The Role of Energy Storage in Meeting Vermont's Energy Goals

Efficiency Vermont R&D Project: Resilience

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Executive Summary

As Vermont's energy goals ramp up to meet State and global climate targets, delivering clean, beneficial electrification means that Efficiency Vermont has an increasingly important role in supporting and accelerating the market adoption of appropriate new technologies for heating and transportation. Accelerating the market toward higher levels of electrification and increasing reliance on renewable energy resources has implications for power reliability and community resilience. At a minimum, more electrification will necessitate increased distribution infrastructure and storage capacity at residential, business, community, and regional power supply levels.

Green Mountain Power (GMP) and the Vermont Electric Co-operative (VEC) supply power to most Vermonters; both aim to supply 100 percent renewable power by 2030. VELCO's Plan (p. 46) specifies a need for 400 MW of strategically placed storage to support thermal and voltage concerns associated with distributed generation, and 250 MW of strategically placed storage with 5 hours of energy supply to support excess renewable energy generation.[1]

Efficiency Vermont's research supports beneficial electrification by examining non-electrochemical storage opportunities for site and statewide electrification, and load management. Applicable Vermont market-ready non-electrochemical thermal energy storage systems are thermal storage in biomass, thermal mass, phase change materials (PCM), electric water heaters, and geothermal applications. Vermont's mechanical energy storage opportunities are flywheels, pumped hydro, compressed air, and liquified air. Well-designed energy storage can lead to lower electricity rates, and increased energy system security and reliability. Load shifting programs decrease the electricity peak demand load and extend the duration of the peak period, which necessitates longer-duration energy storage to sustain a renewably generated power grid.

To meet State electrification and renewable energy production goals, Vermont needs a comprehensive plan for short- and long-duration energy storage. Electric vehicles, flow batteries, and non-electrochemical energy storage technologies could dramatically change the grid and the energy storage market. Vermont will benefit from a cohesive plan among distribution utilities, VELCO, ISO New England, and Efficiency Vermont. Integrating utility generation, energy consumption, energy efficiency, beneficial electrification, and energy storage modeling can offer insights for future energy management programs.

Expanding Efficiency Vermont's knowledge and assistance of non-electrochemical energy storage solutions applicable to site and community energy management will enable Efficiency Vermont to better support residential, business, and municipal customers with resilience planning and energy efficiency cost optimization, in coordination with local utilities. Given the importance of energy storage in meeting Efficiency Vermont's performance targets and State goals, Efficiency Vermont would benefit from integrating energy storage into its flexible load

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[1] The 20-year plan does not specify a year when the storage is needed.

management, greenhouse gas reduction, and residential and commercial programs. Efficiency Vermont can also ensure adequate valuation of energy efficiency, and weatherization specifically, in reducing local and regional energy storage capacity requirements.

As the nation’s first energy efficiency utility, Efficiency Vermont leads the country in energy efficiency innovation. Supporting customers and utilities with energy storage planning and implementation is Efficiency Vermont’s next step in ensuring Vermont’s energy security and affordability.

Introduction

Meeting the collective carbon and renewable energy goals of Vermont's *2022 Comprehensive Energy Plan* and the requirements of the Vermont Renewable Energy Standard will require statewide transmission and non-transmission alternatives to achieve grid transformation. Achieving this objective will necessitate intentional partnerships among the transmission and distribution provider, VELCO; distribution utilities (DUs); and the state's energy efficiency utilities (EEUs). Working as a collaboration of public-service entities, these organizations offer the market the most capable committee for optimizing energy efficiency, electrification, demand response, flexible load management, energy transmission and distribution, and energy storage. To the extent that these public and private actors address the energy factors as a whole, the state can support the market for affordable energy reliability. This is an essential objective for minimizing risks to its residents and businesses, and thus for keeping the Vermont way of life and economy strong amid environmental and economic threats from climate change events and the geopolitical landscape of the 21st century.

As State energy goals ramp up to meet global climate targets, delivering clean, beneficial electrification means that Efficiency Vermont has an increasingly important role in supporting and accelerating the market adoption of appropriate new technologies for heating and transportation. Accelerating the market toward higher levels of electrification has implications for power reliability and community resilience. At a minimum, more electrification will necessitate increased distribution infrastructure and storage capacity at residential, business, community, and regional power supply levels. This paper explores Vermont's statewide need for energy storage, and Efficiency Vermont's role in leading customers to storage solutions that support their and the State's energy security goals.

Background

Vermont's 2022 *Comprehensive Energy Plan* (CEP) sets a three-phase goal of meeting 25 percent of Vermont's energy needs from renewable energy sources by 2025, 45 percent by 2035, and 90 percent by 2050. To align with Vermont's Global Warming Solutions Act of 2020 requirements and the recommendations embedded in the *Vermont Climate Action Plan*, the CEP calls for:

- 100 percent of the electricity sector energy needs are to be met with carbon-free resources by 2032, with at least 75 percent from renewable energy
- 45 percent of the transportation sector energy needs are to be met with renewable energy by 2040
- 70 percent of the thermal sector energy needs are to be met with renewable energy by 2042

Ongoing delivery of energy efficiency services, coupled with beneficial electrification, is an effective strategy for meeting the transportation and thermal sector renewable energy goals. The strategy involves weatherization, heat pumps, and electric vehicles. VELCO's *2021 Vermont*

Long-Range Transmission Plan forecasts Vermont's peak summer load will reach 1,294 MW in 2040, and its winter load will reach 1,499 MW. VELCO's forecast accounts for long-term weather effects, energy efficiency, standard demand response programs, net metering, and load increases from greater market adoption of heat pumps and electric vehicles. Even with energy efficiency and load management included, this "medium forecast scenario" reflects an assumed 31 percent growth, from 2020 levels, in summer peak and 51 percent growth in winter peak.

Vermont's Renewable Energy Standard (RES) requires Vermont DUs to procure 85 to 97 percent of electric retail sales from renewable energy in 2032, as follows:

- Tier I: 55 percent of annual retail electric sales from any source of renewable energy in 2017 and increase by 4 percent every three years to achieve 75 percent in 2032
- Tier II: 1 percent of annual retail electric sales from new, distributed renewable generation[2] in 2017 and increase by 0.6 percent each year to achieve 10 percent in 2032
- Tier III: 2 percent of annual retail electric sales from additional new distributed renewable energy meeting Tier II or fossil fuel savings through energy transformation projects in 2017, and increase by 0.67 percent each year to achieve 12 percent in 2032

The combination of responsibly delivered energy services—energy efficiency, electrification, demand response, flexible load management, energy transmission and distribution, and energy storage—from VELCO, the DUs, and the EEUs, in Efficiency Vermont's view, is a path to optimizing energy security and reliability delivery to customers, statewide in support of Vermont's CEP and RES. Further, as VELCO's *Vermont Long-Range Transmission Plan* (p. 8) opines, "[w]ithout additional collaboration and continued innovation, Vermont's electric grid will not be able to fulfill the requirements of current state statutes and policies."

Vermont's Need for Storage

As the state continues to invest in beneficial electrification, the energy efficiency—of both the electrification technologies and of the thermal shells of buildings in which these technologies operate—will be critical to ensure the load growth is done as efficiently as possible. Collectively, building weatherization, flexible load management controls, and demand response programs can decrease the "peakiness" or height of electricity peak demand, but these efforts also lead to a flattening of peaks, which can extend the duration of the peak demand period. A longer, but less dramatic peak period in grid management, however, requires longer periods of electricity storage. Weatherization decreases the total energy storage needed to maintain critical loads, extends occupant comfort during prolonged periods of reduced power supply, and is essential for minimizing business and occupant risks during power outages.

An increased reliance on intermittent solar and wind renewable energy generation coupled with bi-directional energy flows and greater dependence on electricity for heating and transportation

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[2] *Distributed renewable generation:* electric generation facilities with ≤5 MW capacity that commenced operation after June 30, 2015 (RES definition). Further, the facility must be directly connected to a DU's subtransmission or distribution system, or listed in an approved plan as deferring transmission upgrades; or it must provide net metering where the DU owns the environmental attributes associated with the system.

necessitates strategically placed energy storage systems to ensure continuous power supply during periods of excess and low renewable energy generation, peak demand, and prolonged grid system failure.

