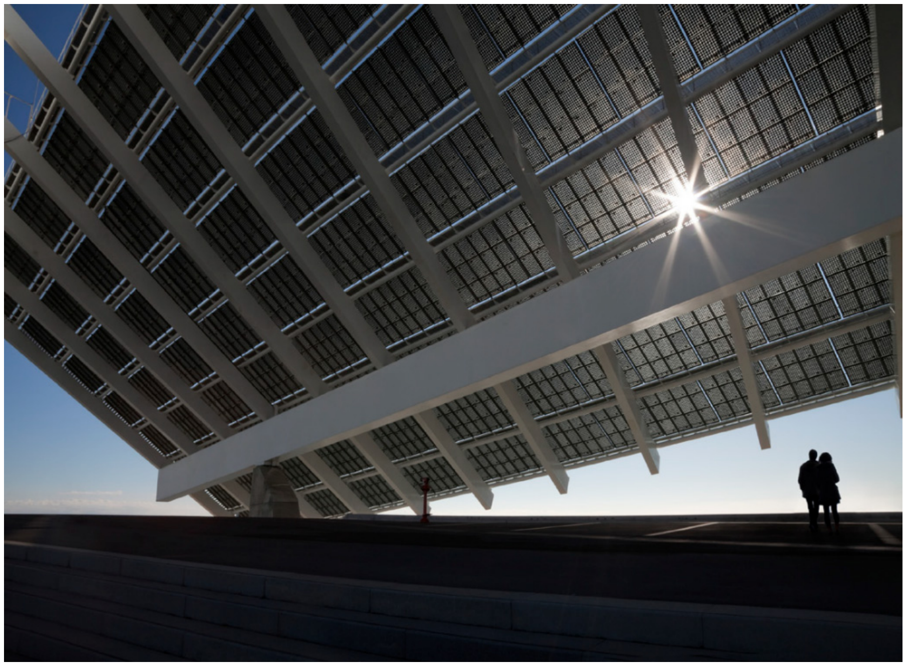
Vermont Solar Market Pathways



Volume 3

Barriers and Integration Brief

December 2016

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Vermont Energy Investment Corporation

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Preface

The growth of solar markets is part of an emerging trend toward a decentralized and well-networked energy system. Historically, electricity has been generated at large central power plants, with a one-way delivery of electricity to end users via transmission and distribution lines. Advances in solar energy, communications, and end use equipment are now contributing to the steady growth of distributed energy resources (DERs) and a more networked energy system.

Today, energy production and storage are more likely than before to occur at a customer's site. It is also increasingly possible to monitor, manage, and control customer energy in new ways that can help provide greater convenience, enhance energy performance, and lower costs. For example, new technology can sense when you or your visitors are approaching your home, and turns on your lights for you; and there are thermostats that "learn" your behavior patterns and adjust heating and cooling to match.

Volume 3 of the Solar Market Pathways Report looks in detail at issues with the integration of high levels of solar and other intermittent renewable resources into the electric distribution and transmission system. The majority of **Volume 3** material is based on research and on market and regulatory conditions existing in 2015 and reported in September of that year. These all continue to evolve rapidly. This preface to **Volume 3** offers an update on the September 2015 materials, to illustrate the several emerging trends in the past year.

Volume 1 (Summary Report) provides an overview of the project and recent results. **Volume 2** (Focus Area Briefs) is the initial research on the state-of-the-art of growing and high levels of solar generation. **Volume 3** (Barriers and Integration) documents potential problems with high solar generation. The discussions and research in the project were supported by scenario analysis. The team built a model of Vermont's total energy system with scenarios that vary the levels of efficiency, fuel switching, and renewables. The model quantifies demand, supply options, costs, and emissions. **Volume 4** (Methods) provides sources for inputs and more comprehensive results than provided elsewhere in the report.

As of late 2016, solar provides roughly 2.8 percent of Vermont's electricity generation.[1] The Vermont Solar Market Pathways Report and project assume that this value increases more than seven times, so that by 2025, solar resources account for 20 percent of Vermont's total electric generation supply. **Volume 3** examines the technical, regulatory, and business model issues and opportunities with this level of solar generation.

Highlights from **Volume 3:**

- **How much solar can be integrated into the electric distribution system** is an important and complicated question relevant with today's level of solar market saturation and more so in the future. There are locations on the distribution system where it will be expensive and / or difficult to host new solar capacity. However, other areas in the system can host new capacity without upgrades. The issues are complex and depends on interdependent factors such as the design and age of existing equipment, the amount of solar that is already present in a given area, the distance between customers), and the types of size, shape, and location of loads.

[1] With ~150 MW installed capacity, 167,000 MWh per year annual solar generation and ~6,000 GWh of annual electricity consumption (167,000 MWh / 6,000 GWh = 2.8%). Note that Certificate of Public Good (CPG) applications have been filed with the Vermont Public Service Board for more than 250 MW of solar capacity; with net metering rule changes taking place at the end of 2016, an increase in CPG filings before the end of 2016 is expected.

- Improved information is increasing—for example, through Green Mountain Power's (GMP's) Solar Map[2]—on **where the distribution system is most and least likely to be able host new solar capacity** without distribution system upgrades. This type of information, updated weekly, helps developers and customers understand where new applications could face additional costs and / or delays because of system constraints. Rapid market growth increases the need for this type of information.

- The range of **solutions to address potential system constraints** on hosting capacity for new solar is growing, and new solutions and strategies are likely to continue as areas of rapid innovation. For example, in addition to "traditional" upgrades to distribution system poles and wires, there are new options such as on-site storage, load building, and shaping or shifting aggregated load. Smart inverters and detailed forecasting of demand and renewable supply will also help. Physically, solar can be easily curtailed to deal with over generation, but that is bad for the project economics unless a few hours per year of curtailment allow a project to be installed where it otherwise could not. All of these strategies can be used to maintain or increase distribution system hosting capacity.

- Vermont's **revised net metering rules[3]** do not have caps limiting the amount of net metered solar capacity a utility can host. The new rules will lower the credit paid for net metering projects, and creates categories with different rates for projects of different types and sizes. As a result, the pace of net metered capacity is expected to slow somewhat, and to be directed toward more favorable sites. Sites with higher credits include pre-existing structures, disturbed land, or land adjacent to the customers who are consuming the power.

- Processing the quickening permit and interconnection applications, and keeping up with necessary system upgrades for them are expected, even with the new lower credit amount, to put some upward pressure on electric rates. The rate premiums offered for net metered systems will also contribute to additional costs for ratepayers. On balance, however, the Vermont Public Service Board anticipates that **the economic benefits of diversified and distributed solar justify the additional costs** associated with the revised net metering rules. Ongoing monitoring of the costs and market development will continue.

- **Distributed resource planning**—to identify preferred sites, technologies, and integrated solutions—can reduce costs, spur innovation, and provide better certainty for developers and technology and solution providers. Distributed resource planning is a complicated and involved process that will require investments and active participation and resources from several stakeholders. Striking an appropriate balance between strictly letting the market determine where, when, and what type of distributed resources are deployed, and using planning to shape the market, is an emerging regulatory and policy question in Vermont and other jurisdictions.

- The bulk power system provides the interconnection between Vermont's distribution utilities and the rest of the New England power grid. The impacts of Vermont's increasing solar generation are already visible to the Vermont Electric Power Company (VELCO), which owns and operates Vermont's

[2] "Solar Map," *Green Mountain Power*, accessed September 21, 2016, http://www.greenmountainpower.com/innovative/solar/solar-map/.
[3] Vermont Public Service Board, *Revised Rule 5.100 Pursuant to Act 99*, 2016, http://psb.vermont.gov/statutesrulesandguidelines/proposedrules/rule5100.

transmission system. The reduction of loads and / or the export of power during periods of high sunshine and low demand add a new dimension to system operations and planning. **Bulk power system planning** is considering increasing levels of solar and wind, and other distributed resources such as storage and load shaping, in forecasting and resource planning efforts.

- The amount of potential import and export required to support 20 percent of electric supply from solar by 2025 will result in **changes to the timing, scale, direction, and volatility of bulk power flows and market interactions.** Broadly speaking, they are not out of step with what is currently handled by the market and system infrastructure. Vermont is a small component of the regional market and does not have a strong effect on its operation. If solar markets in other states grow at the same pace as Vermont, the implications for bulk power system operations and markets will increase.

- The production of 20 percent of Vermont's electricity with in state solar by 2025 **reduces the amount of imported electricity**. This outcome meets the state's goals of increasing the share of total energy coming from renewable resources. It also makes Vermont more reliant on its own energy resources and encourages in-state economic development.

- Solar markets are part of a rapidly expanding field of distributed energy resources. Along with the evolution of technology in communications, sensors, and interconnection is a vibrant and rapid expansion of research and reports on how markets, regulations, and policies reflect the new opportunities. **Relevant additional research and reports** that have been issued, or were not referenced in the original draft of the September 2015 Market Barriers and Integration brief, are:

    - ***Distributed Energy Resources Rate Design and Compensation*:** A Manual Prepared by the National Association of Regulatory Utility Commissioners (NARUC) Staff Subcommittee on Rate Design, November 2016. This document examines issues and strategies for rate design for net metered solar and other distributed energy resources.

    - ***Smart Electric Power Alliance, The 51st State: Mapping the Dynamics of Energy Transformation*,** Conversations about the Evolution of the Electricity Marketplace from SEPA's 51st State Phase II Summit, Denver Colorado, April 2016.[4] Phase II of the 51st State Initiative draws on a wide range of stakeholder perspectives ("roadmaps"), on how regulatory and markets might evolve. Vermont Solar Market Pathways was presented at the Summit as one of the Phase II Roadmaps.

    - ***Pacific Gas and Electric Company Electric Distribution Resources Plan,*** July 2015. This report is representative of how utilities in some markets, most significantly New York and California, have begun to create distributed energy resource plans that integrate solar, storage, demand response, electric vehicles, and other resources to meet future distribution and bulk power system needs. Appendix C of the Plan presents details on DER growth scenario methods and results, in a fashion that complements and informs the scenario modeling and regional applications of the total energy scenario modeling that has been conducted using LEAP software by the Vermont Solar Market Pathways project.

[4] "The 51st State: Mapping the Dynamics of Energy Transformation" (Denver, CO: Smart Electric Power Alliance, April 2016), http://www.sepa51.org/phaseII/51stState_PhaseII_SummitReport.pdf.

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Executive Summary

Originally released September 2015; copy edited December 2016 for consistency with subsequent work on the project

Vermont has state energy goals, codified in law and described in detail in the 2011 Vermont *Comprehensive Energy Plan*—essentially, to meet 90 percent of all energy needs via renewable sources by 2050. To meet these goals, the state must address the extent to which the various forms of renewable energy can be deployed.

