

STATE OF CHARGE

Massachusetts Energy Storage Initiative

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Massachusetts Energy Storage Initiative Study

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Thank you from the *State of Charge* Study Team.



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LETTER FROM THE COMMISSIONER and INTERIM CEO

State of Charge was commissioned as part of the Baker-Polito Administration's Energy Storage Initiative (ESI), an initial \$10 million investment that recognizes the potential benefits of incorporating advanced storage technologies into Massachusetts energy portfolio. The ESI aims to achieve the benefits by pursuing a multi-pronged approach to establishing an energy storage market structure, building strategic partnerships and supporting storage projects at the electric wholesale system, utility distribution system, and customer side scale.

The Study Team comprised of Customized Energy Solutions, Sustainable Energy Advantage, Daymark, and Alevo Analytics, conducted this report on behalf of Massachusetts Department of Energy Resources (DOER) and Massachusetts Clean Energy Center (MassCEC). This study analyzes the national and Massachusetts storage industry landscape, reviews economic development and market opportunities for energy storage, and examines potential policies and programs to better support energy storage deployment in the Commonwealth.

Stakeholder engagement was the initial phase of this study's process and an integral part of the research. DOER, MassCEC and the Study Team gathered valuable information by contacting over 300 interested parties, and hosted stakeholder meetings with over 150 representatives of utilities, power supply companies, energy technology firms, ratepayers and municipalities. *State of Charge* incorporates qualitative and quantitative analyses of information and data from stakeholders paired with analytic data gathered by researchers across the country in order to further understand the current state of energy storage in Massachusetts and provide recommendations for potential future growth.

Following the release of this study, DOER and MassCEC will work with stakeholders to begin testing and implementing both the regulatory and the policy recommendations detailed herein. In the coming weeks, MassCEC and DOER will release a Request for Proposal seeking interested parties to undertake projects to demonstrate the viability and potential of energy storage technology and innovations in the Massachusetts energy market.

State of Charge makes clear that by embracing advanced energy storage technologies Massachusetts will continue to be a national leader in clean energy and innovation. This study is a first step in a longer process to fully analyze the benefits of advanced energy storage deployment and we look forward to continuing this work to establish the Commonwealth as a leader in energy storage.

Sincerely,



Judith Judson
Commissioner
Massachusetts Department of Energy Resources



Stephen Pike
Interim CEO
Massachusetts Clean Energy Center

There is great potential in Massachusetts for new advanced energy storage to enhance the efficiency, affordability, resiliency and cleanliness of the entire electric grid by modernizing the way we generate and deliver electricity. In order to increase energy storage deployment, this Study presents a comprehensive suite of policy recommendations to generate **600 MW of advanced energy** storage in the Commonwealth by 2025, thereby capturing **\$800 million in system benefits** to Massachusetts ratepayers.

Executive Summary

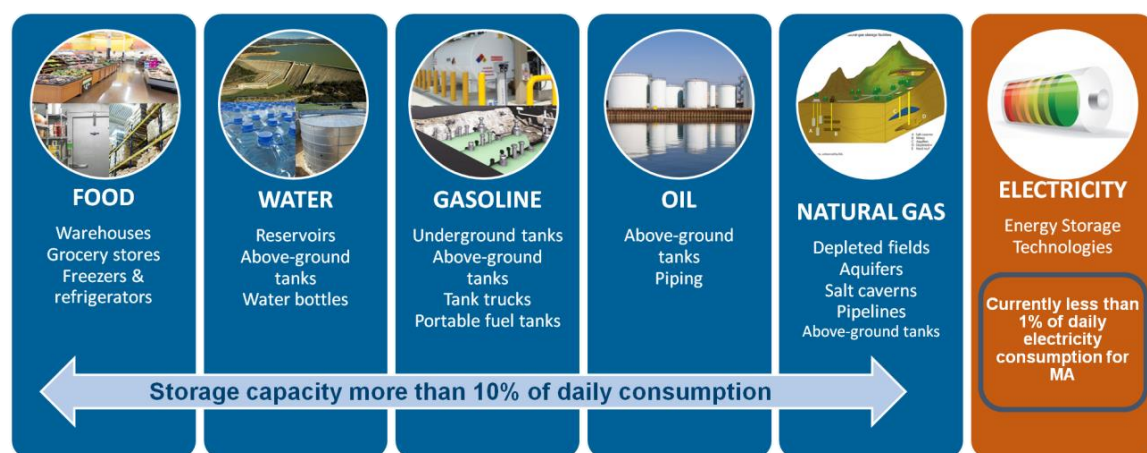


Figure 1: Storage in Commodity Supply Chains

Increasing the amount of storage capacity on the power grid has the potential to transform the way we generate and consume electricity for the benefit of Massachusetts ratepayers. As compared to other commodities, the electricity market currently has the least amount of storage in its supply chain. Other commodities, including food, water, gasoline, oil and natural gas, have an average storage capacity of 10% of the daily consumption (Figure 1). The electricity market currently has only a storage capacity of 1% of daily electricity consumption in Massachusetts. In addition to having a small storage capacity, electricity is also the fastest supply chain traveling at 1,800 miles per second, meaning that without storage electricity needs to be produced, delivered, and consumed nearly instantaneously for the grid to maintain balance. This requires grid infrastructure -- including generation, transmission and distribution systems -- to be sized to manage the highest peak usage of the year, despite consumer electricity demand varying significantly both throughout the day and at different seasons of the year (Figure 2).

The need to size all grid infrastructure to the highest peak results in system inefficiencies, underutilization of assets, and high cost to ratepayers. These high costs can be seen in the highly variable hourly electricity prices. Over the last three years from 2013 – 2015 on average, the top 1% most expensive hours accounted for 8% (\$680 million) of Massachusetts ratepayers' annual spend on electricity. The top 10% of hours during these years, on average, accounted for 40% of annual

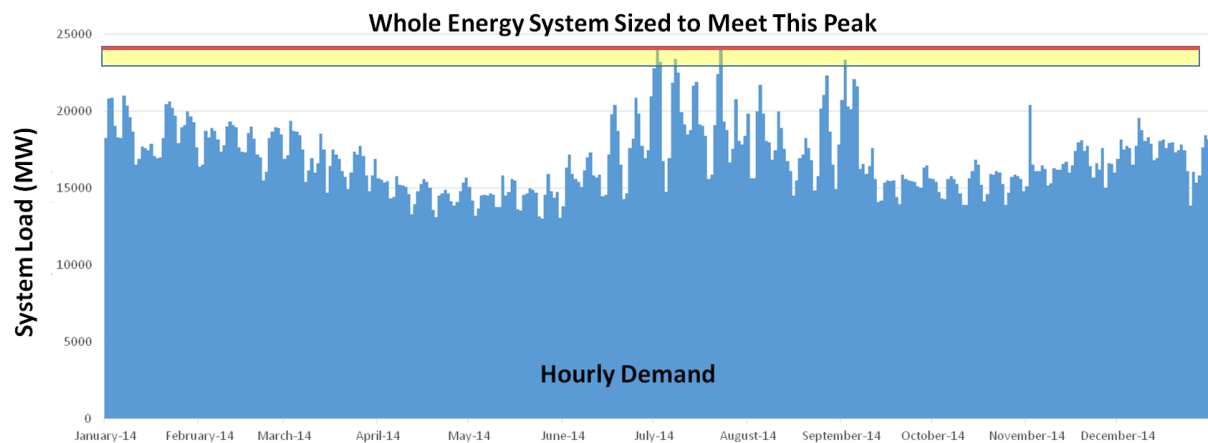


Figure 2: The whole electricity system is sized to meet peak demand

electricity spend, over \$3 billion.¹ Energy storage is the only technology that can use energy generated during low cost off-peak periods to serve load during expensive peak periods, thereby improving the overall utilization and economics of the electric grid (Figure 3). Until recently, the ability to store electricity across the electric grid was limited, but recent advances in new energy storage technologies, such as grid-scale batteries, are making viable the wide-scale deployment of electricity storage.

Advanced storage technologies can also provide the flexibility needed to reliably manage and utilize renewable resources' variable output. Today, the electric system operates on a "just-in-time" basis, with decisions about power plant dispatch that are based on real-time demand and the availability of transmission to deliver it. Generation and load must always be perfectly in balance to ensure high power quality and reliability. As intermittent renewable generation, such as wind and solar, grows in Massachusetts maintaining this perfect balance becomes more challenging. Additionally, storage resources can be an important tool for better managing electric outages caused by severe weather, thus increasing grid resiliency. For these reasons and more, new storage technologies are an important component of a modern electric grid and a resilient clean energy future for the Commonwealth.

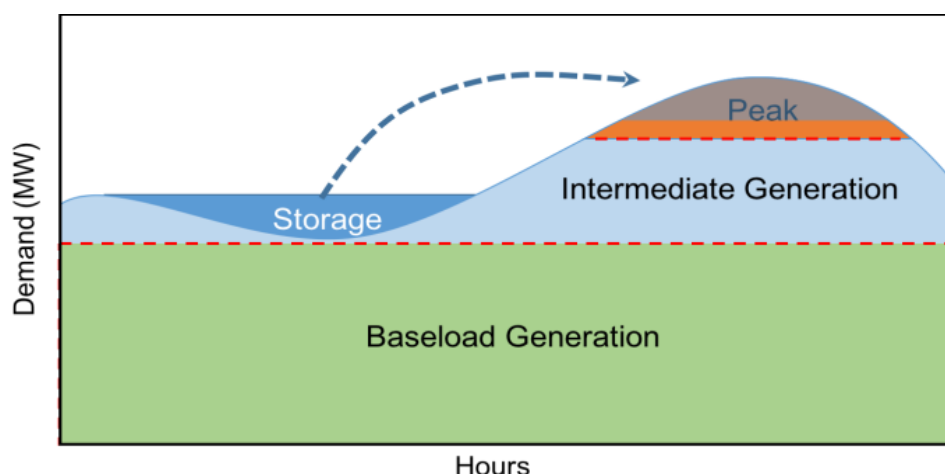


Figure 3: Energy storage can use off peak energy during times of high demand

¹ ISO-NE Hourly Load Data.

Massachusetts Energy Storage Initiative

Recognizing that energy storage can be a valuable component of a diversified energy portfolio for the Commonwealth, in May 2015 the Baker-Polito Administration launched the \$10 million Energy Storage Initiative to evaluate and demonstrate the benefits of deploying energy storage technologies in Massachusetts. As part of the initiative, the Department of Energy Resources (DOER) and the Massachusetts Clean Energy Center (MassCEC) partnered to conduct a study to analyze the economic benefits and market opportunities for energy storage in the state, as well as examine potential policies and programs that could be implemented to better support both energy storage deployment and growth of the storage industry in Massachusetts.

"Massachusetts will continue to lead the way on clean energy, energy efficiency and the adoption of innovative technologies such as energy storage. These efforts, and our legislative proposal to bring additional hydroelectricity and other renewable resources into the region, will ensure we meet our ambitious greenhouse gas emission reduction targets while also creating a stronger economy for the Commonwealth."

– Governor Baker, February 2016

The DOER, MassCEC, and the *State of Charge* Study Consultant Team kicked off the study in late October 2015 with an interactive stakeholder session in Boston. Subsequently, the team held webinars, and conducted numerous surveys and interviews. Over 300 stakeholders including representatives from the utilities, municipalities, competitive suppliers, storage project developers, renewable generation developers, storage technology companies, and the regional grid operator, ISO New England (ISO-NE), participated in the stakeholder process.

The message was clear: **energy storage is recognized as a game changer in the electric sector**. An overwhelming proportion of stakeholders are optimistic about the future of grid-connected energy storage in Massachusetts. Utilities and developers cite renewables growth, technology advances, and technology cost decreases as factors why energy storage will shape the grid both near-term and long-term.

"Given the recent advances in energy storage technology and cost-effectiveness, it is hard to imagine a modern electric distribution system that does not include energy storage."

– Massachusetts utility stakeholder

While recognizing the potential of energy storage, however, stakeholders identified numerous challenges and barriers that are preventing widespread deployment in the Commonwealth. Challenges highlighted are uncertainty regarding regulatory treatment, barriers in wholesale market rules, limitations in the ability for project developers to monetize the value of their energy storage project, and the lack of specific policies and programs to encourage the use of innovative storage technologies.

State of Charge is a comprehensive report prepared by Customized Energy Solutions, Sustainable Energy Advantage, Daymark, Alevo Analytics, and Strategen in conjunction with the DOER and the MassCEC that links Massachusetts' energy challenges to specific energy storage Use Cases, and offers insight into the cost, benefits, and feasibility of deploying new energy storage technologies in Massachusetts. It provides recommendations on policies and programs that can be employed by the Baker-Polito Administration to establish a mature local market for these technologies through

increasing the deployment of storage on the state’s electric grid and supporting the growth of energy storage companies in the Commonwealth.

Energy Storage Technologies and Market Landscape

“Modernizing the electric system will help the nation meet the challenge of handling projected energy needs—including addressing climate change by integrating more energy from renewable sources and enhancing efficiency from non-renewable energy processes. Advances to the electric grid must maintain a robust and resilient electricity delivery system, and energy storage can play a significant role in meeting these challenges by improving the operating capabilities of the grid, lowering cost and ensuring high reliability, as well as deferring and reducing infrastructure investments. Additionally, energy storage can be instrumental for emergency preparedness because of its ability to provide backup power as well as grid stabilization services.”

— U.S. Department of Energy Whitepaper on Grid Energy Storage (Dec 2013)

The term “energy storage” applies to many different technologies (Figure 4), including: batteries, flywheels, thermal storage, and pumped hydroelectric storage. All technologies can store energy during periods when the cost is low and then make the energy available during periods when the costs are higher.

Pumped hydro storage is often referred to as a “conventional” storage technology and involves pumping water into a large reservoir at a high elevation—usually located on the top of a mountain or hill – and then using hydroelectric turbines to convert the energy of flowing water to electricity. Newer and more flexible forms of energy storage such as batteries, flywheels, thermal, and new compressed air energy technologies are often referred to as “advanced energy storage.” Advanced energy storage resources are capable of dispatching electricity within seconds. They can provide various storage durations – from 15 minutes to over 10 hours – and range in scale from small systems used in homes for backup power to utility-scale systems that interconnect to the bulk power grid.

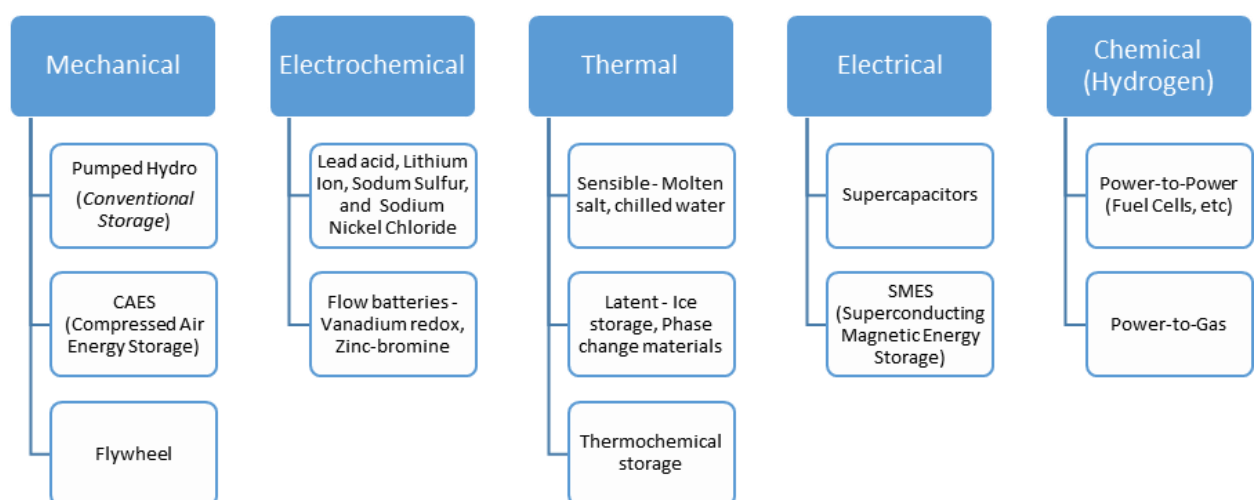


Figure 4: Classification of Energy Storage Technologies

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To date, energy storage in Massachusetts has primarily been limited to pumped hydro storage in Northwest Massachusetts and provides bulk energy to the New England grid operator, ISO-NE. The evolution and diversity of energy storage technologies, applications, and grid locations has gone well beyond the limits of pumped hydro storage. While Massachusetts has benefited from pumped storage operating in the region, geographic and environmental limitations make it unlikely that new pumped storage will be built. Therefore, the *State of Charge* study focuses on new advanced energy storage technologies that are now available.

Many advanced energy storage technologies are commercially viable and today are currently being used by utilities and grid operators throughout the United States and around the world, driven by growth in renewable energy generation and local reliability needs.

According to the U.S. Department of Energy (DOE), there are already more than 500 MW of advanced energy storage in operation in the U.S. In 2015 alone, there were 221 MW of new deployments of advanced energy storage in the U.S., an increase of 243% over the installations in the U.S. for the year 2014². It is expected that annual deployments of advanced energy storage will exceed 1 GW per year by 2019 and be at nearly 2 GW per year by 2020 (Figure 5). It is expected that there will be nearly 4,500 MW of advanced storage technologies operating on the U.S. grid by 2020.³ Overall, the U.S. Market for advanced energy storage technologies is expected to grow by 500% in five years.

Prices for advanced storage technologies have decreased significantly in recent years.⁴ According to IHS, a leading business data provider, average lithium-ion battery prices decreased in cost over 50% between 2012 and 2015, and are expected to decrease over 50% again before 2019.⁵

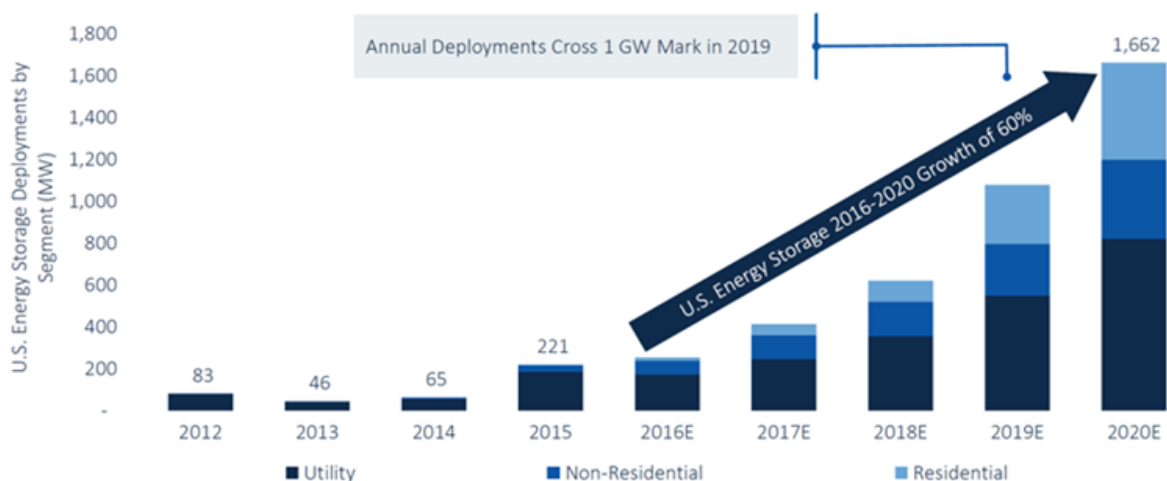


Figure 5: GTM Research Estimate of Energy Storage Growth

² Energy Storage Association & GTM Research, U.S. Energy Storage Monitor: 2015 Year in Review, March 9, 2016.

³ *ibid*

⁴ Energy Storage Update, Lithium-ion costs to fall by up to 50% within five years, July 30, 2016;

<http://analysis.energystorageupdate.com/lithium-ion-costs-fall-50-within-five-years>

⁵ IHS, *Price Declines Expected to Broaden the Energy Storage Market*, IHS Says, November 25, 2015;

<http://press.ihs.com/press-release/technology/price-declines-expected-broaden-energy-storage-market-ihs-says>

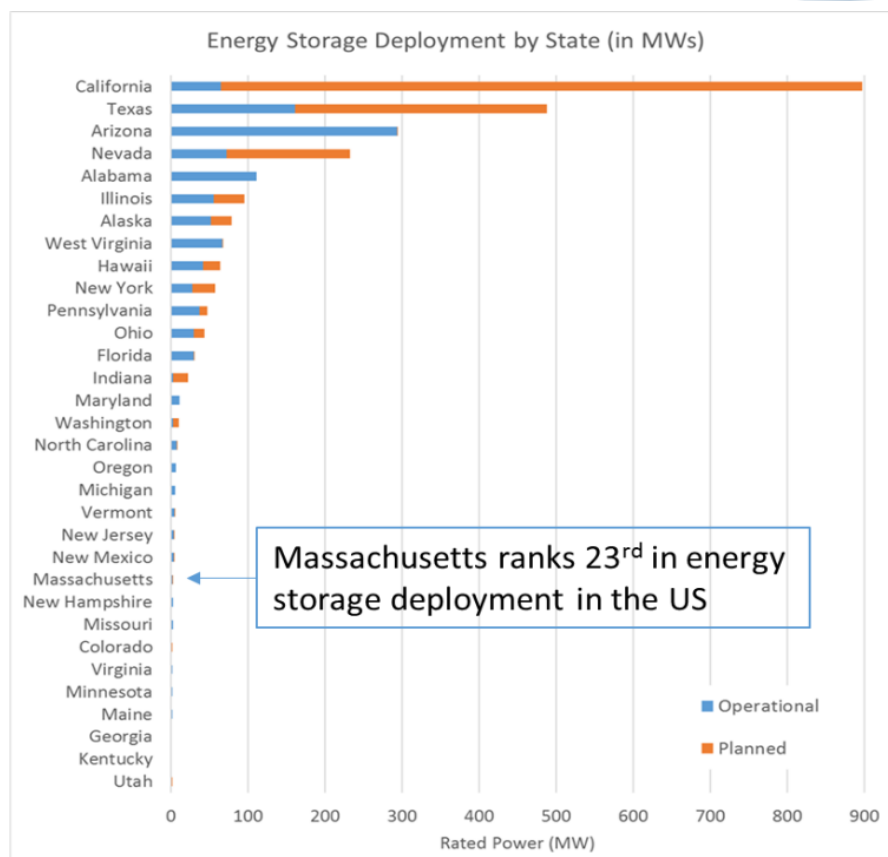


Figure 6: Planned and Operational Energy Storage Deployment by State

Although advanced energy storage deployment to date in Massachusetts has been limited to less than 2 MW, interest in utilizing advanced energy storage is growing. With the significant cost decrease for advanced energy storage, and the progression of the technologies' capabilities, Massachusetts has immense room for growth and expansion. Currently, Massachusetts ranks 23rd in the country in installing advanced energy storage (Figure 6). Other states are far ahead in terms of integrating energy storage into their electric power infrastructure to address retiring generation capacity, peak demands and intermittent renewable generation.

In California, for example, Southern California Edison utility announced the procurement of 261 MW of energy storage resources in November 2014 as part of a comprehensive solution to mitigate the closing of a 2,200 MW nuclear plant. In Texas, the state with the highest amount of installed wind capacity, advanced storage is being deployed to help balance or "smooth" the intermittent output of these renewable resources. In New York, Con Edison utility has received approval from the NY Public Service Commission to utilize advanced energy storage as part of a solution to avoid the construction of a new \$1 billion substation in Brooklyn.

Storage Can Help Address Massachusetts' Energy Challenges

Like other states that are utilizing new advanced energy storage solutions to solve electric system challenges, Massachusetts could similarly benefit from these technologies.

Generation Retirements

The New England region is experiencing significant amounts of generation retirements with the planned shutdown of 4,200 MW of generation by 2019 and an additional 6,000 MW at risk of retirement by 2020, including several plants located in and serving the populated load centers in Eastern Massachusetts. Energy Storage can operate as an emissions free source of “local” peak generation in highly populated areas to mitigate these retirements.

Advanced storage projects typically require a much smaller footprint and shorter construction timeline than conventional generation; a grid-scale energy storage project can be constructed within months, not years. The modular design of storage resources means that the projects can be sized to any level. Increments of capacity can easily be added to increase the size of the project. The “plug and play” concept of new storage technologies makes them easy to locate near an existing power plant, a utility substation, or at a consumer site (such as a house, a factory or a shopping center).

Peak Demand is Growing

Massachusetts has successfully implemented aggressive energy efficiency programs which have reduced average energy consumption. However, according to ISO-NE’s *State of the Grid 2016* report, the peak demand continues to grow in the region at a rate of 1.5% per year (Figure 7) resulting in added costs to ratepayers to maintain reliability.⁶ In order to provide enough energy during peak periods new natural gas “peaker” plants are being built even though they are needed only for a small amount of hours per year.⁷ According to the U.S. Energy Information Administration (EIA) peaker plants only operate 2% – 7% of the hours in a year (Figure 8). Instead of generating electricity with natural gas “peaker” plants during times of high electric and fuel prices, storage can be used to “peak shift” by using lower cost energy stored during off-peak periods to meet this demand.

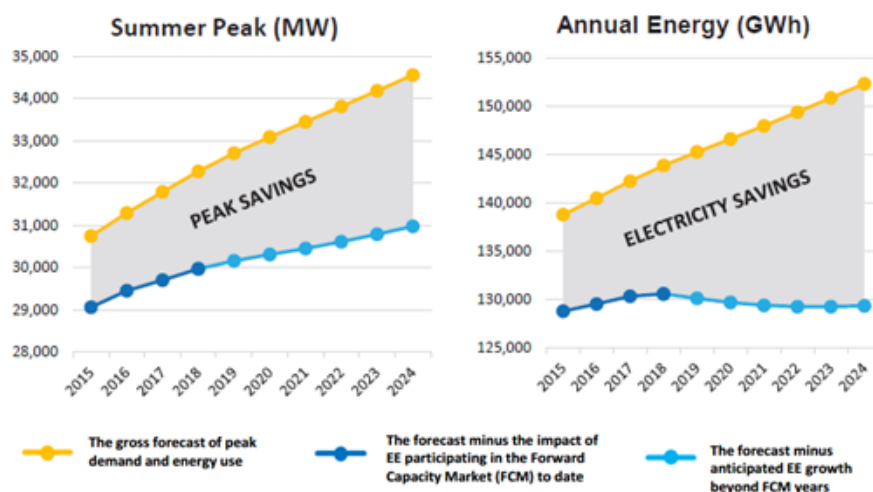


Figure 7: While Energy Efficiency has Decreased Average Energy Consumption, Peak Continues to Grow (1.5% per year)⁸

⁶ ISO-NE, State of the Grid: 2016, January 26, 2016; http://www.iso-ne.com/static-assets/documents/2016/01/20160126_presentation_2016stateofthegrid.pdf

⁷ Currently, there are three natural gas peaker plants in these zones accounting for approximate potential 600 MW capacity undergoing Massachusetts Environmental Protection Act (MEPA) review at the Executive Office of Energy and Environmental Affairs (EEA).

⁸ ISO-NE, State of the Grid- 2016, January 26, 2016.

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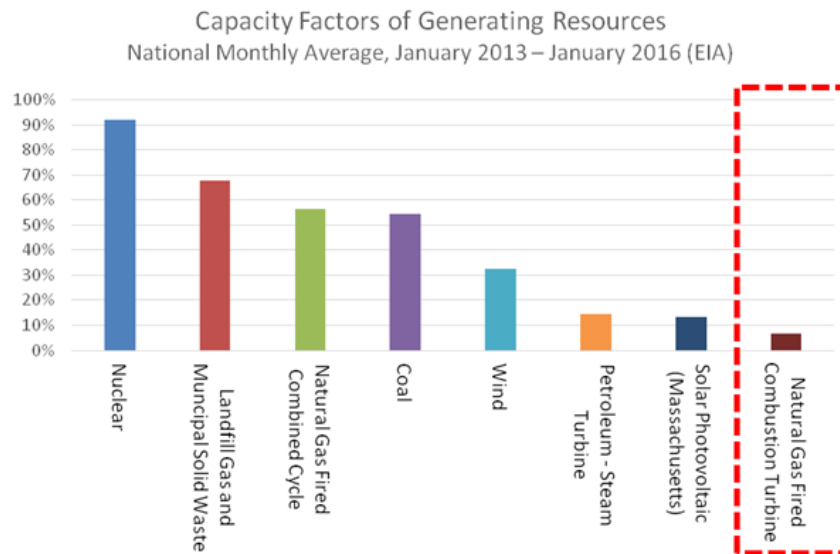


Figure 8: Peaker Plants Only Operate 2-7% of the Time

Integrate Intermittent Renewable Generation

To meet the state's goals for reducing greenhouse gas (GHG) emissions, the use of intermittent renewable generation, such as wind and solar, is growing in the New England region. To maintain reliability with a large penetration of renewable resources, new resources are needed that can quickly follow the variable and unpredictable changes in renewable resource output. According to ISO-NE *State of the Grid – 2016* report, fast and flexible resources will be needed to balance intermittent resources' variable output. Across the country advanced storage technologies that can change output very quickly (in less than 1 second) in response to a change in output from a renewable resource have been seen as an ideal technology to provide fast accurate balancing services to the grid (see Figure 9).

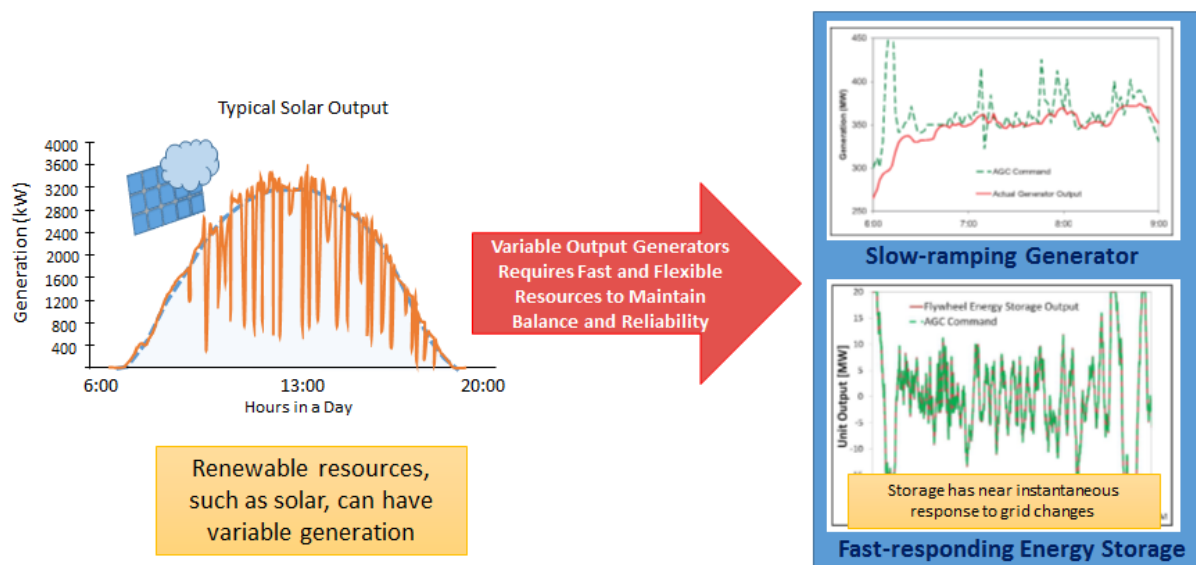


Figure 9: Energy Storage Can Respond Quickly to Variable Output to Smooth Output and Provide Frequency Regulation

Skyrocketing Growth in Distributed Generation

The amount of installed distributed generation, particularly solar photovoltaic (PV) resources, has skyrocketed in the Commonwealth. There are over 40,000 distributed solar PV projects operating today with 400 newly installed projects per week. As more solar PV resources are connected to the distribution system, utilities are challenged to manage two-way power flows at the substations. Distributed storage located at substations can help manage flows more effectively and alleviate reliability issues caused by reverse power flows. Reverse power flow is an excess of power flowing from the solar generator into the grid, which may damage the grid's protective systems. This may occur during times of light load and high solar generation where protection systems are not designed for this overload. Using energy storage on the distribution side of the system will eliminate reverse power flow concerns by charging with the solar surplus (seen in the green portion of Figure 10) and discharging during times of high demand (seen in the red portion of Figure 10). Eliminating the reverse power flow concerns will provide reliability benefits and lower the interconnection cost of integrating distributed solar resources.

Major Outages from Severe Weather

Major electric outages resulting from severe weather impacts are becoming more commonplace. Although the total number of weather days has decreased, the severity of storm events and the number of customer outages has increased in recent years. For businesses and residents, the costs of lost productivity due to an outage can be tremendous. Storage distributed across the Massachusetts utility system can greatly increase the electric grid's resiliency in storm events.

High Electricity Prices

Massachusetts has one of the highest electricity rates in the nation. Commercial and industrial businesses, especially those with high electricity use and demand charges,⁹ could utilize storage at their facilities to better manage their peak electric consumption, integrate any on-site generation, and reduce their electricity bills.

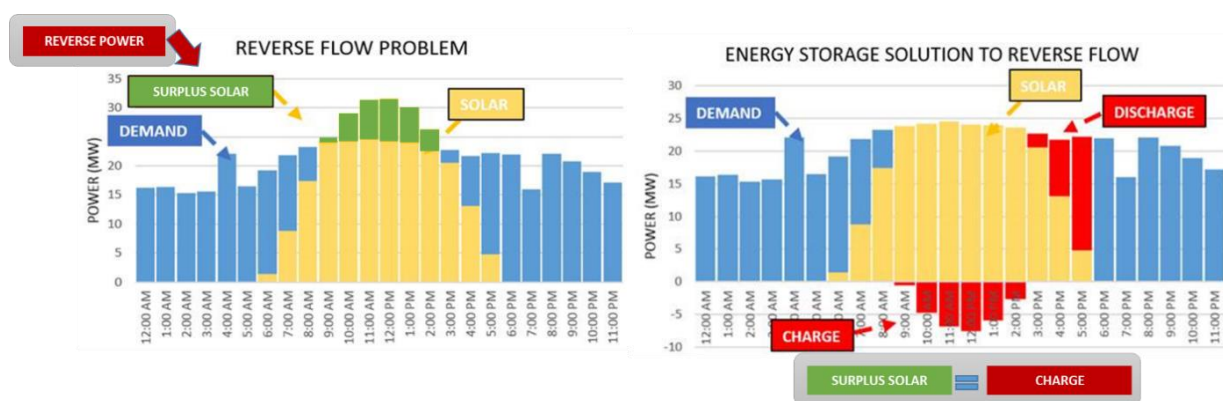


Figure 10: Storage Can Avoid Reverse Power Flows with Solar PV

⁹ Demand charge refers to a fee that C&I customers pay based on their monthly peak electricity usage. The demand charge is calculated based on the highest capacity required during a given billing period.

Storage Opportunity Analysis

In order to better quantify the impact of adding storage to the Massachusetts grid, the *State of Charge* Study Consultant Team performed a comprehensive modeling analysis, using Alevo Analytics' Advanced Storage Optimization tool, to evaluate and quantify the potential benefits that energy storage distributed across Massachusetts' electric grid can provide ratepayers. Specifically, modeling was conducted to determine:

- The optimal amount of advanced storage in MW and MWh to be added over the next 5 years – through 2020 – that will add maximum benefit to ratepayers;
- The distribution of energy storage locations across Massachusetts where adding storage will achieve maximum benefits to the ratepayers; and
- A quantification of the reduction in GHG emissions that can be achieved with the optimum level of energy storage deployments across the state.

Alevo Analytics' Advanced Storage Optimization tool utilizes multiple iterations of both Capacity and Production Cost modeling, capturing both hourly and sub-hourly Massachusetts grid conditions, to predict future grid needs and challenges. The data utilized for the model include detailed Massachusetts specific generation, transmission and distribution data in a simulation of the ISO-NE markets that co-optimize energy and ancillary services subject to transmission thermal constraints. The existing generation resource mix (including all installed pumped storage in ISO-NE) is used in the simulation. The model also accounts for expected generation retirements and additions during the study period. The model was stress tested with varying levels of load requirements, fuel prices, and renewable deployment.

By evaluating current and predicted energy storage costs, other technology costs, and economic conditions, the model determines the amount of advanced energy storage that will optimize the overall operation and cost of the Massachusetts electric system (see Figure 11 model flow chart).

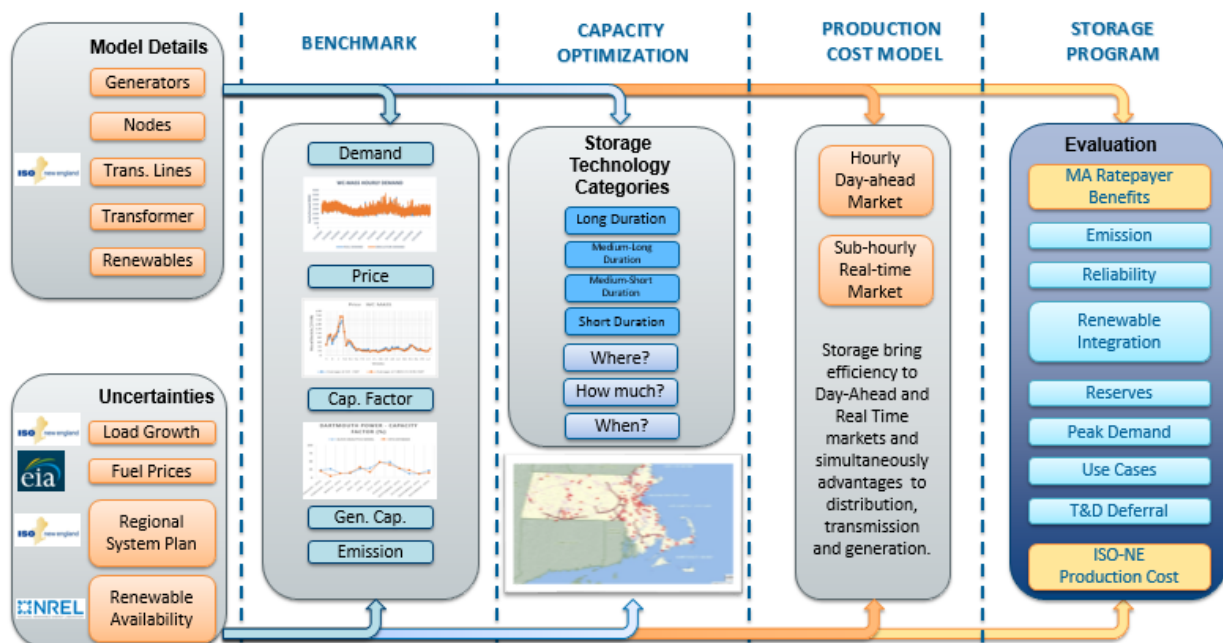


Figure 11: Advanced Storage Optimization Model/Process

The model analyzed 1,497 nodes and 250 substations in Massachusetts that include generator, transmission and load substations where storage could be located. The model simulated the electric system to determine where and at what quantity storage could be added in Massachusetts in order to achieve the following benefits:

- Minimization of wholesale market costs
- Minimization of Massachusetts emissions
- Increased utilization of transmission and distribution assets
- Minimization of incremental new transmission assets
- Increased resiliency from wide-scale transmission, distribution, and generation outages
- Reduced requirements for new peaker power plant capacity

For each location, the algorithm determines the optimal amount of energy storage by MW and MWh by identifying where the cost of the storage deployment is less than the total benefits to the system.

