar capacity across that decade is not expected to change drastically from the rate of added solar occurring in 2015. Employment in the industry is more closely tied to the installation rate than to the total installed capacity, so the Team forecast moderate growth in Vermont's solar industry across that period.

Vermonters spent $3.3 billion for energy in 2014.[38] By annually investing less than 1 percent of that amount in efficiency, fuel switching, and renewable energy, these high renewable scenarios can be achieved. Compared to the Reference scenario, all three advanced solar scenarios have higher net present value costs, ranging from $91 million to $209 million for the 2010-2025 period, as shown in **Table 3**. That is the timeframe for the 20 percent solar goal; if the period is extended, the three scenarios all show net positive economic results by the 2030s.

Table 3. Cumulative costs and benefits: 2010 – 2025, relative to the Reference scenario (discounted at 3.0% to 2015, in millions of 2015 U.S. dollars)

	90 x 2050_{VEIC}	**Advanced Solar**	**Delayed Deploy**	**Low NM**
Demand	**$851**	**$851**	**$851**	**$851**
Residential	$416	$416	$416	$416
Commercial	$261	$261	$261	$261
Industrial	$58	$58	$58	$58
Transportation	$115	$115	$115	$115
Transformation	**$306**	**$498**	**$319**	**$488**
Transmission and distribution	-$3	$13	$13	$13
Electricity generation	$308	$485	$306	$475
Resources	**$-1,079**	**$-1,139**	**-$1,078**	**$-1,148**
Production	$82	$82	$82	$82
Imports	$-1,162	$-1,222	-$1,160	$-1,230
Exports	-	-		-
Environmental externalities	-	-		-
Net present value	**$77**	**$209**	**$91**	**$190**
GHG savings (million tonnes CO_{2e})	7.1	7.1	7.1	7.1
Cost of avoiding GHGs ($ / tonne CO_{2e})	$10.7	$29.3	$12.8	$26.7

Over time, the benefits from investments in efficiency and solar far outweigh the costs, producing significant economic value for the state. The model projects close to $8 billion in cumulative net positive benefits by 2050, as shown in **Figure 15**. Overall, the economic analysis results indicate that a slight net investment (<1 percent of annual energy expenditures) in developing the advanced solar economy through 2025 creates very large positive net benefits over time. Vermont policy makers and consumers are increasingly recognizing the benefits of this value proposition, driving the levels of investment and savings emerging in the market.

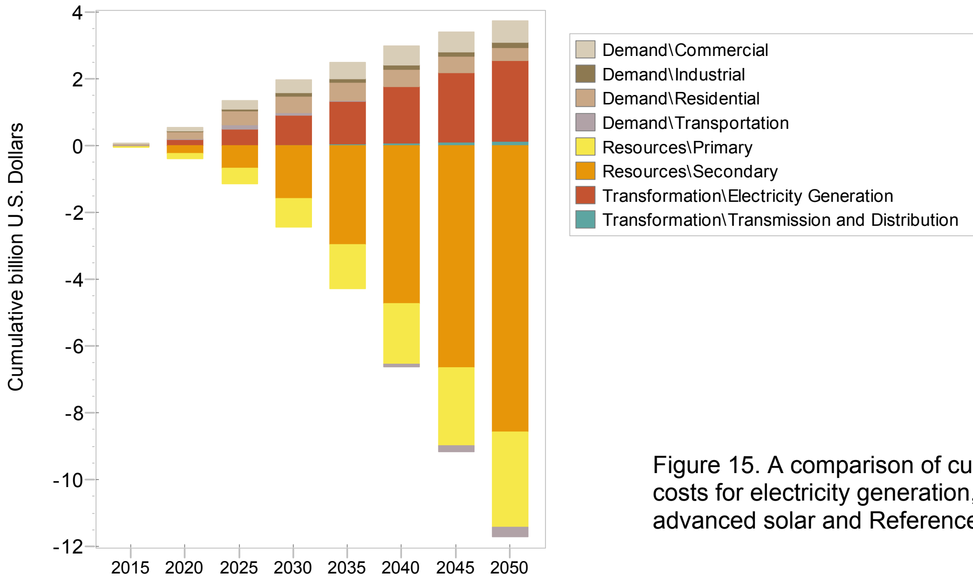

Figure 15. A comparison of cumulative discounted costs for electricity generation, between the advanced solar and References scenarios.

Figure 16 illustrates a comparison of the annual costs for electric generation between the advanced solar scenario and the Reference scenario. The advanced solar scenario has higher costs for solar, new wind, and new in-state hydropower. The increased costs for these resources are partially offset by a reduction in costs for natural gas-fired electricity imported from the regional power markets.

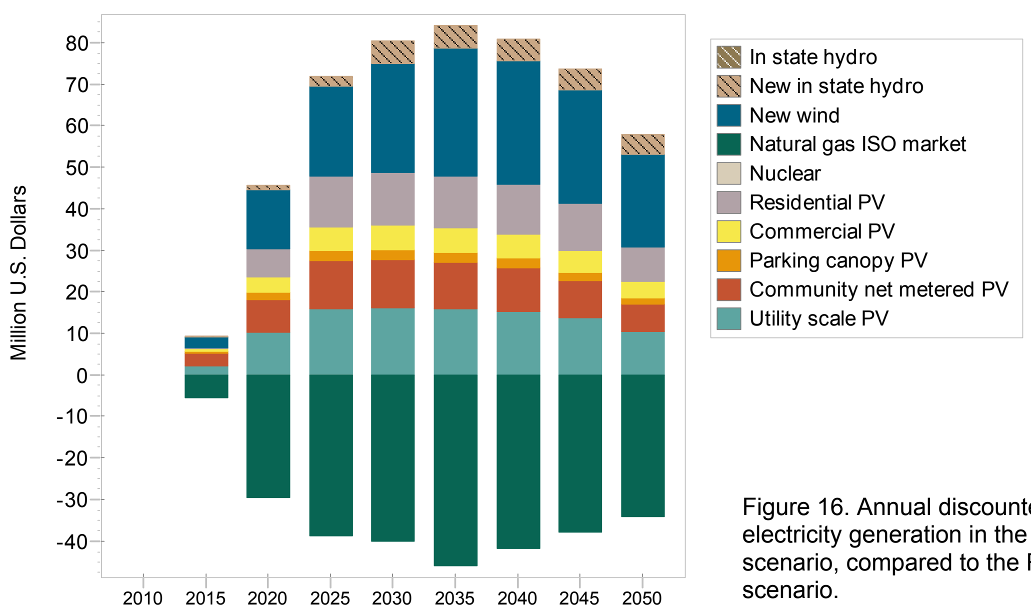

Figure 16. Annual discounted costs for electricity generation in the advanced solar scenario, compared to the Reference scenario.

3.4 Environmental Outcomes

The advanced solar scenario reduces greenhouse gas emissions by roughly 20 percent by 2025, and by more than 80 percent by 2050. **Figure 17** illustrates these effects.

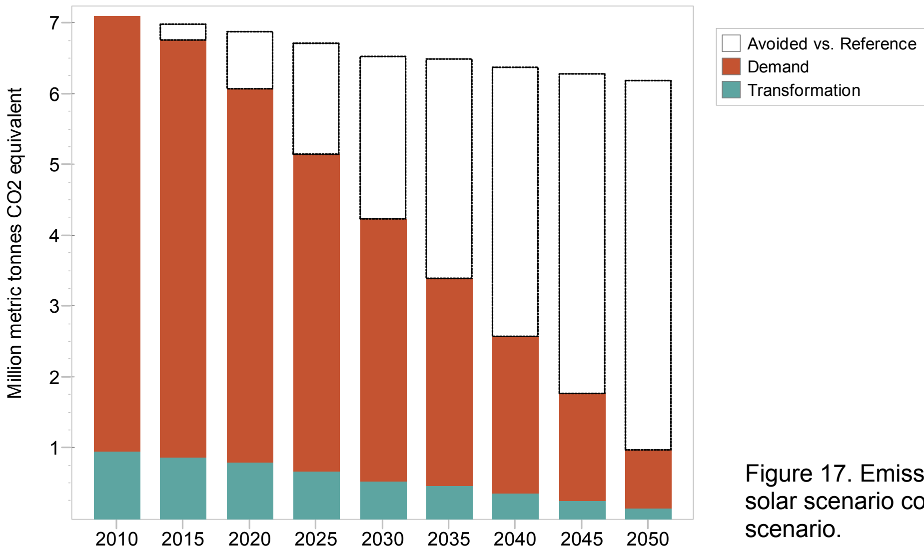

Figure 17. Emissions of the advanced solar scenario compared to the Reference scenario.

By 2050, Vermonter's emissions per person fall below 2 metric tonnes per person, a limit suggested for mitigating climate change. Vermonters will see much more of the energy system as in-state renewable projects replace imported energy. Careful siting and project design can limit the impact.

4. Strategies for Becoming an Advanced Solar Economy

4.1 How the Results Can Be Attained

Task 6: Conduct Year 2 (calendar year 2016) Priority Analyses

After identifying potential issues to meeting the solar target in Task 4, and revising the scenario models in Task 5, the project team sought strategies to overcome the identified challenges and applied them to the advanced solar scenario for Vermont. These strategies are summarized in this Section 4 and was complete June 2016.

Task 7: Make Initial Recommendations for the Vermont Solar Pathways Plan

By documenting the strategies to enable an advanced solar future in Vermont, the project team began to set expectations and frame the final report. This task was completed concurrently with Task 6 June 2016.

Siting and System Integration

The Team identified the target of 20 percent of total electric needs met by solar power by 2025 as an ambitious but achievable solar energy goal. To achieve 20 percent of annual electricity supplied by solar in Vermont requires approximately 1 GW of solar, which is equal to Vermont's peak electric demand—before the electrification of transportation and heat.

To determine how to reach that target, the Team evaluated the impact of 1 GW of solar within the state's bulk power mix, and how that much solar would affect the distribution circuits where it would be connected.

This approach, identifying a goal and illustrating and exploring multiple ways of reaching it, allowed the Team to test several different scenarios. No predictive analysis will be 100 percent accurate, particularly one with a time span as long as 35 years. The end-oriented approach has provided a structure through which to test hypotheses and to elicit stakeholder feedback on likely issues. Other analyses screen for cost effectiveness or use economic optimizations. However, people do not always make consistent, rational economic decisions, nor do they immediately switch when a new, more cost-effective product or service becomes available.

This project described a future that people want, even though they are not certain that it is achievable. The team built support for the 20 percent goal and then worked through issues to build confidence in the feasibility. **Volume 3, Barriers and Integration Brief** documented several possible problems from a future that offers high solar penetration. This section identifies potential solutions to each.