Vermont Solar Market Pathways, the primary document to be produced by and for stakeholders of a U.S. Department of Energy SunShot Initiative award,[5] maps the steps for developing solar energy generation with sufficient scope to maximize the role of solar energy in meeting the state's goals.

Vermont Solar Market Pathways is based on detailed scenario analyses of future energy and supply mixes in Vermont. The first scenarios were completed during the first six months of the project. They provided the foundation for the next phase of the project, to examine the issues and barriers associated with obtaining 20 percent of Vermont's total projected electric generation supply from solar by 2025.

Developing comprehensive solar pathways, similar to the one being created for Vermont by this project, is expected to 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, the approach of *Vermont Solar Market Pathways* will help policy makers, local planning commissions, and the market understand both the potential for, and the potential barriers to, an advanced solar market. This understanding will improve the chances for sustained market growth and investment.

This brief is a critical element of that mapping exercise, because it identifies and discusses the major technical, policy, regulatory, and market barriers to solar's ability to provide this level of contribution to the state's energy mix. During the coming phases of the project, the issues and market barriers identified in this brief will be prioritized for in-depth analysis, and will inform scenario revisions and the final *Vermont Solar Market Pathways.*

Three initial policy and market scenarios provide the basis for examining solar energy's potential to meet the goals:

1. Business as usual (Reference scenario);
2. A "90 x 2050_{VEIC}" scenario that VEIC developed and which meets the State's *Comprehensive Energy Plan* goals of obtaining 90 percent of total energy from renewables by 2050. The VEIC subheading on this scenario should be understood to indicate that it has been developed by VEIC, but with significant input from project stakeholders.
3. The Solar Development Pathways (SDP) scenario meets the 90 x 2050 target and increases solar development so that 20 percent of electric generation supply comes from solar by 2025.

The 90 x 2050_{VEIC} and SDP scenarios assume the anticipated increase in the installations of cold-climate heat pumps and sales of electric vehicles, along with continuing improvements in energy efficiency across all sectors.

The SDP scenario initially allocates solar into three types of project classes. Rooftop or ground-mounted systems at individual customer sites are expected to account for roughly 300 MW of capacity by 2025. Community solar, which will be primarily ground mounted, but will also occupy some rooftops, is expected

[5] Award DE-EE-0006911, to the Vermont Energy Investment Corporation; David Hill, Ph.D., Principal Investigator.

to account for 300 MW. Utility scale ground-mounted systems with wholesale power purchase contracts are expected to account for 400 MW of new capacity.

The level of solar growth in the SDP scenario reflects approximately 10 times more solar than is currently connected or in project development. This level of growth raises technical, regulatory, policy, and market issues and barriers. The initial analysis of the net demand resulting from 1 GW of installed solar capacity shows negative net demand in times of high solar output, and lower demand for 3 percent of the hours in the year. This analysis is by nature very highly aggregated. The nature of net demand is very specific according to the loads, and according to the distribution system infrastructure, equipment, and controls for each feeder, substation, and region.

This project is not designed or intended to replace detailed system impact reviews and planning, but rather to provide a framework for coordinating and prioritizing methods for addressing the technical issues raised by this level of solar market development. During subsequent phases of research, the Project Team undertook several more detailed analysis related to the technical issues. Results can be found in **Volume 1**.

This brief also addresses the expected regulatory and policy issues that will be priorities for further investigation in the next research phase. Finally, this brief discusses potential business model and market-related barriers. In all cases, the Project Team's objectives in this brief are to provide solid information and analysis to support further discussion and research with partners and stakeholders, to enhance the final *Vermont Solar Market Pathways* report, scheduled to be completed in 2016.

Introduction

This brief presents the findings and recommendations on how to address barriers and issues related to high levels of solar integration in Vermont's energy economy. The brief is a deliverable in the comprehensive scope of work and project objectives for the Vermont Solar Market Pathways Project supported by Department of Energy's SunShot Initiative.

VEIC, along with our partners—the Vermont Public Service Department and the Regulatory Assistance Project (RAP)—are working with a broad range of stakeholders to develop a comprehensive plan to address how Vermont can obtain 20 percent or more of its total electric energy requirements from solar energy by the year 2025. During the first 9 months of the project, the Project Team has held three large meetings, attended by more than 85 stakeholders representing Vermont's energy, planning, legislative, and regulatory communities.

The project has a 3-year work plan, and the market barriers and integration brief is a deliverable at the end of the third quarter.

Objectives

Vermont has recently experienced rapid growth in solar energy installations. There is increasing public interest, investment in—and in some cases, opposition to—examining the potential for solar to make more significant contributions to meeting Vermont's *Comprehensive Energy Plan* targets.

Our objectives are to identify issues and barriers that will arise as solar energy significantly increases its presence in the state. The scenarios developed in early phases of the project have been designed to provide an analytic framework that includes both supply and demand resources, for what is required to get 20 percent of Vermont's electric energy supply from solar by 2025.

This is an increase of more than 10 times what is currently installed. Before policy makers, utilities, consumers, ratepayers, businesses, and other stakeholders in Vermont can be expected to support or oppose this level of solar development, it is important to provide accurate and up-to-date information about what the barriers, issues, benefits and costs of this level of development entail. This Barriers and Integration Brief identifies and provides recommended methods for examining the issues and barriers. Later work in the project will quantify the costs and benefits with the Solar Development Pathways scenario, in comparison to reference cases.

Methods

Vermont Solar Market Pathways will be based on comprehensive scenario modeling of the supply and demand sectors of Vermont's energy economy. The Project Team is including transportation and thermal fuel use, as well as electricity use, within the scenario planning so that the full impacts of higher levels of renewables and of reaching Vermont's *Comprehensive Energy Plan* targets can be fully understood.

The energy scenario modeling in the project is being conducted with the Long Range Energy Alternatives Planning (LEAP), a planning system developed by the Stockholm Environment Institute.[6] The LEAP system provides a structured accounting framework for developing and comparing internally consistent energy future scenarios. It offers excellent visual reporting and graphics to help stakeholders understand the implications of various options.

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[6] Heaps, C.G., *Long-Range Energy Alternatives Planning (LEAP) System*, version 2015.0.24 (Somerville, MA, USA: Stockholm Environment Institute, 2016), https://www.energycommunity.org/default.asp?action=introduction.

VEIC analysts have worked with Team Partners and stakeholders to develop initial scenarios during the first nine months of the project. These reflect current and recent historic energy use, and project future demand and supply based on state and utility plans. The scenarios will continue to be reviewed and refined as the project continues, and they are now providing the basis for additional complementary analyses and discussions such as the work conducted for this integration and market barriers brief.

Document Overview

This brief provides guidance to stakeholders of Vermont Solar Market Pathways, a project funded by the U.S. Department of Energy within the SunShot Solar Market Pathways Program.

The project itself coordinates and facilitates a broad stakeholder process and develops a stakeholder-informed—and where possible, an agreement-based—solar development plan for the State of Vermont. The resulting document, *Vermont Solar Market Pathways,* will play an important role in putting Vermont on target to meet its ambitious *Comprehensive Energy Plan* (CEP) goal of obtaining 90 percent of total energy supply from renewable resources by 2050. *Vermont Solar Market Pathways* will specify the necessary policy, regulatory, and market conditions in 2020 (5 years ahead) and 2025 (10 years ahead) for allowing distributed and central solar generation to fulfill this role. Informed by this broad objective, VEIC expects *Vermont Solar Market Pathways* to examine the requirements and constraints with 1+ GW of PV deployed in Vermont by 2025.

In this brief, the Project Team addresses Vermont's long-term economic realities under several key scenarios for a high-saturation solar future that is also consistent with and contributes to the overall energy supply goals of the CEP. This brief looks at the barriers of integrating this level of solar energy into the electric generation mix, and recommends specific steps for the stakeholders and Project Team to take during the next phases of research to address these issues.

Project Context

The Program advances solar deployment across the United States, while concurrently addressing ways to reduce the non-hardware ("soft") costs of solar energy deployment. *Vermont Solar Market Pathways* is one of 15 awarded projects under the Program, which seeks effective approaches for strategic plans to expand solar electricity use for residential, community, and commercial properties.

The lessons learned from these projects will offer replicable examples for deployment throughout the United States. This is considered "an important step towards making solar deployment faster, easier, and cheaper across the country," a major goal of the SunShot Initiative.

In general, comprehensive solar development pathways strategies and plans are expected to provide greater certainty to the development, planning, and investment communities. This certainty is expected to help lower the soft costs associated with solar energy. Also by sharing experience and approaches to identifying and addressing barriers to high levels of solar, plans such as that being undertaken by this project will also help lower the costs of addressing these barriers.

Vermont Energy Future Scenarios

Initial Supply and Demand Scenarios through 2050

Three scenarios of Vermont's energy future have been developed to support the stakeholder discussions and process under the project:

Reference scenario: "Business as usual" (BAU), similar to today, but it assumes more efficient cars due to Corporate Average Fuel Economy (CAFE) standards and expanded use of natural gas. It is based on the BAU scenario of the Vermont *Total Energy Study* (TES).[7] The Project Team revised the model to slow the growth of natural gas after the cancellation of a second phase of a pipeline project. State regulators have since held hearings to decide whether to reopen and possibly revoke the Phase 1 permit, because of new cost estimates that are nearly double the ones made available during the initial permit application review.[8]

90 x 2050$_{\text{VEIC}}$ scenario: Stronger efficiency 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.[9] The efficiency gains include electrification of space and water heating, and transportation. This scenario greatly lowers the total energy demand, while increasing the amount of electricity consumption.

Solar Development Pathways (SDP) scenario: Very similar to 90 x 2050$_{\text{VEIC}}$ but with more solar, accounting for more than 20 percent of electricity by 2025 and over 30 percent by 2050.

End Use Efficiency

Efficiency is widely recognized as the most cost-effective and lowest-impact way to reduce greenhouse gas (GHG) emissions. Vermont has a strong history of effective electrical efficiency programs and is moving toward a total energy perspective that can expand those results to the thermal and transportation sectors. The effectiveness of these programs causes a downward trend over time in the Reference scenario, shown by the dashed line in **Figure 1.** The demand in the SDP scenario drops more dramatically, shown by the colored areas in **Figure 1,** particularly in the residential and transportation sectors. The total demand falls by about 35 percent from 2010 to 2050, assuming the State's continued progress on improving efficiency across time.

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[7] "Total Energy Study: Final Report on a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals" (Montpelier, VT: Vermont Department of Public Service, December 8, 2014), http://publicservice.vermont.gov/publications-resources/publications/total_energy_study.