Modeling Results: Cost and Benefit Analysis

Through this modeling effort, it was found there is a potential for a large cost effective deployment of advanced energy storage in Massachusetts. The modelling results show that up to 1,766 MW of new advanced energy storage would maximize Massachusetts ratepayer benefits. The results show that this amount of storage, at appropriate locations with sizes defined by system requirements and dispatched to maximize capability, would result in up to \$2.3 billion in benefits. These benefits are cost savings to ratepayers from:

- Reducing the price paid for electricity
- Lowering peak demand by nearly 10%
- Deferring transmission and distribution investments
- Reducing GHG emissions (reducing the effective cost of compliance)
- Reducing the cost to integrate renewable generation
- Deferring capital investments in new capacity
- Increasing the grid's overall flexibility, reliability and resiliency

The model found that this optimized amount of storage in Massachusetts would provide an additional \$250 million in regional system benefits to the other New England states due to lower wholesale market prices across all ISO-NE zones. The model estimates that this optimal amount of storage provides a reduction in GHG gas emissions by more than 1 MMT CO₂e over a 10 year time span and is equivalent to taking over 223,000 cars off the road over the same time span. The breakdown of the total modeled benefits is shown in Table 1.

This optimized amount of storage is estimated to cost \$970 million to \$1.35 billion. Considering the Massachusetts ratepayer benefits alone of \$2.3 billion, 1,766 MW of storage provides net benefits to ratepayers with a benefit-cost ratio ranging from 1.7 to 2.4.

In addition to system benefits that accrue to all ratepayers, the modeling results also show the potential for \$1.1 billion in direct benefits to the resource owners from market revenue. The modeling results indicate that there will be a total storage value of \$3.4 billion, where \$2.3 billion comes from system benefits, i.e. cost savings to ratepayers, and \$1.1 billion in market revenue to the resource owners. Figure 12 shows the overall value proposition of investing in 1,766 MW of energy storage.

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Benefit Description	Ratepayer Savings
Energy Cost Reduction Energy storage uses lower cost energy stored at off-peak to replace the use of higher cost peak generation: <ul style="list-style-type: none"> • reduced peak prices • reduced overall average energy price 	\$275M
Reduced Peak Capacity Energy storage can provide peaking capacity to: <ul style="list-style-type: none"> • defer the capital costs peaker plants • reduce cost in the capacity market 	\$1093M
Ancillary Services Cost Reduction Energy storage would reduce the overall costs of ancillary services required by the grid system through: <ul style="list-style-type: none"> • frequency regulation • spinning reserve • voltage stabilization 	\$200M
Wholesale Market Cost Reduction Energy storage provides system flexibility, reducing the need to ramp generators up and down and resulting in: <ul style="list-style-type: none"> • less wear and tear • reduced start up and shut down costs • reduced GHG emissions (lower compliance cost) 	\$197M
T&D Cost Reduction Energy storage: <ul style="list-style-type: none"> • reduces the losses and maintenance of system • provides reactive power support • increases resilience • defers investment 	\$305M
Integrating Distributed Renewable Generation Cost Reduction Energy storage reduces cost in integrating distributed renewable energy by: <ul style="list-style-type: none"> • addressing reverse power flow at substations • avoiding feeder upgrades at substations 	\$219M
Total System Benefits	\$2,288M

Table 1: Total System Benefits

Storage projects can simultaneously provide both system benefits to all ratepayers and direct revenue to the resource owners. For example, if an entity develops an energy storage system in a load constrained area for the purpose of storing cheap electricity to sell during times of higher electricity price, not only does that developer receive sales revenue, ratepayers also see lowered prices. This ratepayer cost reduction results from deferring the cost of a new transmission line into the load zone to meet an ever increasing peak demand or it can be an energy cost reduction created by the storage resource's peak shifting suppressing energy prices. Either way, ratepayers see a benefit from that storage development and the storage project developer sees revenue from the investment.

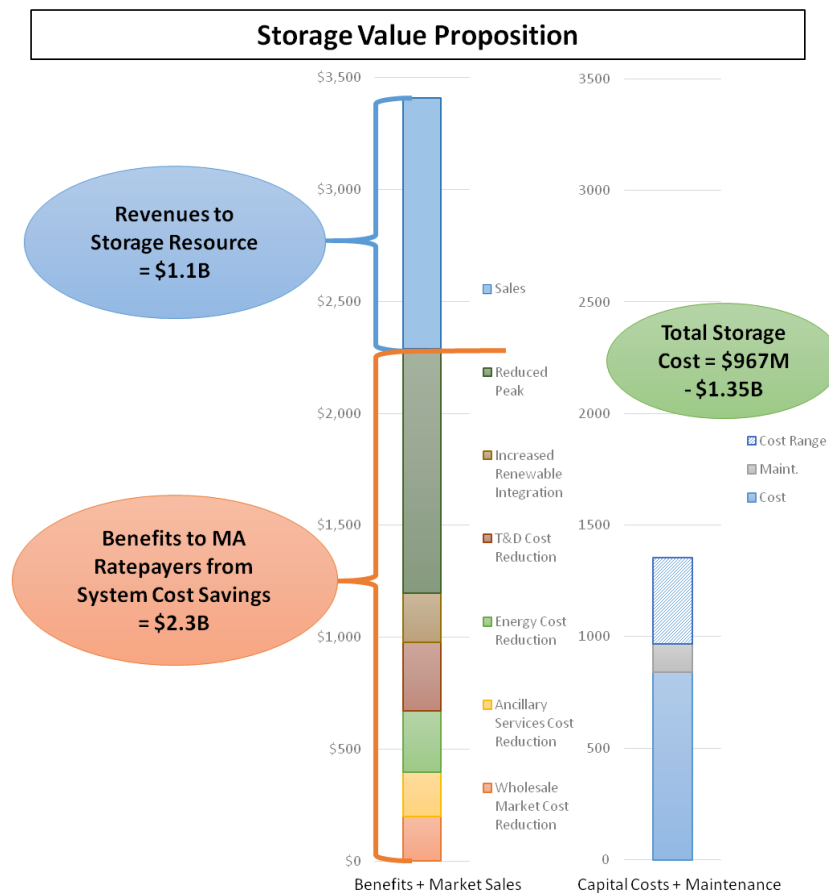


Figure 12: Storage Value Proposition

In addition to energy price hedging and other services, storage projects have the potential to earn additional revenues in the wholesale electricity market for energy, capacity, and ancillary services. However, as further discussed in Chapter 8, this will require that ISO-NE remove barriers in their market rules that currently limit the full participation of advanced energy storage projects in their wholesale markets. Additionally, storage projects can earn revenue if located at a customer site by reducing the customer's electricity bill.

Generally, in order for a private entity to make an investment in storage, the revenue from the entity's investment in the storage technology has to outweigh the capital investment cost. As shown in Figure 12, from a ratepayer perspective, the system benefits alone justify an investment in storage. However, the existing revenue mechanisms that would encourage investment from a private storage developer are often insufficient. Private investors will simply not invest in building storage projects in Massachusetts without a means to be monetarily compensated for the value the storage resource provides to the system, even though doing so would result in cost benefits to ratepayers that substantially outweigh the cost of investment. **This finding explains why the Alevo Analytics modeling shows that Massachusetts ratepayers could benefit from a large potential of advanced energy storage deployed across the Massachusetts grid, yet today there is only a limited amount (less than 2 MW) of advanced storage actually operating in the Commonwealth.**

The biggest challenge to achieving more storage deployment in Massachusetts is the lack of clear market mechanisms to transfer some portion of the system benefits (e.g. cost savings to ratepayers)

created to the storage project developer. This limit on existing energy storage opportunities prompts a fresh look into how to account for the complete energy storage benefits by the wholesale and retail market electricity markets, as well as by regulators and policy makers.

As described in Chapter 6, other states are advancing regulatory and policy initiatives that recognize and seek to correct this discrepancy. Therefore, the Study Team evaluated approaches being pursued in other states to analyze their applicability for Massachusetts.

Energy Storage Application Use Cases

Based on the modeling results and feedback from stakeholders, the Study Team analyzed the economics of ten specific storage Use Cases to evaluate how storage economics vary by business model, market involvement and location. The Use Cases include merchant wholesale applications, storage paired with renewable generation projects, use as a utility grid modernization asset, and behind the meter applications at both commercial and residential locations. The Use Cases illustrate how storage owners and developers can capture value from owning, operating, or contracting for services from energy storage resources, as well as the system benefits that are created from the Use Case application. The economic analysis of these Use Cases is then used to inform specific policy and program recommendations to grow the cost-effective and beneficial use of storage in Massachusetts. The Use Cases are visualized in Figure 13 and described in Table 2. A detailed analysis of the Use Cases is presented in Chapter 5.

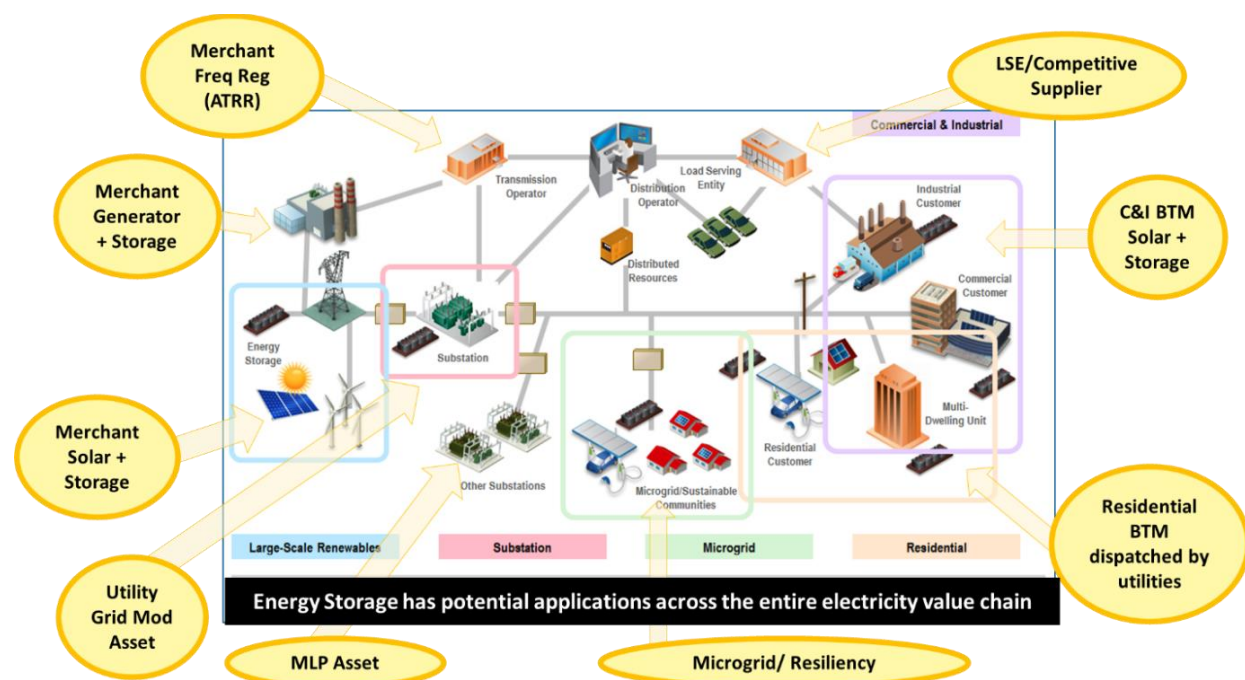


Figure 13: Energy Storage Application across Electricity Enterprise Value Chain

<i>Use Cases</i>		
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		The storage systems would be owned and dispatched by the Investor Owned Utilities, i.e. Unitil, Eversource, and National Grid. The systems would be likely located at distribution substations with the locations selected by the IOUs to address local needs including high demand, reliability conditions, and renewables integration.
Municipal Light Plant (MLP) Asset		The storage systems would be owned and operated by a Massachusetts MLP and located within the municipality. Uses for the systems would be to lower the municipality's peak demand, capacity and transmission costs, as well as to provide local resiliency.
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		In Massachusetts LSE's provide the energy supply portion of a ratepayers IOU electricity bill. LSE's either offer competitive supply direct to consumers or provide IOU's basic service supply. An LSE would utilize storage as a means to hedge energy costs, purchasing low cost energy and providing stored energy during times of high energy cost, and to sell services in the ISO-NE markets.
Behind the Meter	C&I Solar Plus Storage	A commercial or industrial customer with on-site solar would own and operate a storage system to better utilize and firm the energy from the solar installation, allowing the C&I customer to reduce their reliance on grid energy during peak times, decreasing demand charges, and capturing the full value of their solar energy regardless of net-metering structure.
	Residential Storage	A behind the meter residential storage system can be owned by the customer and located within the home for resiliency during grid outages.
	Residential Storage Dispatched by Utility	Similar to the above Use Case, the storage system would be located in the home and provide resiliency but the utility would be able to dispatch the system to capture the grid benefits of peak demand reduction. The system could be owned by either the utility or the customer.
Merchant	Alternative Technology Regulation Resource	A merchant storage developer operates the storage system as an Alternative Technology Regulation Resource (ATRR) to provide frequency regulation in the ISO-NE market.
	Storage + Solar	A solar merchant project developer operates a storage system co-located with the solar resource to better integrate the solar generation into the energy market. The storage system allows the project developer to sell "dispatchable" and firm solar energy better aligned with peak demand, as well as ancillary services.
	Stand-alone Storage or Co-Located with Traditional Generation Plant	A gas or other fossil fuel generator would own and operate a storage system on site to allow the plant to run at optimal heat rate levels, utilizing the storage to provide fast ramping response and ancillary services.
Resiliency/Microgrid		A municipality or another localized energy user such as a university campus or medical center owns and operates the energy storage systems to provide peak demand reduction, reducing capacity or demand charges, while reducing the costs to provide backup power in the event of an outage.

Table 2: Use Case Descriptions

For each Use Case the Study Team evaluated the economics for making the investment in the storage by assessing:

- (1) The value the storage owner/developer can monetize through existing market mechanisms, and
- (2) The system benefits that would accrue to Massachusetts ratepayers should the investment in storage be made.

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Use Case		Estimated Share of 1766 MW Recommendation		Millions \$		Benefit/Cost Ratio
		%	MW	Combined Benefits (Market Revenue + System Benefits)	Cost	
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		40%	707	1301	387	3.36
Municipal Light Plant (MLP) Asset		10%	177	446	97	4.60
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		8%	141	158	77	2.05
Behind the Meter	C&I Solar + Storage	6%	106	103	58	1.78
	Residential Storage	4%	71	19	53	0.49
	Residential Storage Dispatched by Utility	5.5%	96	129	39	2.43
Merchant	Alternative Technology Regulation Resource	1.5%	28	45	15	3.00
	Storage + Solar	10.5%	185	373	102	3.66
	Stand-alone Storage or Co-Located with Traditional Generation Plant	9.5%	168	405	92	4.40
Resiliency/Microgrid		5%	87	133	48	2.77

Table 3: Use Case Benefit-to-Cost Ratio

By examining the combined benefits from both the value the storage resource could earn through market mechanisms, as well as the benefits the storage resource would provide the system through reductions in system costs, a determination can be made as to whether it would be cost-effective to Massachusetts ratepayers to utilize storage for each Use Case. Table 3 shows that when the potential revenue streams available to the project owner and the benefits that would accrue to the overall electric system are combined, the analysis resulted in benefit-to-cost ratios greater than 1 in most Use Cases. However, as discussed in detail in Chapter 5, while the all-in benefits outweigh the cost of investment, in many Use Cases the value that the storage owner/developer can monetize through existing market mechanisms and regulatory constructs is too small for the investment to be made by the storage owner/developer even though doing so would result in net benefits to electric ratepayers. To realize the system benefits modeled, mechanisms are needed to bridge the gap between the cost of energy storage and the revenue captured by the storage owner/developer.

Regulatory and Policy Recommendations

Based on the Modeling analysis in Chapter 4 and the Use Case analysis in Chapter 5, as well as the review of other state's storage policies and programs in Chapter 6, a roadmap is proposed for Massachusetts to facilitate the deployment of energy storage within the state to achieve optimal system benefits to rate payers. The study provides a suite of recommendations to support 1) the growth of cost-effective storage deployment on the MA grid and 2) the growth of storage companies as part of Massachusetts' robust clean tech economy. These recommendations are expected to yield **600 MW of new energy storage technologies** on the Massachusetts grid **by 2025** providing over **\$800**

million in cost savings to ratepayers and approximately **350,000 metric tons reduction in GHG emissions** over a 10 year time span which is equal to taking over **73,000 cars off the road**.

Chapter 7 provides a comprehensive list of recommendations for Massachusetts policy and programs to help realize energy storage system benefits and increase the amount of storage deployed in Massachusetts. These policy recommendations seek to maximize the system benefits of energy storage via long-term ratepayer cost reductions, increased grid resilience and reliability, and decreased GHG emissions. The recommendations can unlock the game-changing potential of energy storage growth on the Massachusetts electric grid and encourage promising storage companies to locate in Massachusetts.

Policy Recommendations include:

- Grant and rebate programs
- Storage in state portfolio standards
- Establishing/clarifying regulatory treatment of utility storage
- Options that include statutory change to enable storage as part of clean energy procurements
- Other changes: easing interconnection, safety and performance codes and standards, and customer marketing and education

Chapter 8 provides recommendations for ISO-NE market rule changes to enable advanced storage to participate in the New England wholesale market. Chapter 9 suggests mechanisms to grow storage companies and create a thriving energy storage industry in the state. Table 4 below shows which policies and programs, further described in Chapters 7 and 8, would jumpstart specific Use Cases and begin wider deployment of storage in the Commonwealth.

The Study Team assigned the recommendations into two broad categories: (1) policy and program recommendations to grow the deployment of advanced energy storage in Massachusetts, and (2) policy and program recommendations to grow the energy storage industry in Massachusetts.

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		Policies & Programs								Statutory Change: Storage in Future Renewable Procurements	ISO-NE Market Rule Changes
		Grant and Rebates				State Portfolio Standard		Regulatory Treatment			
Use Cases		ESI Funding for Storage Demonstrations	MOR-Storage Rebates for MA Businesses	Resiliency Grants	Make Storage Eligible for Green Communities Grants	Add Storage to Alternative Portfolio Standard	Storage + Solar Option in Next Solar Incentive Program	DPU Grid Modernization	Energy Efficiency Programs for Peak Demand Savings		
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		•				•	•	•	•		•
Municipal Light Plant (MLP) Asset		•				•	•				•
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		•				•	•				•
Behind the Meter	Commercial & Industrial Solar + Storage	•	•		•	•	•		•		•
	Residential Storage Dispatched by Utility	•				•	•		•		•
Merchant	Alternative Technology Regulation Resource	•				•					•
	Storage + Renewable	•				•	•			•	•
	Stand-alone Storage or Co-Located with Traditional Generation Plant	•				•					•
Resiliency/Microgrid		•		•	•	•	•				•

Table 4: Use Cases and Policies

1. Policy and Program Recommendations to Grow the Deployment of Advanced Energy Storage in Massachusetts

The following recommendations capture the opportunities for monetizing system benefits and increasing the amount of new advanced energy storage in Massachusetts to 600 MW through state policies and programs. The recommendations include establishing and clarifying regulatory treatments of storage, grant and rebate programs, integration of storage into State Portfolio Standards, potential statutory changes for inclusion of storage in long-term clean energy procurements, and recommendations for ISO Market Rules.

Recommendations to Establish and Clarify Regulatory Treatments of Utility Storage:**Storage as a Utility Grid Modernization Asset**

In June 2014, the Massachusetts Department of Public Utilities (DPU) issued Order 12-76-B (Order) requiring each electric distribution company (EDC) to develop Grid Modernization Plans (GMPs) to meet four objectives: (1) reduce the effect of outages; (2) optimize demand which includes reducing system and customer costs; (3) integrate distributed resources; and (4) improve workforce and asset management. Energy storage would successfully address several objectives of the Order particularly optimizing demand, integrating distributed resources, and mitigating outages. “Energy Storage Technologies” is included as one of the categories of grid modernization assets that is eligible for rate recovery if justified with a business case that includes all quantifiable and unquantifiable benefits and costs. Current utilities’ GMPs, filed with the DPU, include small storage demonstration projects. As GridMod is an ongoing DPU proceeding, utilities could amend their GMPs to propose expanded energy storage programs. To provide further clarity on the regulatory treatment of utility storage, the DPU could conduct an investigation on storage-specific issues, create Guidelines for the Methods and Procedures for the Evaluation and Approval of Energy Storage, and investigate the ability of utilities for contracting with third-parties for operating storage to enable sales to the ISO wholesale markets.

Storage as Peak Demand Savings Tool in Energy Efficiency Investment Plans

Massachusetts state law, M.G.L. c.25, §21, the Green Communities Act (the “Act”), requires that investor-owned utilities and approved municipal aggregators (“Program Administrators”) seek “...all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply.” In 2016-2018 the Statewide Three Year Energy Efficiency Plans have a new focus on Peak Demand Savings, including demonstrations and assessment of current incentives and cost-effectiveness framework. Energy storage, used to shift and manage load as part of peak demand reduction programs, can be deployed through this existing process but may require changes in the current DPU Guidelines’ benefit-cost test methodology to accommodate storage in these demand reduction programs.

Recommendations for Grant and Rebate Programs:**Energy Storage Initiative (ESI) RFP**

In order to jump start the market, the DOER and MassCEC plan to issue an RFP for storage project demonstrations using the \$10 million ESI funding. Given the large amount of interest from study stakeholders and the study results showing substantial benefits to ratepayers from advanced storage, increasing demonstration project funding from \$10 million to \$20 million is recommended. This additional amount can be funded through DOER’s Alternative Compliance Payment (ACP) funds or MassCEC trust funds.

Massachusetts Offers Rebates for Storage Program (“MOR-Storage”) for Customer-sited Storage Projects

Rebate programs have been very successful in rapidly accelerating new technology adoption. This program would be modeled after DOER’s successful MOR-EV Rebate program that provides funding to Massachusetts residents who purchase electric vehicles. The goal of the MOR-Storage program is to encourage Massachusetts commercial and industrial businesses to invest in storage that will 1) assist the business in lowering their electricity bills, 2) better utilize any on-site generation, and 3) provide benefits to the grid by reducing peak demand. Funding would be from DOER ACP funds.

Grant Funding for Feasibility Studies at Commercial and Industrial Businesses

Small to medium sized commercial and industrial (C&I) customers, particularly Massachusetts manufacturers, often struggle with high and volatile energy costs, which can dramatically impact their competitiveness. At the same time, these customers rarely have the time, nor the in-house expertise to evaluate potentially cost saving storage, or solar plus storage, options for their facilities. The Solar plus Storage pilot program will fund site assessments that qualify the technical and financial feasibility of storage only, or solar plus storage systems at participating manufacturing facilities. Funding of \$150,000 from MassCEC.

Community Resiliency Grants – Part III

DOER’s “Community Clean Energy Resiliency Initiative” is part of the Administration’s comprehensive climate change preparedness effort. Round III of the grant program will be focused on C&I and municipal resilience projects using clean energy plus storage solutions to protect from service interruptions. Projects funded through the Community Resiliency Initiative grants will protect critical facilities (hospitals, shelters, gas stations, transportation, schools, etc.) by implementing clean energy technologies to keep facilities operable in times of power outages due to severe climate events or other emergency situations. Utilizes \$14.2 million remaining from the original \$40 million of DOER ACP funding.

Grant Program to Demonstrate Peak Demand Savings

DOER will be funding demonstration grants where utility and market actors can directly address the technical, regulatory, and market challenges of peak demand management in our state-wide Energy Efficiency programs. The goal of the grant program is to test a variety of program designs against Massachusetts market conditions to gain a better understanding of how peak demand management can be a viable system resource moving forward.

Add Storage to Eligible Green Communities Grant Projects

While no energy storage projects have been funded through the Green Communities program to date, it could be added as an eligible technology in future grant opportunities. Energy storage has the ability to meet objectives of the program through prioritizing demand reduction and the integration of renewables into communities.

Recommendations for Storage in State Portfolio Standards:**Amend Alternative Portfolio Standard (APS) to Include all Types of Advanced Energy Storage**

Inclusion of a broader range of energy storage systems (beyond the currently-eligible flywheel storage) in the APS would expand an existing financial mechanism to encourage increased deployment of energy storage by helping to monetize the system benefits. This would help close the revenue gap for storage project developers by creating an additional revenue stream to monetize the system benefits not readily captured by storage developers, but which ultimately flow to all ratepayers in the form of lower electricity prices. Since the Alternative Energy Credits (AEC) are paid by ratepayers, as long as the AEC value is lower than the system benefits created by the investment in storage, this is a win/win for ratepayers and storage developers. The expected deployment of energy storage as a result of such a program is difficult to estimate without a thorough competitive market analysis, but could be very significant.

Evaluate Storage in the Development of the Next Generation Solar Incentive Program.

Incorporating solar with behind-the-meter energy storage within the Commonwealth's future solar incentive program would encourage the use of storage where "solar plus storage" provides value to both the system owner and ratepayer, by enabling the solar's intermittent production to reliably match load, driving both greater value to the owner and increased benefits to the system.

Recommendations for ISO Market Rules:**Create an Advanced Storage Working Group at ISO-NE**

This Working Group could be created to ensure a level playing field for the inclusion of advanced energy storage resources in all ISO-NE markets and to recommend market rule changes to remove barriers to new storage technologies participation. Expanding ISO-NE markets that currently utilize advanced storage resources, namely the Frequency Regulation market, could increase advanced storage deployment.

Recommendation that Require Statutory Change:**Allow bids that have energy storage components in any possible future long-term clean energy procurements.**

* As of August 8, 2016, Massachusetts' newly passed comprehensive energy diversification legislation incorporated this recommendation.

Currently, Massachusetts statutes do not provide clarity on the ability to include storage as part of a project bidding into a clean energy RFP. For example, procurements under the Massachusetts Acts of 2012, Chapter 209, Section 36 require, among other things, that the clean energy to be qualified as Renewable Portfolio Standard Class I, and does not specify how energy storage is treated. Eliminating the ambiguities surrounding energy storage systems and including them into future long-term renewable energy procurements will enable the projects to utilize the benefits of storage to firm the renewable portion of the project by creating a long-term revenue stream to support the financing of the storage portion of the project. A clear definition of what constitutes a qualifying "Energy Storage System" should be included within the statutory language, allowing the consideration of storage in any future clean energy procurements.

2. Policy and Program Recommendations to Grow the Energy Storage Industry in Massachusetts:

The following recommendations capture the opportunities for strengthening the storage industry in Massachusetts through state policies and programs including recommendations to grow companies through increased investment, workforce development, and utilization of academic expertise to support storage startup growth and R&D.

Recommendations to Grow Companies:**Increase Investment in Storage Companies.**

Promote the growth of an energy storage cluster in Massachusetts to expand jobs and maintain leadership in storage and expand the MassCEC Investment Programs to support energy storage companies in Massachusetts.

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Workforce Development.

Expand MassCEC programs to develop the trained workforce required to support the large scale deployment of energy storage and the growth of the energy storage industry in the Commonwealth.

Continue Support of New Technology Development.

Utilize the energy storage expertise in Massachusetts' world class universities to support energy storage startups in Massachusetts and invest in research and development and testing facilities to anchor an energy storage cluster in Massachusetts.

Conclusion

New advanced storage technologies provide an opportunity to modernize our electric system for the benefit of our ratepayers and to grow the clean tech industry here in the Commonwealth. By adopting the policies and recommendations contained herein Massachusetts will continue to lead the way on clean energy, energy efficiency and the adoption of innovative technologies such as energy storage. Storage can provide an important component of a diversified energy portfolio that will achieve the Baker-Polito Administration's goal to create a clean, affordable, resilient energy future for the Commonwealth.

ACRONYMS

A/C	Air conditioning		Energy and Environmental Protection
AB	Assembly Bill		
ACP	Alternative Compliance Payment	DBI	Declining block incentive
AECs	Alternative Energy Certificates	DER	Distributed energy resources
AEO	Annual Energy Outlook	DG	Distributed generation
AGC	Automatic generator control	DOE-OE	DOE Office of Electricity
APS	Alternative Portfolio Standard	DOER	Department of Energy Resources
APS	Arizona Public Service	DPU	Massachusetts Department of Public Utilities
ARR	Annual Reliability Report	DR	Demand response
ATRR	Alternative technology regulation resources	DRPs	Distribution Resources Plan Proposals
AWEA	American Wind Energy Association	EDCs	Electricity Distribution Companies
Bcf	Billion cubic feet	EEAC	Energy Efficiency Advisory Council
BPU	New Jersey Board of Public Utilities	EIA	Energy Information Association
BQDM	Brooklyn Queens Demand Management Program	EM&V	Evaluation, Measurement and Verification
BTM	Behind the meter	EOEEA	Executive Office of Energy and Environmental Affairs
C&I	Commercial and industrial	EOL	End of life
CAES	Compressed air energy storage	EPA	Environmental Protection Agency
CAGR	Compound annual growth rate	EPIC	Electric Program Investment Charge (CA)
CAISO	California ISO	EPRI	Electric Power Research Institute
CES	Community energy storage	EPSA	Electric Power Supply Association
CESA	Clean Energy States Alliance	ERCOT	Electric Reliability Council of Texas
CGS	Customer grid supply	ESA	Energy Storage Association
CHP	Combined heat and power	ESI	Energy Storage Initiative
CO2	Carbon dioxide	ESR	Energy Storage Resource
ConEd	Consolidated Edison	ESS	Energy storage system
CPUC	California Public Utilities Commission	ESVT	Energy Storage Valuation Tool
CSP	Concentrating solar power	ETA	Electric thermal storage
CSR	Codes, standards, and regulations	EV	Electric vehicle
CSR	Capacity Storage Resource	EWEB	Eugene Water & Electric Board (OR)
CSS	Customer self supply	FCA	Forward Capacity Auction
CT	Simple cycle combustion turbine		
CT DEEP	Connecticut Department of		

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FCM	Forward Capacity Market	MLP	Municipal Light Plant
FERC	Federal Energy Regulatory Commission	MMBTU	Million British thermal units
GHG	Greenhouse gas	MMTCO ₂ e	Million metric tons of carbon dioxide equivalent
GMP	Green Mountain Power	MOR	Massachusetts Offers Rebates
GMPs	Grid Modernization Plans	MW	Megawatts
GW	Gigawatts	MWD	Minwind Energy LLC
GWh	Gigawatt hour	MWh	Megawatt hour
GWSA	Global Warming Solutions Act	Na-ion	Sodium Ion
HECO	Hawaii Electric Company	NaS	Sodium-sulfur battery
HG&E	Holyoke Gas and Electric	NCPC	Net Commitment Period Compensation
HQ	HydroQuebec	NEM	Net energy metering
Hz	Hertz	NEMA	Northeast Massachusetts - Boston
I	Current	NERC	North American Electric Reliability Corporation
IEC	International Electrochemical Commission	NFPA	National Fire Protection Association
IOU	Investor owned utility	NGO	Non-Governmental organization
IPP	Independent power producer	NGR	Non-generator resource
ISO-NE	ISO-New England	NH PUC	New Hampshire Public Utility Commission
ISO	Independent System Operators	NiCd	Nickel cadmium
ITC	Investment tax credit	Nox	Mono-nitrogen oxides
ktons	Kilotons	NPCC	Northeast Power Coordinating Council
kV	Kilovolt	NPR	Non-price retirement requests
kWh	Kilowatt hours	NTA	Non-transmission alternative
LCOE	Levelized cost of electricity	NWA	Non-wires alternatives
Li-Ion	Lithium Ion	NYSERDA	New York State Energy Research and Development Authority
LMP	Locational marginal price	O&M	Operations and maintenance
LMU	Locational Marginal Unit	OATT	Open Access Transmission Tariff
LSE	Load serving entity	ORTP	Offer review trigger price
LTPP	California Long Term Procurement Process	PDR	Proxy Demand Resource
MACRS	Modified Accelerated Cost Recovery System	PHS	Pumped hydro storage
MassCEC	Massachusetts Clean Energy Center	PIER	Public Interest Energy Research (CA)
ME PUC	Maine Public Utility Commission	PJM	PJM Interconnection LLC
MECO	Maui Electric Company	PNNL	Pacific Northwest National Laboratory
MEPA	Massachusetts Environmental Protection Act	PV	Photovoltaic
MGE	Minimum generation emergency		
MISO	Midcontinent ISO		
MIT	Massachusetts Institute of Technology		

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R	Resistance	SGIP	Small Generator Incentive Program (CA)
RD&D	Research, development, and demonstration	SIRI	Systems Integration Rhode Island
RA	Resource Adequacy	SMES	Superconducting magnetic energy storage
REIP	Renewable Energy Incentive Program (NJ)	SMUD	Sacramento Municipal Utility District
REV	Reforming the Energy Vision (NY)	SO2	Sulfur dioxide
RFGA	Request for Grant Applications	SONGS	San Onofre Nuclear Generating Station
RFI	Request for Information	SQ	Service quality
RFP	Request for Proposals	SREC	Solar Renewable Energy Certificate
RI EERMC	Rhode Island Energy Efficiency and Resource Management Council	STIP	Short Term Investment Plan
RI OER	Rhode Island Office of Energy Resources	T&D	Transmission and distribution
RNL	Regional network load	TES	Thermal energy storage
RPA	Regional planning agency	TOU	Time-of-use
RPS	Renewable Portfolio Standard	U.S. DOE	United States Department of Energy
RTEG	Real-Time Emergency Generation	VRB	Vanadium redox battery
RUCO	Residential Utility Consumer Office (AZ)	VVO	Volt VAR Optimization
SAIDI	System Average Interruption Duration Index	W2B	Wind-to-Battery
SCE	Southern California Edison	WACC	Weighted average cost of capital
SDG&E	San Diego Gas and Electric	WCMAS	Western-Central Massachusetts
SEMA	Southeast Massachusetts		

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1 Introduction to Energy Storage - Technologies and Market Landscape

Energy storage can enhance the efficiency, resiliency, and sustainability of the entire electric power grid. Energy storage is the only emissions-free technology that can store electricity for use in future periods when there is a higher demand. It modernizes the way we generate and deliver electricity and can help utilities avoid costly distribution and transmission system infrastructure upgrades. With the use of storage, the system operator can more efficiently manage the variability on the power grid that comes with increased penetration of renewable resources. It can assist large energy users and municipalities achieve security and resilience of supply, and lower their overall costs as well as support households in managing their energy costs.

Energy storage can assist in the achievement of numerous interrelated policy mandates, which include: expanding renewable generation, addressing climate change risks, and transforming an aging power system infrastructure — including the potential retirement of many of the country's fossil fuel power plants. These emerging trends are impacting the decisions of system operators, utilities, developers, regulators, and policy makers in developing policies and investments for a new modernized grid.

Significant change is happening in the Massachusetts power sector. Though demand continues to grow, average demand is decreasing due to policies encouraging increased energy efficiency investments and the installation of renewable resources at customer sites. There has also been considerable growth of grid-scale renewables due to renewable portfolio standards, utility development, and long-term contracts for renewable resources. Adding to these conditions are lower natural gas prices, older fossil generators, and nuclear power plants that are not economical and are retiring. Finally, the state has an aging transmission and distribution infrastructure.

To help address these issues, the Massachusetts Baker-Polito Administration has introduced the \$10 million Energy Storage Initiative (ESI) aimed at making the state a national leader in energy storage.

*"The Commonwealth's plans for energy storage will allow the state to move toward establishing a mature local market for these technologies that will, in turn, benefit ratepayers and the local economy," Baker said. "Massachusetts has an exciting opportunity to provide a comprehensive approach to support a growing energy storage industry with this initiative's analysis, policy and program development."*¹⁰

As part of the initiative, the Department of Energy Resources (DOER) has partnered with the Massachusetts Clean Energy Center (MassCEC) to embark on a study to analyze the storage industry landscape, review economic development and market opportunities for energy storage, and examine potential policies and programs that could be implemented to better support energy storage deployment in Massachusetts. The study also provides policy and regulatory recommendations along with cost-benefit analysis for state policymakers. DOER can utilize the results of the study to identify target areas for further analysis and potential policy recommendations.

Massachusetts is a leader in seeding and facilitating the growth of emerging advanced energy technologies, such as energy storage. Massachusetts has supported these technologies through

¹⁰ Executive office of Energy and Environmental Affairs. May 28, 2015. *Baker-Polito Administration Announces \$10 Million Energy Storage Initiative* www.mass.gov/eea/pr-2015/10-million-energy-storage-initiative-announced.html

research and development funding and other policies aimed at moving local, clean technology products from the laboratories to commercial success. By leveraging the years of work in the solar and wind industries, the Commonwealth is well-positioned to nurture and grow the energy storage industry through programs and initiatives aimed at both attracting business and deploying the technology.

1.1 The Fundamentals of Energy Storage

The term “energy storage” applies to many different technologies, including: batteries, flywheels, and pumped hydroelectric storage among other technologies. All technologies can store energy during periods when the cost is low and then make the energy available during a period when the costs are higher. Energy storage can absorb energy from renewable resources, such as solar power, that may over-produce in certain periods and then use it in later periods when it is more valuable to the customer and the power grid.

Storage technologies range in scale from small systems used in homes for backup power to utility-scale systems that interconnect to the power grid. Energy storage has already begun seeing adoption in many markets around the world, driven by both renewable energy generation and local reliability needs.

Many advanced energy storage technologies have matured beyond the research and development phase. They are commercially viable and are operating throughout the U.S. and around the world.

To date, energy storage in Massachusetts has primarily been limited to Pumped Hydro Storage (PHS) in Northwest Massachusetts providing bulk energy to the New England grid operator, ISO-New England (ISO-NE). These PHS resources were built in the 1970’s to provide approximately 1,600 MW of capacity quickly in the event of a nuclear plant trip. The evolution and diversity of energy storage technologies, applications, and grid locations has gone well beyond the limits of pumped hydro storage. While Massachusetts has benefited from pumped storage operating in the region, geographic and environmental limitations make it unlikely that new pumped storage will be built. Therefore, the Energy Storage Study focuses on new, advanced energy storage technologies that are now available.

Massachusetts is facing the possibility of over 10,000 MW of power plant retirements in the region by 2020 and an increasing reliance on natural gas.¹¹ This transition is happening at the same time as technological advances are blooming in the renewable and smart grid arenas. It is pivotal, therefore, for policy makers to understand the progress being made in the energy storage industry; it is no longer a technology of the future. Energy storage has arrived, and it is available today. At present there are numerous energy storage projects operating worldwide, and many are participating in competitive markets without any subsidies.

¹¹ “More than 4,200 MW of coal, oil, and nuclear generating capacity has retired or will retire by mid-2019. Another 6,000 MW of coal- and oil-fired generators are at risk for retirement by 2020.” ISO-NE, Regional Energy Outlook, March 2, 2016; http://www.iso-ne.com/static-assets/documents/2016/02/NE_Power_Grid_2015-2016_Regional_Profile.pdf

“Energy storage is changing the paradigm on how we generate, distribute and use energy. With exponential growth predicted over the next couple of years, energy storage solutions will deliver smarter, more dynamic energy services, address peak demand challenges and enable the expanded use of renewable generation like wind and solar. The net result will be a more resilient and flexible grid infrastructure that benefits American businesses and consumers.”