Methods

To determine an appropriate role for Efficiency Vermont in supporting customers with their storage needs and utilities and trade partners with their service delivery needs, Efficiency Vermont identified the following research topics and posed corollary questions for each topic:

1. Energy storage in Vermont
    a. How much short- and long-duration energy storage is needed for Vermont to meet State energy generation and thermal and transportation electrification goals?
    b. What short- and long-duration non-electrochemical energy storage technologies are viable for Vermont?[3]
2. Customer value of energy storage
    a. What is the Vermont customer value proposition for energy storage?
3. Efficiency Vermont's role
    a. What is Efficiency Vermont's value proposition for driving non-electrochemical energy storage deployment to support flexible load management, electrification, and thermal efficiency programs?

The author examined publications, interviewed stakeholders, and attended local and national conference presentations on these topics to answer the research questions.

Results

Energy Storage in Vermont

How much storage does Vermont need, and for what durations?

Green Mountain Power (GMP) and the Vermont Electric Co-operative (VEC) supply power to 82 percent of Vermonters; both aim to supply 100 percent renewable power by 2030.

As of 2021, GMP can manage approximately 10 percent of its average peaks with 60 MW of dispatchable flexible capacity, via battery storage, water heaters, EV chargers, and rate-based load management measures. GMP's *2021 Integrated Resource Plan* (Ch. 2, p. 31) models increasing residential energy storage to approximately 100 MW by 2030 under a medium forecast scenario. Long-term, GMP strives "for every customer to have a back-up solution for long-duration outages."

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[3] For an overview of the opportunities for deploying energy storage in Vermont, and their constraints, see the 2017 report from the Vermont Department of Public Service: *Act 53 Report: A Report to the Vermont General Assembly on the Issue of Deploying Storage on the Vermont Electric Transmission and Distribution System*.

GMP is also planning the creation of six "resiliency zones" to improve local system reliability. The zones support GMP's preparedness for climate-driven events and increased electrification from transportation by assuming the deployment of technology, distributed energy resources, storage, and other resources. The Plan (Ch. 6, p. 25) describes:

> We expect that over the IRP planning horizon we will add meaningful quantities of storage resources to the power supply portfolio to address our need for capacity (peaking) resources, and to provide energy balancing to a portfolio more heavily weighted toward renewable supplies. … [W]e anticipate that future IRPs will explore opportunities to integrate large-scale storage with intermittent generation to help manage and smooth intermittent generation profiles.

Finally, "GMP expects battery storage will replace fossil-fuel peaking generators in most short-duration reliability applications over the IRP planning horizon" (Ch. 6, p.25). If GMP replaces Vergennes diesel generators, and Rutland and Ascutney gas-turbine units with equal amounts of energy storage for peaking capacity, that would equate to an additional 29 MW of energy storage capacity in Vermont.

The first strategy in VEC's *2021 Strategic Planning* document targets:

- 1.2 to 2.5 MW of cost-effective storage for peak shaving and grid and financial benefits
- 125 to 300 smart storage devices managed for personal and business resiliency
- 3 to 10 new, region-specific grid-constraint solutions involving storage, electrification, new business, and infrastructure[4]

VELCO's Plan (p. 46) specifies a need for 400 MW of strategically placed storage to support thermal and voltage concerns associated with business-as usual distributed generation distribution, and 250 MW of strategically placed storage with 5 hours of energy supply to support excess renewable energy generation in an optimized distributed generation distribution scenario based on modeling completed in 2018 for a 2025 forecast.

ISO New England's 2022 capacity auction for power system resources for 2025-2026 cleared 700 MW of storage capacity to meet peak demand in the region—an increase of 70 MW over the 2021 capacity auction for 2024-2025.[5]

Though the research team was unable to quantify the total amount of storage needed or duration capacity of those systems given the variability in modeling scenarios and rapid advancements in storage technologies and flexible load management deployment, it is evident that Vermont's energy storage capacity needs to grow substantially in order to meet State energy and decarbonization goals.

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[4] The specific target area is known as SHEI, the Sheffield-Highgate Export Interface. It is a region in northern Vermont where power generation from the Kingdom Community Wind plant is regularly curtailed due to power export capacity limitations in the transmission system. More information on this constraint can be found at the Vermont System Planning Committee's "Information about the Sheffield-Highgate Export Interface."

[5] Collectively, solar and wind renewable energy, energy storage, and demand resources represented 15 percent, or 5,000 MW, of all capacity clearing the auction in 2022.

Opportunities to reduce storage demand

Energy efficiency continues to offer the least-cost opportunity for meeting customer energy needs. ACEEE calculates the levelized cost of energy efficiency at $0.024 per kWh—less than half the U.S. Department of Energy's (DOE) Long Duration Storage Shot goal for storage pricing.

All energy efficiency supports reductions in storage size during normal grid operations and can increase the duration capacity of local energy storage systems through demand reduction. However, building weatherization also reduces storage requirements during grid constraints and outages. Weatherized buildings require less heating input, which in turn enables the installation of smaller heat pumps that require less energy to power, compared to unweatherized buildings. When no power is available, weatherized buildings maintain comfortable temperatures for longer periods. The Lawrence Berkeley National Laboratory has calculated the levelized cost of saved electricity from weatherization programs at $0.094 per kWh. When program designers consider co-benefits such as smaller storage system requirements, improved occupant health outcomes, and increased building durability, weatherization presents a valuable opportunity for cost effectively supporting grid and site resilience.

Figure 6 shows the importance of efficiency in managing grid load. ACEEE projected a 2040 polar vortex event and modeled the New England load profile for that event with 1.46 million installed residential heat pumps, using electric resistance back-up supply, before and after applying a deep energy efficiency package. Industrial and other commercial loads were not included in the model. The deep energy efficiency package represented over 9,000 MW in peak load savings.

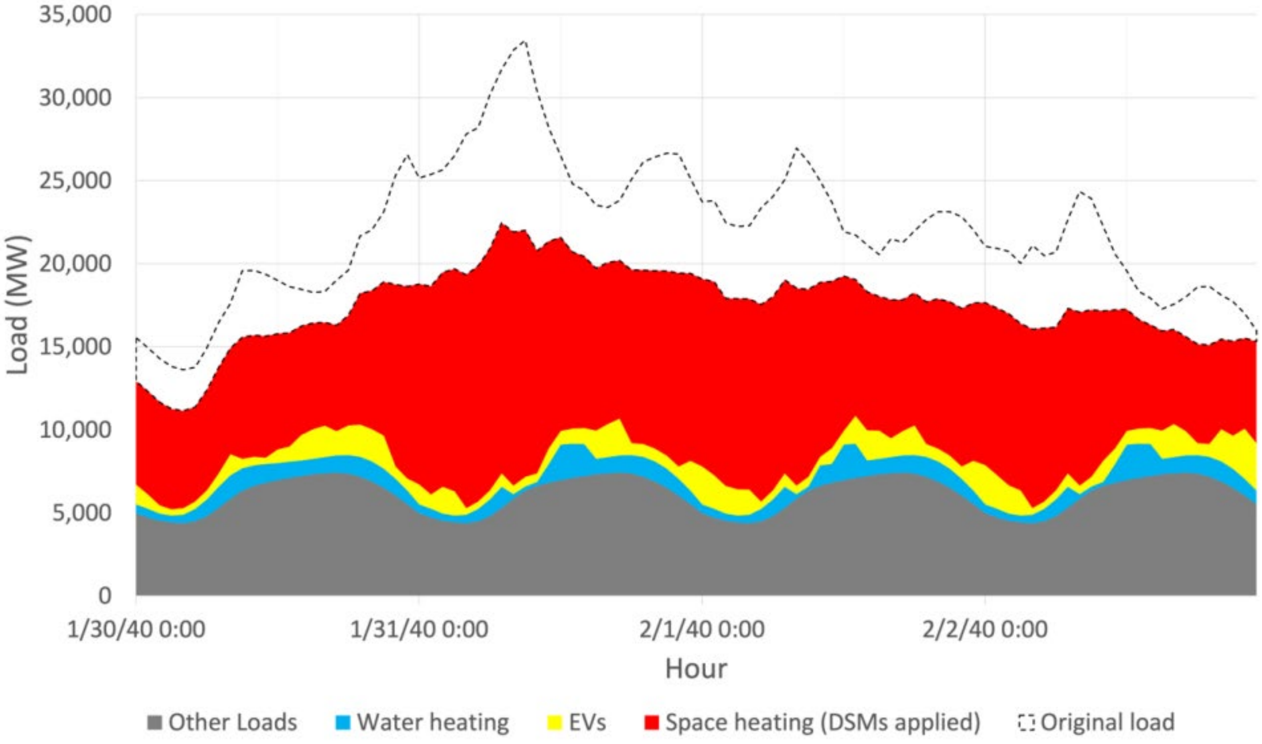

Figure 1. Modeled scenario of New England profile during a 2040 polar vortex event. *Source:* ACEEE, 2021. Demand-Side Solutions to Winter Peaks and Constraints, p. 43.