[8] Pat Bradley, "Vermont Public Service Board Holds Hearings On Pipeline Project" (Albany, NY: Northeast Public Radio (WAMC), June 24, 2015), http://wamc.org/post/vermont-public-service-board-holds-hearings-pipeline-project.

[9] "Total Energy Study: Final Report on a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals."

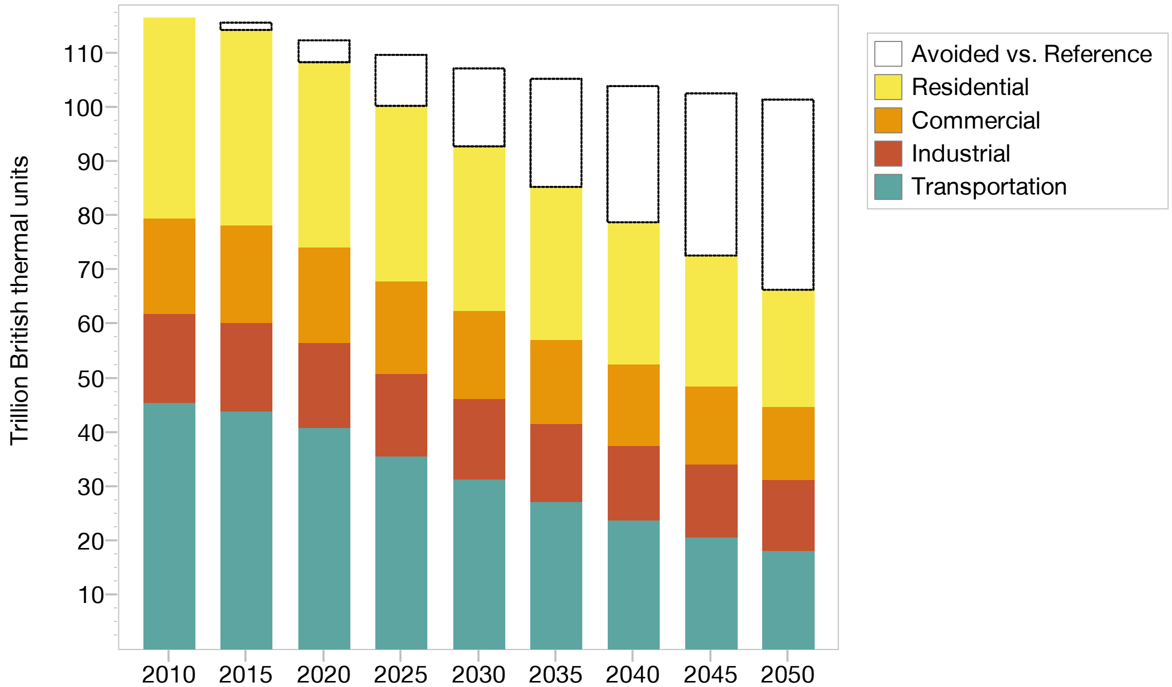

Figure 1. Energy demand by sector, 2010 through 2050, by energy use sector in Vermont.

Electric Supply

In the Reference scenario, electricity supply is determined by the contracts that the distribution utilities held at the end of 2013. **Figure 2** shows the largely flat contracts for hydropower, solar, wind, farm methane, and wood. Nuclear drops off sharply by mid-2015 with the closure of Vermont's only nuclear power plant. The remaining nuclear is imported from regional plants. With no significant new renewables or contracts, the state would rely increasingly on importing electricity from the New England grid, the supply of which is primarily generated with natural gas. As the timeline extends closer to 2050, more gas is required as electric demand rises with projected increasing population and economic activity, and because of a small shift toward electrification of buildings' thermal needs and transportation.

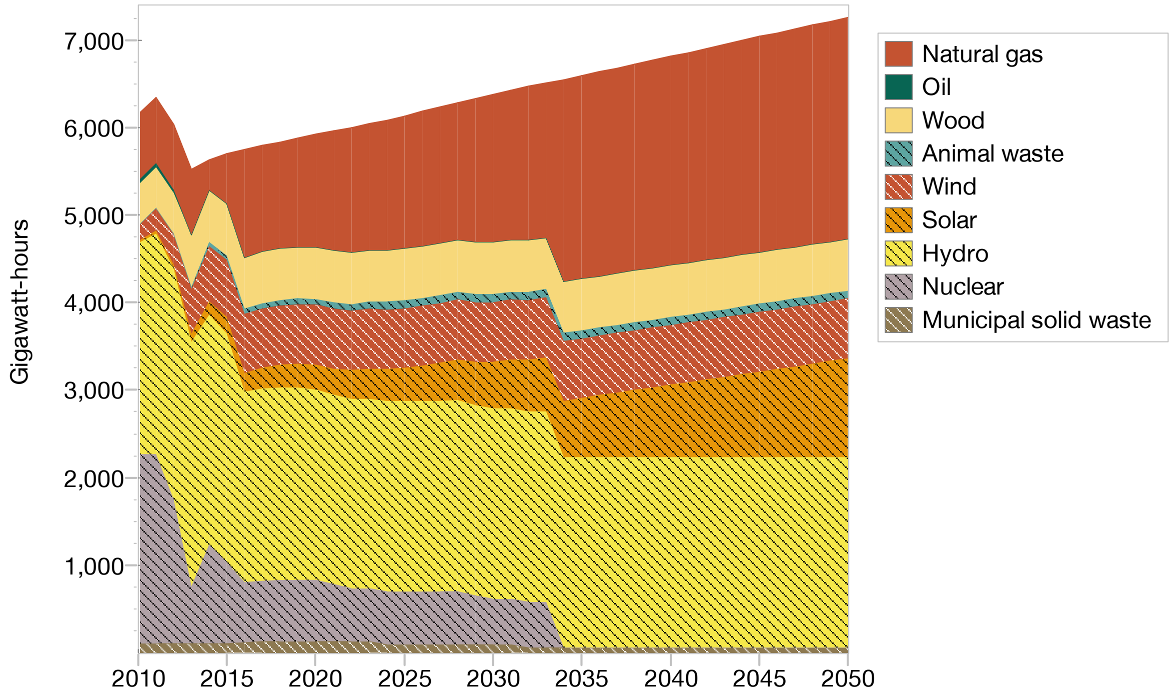

Figure 2. Electric supply allocations in the Reference scenario, through 2050.

The 90 x 2050$_{VEIC}$ and SDP scenarios assume quicker adoption of heat pumps and electric vehicles, both of which are expected to result in twice as much growth in electricity consumption. Sources of electricity in these scenarios are shown in **Figure 3** and **Figure 4.** Both assume additional wind, hydro, and solar in the electricity supply. Some of the hydropower is assumed to be imported from Hydro-Québec; all other renewables are within Vermont. These assumptions diverge from the TES, which assumes more wind generation from turbines sited mostly outside Vermont, and less hydropower.

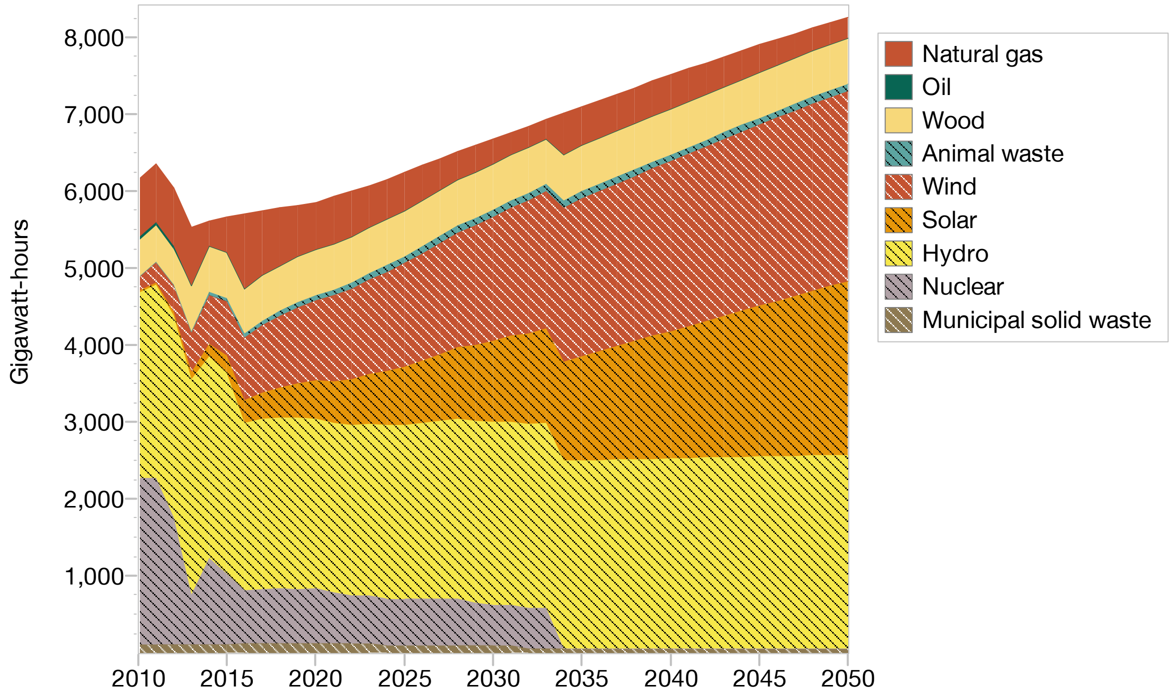

Figure 3. Electric supply in the 90 x 2050VEIC scenario, through 2050.

The SDP differs from the 90 x 2050VEIC by assuming solar exceeds 20 percent of generation by 2025, and 30 percent by 2050. The dispatch model correspondingly reduces wind and hydro.