Space Requirement

Some observers cite the space requirements of solar as a reason for it not to play a major energy supply role. Although sunshine is one of the least dense forms of energy, and siting space might be a limiting factor in cities attempting to become energy self-sufficient, Vermont has more than enough space for solar. For an approximation of the space required for the advanced solar scenario, the Team examined land requirements based on the 2050 solar capacity, shown in **Table 4**. At that point, solar produces close to one-third of annual generation, and the space requirements are just 2/10 of 1 percent. This finding helps to inform the public discussion of land requirements for solar, indicating that solar resource and land are not limiting factors.

Table 4. Land requirements for achieving the targeted 2050 solar capacity

	2050 MW	Percent on open land	MW on open land	Acres required[39]	Percent of state
Residential	360	25%	90	720	0.01%
Commercial	240	50%	120	960	0.02%
Parking canopy	90	0%	0	0	0.00%
Community	510	100%	510	4,080	0.07%
Utility	800	100%	800	6,400	0.10%
Total	**2,000**		**1,520**	**12,160**	**0.20%**

Even though the overall land requirements are modest, the proper siting of solar is an important topic, both for land use and grid integration. Recent Vermont Legislation requires RPCs to develop maps identifying the most and least acceptable areas for development for different types of renewable energy resources. Vermont's new net-metering law provides preferred pricing to net-metered generation located on disturbed sites, sites identified by municipalities as preferred sites for renewable development, or adjacent to the demand for the energy.

The Bennington County Regional Commission (BCRC) produced a map of "prime solar" land near existing power lines and away from floodways, wilderness areas, rare and irreplaceable natural areas, wetlands, agricultural soils, and other constraints. **Figure 18** shows a small section of the map and legend. The yellow prime solar land is near existing development and is not found in the forested mountains, which are shown by dotted elevation lines on the left side of the map.

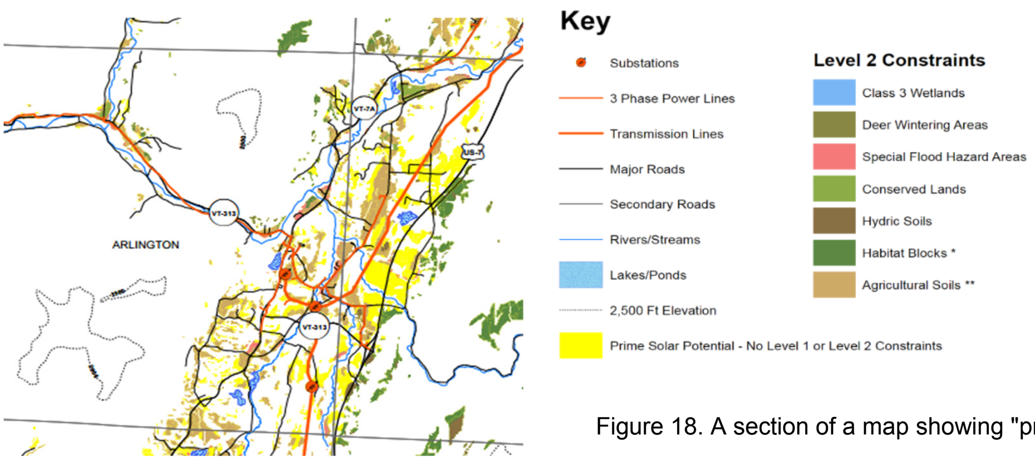

Figure 18. A section of a map showing "prime solar" land.

BCRC also analyzed the geography to summarize the availability of prime solar land in their region. **Figure 19** is an image they produced to help people visualize the vast amount of land, and of prime solar land available, compared to the amount required for their contribution to the statewide target.

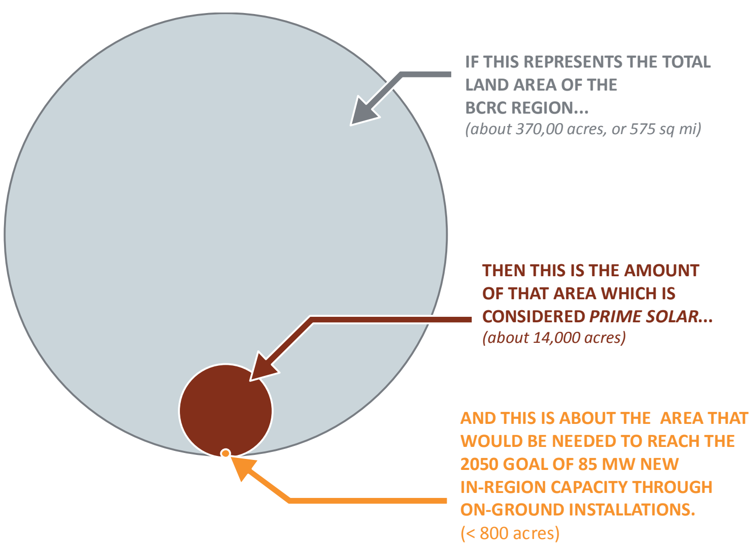

Figure 19. A Bennington County Regional Commission graphic showing more than enough prime solar land to site the targeted capacity of solar.

There are several ways solar can be added with minimal impact to the site. Rooftop systems are widely seen as low impact, and arrays over parking lots have the additional benefit of keeping the cars under them cooler. Ground mounted systems can be integrated into farms by locating them along existing fence lines or separations, in land with poor soil, or in the case of an apple orchard, in the low spots in the land where trees would be vulnerable to late spring frosts. Within large solar arrays, there are alternatives to mowed turf grass.

Animals can graze, though some require taller or stronger solar racks to avoid damage. Wildflower and native grasses can be established to keep growth low and provide foraging habitat for bees and birds while those pollinators benefit nearby agriculture. Pollinator-friendly vegetation also has deeper roots than turf grass, helping retain soil and nutrients and controlling stormwater. Pollinator-friendly vegetation standards have been established in Minnesota and the approach is common in the UK.[40]

Distribution System

A high percentage of solar and other renewables can cause problems on the distribution grid and in bulk power supply. Although this study did not conduct detailed distribution engineering analyses, the Team reviewed related work in other jurisdictions and is following the progress of the Vermont utilities' work with Sandia National Laboratory, funded through DOE's Grid Modernization Initiative.

Relevant outcomes of secondary research are summarized below. Well-designed and executed distribution study analyses provide the following results for substations and individual feeders. These findings are detailed on page 5-14 of Electric Power Research Institute's (EPRI) benefit-cost analysis of an integrated grid framework:[41]

- **Feeder-specific hosting capacity.** Individual feeders, and locations along an individual feeder, vary in their ability to host DERs without violating voltage and protection scheme thresholds. Generally, locations that are closer to the substation on a radial feeder will have a higher hosting capacity than locations at the end of the feeder line. The presence of DERs does not always result in negative impacts. For example, if the end of a radial feeder line is challenged to maintain adequate voltage, the development of DERs with appropriate controls may be able to alleviate the situation.
- **Substation-level hosting capacity.** The hosting capacity at a substation serving several feeders may or may not be the sum of the feeders' capacities. Determining substation hosting capacity helps to inform analysis of the bulk power system and analysis of overall supply adequacy and system reliability.
- **Energy consumption and loss impacts.** The levels of DER on a feeder affect the loading of the feeder which influences distribution system losses. For example, the high end of voltage operating windows results in higher line losses. If distributed generation causes higher current flowing back to the substation than the original load, line losses will increase in that condition. The operations of equipment along a feeder, such as the frequency of changes in voltage tap regulators, can also be affected by additional DER. Sometimes relatively simple solutions are available, whereas in other cases more expensive changes in the system are required.
- **Asset deferral.** The development of well-integrated DER can help to alleviate the need for distribution and substation capacity upgrades.

This type of analysis is already taking place at many leading utilities. An example of asset deferral is Consolidated Edison's Neighborhood program, which aims to defer the need for a $1.2 billion substation upgrade with investments in demand response and distributed resources.[42]

Data from Pepco distribution analysis shown in **Figure 20** echoes the EPRI study results:

- The ability of distribution feeders to accommodate solar varies widely and the average may not be meaningful.
- Some feeders have a high capacity to interconnect solar without any upgrade cost

Ideally, solar installations would be focused on feeders in the lower right corner of the graph, but without investing in studying each feeder's electric and loading characteristics, we do not know where feeders would appear on the chart. A utility stakeholder suggested patterns might emerge in this data if more information on the circuits were available. He expects that higher voltage feeders have higher hosting capacity.

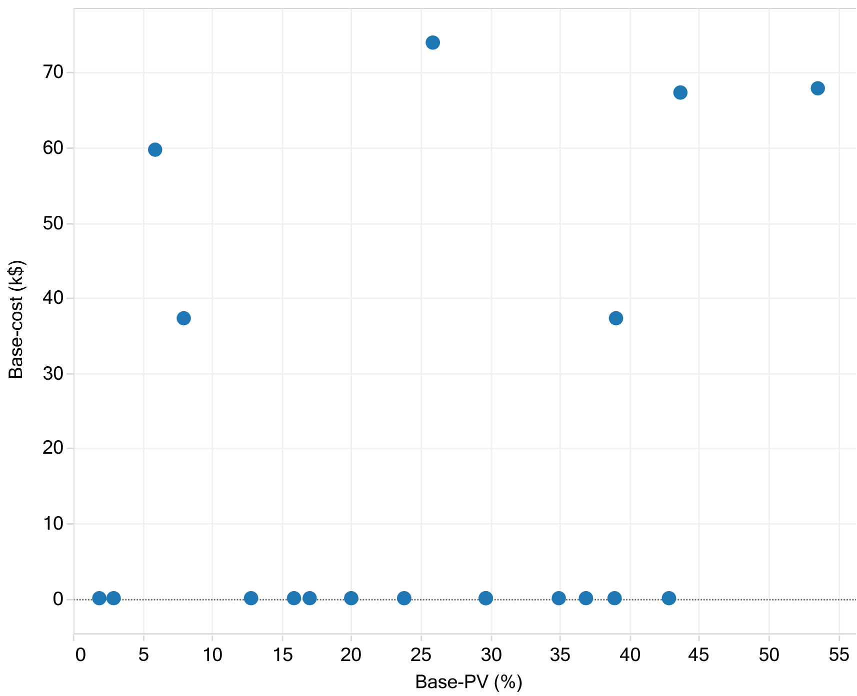

Figure 20. Solar capacity as a percentage of feeder rated capacity versus distribution system upgrade cost, the base case before optimizing for PV. Data from Pepco analysis is presented as part of "Preparing for a Distributed Energy Future: What Can Be Done Today to Integrate DERs Cost Effectively."[1]

Navigant performed similar analysis for the Virginia Solar Market Pathways project.[43] This analysis had similar results and showed that many feeders can host relatively high solar penetration without any upgrades. Very high solar penetration that generates power beyond the local needs and pushes power back onto the transmission or sub-transmission grid is likely to require utility upgrades.