Figure 7 shows the load savings from Figure 6, provided by each measure in the deep energy efficiency package. Note the high savings associated with residential and commercial thermal envelope improvements / weatherization.

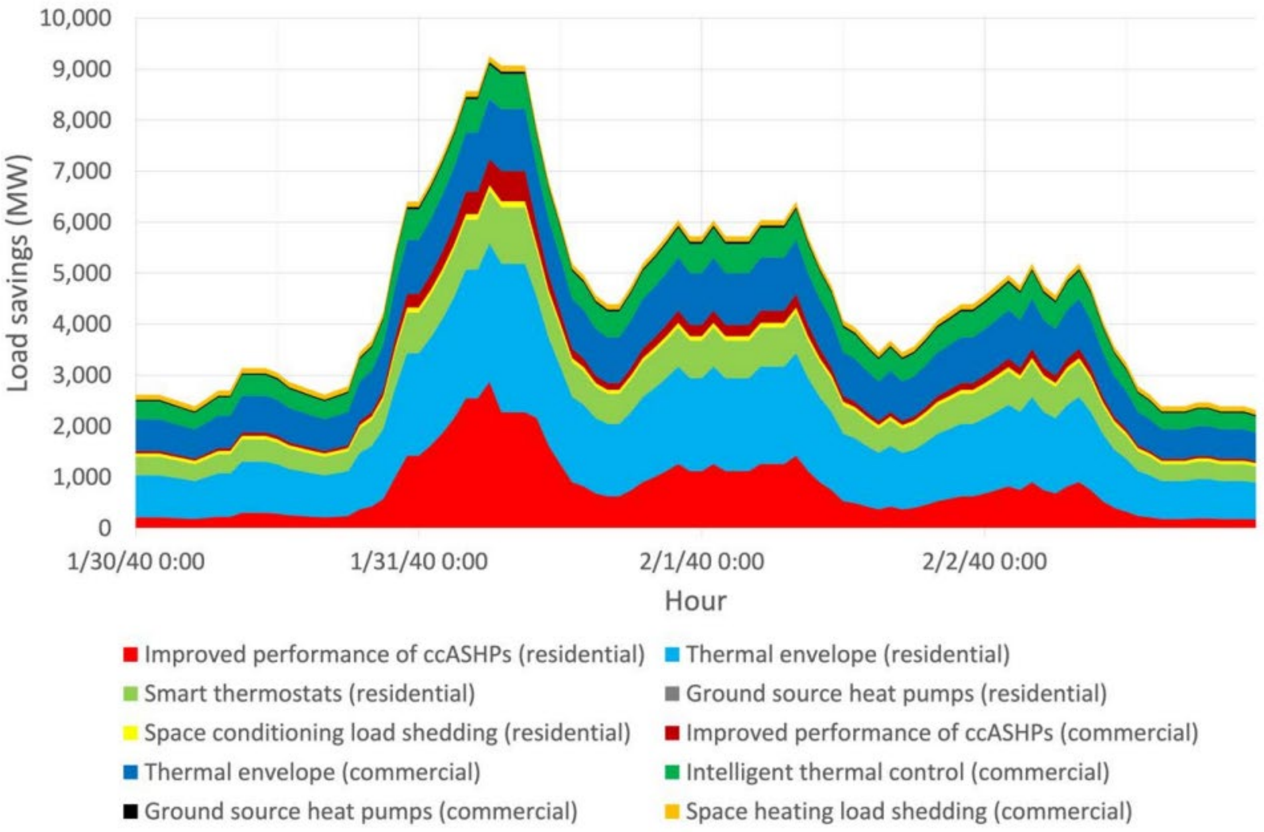

Figure 2. Load savings in Figure 6, from the deep energy efficiency package. *Source:* ACEEE, Demand-side Solutions, p. 44.

The EEUs and building industry have a special role to play in supporting Vermont's goals for carbon-free, renewable, and electrified thermal and transportation energy.

What short- and long-duration non-electrochemical energy storage technologies are viable for Vermont?

Energy storage systems absorb energy, store it, and release the energy at specified times. Energy is stored in electrical (e.g., capacitors), chemical (e.g., hydrogen), electrochemical (e.g., lithium ion), thermal (e.g., thermal mass and phase change materials), and mechanical forms (e.g., pumped hydro, compressed air, and flywheels).

Energy storage technologies vary in charge-, storage-, and discharge-capacity cost and in charge and discharge efficiency. The charge and discharge efficiency represents round-trip efficiency—the percentage of electricity placed into storage that can be recovered for later use. The valuing of these costs and efficiencies depends on the application in which the storage system will be used.

Short-duration energy storage systems typically charge and discharge energy daily for less than 12 hours, and more commonly, less than 6 hours.

No standard definition exists for *long-duration energy storage*.[6] Absent a standard definition, LDES in this research represents systems capable of delivering electricity for over 12 hours.

Figure 1 estimates capital costs for energy storage types at different stages of commercialization. Storage systems with high energy costs and low power-related costs are well suited for short-duration applications, whereas systems with low energy costs and higher power-related costs are better suited for long-duration applications.

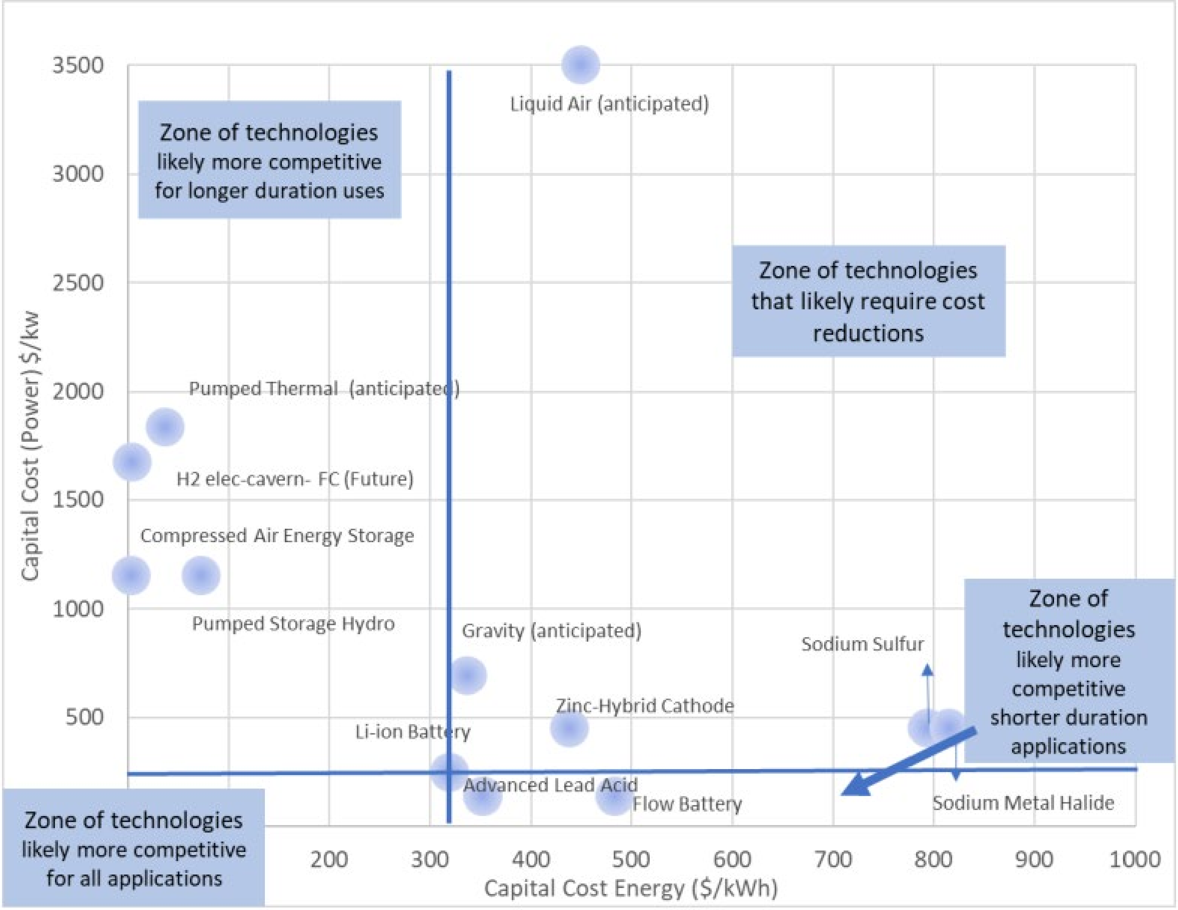

Figure 3. Estimated capital costs for energy ($ / kWh) and capacity ($ / kW) energy storage technologies. *Source:* NREL, *Storage Futures Study* (2022).