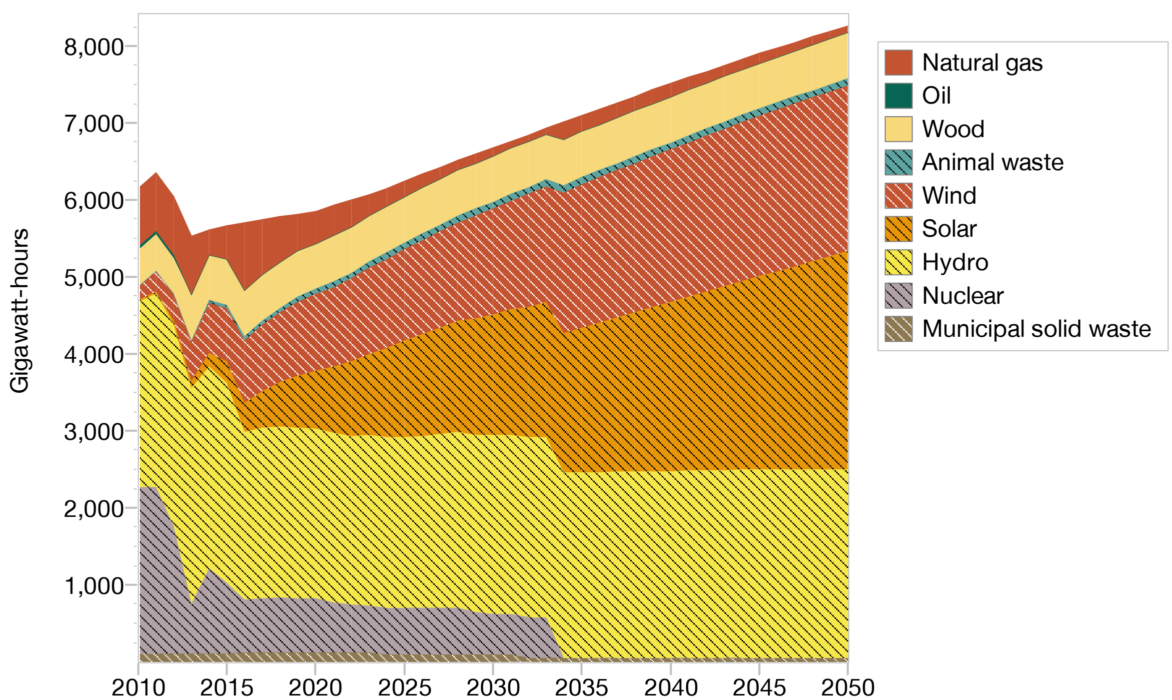

Figure 4. Electric supply in the SDP scenario

Figure 5 shows the difference between the SDP and Reference scenarios. The clear difference is the proportion of solar, wind, and hydro, instead of natural gas.

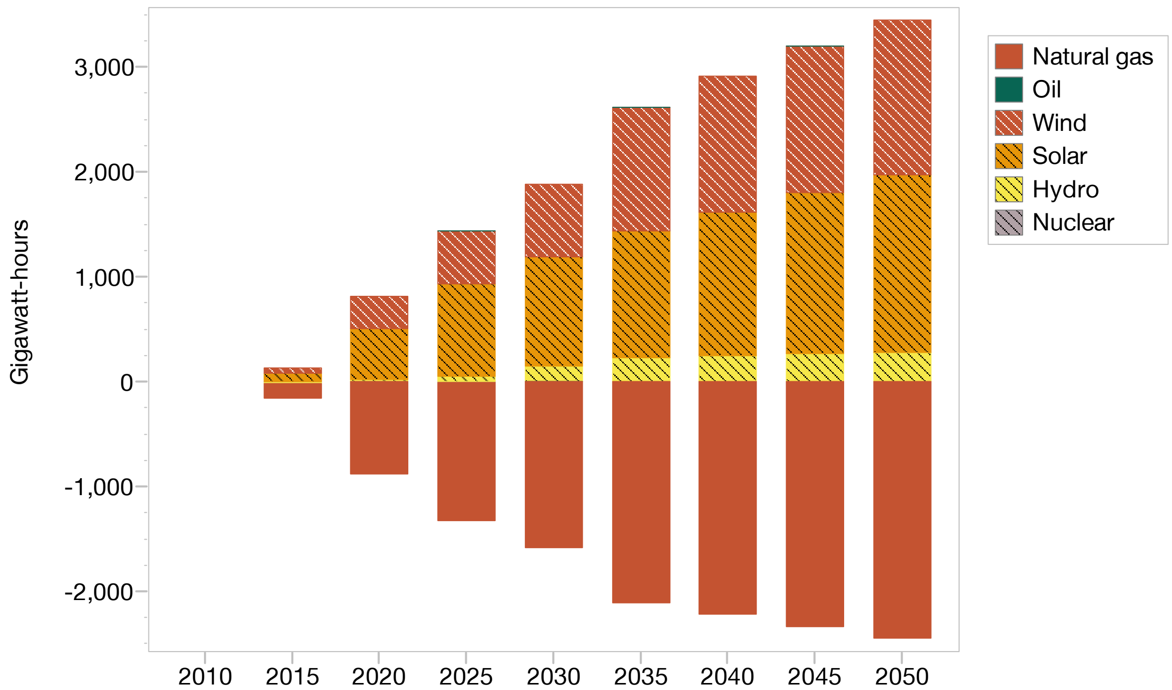

Figure 5. Difference in electric supply between the SDP and Reference scenarios.

Solar and Other Key Metrics

The quick growth of solar and other renewable forms of electricity generation is partially driven by and drives the electrification of end uses traditionally served by fossil fuels. Vermont is experiencing quick growth of electric cold-climate heat pumps for heating and cooling, and of electric vehicles (EVs). Anecdotal evidence suggests that people who adopt these technologies do so to rely on clean electricity, or they adopt solar to cleanly fuel their new heater or car. A local weekly newspaper, *Seven Days,* ran an article last January about a VEIC employee who installed a heat pump and solar panels in an existing home, with the intention to achieving a zero energy home.[10] Further, several Vermont companies—such as King Arthur Flour[11] and Green Mountain Power, as shown in **Figure 6** and **Figure 7**, respectively—are offering their employees solar charging for electric vehicles.

[10] Amy Lilly, "Retrofitting: Saving Energy (and Environment) in a 1950s House," *Seven Days*, January 7, 2015, http://www.sevendaysvt.com/vermont/retrofitting-saving-energy-in-a-1950s-house/Content?oid=2500132.
[11] "King Arthur Flour Charging Station," *Green Energy Times*, December 15, 2013, http://www.greenenergytimes.net/2013/12/15/king-arthur-flour-charging-station/.

Figure 6. A Tesla charging at King Arthur Flour Company, in Norwich, Vermont.[12]

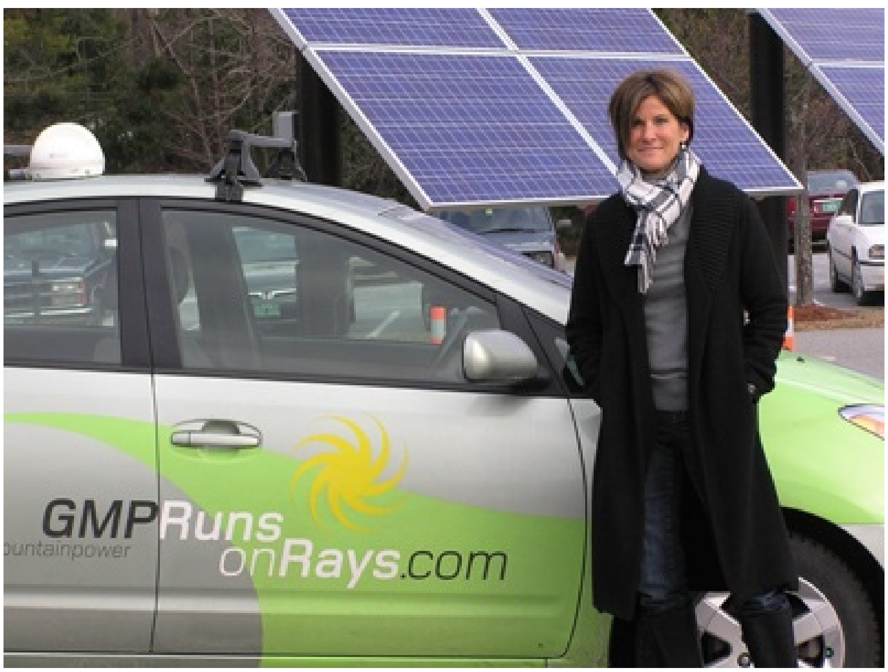

Figure 7. Green Mountain Power CEO Mary Powell with a company EV, charging with solar.[13]

Table 1 shows the expected growth of solar, EVs, and heat pumps through 2025. Each of these technologies is currently seeing exponential growth. It is noteworthy that there is nearly as much solar in permitting now, as the current installed capacity.

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[12] "King Arthur Flour Charging Station."

[13] James Ayre, "Green Mountain Power Is Perfect Example Of How Utilities Can Embrace Distributed Renewables," *CleanTechnica*, July 16, 2014, https://cleantechnica.com/2014/07/16/green-mountain-power-perfect-example-utilities-can-embrace-distributed-renewables/.

Table 1. Increasing use of solar energy and electrification

Type of application	Units	2010	2025
Behind-the-meter PV	MW	13	300
Community solar	MW	0	300
Utility scale PV	MW	5	400
Electric vehicles	Vehicles	10	33,000
Heat pumps	Households	0	54,000

This growth is strong. Concurrently, there is strong support for clean energy among Vermonters and in the Statehouse. During the 2014-2015 session, the Vermont General Assembly passed Act 56, which includes Renewable Portfolio Standards (RPS; referred to in the law as a Renewable Energy Standard) requirements of 55 percent in 2017 and 75 percent in 2032.[14] The Project Team's supply model shown in **Figure 4** would meet those targets. The Act includes transportation and heating fuels within the RPS. Because electric utilities bear the responsibility of meeting the targets, they may support electrification as a path that brings additional end uses into their business models. The State and VEIC support electrification, instead of imported combustion fuels, for the emissions, safety, and local economic benefits.

[14] Anthony Klein and Rebecca Ellis, *H.40*, 2015, 40, http://legislature.vermont.gov/assets/Documents/2016/Docs/BILLS/H-0040/H-0040%20As%20Passed%20by%20Both%20House%20and%20Senate%20Official.pdf

Barriers and Integration

This study investigates the requirements and possibilities of transitioning to an advanced solar economy, where 20 percent of Vermont's total electric energy requirements are met by solar. As prices for solar installation have continued to decline, and policy objectives such as the targets set by Vermont's *Comprehensive Energy Plan* are codified, it is necessary to examine the extent to which solar and other renewable resources can be safely and reliably connected. It is also important to determine if this can be done economically.

Space Required for Solar

Vermonters appreciate the "working landscape" of the state. Open agricultural land in valleys offers wide views of the mountains and lush greenery that attract visitors and those who want to move to the state. There is strong opposition to energy projects that encroach on wooded or agricultural land. Solar can affect agricultural land and thus may be sited near populated areas. In Vermont, solar projects are primarily subject to State regulation, with sometimes limited reference to local zoning rules or review. To address concerns about quick solar development with sometimes-limited local input, the Legislature created the Solar Siting Task Force in Summer 2015. The *Vermont Solar Market Pathways* project defers to the Task Force for leadership on siting, but the Team is cognizant of the concerns and seeks to minimize the impact of solar on agricultural land, open space, or forests.