- M. Roberts, Executive Director, Energy Storage Association.¹²

As decision-makers evaluate whether to spend billions of dollars in new, conventional generation and transmission, consideration of energy storage should not be ignored. As this Energy Storage Study shows, energy storage is an economically and technically viable solution for alleviating future reliability and environmental challenges while integrating renewable generation.

1.2 Storage Technologies

There are many different kinds of energy storage technologies with various capabilities. While all technologies store energy, the way in which each operates can differ. Thus, the variety of technologies provides flexibility in matching energy storage solutions to diverse energy related challenges faced by the consumer and the power grid operator.

1.2.1 Description of Storage Technologies

Batteries, pumped storage systems, ice storage, and heat-based thermal storage make up some of the more common types of energy storage. Pumped Hydro Storage is often referred to as “conventional energy storage”. More recent emerging forms of energy storage, such as batteries, flywheels, and new compressed air energy technologies, are often referred to as “advanced energy storage”. Energy storage technologies can be broadly classified as: mechanical, electrochemical, thermal, electrical and chemical storage. See Figure 1-1 for the many storage technologies contained in each category.

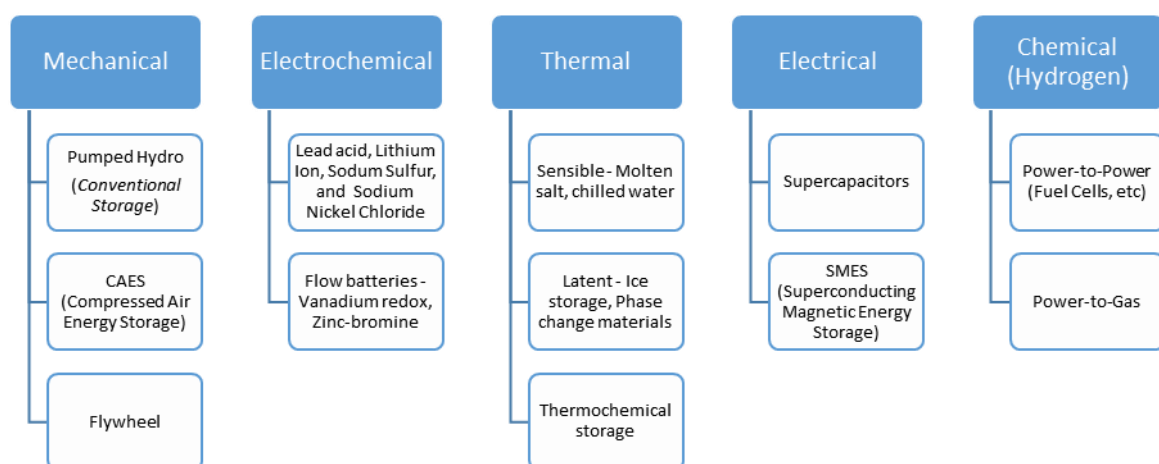


Figure 1-1: Classification of Energy Storage Technologies

¹² Quote by Matt Roberts, Executive Director of the Energy Storage Association (ESA), regarding GTM Research/Energy Storage Association’s *U.S. Energy Storage Monitor 2015 Year in Review*

- *Mechanical Storage* includes Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES) and Flywheels:
 - *Pumped Hydro Storage (PHS)* stores electrical energy as the potential energy of water. Generally, this involves pumping water into a large reservoir at a high elevation—usually located on the top of a mountain or hill. When energy is required, the water in the reservoir is guided through a hydroelectric turbine, which converts the energy of flowing water to electricity. PHS is often used to store energy for long durations for use in a future period. The location of these systems is dictated by the presence of the required geology. Proposed pumped storage projects are also subject to rigorous environmental clearances, which can add significantly to the time required for the installation of such a system. Projects can take five to fifteen years to be sited, permitted and built.



Figure 1-2: Northfield Mountain Pumped Storage Project in Massachusetts

- *Compressed Air Energy Storage (CAES)* converts electrical energy into compressed air, which is stored either in an underground cave or above ground in high-pressure containers. When excess or low cost electricity is available from the grid, it is used to run an electric compressor, which compresses air and stores it. When electrical energy is required, the compressed air is directed towards a modified gas turbine, which converts the stored energy to electricity. A recent advancement that is maturing through research and development by several startups is storage of the heat produced during the compression. This type of CAES does not use natural gas to reheat the air upon decompression and is therefore emissions-free, as well as more efficient overall. Similar to pumped hydro, CAES systems are used for storing energy over longer periods.
- *Flywheel storage systems* store electrical energy as the rotational energy in a heavy mass. Flywheel energy storage systems typically consist of a large rotating cylinder supported on a stator. Stored electric energy increases with the square of the speed of the rotating mass, so materials that can withstand high velocities and centrifugal forces are essential. Flywheel technology is a low maintenance and low environmental impact type of energy storage. In general, flywheels are very suitable for high power applications due to their capacity to absorb and release energy in a very short duration of time.

- *Electrochemical storage* includes various battery technologies that use different chemical compounds to store electricity. Each of the numerous battery technologies have slightly different characteristics and are used to store and then release electricity for different durations ranging from a few minutes to several hours. There are two main categories of batteries: (1) traditional solid rechargeable batteries where the chemical energy is stored in solid-based electrodes, and, (2) flow batteries where chemical energy is stored in varying types of flowing liquid electrolytes kept in tanks separate from the actual electrochemical cells.
 - *Solid Rechargeable Batteries:*
 - *Lead Acid:* Lead acid batteries have been in commercial use in different applications for over a century. Lead acid is the most widely used battery technology worldwide. High performance variations of lead acid batteries are classified as *advanced lead acid* and are known to have a longer life.
 - *Lithium Ion* batteries are increasingly used in many applications in buildings, factories, on the power grid, and in electric vehicles. They include various types of chemistries, and include lithium-containing anodes combined with cobalt, nickel, manganese and phosphate based cathodes. They can be adapted to many different Use Cases and are quickly becoming a dominant technology for new energy storage projects.
 - *High Temperature Sodium:* This type of battery is made from inexpensive, non-toxic materials. The battery operates at a high temperature (above 300°C) and has been shown to have a long cycle life.
 - *Zinc-based batteries* combine zinc with various chemicals and are earlier in their development stage than some of the other battery technologies. Historically, zinc batteries were not rechargeable, but developers are overcoming challenges to produce fully rechargeable zinc-based chemistries. This technology is known for being lightweight, low-cost, and non-toxic.
 - *Flow Batteries*
 - Flow batteries differ from conventional batteries in that energy is stored in the electrolyte (the fluid) instead of the electrodes. The electrolyte solutions are stored in tanks and pumped through a common chamber separated by a membrane that allows for transfer of electrons—flow of electricity—between the electrolytes.
 - There are many different types of flow batteries, of which at least three varieties are currently commercially available: vanadium redox flow batteries, zinc-iron flow batteries, and zinc-bromine batteries. Variations such as zinc-iron flow batteries and hydrogen-bromine flow batteries are also under development.
- *Thermal energy storage* includes ice-based storage systems, hot and chilled water storage, molten salt storage and rock storage technologies. In these systems excess thermal energy is collected for later use. Examples include storage of solar energy for night heating; summer heat for winter use; winter ice for space cooling in the summer; and electrically generated heat or cooling when electricity is less expensive, to be released in order to avoid using electricity when the rates are higher.

- *Electrical Storage - Supercapacitors and Superconducting Magnetic Energy Storage (SMES)* systems store electricity in electric and electromagnetic fields with minimal loss of energy. A few small SMES systems have become commercially available, mainly used for power quality control in manufacturing plants such as microchip fabrication facilities. These technologies are ideal for storing and release high levels of energy over short bursts.
- *Chemical storage* typically utilizes electrolysis of water to produce hydrogen as a storage medium that can subsequently be converted to energy in various modes, including electricity (via fuel cells or engines), as well as heat and transportation fuel (power-to-gas).

1.2.2 Energy Storage Technologies - Performance Characteristics

Each type of available energy storage system (ESS) has specific attributes. These factors must be evaluated in order to choose the suitable technology for a specific purpose. Table 1-1 provides a comparison of different technical parameters, such as operating costs and technology maturity, as well as practical considerations, such as space requirements and development and construction periods for select ESS.

The C-rate of the system is an important parameter that varies significantly between different energy storage types. C-rate is an inverse measure of the rate (length of time) over which a system can provide its maximum rated power. The range of discharge duration is therefore directly linked to the C-rate. It is normally expressed in terms that look like 1C, 2C or C2. For instance, a system with a C-rate of 2C can supply all its stored energy in ½ hour while a system with a C-rate of C2 (or 0.5C) can do the same in 2 hours. Therefore, a system with a higher C rate can discharge at a higher maximum power than a similarly-sized system with comparable energy capacity but a lower C rate. In other words, systems with a higher C-rate have a higher power to energy ratio. High power applications typically require systems with a high C-rate and short discharge duration. These applications are particularly suitable for lithium ion and advanced lead acid batteries, as well as flywheels. Sodium based batteries and flow batteries, as well as CAES and PHS, are more suitable for high energy and longer duration applications. C-rate is typically not used for CAES and Pumped Hydro because the duration of energy storage is not limited by the technology as in the case of electrochemical batteries, but is typically based on physical availability of storage capacity.

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Energy Storage System Attributes	Lead Acid	Li-Ion	NaS	Flow Batteries	Flywheel	CAES	Pumped Hydro
Round Trip Energy Efficiency (DC-DC)	70-85%	85-95%	70-80%	60-75%	60-80%	50-65%	70-80%
Range of Discharge Duration	2-6 Hours	.25-4+ Hours	6-8 Hours	4-12 Hours	.25-4 Hours	4-10 Hours	6-20 Hours
C Rate	C2 – C6	4C – C6	C6-C8	C4-C12	4C-C4	N.A.	N.A.
Cost range per energy available in each full discharge (\$/kWh)	100-300	400-1000	400-600	500-1000	1000-4000	>150	50-150
Development & Construction Period	6 months - 1 year	6 months - 1 year	6 months - 1.5 year	6 months - 1 year	1-2 years	3-10 years	5-15 years
Operating Cost	High	Low	Moderate	Moderate	Low	Moderate	Low
Estimated Space Required	Large	Small	Moderate	Moderate	Small	Moderate	Large
Cycle life: # of discharges of stored energy	500-2000	2000 -6000+	3000-5000	5000 - 8000+	100,000	10,000+	10,000+
Maturity of Technology	Mature	Commercial	Commercial	Early - moderate	Early - moderate	Moderate	Mature

Table 1-1: Parameters for Select Energy Storage Systems (ESS)¹³

As shown in the above table, the systems' prices vary greatly, especially in terms of initial capital costs. Overall, the cost of energy storage is rapidly declining with scaling up of manufacturing and lessons learned from the early deployments. The cost of energy storage technologies have significantly decreased in recent years, driven by the growth of battery manufacturing for consumer electronics, stationary applications, and electric vehicles. As battery costs contribute to approximately 60-75% of an energy storage project (depending on the duration or energy capacity required), capital cost reductions can drive energy storage project development.¹⁴ According to IHS, average lithium-ion battery prices have decreased over 50% between 2012 and 2015, and are expected to decrease over 50% again before 2019.¹⁵ Advanced lead acid systems are typically the least expensive and have the most prolific application worldwide, even though they have a lower cycle-life (less lifetime based on the number of possible charge-discharge cycles of stored energy before capacity significantly degrades) compared to newer technologies. Flow batteries, in contrast, may appear to be higher priced relative to other technologies due to their higher up front capital cost. However, they can have a much longer cycle life (greater number of charges and discharges in the system's lifetime), and therefore do not need to be replaced as quickly as other technologies. Therefore, their "levelized" cost (full cost over the lifetime of a project) is lower. Accordingly, a levelized cost method is often used to compare costs across different energy sources or technologies.

Other critical factors in the selection of energy storage technologies include space requirements and maturity of technology. With improvements in materials as well as system design, energy density of

¹³ DOE-EPRI Energy Storage Handbook, and Customized Energy Solutions Analysis

¹⁴ Energy Storage Update, Lithium-ion costs to fall by up to 50% within five years, July 30, 2016; <http://analysis.energystorageupdate.com/lithium-ion-costs-fall-50-within-five-years>

¹⁵ IHS, Price Declines Expected to Broaden the Energy Storage Market, IHS Says, November 25, 2015; <http://press.ihs.com/press-release/technology/price-declines-expected-broaden-energy-storage-market-ihs-says>

most storage technologies is increasing and particularly Li-Ion batteries are finding applications where space and/or weight is a critical consideration. In terms of maturity, Lead Acid batteries have been around for over 100 years and are very mature in terms of technology performance and manufacturing. Li-Ion batteries have also reached commercial maturity with multiple companies setting up gigawatt-hour scale manufacturing.

Figure 1-3 depicts the steadily decreasing capital costs (\$/kWh-cycle) of certain storage technologies. The depicted levelized cost shown takes into account the total predicted cycle life, or the operational lifetime of the technology, and thus normalizes the capital cost over the entire lifetime of the project.

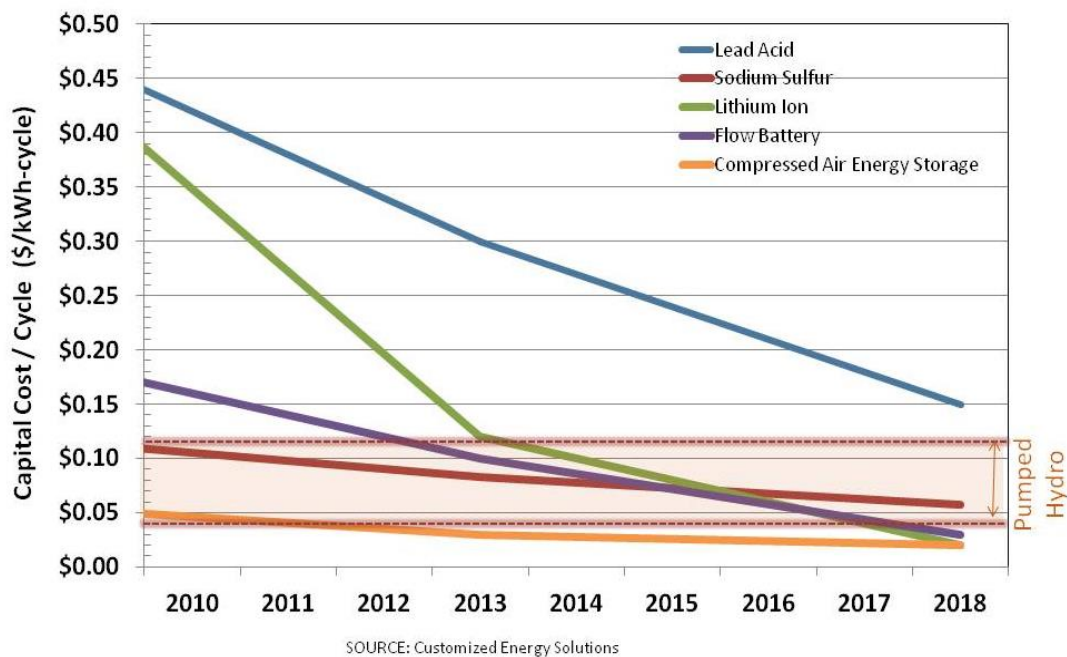


Figure 1-3: Forecast of Estimated Capital Costs by Storage Technology and Type¹⁶

Costs are significantly decreasing for storage technologies and other storage system components such as inverters or battery management systems. Lead-acid batteries, such as car batteries, have a limited lifetime of use and therefore have a high cost of lifetime energy. Lithium-ion batteries have the most significant expected decrease in cost, making them potentially the least expensive of all storage technologies (including PHS) by the year 2018. GTM Research forecasts a 40% decline in the cost of all the secondary components of a storage system (for example the inverters, wiring, temperature regulation, and other equipment constituting the Balance of System), excluding the primary system (for example, any co-located PV panels), in the next five years.¹⁷

¹⁶ Source: Customized Energy Solutions and India Energy Storage Alliance analysis.

¹⁷ GTM Research, Grid-Scale Energy Storage Balance of Systems 2015-2020: Architectures, Costs and Players, January 2016; <http://www.greentechmedia.com/research/report/grid-scale-energy-storage-balance-of-systems-2015-2020>

1.3 Benefits of Storage

1.3.1 Energy Storage is “Dispatchable”

Advanced energy storage resources are capable of dispatching electricity within seconds. Electric power grid operators need to keep the electric power system in balance reacting rapidly to small changes in load and demand. For example, when a wind plant is generating more than is needed to serve the load, an energy storage resource can respond to the grid operator’s dispatch signal to absorb the extra electricity on the grid as opposed to curtailing – or shutting down – the renewable resource. This provides a reliability benefit to the system operator, while also storing clean energy for future use. A storage resource can also be dispatched instantly to generate electricity on the grid during a peak period where additional supply is needed, thus replacing the need for natural gas or oil fired peaking generation. Additionally, many advanced energy storage technologies such as batteries and flywheels can be dispatched to their full power nearly instantaneously. Unlike older technologies like PHS, which require several minutes to ramp up, advanced storage can provide second-by-second balance of fluctuations on the grid.

1.3.2 Energy Storage is a Proven Technology

Many energy storage technologies are used today by utilities and grid operators in commercial operation throughout the world, providing validation that they can perform 24 hours a day, seven days a week. Testing and validating the performance of electrical equipment is a critical step in the process to deploy technologies in the grid. The U.S. Department of Energy, for example, has been providing independent testing and validation of electrical energy storage systems on both a small and large scale for many years through its Energy Storage Program.¹⁸

1.3.3 Energy Storage and Ease of Siting

Advanced energy storage projects are easier to site than many traditional generation projects. One advantage is that these projects do not produce direct air emissions, meaning they do not have to complete significant modifications to comply with air quality standards. Their ability to store energy is not reliant on natural resources, such as running water, or natural gas infrastructure, such as pipelines. As a result, the permitting process is simpler for such projects and construction timelines considerably reduced.

Another major benefit is that advanced energy storage projects require a much smaller footprint than conventional power plants. With impending power plant retirements in local load pockets, building new power plants or transmission lines is an extensive undertaking with large land requirements. Advanced energy storage, in contrast, can easily be added to local areas to provide grid stability, eliminating the need for new gas-fired generation or transmission to solve these local reliability needs.

¹⁸ U.S. Department of Energy Resources, Energy Storage : <http://energy.gov/oe/services/technology-development/energy-storage>

1.3.4 Energy Storage is “Quick to Market”

As previously mentioned, advanced energy storage systems have very short construction periods. Once an order is placed to the factory, the energy storage project can be delivered within months – not years – to the site. Figure 1-4 illustrates siting, permitting and installation times for energy storage compared to traditional generation and transmission lines.

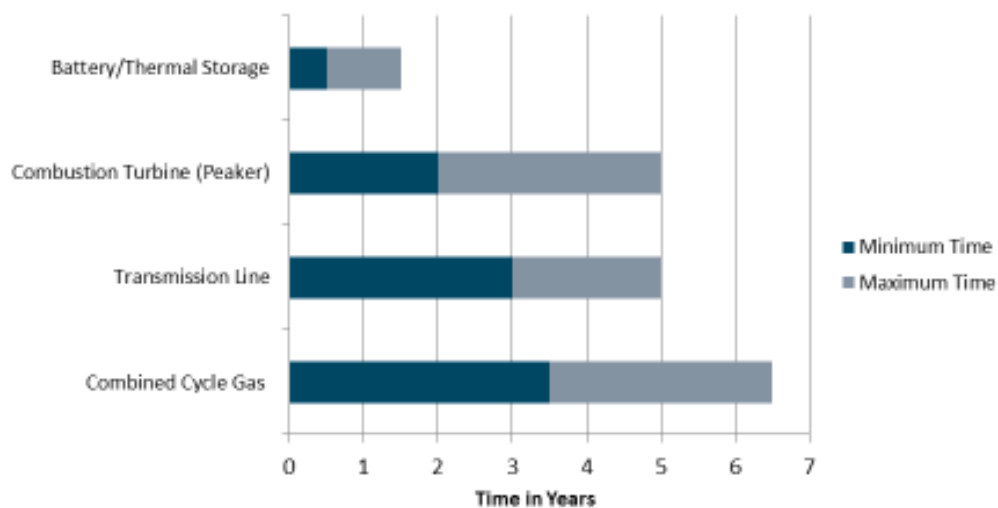
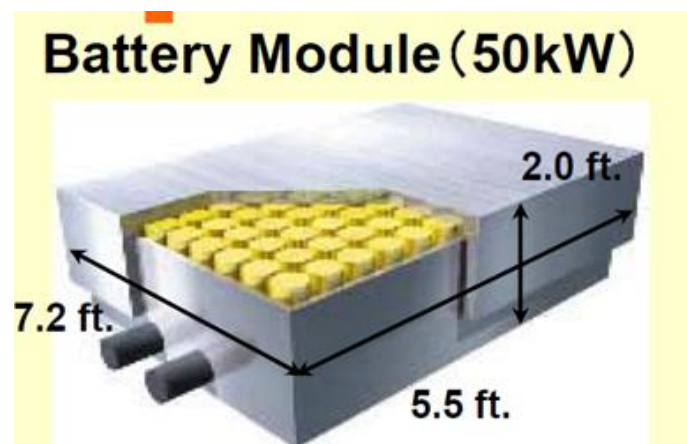


Figure 1-4: Energy Storage: Siting, Permitting, and Installation Times by Resource¹⁹

1.3.5 Energy Storage is Modular in Design

Since energy storage systems are often modular in design, the components to operate and interconnect the storage resource are enclosed in simple containerized structures. This “plug and play” concept makes energy storage easy to locate at an existing power plant, a utility substation, or at a consumer site (such as a house, a factory or a shopping center). The modular approach also means that increments of capacity can be added easily to increase the size of the project. The modules, or many storage cells, can also operate in parallel, providing redundancy and thus a stable and continuous power supply, as seen in Figure 1-5. The failure of one component will not lead to failure of the system.

¹⁹Source: Strategen

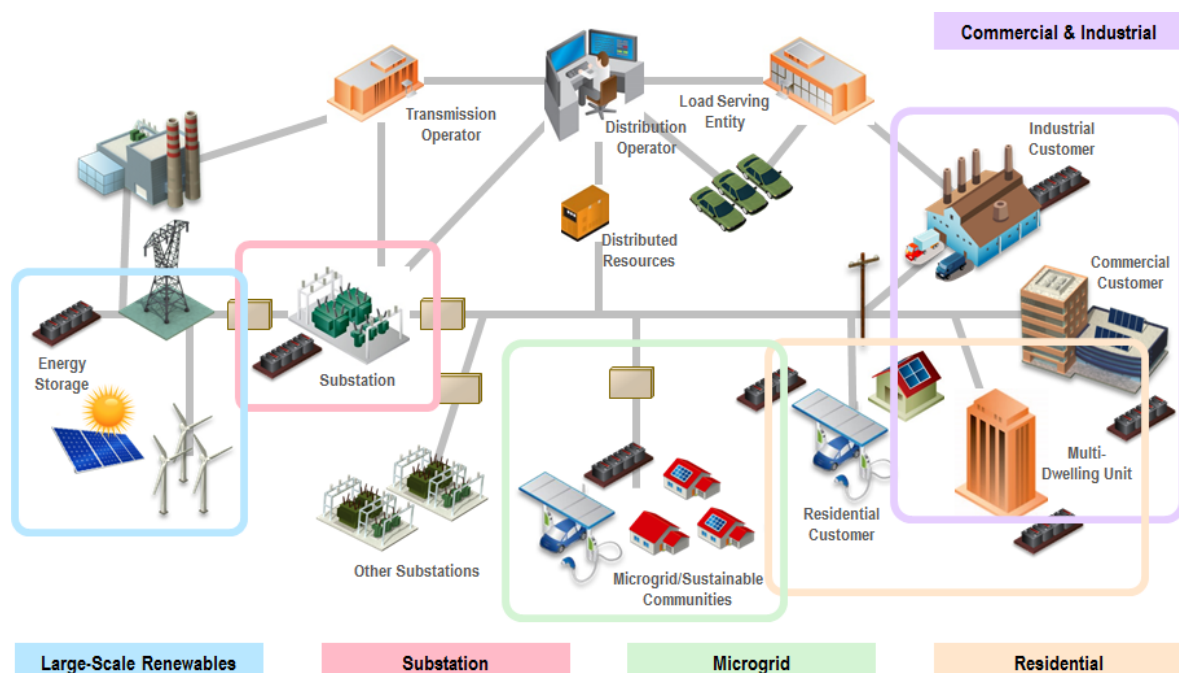


The battery stack for a sodium-sulphur (NaS) system. Each of the yellow containers is a single battery cell. Multiple cells are packed together to produce a 50 kW stack. An entire storage system consists of multiple stacks assembled together along with the appropriate thermal management system, battery management system and power conditioning equipment. (Source: NGK Insulators).

Figure 1-5: Components of a Battery Module

1.4 Energy Storage Applications

Storage's unique physical characteristics, described above, enable it to perform multiple functions on the electric grid and at the customer level, as diagrammed below in Figure 1-6. The ability to store energy when there is no demand and deploy energy when needed to serve load can be applied to all aspects of the energy system. In addition, storage systems can function like a power plant, dispatching electricity. When renewable resources such as solar, wind or hydropower produce excess energy, storage can store it for later use, reducing energy waste.



Energy storage has potential applications across the entire electricity enterprise value chain

Figure 1-6: Representation of the Diversity of Potential Storage Grid Locations (Source: EPRI)

Use of energy storage at the transmission level can assist planning, operations, and reliability. By providing flexibility at locations where electricity is dispatched, transmission planning can be more cost effective and efficient. Installing storage along transmission infrastructure can help manage the flow of electricity by maintaining constant voltage and reducing overheating. Energy storage can ensure there is enough electricity in reserve and provide a quick response if the system is not in balance.

Generators, utilities, and customers can utilize storage to shift energy use from high price periods by charging their systems during periods of low cost. It can supply electricity in highly localized areas that can help defer the need to upgrade existing generation or transmission infrastructure. It can also be located directly at substations to store electricity until it is needed to service loads on distribution lines. At the customer level, energy storage can provide back-up power for times when the power grid goes down and can shift energy usage to reduce the customer's electric bill. It can also integrate with the wholesale electricity market by discharging stored energy during periods when there is not enough electricity being generated to meet the demand. The applications and benefits of storage to the Massachusetts energy system are described in greater detail in Chapter 2.

1.5 U.S. and Global Market for Advanced Energy Storage

Although advanced storage is often presented as a new set of technologies, there are many examples of energy storage projects that are in operation throughout the United States and around the world.

According to the U.S. Department of Energy, there are already more than 400 MW of advanced energy storage in operation in the U.S. (See Figure 1-7). In 2015 alone, there were 221 MW of new deployments of energy storage in the U.S., an increase of 243% over the installations in the U.S. for the year 2014.²⁰ Massachusetts has also seen a growth in the interest in energy storage, with 1.4 MW of currently operational advanced storage and 12.5 MW announced or proposed for development, an increase of almost 900%.

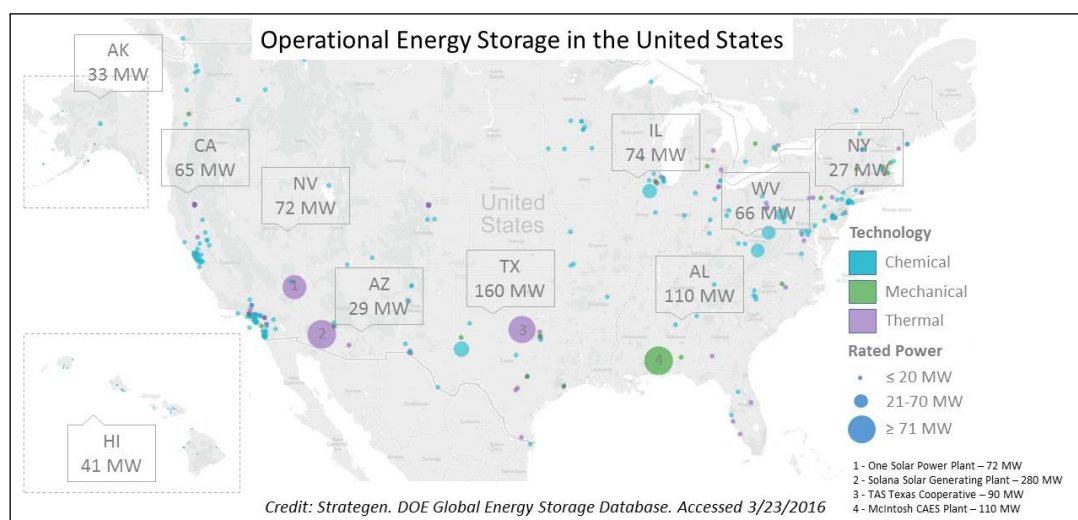


Figure 1-7: Operational Advanced Energy Storage in the United States

²⁰ Energy Storage Association & GTM Research; U.S. Energy Storage Monitor: 2015 Year in Review. March 9, 2016.

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By 2020, the rate of storage installations in the U.S. is estimated to grow to 1.7 GWs of annual deployments, which equates to an annual market of \$2.5 billion in 2020, according to the U.S. Energy Storage Monitor: 2015 Year in Review and presented in Figure 1-8 and Figure 1-9.²¹ This report also estimates that there will be over 4 GWs of installed energy storage in the U.S. by 2020.

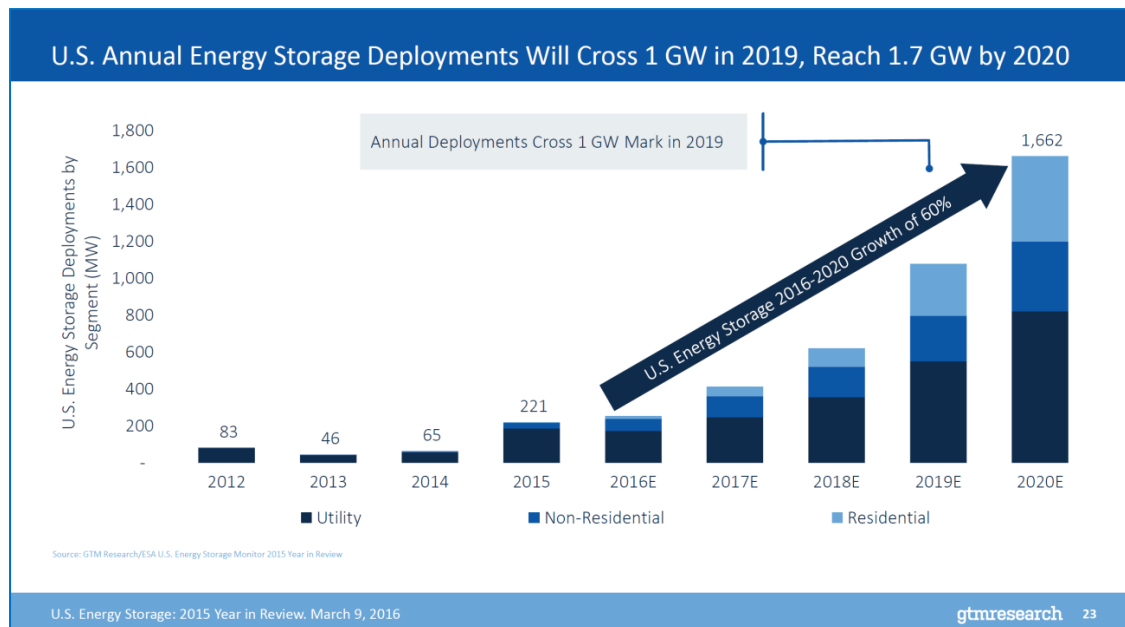


Figure 1-8: GTM Research Estimate of Energy Storage Growth

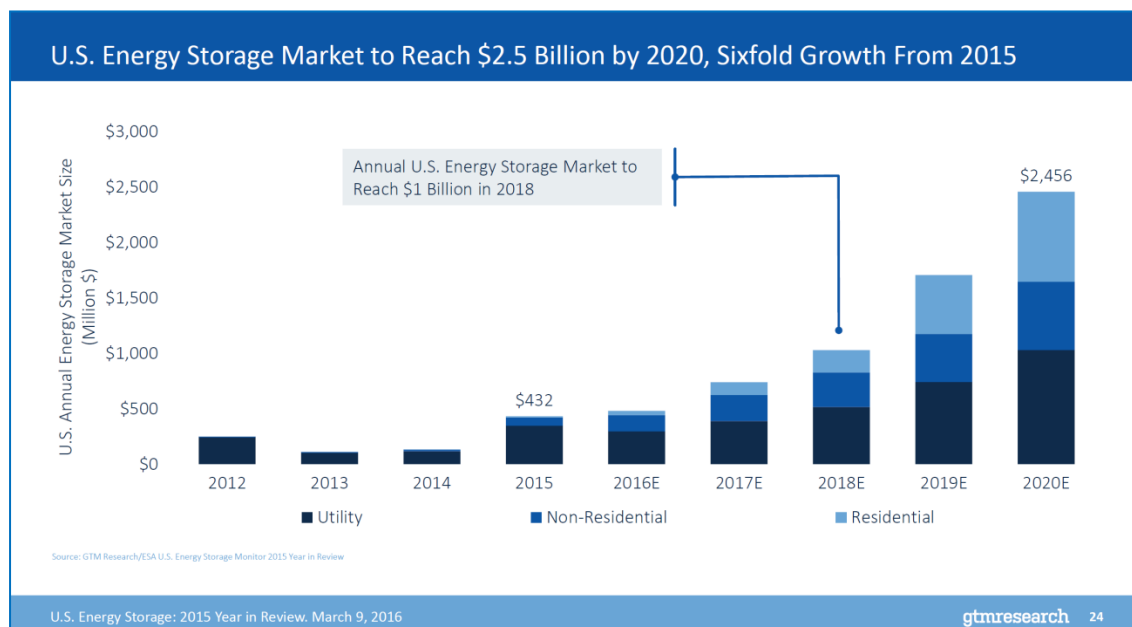


Figure 1-9: GTM Research Estimate of Energy Storage Market

²¹ Energy Storage Association & GTM Research; U.S. Energy Storage Monitor: 2015 Year in Review. March 9, 2016.

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The GTM market outlook predicts significant growth in the U.S. market with annual energy storage deployments from 2012 to 2020 totaling **4,445 MW** of deployed storage in the U.S. by 2020 (Figure 1-10).

Market Outlook (MW)

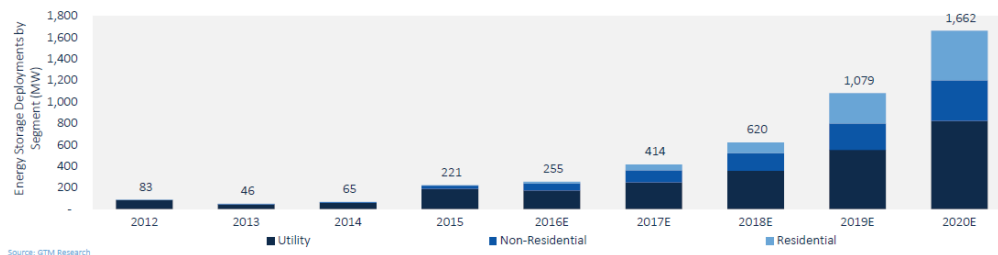


Figure 1-10: GTM Research Storage Market Outlook 2012-2020²²

Globally, the total of energy storage projects in 2016 amounts to almost 2 GWs, not including pumped hydro (see Figure 1-11). Energy storage deployments are growing around the world — particularly in the United States, Spain, Germany, the UK, Canada, France and Japan.²³

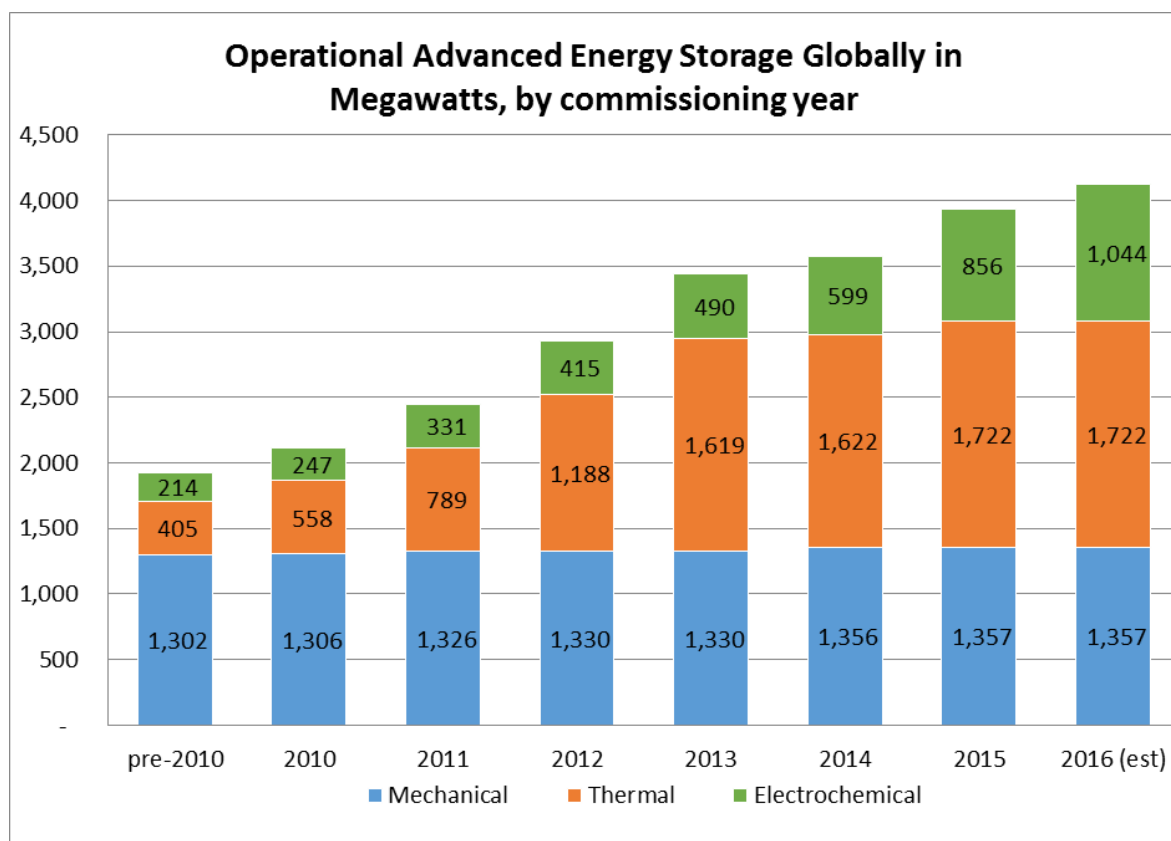


Figure 1-11: Operational Advanced Energy Storage Globally in Megawatts, by Commissioning Year²⁴

²² Energy Storage Association & GTM Research; U.S. Energy Storage Monitor: 2015 Year in Review. March 9, 2016.