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[6] The National Renewable Energy Laboratory (NREL; Blair, Nate, Chad Augustine, Wesley Cole, et al. 2022. *Storage Futures Study: Key Learnings for the Coming Decades*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-81779. https://www.nrel.gov/docs/fy22osti/81779.pdf) attempted a uniform definition to represent duration and application of LDES, and determined that it is not possible, given the variability in regional grid energy production mix and demand patterns. That is, the duration of the storage system is dependent on the discharge rate, which is driven by the local load shape.

After pumped storage hydro,[7] electrochemical batteries make up the bulk of existing storage capacity in the United States; battery storage is increasing energy capacity nationwide, with growth in both the large-scale and small-sale battery storage markets. Advancements in electric vehicle to everything technology promises to further propel the benefits of battery storage at the site and grid level. Although batteries provide many benefits and are well accepted in the market, they have more limited discharge times compared to non-electrochemical storage options. Flow battery technology, useful for large-scale energy storage, continues to advance and can improve battery storage and discharge duration. Several Vermont DUs are evaluating flow batteries for use in their service territories. The Energy Storage Association provides electrochemical storage technology specifics which are outside of the scope of this report. Figure 2 shows energy storage system types according to discharge times and system power ratings.

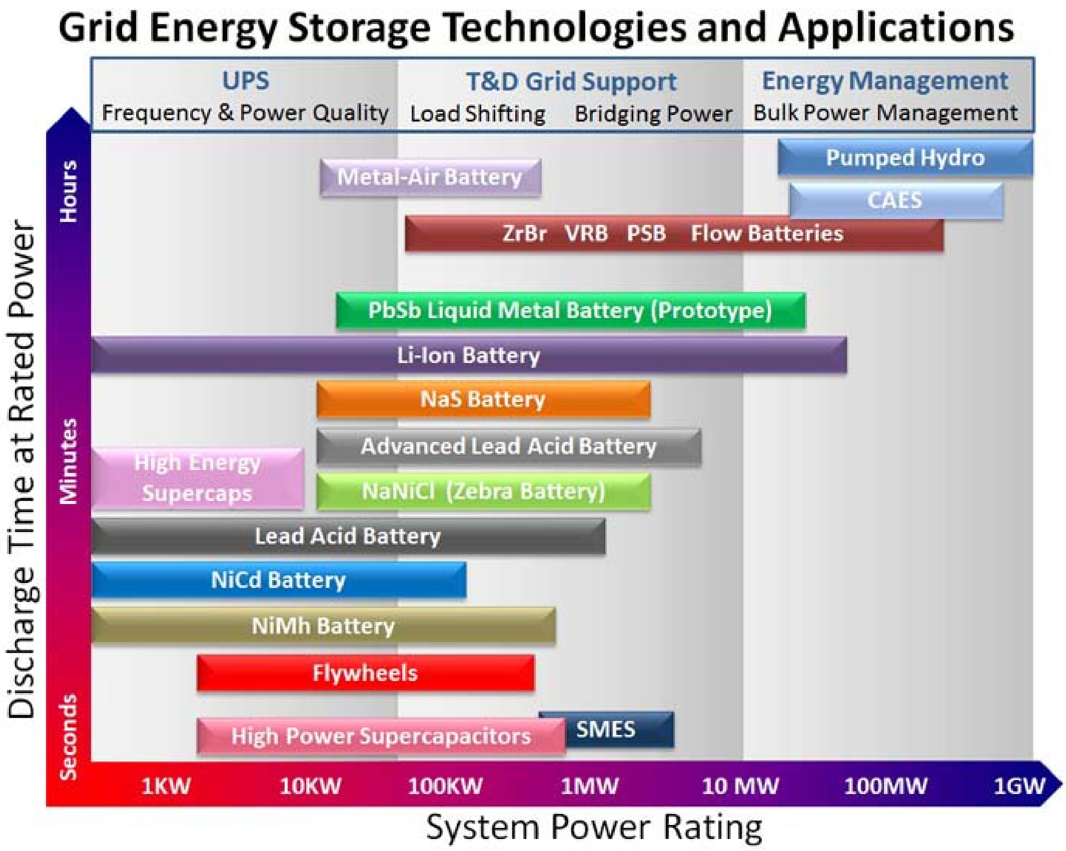

Figure 4. Energy storage technologies, comparing discharge time and power ratings. Source: Electropaedia, *Battery and Energy Technologies: Grid Scale Energy Storage Systems* (2005).

Non-electrochemical storage technologies for Vermont

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[7] Pumped storage hydro is the largest source of energy storage on the grid, accounting for 95 percent of installed storage capacity. More than 21,000 MW of pumped storage in the United State can meet the power demand of 16.7 million households. Much of the pumped storage is in the Mid-Atlantic and Southeast. Source: Clearpath, 2021.

The state's DUs are leading battery storage programs, which support statewide beneficial electrification. Efficiency Vermont's research also supports beneficial electrification, but by examining non-electrochemical storage opportunities for site and statewide electrification, and load management. Applicable Vermont market-ready non-electrochemical thermal energy storage systems are

- Thermal storage in biomass
- Thermal mass
- Phase change materials (PCM)
- Electric water heaters
- Geothermal applications

Mechanical energy storage opportunities are

- Mechanical storage in flywheels
- Pumped hydro
- Compressed air
- Liquified air

Biomass

Solar energy storage in the form of woody biomass is a valuable addition to the Vermont energy system. Wood energy storage has been used as a primary heating source for centuries in Vermont. Biomass applications range from single units for a house to large-district systems: traditional wood stoves, modern chip and pellet stoves and boilers, and biomass power plants. Beyond these units and systems are what could be considered biomass infrastructure: advanced conversions of agricultural residues and energy crops (grasses) to liquid and gas fuels.

In 1984, the McNeil Generation Station, a woodchip facility operated by Burlington Electric Department, used stockpiled woodchips to produce electricity. Today, McNeil and the Ryegate Power Station, near the Connecticut River and approximately 20 miles south of St. Johnsbury, help the state maintain renewable energy production when solar and wind power decrease.

In 2021, the Goodrich Family Farm in Salisbury began supplying methane to Vermont Gas Systems using two 925,000-gallon anerobic digesters. The system can convert food waste and manure biomass into enough biogas to warm 5,000 homes.

Vermont's energy industry expects biomass systems to continue as a mainstay in the state's energy production and storage future. Non-electric biomass systems provide reliable heating during power outages, and all biomass systems can reduce electric heating loads. Any consideration of local and regional geography is likely to improve future biomass system designs, especially in the context of biomass combustion's effect on air quality.

Thermal mass

Long used in passive solar buildings to store sun energy for later use, thermal mass is, in principle, an attractive, clean-energy storage system. An Efficiency Vermont project is testing the duration of comfortable indoor temperatures when thermal slabs are preheated in advance of an expected power outage or winter peak load event. The team is assessing the increased duration of occupant comfort when thermal mass preheating is combined with air sealing improvements in the building envelope.

High-temperature thermal energy storage also holds potential for site-specific and grid level applications. The system's compact size, modularity, and readily available components make it attractive for Vermont. Efficiency Vermont is particularly interested in the extent to which industrialized and scalable heat pump technology can sufficiently charge a thermal mass to improve system efficiency.

Phase change materials

PCMs are special materials that can absorb or release energy when they transition from one state to another—for example, a solid into a liquid. They can be applied in place of thermal mass in numerous energy storage applications. PCMs are a quickly emerging technology for many different types of applications. With new products steadily entering the market, PCMs can perform well at a near-constant temperature designed for the specific application.