Rooftop systems do not require any open space, and most systems on commercial roofs are not visible from the ground. The Team's Policy Brief on net metering estimated the rooftop potential at 375 MW. The Team assumes that not all viable roofs—those that have little to no shade and can carry the weight of PV panels—will receive solar installations. Therefore, the Team has assumed a lower value: 300 MW for rooftop solar by 2025. Reaching such a high proportion of the potential might require innovative models such as an extension of the community solar concept, where interested people lease space on the roofs of uninterested businesses and homeowners.

A carefully refined version of the rooftop potential would benefit the project and help allay concerns about the land impact of solar. The National Renewable Energy Laboratory (NREL) has a method using LiDAR data to find suitable rooftop space. The Project Team submitted a request to NREL's Technical Assistance Center to map all of the Vermont LiDAR data available to them. The response to the request offered information on 12,000 buildings near Montpelier, the state capital. The analysis showed the percentage of buildings and areas large enough to support a solar system at various module efficiencies. For example, 100 percent of large buildings, 52 percent of medium buildings, and 37 percent of small buildings have sufficient south-facing, unshaded roof space for solar.

Although these data are useful, Montpelier is just one of Vermont's 255 municipalities, and has only 8,000 residents, ranking 13th in the state for population. By comparison, the state's biggest city, Burlington, is approximately 5 times larger. A much greater portion of the state is covered by some type of LiDAR than what NREL used. The Team is considering either processing those data to make it possible for NREL's method to be applied statewide, or extrapolating the Montpelier results to other hilly and wooded parts of the state.

Vermont's group or virtual net metering legislation allows anyone within a utility service territory to benefit from a shared renewable energy system in that territory. These types of system are growing quickly, given the combination of economy of scale and retail credit for the energy generated. The Project Team's model assumes 255 MW of ground-mounted community solar and 45 MW mounted on structures or over parking lots. An example of this type of installation that takes up virtually no usable space is at the Unitarian Universalist Society in Burlington, as shown in **Figure 8**.

Figure 8. Solar panels installed over parking spaces at the Unitarian Universalist Society in Burlington.

The Team expects the largest amount of capacity will be utility scale ground-mounted systems. By 2025, the Team anticipates 400 MW of this type of installed solar, with the energy sold wholesale to the utilities. Although most of the utility scale solar that has been installed to date has been 2.2 MW systems under Vermont's Standard Offer Feed-in Tariff (FIT) program, the Team expects larger systems in the future. Project stakeholders initially decided on 5 MW as a likely maximum, so that projects could go through state permitting without additional requirements from the regional transmission organization, ISO New England. However, the transmission operator, Vermont Electric Power Company (VELCO), is aware of three 20 MW projects considering applications.[15]

Overall, the total anticipated level of utility scale systems in the SDP scenario would cover approximately 3,200 acres. Combined with the ground-mount community systems, 655 MW of ground-mounted solar could require over 5,000 acres of land, or 0.09 percent of the state's land surface. It is important to recognize that this amount of land requirement is very small in comparison to other land uses in Vermont, and to acknowledge the State and all stakeholders have a clear interest in the proper siting and permitting of solar in order to minimize adverse impacts.

[15] Personal communication, August 27, 2015.

Negative Net Load and Ramp Rates

The California "duck curve" 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, Power Supply Project Manager at Green Mountain Power and an active stakeholder on this project, used hourly forecasts and simulations to create the Vermont "Champ" Curve shown in **Figure 9**. "Champ" is a mythical creature residing in Lake Champlain, the state's major body of water. The creature is rumored to have the body of an Elasmosaurus.[16] Champ's belly goes below zero between 2025 and 2030 as the installed capacity increases beyond 1 GW.

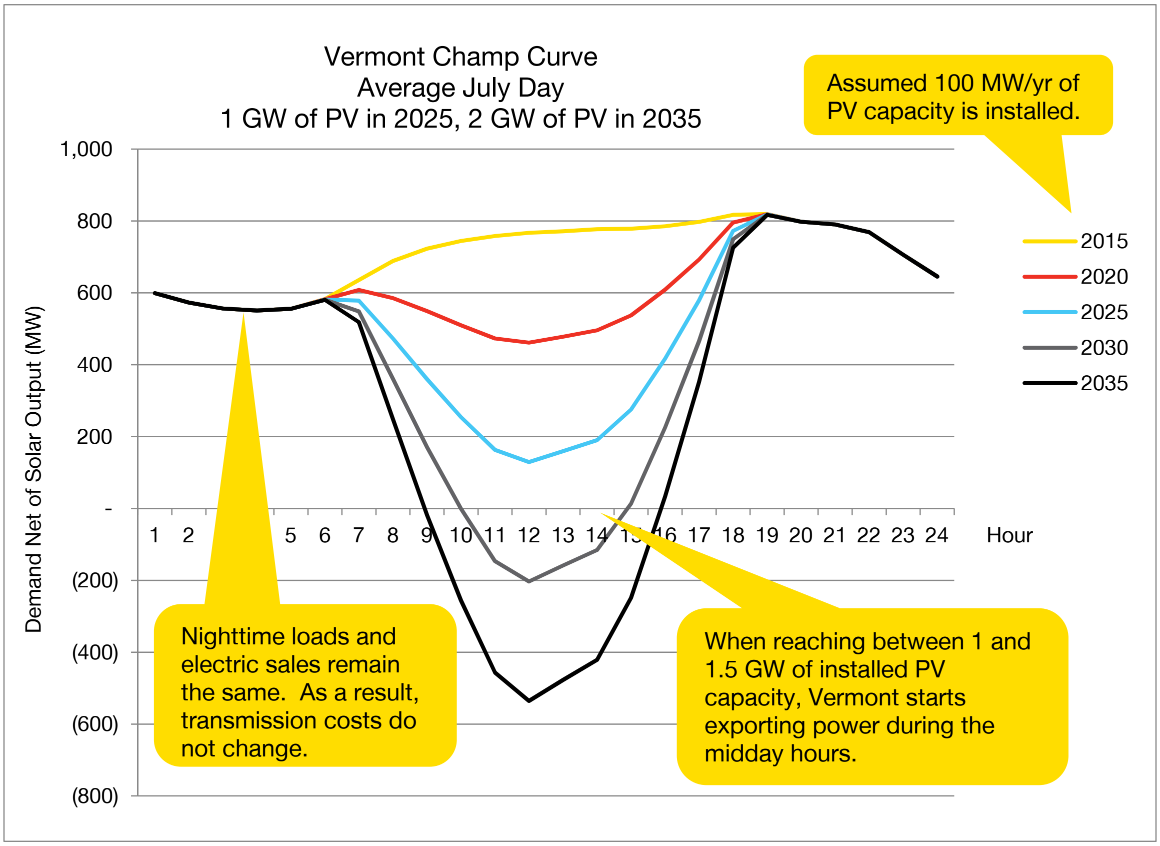

Figure 9. Vermont Champ curve, showing the net load on a July day.

The potential for over-generation is a challenge. **Figure 9** considers only solar generation, so other generation would also need to be off during those hours of negative load. Ramping down hydro 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 event, or else utilities will 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.

To determine how much energy needs to be shifted, stored, or exported—and how often—we used Shawn Enterline's data to look at the entire year of 2025. **Figure 10** shows the hourly load, net of solar, in Vermont. It shows 259 hours of negative net load.

[16] Robert E. Bartholomew, *Untold Story of Champ, The: A Social History of America's Loch Ness Monster* (SUNY Press, 2012).

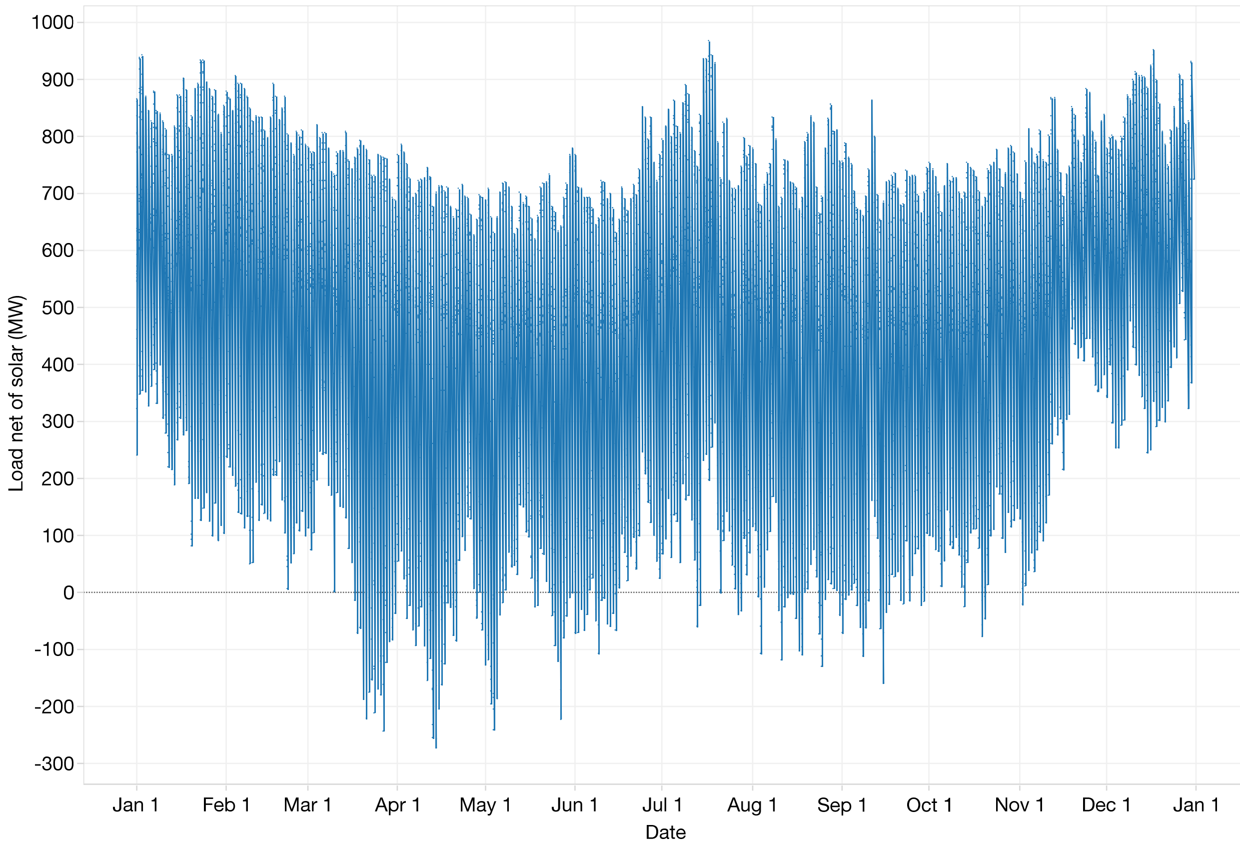

Figure 10. Hourly load, net of solar, across 2025.