²³ U.S. Department of Energy, DOE Global Energy Storage Database, Top 10 Countries, May 12, 2016; http://www.energystorageexchange.org/projects/data_visualization

²⁴ Source: DOE Global Energy Storage Database, March 23, 2016: www.energystorageexchange.org

1.5.1 Advanced Energy Storage Market by State

Many states are now embracing energy storage as a solution for various reliability challenges facing the electric grid. Energy storage is often proving to be a viable solution to challenges from power plant closures and renewable integration, as well as the high cost, lengthy time, and onerous permitting required to build new generation and transmission. Compared to other states, Massachusetts is recognized as a leader in energy efficiency and renewable energy policy, but currently stands 23rd with respect to the amount of storage either built or planned (see Figure 1-12).

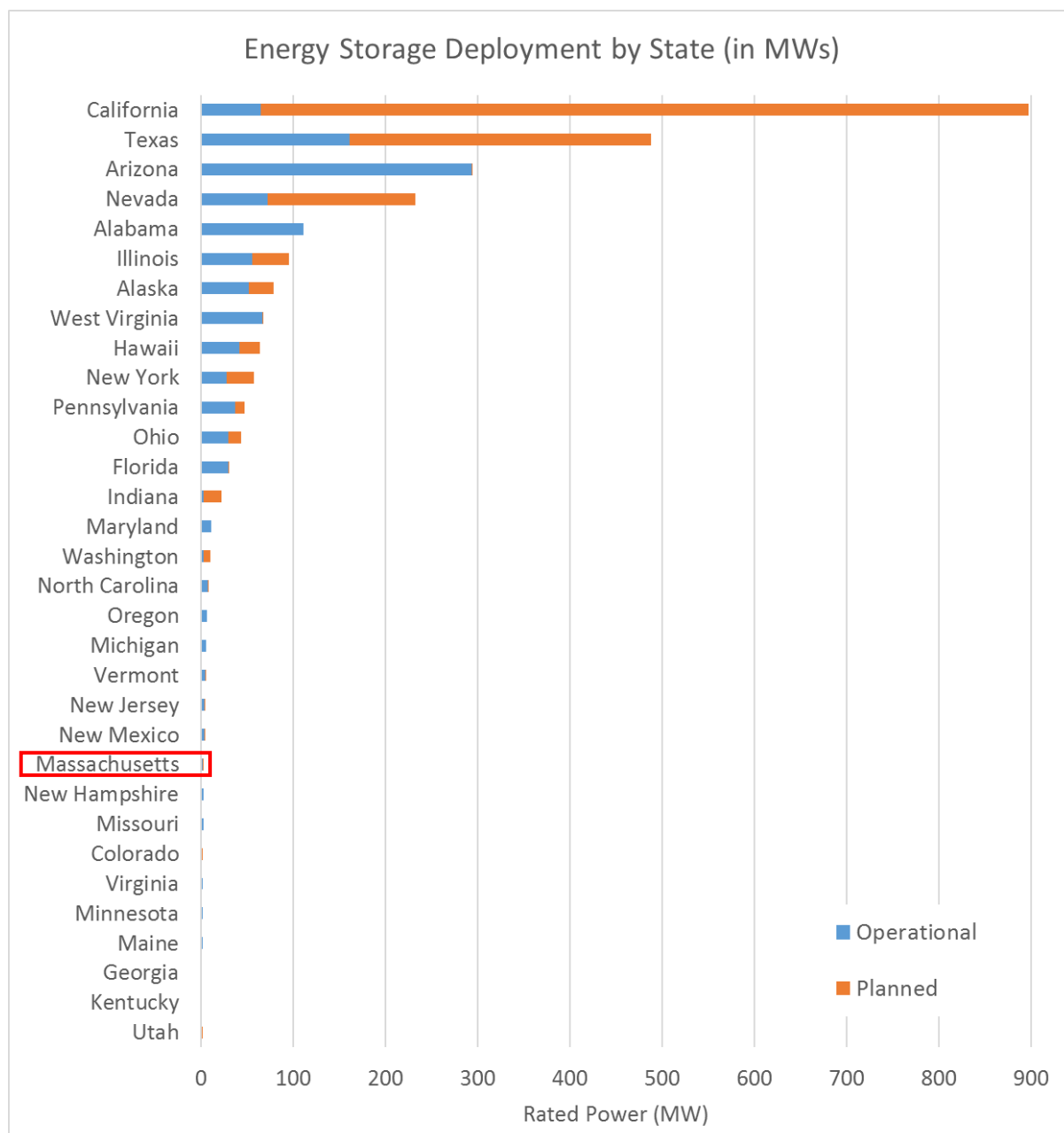


Figure 1-12: Planned and Operational Energy Storage Deployment by State^{25 26}

²⁵ 'Planned' refers to projects listed as either *Announced*, *Contracted*, or *Under Construction* in the DOE Global Energy Storage Database. This excludes pumped storage.

To date, the primary drivers for energy storage development nationally have been a direct result of:

- Market rules that enable advanced energy storage technologies to sell wholesale market services to the regional grid operator — in particular the Mid-Atlantic grid operator (known as “PJM”²⁷) and the California grid operator (known as “CAISO”) have rules for advanced storage participation; and
- State policies and programs to promote the use and development of new energy storage technologies in their state.

1.5.2 State Policies

Many states have implemented programs and policies to realize the benefits of energy storage.

CALIFORNIA

California has many programs in place to encourage the integration of energy storage both at the customer level and at the grid level. In 2010, California enacted legislation, known as Assembly Bill (AB) 2514. The legislation has evolved into state mandated procurement requirements of 1,325 MW of energy storage by 2020. The legislation defined an energy storage system as commercially available technology, and states that it can accomplish one or more of the following:

- Reduce emissions of greenhouse gases.
- Reduce demand for peak electrical generation.
- Defer or substitute for an investment in generation, transmission, or distribution assets.
- Improve the reliable operation of the electrical transmission or distribution grid.

From this mandated procurement, California now has a comprehensive state program aimed at integrating well over 1,000 MW of energy storage at the customer, distribution, and transmission levels.

California has many other examples of programs and policies that have encouraged energy storage development. For example, Southern California Edison (SCE), an investor owned utility with 14 million customers, announced the procurement of 261 MW of energy storage resources in November 2014 in part to mitigate the closing of the San Onofre nuclear plant. The storage will alleviate local reliability concerns in the Los Angeles Basin identified by the California Public Utilities Commission (CPUC) in the Long Term Procurement Planning proceeding²⁸. Once deployed, the systems will provide a number of services to SCE's power grid, including ensuring adequate available electrical capacity to meet reliability requirements.

TEXAS

²⁶ DOE Global Energy Storage Database. December 2015. <http://www.energystorageexchange.org>

²⁷ PJM Interconnection LLC (PJM) is a regional transmission organization (RTO) in the United States. It is part of the Eastern Interconnection, operating an electric transmission system serving all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

²⁸ On February 13, 2013 the California Public Utilities Commission (CPUC) unanimously approved a long term procurement decision ordering Southern California Edison (SCE) to procure between 1,400 and 1,800 megawatts of energy resource capacity in the Los Angeles basin to meet long term local capacity requirements by 2021. Of this amount, 261 MW were new storage resources.

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According to the American Wind Energy Association (AWEA)'s 2015 fourth quarterly report, "Texas continues to lead the nation with over 17,700 MW of installed wind capacity, more than twice the installed capacity of any other state." Energy storage, therefore, is a natural fit to help balance or "smooth" the intermittent output of these renewable resources.

The Duke Notrees project, which began operation in early 2013, is analyzing how the integration of energy storage can compensate for the inherent intermittency of this renewable power generation resource²⁹.



Figure 1-13: Duke Notrees Storage Facility in Texas

NEW YORK

Consolidated Edison (ConEd) in New York recently proposed the \$200 million worth of non-traditional solutions through its Brooklyn Queens Demand Management Program (BQDM) to defer the \$1 billion substation upgrade cost required to support growing urban load. The BQDM program is a large portfolio of load reduction strategies, including energy storage, customer demand management, and traditional utility upgrades. ConEd awarded a contract to install energy storage in Queens,³⁰ which will add both capacity and flexibility to the utilities load management portfolio.³¹ The total BQDM program goal is to provide 52 MW of load reduction by 2018. The distributed storage system is expected to provide 12 MWh of energy (1 MW for 12 hours or 2 MW for 6 hours)

²⁹ U.S. Department of Energy, Duke Energy Business Services: Notrees Wind Storage Demonstration Project; https://www.smartgrid.gov/files/OE0000195_DukeEnergy_FactSheet.pdf

³⁰ The original petition, comments, final order approving and all progress reports on the Brooklyn Queen project can be found here: <http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=45800>

³¹ ConEd, Brooklyn Queens Demand Management Program, August 27, 2015; <https://www.coned.com/energyefficiency/pdf/BQDM-program-update-briefing-08-27-2015-final.pdf>

with construction beginning before the end of 2016.³² The energy storage will serve as an additional power source during the summer peak months when high energy demand results from air conditioning and other appliance use.³³

"This is offsetting some of the megawatts needed so that all the customers can be serviced even on the hottest day when all the air conditioners are running, which is what the full Brooklyn Queens Demand Management (BQDM) program is designed for." Carol Conslato, Queens Director of Consolidated Edison Public Affairs."

Background: Brooklyn / Queens without Load Relief

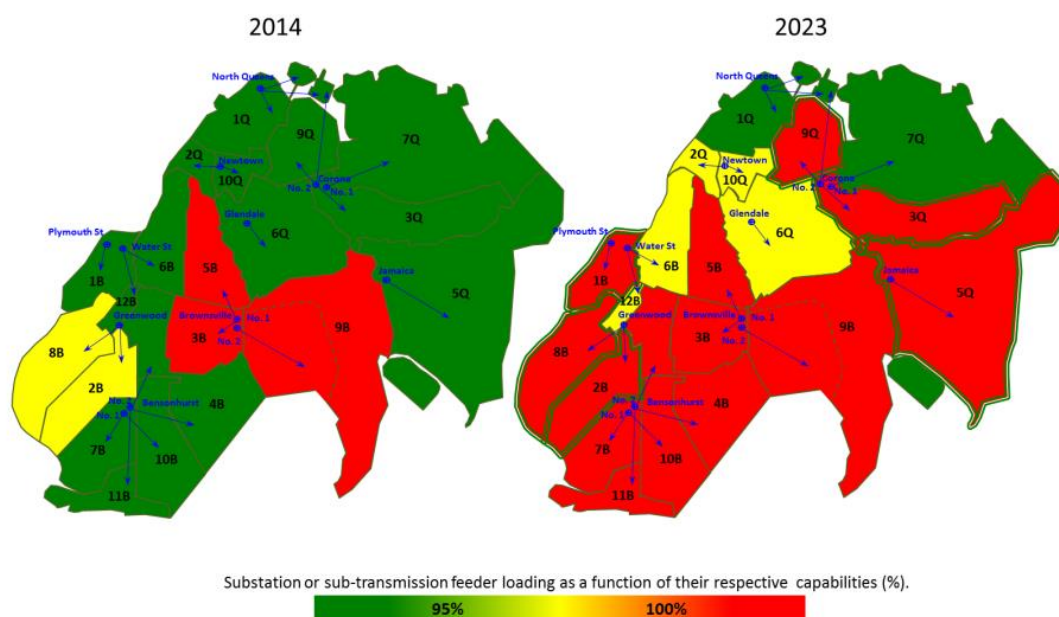


Figure 1-14: Estimated Load Growth in Brooklyn and Queens, New York City³⁴

MID-ATLANTIC AND NORTHEAST STATES

PJM, the regional grid operator for the mid-Atlantic region covering 13 states and the District of Columbia, is currently home to the majority of the operating grid-connected advanced energy storage project capacity in the U.S., with almost 300 MW of batteries and flywheels installed. These resources were attracted to PJM because changes to the wholesale market rules removed barriers to advanced energy storage projects by not only enabling full participation of advanced storage in the markets, but also by valuing their high speed of response and accurate performance in providing grid-balancing services. Some examples of operating energy storage projects in PJM are below.

In 2011, AES Energy Storage, a subsidiary of global power company AES Corporation, installed the 32 MW Laurel Mountain Energy Storage Project at AES's Laurel Mountain wind plant in West Virginia to

³² ConEd, BQDM Quarterly Expenditures and Program Report, November 30, 2015;

<http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={A2CA7AA5-35BD-47C7-88DE-680FD3FCD47F}>

³³ QNS, Con Ed hopes battery system will keep south Queens charged all summer; <http://qns.com/story/2016/02/08/con-ed-hopes-battery-system-will-keep-south-queens-charged-summer/>

³⁴ Consolidated Edison Company of New York, Inc., Brownsville Load Area Plan, Case 13-E-0030, August 21, 2014; <http://www.bkreader.com/wp-content/uploads/2016/02/FA6E8548-E790-4E6A-8BF2-61DDF62EAB4E.pdf>

provide fast-response Frequency Regulation service to PJM and to help manage ramping of the wind plant.



Figure 1-15: AES Laurel Mountain Energy Storage Project in West Virginia

In 2015, Invenergy, a developer, owner and operator of power generation and energy storage facilities, installed the 31.5 MW Grand Ridge Energy Storage Project at Invenergy's Grand Ridge wind plant in Illinois to also provide fast-response Frequency Regulation service to PJM.



Figure 1-16: Invenergy Facility in Grand Ridge, Illinois

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"Energy storage technology is the silver bullet that helps resolve the variability in power demand," said Terry Boston, PJM president and CEO. "Combining wind and solar with storage provides the greatest benefit to grid operations and has the potential to achieve the greatest economic value."

VERMONT

Vermont specifically addresses energy storage in their recently updated Comprehensive Energy Plan — its key policy goal is meeting 90% of its energy needs from renewable resources by 2050 (40% by 2035). The state's drive for a more distributed renewable mix of generation resources combined with the decreasing costs of energy storage should drive increased opportunities — and incentives — for broader implementation of storage technologies.

Vermont is also leading the way in offering energy storage systems to the mass market. In December 2015, Green Mountain Power announced a program to offer Tesla's Powerwall energy storage system to residential customers. Deployment of the systems into homes began in May 2016. At the grid level, Vermont, again with Green Mountain Power, is demonstrating a 4 MW battery energy storage system combined with 2 MW of photovoltaic solar generation as part of the Rutland "Energy City of the Future" project.



Figure 1-17: Residential Application of Tesla Power Wall to be deployed in Vermont

In summary, the storage industry is expanding both nationally and globally. Energy storage is currently a viable technology resource and in commercial operation for many different types of applications throughout the world.

1.6 Opportunities for Storage in Massachusetts

1.6.1 Projects in Massachusetts

The energy storage community is already active in Massachusetts and the New England region, especially with participation from the region's superior academic institutions and cutting-edge industry. Utilities, project developers and end-use customers are eager to integrate energy storage into their businesses.

Advanced energy storage project development is already happening in Massachusetts — albeit on a smaller scale than many other states — totaling less than 2 MW currently in operation. The operational projects include nearly 500 kW of flywheel capacity at Boston's Beth Israel Deaconess Medical Center, where the flywheels provide emergency datacenter backup power. There are 1.4 MW of battery storage installations in Massachusetts, with one project at BJ's Wholesale Club in Framingham, which has adopted a third party battery and energy management platform, and two demonstration projects by National Grid, an Investor Owned Utility (IOU). Advanced storage has seen a rapid increase in interest with many more projects, recently proposed or announced, totaling an additional capacity of over 19 MW and even more projects announced that have yet to finalize their capacity.

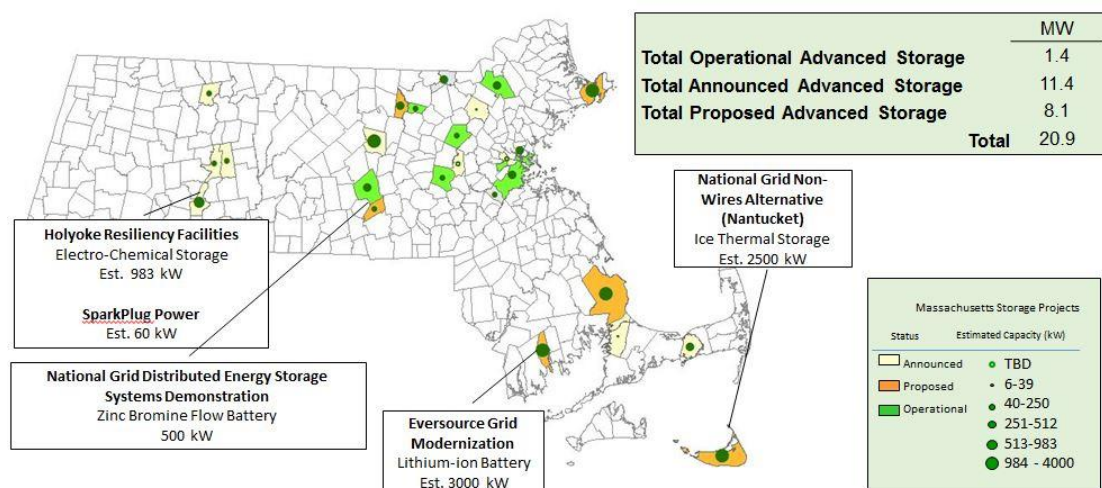


Figure 1-18: Advanced Storage in Massachusetts³⁵

While the deployed amounts to date are low in Massachusetts, especially as compared to other states, there are plans underway to expand energy storage. Each of the three IOUs in Massachusetts considered energy storage in their Grid Modernization Plans (GMPs) submitted in 2015 to the DPU.

- Eversource includes one storage project in its Short Term Investment Plan (STIP) within five years — a distribution-level energy storage project for renewable integration of solar at a substation in the City of New Bedford, MA.
- National Grid and Unitil include energy storage in the research, development and demonstration (RD&D) portion of their GMPs over the next ten years. National Grid's energy storage program will investigate the benefits provided by both large and small

³⁵ DOE Global Energy Storage database; <http://www.energystorageexchange.org/> and Massachusetts Department of Energy Resources

customer behind the meter installations, distributed storage programs to improve power delivery, and high-density community energy storage.

The GMPs cite storage as a key strategic asset for the future of grid modernization. The plans will create proving grounds for an array of energy storage systems and Use Cases. Further discussion of the Grid Modernization proceeding and the accompanying utility plans can be found in Chapter 2.

1.6.2 Storage is an Important Part of Massachusetts Clean Energy Economy

The Commonwealth's framework of public policy, invention, innovation, and increased adoption of clean energy technologies is well underway. The Massachusetts framework involves governmental RD&D funding, establishment of consensus and industry standards, incentive programs, and industry programs and initiatives, all operating within the context of a competitive energy market place.

In 2015, the Massachusetts Clean Energy Center calculated how investments in clean energy economic development have paid off for the Commonwealth. The following graphic shows the financial impact on the Massachusetts economy. Energy storage can add to this success by creating jobs and bringing business to Massachusetts.

Clean Energy Contributions to State Economic Development

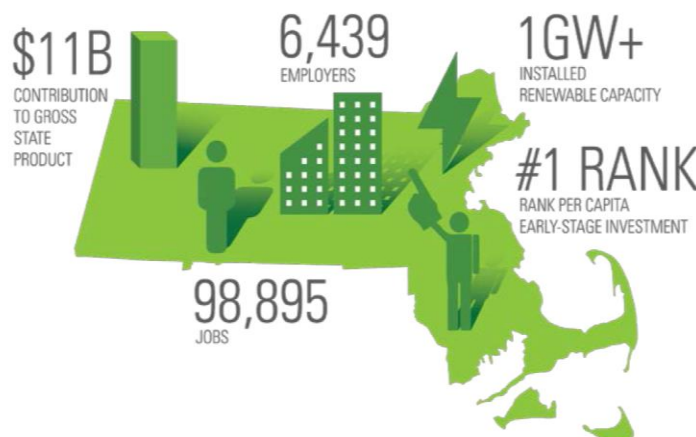


Figure 1-19: Clean Energy Contributions to State Economic Development³⁶

Energy storage is already a part of the existing Massachusetts clean energy landscape. In January 2016, the Study Team for this report identified 67 organizations with offices and local staff in Massachusetts directly linked to energy storage in the areas of: project development, investment, and research. Institutions such as the Massachusetts Institute of Technology (MIT), Boston College, Fraunhofer, and others have robust research facilities and teams in the region that contribute to developing early stage start-ups. Companies such as Ambri Inc. (an MIT spinout) have emerged either directly from these institutions or with their support and funding. NEC Energy Solutions, one of the largest suppliers of grid storage, is based in Massachusetts. General Electric, another frontrunner in the energy storage space, will soon be moving its headquarters to Massachusetts.

³⁶ Massachusetts Clean Energy Center: 2015 Massachusetts Clean Energy Industry Report; <http://www.masscec.com/2015-massachusetts-clean-energy-industry-report>

This growing energy storage industry can expand on the success of the clean energy industry, bringing in new business to Massachusetts and creating new jobs.

1.7 Conclusion

Massachusetts is a renowned leader for its policies promoting the implementation of energy efficiency investments and renewable power development. These efforts, among others, seek to further the deployment of distributed, clean energy resources for the benefit of the environment, electricity ratepayers, and the Commonwealth's economy. Policy makers have the ability to consider energy storage in their ongoing plans to ensure the provision of safe, reliable, clean, secure, and cost effective energy for consumers.

Investment decisions made today — in transmission, generation, and new technologies — to meet Massachusetts' long-term economic, reliability, and greenhouse gas (GHG) reduction goals, will impact the Massachusetts' customer and economy for decades to come. The variety of storage technologies and their diverse physical attributes give storage a wide selection of possible applications. In the next chapter, we will review how the benefits of storage systems can be applied to Massachusetts' energy challenges.

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2 Massachusetts Energy Challenges and Storage Applications

“Modernizing the electric system will help the nation meet the challenge of handling projected energy needs—including addressing climate change by integrating more energy from renewable sources and enhancing efficiency from non-renewable energy processes. Advances to the electric grid must maintain a robust and resilient electricity delivery system, and energy storage can play a significant role in meeting these challenges by improving the operating capabilities of the grid, lowering cost and ensuring high reliability, as well as deferring and reducing infrastructure investments. Additionally, energy storage can be instrumental for emergency preparedness because of its ability to provide backup power as well as grid stabilization services.”

U.S. Department of Energy Whitepaper on Grid Energy Storage (Dec 2013)

2.1 Introduction

The Massachusetts’ electric grid is experiencing unprecedented change and challenges, including, the planned and at risk retirement of almost 10,000 megawatts (MW) of traditional baseload power plants, a growing reliance on natural gas for electric generation, the use of high-emitting oil generation to meet winter peak demand, an increase in clean, but intermittent, variable generation resources, such as wind and solar, and a transition to more consumers generating their own electricity. These changes create challenges for energy policy makers and system operators , as well as opportunities to employ new technologies, such as energy storage, to address these challenges.

The electricity system operates on a "just-in-time" basis – with decisions about power plant dispatch that are based on real-time demand and the availability of transmission to deliver it. Generation and load must always be perfectly balanced to ensure high power quality and reliability to end customers. With power plant retirements and the rapidly growing amounts of variable wind and solar generation now being deployed, guaranteeing this perfect balance is becoming more challenging.

Although there is no one solution, a suite of energy policies that include energy storage can address these many changes. Massachusetts is already a leader in energy efficiency investments, renewable power development, and grid modernization planning. Energy storage complements these policies, which benefit the Commonwealth, its electricity ratepayers, and the environment.

Opportunities for energy storage include the following:

- Firming renewable energy. Wind and solar resources are increasing in numbers but are considered “intermittent resources”. There is less certainty about their output as they rely on the wind and the sun. Even small events, such as clouds blowing over a solar farm, require the grid operator to quickly dispatch other generation, typically natural gas generators, to make up the difference. Energy storage can be used to “firm” and balance renewable energy generation thereby enhancing reliability and providing both economic and environmental benefits.
- Lowering electricity prices by enabling use of low-cost energy that is stored during off-peak periods to be used to serve load during more expensive peak periods.

- Avoiding or deferring the need for transmission line upgrades in locally constrained areas of the state that have lost significant local generation resources.
- Enabling utilities to reliably and cost-effectively interconnect distributed energy resources, particularly distributed solar, at their substations.
- Increasing grid resiliency by mitigating the impacts of power outages due to severe weather, including direct and indirect economic impacts for residents, businesses and municipalities, particularly for those with critical facilities.
- Helping Massachusetts businesses and residents better manage their electricity use and reduce electricity costs, by using on-site storage.
- Supporting the growth of the Massachusetts' clean energy sector by furthering industry growth and job creation.

The following chapter discusses how energy storage can be used to address Massachusetts energy challenges to ensure a clean, affordable, resilient energy future for the Commonwealth. In subsequent chapters the study will review a detailed analysis of how much storage could be cost effectively utilized by Massachusetts' energy system and the barriers to development.

2.1.1 Massachusetts Energy Policy

The Baker-Polito Administration is taking a balanced approach to address the energy challenges facing the Commonwealth. Energy policy is focused on meeting three objectives:

- 1) Reducing and stabilizing the rising cost of energy for consumers
- 2) Continuing the Commonwealth's commitment to a clean energy future and compliance with the Global Warming Solutions Act (GWSA) which requires greenhouse gas emissions reductions of 25 percent by 2020 and 80 percent by 2050 over 1990 baseline levels, and
- 3) Ensuring a safe, reliable, and resilient energy infrastructure for the Commonwealth's residents and businesses.

To meet these objectives the Baker-Polito Administration is pursuing a balanced and diversified energy portfolio, a "combo platter" approach that includes:

- Hydroelectric power
- Solar and wind power
- New electric and gas transmission
- Energy Efficiency
- Energy storage and other grid innovations

Recognizing that energy storage can be a valuable component of a diversified energy portfolio for the Commonwealth, in May 2015 the Baker-Polito Administration launched the \$10 million Energy Storage Initiative to evaluate and demonstrate the benefits of deploying energy storage technologies in Massachusetts. As part of the initiative, the Department of Energy Resources (DOER) and the Massachusetts Clean Energy Center (MassCEC) partnered to conduct a study to analyze the economic benefits and market opportunities for energy storage in the state, as well as examine potential policies and programs that could be implemented to better support both energy storage deployment and growth of the storage industry in Massachusetts. The Energy Storage Initiative will

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assist Massachusetts policy makers in determining how best to utilize this resource. Energy storage can be a game changer for reliably and cost-effectively moving towards the grid of the future.

"Massachusetts will continue to lead the way on clean energy, energy efficiency and the adoption of innovative technologies such as energy storage. These efforts, and our legislative proposal to bring additional hydroelectricity and other renewable resources into the region, will ensure we meet our ambitious greenhouse gas emission reduction targets while also creating a stronger economy for the Commonwealth."

- Gov. Baker, Governors' Accord for a New Energy Future press release, February 2016

2.2 Massachusetts' Energy Challenges where Storage can play a role

2.2.1 System must be Sized to Peak Demand to Maintain Reliability

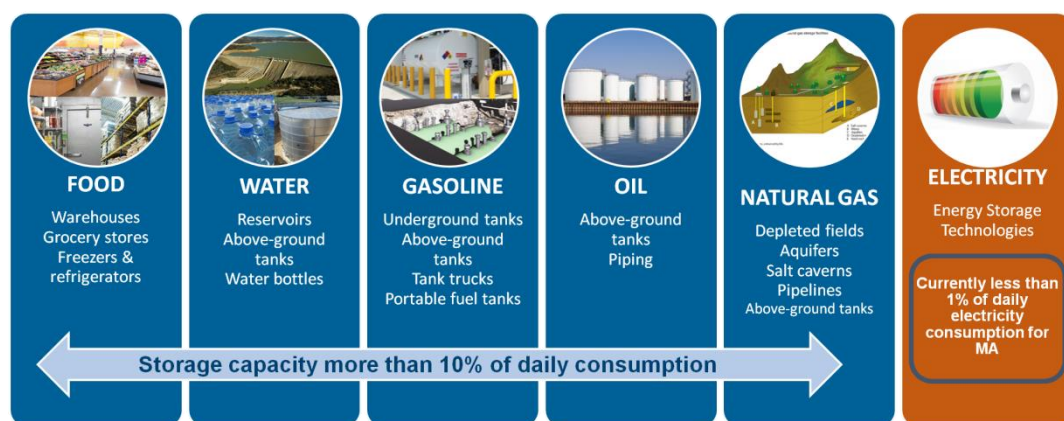


Figure 2-1: Storage in Commodity Supply Chains

Increasing the amount of storage capacity on the power grid has the potential to transform the way we generate and consume electricity for the benefit of Massachusetts ratepayers. As compared to other commodities, the electricity market currently has the least amount of storage in its supply chain. Other commodities including food, water, gasoline, oil and natural gas, have storage capacity to meet more than 10% of the daily consumption whereas (Figure 2-1) storage currently makes up less than 1% of daily electricity consumption in Massachusetts. Because electricity travels at approximately 1,800 miles per second, it is also the fastest supply chain, meaning that without storage electricity needs to be produced, delivered and consumed nearly instantaneously for the grid to stay in balance. This requires the electric grid to have substantial infrastructure to maintain reliability. All grid infrastructure — including generation, transmission and distribution — must be sized to manage the highest peak usage of the year, even though the amount of electricity needed by consumers varies significantly both throughout the day and at different seasons of the year (Figure 2-2).

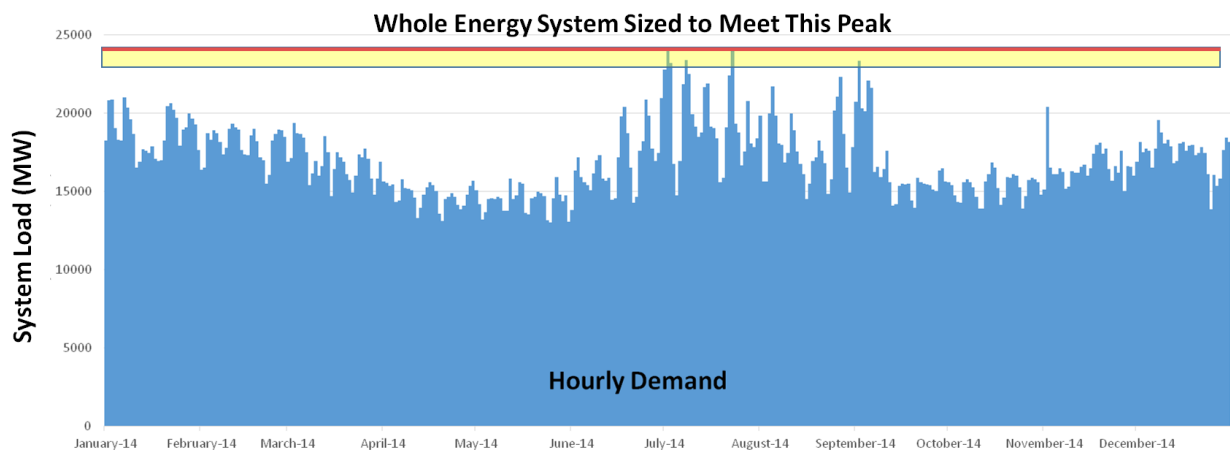


Figure 2-2: ISO-NE System Annual Hourly and Weekly Demand 2014³⁷

The need to size all grid infrastructure to the highest peak results in system inefficiencies, underutilization of assets and high cost to ratepayers. Figure 2-3 shows that energy costs are heavily skewed to a few high cost hours which have a significant impact of the total annual energy cost to ratepayers. Over the last three years from 2013 – 2015, on average, the top 1% of hours in the year (87 hours) accounted for 8% of Massachusetts ratepayers annual spend on electricity representing \$680 million. The top 10% of hours during these years, on average, accounted for 40% of annual electricity spend or over \$3 billion in cost to ratepayers per year.³⁸

³⁷ Source: ISO-NE Hourly Load Data

³⁸ Ibid.

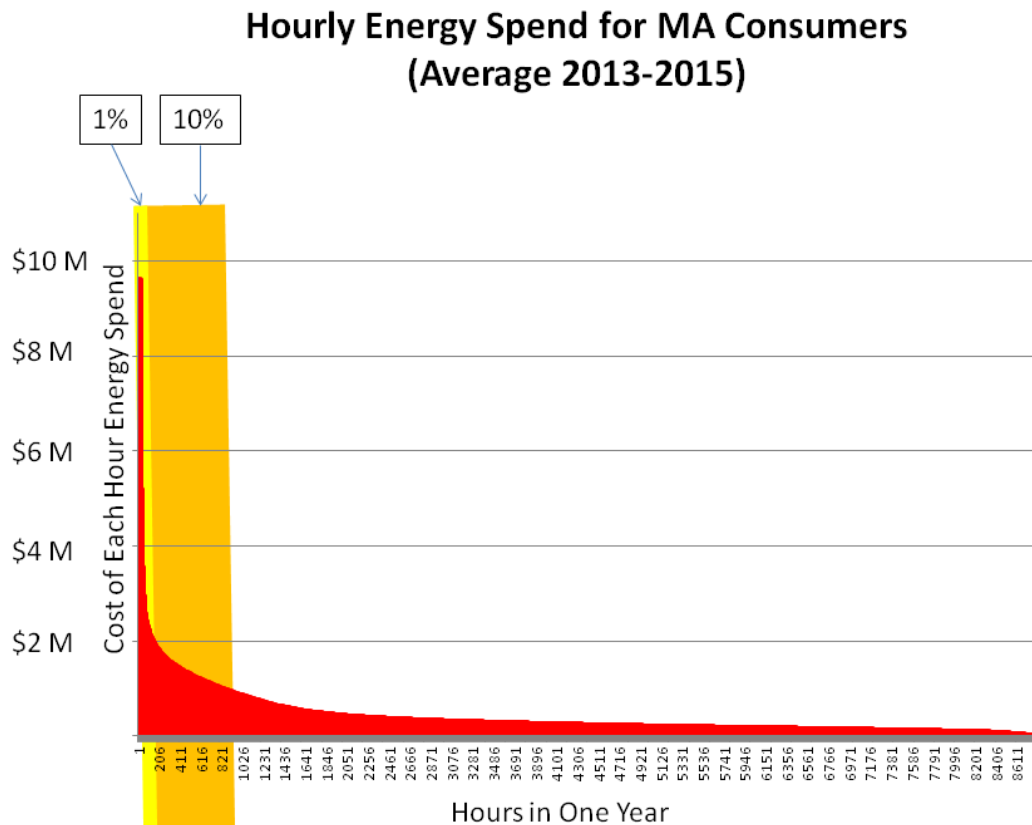


Figure 2-3: Hourly Energy Spend for Massachusetts ³⁹

Figure 2-4 illustrates the cost disparity for a peak winter and summer day. In 2014, one summer day's electricity cost surged from \$33/MWh to \$94/MWh, almost a 3-fold increase. Peak electricity costs are even more pronounced during winter peaks because of natural gas constraints and coincident demand for heating and electric generation. On one winter day in 2014, energy costs increased from \$70/MWh during the night to over \$700/MWh at evening peak, a more than a 1000% increase.

³⁹ Source: Department of Energy Resources and ISO-NE Pricing Reports; <http://www.iso-ne.com/isoexpress/web/reports/pricing>

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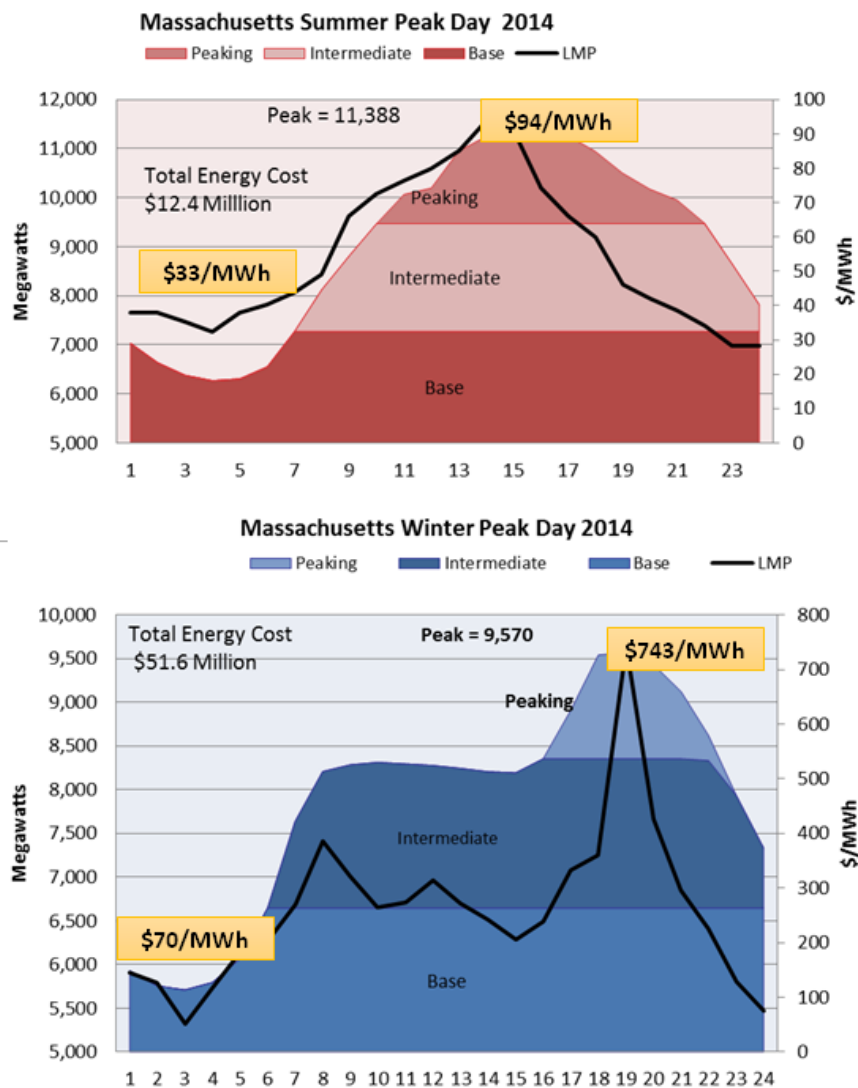


Figure 2-4: Average Demand and Price Peaks for a Peak Summer and Winter Day in Massachusetts 2014⁴⁰

Until recently the ability to store electricity across the electric grid was limited, but now advances in new energy storage technologies, such as grid-scale batteries, is making wide-scale deployment of electricity storage viable. With advances in new electric storage technologies, the need to size the grid to peak can be transformed.

Energy storage is the only technology that can use energy generated during low cost off-peak periods to serve load during expensive peak periods, thereby improving the overall utilization and economics of the electric grid (Figure 2-5).

⁴⁰ Source: Massachusetts Department of Energy Resources and ISO-NE Pricing Reports; <http://www.iso-ne.com/isoexpress/web/reports/pricing/-/tree/zone-info>

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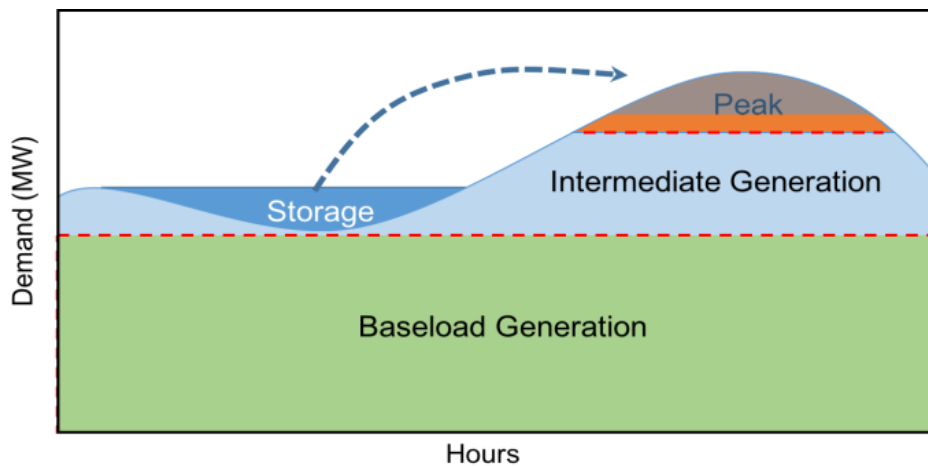


Figure 2-5: Energy storage can use off peak energy during times of high demand

2.2.2 Peak Demand is Growing

In 2015, the peak demand for Massachusetts was 11,443 MW. Figure 2-6 depicts the significant impact that energy efficiency has had on reducing annual energy consumption, but also shows that peak demand continues to grow at a rate of 1.5% per year. As the peak continues to rise, Massachusetts and New England will have to expand the capacity of the energy system despite little or no increase in average load. Funding the required investments to meet this peak will drive up electricity prices.