Both of the Pepco and Navigant analyses also show that some feeders can host zero or small amounts of solar before requiring upgrades.[44] This highlights the needs for strategic siting. Vermont has many opportunities to apply these analyses in its siting practices.

In the typical process, a homeowner, business, or solar developer designs a solar system, applies for a permit (in Vermont it is a Certificate of Public Good) and applies for interconnection with the utility. If the project requires the utility to upgrade their equipment, the project is charged for the cost of that upgrade.

Stakeholders discussed two problems with this approach: First, it is inefficient and wastes system design time when cost-effective interconnection is not possible. Second, it may fully burden one project with upgrade costs that were partially caused by the systems that came before it, and systems that come later may get free use of the newly added hosting capacity.

Green Mountain Power provides potential developers with a Solar Map,[45] a section of which is shown in **Figure 21** that gives an initial indication of where projects are more or less likely to have high interconnection costs. This initial hosting capacity analysis has been helpful to guide development away from areas already constrained, but it is fairly simplistic. In 2017, GMP implemented circuit-level modeling to create a proactive distribution plan for every GMP circuit.

Figure 21. GMP's Solar Map shows areas of the grid that have capacity, are approaching the limit, or have little to no capacity available.

In new net-metering rules for 2017, Vermont added a siting incentive to encourage solar installations on buildings and disturbed land. A similar incentive could encourage siting based on the needs and capabilities of the distribution system. Publically available information about the needs of the grid could also encourage strategic siting. If a grid siting incentive were used, it should be fair, predictable, and should not unduly influence land values.

In addition to analysis and upgrades, the utilities can do to estimate and increase solar hosting capacity, technology on the project side of the meter increases capacity by reducing the project's impact. Advanced, or smart, inverters will become an important tool in reducing the impact of so much solar on the grid. The standard for their operation was not yet available in 2016, but by 2025 these inverters could alter their voltage in support of the grid and remain steady during short-term frequency fluctuations, thus helping avoid what one stakeholder described as "the largest power plant in the state cycling on and off as clouds pass." Additional improvement is available through load management and storage.

Bulk Power System Integration

Looking at Vermont as a whole, high levels of solar generation can cause different issues. Solar generation varies in predictable and less predictable ways according to the position of the sun and the weather. While solar generation prediction software is rapidly improving, the bulk power system must provide adequate, complementary generation. This report summarizes potential issues on the bulk power system and explores how Vermont's system might be affected.

As detailed in a recent EPRI report, bulk power system impacts can include the following: [46]

- **Resource adequacy.** Are the existing and planned generating capacity levels sufficient to meet demand? For renewable resources, the daily and seasonal variability in output and the matching of generation to demand load shapes need to be considered. The National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS) system provides a national-level visualization of scenario modeling illustrating the mapping of generation loads and transmission in a high renewable energy future.[47]
- **Flexibility assessment.** The intermittent nature of solar and wind resources increases the need for resources on the system that are sufficiently flexible to adapt to increased ramping up and down.
- **Operational scheduling and balancing.** Operational processes and market structures to allow for adequate balancing of supply and demand, given the reliability, safety, and power quality standards and requirements.
- **Transmission system performance, deliverability, and planning.** Analysis and planning that considers constraints and congestion on the delivery of power on the transmission system. Increased renewable generation might result in generation that is both closer to load (in the case of DERs) and more distant from it (for example, large wind resources).

As levels of DERs increase and electrification of heating and transportation services changes the timing of demand, impacts from the distribution and sub-transmission levels affect the transmission system. Therefore, iterative analyses and planning processes are often required for a comprehensive assessment.

The Team simulated Vermont's electricity demand and supply in 2025 to look for these issues and determine the amount of flexible demand, storage, or additional supply needed. Using hourly data described in **Table 2** of **Volume 4,** the Team compared the sum of renewable and contracted supply to the forecast demand. The demand shape is from 2013, but is increased to reflect expected electrification.[48] **Figure 22** shows three sample days from the advanced solar scenario in 2025. When presented with similar graphs, **the utility stakeholders were not especially concerned with the mismatch between demand and supply;** they manage similar daily mismatches today using the regional spot market for wholesale electricity. The January day shows especially low generation, with both wind and solar at low levels. Large-scale storage such as pumped hydropower or additional winter supply might be necessary to manage extended periods of low renewable output.

One stakeholder noted that in times of low load and high solar, such as the example April day, the market price for power is likely to be low because the rest of the region, especially Massachusetts, would be experiencing the same situation. The excess power could sent the wholesale price of electricity below zero. Thus, selling the excess energy to other parts of New England might not be a good strategy. The supply mix is able to meet demand on the July summer peak, but solar output decreases much more quickly than demand. In the figure, the dispatchable wood+biogas plants turn off during the short midday period that would otherwise have over-generation. Given the deficit all afternoon, the wood+biogas could continue running midday to pre-cool homes and buildings and charge batteries in preparation for the afternoon.

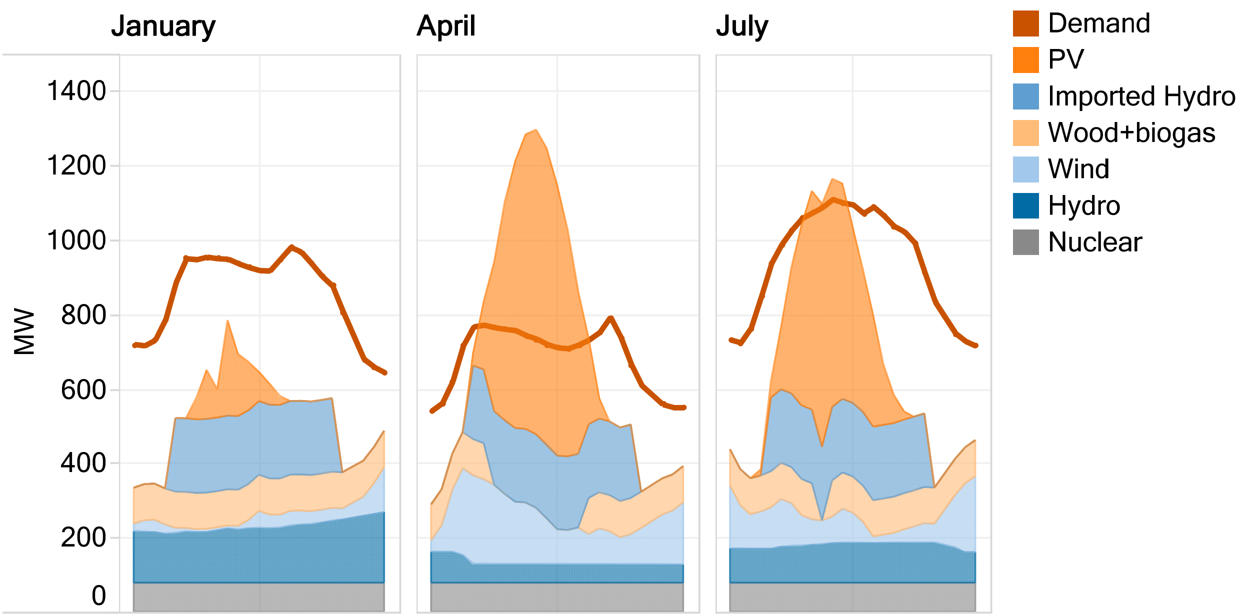

Figure 22. Projected supply and demand in 2025 show sample days with under-supply and over-generation. The January day suffers from a lack of wind and solar generation. The April day has lower load, some wind, and a lot of solar, creating 600 MW of excess capacity. The situation would be even worse if hydro was at a typical spring high. On the July day, supply matches demand in the afternoon.

Using the year of hourly data, the Team calculated the "imbalance" between demand and supply, defined as the sum of contracted supply and renewable output minus gross demand. In **Figure 22**, deficit imbalance is the white space below the demand line and above the stacked supply, and surplus imbalance is the area of supply above the demand line.

Optimal strategies for dealing with imbalance depend on the magnitude (MW), duration (hours), and the product of those, the energy imbalance in megawatt-hours. The choice of strategy also depends on proximity to an opposite balance, e.g. oversupply is easy to use effectively if it happens just before a period of shortage since the excess could be used for pre-cooling or pre-heating buildings and charging batteries. **Figure 23** shows the imbalance for each of the days in **Figure 22** and for the two days before and two days after. Unfortunately, this shows that the difficult conditions on the January and April days are the predominant conditions for several days. This limits the effective balancing strategies to additional generation or purchase, curtailment, or long-term storage. The days surrounding the sample July day offer a better balance of surplus and deficit conditions that offer more strategies.

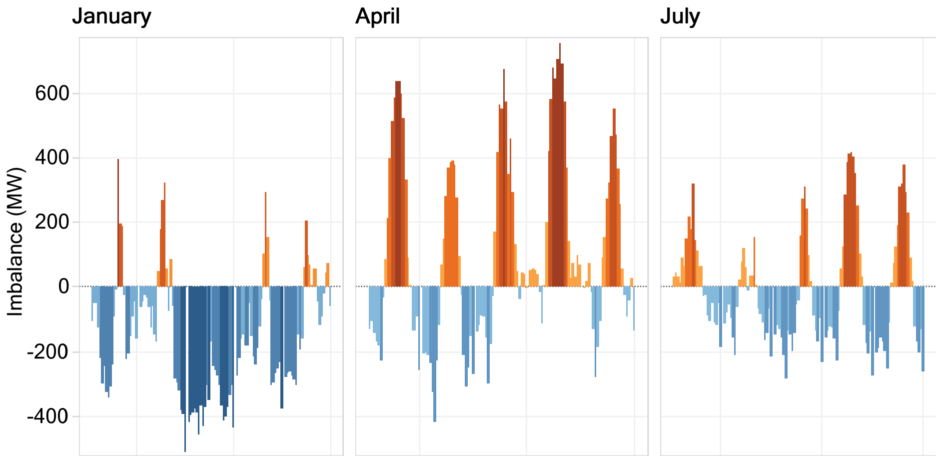

Figure 23. The demand/supply imbalance for each of the sample days above and two days before and after, show that the daily imbalance can be the prevailing condition for several days during the most challenging times of year.