Efficiency Vermont has researched PCM applications in cold chain storage, and collaborated with Dynamic Organics (a Vermont renewable energy company) and GMP to restore an ice storage system for load flexibility in space conditioning. Currently, Efficiency Vermont is field-testing PCMs in two other applications: building thermal envelope tiles, and a storage tank for an air-to-water heat pump.

Electric water heaters

Efficiency Vermont collaborated with Washington Electric Co-op in 2019 and 2020 to test load-shifting capability from thermal storage in electric water heaters. The program ended when a large manufacturer bought the company that had created the technology controlling the water heaters; the larger company declined to support that equipment. Despite this setback, Efficiency Vermont recognizes a viable market for electric water heater storage programs. For example, the Minnesota wholesale electric power co-operative, Great River Energy, operates a successful water heater storage program. GMP reports load managing domestic water heaters using Aquanta and Rheem's EcoNet. Efficiency Vermont continues to research new control technologies, in collaboration with Vermont utilities, to inform future electric water heater storage programing.

Geothermal applications

Site-specific and centralized geothermal systems offer high efficiency space conditioning—and enable thermal storage. Geothermal systems use thermal energy stored in the earth to pre-heat and pre-cool fluids used in mechanical building conditioning systems. When centrally located, geothermal loops can provide district heating and cooling support, reducing the per-building expense of installation, operations, and maintenance. Efficiency Vermont incentivizes geothermal systems, and is collaborating with Vermont Gas Systems on their district geothermal pilots. When coupled with cold-climate heat pump and advanced biomass technologies, geothermal systems can significantly reduce forecasted winter peak demand.

Flywheels

At the grid level, flywheels, like the ones run by Beacon Power in Stephentown, NY, can replace natural gas peaking plants. In the near future, GMP is planning to retire all fossil fuel peaking plants—the plants that handle excess power demand during peak hours—and replace them with storage technologies. This decision supports GMP's goal to be powered exclusively by renewable energy sources by 2030.

Local businesses can use site-based flywheels for uninterruptable power supply and to manage peak demand; manufacturers market smaller systems to residential customers for daytime storage. Velkess, Omnes, Amber Kinetics, Revterra, and Active Power each offer flywheel systems for site-based energy storage. Efficiency Vermont can support customer-sited flywheel installations that provide flexible load management in coordination with the local utility.

Pumped hydro

Hydropower reservoirs across Vermont store and release water for energy generation. Choreographing these resources with renewable energy production to achieve their maximum storage potential could support future grid management, in a way similar to how energy storage is applied in Vermont.

Accelerating pumped hydro storage is possible in Vermont, given the state's topography and presence of abandoned, water-filled quarries. Efficiency Vermont is unaware of plans for new pumped hydro storage systems in the state. However, the U.S. Department of Energy has targeted $28 million in funding opportunities (announced in October) for advancing and preserving hydropower, including pumped hydro storage. Efficiency Vermont can offer customer assistance for site-based pumped hydro storage in collaboration with the local utility.

Compressed and liquified air

Compressed and liquified air storage systems are promising for Vermont, because they provide high-capacity long-duration energy storage (LDES) on compact sites. The systems use components from existing (and soon to be decommissioned) gas generators, enabling smooth market transformation using current supply chains and trade skills.

The media heavily promoted a liquefied air system proposed for Vermont in 2019 (Figure 3), but Efficiency Vermont discovered the system was a preliminary idea and was never approved for planning or development.

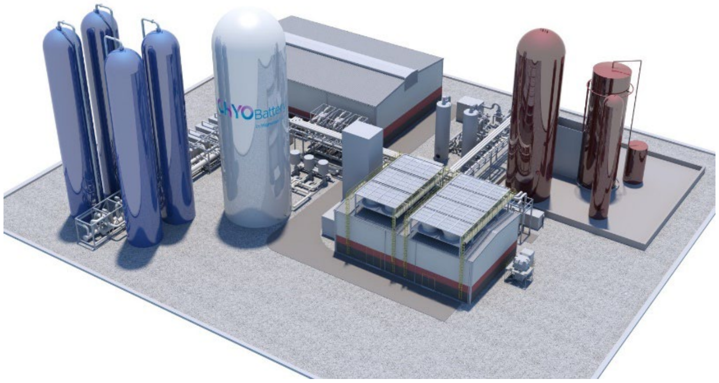


Figure 5: Liquefied air energy storage system proposed for Vermont. Source: Highview Power.

Table 1 summarizes other energy storage systems Efficiency Vermont has evaluated and considers unfeasible.

Table 1. Non-electrochemical storage systems deemed unfeasible for Vermont

System	Unfeasibility factors for application in Vermont
Energy vault	• System size (area and height)
Advanced rail energy storage (ARES)	• System size • Probability of extreme weather (snow and ice) concurrent with system discharge
Underground compressed air	• Lack of existing caverns or prior mines suitable for this type of storage; expense of developing new underground caverns

The case for LDES in Vermont

LDES will grow in importance for Vermont, as flexible load management and energy storage extend the peak demand period, and as the state increases its reliance on renewable energy resources with daily and seasonal variability in supply. Figure 4 provides an example of diurnal load, net load with variable generation, and peak duration under two storage scenarios for California. These values come from a modeled summer peak event, demonstrating the value of LDES for optimizing grid load management. It is easy to imagine a similar scenario in Vermont during a prolonged heat wave, or an extreme cold spell. During such times, renewable energy is not available for an extended period, and grid demand for space conditioning and transportation are high. GMP has a long-term goal for every customer to have a backup solution for long-duration outages.