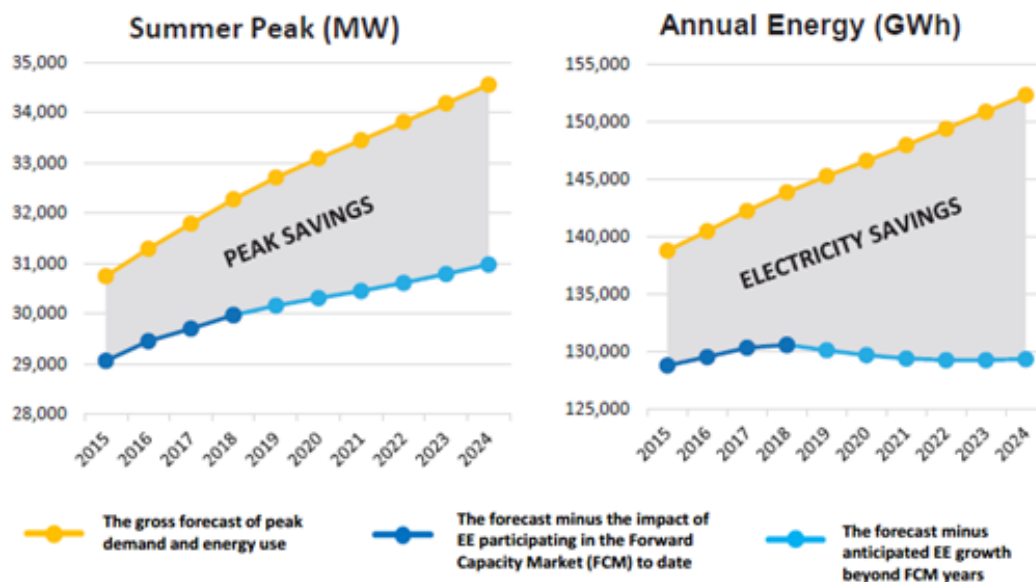


Figure 2-6: While Energy Efficiency has Decreased Average Energy Consumption, Peak Continues to Grow⁴¹

⁴¹ ISO-NE, *State of the Grid - 2016*, January 26, 2016; http://www.iso-ne.com/static-assets/documents/2016/01/20160126_presentation_2016stateofthegrid.pdf

The peak-to-average demand ratio, which represents the difference between the peak demand and the average of the total demand, is growing year over year (Figure 2-7). Although many regional electric systems are seeing an increase in peak-to-average demand ratio, no area has increased as much as ISO-NE.⁴² This change can be attributed to many factors including a shift from an industrial-commercial base to a service-based economy, a reduction in average energy use due to increased energy efficiency, and a greater use of climate control technologies like air conditioners that are used depending on the weather.

In order to provide enough energy during peak periods new natural gas “peaker” plants are being built even though they are needed only for a small amount of hours per year.⁴³

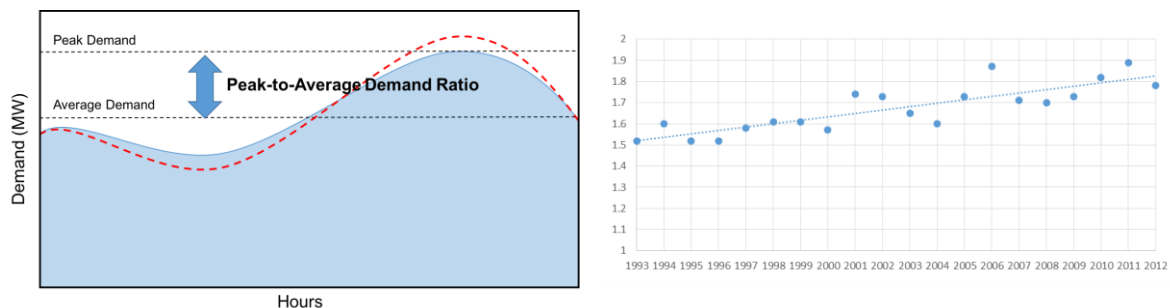


Figure 2-7: Peak-to-Average Demand Ratio Illustration and ISO-NE Annual Increase (1993-2012)⁴⁴

According to the U.S. Energy Information Administration (EIA) peaker plants only operate 2% – 7% of the year (Figure 2-8).

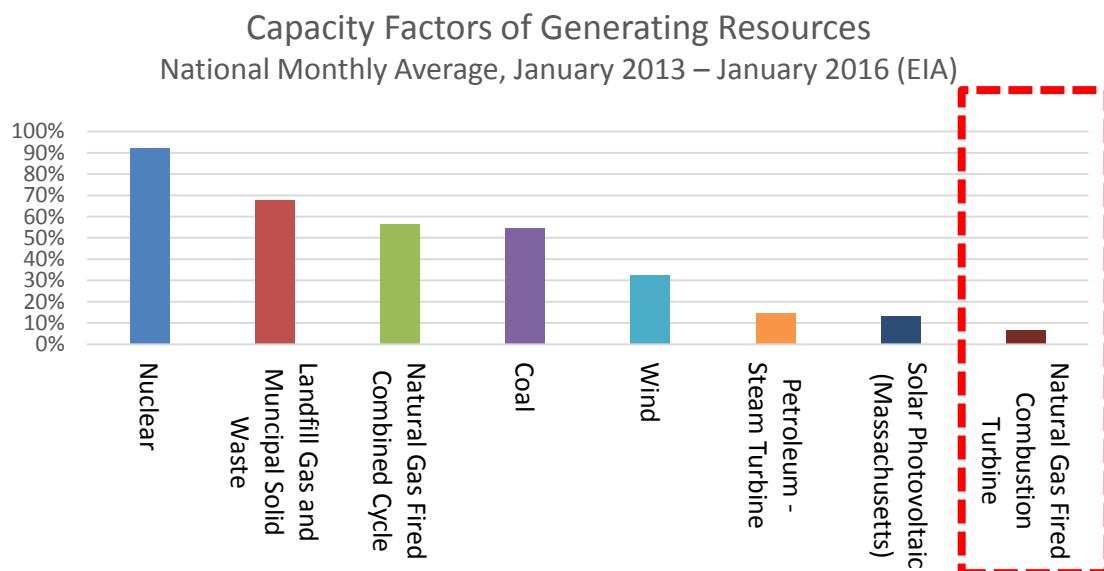


Figure 2-8: Average Monthly Capacity Factors⁴⁵

⁴² EIA, Peak-to-average electricity demand ratio rising in New England and many other U.S. regions, February 18, 2014; <https://www.eia.gov/todayinenergy/detail.cfm?id=15051>

⁴³ Currently, there are three natural gas peaker plants in these zones accounting for approximate potential 600 MW capacity undergoing Massachusetts Environmental Protection Act (MEPA) review at the Executive Office of Energy and Environmental Affairs (EEA).

⁴⁴ EIA, Peak-to-average electricity demand ratio rising in New England and many other U.S. regions, February 18, 2014; <https://www.eia.gov/todayinenergy/detail.cfm?id=15051>

Additionally, natural gas peaker plants tend to have some challenges:

- Relatively low fuel efficiency creating high fuel costs;
- Relatively high air emissions (per kWh of energy generated), especially when not operated optimally; and,
- High cost to operate when required to start and stop generation.

Instead of generating electricity with natural gas “peaker” plants at times of high electric and fuel prices, storage can be used to “peak shift” by using lower cost energy stored during off-peak periods to meet this demand. Storage requires no fuel, has no independent emissions, requires minimal maintenance, and it can be dispatched quickly. This reduces the costs associated with peak demand and provides significant savings for Massachusetts ratepayers. If peak demand can be shifted and reduced, new peaker plants could be avoided and the cost of serving that peak time would decrease.

In addition to the fundamental benefit of storage which is being able to charge during low-cost times, most types of storage have other qualities that make it a competitive technology and responsive to demand including:

- Start-up is very quick (fast response time)
- Output can be varied rapidly
- Can be operated at part load easily and efficiently

2.2.3 Generation Retirements are Creating a Need for New Resources

The blue pins in Figure 2-9 below delineate power plant retirements from 2014-2019 resulting in 4,200 MW of capacity lost to the ISO-NE.⁴⁵ Recently announced retirements in Massachusetts include the 1,535 MW coal and oil-fired Brayton Point Station, and the 680 MW nuclear-fuelled Pilgrim Power Station. In addition to these known retirements, other generation is currently at risk due to plant age and economics. These facilities, marked by the orange pins in Figure 2-9, total an additional 6,000 MW or more of capacity at risk to retirement. These facilities include the 1,100 MW Canal Generating Plant, in service since 1968, which utilizes both oil and natural gas.

⁴⁵ EIA Electric Power Monthly, Table 6.7.A. Capacity Factors for Utility Scale Generators Primarily Using Fossil Fuels, January 2013-January 2016; https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_a; and Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-January 2016; https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b; Massachusetts Solar PV Capacity from Massachusetts DOER, Calculation of Solar PV Capacity Factor; <http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out/current-status-of-the-rps-solar-carve-out-program.html>

⁴⁶ ISO-NE, Status of Non-Price Retirement Request, <http://www.iso-ne.com/markets-operations/markets/forward-capacity-market>

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Figure 2-9: Generation Retirements, illustrated by ISO-NE in Today's Grid Challenges⁴⁷

In order to maintain grid reliability, ISO-NE must develop new capacity to replace the above-mentioned retirements. Currently, the ISO-NE Interconnection Queue is dominated by new intermediate and peaker natural gas-fired and dual fuel generation (natural gas and oil), for a total of over 8,000 MW of fossil fuel-fired capacity. The remaining capacity is mostly onshore wind generation with some solar photovoltaic (PV) generation (See Figure 2-10 – by Fuel Type).

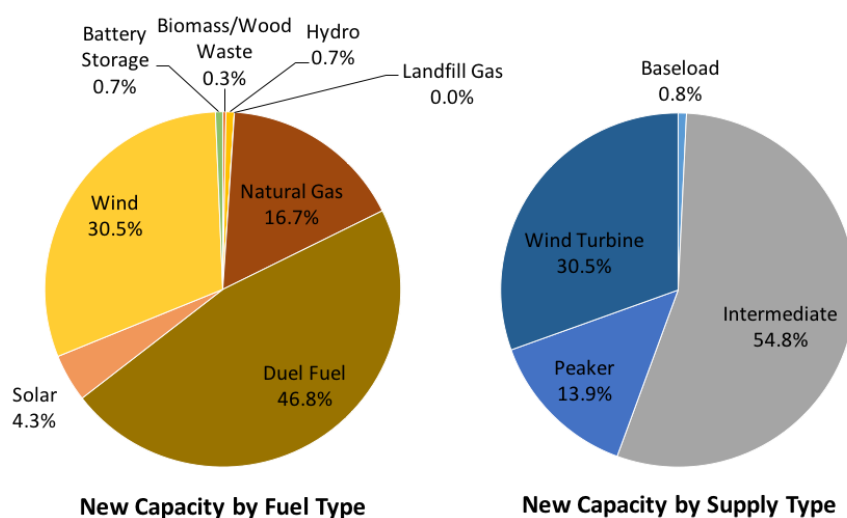


Figure 2-10: All Proposed Generation to ISO Generator Interconnection Queue⁴⁸

⁴⁷ ISO-NE, Regional Energy Outlook; <http://www.iso-ne.com/about/regional-electricity-outlook/grid-in-transition-opportunities-and-challenges/power-plant-retirements>

In 2015 alone, ISO-NE added over 2,500 MW⁴⁹ of natural gas plants targeted for development in Massachusetts to the interconnection queue.⁵⁰ These natural gas and dual fuel facilities are considered either intermediate or peaker resources (see Figure 2-10 – by Supply Type).

Some areas in New England require more capacity because of high demand from dense population. Figure 2-11 illustrates New England's densist load. In Massachusetts, the Boston and the Southeastern areas are import constrained zones in which the retiring Brayton Point and Pilgrim plants are located. Peak demand is generally met by local generation instead of importing energy from outside the zone. Currently, there are three natural gas peaker plants in these zones accounting for approximate potential 600 MW capacity undergoing Massachusetts Environmental Protection Act (MEPA) review at the Executive Office of Energy and Environmental Affairs (EEA).

The retirement of zero-emission nuclear generation challenges Massachusetts' goals to reduce electric sector emissions. Pilgrim's capacity, as a nuclear resource, is currently emission free but if its capacity is replaced by natural gas capacity, emissions for the Commonwealth will increase.

Energy storage deployment can assist ISO-NE in meeting local sourcing requirements within a capacity zone. Utilizing storage systems within areas of high demand can help mitigate peak price spikes by discharging stored energy and can help meet local demand without requiring additional energy imports. Import constraints contributed to elevated forward reserve pricing in the northeast Massachusetts/Boston (NEMA) reserve zone for the summer 2015 period.⁵¹ Transmission constraints can also contribute to the un-economic operation of generation resources. ISO-NE compensates generators that are uneconomically dispatched with payments called Net Commitment Period Compensation (NCPC) or 'uplift' payments that are directly allocated to ratepayers. NCPC costs in New England over the 12 months ending December 2015 amounted to more than \$118 million, of which Massachusetts ratepayers paid \$54 million.⁵² This represents the un-economic, or "out-of-merit," operation of generators, which can serve to mask the true cost of energy to ratepayers. Strategically deployed energy storage can play a valuable role within import constrained zones such as NEMA/Boston and SEMA (southeast Massachusetts)/RI as these regions experience some of the highest energy costs in the region, resulting ultimately in lowered energy costs to ratepayers.

⁴⁸ Vamsi Chadalavada, NEPOOL Participants Committee Report, March 6, 2016; <http://www.iso-ne.com/static-assets/documents/2016/03/march-2016-coo-report.pdf>

⁴⁹ ISO-NE, Interconnection Request Queue 02-01-16, ISO New England; http://iso-ne.com/static-assets/documents/2014/09/interconnection_request_queue.xls

⁵⁰ Non-price Retirement Requests (NPRs) are one of the mechanisms that Forward Capacity Market (FCM) Participants can use to exit the FCM. NPRs are irrevocable requests to retire all or a portion of a resource from the FCM and all other markets administered by the ISO.

⁵¹ Forward reserve clearing prices for NEMA for this past summer (2015) were 2.4 times greater than the clearing prices for reserves in the rest of the system (\$14/kW-mo versus \$5.83/kW-mo).

⁵² ISO-NE, NEPOOL Participants Committee Report, March 4, 2016 March 2016 COO report, slide 78; <http://www.iso-ne.com/static-assets/documents/2016/03/march-2016-coo-report.pdf>

Energy Storage can be an emissions free source of “local” peak generation in highly populated areas. Advanced storage projects typically require a much smaller footprint and shorter construction timeline than conventional generation; a grid-scale energy storage project can be constructed within months, not years. The modular design of storage resources means that the projects can be sized to any level. Increments of capacity can easily be added to increase the size of the project. The “plug and play” concept of new storage technologies makes them easy to locate near an existing power plant, a utility substation, or at a consumer site (such as a house, a factory or a shopping center).

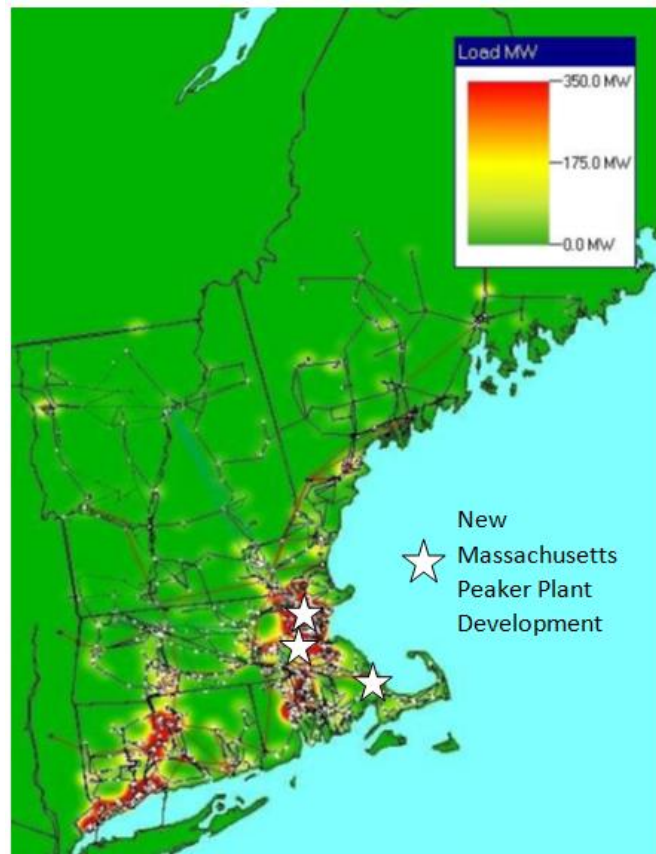


Figure 2-11: Load Distribution within New England - Representative Summer Peak⁵³

There are two versions of storage installations that can be used as a peaker resource:

1. Bulk/central facilities which are comprised of one large advanced storage plant connected to the transmission grid. Bulk energy storage resources that can help with meeting the system peaking capacity needs are most likely to involve medium to long duration technologies, such as a flow batteries or longer duration lithium ion batteries.
2. Modular/distributed storage systems which are located near or within load centers connected to the distribution system either at substations or behind customer meters.

⁵³ Source: ISO-New England

Energy Storage to Replace Retiring Generation in California

In 2013, Los Angeles, California and Orange County lost over 2,200 MW of generation capacity with the San Onofre Nuclear Generating Station (SONGS) closure, leaving the resource-constrained area in need of additional generation capacity. The California Public Utilities Commission (CPUC) authorized Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) to procure up to 2,500 MW of new generation capacity. In November 2014, SCE announced procurement of a combination of new generation capacity to replace the nuclear plant that included 261 MW of energy storage resources in conjunction with new natural gas generation and new renewable generation. By procuring storage, the LA region was able to utilize renewable generation and less natural gas generation to replace the closing nuclear plant.

Storage can benefit the system by minimizing the amount of generation that is on-line at minimum load when demand is low. Generators are often called to operate at minimum load to be ready and capable to ramp up to serve during higher load periods because fossil generation cannot turn on and off quickly. This type of operation increases emissions and costs from these plants. During periods of low demand, there can be excess energy on the grid due to conventional resources being on-line and sitting at their minimum load. Energy storage resources could store this excess energy for times when demand increases. Using energy storage in this way could also even reduce the amount of conventional generation that is needed to come on to minimum load, thus reducing overall costs on the system.

2.3 Renewable Generation Integration

Energy storage can facilitate and enhance the use of new and existing intermittent renewable generation, to replace Massachusetts' and New England's retiring generation.

Presently, large utility-scaled renewable generation facilities raise two main challenges for the Massachusetts market: (1) generation supply does not always match the time of demand and (2) unpredictable intermittence. For example, large scale on-shore wind facilities are capable of producing a large quantity of energy but often mostly at night when the wind is strongest. This generation supply often does not coincide with the time of greatest energy use, during the day and early evening. Solar is generating during the day but not during evening peak. This can be seen in Figure 2-12 which shows that solar and wind generation does not match in time with energy demand. This creates a gap where additional energy is required. This gap can be met with either traditional fossil fuel generation or energy storage. Storage technologies can store the energy generated at times of low demand and act as the renewable power source during periods of high demand, firming the renewable resource.

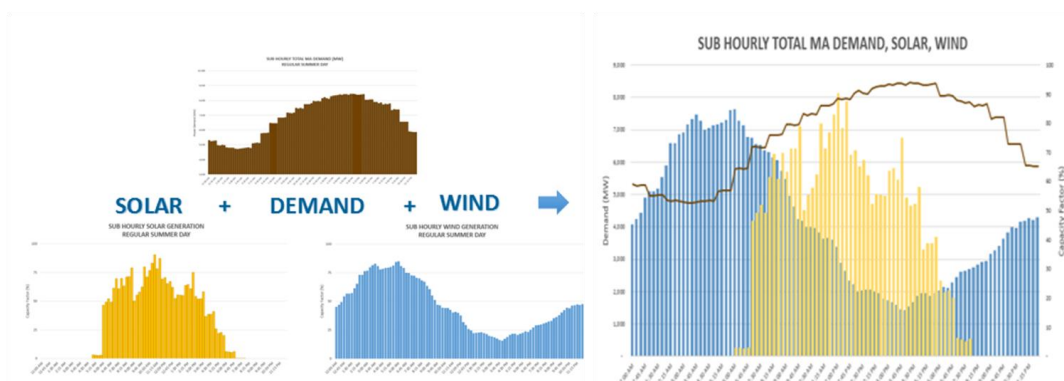


Figure 2-12: Renewable Generation and Demand

Storage can help prevent situations where inflexible wind and solar generation exceed demand and create balancing issues. For example, on Sunday afternoons in spring when there is low demand and there may be excess solar generation. There also have been instances where wind generation at night and solar generation contribute to “negative prices”, where the electricity supply exceeds demand and the output from the on-line generation cannot be immediately reduced⁵⁴. This situation also creates voltage drops (or voltage instability) along transmission lines, especially longer lines. When this occurs, ISO-NE experiences a minimum generation emergency (MGE) and requires generators to operate at their emergency minimum dispatch levels which creates uneconomic ‘uplift’ costs to ratepayers.

Storage could help avoid the triggering of an MGE by storing excess generation from renewable resources when generation is higher than demand. In some situations, energy storage could even receive payment to charge when prices become negative. ISO-NE has sought to address the “light load” problem through a few initiatives including continued efforts to require all generators to be dispatchable or flexible. In 2016, ISO-NE will implement rules that will require intermittent wind and hydro resources to become, essentially, dispatchable. These efforts should help alleviate some problems, but are not expected to fully mitigate the issues. The addition of storage enhancing the ability of inflexible resources such as wind and solar become more dispatchable could help renewable generators comply with ISO-NE rules.

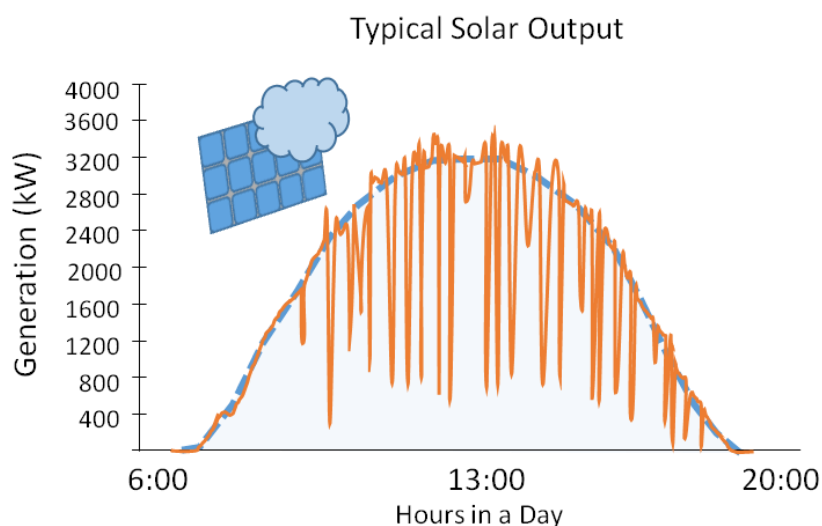


Figure 2-13: Solar generation can have variable output because of cloud cover or other weather

The growth of intermittent variable wind and solar generation has increased the challenge for grid operators to reliably balance supply and demand. For example, renewable resources such as solar generation may change output frequently and unpredictably throughout the day due to cloud cover.

According to the ISO-NE *State of the Grid – 2016* report, fast and flexible resources will be needed to balance intermittent resources’ variable output. With storage, new and existing renewable resources can manage their inherent intermittence and be more agile resources.

Another service storage can provide is Frequency Regulation, an ancillary services product that is used to reconcile momentary differences caused by fluctuations in generation and loads. The need for Frequency Regulation increases with greater renewable penetration due to the associated

⁵⁴ Negative energy prices occur with some frequency particularly in northern New England where there are sizable amounts of non-dispatchable generation (e.g. wind) that is export constrained.

variability caused by renewables' intermittent output. In order to manage Frequency Regulation, ISO-NE requires an available capacity of Frequency Regulation resources. Advanced storage is an ideal technology for Frequency Regulation because it can quickly and accurately respond to instantaneous load requirements, as compared to a slow ramping generator, as seen in Figure 2-14.

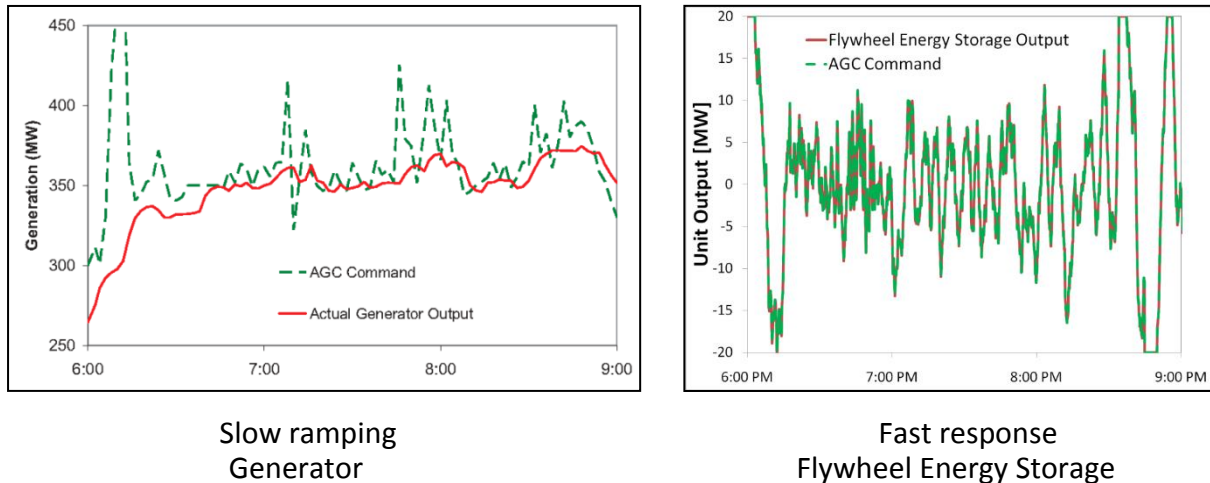


Figure 2-14: Energy storage can respond quickly to frequency regulation^{55,56}

Storage technologies have been participating in the ISO-NE Frequency Regulation market as a single-market-dedicated technology. With renewable resources growing in New England, and the associated variability caused by their intermittent output increasing, ISO-NE's Frequency Regulation market has grown by about 15% in the last year, from an average of 60 MW per hour to an average of 70 MW per hour. As renewable resources grow the Frequency Regulation market is expected to continue to grow. In December 2010, ISO-NE released the final report of its New England Wind Integration Study.⁵⁷ The study assessed a number of growth scenarios for wind in New England up to year 2020, and the potential impacts on the ISO-NE power grid. The study identified a need for an increase in the Regulation requirement even in the lowest wind penetration scenario (2.5% wind energy, ~1,100 MW), and the requirement would have noticeable increases for higher penetration levels. For example, this regulation requirement increases to 161 MW in the 9% wind energy scenario (~ 4,000 MW of wind), and to as high as 313 MW in the 20% scenario (8,000 – 10,000 MW) (see Figure 2-15).

⁵⁵ Left: Brendan Kirby Ancillary Services: Technical and Commercial Insights July 2007, http://www.consultkirby.com/files/Ancillary_Services_-_Technical_And_Commercial_Insights_EXT_.pdf

⁵⁶ Right: Beacon Power.

⁵⁷ ISO-NE, "Final Report: New England Wind Integration Study", Dec 2010. http://uvig.org/wp-content/uploads/2013/01/newis_report.pdf

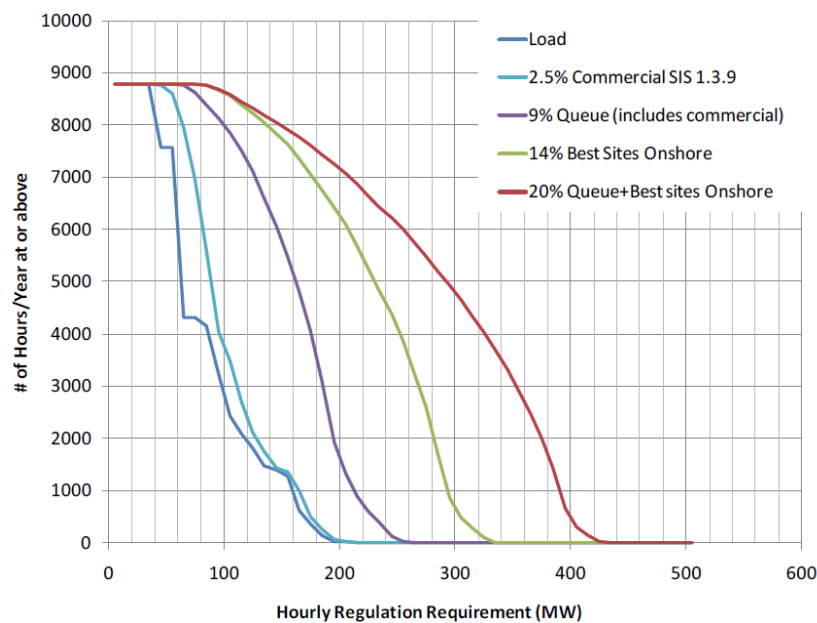


Figure 2-15: Duration curve of estimated hourly regulation requirements for load and selected wind scenarios⁵⁸

2.3.1 Capacity Market and Renewable Integration

Storage can also help intermittent renewable resources reduce their exposure to ISO-NE's "Pay for Performance" Capacity program, a program that penalizes capacity resources for being unavailable during reliability events. The market rules take effect as of June 2018. Under this program, during periods when ISO-NE is experiencing reserve shortages (insufficient generation to meet demand plus reserve margins), resources with awarded capacity supply obligations through the ISO's forward capacity market will be required to provide every bit of energy and/or reserves to cover the capacity supply obligation. Failure to do so will result in the resource owner incurring significant financial penalties. During a shortage event, a generator stands to lose the gross revenue earned over an average of 50 hours of operation for each hour that it fails to provide sufficient energy and/or reserves to the ISO.

Pay-for-Performance penalty provisions increase the cost of non-performance to all generators that are participating in ISO-NE's forward capacity market, but present a more pronounced risk to owners of intermittent renewable resources. Although significant strides have been made in improving solar and wind forecast tools and techniques, without the benefit of energy storage, intermittent resource owners will have very limited ability to hedge their exposure to such penalties.⁵⁹ Adding energy storage to a renewable portfolio can contribute to lowering over-all capacity market costs, which ultimately trickles down to the ratepayer.

2.4 Emissions Reductions

The pairing of energy storage with Massachusetts' renewable energy capacity would be beneficial to emissions reduction goals while also providing additional energy capacity. Since energy storage has

⁵⁸ ISO-NE, "Final Report: New England Wind Integration Study", Dec 2010. http://uvig.org/wp-content/uploads/2013/01/newis_report.pdf

⁵⁹ ISO-NE does provide a mechanism for resources to trade their performance obligation bilaterally under certain conditions, to mitigate the risk of incurring a pay-for-performance penalty. However, it is unlikely that such trades would provide much financial protection to the intermittent generator as the cost to trade the obligation will likely approximate the total cost of likely penalties.

zero independent emissions, integration of storage technologies can be done without sacrificing the benefit of renewable energy. According to the EPA's Clean Power Plan⁶⁰, this use of energy storage can adjust the CO₂ emission rate of electricity generation. Because the energy released by storage technologies reflects the energy used to charge the technology, the emissions of renewable generation plus storage remains zero.

Energy storage can also reduce emission by increasing overall generation efficiency of existing fossil fuel generators. Fossil fuel generation accounts for approximately 54% of the existing generation in ISO-NE. Natural gas is the primary fuel at 48% while oil and coal account for 6% (see Figure 2-16).⁶¹ Storage can help with system operations so that conventional generators operate more efficiently, decreasing the fossil fuel burned, and therefore reducing the associated emissions. Storage can also reduce the overall energy system emissions by reducing the time oil and coal generators are utilized to meet peak demand, particularly in winter.

Generation for ISO-NE 2015

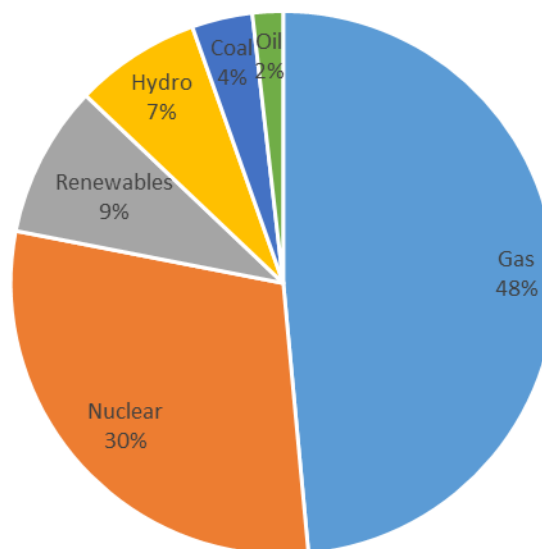


Figure 2-16: Generation Mix by Fuel Type for ISO-NE, 2015

Additionally, utilizing storage technologies can reduce emissions by avoiding ramping up and down natural gas facilities traditionally used to balance load and demand. A study by Carnegie Mellon estimated that 20% of the CO₂ emission reduction and up to 100% of the NO_x emission reduction expected from introducing wind and solar power will be lost because of the additional ramping requirements these resources impose on traditional generation.⁶² Storage provides the ramping capability to integrate renewables into the electric grid without consuming additional fossil fuels.

⁶⁰ EPA. Clean Power Plan. <https://www.epa.gov/cleanpowerplan>

⁶¹ ISO-NE, Resource Mix; <http://www.iso-ne.com/about/key-stats/resource-mix>

⁶² Katzenstein, W., and Jay Apt., Air Emissions Due To Wind and Solar Power. *Environmental Science & Technology*, 2009, 43, 253-258; (<http://pubs.acs.org/doi/pdf/10.1021/es801437t>)

2.5 Non-Wires Alternative to Transmission Infrastructure Investments

The transmission system is designed, built, and operated so that generation can reach the load without risking overloading failures to the generation and transmission equipment. With more renewables integrated onto the system and major power plant retirements, combined with severe weather conditions, the transmission system is often stressed and requires upgrades. For example, renewable generation projects connected to the grid in more remote locations can often experience bottlenecks that prevent delivery of that energy to where it is needed most – at the load centers in urban areas. Uneconomic utilization of generators and the transmission infrastructure ultimately puts heavy stress on the substations and power lines which can result in the need to curtail scheduled generation and make costly upgrades.

Energy storage can be a lower cost alternative to transmission infrastructure investment, often called a “non-wires alternative.” This application is especially compelling because the benefits can be quite significant. A small amount of storage can: a) delay the need for a significant replacement and/or a “lump” addition of Transmission and Distribution (T&D) capacity, or b) reduce loading on existing equipment such that the equipment’s life is extended. For example, an upgrade in the transmission system may be needed to transport electricity to meet a peak load which only occurs for a limited amount of hours in the year. Instead of building new transmission, energy storage can modify the peak load by charging during non-peak hours, and discharging during the peak period.

In Massachusetts, the best example of this non-wire alternative planning is on the geographically isolated Nantucket Island. Nantucket is served by two undersea cables, limiting the power supply that the island’s consumers can access. In addition, National Grid’s load forecast predicts that the island will see a large growth of peak demand in the near future.⁶³ Traditionally a utility would consider the construction of an additional, and costly, undersea cable to increase reliability both for the peak demand increase and emergency contingency. Instead, Massachusetts Electric Company and Nantucket Electric Company, doing business as National Grid, have recently submitted a proposal to the Massachusetts Department of Public Utilities (DPU) that is currently under review for a non-wire alternative pilot costing approximately \$20.6M, which includes storage and other technologies. By addressing the Island’s two challenges with a cost effective strategy, National Grid expects ratepayers will save approximately \$23.6 million by deferring the cost of traditional grid updates by seven years.⁶⁴

2.6 Outages and Reliability

As in the wholesale electric power system, the distribution system must also be managed to balance supply and demand. With a complicated network of distribution lines, utilities must ensure that the varying voltage and load requirements are operated reliably. Energy must be quickly dispatched to specific areas in response to small and immediate changes in demand to ensure there are not overloads, reverse power flow, ground faulting (if a wire touches the ground or other grounded object like a tree branch), or a voltage drop or surge.

The electric utilities are required by the DPU and North American Electric Reliability Corporation (NERC) to maintain specific reliability standards. The DPU oversees the activities and performance of

⁶³ Massachusetts Electric Company and Nantucket Electric Company, each d/b/a National Grid, D.P.U. 16-06 – Petition of Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid for Approval of Non-Wires Alternative Pilot, and of Non-Wires Alternative Provision; Initial Filing, pg. 2 (January 11, 2016).

⁶⁴ Ibid. Pending approval at DPU.

the Investor-Owned Utilities (IOU), i.e. National Grid, Eversource, and Unitil. The DPU responsibilities include ensuring reliable service and the lowest possible cost, protecting public safety, and protecting rate-payer rights.⁶⁵ Regulators commonly use metrics to measure and quantify customer reliability for each utility to ensure that service quality (“SQ”) guidelines are met. In 2014, DPU shifted its SQ goals from preventing degradation of service to a goal of improving service based on historic performance metrics.⁶⁶ DPU has cited the increased access to cost effective modern technology as a reason they expect metrics to show an improvement in service quality.⁶⁷ The two most common metrics are SAIDI (System Average Interruption Duration Index), which measures the average outage duration, and SAIFI (System Average Interruption Frequency Index), which measures the average number of interruptions per customer, regardless of duration. Combined these two metrics provide a sense of both severity and frequency of customer outages. Overall, since the SQ guidelines were first implemented in 2002, there has been a significant improvement, especially in SAIDI.⁶⁸ Over the last 5 years, reliability metrics have shown utilities have maintained a fairly constant level of reliability with some utilities becoming more reliable (as shown in Figure 2-17 below). Utilities may face penalty payments if service quality standards are not met. Penalty payments are based on multiple metrics including the utilities’ SAIDI/SAIFI performance as compared to a state-wide average of aggregated historical data from 1996-2012.^{69;70}

⁶⁵ In order to fulfil their responsibility to ensure reliable distribution service, the DPU requires the IOUs to submit an Annual Reliability Report (ARR) (D.T.E. 98- 84/EFSB 98-5 (2003); <http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=98-84%2f88order.pdf>). These reliability reports must include peak demand forecasts for the distribution companies’ service area, the distribution system planning process, power flows and voltages under normal and emergency conditions, a list of critical loads, and any planned significant reliability and infrastructure improvement projects. Reliability projects can include tree and vegetation management plans, infrastructure repair and replacements, and load management technologies.