To help determine whether investments in long-term storage or new generation are warranted, and if curtailment should be included in renewable energy financial planning, planners need to estimate how often each of these imbalance conditions occurs. The sample days were chosen because of the difficulty they presented, not because they characterize average days. The examples could be thought of similar to today's peak conditions—important but infrequent. **Figure 24** presents the year's imbalance in the shape of a load duration curve, one for daylight hours, and one for dark hours. Predictably, there is much more surplus during daylight.

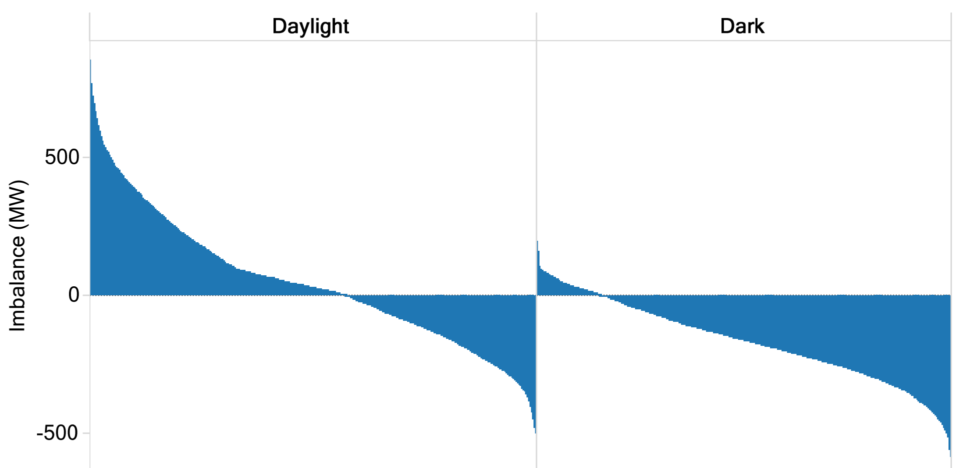

Figure 24. Imbalance Duration Curve by Daylight and Dark.

Figure 25 categorizes the imbalances in ways that inform the solutions: **Figure 25 A** shows that in the sample year, nearly all imbalances last for less than 25 hours, though a deficit can last for more than 80 hours and a surplus can last for more than 40 hours. Battery storage and demand management could likely address the most common, shorter duration imbalances. **Figure 25 B** provides a histogram of the magnitude of the imbalances. Most surplus imbalances are not more than 80 MW, and deficits commonly range up to 400 MW. The dual peak is because of the 97 MW of wood+biogas that is dispatchable in this model. **Figure 25 C** is the histogram for the energy of each imbalance period. Most surpluses and deficits are less than 500 MWh; deficits have a larger range of MWh than surpluses.

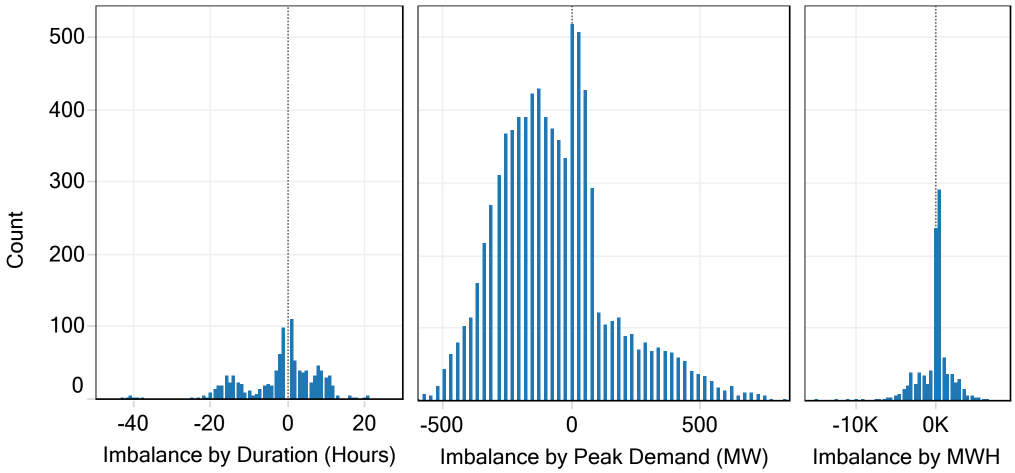

Figure 25. A. Imbalance by Duration (hours). B. Imbalance by Peak Demand (MW). C. Imbalance by MWH.

Smart Grid, Demand Management, and Storage

The smart grid offers opportunities to integrate improved forecasting (of weather, load, and generation) with grid system operations and management. The Vermont Weather Analytics Center, a collaboration between VELCO, IBM, GMP and others, is providing this type of cutting edge information today. 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 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). This communication and coordination helps manage the localized and system wide variability of PV system supply.
- As battery prices drop, “grid-scale” storage and distributed storage will be part of the smart grid 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 a primary concern for grid balancing, 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 and must address concerns with cybersecurity and privacy protection.
- 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. New utility regulatory paradigms which incentivize on-peak renewable generation and investments in non-traditional resources needed to decarbonize the grid may further bolster cost savings. Ensuing that utilities can recover the related investments in IT is also important.

- 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.

Business Models

The following two sections present several options for how business models and regulatory oversight can evolve in ways that are consistent with and supportive of an advanced solar economy. These are examples and are not meant to be prescriptive, or as predictions of the business and regulatory models that will necessarily emerge. The business models and regulatory structures associated with the actual development of Vermont's advanced solar economy will by necessity be informed and influenced by new market conditions and the process of public and stakeholder engagement, negotiation, and review.

Solar business models. The scenario analyses indicate that a mix of business approaches to solar projects will be required to accomplish the Vermont Solar Pathways target**.**

Individually and third-party-owned rooftop and ground-mounted systems will provide consumers with the opportunity to host or own solar generation on their properties. In the advanced solarα scenario, the share of solar expected to be located on site, in ground, and / or as rooftop systems is roughly 300 MW, by 2025.

Vermont's virtual net metering regulations enable **community solar,** one of the more rapidly evolving markets. Community solar allows a single system to provide credits for solar generation to virtually net-metered groups of customers who reside in the same utility service territory. Innovation, research, and market testing for community solar business models, including those offered by third parties and those offered directly by utilities, are under way in Vermont. This is also true of other parts of the country. Several of the other national Solar Market Pathways projects have community solar as integral components to their awards (the Solar Market Pathways projects addressing community solar are the Solar Electric Power Association, Cook County, the Center for Sustainable Energy, and Extensible Energy). Further, a community solar affinity group has been established to share information.[49] The U.S. Department of Energy has also launched a national community solar partnership with a specific emphasis on serving moderate- and low-income households. The White House announced this initiative on July 7, 2015.[50] In the advanced solarα scenario, the share of solar expected to be allocated to community solar is roughly 300 MW by 2025, with the majority of this being ground mounted.

The rooftop and community solar installations are based on principles of both direct and virtual net metering, and therefore offset consumption at retail electric rates. **Projects that have direct power purchase agreements with utilities** are also expected to play an important role in the growing market. Under Vermont's Standard Offer Program, projects of up to 2.2 MW are eligible for long-term contracts. Once online, these projects are made publicly available on the Vermont Standard Offer website.[51] Another option for larger projects is to apply for long-term contracts under Rule 4.100, Vermont's Small Power Production and Cogeneration structure for implementing the federal Public Utility Regulatory Policies Act (PURPA). Recently, the Vermont Public Service Board and VELCO received applications for several projects that are much larger (20 MW each) than what has currently been built in Vermont.[52] The process for review and interconnection of projects at this scale is not yet clear, but it indicates how evolving market strategies and business models will likely influence the technical and regulatory issues, and vice versa.

Complementary DER business models. Several distributed energy resources will enable, help to drive, and be driven by increasing solar saturation. The primary resources are storage (customer on-site, and storage located on the utility distribution system); electric vehicles with smart charging and vehicle-to-grid enabled capacities; controllable customer loads such as heat pumps, hot water heaters; and high-performance zero energy buildings, including high-performance modular housing. This project explicitly recognizes the importance of these markets and technologies through its Focus Area working groups. The project scenarios are examining the potential scale of development and potential barriers to progress in each.

Research conducted in Europe for the Power Perspective 2030 study illustrates the importance of integrating other DERs as part of the advanced solar scenarios.[53] These findings indicate that a shift of 10 percent of aggregate demand in a day results in a 20 percent reduction of investment required in the supply side infrastructure over a 15- to 20-year horizon.[54]

The distributed and networked attributes of the technologies contributing to an advanced solar economy increase the need and opportunities for aggregation of energy services. Community solar is one example. Another is aggregation of electric vehicles for coordinating charging or vehicle-to-grid services. The scale of service and value from an individual vehicle or other DER, such as an electric water heater, is not large enough to justify individuals' participating in a market. However, through aggregation, the coordination and value from a larger number of devices can be captured. Innovative approaches to aggregation can be combined. For example, through the coordination and aggregation of electric water heaters, a community solar power project in West Virginia was able to generate revenues sufficient to fund the investment required for installation of a community solar array on roof of the local church.[55]

Including Households with Low-Income: A Societal Imperative

A 2014 analysis by the Vermont Law School has sharpened statewide awareness of high-energy burdens on low-income households in Vermont.[56] The study found that those who spend more than 10 percent of their monthly income on energy services are considered "fuel poor." Further:

- One in five Vermonters lives in fuel poverty.
- People who lack sufficient energy to keep warm in winter face a higher-than-average risk of stroke, heart attack, influenza, pneumonia, asthma, arthritis, depression, anxiety, and accidents in the home.
- Between 1999 and 2011, Vermont averaged 172 excess winter mortalities per year.
- Annual excess winter deaths caused largely by fuel poverty account for more Vermont deaths than do car crashes.

It is a tenet of energy efficiency and renewable energy advocates that reducing the energy burden for people at risk strengthens economies. This message has relevance for the Vermont Solar Market Pathways stakeholders.

Of particular importance will be explicit goals for reducing the energy burden (the total costs for energy services as a percent of household incomes) for low- and moderate-income households.

Building practices and systems, such as the high-performance modular home (see sidebar on the model for affordable living) will help shift the retail energy market from one that is concerned about annual energy operating costs to one concerned about investment opportunities in new construction and retrofits. **Figure 26** illustrates how the efficient construction practices and energy systems reduce consumption and result in lower total costs.

A Model for Affordable Living

Highly efficient housing and end use services will be prevalent in Vermont's advanced solar economy. So will be an attention to the nexus of energy security for low- income and at-risk populations and community-level economic security.