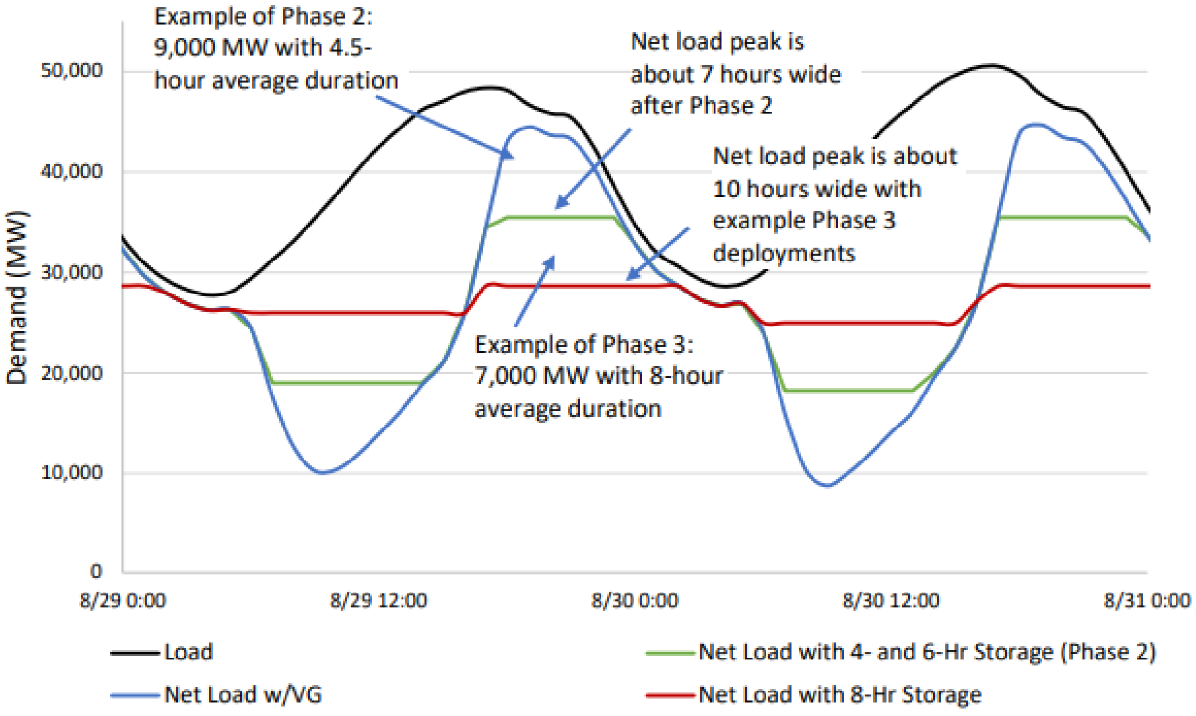
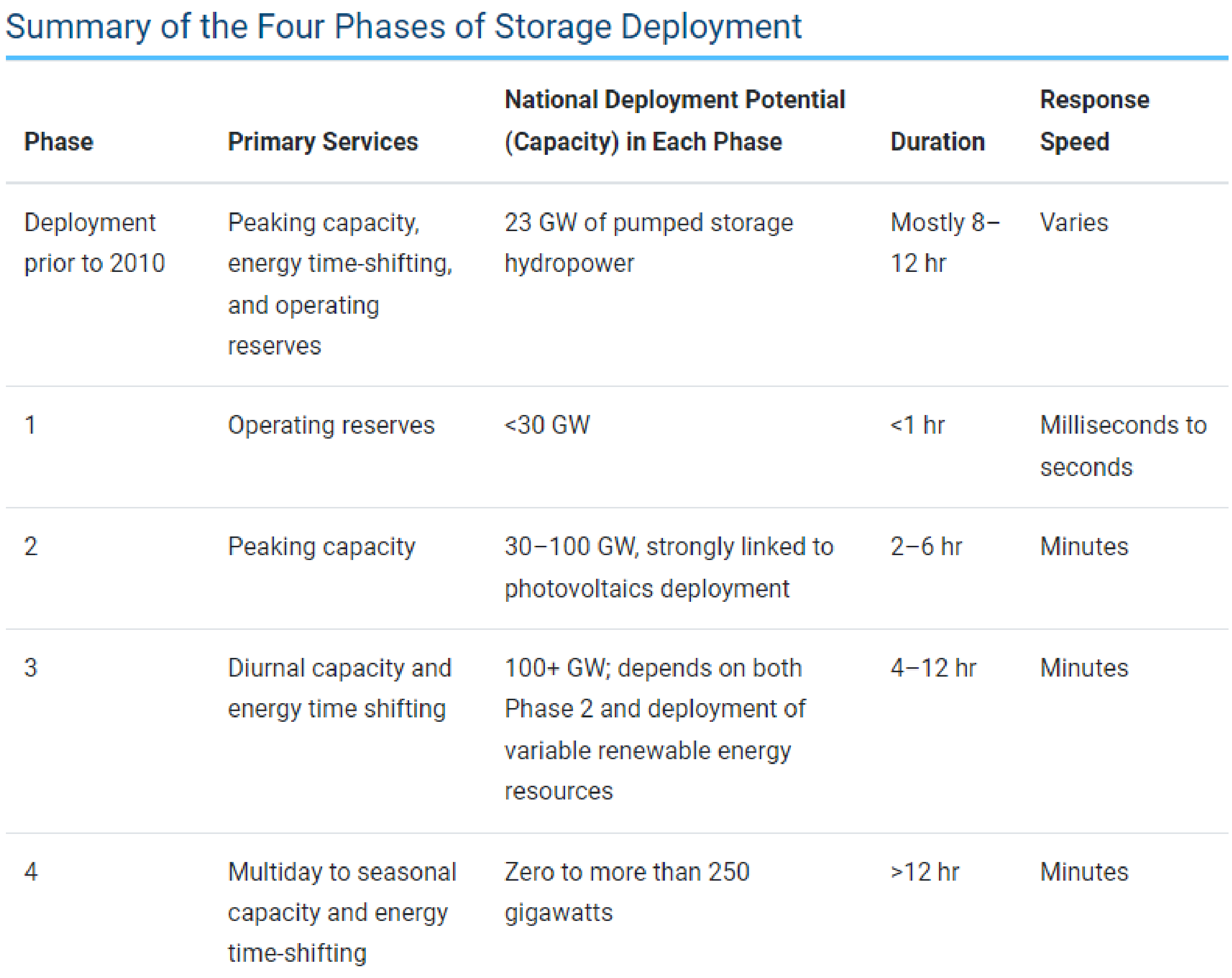


Figure 6. Example of long-duration storage providing system capacity in California during summer peak. *Source:* NREL, *Storage Futures Study* (p. 27).

Appreciating the importance of LDES in achieving the grid of the future, the United States is investing heavily in LDES technology. Between fiscal years 2017 and 2020, the U.S. DOE spent over $1.6 billion in energy storage research and development. Leaders from energy and technology companies launched the LDES Council in November 2021, following the 2021 United Nations Climate Change Conference (COP26). Its mission is to "replace the use of fossil fuels to meet peak demand by accelerating the market for long duration energy storage." LDES Council estimates needing 400 times more LDES systems by 2040 to create a worldwide, cost-optimal net-zero energy system.

DOE's 2021 Long Duration Storage Shot program seeks to reduce storage costs in 10 years by 90 percent. It is using a 2020 lithium-ion baseline to get to $0.05 per kWh, in storage systems that deliver 10 or more hours of duration. The DOE's 2022 LDES for Everyone, Everywhere Initiative will invest $505 million in demonstration projects, pilot grants, and a demonstration initiative seeking to achieve widespread commercial deployment through energy storage cost reduction and duration increases. In terms of the full scope of federal investment, the 2022 Inflation Reduction Act provides an additional $369 billion for clean energy, including investments in energy storage.

NREL's *Storage Futures Study* has defined four phases of storage development, as shown in Figure 5. Achieving Vermont's, and the nation's, grid of the future (that is, a clean and reliable grid) requires all four phases. Vermont is contributing to Phase 3 through utility-scale energy storage and bring-your-own-device programs, and Efficiency Vermont's flexible load management programs.



Summary of the Four Phases of Storage Deployment

Phase	Primary Services	National Deployment Potential (Capacity) in Each Phase	Duration	Response Speed
Deployment prior to 2010	Peaking capacity, energy time-shifting, and operating reserves	23 GW of pumped storage hydropower	Mostly 8–12 hr	Varies
1	Operating reserves	<30 GW	<1 hr	Milliseconds to seconds
2	Peaking capacity	30–100 GW, strongly linked to photovoltaics deployment	2–6 hr	Minutes
3	Diurnal capacity and energy time shifting	100+ GW; depends on both Phase 2 and deployment of variable renewable energy resources	4–12 hr	Minutes
4	Multiday to seasonal capacity and energy time-shifting	Zero to more than 250 gigawatts	>12 hr	Minutes

Figure 7. The four phases of storage development. *Source:* NREL, Storage Futures Study (p. 38).

Under current grid conditions, storage has a role to play when electricity suppliers experience conventional-fuel supply chain challenges. In September 2022, ISO New England stressed the importance of LDES for addressing the natural gas shortages expected this winter:

> Because New England is at the end of the interstate pipeline system and lacks large scale, long duration energy or fuel storage, both the gas distribution system and the electric power system have a dependence on imported LNG,

> and this reality will persist until the region invests in access to alternative long duration energy storage infrastructure.[8]

Vermont's energy goals can be met if the building industry couples its current weatherization and energy efficiency work with short- and long-duration storage solutions. As the research shows, this combination of strategies can supply enough energy during demand peaks and seasons of low solar and wind power generation. The amount of storage needed to meet those needs depends on the features of the storage technology, the estimated duration of power to be supplied, and a valuation of the role of efficiency in reducing and managing energy loads.

Customer Value of Energy Storage

Grid benefits that relate to customer value. Customers benefit indirectly from services that grid storage systems provide. Storage can lead to lower electricity rates and increased system resilience and reliability. Figure 8 both lists and demonstrates the value of energy storage systems' grid benefits.

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[8] This statement is from Kevin Flynn, Chief Counsel, FERC Relations, ISO New England. It is among the comments filed with the Federal Energy Regulatory Commission during the New England Winter Gas-Electric Forum, September 8, 2022. The full statement is available by going to the "Agenda" link on the Forum's webpage and locating the link to a downloadable statement presented by Stephen George, Director, Operational Performance, Training, and Integration, ISO New England.