⁶⁶ D.P.U. 12-120c, “Order Adopting Revised Service Quality Guidelines,” December 22, 2014, pg. 14; <http://www.mass.gov/eea/docs/dpu/12-120c-order.pdf>

⁶⁷ Ibid. Page 15.

⁶⁸ D.P.U. 12-120-C, “Order Adopting Revised Service Quality Guidelines,” December 22, 2014, pg. 14; <http://www.mass.gov/eea/docs/dpu/12-120c-order.pdf>

⁶⁹ The formula for calculating a penalty is included in the SQ guidelines where the maximum penalty is defined as “2.5 percent of Annual Transmission and Distribution Revenues of a Company allocated to the metric.” D.P.U. 12-120-C Order, pg. 44

⁷⁰ D.P.U. 12-120-C, “Attachment A: Service Quality Guidelines,” December 22, 2014, pg. 17; <http://www.mass.gov/eea/docs/dpu/12-120c-orderata.pdf>

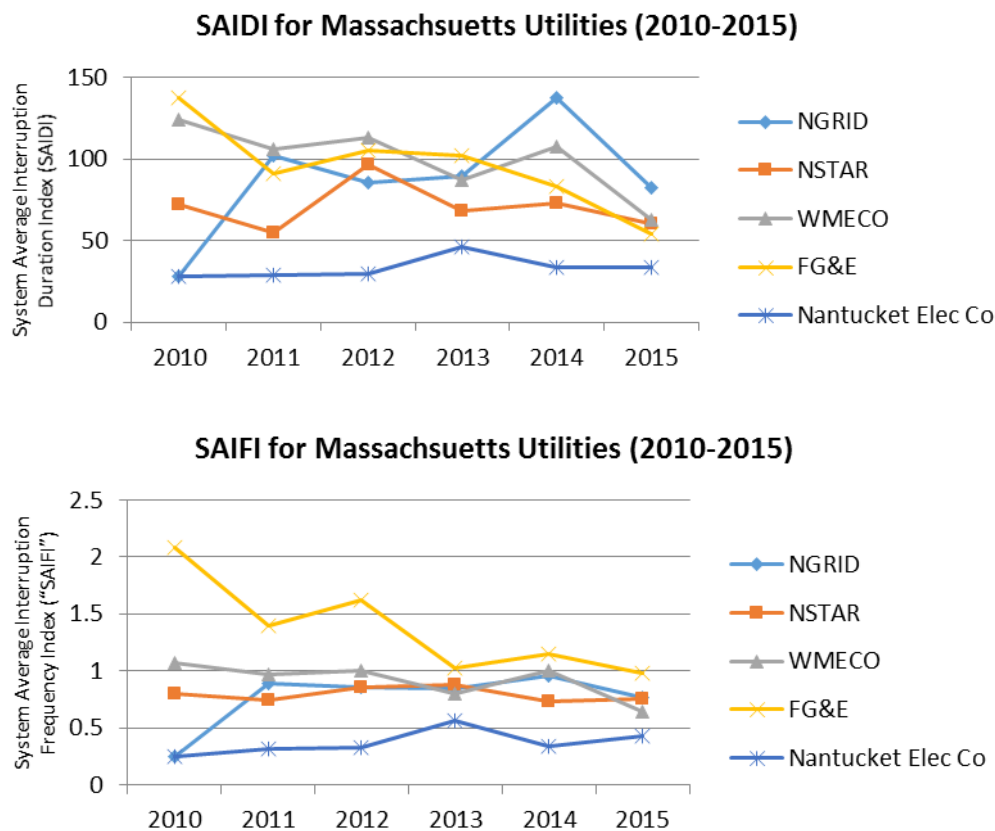


Figure 2-17: Reliability Metrics (SAIDI/SAIFI) for Massachusetts Utilities (2010-2015)⁷¹

Utilities can use storage within the distribution network to meet required reliability metrics by dispatching and storing energy rapidly in response to load balance changes, therefore avoiding the challenges that can create outages or poor power quality.

Maintaining this reliability and power quality requires utilities to uphold constant voltage within proper limits by utilizing reactive power, measured in volt-ampere reactive or VAR. Traditionally, utilities regulate voltage and reactive power (volt-VAR) within these specified limits by tap changing regulators at the distribution substation and by switching capacitors to follow load changes. This is especially important on long, radial lines where a large load such as an arc welder or a residential PV system may be causing unacceptable voltage excursions, i.e. power quality issues for neighbouring customers.

Energy storage can provide voltage support as an alternative or in conjunction with Volt Var Optimization (VVO). VVO are new data communication devices and they can automatically coordinate distribution level devices to more efficiently operate and reduce line losses. Utilities are currently considering VVO technologies to cost effectively reduce line losses. Voltage fluctuations can be effectively damped with minimal draw of real power from an energy storage system and such services can be offered by installed storage systems. The concept is illustrated below in Figure 2-18.

⁷¹ Investigation by the Department of Public Utilities into each Electric Company's 2015 Service Quality Report filed pursuant to Service Quality Standards for Electric Distribution Companies and Local Gas Distribution Companies, D.T.E. 04-116-B (2006) and D.T.E. 04-116-C (2007). (D.P.U. 16-SQ-10; D.P.U. 16-SQ-11; D.P.U. 16-SQ-12; D.P.U. 16-SQ-13; D.P.U. 16-SQ-14)

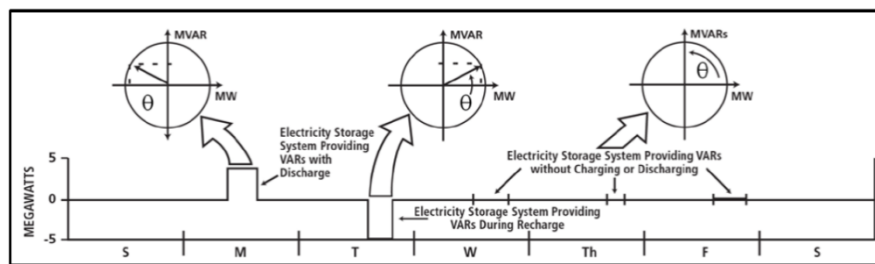


Figure 2-18: Illustration of voltage support for improving power quality⁷²

Major storm events often create a large number of concentrated power outages that cannot be predicted or prevented by utility reliability management plans. Therefore, these outages are generally not captured in utility reliability statistics. Despite their unpredictable nature, major storm events will certainly continue to occur at great cost to both utilities and their electricity customers. Utilities may face penalty payments for poor storm recovery response. In December of 2012, the DPU found that National Grid, NSTAR, and Western Massachusetts Electric Company (WMECo) failed in their public safety obligation in their responses to Tropical Storm Irene and the October 2011 snowstorm.⁷³ The utilities were fined \$18.725 million, \$4.075 million, and \$2 million, respectively, based on poor response and coordination with municipal officials around downed wires.

In addition to any utility investments and penalties, outages also create significant costs for Massachusetts residents and businesses. Nationally, outages are estimated to have an annual cost of \$30-130 billion.⁷⁴ Estimating outage costs is highly variable as they affect multiple types of customers, small residents to large industries, at different times for different durations. As utilities have limited liability for outages, electric customers generally bear the burden of these costs.

Resiliency is an evolving need for the electric grid that was catalysed by the occurrence of Superstorm Sandy, a watershed industry event in regards to system planning. The Edison Electric Institute, a representative body of all the investor-owned utilities (IOUs), released a report in 2012 investigating grid reliability in the context of underground transmission and distribution lines. This report showed the number storm events causing major system incidents have been increasing.⁷⁵ For Massachusetts, although the number of days with weather events has decreased, the severity of the weather events has increased. For example, 2011 was one of the worst years for major outages with the January 2011 Blizzard, Hurricane Irene on August 28, and the 2011 Halloween Nor'easter despite having only 52 days with weather events, as shown in Figure 2-19.⁷⁶

⁷² Source: DOE/EPRI/NRECA 2013 Electricity Storage Handbook, July 2013;

<http://www.sandia.gov/ess/publications/SAND2013-5131.pdf>

⁷³ Commonwealth of Massachusetts Department of Public Utilities, "Press Release: Department of Public Utilities Imposes \$24.8 million in Penalties for Utilities' 2011 Storm Responses," December 11, 2012;

<http://www.mass.gov/eea/docs/dpu/news/pr-dpu-storm-decisions-12-11-2012.pdf>.

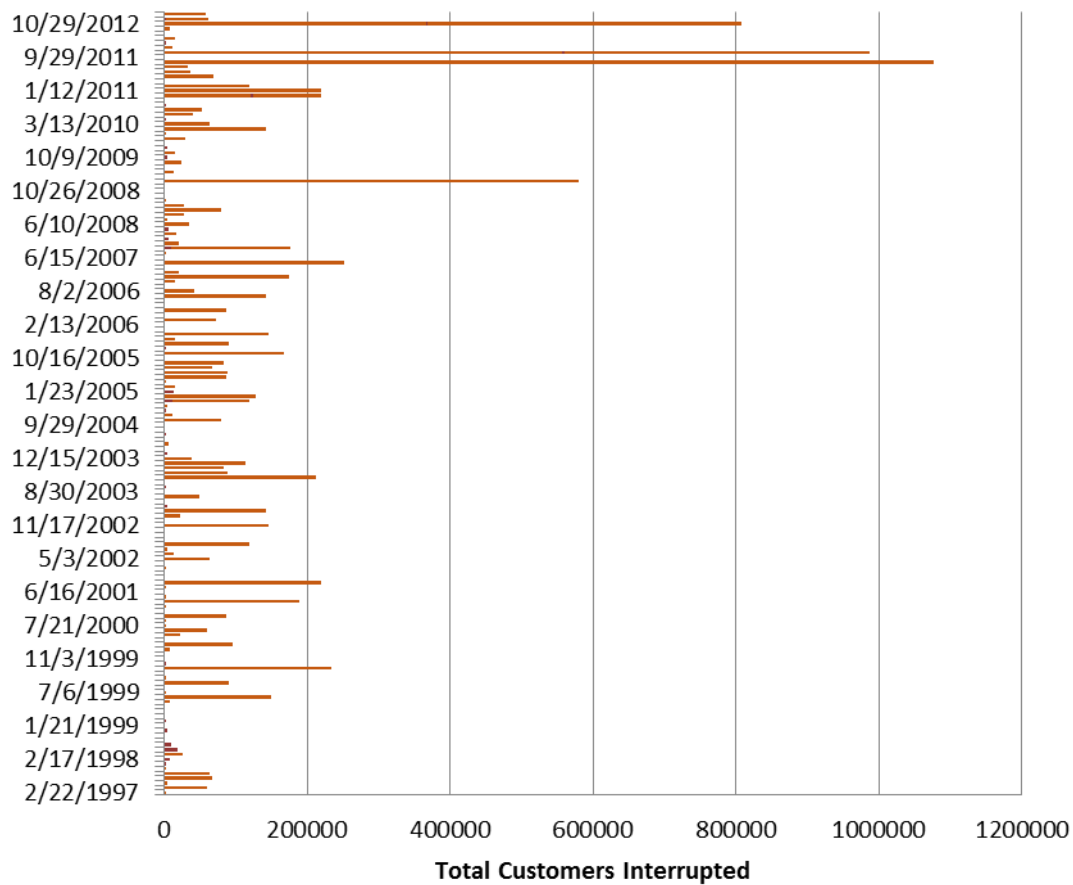
⁷⁴ Ernest Orlando Lawrence Berkeley National Laboratory, "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," September 2004; (<https://emp.lbl.gov/sites/all/files/REPORT%20lbnl%20-%2055718.pdf>)

⁷⁵ Out of Sight, Out of Mind 2012: An Updated Study on the Undergrounding of Overhead Power Lines, January 2013, prepared by Kenneth, L. Hall, P.E. of Hall Energy Consulting, Inc. for Edison Electric Institute, page 10;

<http://www.eei.org/issuesandpolicy/electricreliability/undergrounding/documents/undergroundreport.pdf>

⁷⁶ National Ocean and Atmospheric Administration Storm Events Database, (<http://www.ncdc.noaa.gov/stormevents/>)

Major (5% or greater) Outages in Massachusetts



2/8/2013	February Nor'easter ("Nemo")
10/29/2012	Hurricane Sandy
10/29/2011	2011 Halloween Nor'easter
8/28/2011	Hurricane Irene
1/12/2011	January 2011 Blizzard
12/26/2010	December 2010 Blizzard
12/11/2008	2008 December Ice Storm
4/15/2007	April 15 Rain Storm
6/30/2001	June 30 Wind Storm
9/16/1999	Hurricane Floyd

Figure 2-19: Major Outages and Major Storm Events in Massachusetts (1997-2013)⁷⁷

Storage distributed across the Massachusetts utility system can greatly increase the electric grid's resiliency in storm events. Resiliency initiatives such as the Community Clean Energy Resiliency Initiative by the Massachusetts DOER will also further drive market growth of energy storage for resiliency.

⁷⁷ Massachusetts Department of Energy Resources and Department of Public Utilities, Emergency Response Plans, Dockets 14-ERP-08 through 14-ERP-11

This \$40 million initiative is part of the Commonwealth's broader climate adaptation and mitigation efforts. It is a grant program focused on municipal resilience that uses clean energy technology solutions to protect communities from interruptions in energy services due to severe climate events made worse by the effects of climate change. The projects that received funding were analyzed and an estimate was made of the likely energy storage deployment from the grant.

For example, Sterling Municipal Light Department is conducting an energy storage pilot project focused on resiliency at a police and dispatch station located in the town of Sterling. The storage system will provide backup power during a blackout due to major storms or other events. Paired with a nearby 3.2 MW solar array, the storage system could sustain backup power to the station for a significant period of time. During non-critical events, the storage system could be utilized for peak load reduction and other grid services.

Storage technologies can also replace fossil fuel burning back-up power generators, reducing fuel costs while also reducing greenhouse gas emissions. According to ISO-NE and the EPA, there are ~421 Real-Time Emergency Generation (RTEG) units registered in Massachusetts, which add up to 404 MW of emergency generating capacity.⁷⁸ The stationary generator market is set to grow by a compound annual growth rate (CAGR) of 5-7% from 2015 to 2019.⁷⁹ Assuming that battery cost projections are met, energy storage will be a cost-competitive, emissions-free alternative.

Microgrids can also address the need to protect communities and commercial and industrial facilities from interruptions in energy services due to severe climate and other grid events. A microgrid is any electric system that is capable of operating independently (or islanded) from the grid. More and more microgrids are being developed throughout the country, and especially in the northeast. The U.S. accounts for 1,282 MW of installed microgrid capability⁸⁰ and 80% of the market is driven by 7 states including Massachusetts.

Microgrids and islanded electrical systems involve either: a) remote/isolated power systems or b) a portion of a utility's distribution system. In either case, they must be able to operate autonomously. Microgrids use of a variety of resources that can be co-optimized and shared within a network of loads ranging from residences to high-use buildings, such as hospitals, offices, industrial complexes and data centers. Loads within a microgrid remain connected to the utility "macro" grid when practical. However, generation and storage located within the microgrid can: a) generate power to serve loads locally which reduces reliance on the macro grid, b) provide power to the macro grid or c) allow for continuous operation within the microgrid during macro grid outages.

2.7 Grid Modernization and Integrating Distributed Renewables

The DPU began a Grid Modernization investigation in 2014 with the goal to ensure that the grid is reliable, efficient, clean, and can empower more customer engagement to manage and reduce their energy costs.⁸¹ The expansive Grid Modernization effort currently underway will enable the electric power system to incorporate larger amounts of distributed, clean energy resources. The Department of Public Utilities has required each utility to develop and implement a 10-year grid modernization plan.

⁷⁸ Overview of Emergency Generation in ISO-NE Administered Markets, EPA and New England State Environmental Regulators, March 2013

⁷⁹ Global Residential Stationary Generator Market 2015-2019, Technavio, 11 November, 2015

⁸⁰ GTM Microgrid Research, 2014

⁸¹ D.P.U 12-76-B, Investigation by the Department of Public Utilities on its own Motion into Modernization of the Electric Grid, June 12, 2014; <http://www.mass.gov/eea/docs/dpu/orders/dpu-12-76-b-order-6-12-2014.pdf>.

In their Grid Modernization Plans (GMPs), the utilities cite storage as a key strategic asset for the future of grid modernization enabling:

- increased distributed energy resources (DER) hosting capacity with improved reliability and power quality
- customer optimization of time varying rates (TVR)
- distribution system planning and operational improvement, and
- vehicle-to-grid (V2G) demonstrations.

Integrating storage into the distribution network could help increase DER growth while reducing costs. Distributed solar generation has grown significantly in recent years within Massachusetts. Over the last several years, Massachusetts has been one of the top states for installing solar PV capacity in the country, ranking 4th in the nation in 2014. Last year was no exception in growth, as the Commonwealth saw more than 15,000 projects completed in 2015 with approximately 45,000 projects overall and approximately 1,100 MW direct current of cumulative capacity. This accounts for a rate of approximately 400 projects per week. Figure 2-20 shows the annual and cumulative solar installations in Massachusetts since 2008.

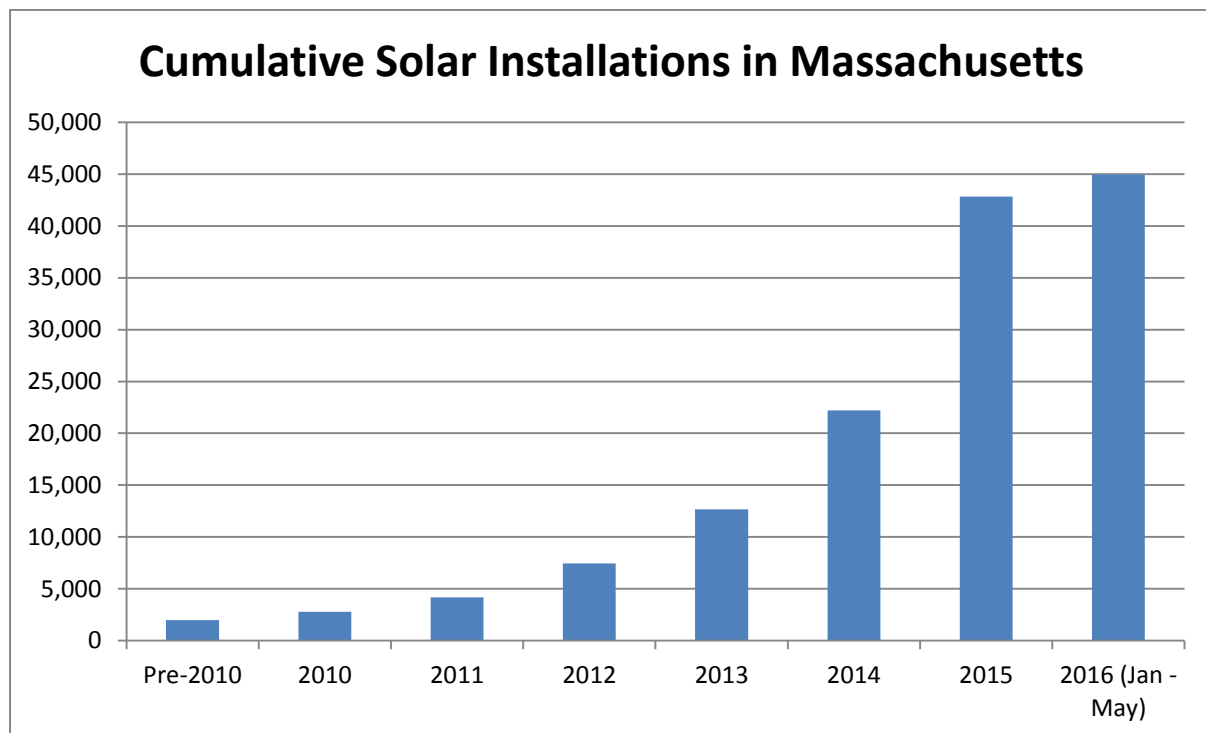


Figure 2-20: Massachusetts Installed Solar Capacity 2008-2016⁸²

As solar has grown, utilities have cited an increase in feeder lines that have reached capacity due to a risk of reverse power flow. Historically the power flow has moved in a single direction: from the large power plants to the customer. With new distributed generation, power may now flow in the opposite direction than planned. When the number of distributed generation systems, such as solar PV, on one feeder generates more energy than the feeder's customers' demand, there is a risk that the generated power has to flow on the feeder back to the substation or "back feed", as shown in

⁸² Massachusetts Department of Energy Resources, "Massachusetts Energy Dashboard;" <http://www.mass.gov/eea/energy-utilities-clean-tech/energy-dashboard/>

Figure 2-21. Due to the single direction transformers installed at these substations, reverse power flow can create serious reliability issues for the utilities.

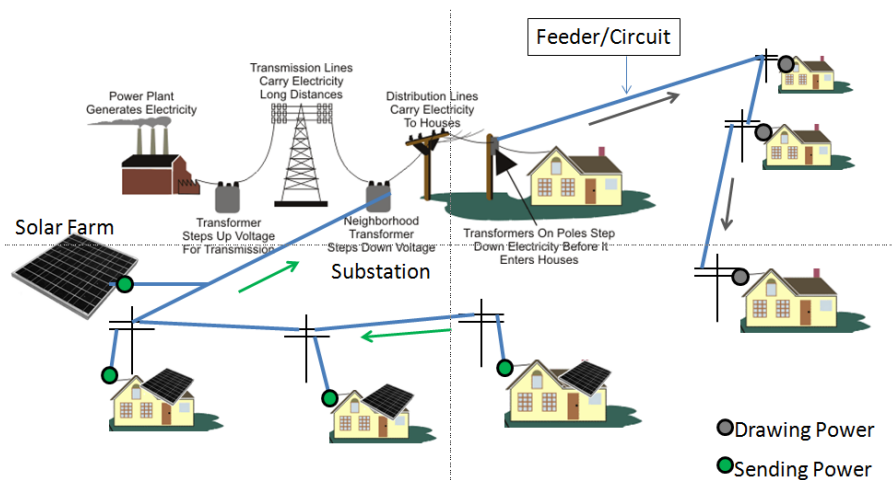


Figure 2-21: Integrating Distributed Renewables: A schematic of electrical transmission to distribution.⁸³

Therefore, before a solar PV project can interconnect to the grid, the utilities evaluate whether the added solar PV system will exceed the feeder's capacity. If there will be too much generation at any time, the utilities will not allow the interconnection until the customer pays for the cost of a new transformer at the feeder's substation. These new transformers can cost up to \$4 million, as shown in

Figure 2-22 below.

Distribution Feeder		
• Regulator	\$60-200K	2-6 mos.
• Cap move	\$3-10K	1-3 mos.
• New Capacitor	\$17-25K	1-6 mos.
• Re-conductor	\$200-400k/mi	6-12 mos.
• Express Feeder	\$350-600k/mi	8-18 mos.
Transformer		
• Line Xfrmr	\$2-25K	1-3 mos.
• Substation Xfrmr	\$2-4 million	18-24 mos.

Figure 2-22: Typical Costs and Schedules for Distribution Upgrades⁸⁴

Storage can be used to avoid these costs by preventing the risk of reverse power flow and avoiding the cost of the transformer upgrade. Excess generation is either stored at the customer site instead of flowing to the substation or stored at the substation in storage equipment added to the substation. In addition to avoiding these costs, storage can increase the solar PV that can be hosted on any one feeder.

Storage systems can also ensure reliability and DER integration by addressing voltage dips or spikes caused by renewable power production or reduce the magnitude of power swings due to cloud

⁸³ Graphic Source: US Energy Information Administration

⁸⁴ 2016 DG Interconnection Workshop (National Grid); https://www9.nationalgridus.com/non_html/MA_DG_Seminar.pdf

cover for solar PV. By managing these renewable energy challenges, utilities can improve power quality and reliability, which would otherwise be impacted by a PV installation.

Each of the three IOUs in Massachusetts considered energy storage in their GMPs submitted in 2015.⁸⁵ National Grid's Grid Modernization Plan includes a Research & Development proposal to address the complexities of integrating variable renewable generation sources with the existing electric grid. The objective will be to advance learning on the use of energy storage as a distributed resource, and potentially enable the benefits of energy storage for customers and the distribution system going forward. Examples include: large energy consumer benefits through demand charge management and grid benefits by supporting grid stability. The Distributed Energy Storage proposal would analyze utility-sized battery storage used to complement renewable generation and improve power quality. Eversource has proposed a distribution-level Solar Plus Storage project to address the integration of 20 to 45 MW solar PV capacity in New Bedford. This substation project with 15-30 minute duration would integrate the solar PV variable generation into the urban area, providing reliability and increasing the possible solar PV capacity.⁸⁶ Unitil proposed an Energy Storage Pilot Program in the R&D section of its Grid Modernization Plan. Through this program, Unitil will partner with energy storage vendors to investigate residential, commercial, and utility applications to increase reliability and distributed energy resource integration.⁸⁷

The DPU has recently approved National Grid's plan to include advanced inverters and battery storage to more efficiently integrate solar resources as part of their Phase II solar procurement as allowed by the Green Communities Act of 2008.^{88;89} National Grid plans to install between five and twenty 100 kW Tesla "Gen II" storage units (Li-ion) adjacent to an existing 1.02 MW ground based solar array in Shirley, MA, as part of its Solar Phase II program. National Grid will leverage the storage to provide ramping services, VAR support, and load shifting capability among other benefits. National Grid will leverage the federal energy investment tax credit to help finance the project, which requires the batteries be charged a minimum of 75% from the solar.

In January 2016, the United States Department of Energy (U.S. DOE) announced a SHINES award to fund an energy storage project in the National Grid service territory.⁹⁰ National Grid is a partner with Fraunhofer USA Center for Sustainable Energy Systems and EnerNOC. The partner team proposed a one year demonstration of a highly scalable integrated PV, storage, and facility load-management solution for larger-scale (~1 MW) PV systems on utility feeders in select towns (location to be determined), with a goal to engage in dispatch, participate in multiple energy markets, meet efficiency and cost reductions, and integrate solar.

2.7.1 Aggregating Demand Response

Distributed storage system can be aggregated operationally and utilized as a larger storage installation. Megawatt-scale distributed demand response and energy storage is currently being

⁸⁵ D.P.U. 15-120, D.P.U. 15-121, D.P.U. 15-122, D.P.U. 15-123.

⁸⁶ DPU 15-122, Eversource Grid Modernization Plan, August 19, 2015; pg. 56.

⁸⁷ DPU 15-121, Fitchburg Gas and Electric Light Company (d/b/a/Unitil) Grid Modernization Plan, August 19, 2015; pg. 84.

⁸⁸ DPU 12-134, ORDER. By Chairman O'Connor, Commissioners Westbrook and Hayden, May 2, 2016; pg 4

⁸⁹ Section 1A of Chapter 164, subsection (f) provides for an exception from the prohibition of distribution companies directly owning, operating or controlling generation facilities (per subsection (b)(1) of the same Section) to allow an electric company to construct, own and operate facilities that produce solar energy, subject to a maximum aggregate quantity of 25 MW of such facilities, subject to Department of Public Utilities approval of cost recovery prior to June 30, 2014 and construction prior to June 30, 2016.

⁹⁰ USDOE, Energy Department Announces \$18 million to Develop Solar Energy Storage Solutions, Boost Grid Resiliency, January 19, 2016; <http://energy.gov/articles/energy-department-announces-18-million-develop-solar-energy-storage-solutions-boost-grid-0>

tested in several states including California. The Demand Response Auction Mechanism, introduced by the California Public Utilities Commission, offers resources for an opportunity to bid as aggregated units of at least 100 kilowatts in size. If awarded, these new resources would be dispatched as an alternative to large, centrally controlled power plants. The program received a substantial amount of interest and attracted everything from smart thermostats and EV chargers to behind-the-meter batteries and commercial-industrial load control.

2.7.2 Community Energy Storage

Community Energy Storage (CES) is a concept that was developed by American Electric Power Corporation – a large U.S. electric utility – as a unifying theme for small battery systems. CES installations normally are located near residential customers, are rated at a few tens of kW, and have 2 to 3 hours of discharge duration. CES also includes state-of-the-art communications and controls. CES provides several benefits, especially for electric supply (energy and capacity), T&D deferral, and increased reliability and distributed renewable energy generation integration.



Figure 2-23: Community energy storage as utility infrastructure⁹¹

National Grid has proposed a Community Energy Storage project as part of its Grid Modernization Plan. The High Density Community Energy Storage proposal would analyze the technical and operational aspects of installation and integration of distributed energy storage and would explore benefits of distributed energy storage in areas with a considerable number of distributed small solar installations. Both approaches would use diverse charging/discharging algorithms/strategies that could be used for capacity relief, improvement of asset utilization, participation in the ancillary services market (as a block), reduction of renewables' interconnection costs and improved system operations.

2.8 Customer-Level Energy Storage in Massachusetts

Massachusetts has the 6th most expensive electricity rates in the U.S. which is 44.3% higher than the average U.S. electricity rates.⁹² High rates are particularly felt by low income residents, as well as commercial and industrial customers. While energy storage deployed anywhere on the grid can actually benefit all ratepayers (through the aforementioned system benefits), it also has significant benefits to individual customers when deployed at the customer-level. Deploying customer-sited renewable energy with energy storage has the potential to increase the available options for electric

⁹¹ Source: American Electric Power

⁹² US Energy Information Administration, Oct 2015; <https://www.eia.gov/state/rankings>

power customers and third party providers to manage energy costs in a more sustainable way. The value proposition of storage depends on capturing revenue streams related to energy arbitrage, demand charge mitigation, ISO market participation, and resiliency – and each value can be site-specific.

2.8.1 Reducing Customer Demand Charges

Energy storage technologies provide an opportunity for potentially significant savings by helping a customer to manage their peak demand. Serving the load during a peak period is more costly than during off peak periods. Utilities, therefore assign a demand charge to customers based on how much peak electricity a customer uses to reflect this premium. Reducing the customer's load factor can aid in decreasing this demand charge. The load factor is a ratio of a customer's actual usage in a defined period relative to their peak demand over that same period, and it provides an indication of whether the customer's usage is relatively level (high load factor) or peaky (low load factor). Typical load factors for commercial consumers range from the high 30% to mid 40% range depending on the nature of the business. Modest improvements in load factor can result in significant cost savings depending on the level of the demand charges.⁹³

Storage technologies can facilitate load factor improvement by providing stored energy during periods of highest use thereby lowering the registered peak demand during the period. The source of the stored energy can then be stored at periods of otherwise lower consumption. Figure 2-24 shows two illustrative C&I daily demand profiles. For example, the green customer may face significant demand charges as their daily peak occurs coincident to during the ISO-NE peak. This customer could utilize storage to charge at night and dispatch that energy during the peak to reduce their demand charges. The effect will be an overall leveling of the load across the billing period, a load factor improvement.

⁹³ Demand Charges generally constitute about 40% of a C&I customers electricity bill.

STATE OF CHARGE

Massachusetts Energy Storage Initiative Study

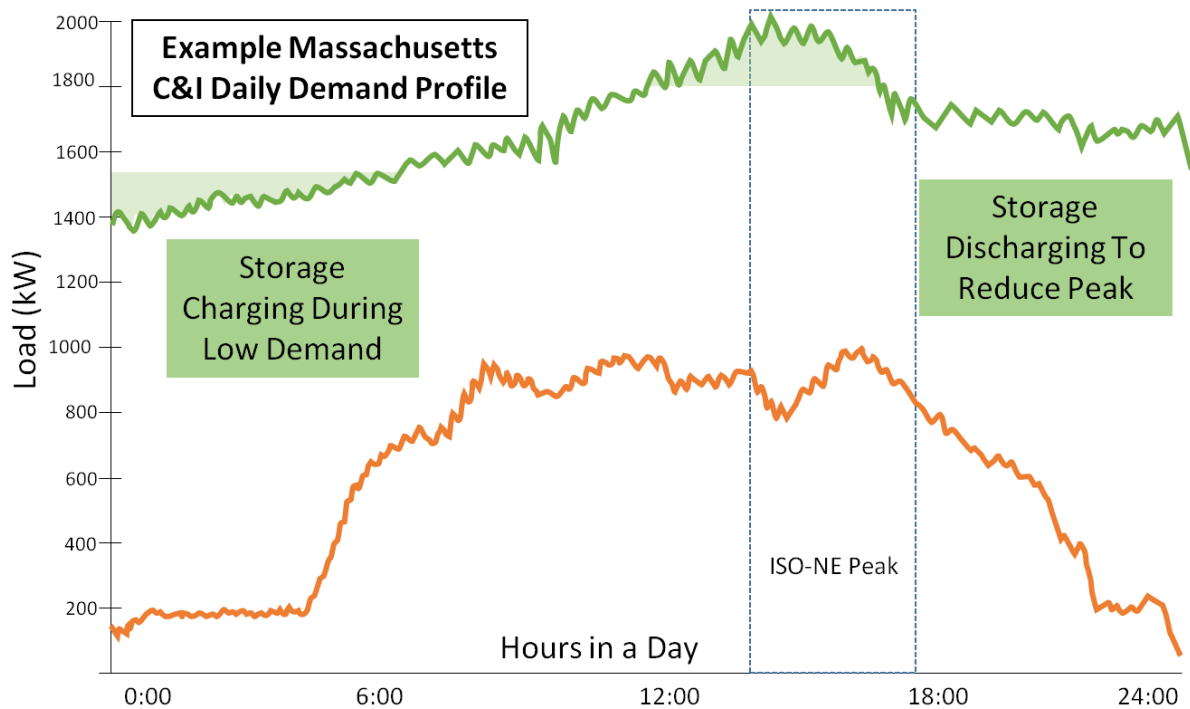


Figure 2-24: Example Customer Load Profile

Peak demand management is generally available only to non-residential customer classes as these classes routinely have a demand component in their tariff rate structures. Demand charges for utilities in Massachusetts (taken from each utility's respective tariff as of November 2015) are listed in the table below:

Utility / Demand \$/kW	Commercial (non-summer / summer)	Industrial (non-summer / summer)
National Grid	\$6.00	\$3.92
Eversource NStar	\$17.37 / \$41.25	\$19.15 / \$25.12
Eversource WMECO	\$13.36	\$10.74
Unitil	\$9.58	\$7.88

Table 2-1: Demand charges by utilities in Massachusetts as of July 2016⁹⁴

In the example illustrated in Figure 2-25 and Figure 2-26 below, we have assumed that a 200 kW/200 kWh lithium ion battery system was used for demand charge reduction at a commercial facility. The maximum peak demand of the facility was 500 kW in summer and is assumed to be billed on the G-3 rate plan⁹⁵ by National Grid.

⁹⁴ The disparity between the above demand charges for the Eversource companies as compared to National Grid and Unitil is that National Grid and Unitil both have per kWh charges in their rate structure for transmission service cost recovery while the Eversource companies recover transmission costs through an additional demand-based charge

⁹⁵ Source Load Data: [California Commercial End Use Survey Reports; 8,760 hourly data of the 500 kW Load Profile was obtained from the ESVT model ver 4.0, the demand reduction was modeled using EnergyToolBase.](#)
Source Billing Rates: https://www9.nationalgridus.com/masselectric/business/rates/4_tou.asp

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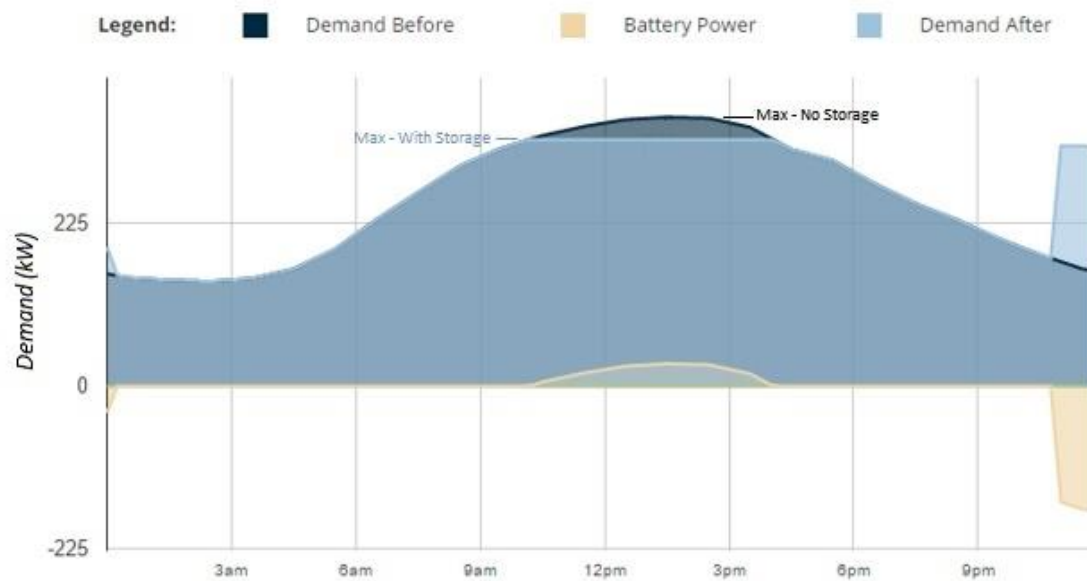


Figure 2-25: Illustrative Example of Potential of Storage for Peak Demand Reduction

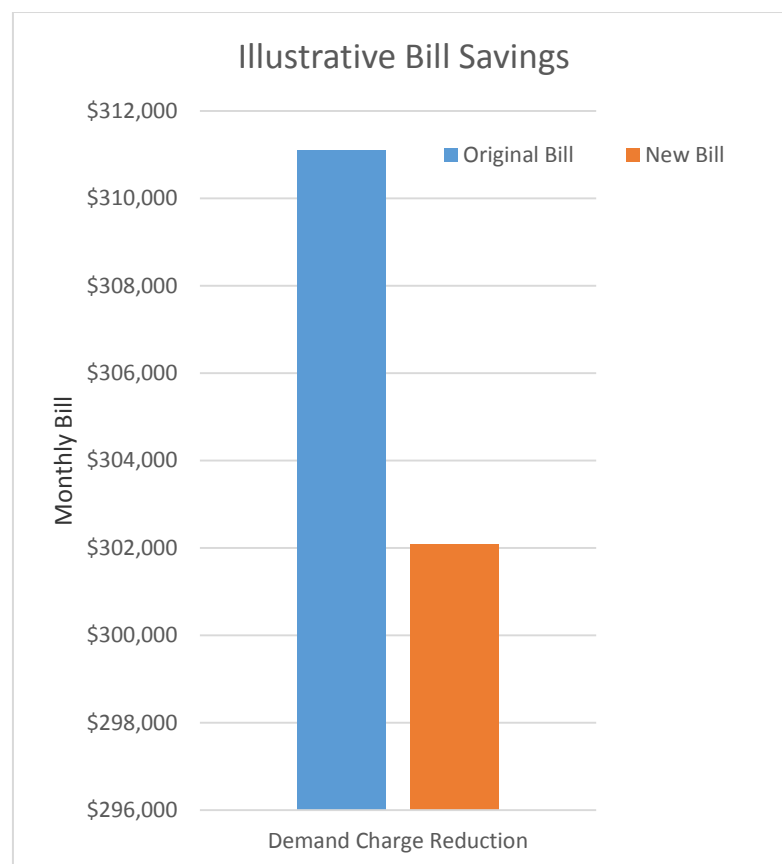


Figure 2-26: Illustrative Energy Bill Savings

As shown in Figure 2-26, the energy storage system enabled a 30kW peak demand reduction and thus could provide a savings of \$4,085 per year by reducing peak demand charges. On other utility rate structures such as Eversource and Unitil, industrial and commercial customers can achieve far

greater demand charge reductions since the \$/kW demand charges are higher in those utility rate structures.