The storage and demand response teams now have these data. They are conducting quantitative analysis to determine how much of what type of storage or load shifting could occur, based on the storage capacity (MWh), time (minutes to hours), and power (MW). Shorter time scales such as frequency regulation are considered as well, but require finer data.

Why Might High Levels of Solar Generation Cause Problems?

The following section reviews the literature, and recommends key questions to help shape the next stages of scenario development and analysis for the Vermont Solar Market Pathways project. The inter-relatedness is significant; however, we use three categories to structure the review: (1) technical considerations, (2) policy and regulatory considerations, and (3) business model.

Innovation, research, and creativity are rapidly emerging and co-evolving in each of these areas, amid the backdrop of an existing century-old system for the generation and delivery of electric power services. This brief provides a condensed literature review, and makes initial recommendations on how to analyze and address the high-priority topics that are considered tractable within the scope and resources of the Vermont Solar Market Pathways project.

When we look at how high levels of solar can be integrated into the existing, or historical, electric system, two fundamental elements should be considered. Solar is variable and a distributed energy resource (DER). Most integration issues arise in relation to one or both of these characteristics of solar as an electric generation resource.

First, solar is variable and intermittent. It does not generate power at all hours of the day; the amount of solar generation varies throughout the year; and when a cloud passes over an array, the amount of generation can be highly variable over the course of minutes and even seconds. Because electric systems need to maintain balance between supply and demand, the variability and intermittency of solar create challenges that are not present with steadily operated and dispatched generation sources that can more easily maintain a constant output level. Wind also shares this variability, to the extent that it has the same seasonal, daily, and short-term fluctuations from weather.

Second, solar is typically a distributed resource. Thus, the location of solar generation on the electric grid and the flow of power from a solar generation source or other "distributed energy resources" are more complex than the historical pattern of centralized generation. That is, centralized generation is delivered via one-way power flows from distribution substations to loads.

Many specific issues and barriers to high solar integration arise from these two fundamental drivers. Advancing technologies, and market and regulatory solutions exist (or are being developed) that reduce or eliminate most of these issues. In the following sections, the Project Team highlights the barriers that are most commonly identified, and through a condensed literature review, examines ways in which these issues might be addressed in Vermont.

Technical Considerations: Distribution System Impacts

In February 2015, the Electric Power Research Institute (EPRI) released *The Integrated Grid: A Benefit Cost Framework*.[17] The report acknowledges that the electric system is "evolving to accommodate changes in the way that electricity is produced, delivered, and used." Technical and market advances now enable distributed energy resources—primarily photovoltaic generation, storage, and demand response—that promise to have profound impacts on the operation of the electric system. These resources also promise to have strong effects on the scale and direction of future system growth and investment. In theory, a transformed electric system that takes advantage of the potential for highly networked aspects of distributed energy resources can enhance value, offer greater flexibility, lower costs, and increase resilience.[18]

Similar to this brief, the EPRI report has sought to create a comprehensive framework for assessing the costs and benefits of a system that safely and reliably integrates a high level of distributed energy resources. That is to say, the EPRI report discusses the frame, method, and elements for such assessments. It does not actually conduct a quantified cost-benefit analysis of a specific, or even a generalized, example.

This stage of the Vermont Solar Market Pathways work plan is similar. The Project Team is in the process of developing a framework for assessing the costs and benefits of integrating a high level of solar and other DERs into Vermont's energy economy in the coming decade. This framework will be the basis for the cost-benefit analysis of Vermont Solar Market Pathways scenarios as the study progresses. If successful, the framework will also offer a helpful structure for further, more detailed studies in the future.

[17] K. Forsten, "The Integrated Grid: A Benefit-Cost Framework" (Electric Power Research Institute, February 2015), http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004878.
[18] Paul De Martini and Jeffrey Taft, PhD., "Value Creation through Integrated Networks and Convergence" (Caltech Resnick Institute and Pacific Northwest National Laboratory, February 2015), http://smart.caltech.edu/papers/ElectricNetworksConvergence_final_022315.pdf.

The EPRI report considers the impacts and solutions for distributed energy resources on the grid. The assessment has two parts, the first of which is the ability of the distribution and sub-transmission systems[19] to host distributed energy resources in a reliable and safe fashion.

The hosting capacity of individual distribution circuits depends on several factors. Further, there are industry-specific tools for conducting distribution circuit analyses. As distributed energy resources are added to a system, an ongoing assessment of the capacity of the distribution system and individual feeders to host additions needs to be conducted. The EPRI report defines *hosting capacity* as the amount of distributed energy resources that a feeder can support under its existing topology, configuration, and physical characteristics.[20] As distributed energy resources are added to a feeder, the most common constraints that arise are related to four categories of root cause: impacts on voltage, protection schemes, energy, and thermal capacity.[21] The increased saturation of DERs on a feeder can provide benefits and create situations that require mitigation costs or changes to operational procedures.

The outcomes of well-designed and executed distribution study analyses will provide the following findings for substations and individual feeders:[22]

1. **Feeder-specific hosting capacity.** Individual feeders and locations along an individual feeder will have varying ability to host DER without violating voltage and protection scheme thresholds. On any given feeder, there are often additional segments in which the hosting capacity is higher than on other portions of the feeder. Generally, locations that are closer to a substation on a radial feeder will have a higher hosting capacity than locations at the end of a feeder line. The presence of DER 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 DER with appropriate controls can be used to alleviate the situation.
2. **Substation-level hosting capacity.** A substation serving individual feeders offers collective impacts that in turn help to inform analysis of the bulk power system and analysis of overall supply adequacy and system reliability.
3. **Energy consumption and loss impacts.** The levels of DER on a feeder affect the loading of the feeder. This, in turn, translates into changes in overall energy consumption and distribution system losses. For example, the high end of voltage operating windows results in higher line losses. 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 to such situations are available, whereas in other cases more expensive changes in the system are required.
4. **Asset deferral.** The development of well-integrated DER can help to alleviate the need for distribution and substation capacity upgrades.

Examples of assessments of distribution system hosting capacities and analyses of distribution system impacts are becoming more common. In California[23] and New York,[24] distribution utilities are now required

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[19] The sub-transmission system consists of the substations, lines, transformers, controls, and communications that operate <=115kV transmission voltage. The transmission system in Vermont is owned and operated by VELCO, the distribution and sub-transmission systems are owned and operated by the distribution utilities.
[20] K. Forsten, "The Integrated Grid: A Benefit-Cost Framework."
[21] Ibid.
[22] Ibid.
[23] "Distribution Resources Plan," *California Public Utilities Commission*, July 1, 2015, http://www.cpuc.ca.gov/General.aspx?id=5071.
[24] "Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision," *New York State Department of Public Service*, accessed December 10, 2016,

to submit plans for investment and operation of the distribution system that explicitly considers how greater levels of distributed energy resources can be integrated.

Southern California Edison and the other major California investor-owned utilities now have online distribution mapping tools that indicate the hosting capacity for segments of the distribution feeder network.[25] In Vermont, Green Mountain Power has a system map that identifies areas of the network where three-phase power is available.[26] The California hosting capacity maps are examples of distribution system "heat maps" that identify areas in which interconnection problems are not likely. These maps also identify areas in which problems are probable, and where hosting capacity has been reached. The distribution hosting capacity mapping and analysis are replacing "rule of thumb" metrics, such as capping the DER on a circuit to a certain percent of the minimum circuit load.

NREL has conducted case studies of specific sub-transmission distribution feeders, where the size of a distributed photovoltaic system represents a high share of the feeder capacity.[27] These cases show where a simple rule of thumb for saturation on a feeder might have prevented or limited the size of new distributed generation. With solutions that involve staged energizing after an outage, dedicated express feeder lines to a substation, and the changing of settings on voltage regulators, the hosting capacities of the feeders in the case studies ranged from approximately 50 percent to over 90 percent of maximum feeder loads.

Depending on the situation, solutions that enable the integration of higher levels of DER are available. These range from modifications to existing operational practices and equipment settings, to the upgrading and installation of new distribution system infrastructure such as conductors, transformers, or substation equipment. Further, changes to protection systems and the use of advanced inverters that can provide active and reactive power control can help alleviate potential problems. They can even be used to improve system efficiency and power quality. Standards for advanced inverters are under development through the process described in the IEEE 1547 Interconnection Standard for Distributed Generation.

The EPRI Integrated Grid Report documents the technology options for supporting greater levels of DER on the distribution system. These range from upgrades to conductors, feeders, substations, control equipment, and improved control and communications.[28] In Vermont, the utilities, the transmission system operator VELCO, and various working groups, are actively exploring the issues and potential solutions. Examples are the Rutland Grid Innovation project, Green Mountain Power's Solar Mapping and Rutland Grid Innovation Projects, the Vermont System Planning Committee, and the GMP Integrated Resource Plan (for example, annual peak load reviews for substations, and plans for voltage conversions).

Technical Considerations: Bulk Power System Impacts

The EPRI Integrated Grid report also addresses how to account for the costs and benefits of increased DER on the bulk power system, which comprises the transmission system above 69 kV,[29] and the

http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=14-m-0101&submit=Search+by+Case+Number.

25 Southern California Edison, "Southern California Edison's Distributed Energy Resource Interconnection Map," November 16, 2016, http://www.arcgis.com/home/webmap/viewer.html?webmap=e62dfa24128b4329bfc8b27c4526f6b7.

26 "3 Phase Service in Vermont" (Green Mountain Power), accessed December 10, 2016, http://www.greenmountainpower.com/innovative/solar_capital/3-phase-service-in-vermont/.

27 J. Bank et al., "High Penetration Photovoltaic Case Study Report," Technical Paper (Golden, CO: National Renewable Energy Laboratory, January 2013), http://www.nrel.gov/docs/fy13osti/54742.pdf.

28 K. Forsten, "The Integrated Grid: A Benefit-Cost Framework."

29 IEEE medium voltage is 69kV, the distribution and sub-transmission system in Vermont operate below 115kV.

generators that provide both the bulk power and ancillary services required to keep the system operating safely and reliably.