High performance modular housing in Vermont offers the highest levels of indoor air quality, building durability, energy system integration and monitoring. A continuous energy recovery ventilation (CERV) system and other high-performance systems, design, and construction give these units an average annual energy intensity of less than 27 kBtu / sq. ft. (regional average = 55 kBtu). www.vermodhomes.com.

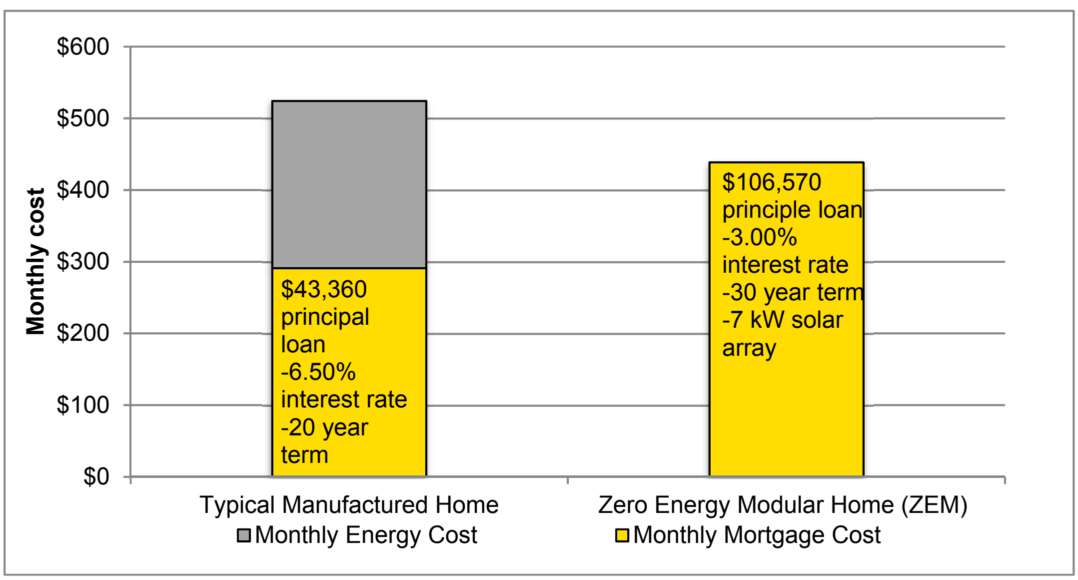

Figure 26. Comparison of total carrying costs for a typical manufactured home and a zero energy modular home.

Utility Business Model

The advanced solar economy opens the door to a wider range of customer service offerings for utilities, and can expand the portfolio of investments on the supply side of the customer's meter—and the demand side.

Current proceedings in California and New York, requiring the distribution utilities to develop and submit distributed energy resource plans, are an example of regulatory expansion of the scope of resources conventionally considered in distribution planning. In other cases, including examples from Vermont, utilities are offering incentives, financing, and leasing for equipment such as on-site storage, heat pumps, and solar generating equipment. These technologies have the potential for coordinated control and operations.

What do "innovative grid services" look like?

Advanced, detailed meteorological forecasting—paired with operation and control of DER assets—are an example of the innovative, value-adding service that grid operators could provide. This can happen if they collaborate with partners, or if they invest in creating this kind of asset, in house.

The distribution utilities may also have business opportunities related to the investments required to support higher levels of saturation on the distribution system, whether these entail upgrades to distribution operation, communication, and control schemes—or direct investment in solar generation that is strategically sited on the distribution network.

The procurement of solar and other DERs and their inclusion in a utility's portfolio will affect the requirements for the balance of the portfolio. For example, they might require other power supply contracts to provide a higher level of flexibility.

Integrating and controlling a large number of DERs and solar will require greater visibility, communications, and control of resources. The required services might be provided by third parties, or directly by distribution and transmission system operators. A study conducted for the California grid operator, CAISO, estimated that the benefits from enhanced visibility and control of DERs far exceed the costs associated with the required costs for the communications and other required infrastructure.[57] Though dated and for a different market, this study might provide a first estimate of what Vermont may see with higher renewable saturation.

4.2 Regulatory Considerations

In some ways, Vermont's advanced solar economy will have a retail market structure that is similar to what we know today. Consumers will still receive basic electric service from a regulated utility under tariffs reviewed and approved by regulators. The tariffs will cover the costs of providing reliable grid service and commodity electricity. The service provided to the retail consumer will progressively reflect economic and environmental policy objectives by increasing the share of renewable resources in the electricity mix.

The mix of ownership of DER assets will vary across time and will be likely to vary from territory to territory, since the assets are tied to local conditions, priorities, and entrepreneurial assets. This progression from more to less regulated DER ownership is seen in **Figure 27**.

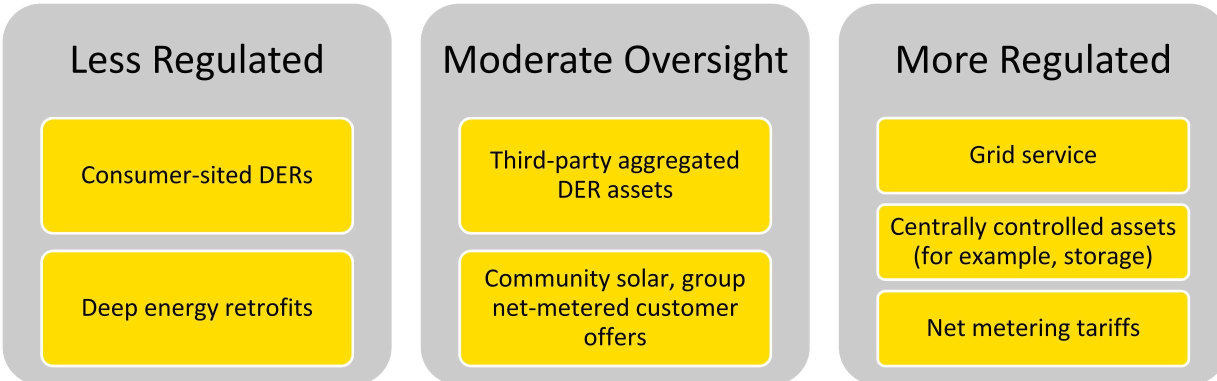

Figure 27. The array of options for consumer support services, under different regulatory levels, in a total service system.

Consumers will also benefit from, and have access to, services provided by a regulated public-benefit DER entity whose mission is to provide consumer support and market facilitation for distributed energy resources—primarily energy efficiency, renewable on-site generation, demand response, load shaping, and storage. We refer to this as a *consumer support entity.* The regulatory and policy oversight for both the grid services and consumer support entities will involve performance indicators and regulator-set metrics addressing the environmental and social economic impacts of energy consumption. The interaction of this type of entity is shown in **Figure 28**.

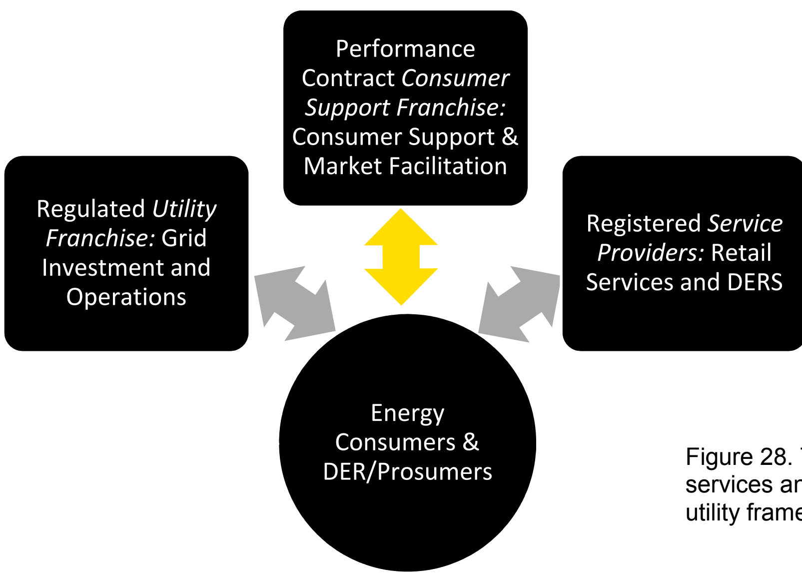

Figure 28. The relationship of various services and service providers in a new utility framework.

One reason to employ a "looking backward from the end" approach is that utility business models can change rapidly, greatly influencing the mechanisms for reaching solar goals. Currently, utilities provide electric power, maintain electric delivery infrastructure, and receive compensation from the rate of return on infrastructure upgrades. This system motivates utilities to sell more power and encourage infrastructure investments. A new utility model, in which utilities are compensated for creating and maintaining a clean, safe, reliable, and efficient grid is possible and will be invaluable in supporting an advanced solar economy.[58] Vermont utilities are already each creating innovative paths while adding new renewable energy. For example, GMP is piloting projects to install utility-operated batteries in homes that stabilize the grid while also benefiting homeowners by providing backup.[59]

5. Outreach and Dissemination Activities in 2017

Task 9: Issue Final Vermont Solar Pathways Plan and Public Summary Report

The Project Team released the final report in December 2016.

Public Release of the *Vermont Solar Pathways Plan*

VEIC held a media event to draw attention to the findings and the report. The event featured introductory comments by U.S. Senator Bernie Sanders (via a staff member), and a panel of stakeholders. The stakeholders spoke about their contributions to, and benefits from, the report and project.