2.8.2 Assisting Combined Heat and Power Systems to Meet Objectives

Storage can also be used to increase the efficiency of Combined Heat and Power (CHP) systems. CHP can achieve both fuel savings and GHG reductions by virtue of the ability to generate both useful thermal energy and electricity. Similar to other fossil fuel electricity generators, CHP systems must vary their energy output to match the real time changes in the energy demand. The addition of energy storage could level demand, allowing the CHP system to operate at their optimal, and most efficient, output.

Storage therefore helps CHP meet its projected economic and environmental performance. A CHP system with storage can be sized to match average demand, instead of installing an oversized system to meet peak. Smaller CHP systems are also more able to meet air permit emission limits. Air pollution control systems are designed to operate within specific ranges. For larger systems, the emissions will increase as efficiency decreased, until they reach a point at which the CHP system has to be shut down in order to remain in compliance with the air permit. Energy storage allows the CHP system to be operated within air emission standards for more hours.

With storage, CHP systems can more effectively meet resiliency objectives. Natural gas fueled CHP systems can operate during electricity grid outages as long as there are no natural gas distribution outages. However, some CHP system resiliency can be diminished if the system cannot respond quickly enough to changes in the facility demand during an outage. If they are unable to maintain output within prescribed parameters, such as over- or under- voltage, frequency or phase, the system may have to enter a safety shutdown. Energy storage systems will eliminate or greatly minimize this problem while the system is operating in the “islanding” resilient mode and thereby substantially increase the energy resiliency of the supported facility.

2.8.3 Net-Metering: Solar Plus Storage

Behind-the-meter storage systems can preserve the full value of all the solar generation regardless of net-metering policies. With net-metering, solar PV customers use the grid as a pseudo-storage system, where they sell energy during times of excess generation and from where they pull energy during times of need.

As distributed solar costs have decreased and the rate of residential installations has boomed, many states are reviewing their retail-rate net metering policies. Instead of allowing solar facilities to sell excess solar generation back to the utilities at the full retail rate, many states, including Nevada, Maine, and California, are investigating alternative incentive structures that reduce the value of the net-metering credit. Hawaii, the state with the greatest percent of solar capacity per capita,⁹⁶ ceased retail-rate net metering and now offers two new tariffs: (1) a grid supply rate which is approximately half the former retail rate and (2) a self-supply rate which credits a solar customer the retail rate only when their solar system is generating.⁹⁷ On April 11th, 2016 Governor Charlie Baker

⁹⁶ Environment America, Lighting the Way: The Top States that Helped Drive America’s Solar Energy Boom in 2014; <http://www.environmentamerica.org/reports/ame/lighting-way-0>

⁹⁷ Herman K. Trabish, The day after: How solar can thrive in the post-net metering era. UtilityDive, November 3, 2015. <http://www.utilitydive.com/news/the-day-after-how-solar-can-thrive-in-the-post-net-metering-era/408357/>

signed legislation that expanded net-metering caps but lowered the net-metering credit rate for private net-metering facilities in Massachusetts to approximately 60% of the retail rate.

Under both of these new tariff structures, behind-the-meter solar becomes less valuable to the customer. With the addition of a paired behind-the-meter storage system, a customer can preserve their system's financial benefit. A home storage system will store excess generation on site and allow the customer to avoid retail-rate electricity purchases later when their PV system is not generating. This preserves the full retail rate value to all the energy the PV system is generating regardless of when the energy is used. No matter what net-metering policy is in place, the PV customer gets the full value of their system.

2.9 Conclusion

Energy storage is a unique technology with far reaching applications at the generation, transmission, and distribution level. The flexibility these technologies offer allow them to be sited in many locations and utilized by all energy system participants. Therefore, the benefits of using storage can be attributed both to the system as a whole and to specific parties participating in the energy markets.

In subsequent chapters, we will evaluate whether energy storage is a viable and cost-effective resource to help meet the challenges identified in this chapter. The following work will focus on different types of storage applications and how their value can be realized. We will also identify barriers that may be hindering energy storage development in the state and formulate recommendations on how to address them.

3 Energy Storage Stakeholder Perspectives

3.1 Introduction

The development of effective public policy requires active and meaningful contributions from the affected stakeholders. To help inform the Massachusetts' Energy Storage Initiative, the Study Team actively solicited stakeholder opinions and suggestions over the course of the investigation. The diversity of stakeholders resulting in different perspectives, expectations and suggested actions. This chapter presents the perspective of each stakeholder segment.

Workshops, surveys and outreach provided insight on stakeholder perspectives regarding key market drivers and barriers, as well as potential solutions that could lead to increased market adoption. The purpose of this chapter is to summarize that input, identify consensus and non-consensus perspectives, identify issues and barriers (particularly those amenable to policymaker influence) and highlight unresolved issues and barriers that hinder energy storage adoption in Massachusetts.

3.1.1 Overview of Key Stakeholders and Input Process

Energy storage stakeholders expressing interest in Massachusetts are at different stages of the deployment process. Some are just beginning to evaluate the potential for storage in their businesses or operations, while others are actively building and operating projects. Stakeholder groups engaged in this input process encompassed the full spectrum of the electricity value chain, including: ISO-NE; IOUs and Municipal Light Plant utilities (MLPs) concerned with the distribution grid and its operation; independent power producers operating in the wholesale market; renewable energy and distributed generation developers/operators; competitive suppliers operating at the retail level; and, of course, the electricity consumer and ratepayer. Energy storage technology developers and system integrators represent another important stakeholder group, some of whom are at the early stages of technology development while others are well advanced in offering proven commercial products.

At the outset of this study, a concerted effort was made to inform energy storage stakeholders across the country and in the ISO-NE region of the study, and to solicit their active participation in an initial stakeholder workshop that was held on October 30th, 2015 in Boston. More than 300 organizations were contacted (~400 individuals), and over 150 people attended the full-day workshop.

The October 30th workshop was structured into stakeholder breakout sessions focused on identifying high level needs and challenges for energy storage deployment in Massachusetts, as well as suggested solutions. The breakout sessions addressed sub-markets in the electrical grid likely to be served by energy storage applications: 1) Wholesale Markets/Transmission; 2) Utility Applications – Distribution; and 3) Behind-the-Meter/Distributed Energy Resources (DER). A fourth breakout session was dedicated to Energy Storage Technology Developers, with the understanding that members of this group (including university researchers) may have technologies that may be too early in their development to associate with a particular market and have resource needs and concerns distinctly different from those participating in the other breakout sessions.

Following the workshop, summaries for each of the four breakout sessions were posted publicly,⁹⁸ with a request for feedback and further stakeholder input. Subsequently, the Study Team conducted more detailed follow-up with certain organizations and individuals via surveys (40 responses), small group webinar sessions and one-on-one interviews (36 interviews). In addition, the team held an Energy Stakeholder Update Webinar on December 15th to present progress to date, and to solicit further feedback (140 registrants, ~100 attendees).⁹⁹ On March 1, 2016 a final survey was distributed to the full list of stakeholders to seek their priorities among issues or barriers identified in the process, as well as their input regarding Massachusetts policymaker ability or level of effort, required to influence change.

Finally, at the completion of the investigation, selected stakeholders were asked to provide final review and feedback, in order to address any potentially significant omissions or misrepresentation of stakeholder perspectives and suggestions.

3.1.2 High Level Findings (Barriers and Solutions)

An overwhelming proportion of stakeholders are optimistic about the future of grid-connected energy storage in Massachusetts. Utilities and Distributed Energy Resource developers cite renewables growth, technology advances, and technology cost decreases as ways energy storage will shape the grid both near-term and long-term.

"Given the recent advances in energy storage technology and cost-effectiveness, it is hard to imagine a modern electric distribution system that does not include energy storage." - Eversource, Grid Modernization Plan 2015-08-19, p56

While recognizing the potential of energy storage, stakeholders mentioned numerous issues and barriers that are preventing widespread deployment in the Commonwealth. The issues fall into four categories: policy issues, resource planning reform, value proposition, and deployment. Most of the presented policy issues can be addressed within the scope of the Energy Storage Initiative and related initiatives in Massachusetts. Resource planning reforms are issues related to transmission and distribution planning processes by ISO-NE and the distribution utilities to ensure that energy storage is sufficiently valued and considered for grid reliability purposes. Energy storage value realization issues address the challenges and uncertainty in the valuation of the range of capabilities and benefits of energy storage technologies. This uncertainty in turn then limits the financeability and optimal siting and operation of energy storage. Finally, energy storage deployment priorities discuss issues regarding the costs and processes of deploying and connecting energy storage systems onto the grid, as well as challenges faced by technology developers in bringing new technologies to market.

3.1.3 Ranking Stakeholder Priorities

As noted earlier, a survey was conducted in March 2016 to complete the 'ranking' of the priorities that resulted from the Energy Storage Workshop on October 30th, 2015 and to gain a better understanding of the perceived level of difficulty addressing the issues identified.

⁹⁸ As of the publication of this report, breakout session summaries may be accessed at the Mass.gov Energy Storage Initiatives (ESI) website: <http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/>

⁹⁹ The presentation from the Update Webinar may also be accessed at the ESI website previously noted.

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The survey was submitted to 300 people, and 129 stakeholders responded and self-identified their sector (more than one could be selected). The breakdown of respondents is shown in Table 3-1.













Energy Storage Technology Provider	27.2%
Distributed Energy Resource Developer - Renewables	27.2%
Microgrid Developer	15.2%
DER Platform Provider	12.8%
Research Organization	12.8%
Consulting Firm	12.8%
Distributed Energy Resource Developer - CHP	8.8%
Utility (publicly-owned)	8.8%
Investor/Financier	8.8%
Energy Storage Supply Chain	8.0%
Competitive Energy Supplier	8.0%
IPP	8.0%
NGO	8.0%
Utility (investor-owned)	6.4%
Distributed Energy Resource Developer - Fuel Cell Developer	5.6%
Power Supply Aggregator/Community Aggregator	4.8%
Government	4.8%
Industry Organization	3.2%
End User	2.4%
Law Firm	2.4%

Table 3-1: Breakdown of survey respondents

Those surveyed were first asked to rate a series of priorities and identify any other priorities not listed. Responses are summarized in Table 3-2.

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Stakeholder Priorities (Ranked from Highest to Lowest)		Breakdown of Importance
		<div>High</div> <div>Medium</div> <div>Low</div>
A	Allow Energy Storage to Capture Multiple Revenue Streams	
B	Allow Distributed Generators to Support System Capacity Needs	
C	Financeability and Cost	
D	Incentivize Non-Wires Alternatives	
E	Pilot Programs to Demonstrate New Business Models	
F	Streamline Interconnection Review Process	
G	Identify, Value, and Increase Data Availability on Locational Benefits and Constraints	
H	Address Value Proposition for Renewable Integration	
I	Coordination and Clarity on Net Energy Metering (NEM) and Renewable Portfolio Standards (RPS)	
J	Coordination of Energy Storage Initiatives Between ISO-NE States	
K	Increase Availability of and Improve Access to Advanced Metering and Customer Data	
L	Resolve ISO-NE Load Reconstitution Issue	

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M	Adopt a Definition for Energy Storage	
N	Clarify and Develop Safety Codes and Standards	
O	Enable the Prosumer Model	
P	Testing Facilities for New Technologies and Applications	

Table 3-2: Stakeholder Priorities from Final Survey

3.2 Stakeholder Feedback

3.2.1 Definition and Classification for Energy Storage

One of the priority actions identified by utility stakeholders during the October 2015 workshop and follow-up utility interviews was for a framework for the classification of energy storage. Though an important foundational element of a comprehensive energy storage strategy, as the survey results in Table 3-2 shows, defining energy storage may fall behind other issues in terms of priority. Regulatory and legislative ambiguity of storage as an asset class may present uncertainty or prevent utilities from being able to properly model and value storage within their systems. A potential solution would be to adopt a consensus definition of storage for the state.

3.2.2 ISO-NE Market Rule Clarity

As part of the question on seeking a definition or classification for storage, utility and non-utility stakeholders have requested more clarity on the ISO-NE rules for energy storage. This call for clarity is aimed at helping market participants understand whether storage can be classified as a generation and/or transmission asset, what wholesale market products storage can provide, and what the associated performance requirements would be depending on its classification. The ISO-NE's recently released paper on "How Energy Storage Can Participate in New England's Wholesale Electricity Market"¹⁰⁰ started addressing these questions. ISO-NE generally describes energy storage as non-intermittent resource(s) that are "unique because many of these technologies operate both as a supply resource and a load resource."¹⁰¹ Due to the complexities of the Market Rule tariffs, the type of registration and market participation of an energy storage resource will determine the compensation and treatment of the resources in the wholesale market. The current view of energy storage in ISO-NE was developed to accommodate hydro pumped storage in Northwest

¹⁰⁰ ISO-NE, How Energy Storage Can Participate in New England's Wholesale Electricity Market, January 2016; http://www.iso-ne.com/static-assets/documents/2016/01/final_storage_letter_cover_paper.pdf

¹⁰¹ Ibid

Massachusetts, which was built in the 1970's to provide approximately 2,000 MW of capacity within a 10-minute timeframe in the event of a nuclear plant trip. Rules accommodating pumped storage – the dominant historical storage technology – are seen as insufficient to support deployment of more diverse advanced storage technologies now entering the marketplace. The evolution and diversity of energy storage technologies, applications, and grid locations has gone well beyond the limits of traditional pumped hydro storage.

3.2.3 Coordination of Energy Storage Regulatory Initiatives

Massachusetts is a national leader in terms of clean energy goals. Stakeholders, however, commented that legislative energy policy goals are often conflicting. Coordination across regulatory proceedings within Massachusetts, as well as across the region, was identified by the distributed generators and project developers as a key priority to streamline market development. Specifically, coordination between the ESI and Grid Modernization Proceedings was highlighted as one such opportunity.

Utilities stressed the importance of legislature and Department of Public Utilities having clear and well-defined rules around utility ownership of storage assets to ensure market certainty. In August, 2016, the Commonwealth passed bill, H. 4568., clarifying that energy storage “may be owned by an electric distribution company” and further appointed DOER to determine a procurement target, if appropriate, for electric companies to procure “viable and cost-effective energy storage systems” by January 1, 2020.

Some utility stakeholders also thought that the implementation of the Massachusetts utility-filed GMPs is an important solution to mitigate barriers for energy storage implementation. The ability to provide the greatest value for customers while funding storage technologies will rely on the accuracy and locational granularity of data associated with the application. This is a challenge for utilities since granular operating information is not currently available throughout the system. Today, detailed information is primarily derived from substation feeder monitors, while little, if any, detailed information is available on the side of the feeders where DG and energy storage will likely be installed as a customer-side resource.¹⁰² For the IOUs, the automation imposed in some GMPs¹⁰³ will provide the granular locational data needed to conduct an accurate analysis of value derived from customer-side resources, and until such granular data is available, it will be difficult to get to this value.

3.2.4 Net Energy Metering (NEM) and Renewable Portfolio Standard (RPS) Solar Policy

While many stakeholders expressed uncertainty about the net-metering and solar policy at the time of stakeholder workshops, much of that uncertainty has clarified since the passage of An Act Relative to Solar Energy in April 2016. Additional clarity about the interaction between storage and new solar policy is discussed as part of Chapter 7 recommendations.

3.2.5 Storage as a Non-Wires Alternatives

DG, wholesale market, and utility stakeholders commented on the lack of incentives for non-wires alternatives (NWA) such as energy storage to be considered in transmission and distribution (T&D) system planning processes that address grid reliability and efficiency. As costs of energy storage systems have come down, energy storage has the potential to compete with traditional “wires”

¹⁰² Utility Stakeholder Phone interview and email follow-up with EPRI on 2015-12-14

¹⁰³ Grid Modernization Plans: <http://www.mass.gov/eea/energy-utilities-clean-tech/electric-power/grid-mod/grid-modernization.html>

solutions to defer or replace the need for specific costlier transmission projects. Energy storage developers highlighted that NWAs such as energy storage often have the additional benefits of: avoiding infrastructure siting concerns of traditional solutions; being deployed and installed on a relatively quicker timeline; having the flexibility to be developed incrementally and developed using existing infrastructure (e.g., co-locating with existing electrical infrastructure); and providing reliability advantages by siting NWAs in diverse geographic locations (See Sidebar below).

Currently in Massachusetts, utilities are not incentivized to propose NWA solutions for distribution planning. Stakeholders indicated that utilities generally prefer to submit their traditional wires solutions because there is no established cost allocation methodology or financing source for NWAs. Traditional wires solutions are usually defined as “transmission assets” that have costs recovered and allocated according to the applicable FERC jurisdictional tariff. By contrast, such cost recovery and allocation methodologies are not available for NWAs that are not defined as “transmission assets.” As a result, developers are unlikely to propose NWAs through financing from their customers alone. With partial rate recovery or some market-based compensation mechanism for energy storage (or distributed energy resources generally) that provide reliability, NWAs would likely be proposed as reliability solutions on a more regular basis.

Furthermore, several stakeholders highlighted that comprehensive and granular modeling is needed to accurately validate the total resource cost of NWAs like energy storage systems. Modeling limitations include the lack of temporal or locational granularity data and the exclusion of certain key benefits such as locational and lower emissions value of NWAs in estimating the benefits of different solutions. Also, resources like energy storage are often modeled as providing a single service rather than the multitude of services they are capable of delivering. System planners have typically shied away from NWAs due to concerns about operational certainty for cross-jurisdictional resources that provide both wholesale and retail services, and due to concerns about whether NWAs can deliver on their promise to provide grid services as needed. Advanced stochastic modeling in the T&D system planning process is needed for a comprehensive and transparent evaluation of traditional wires solutions versus NWAs.

3.2.6 Allow Distributed Generators to Support System Capacity Needs

Distributed generators identified a gap in market rules preventing aggregated energy storage from participating in system capacity markets or otherwise realizing the full capacity benefits they provide to the system. Stakeholders posited that the time is right to explore whether and how aggregated distributed energy storage (either load modifying or supply side) could provide grid service to secure this important value stream in Massachusetts.

“Distributed energy storage has the potential to redefine the nature of the electric power grid. Today, the grid is characterized by the need to balance load and generation every second, primarily by dispatching generation.”

- Eversource, Grid Modernization Plan 2015-08-19, p56

Today, system capacity needs are largely met by traditional generation resources. Distributed generation, demand response (DR), and energy storage resources come in a variety of capacities, with on-site commercial, industrial, and residential systems often falling below the minimum MW threshold for wholesale market participation. If control and capacity of multiple resources are

combined into an aggregated resource, then that resource can potentially be large enough to participate in wholesale markets.

Drawing an analogy, ISO-NE's Demand Response Resource Aggregation Rules provide an excellent example of market rules that have created a vibrant demand response market, which allows participation of aggregated demand response resources. As written, the rules state that Demand Response Resources must be able to produce at least 100 kW of demand reduction and can be comprised of an aggregation of Demand Response Assets located within the same Dispatch Zone and Reserve Zone.¹⁰⁴ Each Demand Response Asset must be able to produce at least 10 kW of demand reduction either by itself or aggregated across multiple end use customers from multiple delivery points within a single Dispatch Zone and Reserve Zone. The results of these rules have been a strong DR marketplace (See Sidebar). Lessons from ISO-NE's demand response market can inform the aggregation rules for a broader set of resources to provide different grid services.

Sidebar: ISO-NE Demand Response Market

The amount of Demand Resource Assets as of February 1, 2016 totals approximately 2,737 MW. Of this amount, about 952 MW or 35% are in the three Massachusetts load zones.¹⁰⁵ The Active Demand Resource Asset enrolled MW as of February 1, 2016 is approximately 1,004 MW comprised of Transitional Price Responsive Demand, Real-time Demand Resource and Real-time Emergency Generation Resource. Passive demand resources are not included here as they are not dispatchable MW. Of the Active Demand Resource Asset enrolled MW, approximately 241 MW or 24% are in Massachusetts load and dispatch zones.

Distributed generators also requested guidance on an appropriate methodology for quantification of system benefits for DERs that improve the system load factor. In addition, a desire for clarity on storage participation as a demand response resource and the complexity of existing DR aggregation rules were also mentioned. These issues could be addressed through ISO-NE stakeholder engagement.

Competitive suppliers noted that energy storage could also play a role in improving overall system (utility level or even ISO-NE level) load factor, thereby lowering system capacity and transmission needs (and ideally costs). An individual customer may employ energy storage to manage their individual contribution to the system peak and thereby their capacity obligation. If large numbers of customers engage in this activity and effectively manage the system peak, material reductions to the overall system peak and reserve capacity needs could be realized. Wide scale deployment of energy storage resources operated in a coordinated manner to manage individual customer peak demands coincident with the system peak would likely yield improved reductions in system capacity needs. Further market development, however, would be necessary to realize this.

¹⁰⁴ ISO-NE, WEM 101: 13 – Demand Resources in New England Markets; http://www.iso-ne.com/static-assets/documents/2015/11/20151019_13_wem101_demand_resources.pdf

¹⁰⁵ Data Source: Demand Resource Working group presentation by the ISO Demand Resource Strategy Department – January 2016. The WCMA, NEMA & SEMA load zones were summed to represent Massachusetts. See <http://www.iso-ne.com/markets-operations/markets/demand-resources/>

Sidebar: FERC Order 745 Update

On January 25, 2016 the U.S. Supreme Court issued an order¹⁰⁶ reversing the DC Circuit Court of Appeals ruling in the case of *Federal Energy Regulatory Commission v. Electric Power Supply Association (EPSA)*. The DC Circuit Court ruled in favor of EPSA, finding that FERC lacked authority to issue Order 745 (Order 745 requires ISO/RTOs to pay DR for energy conservation the same rate as paid to generators for energy supply – i.e., “full LMP”) as it resulted in the FERC directly regulating the retail electricity market, while also holding that the Order’s full LMP compensation methodology is “arbitrary and capricious”.

The Supreme Court’s Order, however, found that:

- FERC does have the authority to regulate DR in the wholesale market
- FERC’s decision to pay DR the full LMP was not arbitrary and capricious

This ruling lifts the clouds of regulatory uncertainty that have plagued DR participants in ISO-NE’s markets over the past several years. It doesn’t, however, require the ISO to alter its currently approved tariff; instead, it permits the ISO to move forward with fully integrating DR into the energy and reserve markets starting on June 1, 2018. Note that DR can presently participate in ISO-NE’s capacity market and, on a limited basis, the energy market.

3.2.7 Load Reconstitution with Energy Storage

Stakeholders identified the ambiguity of the ISO-NE’s Load Reconstitution¹⁰⁷ rule/policy, as it relates to the ability to use energy storage (or other peak reduction methods) to reduce transmission related costs, as an issue for utilities competitive suppliers and MLP utilities alike. MLPs ranked Capacity and Transmission Payment Reduction as a high priority application that has one of the most substantial potential value streams for energy storage systems, but stakeholders noted that Load Reconstitution is a significant regulatory barrier for full monetization of this central MLP application.

The MLPs considered the lack of clarity around the treatment of load reconstitution for capacity and transmission payment calculations as a significant barrier for energy storage. Holyoke Gas and Electric (HG&E) points out that the definition of Regional Network Load (RNL) under *Section I: General Terms & Conditions of the ISO-NE Transmission, Markets & Services Tariff* (page 84) includes the following sentence:

“The Network Customer’s Regional Network Load shall include all load designated by the Network Customer (including losses) and shall not be credited or reduced for any behind-the-meter generation.”

This sentence would effectively require anything that is considered “behind-the-meter generation” to be reconstituted for the purposes of determining Transmission payments pursuant to the Open

¹⁰⁶ Federal Energy Regulatory Commission v. Electric Power Supply Association et al., No. 14–840 (U.S. January 25, 2016); http://www.supremecourt.gov/opinions/15pdf/14-840_k537.pdf

¹⁰⁷ Load reconstitution in this context refers to the process of adding to the sum of electricity that a customer consumed (i.e., “load”), that electricity which was NOT consumed as a result of the customer utilizing a generating resource located behind its electric meter – in this case, an energy storage device. With limited exception, this applies to load that was reduced through the operation of generation “in front of the meter” as well.

Access Transmission Tariff (OATT) (Section II of the Transmission, Markets & Services Tariff). Furthermore, “behind-the-meter generation” is not defined anywhere in the Transmission, Markets & Services Tariff (or by ISO-NE or FERC). According to HG&E’s experiences with reconstituted load, the definition of “behind-the-meter generation” is up to the regional transmission owners. For an MLP, the meter in question is one at the wholesale level as opposed to solely retail meters. In the event that the regional transmission owner does define an energy storage system as “behind the meter generation”, load reconstitution would effectively eliminate the ability of an installed energy storage system to reduce transmission payments.

Insight: Classifying DER’s to Enable Proper Market Participation

An ISO serves as the billing and collection agent responsible for recovering costs associated with the provision of regional network service (RNS) and other services to transmission customers. The Open Access Transmission Tariff (OATT) (Section II of the ISO tariff) governs the allocation of these costs. The ISO determines each Network Customer’s share of the monthly RNS cost based upon a ratio of the Network Customer’s¹⁰⁸ regional network load (RNL) at the time of the system’s monthly peak, to the sum of all Network Customers’ RNL at that same point in time. The more a Network Customer can lower its RNL at the monthly system peak, the more it can lower its allocation of RNS costs. This “avoided cost” is not, however, avoided; it is recovered by way of a commensurate increase to the cost allocations to other Network Customers. The ISO Tariff, however, prohibits the practice of lowering one’s RNL through the use of behind-the-meter generation, stating that RNL “shall include **all load** designated by the Network Customer (including losses) and **shall not be credited or reduced for any behind-the-meter generation.**”¹⁰⁹ The ISO supports this prohibition on the belief that all Network Customers should collectively pay for a system that would provide for the Network Customer’s entire energy needs in the event the generation, behind-the-meter or otherwise, is not available.¹¹⁰

While the ISO Tariff is explicit on its requirement that behind-the-meter generation be added back to the calculation of RNL (also known as load reconstitution), it is the Network Customer, not the ISO that calculates its own RNL values. Each transmission owner memorializes its customized methodology for calculating *Local* Network Load vis-à-vis its local network Schedule 21 of the ISO OATT.¹¹¹ It is here where there seems to be some area for interpretation. Whereas the ISO expects that transmission owners will provide *Regional* Network Load values inclusive of “all load” excluding behind-the-meter generation, transmission owner’s Schedule 21 defines the methodology for calculating *Local* Network Load. Local Network Load is a term that is defined separately in each of the transmission owner’s Schedule 21. As the Schedule 21s don’t refer to RNL, there is a disconnect in the tariff language which seems to create the opportunity for alternate approaches to complying with the ISO Tariff. In at least one instance a transmission owner has chosen to define under what

¹⁰⁸ Network Customer is a Transmission Customer receiving Regional Network Service or Local Network Service.

¹⁰⁹ ISO-NE, Section 1 – General Terms and Conditions; http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_1/sect_1.pdf

¹¹⁰ While the ISO’s Tariff language hasn’t been challenged at FERC, there are a number of cases where the FERC has supported a similar approach to that of the ISO, ruling that behind-the-meter generation should be subject to transmission service charges. See, e.g., <http://www.ferc.gov/CalendarFiles/20150601172527-ER15-710-002.pdf>

¹¹¹ Schedule 21 is a sub-component of ISO’s OATT and represents each individual transmission owner’s terms and conditions for its provision of local service.

conditions behind-the-meter generation can be used to lower Local Network Load¹¹² while in another instance a transmission owner explicitly prohibits the use of any behind-the-meter generation to be used to lower Local Network Load.¹¹³

Because “behind-the-meter generation” is not defined anywhere in the Transmission, Markets & Services Tariff (or by ISO-NE or FERC), HG&E suggests that a solution would be to receive a ruling or clarification from ISO-NE and/or the transmission owners that energy storage systems are not “behind-the-meter generation” assets.

3.2.8 Financeability and Cost

Every stakeholder group identified cost and financeability as a challenge for energy storage, but each group identified somewhat unique issues:

- **Utilities** identified ownership rules, business models, inability to capture multiple value streams, lack of clear valuation metrics, limited smart grid infrastructure, and modeling limitations as major challenges that directly impact a utility’s ability to ensure that storage benefits exceed costs.
- **Utility stakeholders** and **energy customers** identified the economics of energy storage and the difficulties with monetizing all the potential value streams storage can provide. These difficulties can limit potential storage applications. But, they believe the rapidly declining cost of storage will assist in enabling more applications.
- Other **energy customers** that participated noted the complexity of contracts and difficulty in understanding the value proposition as key hindrances to adopting storage. They recommended that the developers and technology providers simplify and better clarify their offerings and the customer’s eventual benefit.
- **Competitive suppliers** listed cost and ability to finance storage at the top of their list of barriers to wider scale adoption at the retail level. Stakeholders point to needing a better understanding and reliability of the value proposition and revenue streams in order to finance energy storage systems at reasonable rates. Otherwise, high financing costs make investments unjustifiable economically.
- **Distributed Generator & DER Provider/Developers** require better understanding of the value proposition and revenue streams in Massachusetts in order to finance projects at a reasonable cost of money (versus typical market rates) and pay risk-adjusted interest rates. The California Renewable Market Adjusting Tariff (Re-MAT), a feed-in tariff incentive program, was noted as a successful example of a market responsive incentive structure.¹¹⁴

¹¹² E.g., Green Mountain Power’s Schedule 21 language specifies that it will “treat as internal generation all behind-the-meter generation units with a capacity greater than or equal to 1 MW....” While instructing that “any such generation occurring at the time of the transmission peak will be added to the metered load of the Network Customer for purposes of calculating the Network Customer’s Local Network Load.” http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_2/sch21/sch_21_gmp.pdf

¹¹³ New England Power’s Schedule 21 defines Network Load as the “load interconnected (not reduced for any generation behind the meter) to the PTF, Non-PTF or Distribution Facilities of NEP or its New England Affiliates either directly or through Distribution Facilities or Non-PTF Facilities of other entities that a Network Customer designates to receive Local Network Service under Schedule 21 and this Schedule. http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_2/sch21/sch_21_nep.pdf

¹¹⁴ CPUC, Renewable Feed-In Tariff (FIT) Program, July 25, 2013; <http://www.cpuc.ca.gov/feedintariff/>

- **DER Providers/Developers** also cited that administrative costs of obtaining a loan for a project are the same regardless of the size of the project, making smaller projects more difficult for developers to build. They noted that while technology and market maturation will invariably lead to standardization and simplification of smaller projects, as well as streamlined financing and lower administration costs, support could be provided for small projects in the interim to ensure that C&I and residential market sectors are developed in tandem with utility and wholesale opportunities.
- **Energy System Manufacturers/Integrators** noted the lack of small project finance as a barrier, and highlighted the need for more investment in technology development. Another challenge is that creditworthiness of counterparties is often un-established due to the size of company and short time since inception, making financing difficult.
- **Technology developers**, unlike other stakeholders, do not perceive “financeability” as a barrier in terms of unfavorable tariffs, or inadequate or non-existent revenue streams or business model. They define it simply as the lack of funds to help bring a technology from R&D to market. They’re interested in mechanisms that can support the technology until it becomes attractive for a manufacturer to purchase it or license it, or accepted in a utility demonstration.

An overarching challenge identified by **all stakeholders** is the reliability and certainty of access to, and the magnitude of, both long and short term revenue streams. The constantly changing regulatory and policy landscape brings the bankability of value streams into question for financiers. Regulatory certainty would provide a long-term policy signal and lead to reduced risk and easier financing.

The Eversource utilities—at least for larger commercial and industrial customers—charge for transmission service based on the monthly peak demand, while smaller commercial and residential rates charge for this service based on kWh consumption (National Grid and Unitil use kWh consumption for the determinant for all customer classes). Energy storage could help to reduce transmission charges by shaving peak demand. Where the transmission charge is consumption (KWh) based, energy storage would not be beneficial for reducing transmission charges. The addition of storage might increase transmission charges in this case due the increased consumption for charging.

However, it is ambiguous whether demand management could be used to reduce transmission costs due to the ISO-NE policy of load. The tariff implies that load reductions—either intentional or unintentional—from behind-the-meter resources would be added back to determine the transmission charges for the network customer. Utility tariffs, however, state that the transmission charge is based on the monthly registered peak demand and do not specifically state that an adjustment will be made for behind-the-meter resources that offset what would have otherwise been the monthly peak.

Additional modeling is required to identify incompatibilities between revenue streams in Massachusetts and formulate recommendations on how to address them. This is further addressed in Chapters 5, 7 and 8.

3.2.9 Enable the Prosumer Model

Competitive suppliers expressed keen interest in allowing customers to participate as “prosumers” who act as both consumers and producers. The continued adoption of distributed generation

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(primarily rooftop solar) and advanced metering and monitoring technologies create the framework for an environment in which utility customers are no longer simply consumers of kWh. Instead, they may establish an interdependent relationship with the utility company in which at certain times of the day they are consuming kWh and at other times committed to provide power to the grid.

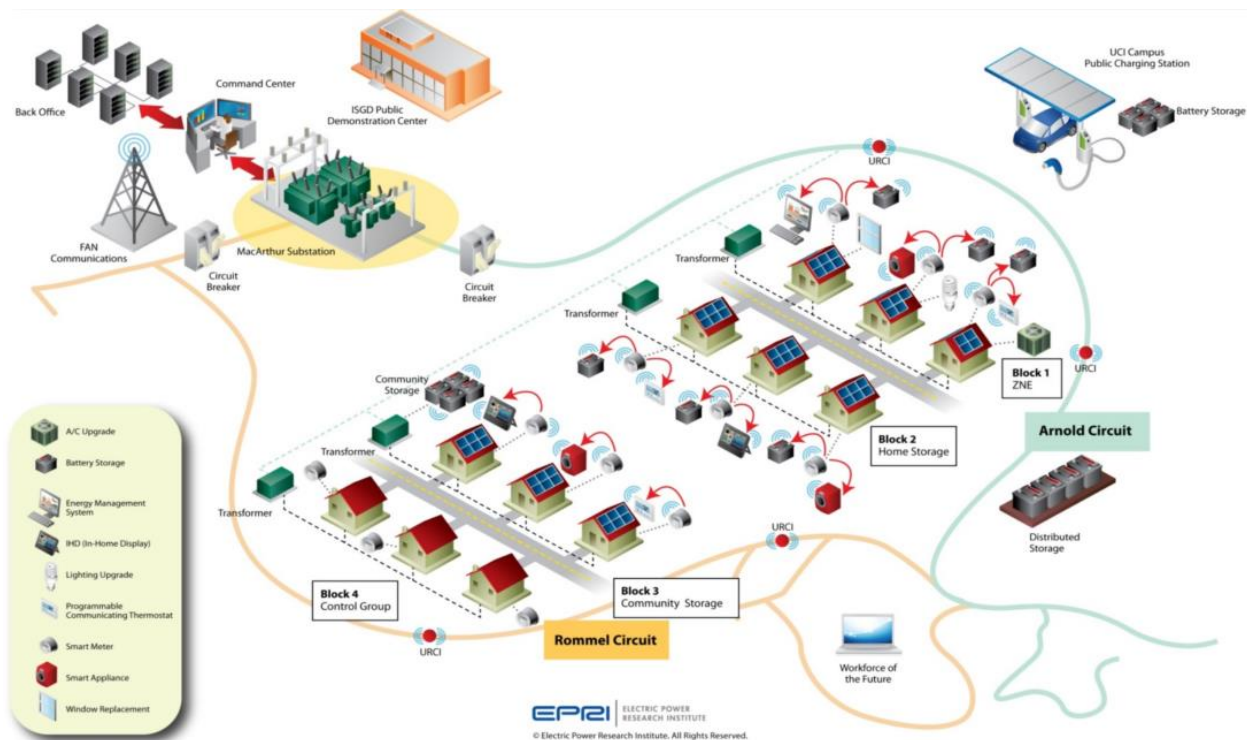


Figure 3-1: Illustration of Irvine Smart Grid Demonstration Project (Source: EPRI / Southern California Edison)¹¹⁵

3.2.10 Availability of and Access to Advanced Metering and Customer Data

Competitive suppliers and DER providers cite the lack of advanced metering data and accessibility (or lack thereof) of existing data as key hindrances in obtaining customer data that is sufficient to process and develop accurate customer value proposition models. Frequently, at least one year of historic customer load data is necessary to generate an annual estimate of savings and revenue for an energy storage customer. With increased transparency and data accessibility of utility customer load data, providers would be able to provide customers and financiers with greater certainty of a project's economic viability.

3.2.11 Data Availability on Locational Benefits and Constraints

Utilities noted the lack of location specific information as a barrier to providing locational incentives. Before initiating an interconnection study, they may be unaware of a locational system constraint and therefore unable to provide guidance to developers, or even to their own system planners.

¹¹⁵ Southern California Edison, SCE's Transactive Energy Demonstration Project, December 10-11, 2013; http://www.gridwiseac.org/pdfs/workshop_121013/yinger_sce_gwac_wkshppres12-2013.pdf

Some customer and grid services of energy storage are only possible in specific siting circumstances and locations. These benefits could accrue to the customer (demand charge management, reliability, time-of-use rate management and power quality) or the grid (transmission congestion relief, T&D upgrade deferral, power quality, voltage support, etc.).

For example, a utility may experience capacity constraints in high demand areas during specific peak periods a few times during the year. This situation could be solved if energy storage were deployed at one or more customers' sites in the congested area and could effectively mitigate the constraint when necessary, while providing other services to the end users at other time. In this case the storage would be able to capture both customer and grid value streams.

However, with the exception of a few projects (see SMUD's 2500R project¹¹⁶ as an example), current regulations, utility business models, and lack of information prevent non-utility owned energy storage systems from providing (and being compensated for) locational grid services. In reality, the opposite is often true; rather than providing a revenue stream, the location choice may actually add to project cost. For example, project developers and distributed generators often seek to interconnect projects in a constrained area (though the developer has no way of knowing this beforehand). After much time and investment, the utility may request payment from the developer for system upgrades to ensure the constraint is not worsened by the energy storage system before approving the interconnection application.

Project developers, including wholesale market participants, and distributed generators encourage utilities to share locational value or constraints, and increase the transparency of the distribution system. For utilities and other stakeholders to effectively structure and monetize locational value, both long and short term transparency is necessary. If developers have access to locational, distribution system constraint data, they could avoid siting projects in areas that would require traditional distribution upgrades, the interconnection process could potentially be streamlined, and ratepayers could potentially save money, which is a key priority for surveyed utilities.

Moreover, this locational information could also be utilized to explore revenue opportunities. Where ownership rules allow, utilities and other stakeholders could explore co-utilization of storage assets in which both the customer and utility receive a benefit.

3.2.12 Address Value Proposition for Renewable Integration

Using energy storage to incorporate renewable energy was ranked as a high priority for utilities and distributed energy resource developers. Each has their own perspective.