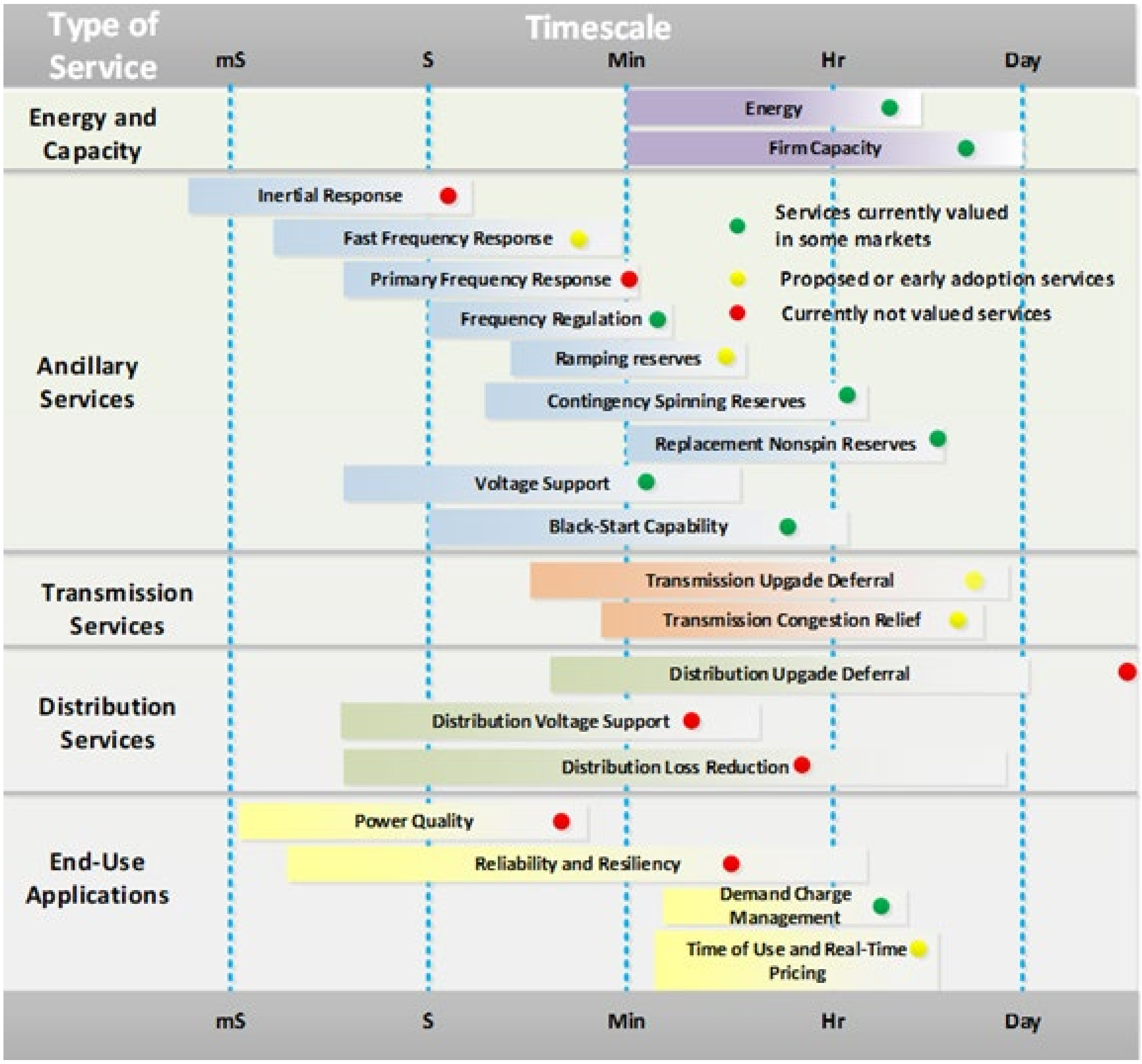
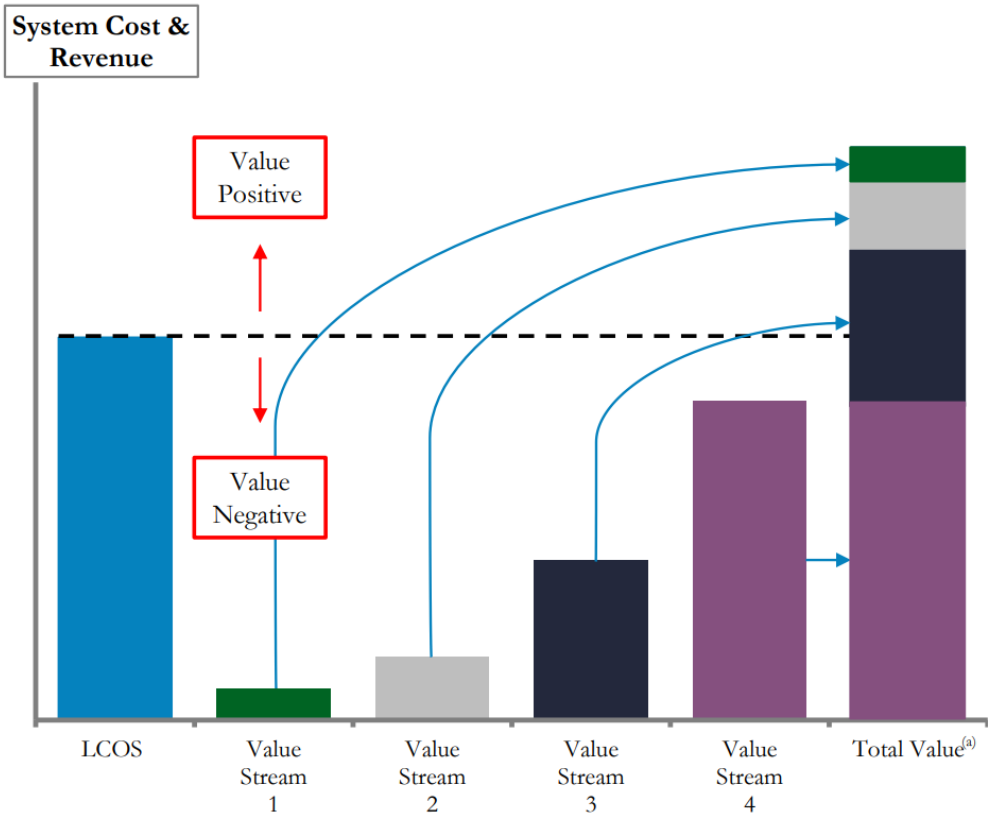


Figure 8. Energy storage system benefits, by type and range of duration. *Source:* Greening the Grid.

The colored dots—green, yellow, and red—in Figure 8 show benefits that customers and utilities might undervalue (and the relative degree of that undervaluing) in current energy systems accounting. Because storage can benefit many services, stacking those value streams helps customers understand how compelling and cost-effective energy storage can be, as shown in Figure 9.



(a) The total value would likely differ from the sum of all available value streams in practice.

Figure 9: Example of value stacking for storage as presented in [Lazard's Levelized Cost of Storage – Version 2.0](#).

Value stacking also shows how important it is to coordinate the services to ensure end users can optimally share storage system benefits, as exemplified in GMP's energy storage system and bring your own device programs. GMP uses the collective storage capacity of the distributed batteries to provide energy arbitrage and lower net power costs, manage distribution system voltage and volt-amps reactive (VAR), and host distributed generation. GMP uses their solar storage facility in Stafford Hill to participate in frequency regulation.

Benefits for residential and C&I customers. Utilities use time-of-use rates to discourage energy consumption when energy production costs are high, such as during peak demand and low renewable energy generation periods. Time-of-use rates are currently available to approximately eighty percent of customers statewide, however very few customers take advantage of them due to lack of awareness that the alternative rates exist or lack of economic benefit to the customer for switching rate structures. Utilities could update rate structures to better account for the economic benefits of shifting energy use to encourage energy storage growth in Vermont.[9]

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[9] In June 2022, the California Public Utilities Commission proposed new time-of-use rates specific to each customer at any time, including real-time energy pricing, real time capacity prices, and bi-directional pricing, to better recover

For both C&I and residential customers, greater energy reliability and resilience lead to less downtime for in-building energy systems, and less likelihood that there will be a loss of goods (for example, from interrupted refrigeration) and less loss of life during an unexpected, long power outage. GMP has proven that power reliability is the number one value proposition for residential customers selecting onsite energy storage.

From a utility perspective, energy storage improves power quality, too, in addition to the reliability and resilience benefits it shares with customers. Improved power quality reduces equipment damage and production losses, and increases overall energy efficiency.

Special benefits for C&I customers. Demand charges can comprise a high percentage of C&I electric bills. Although some C&I processes can be time-phased to reduce or flatten demand on electricity supply, other processes are fixed—and therefore could use stored energy to meet the load.

Benefits for residential customers. Although most residential customers do not incur demand charges from home energy use, demand charge management is important for customers residing in territories with small electric service lines. That is, assuming building electrification will continue to increase, demand charge management is an effective method for avoiding costly service line increase fees. This singular value proposition might not justify the full cost of an energy storage system, but it could contribute several thousand dollars in savings toward a total energy value stack.