VEIC had not been able to schedule the speakers and panel for an event in the first quarter, because that period coincided with a change in Vermont's gubernatorial seat, and corresponding new appointments to the Vermont Department of Public Service, one of the stakeholders. These changes required extra effort to engage new stakeholder staff who were unfamiliar with the project. VEIC Executive Director Scott Johnstone welcomed 50 to 60 people to the media event, which was held on the fourth business day of the second quarter. Sen. Sanders' representative, Outreach Specialist Haley Pero, cited Sen. Sanders' statement about the importance of not abandoning climate change mitigation during changing times. Damon Lane, the Vermont Solar Market Pathways Project Manager and Lead Analyst, introduced the project, introduced the report, where to get it, and its findings. VEIC's Deputy Director of Policy and Public Affairs, Mary Sprayregen, moderated the panel discussion. Panel members were:

- **Riley Allen**, Deputy Commissioner, Vermont Department of Public Service
- **Olivia Campbell-Anderson**, Executive Director, Renewable Energy Vermont
- **Christine Hallquist,** Chief Executive Officer of the Vermont Electric Cooperative
- **Jim Sullivan**, Executive Director and Planning Program Coordinator for the Bennington County Regional Commission
- **David Hill**, VEIC's Distributed Resources Director

News coverage of public release of report:

http://digital.vpr.net/post/vermonts-solar-industry-had-strong-start-whats-next

http://solarindustrymag.com/vermont-study-explores-pathway-20-solar-2025

Task 10: Support Implementation and Resolve Outstanding Issues

Outreach Activities and Implementation Support

In the second quarter of 2017, the Project Team made specific plans for previously identified outreach activities, and continued to disseminate information about the project within and beyond Vermont. The combined Dissemination and Outreach Plan & Issues and Priorities Content Brief, submitted in 2017 Q1, contains a list of broad outreach opportunities that had been brainstormed with stakeholders. It also contains the original version of the table below. The Team discussed the document and plans with DOE on June 28. **Table 5** shows an updated version outreach activities that were specifically planned and denotes which did not happen and why. For nearly all of the events listed, a Team member presented on the project.

Table 5. 2017 outreach activities

April	✓ Public release in Vermont: media, stakeholders, VEIC staff ✓ Public website: www.vermontsolarpathways.org ✓ SEPA Utility Conference, Tucson, AZ • Legislator breakfast, Montpelier, VT (become final stakeholder meeting in October)
May	✓ Solar Market Pathways – Leadership Academy, Sacramento, CA
June	• Renewable Energy Vermont Board (did not schedule)
July	✓ SEPA Grid Evolution, Washington, DC ✓ Vermont System Planning Committee, Burlington, VT. Discussion of Sheffield Highgate Export Interface constraints and potential impact on RE.
August	
September	✓ Solar Power International, Las Vegas, NV (poster) ✓ Vermont Electric Co-op Board presentation • NASEO, New Orleans, LA (submitted proposal, did not attend) ✓ Smart Electric Power Alliance – 51st State White paper on role of utility. Submitted paper.
October	✓ Renewable Energy Vermont, Burlington, VT (presentation) ✓ ASES, National Solar Conference, Denver, CO (panel discussion) ✓ Champlain Valley ASHRAE monthly meeting (presentation) ✓ Final stakeholder meeting, with legislative and regulatory discussion
November	✓ MnSEIA Conference (co-presented with MN Solar Pathways project)
December	✓ Vermont Energy and Climate Action Network Conference
January	✓ VT General Assembly: House Energy and Technology Committee

The Project Team and stakeholders collaborated on regional energy planning, solutions to curtailment in the SHEI area, and working to increase the pace of growth in renewables and efficiency to meet state goals. Details on these activities are documented in the Priorities Issues and Implementation Support brief, submitted in fulfillment of Q11's milestones.

The Team participated in many small meetings to discuss the scenario planning performed in this project and how it may be able to help other initiatives:

- VELCO, Vermont's electric transmission operator

    - Presentation to leadership staff
- Minnesota Solar Pathways project
    - Multiple phone calls and emails about the approach, modeling, stakeholder engagement.
    - VEIC co-presented with this project at the MnSEIA Gateway conference
- Efficiency Vermont's Strategy and Planning group
- Energy Action Network and their Community Energy Dashboard
- Renewable Energy Vermont
- ESource and three western utilities
- Regulatory Assistance Project (RAP)
    - The RAP conversations focused on the supply / demand imbalance analysis previously identified and the possible application of Vermont data to the strategies in *Teaching the Duck to Fly,* in an updated paper.
- Meeting with VELCO and Itron who performs 20-year electricity demand planning for the state's transmission regions. We compared numbers in our model to Itron's and discussed our ability to model change outside econometric constraints.
    - In early November, a VELCO staff person ran into a Project Team member and indicated VELCO is considering using Solar Market Pathways results in their forecasts.
- Presented an introduction at an electric bus workshop, providing the context that electric vehicles in Vermont are powered by clean electricity that increasingly comes from solar, and that EVs and school buses in particular, could become important for balancing demand and renewable supply.
- Vermont Energy and Climate Summit

Perspective on the Full Project Cycle

Task 12: Release Final Project Report: On the Solar Development Path

The 2017Q4 deliverable, *On the Vermont Solar Path,* was a look back at the three-year process to report on early-stage successes, challenges, activities, and lessons learned. The project team used analysis results and secondary research to inform discussions with stakeholders about potential issues. By having those discussions before and away from policy and regulatory hearings, they were more collaborative. The people involved with this project are armed with more information on the potential benefits and issues 20% solar could bring. Knowing the scale, context, and potential mitigations for the issues that arise in policy debates helps lead toward data-based solutions.

Community solar has been a big driver of the Vermont's recent solar growth. However, installers report that a combination of interconnection concerns, siting restrictions, and lower incentives for greenfield installations have recently stopped that type of development. Final 2017 data show a 73% decline in community solar installations compared to 2016. Reports of higher module prices because of the threat of an import tariff could also contribute to slower sales, though people attempting to buy systems before the tariff could have the opposite effect. These short term forces are not the focus of this project, but are important to installers, who need to pay staff regularly even if it's a slow year for solar. Predictable policies help support a consistent solar market and dependable jobs. The Team noted Massachusetts's SMART incentive framework, which melded location adders and subtractors like those in place in Vermont with an incentive that steps down predictably over time and includes incentives for solar co-located with storage.

From the first year of the project, the Project Team and stakeholders identified several challenges that would need to be resolved to reach 20 percent by 2025. While short-term concerns cannot be ignored, long-term issues need to be addressed even to move in the right direction.

Task 11: Report on Priority Analyses and Support

In November 2017, the Team submitted a short report titled Priority Issues and Implementation Support. Its content is summarized below.

Update on Issues

While the study showed attaining the 20 percent goal is possible, it did raise some issues that need to be solved before Vermont can reach the target. This section considers the major issues that were raised and documents any action on them since the project began.

Siting and land use

Land use was not envisioned as a significant limitation in 2014 when the project was proposed and relatively little solar was installed in Vermont. However, public support of solar eroded in some areas because of quick, concentrated development where there was low cost open land adjacent to three-phase power lines. While towns had a say in most local development, they did not in energy projects, which were regulated at the State level in Vermont. This lack of local oversight added to the perception that solar was despoiling the land.

Two policy changes directly addressed this issue. First, the State offered towns and regional planning commissions (RPCs) a stronger voice in the State's decisions on energy projects. Town and regional energy plans that receive State approval will also receive "substantial deference" in energy project siting decisions[60]. Without a State-approved plan, towns or regions still receive "due consideration" in those decisions.

In 2016, data from the energy model created for this project was provided to the state's 11 regions to support their energy planning. VEIC worked initially with three pilot regions: Bennington, Northwest, and Two Rivers-Ottauquechee, to answer questions on the data and provide additional details as requested. The remaining regions and towns are expected to submit plans soon, though some may wait to see which plans get approved to help inform their own plans.

The PSD has issued determinations for the following energy plans submitted:

Bennington, RPC - approved
Northwest, RPC - approved
Two Rivers-Ottauquechee, RPC - approved
Town of New Haven - rejected
Town of Benson - under consideration

The effect of this change will not be completely clear until approved plans have been in place for some time, but incidental evidence suggests developers are heeding the preferences expressed in the plans and thereby avoiding the need to test the power of substantial deference in a Public Utility Commission case.

Second, the State revised the net metering compensation rates, adding several types of preferred sites, lowering the rate for projects in greenfields, and restricting the size of net-metered greenfield projects to 150 kW, while allowing net metered projects up to 500 kW on preferred sites. This rate structure is focused on preferred land use, but it also addresses a distribution grid issue because a project on, or adjacent to, a site that uses 50% or more of the system output also counts as a preferred site.

Equity and Social Justice

A goal of the Vermont Solar Pathways project is to ensure that all Vermonters can benefit from solar, not only homeowners with high income. Vermont's generous community solar definition, in which the community solar system and its members need only be in the same utility territory, made the benefits of solar available to most Vermonters. This policy particularly benefits customers in large service territories, like Green Mountain Power's, where most of the community solar projects have been built. However, some community solar still requires an upfront payment, contract, or other obstacles for participants. Most of the smaller municipal utilities do not have community solar systems, so their customers cannot yet use the community solar option. The new net metering rates, which provide preferred rates to projects on developed sites, may push developers to look for sites in municipal territories because many municipal territories are densely developed.

The new lower net metering rates for greenfields are reported to have stopped development of what was the most common type community solar system, but the same update removed the limit to the total amount of net metered solar capacity. This allows more growth of solar generally, and specifically more of the type that most directly benefits people who participate. It is important therefore, to ensure all Vermonters can participate in community solar.

VEIC created subsidiary called SunShares that uses employers as a backstop off taker for community solar projects to lower risk and cost to employee members. SunShares is carefully designed to make solar accessible. Like other community solar programs with an anchor or backstop off taker, the lower risk means members are not subject to credit checks, and do not need to commit to a contract period. There is no upfront cost, and each month's bill credits appear before the payment for the credits is deducted from members' paychecks. That means this cash flow positive investment does not even have a chance of causing an intra-month cash flow problem for members. The bill credits are worth more than the member payment, so members see savings every month. So far, one system is operational on VEIC's office building roof in Burlington Electric Department territory. SunShares is looking for additional sites in other utility territories in Vermont and beyond.

In November 2017, Vermont's largest utility and largest solar business partnered on an array providing bill credits to households with low income. The system is on the roof of a Green Mountain Power building and offers a 7 percent discount to enrolled members. The partners expect to serve 35 households with income below 200 percent of the federal poverty level. More systems like this are needed to serve many more households meeting that income requirement. However, according to the Vermont Legislature's 2017 "Basic Needs Budgets and the Livable Wage," the income needed to buy "essential items" in Vermont is considerably above 200 percent of the federal poverty level.[61] Therefore, there must be additional opportunities for households with income above 200 percent of the federal policy level, but for whom conventional market rate community solar is inaccessible or unattractive.

Bulk power impacts

Solar power in Vermont is providing a peak reduction benefit. At some point, the peak will shift after sunset and solar will no longer contribute. That has happened on many Vermont feeders and substations, but not yet on the regional grid, which is where regional peak related expenses are calculated. Since 2010, the ISO-New England peak has occurred in either the 2 pm hour or 4 pm, with 4 pm becoming more common. This could indicate regional solar growth but it is not conclusive. The regional peak is trending lower and the states are racing to lower their share of regional demand costs. Each zone's peak is a result of population, economic activity, efficiency and demand response, weather, and behind the meter solar. **Figure 29** shows data from ISO-New England's most recent Special Annual Peak Load report.[62] Vermont is the smallest zone in the ISO-New England area, and its demand during the regional peak is the most consistent, indicating Vermont's electricity use is less correlated to hot weather than the other zones.