A growing number of bulk power and transmission level studies have been and are being conducted to assess the extent to which higher levels of renewable energy (primarily wind and solar) can be integrated on the grid. These are studies at the national level,[30] for the eastern[31] and western[32] interconnection regions, and for individual regional transmission operators.[33]

These assessments consider the impacts of increased variable (renewable) and distributed energy resources on the bulk power system, with respect to current and future planning needs. The EPRI report, which looks at the cost-benefit framework for an integrated grid, identifies the following categories of bulk power system impacts:[34]

- **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[35] provides a national-level visualization of scenario modeling illustrating the mapping of generation loads and transmission in a high renewable energy future.
- **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, impacts from the distribution and sub-transmission levels can be reflected up to the transmission level. Therefore, iterative and repetitive analyses and planning processes are often required for an integrated and comprehensive assessment.

In Vermont, distribution and transmission planning is coordinated among the transmission system owner, distribution utilities, efficiency utility, and other stakeholders via the Vermont System Planning Committee (VSPC). The Vermont System Planning Committee is a statewide collaborative process for addressing electric grid reliability planning.[36] The planning process and cycles used by the VSPC and its members reflect the interactive and iterative process of planning at the transmission level. This planning is informed

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30 Hand, M.M. et al., "Renewable Electricity Futures Study" (Golden, CO: National Renewable Energy Laboratory, 2012), http://www.nrel.gov/analysis/re_futures/.
31 Aaron Bloom et al., "Eastern Renewable Generation Integration Study," Technical Report (Golden, CO: National Renewable Energy Laboratory, August 2016), http://www.nrel.gov/grid/ergis.html.
32 General Electric International, Inc., "Western Wind and Solar Integration Study" (Schenectady, NY: National Renewable Energy Laboratory, May 2010), http://www.nrel.gov/grid/wwsis.html.
33 General Electric International, Inc., "PJM Renewable Integration Study" (Schenectady, NY: PJM Interconnection, LLC., March 31, 2014), http://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx.
34 K. Forsten, "The Integrated Grid: A Benefit-Cost Framework."
35 Hand, M.M. et al., "Renewable Electricity Futures Study."
36 "Planning for the Future of Vermont's Electric System," *Vermont System Planning Committee*, accessed December 10, 2016, http://www.vermontspc.com/.

by the assessment of non-transmission alternatives and distributed resources at the distribution and sub-transmission levels. It primarily involves efficiency, demand response, projected load growth associated with emerging electricity applications such as electric vehicles and plug-in hybrids, and cold-climate heat pumps. The work of the VSPC and VELCO are then reflected through market participation in ISO New England, the regional transmission operator.

Exploring Technical Solutions via this SunShot Solar Market Pathways Study

The range of technical issues and potential solutions is broad, and is fortunately accompanied by a similarly wide range of solutions. It is beyond the scope of the Solar Market Pathways Initiative and this project to comprehensively address the full span of these issues and solutions. However, it *is* possible to make concrete contributions, particularly by presenting some case studies and by helping to catalyze and coordinate discussion around the highest value and most critical opportunities and issues.

One way to delineate and prioritize technical issues is to categorize them according to scale. At one end, we have individual system components (single PV modules, circuit inverters, and controls); at the other end of the scale is the trans-regional interconnection. For Vermont, the latter is the Eastern Interconnection, which consists of more than 60,000 transmission level nodes. In between these two ends, we have micro-grids, distribution feeders, distribution substations, a sub-transmission network, the transmission network, bulk power balancing areas, and regional transmission pools.

For the Vermont Solar Market Pathways project, the Team anticipates exploring the extent to which individual systems affect the distribution feeder, up to the transmission level. The Team will place less emphasis on the scales of regional or trans-regional bulk system impacts. Given the relatively small size of Vermont's presence in ISO New England and the Eastern Interconnection, this allocation of emphases makes sense.

Strategically, approaches to technical impacts can be placed into three categories:

1. **Limited deployment,** or placing caps on specific or general deployment—for example, the legislated 15 percent net metering limit.
2. **Strategic deployment.** Controlling deployment through market or command mechanisms, to add capacity where it has the lowest costs or the highest values.
3. **Enhanced / upgraded distribution or transmission systems or both.** This might involve active load management and storage, as well as modifying the nature of the other power-generating sources or contracts. Within this category are the following subcategories:
    a. Enhancing or upgrading the inverter (via system-based controls)
    b. Load shaping, demand response, and energy storage
    c. Forecasting
    d. Contract or operational shaping of other supply sources to adjust the other balancing mechanisms

To reach the SDP goals and to contribute to the *Comprehensive Energy Plan* goals, we expect that strategies 2 and 3 will be required, and that there might be locations and regions in which only limited deployment associated with Strategy 1 will be applicable.

Next Steps

For the next phase of Vermont Solar Market Pathways, the SDP Team recommends to stakeholders the following next steps related to technical issues and barriers:

1. **Document and characterize the current state of distribution system information and hosting capacity analyses** across the participating utilities. The level of current mapping and how much has been, or is being, developed, to provide segment level hosting capacity for distribution systems should be compared and contrasted. It will be important to discuss areas in which efforts can be beneficially coordinated, and to explore the needs and possibilities for funding. A collaborative e-mail exchange of information, and one or two working group phone calls or short meetings should be adequate to address this task.

2. **Identify and document candidates for consideration as possible case studies**. The SDP Team will identify planned or possible activities related to distribution system operations, upgrades or analyses, demand response, integration of storage, and use of active inverter capacities. The Team will articulate options that represent the varying level of activity and resources across utilities of various sizes, and also seek examples of customer-side demand response resources (active control of water heaters would be one such example), and solutions implemented on the distribution and transmission systems and operations.

3. **Create work plans for detailed case studies**. Steps 1 and 2 will provide the information needed to compare and contrast priority issues and analyses to be selected for deeper analysis in the second year of this Solar Market Pathways study. The Team will discuss recommendations for case studies, with the stakeholder group. The Team will also identify priority issues that are likely to make substantive contributions, and that will enhance the scenario modeling and cost-benefit comparisons that are also scheduled for the first half of 2016. Case study recommendations will consider the need and potential for additional technical assistance or funding to support the identified research.

The most efficient processes for moving forward with these activities will be to seek opportunities to collaborate with other working groups and committees (for example, VSPC), and to coordinate some activities through the Vermont Solar Market Pathways Focus Area leaders.

After this Barriers and Integration Brief was published VEIC sought Technical Assistance for further distribution system analysis. The request was declined in part because of work being planned by the Department of Energy's Grid Modernization Laboratory Consortium. In Vermont, Sandia National Lab is leading this work under the Grid Modernization Initiative. The Vermont Solar Market Pathways team is participating in that project and is providing the results of our analyses, and reports to the grid modernization team.

Policy & Regulatory

In addition to the technical issues and barriers already discussed, *Vermont Solar Market Pathways* must also consider today's policy and regulatory issues and barriers, as much as it must consider issues that could arise as the market saturation of solar increases to meet this SDP scenario objective of providing 20 percent of electric energy generation by 2025. This section provides a brief literature review. It also discusses some key questions for Vermont and recommendations on how to address these issues in the next round of scenario development and analysis.

Policy & Regulatory Literature Review

Increasingly dynamic policy and regulatory discussions reflect the rapid pace of technology and market change in solar and other distributed energy resources. The consequent initiatives and debates vary widely. Some states have adopted or are considering initiatives to reverse, roll back, or put a moratorium on renewable portfolio standards, net metering, and the development of distributed resources.[37] Other jurisdictions are examining how new policies and regulations can be an important driver of and catalyst for transformation. California's distribution resource plans[38] and New York's "Reforming the Energy Vision" proceedings are examples of policy and proceedings taking the more transformational view of distributed resources.

Expanded renewable energy generation, at both the distributed and transmission levels, is also a well-recognized, primary strategy or building block for states and regions that are now designing plans to comply with the Clean Power Plan requirements issued by the Environmental Protection Agency.[39] The National Association of Clean Air Agencies commissioned a study from the Regulatory Assistance Project, which compiled options for implementing the Clean Power Plan.[40] The options involved improved integration of renewables into the grid; optimizing distribution and transmission system operations; and taking greater advantage of distributed resources such as storage, demand response, and customer-sited generation. These are all elements that regulators, planners, and policy makers should consider as they evaluate, design, and implement compliance plans.

New market structures, such as the energy imbalance market now operating in the California ISO, have begun to emerge. They are driven by current and future expectations or requirements for increasing the mix of variable renewable resources in the supply mix. The energy imbalance market provides a platform for generators or load sinks that can ameliorate differences between day-ahead and real-time forecasts of renewable energy generation, by providing the ability to source or sink power that results from the energy imbalance.[41]

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[37] Ohio and Arizona are examples of where recent policy and regulatory discussions have tended toward consideration of how it may be necessary to restrict contributions from renewable energy and distributed resources.
[38] California Assembly Bill 327 directed utilities to submit a distribution resources plan to the California Public Utilities Commission by July 1, 2015. Stakeholder working groups and comments on these plans are underway as this brief is being drafted. The filed plans provide insight into the utilities broad DER strategies and recommend specific pilots for Commission review and approval. According the statute Distributed Energy Resources include: Distributed renewable generation, energy storage, energy efficiency, demand response and electric vehicles.
[39] "Clean Power Plan for Existing Power Plants," Policies and Guidance, *US Environmental Protection Agency*, (August 3, 2015), https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants.
[40] "Implementing EPA's Clean Power Plan: A Menu of Options" (National Association of Clean Air Agencies, May 2015), http://www.eesi.org/files/NACAA_Menu_of_Options_LR.pdf.
[41] Mike Hogan et al., "What Lies 'Beyond Capacity Markets'? Delivering Least-Cost Reliability Under the New Resource Paradigm" (The Regulatory Assistance Project, August 14, 2012), http://www.raponline.org/wp-content/uploads/2016/05/rap-hogan-whatliesbeyondcapacitymarkets-2012-aug-14.pdf.

Taking a "blank slate" approach to how distributed energy resources and renewables can most effectively contribute to reliable, safe, clean energy systems that maximize consumer choice, the Solar Electric Power Association has initiated the 51st State project.[42] A call for ideas for how new energy markets could be created in a hypothetical "51st State" resulted in submissions that addressed the emergence of a transactive energy economy, where the transmission and distribution systems provide a platform for an innovative, market-based exchange of energy services.[43]

Regulatory and Policy Issues Vermont Context

Vermont has recently issued a draft for public comment of the update to the *2011 Comprehensive Energy Plan* (known now as the 2016 *Comprehensive Energy Plan)*.[44] The 2016 update builds from planning undertaken in 2008 and 2011. The Project Team has designed the SDP scenario within Vermont Solar Market Pathways to be consistent with reaching the long-term CEP targets, and to illuminate how accelerated solar market development can contribute to meeting these targets.