Opportunities exist for applying value stacking to LDES to improve system feasibility in Vermont. Using advanced metering infrastructure modeling tools Efficiency Vermont can support utilities and customers in evaluating the value stack of proposed energy

Case Studies of the Customer Value from Energy Storage: Two Utilities' Programs

GMP's battery storage program (Bring Your Own Device, or BYOD) reduces the capital cost for residential customers. Customers share access to their battery with GMP. GMP uses a portion of the batteries' capacity for demand response, energy arbitrage (purchasing energy during off-peak periods and storing it), and frequency regulation (ensuring electricity supply and demand are balanced, system-wide). When severe weather or unforeseen events turn off grid power, the customer uses the batteries for power. Targeting this program for customers on the least reliable circuits enables GMP to harden their system assets and greatly improve customer experience and safety.

VEC's utility-scale battery storage program found enough value from reducing peak demand loads for up to 400 kWh per year. The remainder of the time, the owner of the battery, Viridity Energy Solutions, uses it for frequency regulation.

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the cost associated with energy generation, distribution, and transmiss
resources.

storage projects.[10] As LDES systems increase in capacity, they also bring added benefits to more people.

LDES systems that support regional grid reliability can be funded from load ratio share. That is, Vermont's load share is approximately 4 percent of ISO New England's capacity. Spreading costs over a large pool of customers is advantageous in supporting large-scale systems, but increasing the scope of storage increases system planning complexity, and necessitates longer planning cycles.

Efficiency Vermont's Role in Storage

To keep electric costs affordable, Efficiency Vermont has a regulatory obligation to reduce total and peak load energy consumption. To meet this requirement, Efficiency Vermont programs offer incentives for energy-efficient lighting; appliances; heating, ventilation, and air conditioning systems (HVAC); building thermal improvements; system controls; industrial process enhancements; and electric vehicle charging equipment. Through these programs, Efficiency Vermont promotes the efficient electrification of heating, transportation, and industrial processes. The increased reliance on electricity puts increased pressure on maintaining grid resilience. Thus, promoting electrification successfully requires getting customers comfortable with and confident in adopting grid reliability measures.

Energy storage can support grid resilience and can be integrated into each of these Efficiency Vermont programs with early technology advancements in HVAC, building thermal envelope, and industrial processing. System controls + storage can significantly shift the time of energy consumption. This is an operational requirement for the grid of the future to meet the anticipated electricity demand. As demonstrated by the project with the Brattleboro Retreat, HVAC-integrated storage provides substantial flexible load management via peak shaving.

VELCO's long range transmission plan estimates 75 percent of Vermont's electric vehicles will participate (p. 20) in demand response programming in the high load sensitivity forecast analysis if the region is to avoid costly transmission system upgrades.

Efficiency Vermont intentionally avoids bidding storage into the ISO New England Forward Capacity Market to ensure participating utilities offering systems providing energy storage services manage them. Even so, Efficiency Vermont has considered supporting utilities in contracting a statewide aggregator for the purpose of achieving economies of scale for them, and could play a similar role for large-scale, long-duration storage if needed.

Expanding Efficiency Vermont's knowledge of non-electrochemical storage solutions applicable to site and community energy management will enable better support to residential, business, and municipal customers with resilience planning and energy efficiency cost optimization. This can be achieved while still meeting Efficiency Vermont's flexible load management targets. All

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[10] Examples of Efficiency Vermont's modeling capabilities that could support site and regional energy storage project evaluation include: AMI 360: Deeper Energy Efficiency via Advanced Regression Modeling, and Assessing the Electrical Grid Greenhouse Gas Impact of Strategic Electrification.

storage discussions necessitate direct engagement with DUs, since large storage systems could negatively affect grid operations when current grid conditions are not considered in project planning, according to VELCO (p. 7).

Recommendations

Concluding this exploration into Vermont energy storage needs, Efficiency Vermont presents the following observations:

1. **Comprehensive planning for short- and long-duration energy storage.** To meet State electrification and renewable energy production goals, Vermont needs a comprehensive plan for short- and long-duration energy storage. Electric vehicles, flow batteries, and non-electrochemical energy storage technologies could dramatically change the grid and the energy storage market. Vermont will benefit from a cohesive plan among DUs, VELCO, ISO New England, and EEUs.

2. **Moving the market toward more LDES.** Load shifting programs decrease the electricity peak demand load and extend the duration of the peak period, which necessitates longer-duration energy storage to sustain a renewably generated power grid. Long-duration storage systems are large capital projects requiring coordination across many stakeholders—and permitting. Financing can be challenging for the seemingly nascent non-electrochemical energy storage options because banks are unfamiliar with the systems. Location too drives many considerations for these systems. It is difficult to determine the level of application within the transmission and distribution system because size is the main factor in who pays for the system. DUs could consider innovative rate designs to account for time-of-use and location-specific benefits from energy storage, further supporting storage system economics.

3. **Meeting critical targets.** If Vermont is to meet its electrification and renewable energy generation goals, comprehensive planning for these projects needs to begin. The Vermont Public Service Department recently announced the formation of a technical working group to "investigate and discuss visibility, communication and control for distributed energy resources including load, generation, and storage" and report quarterly to the Vermont System Planning Committee.

4. **The role of data teams.** Efficiency Vermont's data analytics team is fully qualified to support utilities in planning large LDES projects. The vendor market sometimes reveals gaps in technical support in modeling potential project scenarios that Efficiency Vermont's team may be equipped to fulfill. Integrating utility generation, energy consumption, energy efficiency, beneficial electrification, and energy storage modeling can offer insights for future energy management programs.

5. **The role of Efficiency Vermont in supporting energy storage.** Efficiency Vermont needs to expand and promote its role in supporting customers with their energy storage goals, in collaboration with the DUs. Given the importance of energy storage in meeting Efficiency Vermont's performance targets and State goals, Efficiency Vermont would benefit from integrating storage into its flexible load management, greenhouse gas reduction, and residential and commercial programs. Efficiency Vermont can also ensure adequate valuation of energy efficiency, and weatherization specifically, in reducing local and regional energy storage capacity requirements. Collectively, the storage projects within these programs establish a non-electrochemical energy storage roadmap for future Efficiency Vermont strategies. The roadmap can help staff prioritize research and pilot demonstrations that align with customer and utility partner needs, while meeting program targets for savings and performance.

Through implementation of these recommendations Efficiency Vermont can further support Vermont in cost-effectively meeting its energy and climate goals in collaboration with the other EEUs, DUs, and VELCO.

Conclusion

Meeting Vermont's carbon and renewable energy goals will require statewide transmission and non-transmission alternatives to achieve grid transformation. Energy efficiency continues to provide benefits to Vermont's energy system and customers—it can reduce storage size requirements during normal grid operations and can increase the duration capacity of local energy storage systems through energy demand reduction. Building weatherization has an added benefit of reducing storage requirements during grid constraints and outages. Though energy efficiency continues to offer the least-cost opportunity for meeting customer energy needs, several hundred megawatts of energy storage will be necessary to support Vermont and ISO NE's energy forecasting by 2025.

Supporting customers and utilities with energy storage planning and implementation is Efficiency Vermont's further exploration into ensuring Vermont's energy security and affordability. In addition to electrochemical batteries, thermal and mechanical energy storage technologies offer opportunities for Efficiency Vermont's customers to improve power quality, increase energy reliability and resilience, and reduce energy costs through demand management and time of use flexibility. Energy storage system value can extend from the owner to provide energy system-wide benefits, and properly valuing these benefits can improve a storage system's cost effectiveness.

Given the importance of energy storage in meeting Efficiency Vermont's performance targets and State goals, Efficiency Vermont would benefit from integrating energy storage into its flexible load management, greenhouse gas reduction, and residential and commercial programs in coordination with the DUs. Efficiency Vermont can also support adequate valuation of energy efficiency, and weatherization specifically, in reducing local and regional energy storage capacity requirements.

Additionally, Vermont would benefit from a comprehensive plan for short- and long-duration energy storage, and Efficiency Vermont is well positioned to contribute to the planning process alongside the other EEUs, VELCO and the DUs. Further integrating utility generation, energy consumption, energy efficiency, beneficial electrification, and energy storage modeling can offer insights for future energy management programs.