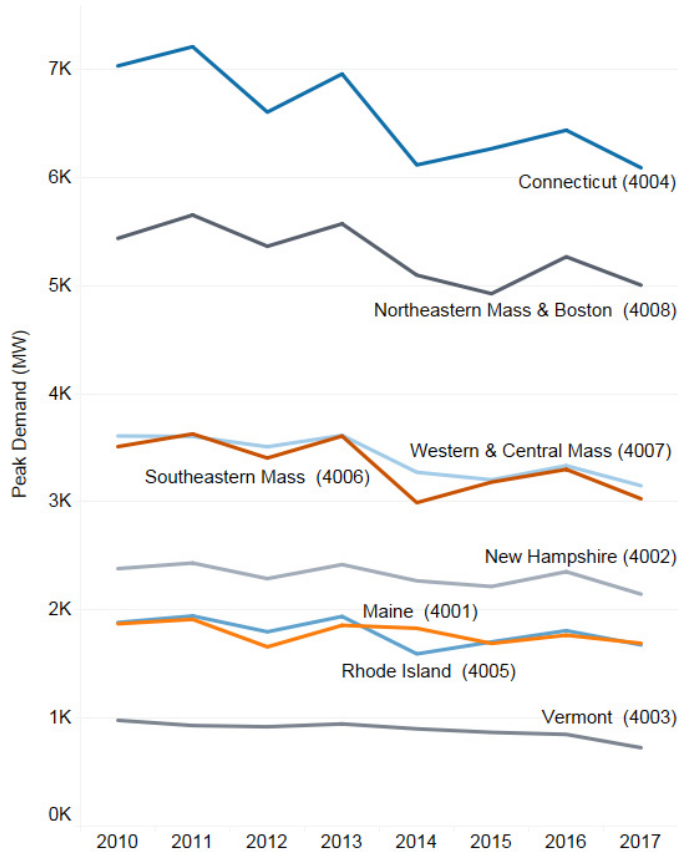

Figure 29. Peak demand (MW) by year and zone.

Vermont's share of the regional peak was the same in 2010 and 2014, and it has decreased in each of the three years since, as shown in **Table 6**. That timeframe corresponds to solar growth in Vermont, so solar may be a contributing factor. However, the very low 2017 number is probably more the result of the mild weather Vermont had while a heat wave in southern New England caused the regional peak.

Table 6. Vermont's share of the ISO-NE peak demand

	2010	2011	2012	2013	2014	2015	2016	2017
Vermont	3.7%	3.4%	3.6%	3.5%	3.7%	3.6%	3.4%	3.1%

The high share of variable renewable generation Vermont will have in 2025 if solar grows to 20 percent increases the hourly imbalance between supply and demand. To help inform the set of solutions to address that issue, the Project Team characterized the timing (date, weather, sun up/down), magnitude (MW), direction (insufficient or excess supply), duration (hours), and size (MWh) of imbalances during the simulated 2025 year. Using that information, the stakeholder groups discussed the benefits, costs, and practicality of different possible solutions. Under Vermont's Renewable Energy Standard (RES), utilities can get credit for helping customers switch from fossil fueled heating or transportation to renewable, in addition to the traditional renewable portfolio standard activity of switching the electric supply to renewable. The utilities have been introducing their offerings, including these flexible load measures from Green Mountain Power (GMP):[63]

- Free Nest or controllable LED kit for allowing GMP to control an electric water heater
- Free EV charging station for new EV
- Free device that converts a heat pump's remote control capability to smart phone control
- Tesla Powerwall 2, buy for $1500 or lease for $15 per month

All of these incentives come with GMP control of the device's grid interaction. The other utilities do not appear to be offering incentives for flexible load yet and are instead focusing directly on the RES requirement of shifting from fossil fuels to renewable energy. However, Vermont Electric Cooperative has built two community solar arrays outside of the SHEI area so that their members, most of whom live in the SHEI area, could access the same solar benefits as other Vermonters, without adding excess generation to constrained areas on the grid.

Distribution grid impacts

The quick growth of 150 kW community solar systems in greenfields also affected the distribution grid. Greenfield sites are not often close to load and may or may not have a strong grid connection. As previously reported, the state's largest utility, Green Mountain Power, created a solar map to guide developers to stronger parts of the grid. This proactive effect was discussed at stakeholder meetings. The Project Team appreciates the voluntary effort and believes the methodology could be improved to be more precise and less conservative. Additionally, the smaller utilities would also benefit from solar maps as some of them already have a significant amount of solar installed.

The Packetized Energy effort, along with other types of demand response, can help reduce distribution grid impacts. The stakeholder group discussed the possibility of a solar developer bundling electrification and flexible load with their solar project to interconnect in an area where it would not otherwise be possible. The Project Team is not aware of this idea being implemented, but Packetized Energy is working with multiple utilities to demonstrate their capabilities.

Update on Process Effectiveness

This project shifted the conversation in Vermont and helped to accelerate change. Despite accelerating solar growth during the project, which could have put them on the defensive, utility and regulatory leaders became more supportive of higher solar capacity. They worked within their jurisdictions to guide where solar is installed, but they removed limits to how much is installed. This type of thoughtful approach, based on real limitations of the grid or other public policy goals, instead of reactionary fear, mirrors the project methodology. We cannot take credit for recent policy wins and losses, but the project provided a comfortable and effective space for utilities, regulators, and advocates to work out the kinks of a high solar future and to start to see it as beneficial, exciting, and inevitable.

Replication Efforts

- Vermont's Regional Planning Commissions are creating energy plans that document how the regions will contribute to reaching the state's renewable energy and emissions goals. VEIC is using the energy model developed for the Vermont Solar Pathways project to estimate each region's share of energy use by fuel, and how it needs to change over time in different scenarios. VEIC and the Regional Planning Commissions received contracts from the Public Service Department, but VEIC's only covered the allocation of statewide model to regions; the State and regions got free access to the model. This allowed them to use detailed and vetted data for very low cost.
- The success of the stakeholder engagement approach to obtaining sound and relatively rapid understanding of the policy factors needed for increased solar market growth will be put to the test in 2017 and 2018 in a much larger market, Pennsylvania. This project, funded under a DOE Solar Energy Evolution and Diffusion Studies II State Energy Strategies (SEEDS II-SES; Topic 2) award, involves a similar approach for shaping that state's solar future to 2030.
    - VEIC is a subcontractor to PennFuture, a Subrecipients of that award.

Task 13: Participating in the Solar Market Pathways Network: Common Activities

The project team sent two or more members to each annual workshop of the Solar Market Pathways cohort, and participated in all of the quarterly calls. The Team made connections with several other teams, including the introduction that connected the Vermont project to the Minnesota Solar Pathways project, and has provided support to the Northeast Solar Coalition.

6. Conclusions

The most important conclusion of this study is that solar can provide 20 percent of Vermont's electricity by 2025, and can do so with costs that are less than 1 percent of total annual energy expenditures. Over the longer term, through 2050, the study analyses suggest net economic benefits from investing in Vermont's advanced solar economy are in the billions of dollars.

The Team and stakeholders have considered the most commonly cited limitations of solar—primarily cost, space requirements, and intermittency. They concluded it is possible and profitable to overcome those limits and move toward a future in which more of Vermont's energy comes from its own renewable sources, owned by Vermonters. In addition to cleaner air and billions of dollars a year stopped from leaving the state, there are co-benefits from enhanced affordability, occupant health, and building durability and resilience.

Table 7 lists some of the questions that are addressed in the Vermont Solar Market Pathways Report and refers to where in this document and other volumes more detail can be found.

Table 7. Questions answered in the Summary Report

Question	Quick answer	Where to look in the *Plan*
Does Vermont have enough solar resource and sites to meet the target?	Yes, Vermont has plentiful solar resource.[64] By 2050, up to 0.2% of the state's land area could be used to meet close to 1/3 of total generation. Siting constraints for land use, and physical and cultural considerations, leave plenty of suitable "prime solar" siting areas for meeting energy needs. Results can support regional and local planning and siting guidance.	**4.1** Siting and System Integration **4.1** Space Requirement
How much will be ground versus roof mounted?	It depends. There is good flexibility to be able to meet targets with a mix of ground- and roof-mounted systems. Roof-mounted solar is not likely to account for more than 300 MW or 1/3 of the 1,000 MW required to meet the target of 20% by 2025.	**4.1** Business Models
Can this much solar be integrated into distribution system?	Yes. Individual sites will continue to need to be evaluated to determine possible distribution grid impacts. However, many sites can host additional PV without costly modifications. Options for storage, load shifting, demand response, and curtailment exist and are emerging to complement traditional solutions of distribution utility hardware upgrades.	**4.1** Distribution System
What about integration with the regional market and transmission system?	It can also be done. Mismatch of supply and demand in 2025 in the SDP is not unlike what utilities manage today. In addition to the distribution tools, utilities can use time-of-use rates and possible regional trading to balance the system. The value of trading will diminish as	**4.1** Smart Grid, Demand Management, and Storage

Question	Quick answer	Where to look in the *Plan*
	neighboring states add similar levels of renewable energy.	**4.1** Bulk Power System Integration
Will business models change?	It is likely. New approaches and business models will emerge across utility, building services, transportation, and solar industries. Innovation relying on advances in information technologies and systems integration will create new value and enable higher saturation solutions.	**4.1** Business Models **4.1** Utility Business Model
What about changes to regulatory and tariff structures?	These will also evolve and change. Rates and regulations enable and catalyze growth of integrated distributed energy resources. There is a mix of more and less regulated elements supporting businesses and consumers in making long-term investment decisions.	**4.1** Smart Grid, Demand Management, and Storage **4.2** Regulatory Considerations
Does the solar future make economic sense?	Yes, the net costs of an advanced solar scenario equal to an annual investment of ~1% of Vermont's total energy expenditures through 2025. By 2050, present value of net benefits is almost $8 billion.	**3.3** Economic Outcomes
Can solar be socially equitable?	Yes, for example, high-performance housing with solar options combine to lower total housing costs, while enhancing occupant health and building durability.	**4.1** Addressing Low-Income People: A Societal Imperative
What about environmental impacts?	The Advanced solar scenario reduces greenhouse gas emissions by ~20% by 2025, compared to the Reference scenario, and 90% by 2050.	**3.4** Environmental Outcomes

7. Budget and Schedule

The budget periods were the three calendar years 2015, 2016, and 2017. The project spent more than the original budget. As shown in **Table 8**, the resolution was to use DOE funding up to the original budget and to count the overage as additional cost share. The overage was mostly due to providing more implementation support than anticipated. As documented in Task 10: Support Implementation and Resolve Outstanding Issues

Outreach Activities and Implementation Support and Replication Efforts, many organizations who participated in the study, and some who didn't, requested the Team's help in applying the method and results to their work. The Team was open to these requests and committed to more than the budget could support, before it was clear how much time they would require, and intentionally erring on the side of higher impact instead of risking underspending the budget. Throughout the project, a member of the team has been working to implement solar plus electrification for people with limited incomes and has done more of that work than anticipated, driving the project's cost share and total budget higher. DOE granted a modification at the beginning of budget period three recognizing the higher cost share and total budget as well as a shift from contractual to personnel.