Stakeholder workshops are also under way to review potential changes to net metering and interconnection requirements in Vermont. These will lead to recommendations from the Vermont Public Service Board on new rules and requirements, with a target date of 2017 for implementation. The Legislature also directed the Public Service Department to convene a solar siting task force, which is reviewing and investigating issues and potential modifications for solar siting criteria.[45]

The working group and task force do not directly address the levels of solar market development being investigated as part of this study. They do, however, provide an indication of the overall direction of policy and regulatory discussions in Vermont, pointing toward initiatives and other planning that expand the use of solar resources. At the same time, they acknowledge that careful consideration must be given to developing siting criteria and processes.

Critical Questions

The next phases of Vermont's Solar Market Pathways project will address several critical questions related to policy and regulatory issues.

1. **Market forces versus targets.** The SDP Team's scenario modeling indicates that 10-fold solar market growth is required to achieve the objective of meeting 20 percent of Vermont's electric generation supply by 2025. As the Team refines scenarios, and begins to conduct priority analyses in the next phase of this project, it will be important to consider if the projected level of growth is catalyzed and guided solely by market forces. For example, how much solar is developed? Where and when? Or are there specific targets set by policy or regulatory decisions that set targets—for example, by project type (rooftop, community solar, utility scale grid connected), or location by region, or with respect to existing infrastructure? Market or policy directions might also play a critical role in determining to what extent the grid evolves toward stand-alone micro-grids with customer defection from the grid, versus a more networked system.

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[42] Smart Electric Power Alliance, "The 51st State Initiative," accessed December 11, 2016, http://sepa51.org/about.php.
[43] Jon Wellinghoff, James Tong, and Jenny Hu, "The 51st State: Market Structures for a Smarter, More Efficient Grid" (Smart Electric Power Alliance, February 27, 2015), http://sepa51.org/submissions/submissions/Tong_Wellinghoff_Hu_51st_State.pdf.
[44] "2016 Comprehensive Energy Plan" (Montpelier, VT: Vermont Department of Public Service, December 2015), http://publicservice.vermont.gov/publications-resources/publications/energy_plan/2015_plan.
[45] "Vermont Solar Siting Task Force," *State of Vermont*, June 11, 2015, http://solartaskforce.vermont.gov/.

2. **Cost projections.** Cost declines for solar have continued, and recently large utility scale projects have been announced with long-term power purchase agreements at or less than 4 cents per kilowatt hour.[46] As part of this Solar Market Pathways project, the SDP Team will project forward prices for solar at various scales, and will conduct price-driven sensitivity analyses. The potential reduction of the federal Solar Investment Tax Credit (ITC) at the end of 2016 will have important implications for cost projections. The Project Team expects to conduct a sensitivity analysis of the implications for an extension of the ITC, with a base case assumption that the credits will be reduced at the end of 2016.

3. **Energy "stance" of the state and regions.** In designing and evaluating scenarios that meet both the *Comprehensive Energy Plan* and Solar Market Pathways targets, the SDP Team recognizes important questions regarding the extent to which Vermont wants to rely on imported energy, and how much Vermont wants to develop in-state resources. The same questions apply to regions within the state. For example, some regions might want to develop renewable or other energy resources and seek to export energy. Other regions or the state might not want to host energy development, and might prefer to import energy resources.

4. **Rate impacts and opportunity to participate.** The revised scenarios to be developed by the end of the year will become the basis for estimating the costs and benefits associated with attaining the high-saturation solar goals. It will be important to address the allocation of the costs and benefits, and the mechanisms by which the utilities or other market actors will be able to fairly and equitably recover costs. It will also be important to ask whether incentives or other mechanisms will be required to assure that low- and moderate-income households, smaller utilities, or other market segments can participate in the growing market. Vermont's potential transition to an advanced solar market might face a lower level of "stranded assets" than other U.S. regions, where changes in the power market might result in the early retirement of resources for which prior approved costs have not been fully recovered.

Next Steps

In the next phase of the study, the Project Team recommends the following steps related to regulatory and policy issues:

1. **Review scenario results with stakeholders and examine them with respect to the 2015 *Comprehensive Energy Plan* and current net metering, interconnection, and siting proceedings.** The Project Team will solicit feedback via individual outreach and through the Focus Area working groups in October and early November 2015.

2. **Examine if there are "gaps" between the emerging regulatory and policy initiatives and the scale and nature of solar development under the solar pathways scenarios.** Based on the feedback from stakeholders, the Project Team will determine if there are significant policy and regulatory gaps that need to be addressed in the revised scenarios. The SDP Team will review findings from this analysis with stakeholders in early December 2015.

[46] Stephen Lacey, "Cheapest Solar Ever: Austin Energy Gets 1.2 Gigawatts of Solar Bids for Less Than 4 Cents," *Greentech Media*, June 30, 2015, https://www.greentechmedia.com/articles/read/cheapest-solar-ever-austin-energy-gets-1.2-gigawatts-of-solar-bids-for-less.

3. **Prioritize regulatory and policy issues and analysis to be conducted in Year 2.** Once the revised scenarios are completed, and in Year 2 of the study, the Project Team will work with stakeholders to prioritize and investigate potential policy and regulatory issues for further analysis, research, and inclusion in the final report. Experience from other states, such as further progress or problems with the approval and early-stage implementation of the distributed energy resource plans in California will provide valuable information as this work proceeds during the first half of 2016.

Markets / Business Models

The sustained and orderly development of solar markets in Vermont will create and require innovative market structures and business models. Existing and new firms will develop, test, and offer expanded services to consumers and utilities. The new services and business structures will help unlock the increased value from a well-networked system. Technologies that enable the interconnectivity of energy-producing and energy-consuming devices create a new landscape of consumer choice, consumer aggregation, and control / operations of the utility system.

The technical and policy issues discussed in the prior sections of this brief will influence the evolution of business models, but the inverse is also true. The development of new business models will help to shape and drive changes in technology and policy. This section provides an overview of the types of business models and services that might emerge as Vermont makes progress on the path toward becoming an advanced solar economy.

Solar Business Models

The scenario analyses indicate that a mix of business approaches to solar projects will be required to accomplish the Solar Development 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 Solar Development Pathways scenario, the share of solar expected to be located on site, in ground, and / or as rooftop systems is roughly 300 MW by 2025.

Community solar is enabled by Vermont's virtual net metering regulations, and is one of the more rapidly developing and evolving markets. Community solar permits a single system to provide credits for solar generation to a group of virtually net metered 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, is 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 to their awards,[47] and a community solar affinity group has been established to share information. 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.[48] In the SDP 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.

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[47] "Solar Market Pathways," *Department of Energy: Office of Energy Efficiency & Renewable Energy*, accessed September 22, 2016, http://energy.gov/eere/sunshot/solar-market-pathways.
[48] "National Community Solar Partnership," *Department of Energy*, accessed September 22, 2016, http://energy.gov/eere/solarpoweringamerica/national-community-solar-partnership.

Under Vermont's Standard Offer Program, projects of up to 2.2 MW are eligible for long-term contracts.[49] Another option for larger projects is to apply for long-term contracts under Rule 4.100, which is Vermont's structure for implementing the Public Utility Regulatory Policies Act (PURPA). Recently the Vermont Public Service Board and VELCO have received applications for several projects that are much larger (20 MW each) than what has currently been built in Vermont.[50] 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. In the Solar Development Pathways scenario, the share of solar expected to be based on direct connection to the transmission or distribution utilities with wholesale contracts are expected to be 400 MW by 2025.

Complementary Distributed Resource Business Models

Several distributed energy resources will enable, help to drive, and also 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.

The scenario results presented in **Volume 4** illustrate the net demand and ramp rate impacts associated with the SDP scenario. The Focus Area briefs drafted in May 2015 provided initial inputs for the scenario development. In the next phase of the work, based on the net demand and ramp rate analyses, the Project Team will assign high and low levels of development to each of the complementary DERs. This will provide insights to the levels of investment and market developments for each market. The analysis will be similar in approach to the allocation of the total 1 GW of solar capacity to categories of size and project type.

The importance of integrating other DER resources as part of the advanced solar scenarios is illustrated by findings from research conducted in Europe for the Power Perspective 2030 study. 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.[51]

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 the local church.[52]

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[49] Vermont Electric Power Producers, Inc., "SPEED Solar Online Projects - Comparison DC/AC" (Vermont Standard Offer, April 24, 2015), http://static1.1.sqspcdn.com/static/f/424754/26167074/1429817055967/SOLAR+AC-DC+ON+LINE+PROJECTS+4-24-15.pdf?token=1Yt%2FAygme2klyXP2dW2SjliFs2M%3D.

[50] Erin Mansfield, "State Concerned about Proposal for Giant Solar Project," *VTDigger*, September 8, 2015, http://vtdigger.org/2015/09/08/state-concerned-about-proposal-for-giant-solar-project/.

[51] Christian Hewicker, Michael Hogan, and Arne Mogren, "Power Perspectives 2030: On the Road to a Decarbonised Power Sector," accessed September 22, 2016, http://www.roadmap2050.eu/reports.

[52] "Shepherdstown Presbyterian Church," *Solar Holler, Inc.*, accessed September 22, 2016, http://www.solarholler.com/shepherdstown-presbyterian-church-project-gallery/.

Utility Business Models

The solar and other DER technologies create business model opportunities for non-utility market participants, but they also open the door to a wider range of customer service offerings for utilities, and expand the potential portfolio of investments on the supply and demand side of the customer's meter.

The 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.

The distribution utilities 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 DER resources and their inclusion in a utility's portfolio will affect the requirements for the balance of the portfolio. For example, they might require that other power supply contracts 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-party providers, or directly by distribution and transmission system operators. A study conducted for the California ISO 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.[53]

Business Models Recommendations for Next Steps

The net demand and ramp requirements associated with the SDP scenarios will be used to allocate the nature of resource flexibility and response to DER resources. The initial allocations will be presented and reviewed with stakeholders, and will be used to examine and prioritize potential case studies that can be conducted as priority analyses during the first quarter of 2016. The characteristics of the DER control and response that is required will inform consideration of the possible business models, and / or cost recovery required to support needed investments.

[53] KEMA, Inc., National Renewable Energy Laboratory, and Energy Exemplar, LLC, "Final Report for Assessment of Visibility and Control Options for Distributed Energy Resources" (California Independent Systems Operator Corporation, June 21, 2012), https://www.caiso.com/Documents/FinalReport-Assessment-Visibility-ControlOptions-DistributedEnergyResources.pdf.