Table 8. Spending Summary as of final invoice

Recipient:	Vermont Energy Investment Corporation
DOE Award #:	DE-EE0006911
Invoice Number	23
Current Invoice dates (To/From)	12/01/2017-12/31/2017
Invoice Submission Date	1/16/2018
Project	Sun Shot
Current Budget Period	3

Spending Summary for Invoice Review

Categories Per Approved Budget	Approved Budget $ thru current budget period	Spent as of previous Invoice	Current Invoice	Cumulative TOTAL SPENT
a. Personnel	461,098.00	487,422.61	1,066.87	488,489.48
b. Fringe Benefits	168,244.00	178,114.78	400.08	178,514.86
c. Travel	11,377.00	16,574.66	0.00	16,574.66
d. Equipment	0.00	0.00	0.00	0.00
e. Supplies	800.00	587.50	0.00	587.50
f. Contractual	40,819.00	35,348.69	0.00	35,348.69
g. Construction	0.00	0.00	0.00	0.00
h. Other	11,724.00	14,391.87	0.00	14,391.87
i. Total Direct Charges (sum of a to h)	694,062.00	732,440.11	1,466.95	733,907.06
j. Indirect Charges	46,284.00	49,631.93	136.43	49,768.36
k. Totals (sum of i and j)	**740,346.00**	**782,072.04**	**1,603.37**	**783,675.41**
DOE Share	533,341.00	533,317.32	27.76	533,345.08
Cost Share	207,005.00	248,754.72	1,575.61	250,330.33
Calculated Cost Share Percentage	28.0%	31.8%	98.3%	31.9%

8. Path Forward

As previous mentioned, the Project Team is working on a similar project in Pennsylvania under SEEDS II-SES funding, and trying to help northern Vermont find the best solution to a renewable overgeneration problem in the SHEI area. In addition to those and other collaboration efforts previously mentioned, VEIC team members have recently been reorganized into a scenario analysis and planning team from previously disparate assignments on energy planning and policy teams. This recognizes the value of the approach and puts a focus on attracting more similar work.

Abbreviations and Acronyms

Abbreviation or acronym	Description
AMI	Advanced Meter Infrastructure
ARRA	American Recovery and Reinvestment Act of 2009
AWD	All Wheel Drive
BAU	Business-as-usual
BCRC	Bennington County Regional Commission
BED	Burlington Electric Department, the utility that serves the state’s largest city
CAFE	Corporate Average Fuel Economy
CAISO	California Independent System Operator
CCF	hundreds of cubic feet
CEDF	Vermont Clean Energy Development Fund
CEO	Chief Executive Officer
CEP	Comprehensive Energy Plan
CESA	Clean Energy States Alliance
CNG	Compressed Natural Gas
COP	Coefficient of Performance
DER	Distributed energy resource
DHW	Domestic Hot Water
DOE	Department of Energy
DPS	Department of Public Service
DRP	Demand Resources Plan
DSM	Demand-Side Management
EEU	Energy Efficiency Utility
EIA	U.S. Energy Information Administration
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EVSE	Electric Vehicle Supply Equipment
FACETS	Framework for Analysis of Climate-Energy-Technology Systems
FIT	Feed-in Tariff
GHG	Greenhouse Gas
GMP	Green Mountain Power, the state’s largest utility and its only investor-owned utility
GW	Gigawatt, a unit of power demand; 1 GW is about equal to Vermont’s peak demand
GWh	Gigawatt-hour, a unit of energy demand equal to one gigawatt of power for one hour
GWP	Global Warming Potential
HDV	Heavy Duty Vehicle
HOV	High Occupancy Vehicle
HPH	High-Performance Home

Abbreviation or acronym	Description
HPMH	High-Performance Modular Home
HUD	U.S. Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-owned utility
ISO-NE	Independent System Operator, New England
ITC	Investment Tax Credit
LDV	Light Duty Vehicle
LEAP	Long-Range Energy Alternatives Planning System
LIHEAP	Low-Income Home Energy Assistance Program
LLC	Limited Liability Corporation
LPG	Liquefied Petroleum Gas (Propane)
MACRS	Modified Accelerated Cost-Recovery System
MMBTU	Million British Thermal Units
MW	Megawatt, a unit of power demand; in Vermont, 1 MW is equal to the energy demand of approximately 500 homes
MWh	Megawatt-hour, a unit of energy demand equal to one megawatt of power for one hour
NARUC	National Association of Regulatory Utility Commissioners
NREL	National Renewable Energy Laboratory
NYPA	New York Power Authority
PHEV	Plug-in Hybrid Electric Vehicle
PPA	Power purchase agreement
PSB	Public Service Board
PURPA	Public Utility Regulatory Policies Act
RAP	Regulatory Assistance Project
RBES	Residential Building Energy Standards
REC	Renewable Energy Credit
RECS	Residential energy consumption survey
RESET	Renewable Energy Standard and Energy Transformation, Vermont RPS
RFS	Renewable Fuel Standard
ROI	Return on investment
RPC	Regional Planning Commission
RPS	Renewable portfolio standard
SEP	Smart Energy Profile
SEPA	Smart Electric Power Alliance
SPEED	Sustainably Priced Energy Enterprise Development

Abbreviation or acronym	Description
SPEED	Sustainably Priced Energy Enterprise Development
SRECs	Solar Renewable Energy Credits
SSREIP	Small Scale Renewable Energy Incentive Program
TBD	To Be Determined
TES	Total Energy Study
TOU	Time-of-Use
TREES	Total Renewable Energy and Efficiency Standard
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
VAR	Volt-Ampere Reactive
VEC	Vermont Electric Cooperative, the state's 3rd-largest utility
VEIC	Vermont Energy Investment Company
VELCO	Vermont Electric Power Company
VMT	Vehicle Miles Traveled
VSPC	Vermont System Planning Committee
WEC	Washington Electric Cooperative, the state's 4th-largest utility
ZEM	Zero energy modular home
ZEV	Zero Emission Vehicle

Stakeholder List

Name	Organization
Alex DiPillis	Agency of Agriculture
Allison Rogers Furbish	Solarize Upper Valley/Vital Communities
Amy Hollander	NREL
Andi Colnes	EAN
Andrea Cohen	VEC
Andrew Perchlik	CEDF
Andrew Savage	AllEarth
Asa Hopkins	PSD
Austin Thomas	UVM
Ben Gordesky	DC Energy Innovations
Ben Walsh	VPIRG
Betsy Ide	GMP
Bill Kallock	Integral Analytics
Bill Miller	Green Lantern Group
Bill Powell	WEC
Billy Coster	ANR
Bob Barton	Catalyst Financial Group
Bridgette Remington	Legal Counselors and Advocates, PLC
Charlie Smith	Move the Peak

Name	Organization
Chris French	Clean Power Research
Chris Wetherby	Stiebel Eltron
Christine Hallquist	VEC
Christine Salembier	RAP
Dan Belarmino	GMP
Dan Kinney	Catamount
Darren Springer	PSD
David Blittersdorf	AllEarth
Deb Markowitz	ANR
Debra Perry	ISC
Deena Frankel	VELCO
Diane Bothfield	Agency of Agriculture
Dorothy Wolfe	Wolfe Energy
Dotty Schnure	GMP
Doug Smith	GMP
James Moore	SunCommon
Dylan Zwicky	KSE
Edward Son	
Elaine O'Grady	NESCAUM
Ernie Pomerleau	Pomerleau Real Estate
Evan Forward	Smart Resource Lab
Gabriella Stebbins	Energy Futures Group
Gaye Symington	High Meadows Fund
Gina Campoli	Vtrans
Hannah Huber	VNRC
James Gibbons	BED
James Tong	Advanced Grid Consulting
Jared Alvord	Conergy
Jeff Forward	REV
Jeff Wolfe	groSolar
Jeff Wright	VEC
Johanna Miller	VNRC
John Woodward	PSD
Katie Michels	High Meadows Fund
Ken Nolan	BED
Kevin Jones	Vermont Law School
Kevin McCollister	Catamount
Kim Jones	GMP
Kirk Herander	Vermont Solar Engineering
Kirk Shields	GMP
Lauren Hierl	VCV
Leigh Seddon	LW Seddon LLC
Linda McGinnis	EAN
Lisa Morris	VEC
Luke Shullenberger	Green Lantern Group
Mads Almassalkhi	UVM
Mary Powell	GMP

Name	Organization
Matt Fraijo	Positive Energy NY LLC
Meghan Dewald	AllEarth
Melissa Bailey	VPPSA
Mike Trahan	SolarConnecticut/NESEMC
Nate Freeman	GridMarketplace
Nate Hausman	Clean Energy Group/Clean Energy States Alliance
Nicole Denering	ISC
Olivia Campbell Andersen	REV
Pam Allen	GMP
Patricia Kenyon	NRG
Patty Richards	WEC
Paul Hines	UVM
Rep. Mary Sullivan	Legislature
Rep. Rebecca Ellis	Legislature
Rep. Tony Klein	Legislature
Richard Watts	UVM
Robert Dostis	GMP
Ryan Garvey	VPIRG
Sarah McKearnan	ANR
Sarah Simonds	Solarize Upper Valley/Vital Communities
Sarah Wolfe	VPIRG
Scott Pellegrini	Faraday
Sen. Chris Bray	Legislature
Sen. Virginia Lyons	Legislature
Senowa Mize-Fox	
Shawn Enterline	GMP
Stephanie Smith	Agency of Agriculture
Steve LeTendre	Green Mountain College
Stu Fram	High Meadows Fund
Theo Fetter	
Kerrick Johnson	VELCO
TJ Poor	VPPSA
Tom Buckley	BED
Tom Lyle	BED
Will King	AEDG
Will Smith	REV

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