Several Massachusetts utilities shared their plans to use energy storage at the distribution and customer levels for renewable energy integration. MLPs are "seriously looking into energy storage"¹¹⁷ at the MW-scale for their distribution systems. Several renewable energy developers discussed using energy storage co-located with renewable energy projects as a valuable risk mitigation tool for intermittent capacity resources. Examples shared during the stakeholder input process are described in detail in Chapter 5.

¹¹⁶ SMUD, 2500 R Midtown Sacramento Municipal Utility District; April 28, 2014;

<http://smartgridcustomereducation.com/presentations/SGCES-LupeJimenez-SMUD.pdf>

¹¹⁷ Kevin Sullivan, Assistant Superintendent, Wellesley Municipal Light Plant's verbal comments during MLP follow-up call on 2015-11-30

“Energy Storage is an important tool for utilities in addressing the challenges of intermittent PV generation. A solution to address voltage fluctuations will make it possible for more facilities to come on line at the substation with a relatively less complex interconnection study process and lower system modification costs.”

- Eversource, Grid Modernization Plan 2015-08-19, p58

“We aggressively work to identify ways to expand our carbon-free portfolio and improve efficiency and resiliency on our electrical grid. For several years we have viewed energy storage as a potential means of doing just this and have conducted substantial research to that extent.”

– Anonymous Utility Representative

3.2.13 Diversity of Energy Storage Technologies

While batteries are most frequently thought of when the topic of energy storage arises, there are many other technologies with a wide variety of performance characteristics, costs, safety and siting considerations, and optimal Use Cases. Energy storage manufacturers, though, observe that not all energy storage technologies have an equal seat at the table. Most notably hydrogen and thermal energy storage providers identified under-representation of their respective technologies in the industry and market conversation. They noted that technology-agnostic solicitations and incentives that value services and performance, regardless of what technology is deployed, would help address the issue.

3.2.14 Energy Storage Research and Development

While some technologies are considered by many to be fully emerged and commercially ready for adoption, like batteries, other storage technologies are better classified as ‘emerging’ and are promising for the future with proper support. Pilot projects were identified as a key enabler of commercialization, but technology developers, energy storage manufacturers, utilities, distributed generators and project developers identified several priorities and challenges related to pilot projects including:

- Difficulty in securing funding to build the first demonstration project for a new technology or application, causing potential financiers and buyers to be very reluctant to finance “unproven” technologies.
- Lack of adequate competition in demonstration project solicitations where one technology type is favored over others.
- Lack of information and understanding regarding technology performance for immature technologies, as well as a lack of independent verification of such information.
- Lack of utility operating experience, leading to high soft costs of implementation.

One stakeholder recommended that establishing a pilot program that funds emerging energy storage technology and tests Use Cases would address the priority areas listed above. Technology pilots could limit exposure to technology risk and provide an opportunity to test applications that may not be cost effective today, but may be commercially viable in the future. This would allow newer companies and technologies to gain experience and prove their technologies, while allowing all stakeholders to learn from other projects before taking risks on building their own. Importantly,

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solicitations and awards should be competitive and technology agnostic and the pilots should be well designed and documented to provide the best possible data.

“A two phased approach should be adopted; first initiate the market with a target, then work on getting rules in place to ensure that there's a long term opportunity.”

- Anonymous DG Developer

3.2.15 Interconnection Review Process

The purpose of the interconnection study process is to ensure safe and reliable interconnection of the distributed energy resource (DER) on the distribution grid and to determine whether infrastructure upgrades are needed to accommodate the interconnecting resource. However, according to DG stakeholders, the interconnection processes in the Commonwealth are currently not in alignment with the operational profile and capabilities of the interconnecting energy storage resource (See Table 3-3 for an illustration of National Grid's standard and expedited interconnection process). Developers identified four broad operational profiles for behind-the-meter energy storage resources, which are based on their export capabilities and configurations:

- Systems that operate only when grid power is down and do not export to the grid
- Systems that operate in parallel with the grid but do not export to the grid
- Systems that operate in parallel with the grid with limited export to the grid
- Systems that operate in parallel with the grid and operate independently of load, with full export capability

Each of the above operational profiles have different impacts to the grid and therefore warrant different interconnection review processes, according to DG stakeholders. Specifically, energy storage system operational profiles with no export or limited export to the grid present relatively fewer concerns to utilities of reverse power flows that may jeopardize the reliability of the distribution grid, as compared to those with full export capability.¹¹⁸ Therefore, DG stakeholders believe that the operational profiles with limited grid impacts (i.e., non-export and/or limited export) should have an option available to undergo a quicker interconnection process, whereas operational profiles with full export capability should be subject to a more detailed interconnection review to ensure grid reliability.

¹¹⁸ Emergency generators are not required to follow the utility interconnection process because they are configured to operate only in island mode (i.e., they never run in parallel with the grid).

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	Expedited		Standard
Eligible Facilities	Listed Inverter DG	Eligible Facilities	Any DG
Acknowledge Receipt of Application (Note 2)	(3 days)	Acknowledge Receipt of Application (Note 2)	(3 days)
Review Application for Completeness	10 days	Review Application for Completeness	10 days
Complete Review of All Screens	25 days	Complete Standard Process Initial Review	20 days
Complete Supplemental Review (if needed) (Note 3)	20 days or Standard Process	Send Follow-on Studies Cost/Agreement	5 days
Send Executable Agreement (Note 4)	10 days	Complete Impact Study (if needed)	55 days
Construction Schedule	By Mutual Agreement	Complete Detailed Study (if needed)	30 days
Total Maximum Days (Note 5)	45/65 days (Note 5)	Send Executable Agreement (Note 3)	15 days
Notice/ Witness Test	< 1 day with 10 day notice or by mutual agreement	Construction Schedule	By Mutual Agreement
		Total Maximum Days (Note 5)	135/200 days (Note 5)
		Notice/ Witness Test	10 days or by mutual agreement

Table 3-3: Overview of Expedited and Standard Interconnection Process (Source: National Grid)

At the same time, even for full export operational profiles, energy storage systems could be configured to operate on highly congested feeders or during peak demand hours that improve grid reliability, in which case such systems could also be subject to an expedited interconnection review process. With standardized and pre-approved configurations across certain locations and times, these full-export systems could also be subject to expedited interconnection review. For this to occur, however, the utilities will need to work with DG stakeholders to conduct a locational benefits analysis for siting DG along highly congested or overloaded infrastructure, to conduct a net load analysis to identify time-of-use periods for peak demand, and to make the data from the aforementioned analyses available to DG developers.¹¹⁹

DG stakeholders also identified the lack of enforcement of the cost and turnaround time of the interconnection review process.¹²⁰ One developer recounted an instance where the servicing utility identified \$1 million in necessary upgrades to approve their project, after already having invested six months and \$25,000 in the interconnection review process. More efficient use of resources and time could be accomplished by providing added transparency to the costs and timeline for different interconnection review processes. With this information provided in advance of the interconnection review process, developers will be afforded greater cost and time certainty in their project development and may even configure their systems to the standardized and pre-approved configurations to take advantage of expedited review processes.

Lastly, developers also have a lack of understanding around the different utilities' approaches to interconnection, as well as the ISO's approach to interconnecting storage resources. There are three different interconnection processes for the IOUs, MLPs, and the ISO. These differences need to be clarified publicly and processes should be put in place that allow energy storage systems to advance through interconnection study processes that cross the jurisdictional divide between wholesale and retail.

¹¹⁹ The US-DOE funded Fraunhofer grant will explore the potential for a one-week interconnection review process.

¹²⁰ For a description of the existing timeframe enforcement mechanism required by the Massachusetts Legislature, see DPU 11-75-F; 15-28; 15-29; 15-30; 15-31.

3.2.16 Safety Codes and Standards

For certain technologies codes, standards, and regulations (CSR) for energy storage currently lag behind in technological development. CSR address components, entire assembly, installation, commissioning, operations and maintenance, incident response, system transport, and end of life.

Competitive suppliers and project developers note that the lack of applicable standards makes siting and installing energy storage at customer locations difficult. Current building and fire codes that address energy storage (and the disparity in jurisdictional adoption of those that do exist) provide limited guidance to officials responsible with ensuring the safety of such systems. This uncertainty for every stakeholder results in slow (or failed) permitting processes, added expenses for redundant safety features and/or fire protection systems, and creates doubt as to what actually constitutes a “safe” energy storage system.

Utilities and technology manufacturers identified clarification and implementation of performance and testing protocols and interoperability standards as key priorities/solutions to help address CSR uncertainty. EPRI’s Energy Storage Integration Council¹²¹ is currently working to develop such protocols and standards that could be revised and adopted to the satisfaction of Massachusetts’ stakeholders.

3.3 Stakeholder Suggestions for Areas of Further Investigation

Utility stakeholders recommended an expansion from a comparative analysis between conventional resources versus energy storage alternatives to one comparing the cost effectiveness of a broad range of non-wires solutions (including energy storage) versus conventional resources. Utilities should be encouraged to explore a variety of non-conventional technologies, particularly as the grid evolves from a central station model to a more distributed future.

An additional stakeholder suggestion encourages the state of Massachusetts to consider development of a test lab. Given Massachusetts utilities’ relative lack of operational experience with many energy storage technologies, the presence of a test lab would provide value to the state’s utilities and to storage technology companies alike. The wind blade test facility operated by MassCEC could provide a working model for such an energy storage test lab.

Utilities also recommended consideration of grid-connected energy storage alternatives for EV charging integration.

Customer stakeholder requests for regulatory clarity on energy storage asset classification and reconstitution of load is expected to continue to surface as an unresolved issue.

3.4 Conclusion

The above stakeholder engagement process showed a strong interest in energy storage. The stakeholders identified many applications for storage to address energy challenges but expressed concerns that current regulatory and policy frameworks can and do create barriers to development. The market is still at an early stage due to a lack of uniform and streamlined policy frameworks, as well as uncertainty regarding market rules and energy storage value streams. Several DER developers have expressed the view that there are no clear drivers for developing energy storage

¹²¹ EPRI, EPRI Energy Storage Integration Council (ESIC); [http://www.epri.com/Pages/EPRI-Energy-Storage-Integration-Council-\(ESIC\).aspx](http://www.epri.com/Pages/EPRI-Energy-Storage-Integration-Council-(ESIC).aspx)

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projects in the Commonwealth. Several key regulatory barriers must be addressed at the state level, in order for storage market development to take place in Massachusetts.

Stakeholders expressed a desire to better understand the value streams of energy storage. Additional cost benefit analyses of energy storage Use Cases is necessary to understand the primary revenue streams of energy storage in Massachusetts as well as the depth of certain markets.

Overall, the active engagement of a broad range of stakeholders revealed great interest in and excitement about the prospects for energy storage in the Commonwealth. Stakeholders provided important guidance on the issues, barriers and concerns they face that today prevent or slow the increased deployment of advanced energy storage installations. Stakeholders provided substantial input to the Study Team on the nature of the barriers and concerns and their relative importance, as well as identifying which concerns they felt would be amenable to influence by Massachusetts policymakers and thus merit prioritized attention for policy recommendations from this Energy Storage Initiative. This input was used to influence the recommendations highlighted later in this study.

The following chapters review the many applications for energy storage to address Massachusetts' energy challenges and describe the modeled cost benefit analysis for both a system of storage assets and also specific Use Cases.

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4 Modeling Grid Benefits of Storage in Massachusetts

4.1 Introduction

This chapter presents optimized modeling results suggesting that the Massachusetts electricity system could cost effectively utilize a large amount of storage, an estimated 1,766 MW, by 2020. At current costs, projected by year, the capital cost to deploy 1,766 MW of storage could be in the range of \$968M - \$1,355M, and the total value of storage over 10 years could be around \$3.4 billion. In addition to economic savings, the model projects an almost 10% reduction in Massachusetts peak demand as well as enhanced integration of renewables with an estimated reduction in CO₂ gas emissions of 1.06 MMTCO₂e. These results are based on an analysis of the electric grid system in Massachusetts and ISO-NE, and do not take into account the future changes that may need to occur to existing constraints such as regulatory policies and value recognition by various agencies, nor does it consider the time to build the systems under actual conditions. Nevertheless, as described in further detail, these results clearly indicate the real and multiple benefits that energy storage can provide to the Commonwealth.

Alevo Analytics, a sub-contracted consultant with a primary focus on advanced analytics in the power and energy sectors, completed the modeling effort for this study. For this storage analysis, the consultant used a model that incorporates multiple data sets including the complex structure of the electric grid, the physical characteristics of multiple types of storage systems, and predicted changes in costs and revenue of storage, fuel prices, and demand over time. This simulation effort can represent any sized power grid, ranging from smaller local systems to larger full-scale systems with thousands of generation units and transmission nodes. Using this combined, extensive data set, the model identified specific locations and quantities of storage through multiple iterations of capacity and production cost optimization.

The goal of the modeling effort is to demonstrate the potential benefits that energy storage can provide in Massachusetts. These benefits include: reducing the price paid for electricity consumption, reducing peak demands, deferring transmission and distribution investments, deferring capital investments in new capacity, reducing GHG emissions (reducing the effective cost of compliance), increasing renewable penetration, and increasing the grid's flexibility, reliability and resiliency. The model can quantify benefits that both represent revenue streams to the owners and operator of energy storage technologies and system wide cost savings for Massachusetts ratepayers. A project owner will need revenue to justify investing in a storage system but once that storage system is developed and can address Massachusetts energy challenges, the system operates more efficiently, creating cost savings to all ratepayers. These benefits are not double counted and under most traditional business models a storage developer cannot monetize system benefits to fund investment. More discussion about how projects can be developed taking into account both revenue and system benefits can be found in Chapter 5.

4.2 Modeling Results

The modeling results identify specific locations where energy storage of varying capacity and duration could cost effectively benefit the grid considering real time energy challenges. The general methodology for this analysis was a chronological capacity optimization model comparing energy storage technologies with other capacity technologies. The results were then fed into a production cost optimization model with the results then fed back into the capacity optimization model for further refinement. To begin the modeling process, Alevo Analytics identified the candidate

locations for energy storage deployment in Massachusetts using industry-accepted models, practices, and simulations. The optimizer site identification process narrowed down from 1400 to 250 different load points in the Massachusetts electricity system.

After refinement through both the production cost optimization model and the capacity optimization model, 78 sites were selected for energy storage deployment. The model determined the optimal storage size (in MW/MWh) at these locations at current projected cost. These sites account for, in aggregate, 1,766 MW/2,125 MWh of energy storage that is most beneficial to the rate payers. The optimizer indicates that the most benefits could be attained if storage is deployed earlier than 2017, however, in order to account for the amount of time it takes to develop a grid-connected energy storage project, it is recommended to spread the deployments over five years (2016-2020).

This five-year deployment recommendation has the benefit of using future lower projected energy storage costs of technology and thus greater benefit-cost ratios. Even with the build constraint, the modeled deployment is likely in excess of what could be reasonably deployed even with an aggressive ramp-up in installations. At current costs, projected by year, the capital cost to deploy 1,766 MW of storage could be in the range of \$968M - \$1,355M, and the total value of storage over 10 years could be around \$3.4 billion.

4.3 Value and Benefits Summary

Storage can provide both direct benefits to the storage developer in the form of revenue but also system benefits to the ratepayers in the form of cost reductions. In order for a merchant to make an investment in storage, generally the revenue from the technology has to outweigh the capital investment cost.

In addition to traditional direct merchant benefits, storage can also increase the efficiency of the electric system, reducing costs for all participants whether storage owners or not. This benefit is generally seen as lower electricity costs for ratepayers. As described in detail in Chapter 2, storage can flexibly balance generation and demand to increase overall energy system efficiency. This increased system efficiency creates lower costs that are passed onto customers as lower prices. For example, if an entity develops an energy storage system in a load constrained area for their own energy arbitrage benefit, not only does that developer receive sales revenue but ratepayers see lowered prices. This ratepayer cost reduction can be caused by deferring the cost of a new transmission line into the load zone to meet an ever increasing peak demand or it can be an energy cost reduction created by the increased competition in supply suppressing prices. Either way, ratepayers see a benefit from that storage development and the storage project developer sees revenue from the investment. Neither the value to the storage developer nor the system benefits are double counted.

Energy efficiency benefits are considered in a comparable way. A homeowner or business will consider investing in energy efficiency in order to reduce their own energy costs. This is similar to the direct benefits that flow to a storage developer. As long as the direct benefits from the energy efficiency measure outweigh the capital costs, the resident, business, or developer are justified to invest. After investment, the increased energy efficiency not only saves money for the resident and business but also for all ratepayers. Energy efficiency decreases overall demand for the system, deferring infrastructure investments that would have to be paid for by all ratepayers. Because all ratepayers see these investment deferrals as a cost reduction, it is in the interest of all ratepayers

that policy makers pursue an energy efficiency program. Providing rebates or incentives helps customers implement energy efficiency measure, reducing overall system costs.

In the modeling results both the direct sales benefits and the system-wide benefits are presented, stacked together, and compared to cost. This represents the idea that if the total combined benefit from the storage development is greater than the cost, it is in the ratepayers' interest for the project to be developed. First, a developer will compare the capital costs to the potential revenue. If this value is greater than one, the developer will invest. But there are some situations where the direct revenue will not be greater than cost and the project will not be developed. In these cases, the potential system benefits will not be realized. In order to capture those ratepayer benefits, there needs to be a mechanism that allows the developer to monetize some of the system benefits. More discussion on the existing and potential mechanisms to close the revenue gap and capture system benefits can be found in Chapter 5.

The modeling and optimum utilization of energy storage in the state of Massachusetts shows that a large amount of storage could be beneficial and cost effective to the rate payers. The total 10 year value of 1,766 MW of storage is estimated to be \$3.4 billion for Massachusetts which includes \$2.3 billion in system benefits to rate payers and \$1.1 billion in potential economic value of market sales. The deployment of 1,766 MW energy storage by 2020 will provide \$250 million in additional regional system benefits to the other states in ISO-NE, yielding consistently lower annual average energy price across all ISO-NE zones. In addition to economic savings, the model projects an almost 10% reduction in Massachusetts peak demand as well as enhanced integration of renewables with an estimated reduction in CO₂ gas emissions of 1.06 MMTCO₂e. There are several other benefits to the quality of life and property from increased system resiliency as well as economic impacts that have not been quantified in this chapter.

The following sections in the chapter describe the inputs, outputs and optimization that was undertaken to determine the amount of storage that will bring optimal benefits to ratepayers. These benefits result from the above energy storage deployment scenario over five years. The cost range is due to the potential for regional cost differences for storage and the variability in the projected decline in storage costs.

4.4 Need for Modeling

The interconnected nature of the electricity systems with hundreds of generators spread over a vast region and thousands of miles of transmission and distribution networks with system conditions is changing every minute and needs advanced analytics to model the systems of the future and to understand the changes over several hours to over several years to find the most optimal solution for a given system. Traditionally, deterministic planning methods based on snap-shot power flows and peak power flow conditions were sufficient for planning a transmission and distribution system for electricity, but these methods are no longer sufficient to plan a system with distributed resources. The traditional planning processes are evolving with enhancements to reflect the eventualities and realities that distributed resources are forecasted to provide. The main paradigm shift in planning and modeling of traditional practices versus methods for distributed resources is that, with distributed energy resources, renewables, and emerging technologies, enhancements to grid planning are taking shape to plan systems based on how they will actually be operated minute to minute and hour to hour, and not just with snapshot power flow analysis. This shift takes into account more chronologic characteristics in long term planning such as intermittency, ancillary

services, net peak load reduction, outages, and moving dynamic voltage and frequency controls to the distribution systems and demand centers.

Figure 4-1 highlights the many potential Use Cases and value propositions of grid-scale energy storage and demonstrates how the deployment of energy storage can impact the entire electricity supply chain of generation, transmission, distribution, and demand.



Figure 4-1: Potential Use Cases and Value Propositions of Grid-Scale Energy Storage

Distributed Storage Resources can provide several benefits to the system where they are deployed, including:

- Reduced costs to ratepayers
- Increased reliability of demand centers
- Accelerated renewables integration
- Optimization of T&D assets
- Optimization of Massachusetts import transmission asset (HQ, ME, NY and other New England states)
- Minimization of transmission development in state, such as to the Cape.
- Reduction of emissions

4.5 Alevo Analytics

Alevo Analytics is a consultant that applies economic and reliability based analytics and simulation capabilities, business intelligence and advisory services with a primary focus on the power and energy sectors. Alevo Analytics uses its supercomputer system with a team of experts to (1) examine large amounts of data regarding the performance of the generation and transmission assets that currently make up the grid, (2) collect and aggregate this data, and (3) provide planning and operational analysis which then is used to predict where the potential shortfalls and inefficiencies in the grid are today and where they will be in the future. It has the capability to model the system with distributed energy resources and optimize the size and location of storage for several different Use Cases based on the relative cost of technologies and to show system benefits.

The Alevo Analytics power market modeling tools are extremely scalable and allow for simulations of any sized power grids, ranging from small to medium sized local and regional systems to large full-scale systems with thousands of generation units and transmission nodes.

4.6 Modeling Scope

The model is built to investigate the use of storage in a variety of Use Cases including peak reduction, integrating renewables, outage mitigation, and improving grid efficiency. The model covers generation, transmission, distribution, and end-user applications.

The modeling and optimization scope for Alevo Analytics includes:

- Determining the distribution of energy storage locations across the state of Massachusetts that will achieve maximum benefits to ratepayers.
 - This required Alevo Analytics to quantify the storage by transmission, distribution and/or behind the meter applications.
- Determining the optimal storage in KW and KWh that will add maximum benefit to ratepayers with energy storage technologies at different costs.
 - This required Alevo Analytics to qualify and quantify energy storage in KW and KWh that can achieve the benefits at different costs of technologies.
- Quantifying the reduction in GHG emissions that can be achieved with the optimum level of energy storage deployments across the state.
- Finally, quantifying and estimating the cost savings and benefits to Massachusetts.

4.6.1 Modeling and Optimization Description

As shown in Figure 4-2, the Alevo Analytics model determines where the storage resources will provide value throughout the state, allowing for storage installations of varying size and duration at different locations. For each substation, the algorithm determines the optimal amount of energy storage by MW/MWh. The model quantifies the benefits of the storage resource at the substation level. The output of the model identifies where the cost of the storage is less than the benefits to the system and there is a reduction in wholesale costs.

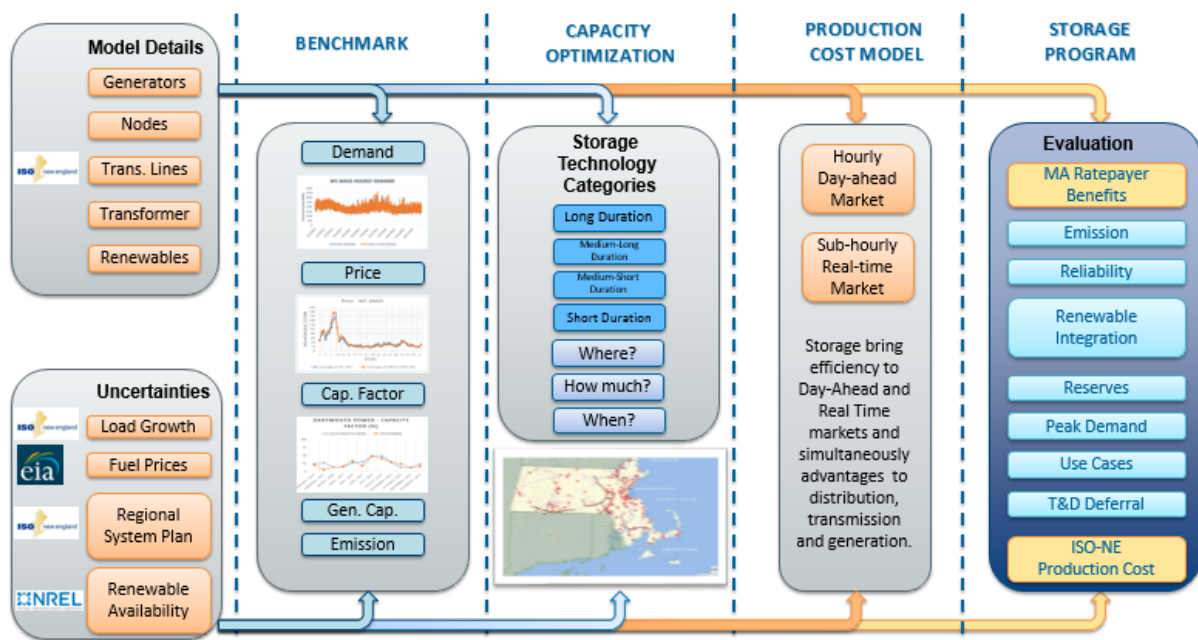


Figure 4-2: Advanced Storage Optimization Model/Process

The data utilized for the model is a simulation of the ISO-NE markets that co-optimize energy and ancillary services subject to transmission thermal constraints with detailed Massachusetts specific generation, transmission and distribution data. The simulated model includes an import and export flow model to represent the interfaces with NYISO, IESO, Hydro Quebec and New Brunswick Power. The existing generation resource mix (including all installed pumped storage in ISO-NE) is used in the simulation. The model also accounts for the generation retirements and additions during the study period. The inputs to the simulation were reviewed and carefully refined to ensure they accurately depict the resource mix. The model was benchmarked for 2015.

The Alevo Analytics storage capacity optimization was then executed to answer the questions of where, how much, and when storage should be deployed for each location. The next step involved further testing of the data with hourly and sub-hourly production cost simulations of the day-ahead and real-time markets in order to evaluate different Use Cases.

4.6.2 Energy Storage Technologies

Energy storage technologies not only come in different shapes and sizes but also vary by the medium used to store energy. Based on the medium used to store energy, the following different technologies with characteristics as defined in the table were included in this analysis. The technologies that were considered in this study including Lead Acid battery, Compressed Air Energy Storage (CAES), Sodium Sulfur battery (NaS), Lithium Ion battery (Li-Ion), Sodium Ion battery (Na Ion), Flow battery, Sodium Nickel Chloride battery (NaNiCl₂), Nickel Cadmium battery (NiCd), Nickel-metal Hydride (NiMH), Thermal Storage, and others.

For the purpose of the model, the range of storage technologies was organized into four categories as seen in Table 4-1.

Storage Technology Category	Duration at Full Power	Examples
Long Duration	4+ Hours	CAES, Flow Battery, NaS Battery
Medium-Long Duration	2 Hours	Lithium Ion, Flow Battery, NaS Battery, NaNiCl ₂ Battery, Advanced Lead Acid
Medium-Short Duration	1 Hour	Lead Acid, Lithium Ion, NiCd, NiMH
Short Duration	30 Minutes	Lithium Ion Flywheel, High Power Supercapacitors, Thermal Storage

Table 4-1: Categories of Storage Technologies

As the model is executed, it “chooses” specific technology characteristics that are vendor agnostic and would be beneficial and cost effective based on the specific assumptions. The technology assumptions that define how the model assigns both cost and benefit values are presented in greater detail in Appendix A.

4.6.3 Location Selection

The current model of the Massachusetts power systems has 1,497 nodes in the zones of NEMA-BOST, SE-MASS, and WC-MASS. Those nodes include the generator substations, transformer substations, transmission line from and to substations and load substations. The number of load substations in the model is 507. In order to integrate more distributed solar generation and optimize the overall operation and cost for the Massachusetts system, Alevo Analytics selected 250 substations to distribute the deployment of energy storage units in the entire state of Massachusetts.

The optimization selects candidate substations based on values associated with the wholesale market, and the transmission/distribution systems. It does not take land and space into consideration.

Among the 250 candidate substations for energy storage, 66 are aggregated substations with distributed-level solar, while the other 184 substations are selected based on their peak load in a year. The numerical distribution for all 250 substations in three zones is as follows:

- 83 Substations in NEMA-BOST
- 80 Substations in SEMASS
- 87 Substations in WCMAS

For each candidate substation, the ratings of transformers are also considered. All candidate substations are assumed to have available capacity to deploy storage up to an equivalent of 50% of the peak demand at the candidate substation.

The geographical distribution of 250 substations is illustrated in Figure 4-3. The candidate substations are close to load points including, but not limited to, the following sites:

- Boston
- Lawrence
- Brockton
- Framingham
- Cape Cod
- Worcester
- Springfield
- Pittsfield



Figure 4-3: Geographical Distribution of Candidate Substations in MA¹²²

4.6.4 Capacity Optimization

Step 1: The candidate list of 250 potential substation locations was fed into the model's capacity optimization process to determine the most economic candidates for storage deployment. The capacity optimization then selected the substations out of the candidate pool based on the cost and benefit analysis. If the deployment of any type of energy storage unit was beneficial at a candidate substation, this station was selected and the power deployment was optimized in units of MW.

Step 2: The optimization tool calculates the necessary size of the energy storage deployment to minimize the cost to ratepayers, and quantifies the net benefit of deployment to the system without considering the cost of storage deployment.

Step 3: The tool then quantifies the storage by transmission, distribution and/or behind the meter applications. To do this, the capacity optimization algorithm considers the following parameters:

- Minimization of wholesale market costs
- Minimization of Massachusetts emissions

¹²² The base map used for this figure is taken from the OLIVER: Mass GIS Online Mapping Tool and the red candidate substations are selected using the New England Geographical Transmission Map substation points as a reference.

- Increased utilization of transmission and distribution assets
- Minimization of incremental new transmission assets
- Increasing resiliency with wide scale transmission and distribution and generation outages
- Minimization of requirements for peaker power plants
- Stress testing with varying levels of power demand, fuel price, and renewable deployment

4.6.5 Production Cost Optimization with Energy Storage

The objective function of the production cost optimization determines the least cost system operations including generation cost, emission cost, and cost of lost load. These considerations are subject to maintaining system reliability of operations in terms of transmission line flows, generators' physical limitations, power balance, and chronological ramping constraints of the generation fleet.

The production cost optimization with unit commitment and economic dispatch algorithms was run at hourly intervals, representing the day-ahead market, and sub-hourly intervals, representing the real time market, to demonstrate the operations of the energy grid throughout Massachusetts with the deployment of energy storage systems at transmission and primary distribution stations. The production cost studies enforce the transmission thermal constraints as well as many other system constraints.

Hourly and sub-hourly production cost simulations were further executed for model uncertainty such as demand risk, intermittency, and outage risk of resources and transmission. Stochastic distributions were then prepared demonstrating the Use Cases for the systemic deployment of energy storage and how distributed energy storage provides flexibility to respond to uncertainty of system operations.

4.7 Optimization Results

Based on the transmission infrastructure, solar integration, and demand profile of Massachusetts, the Capacity Optimization tool selected 78 substations for storage deployment. The capacity and production cost optimization resulted in broad groupings of the size of the storage into different components of the electricity supply chain in Massachusetts and yielded a 1,766 MW/2125 MWh deployment of energy over the study horizon to give the most benefit to the system.

The optimization results demonstrate a grid need for both short duration high power energy storage and long duration energy storage. The use of short duration, high power energy storage, where feasible, will result in a lower cost and higher flexibility of the electricity system (Figure 4-4). Energy duration of the storage can be extended by decreasing the power output for a given installation of MW/MWh ratio.

■ Long Duration ■ Medium-long Duration ■ Medium-short Duration ■ Short Duration

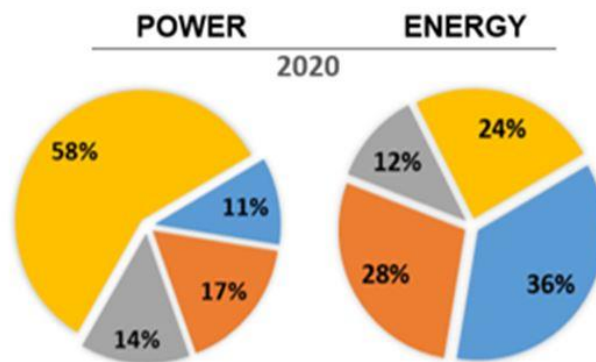


Figure 4-4: Distribution of storage in 2020 by power and energy

4.8 Assessment of Benefits

This section discusses the quantified and qualified benefits of energy storage deployment as part of the optimized storage program results.

4.8.1 Massachusetts Benefit Analysis

The modeling results show that by adding 1,766 MW of energy storage by 2020, there will be a total 10-year storage value of \$3.4 billion, where \$2.3 billion comes from system benefits, i.e. cost savings to ratepayers, and the other \$1.1 billion comes from potential market revenue. The deployment of 1,766 MW energy storage by 2020 in Massachusetts would provide an additional \$250 million in regional system benefits to the other New England states due to lower wholesale market prices across all ISO-NE zones. The categories of system benefits that storage can provide to the system are summarized in Table 4-2 below.

The breakdown of \$2.3 billion in system benefits from energy storage deployment includes six primary benefits: (1) \$275 million energy cost reduction when energy storage replaces the higher cost peak generation with lower cost energy stored at off-peak times; (2) \$1093 million as a result of energy storage providing peaking capacity to defer the capital costs of peaker plants and reduce the cost in the capacity market; (3) \$200 million in ancillary services cost reduction as a result of energy storage reducing the overall costs of ancillary services required by the grid system through provision of frequency regulation, spinning reserve, and voltage stabilization; (4) \$197 million in wholesale market cost reduction due to utilizing energy storage to provides system flexibility reducing the need to ramp fossil fuel generators up and down thereby minimizing wear and tear and reducing GHG emissions; (5) \$305 million T&D cost reduction as an outcome of energy storage reducing the losses and maintenance of system, providing reactive power support, enabling deferred T&D investment, and increasing resilience; and finally (6) \$219 million from incremental benefits associated with distributed renewable integration due to energy storage reducing the cost of reverse power flow and avoiding feeder upgrades in areas where there are distributed renewable resources.

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Benefit Description	Ratepayer Savings
Energy Cost Reduction Energy storage uses lower cost energy stored at off-peak to replace the use of higher cost peak generation: <ul style="list-style-type: none">• reduced peak prices• reduced overall average energy price	\$275M
Reduced Peak Capacity Energy storage can provide peaking capacity to: <ul style="list-style-type: none">• defer the capital costs peaker plants• reduce cost in the capacity market	\$1093M
Ancillary Services Cost Reduction Energy storage would reduce the overall costs of ancillary services required by the grid system through: <ul style="list-style-type: none">• frequency regulation• spinning reserve• voltage stabilization	\$200M
Wholesale Market Cost Reduction Energy storage provides system flexibility, reducing the need to ramp generators up and down and resulting in: <ul style="list-style-type: none">• less wear and tear• reduced start up and shut down costs• reduced GHG emissions (lower compliance cost)	\$197M
T&D Cost Reduction Energy storage: <ul style="list-style-type: none">• reduces the losses and maintenance of system• provides reactive power support• increases resilience• defers investment	\$305M
Integrating Distributed Renewable Generation Cost Reduction Energy storage reduces cost in integrating distributed renewable energy by: <ul style="list-style-type: none">• addressing reverse power flow at substations• avoiding feeder upgrades at substations	\$219M
Total System Benefits	\$2,288M

Table 4-2: Description of Storage System Benefits¹²³

4.8.2 Revenues to Storage

In addition to the benefits to the system from deploying storage, energy storage projects can earn revenues by participating in the wholesale electricity market for energy, reserves, and Regulation. However, this may require that ISO-NE implements rule changes that enable energy storage projects

¹²³Renewable Integration Cost Reduction is associated with incremental benefits associated with distribution renewable integration. Larger benefits associated with renewable integration are already accounted for in the other benefit categories.

to participate in capacity and other markets, as further discussed in Chapter 8. Including all value streams, the 10-year total revenue for energy storage projects could be around \$1.1 billion.

4.8.3 System Cost-Benefit Analysis

Based on the proposed energy storage deployment scenario, the capital cost of 1,766 MW/2,125 MWh storage is estimated as \$842 million and, with an estimated 15% maintenance cost included, a total cost of \$968 million. However, due to the potential for regional cost differences for storage and uncertainty in the projected decline in storage costs, it is estimated that there can be around 40% higher costs thus leading to a storage cost range of \$968 million to \$1,355 million. This amount of storage will add \$2.3 billion of quantified system benefits to ratepayers over 10 years. In Chapter 5, there will be a further description of the resource owner benefits of \$1.1 B that are quantified by market revenues. The market benefits are further discussed in Chapter 5. Considering ratepayer benefit alone, this analysis leads to a benefit-cost ratio of 2.4 as shown in Figure 4-5. However, the benefit calculations may yield higher results than the ones displayed here due to the uncertainty in the input parameters such as fuel prices, renewable source availability, and demand growth.

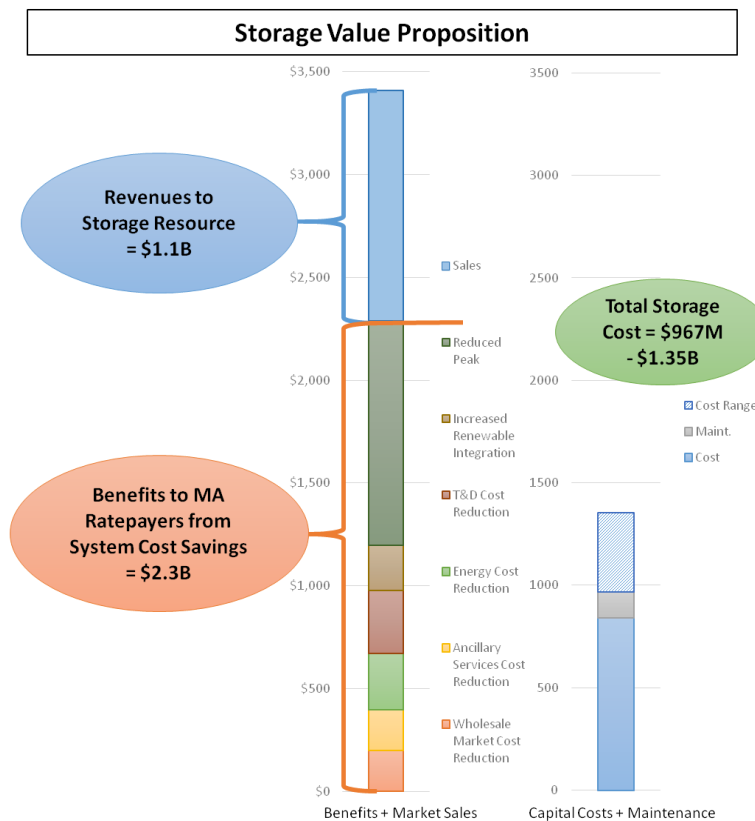


Figure 4-5: Storage Value Proposition

4.9 Description of the Benefits

The following sections describe the \$2.3 B of system benefits that have been identified in the Alevo Analytics study.

4.9.1 Energy Cost Reduction

Benefit Description	Ratepayer Savings
Energy Cost Reduction Energy storage uses lower cost energy stored at off-peak to replace the use of higher cost peak generation: <ul style="list-style-type: none"> reduced peak prices reduced overall average energy price 	\$275M

4.9.1.1 Price of Electricity Reduction

By adding energy storage, the system is expected to see an energy cost reduction of \$275 million. Deployment of energy storage units has an impact on the price of electricity in the wholesale market. The efficiencies gained by storing electricity in off peak periods result in lower wholesale locational marginal price (LMP) for energy. Likewise, utilization of energy storage units within transmission system reduces the congestion of the system as well as transmission losses which also contribute to a lower LMP.

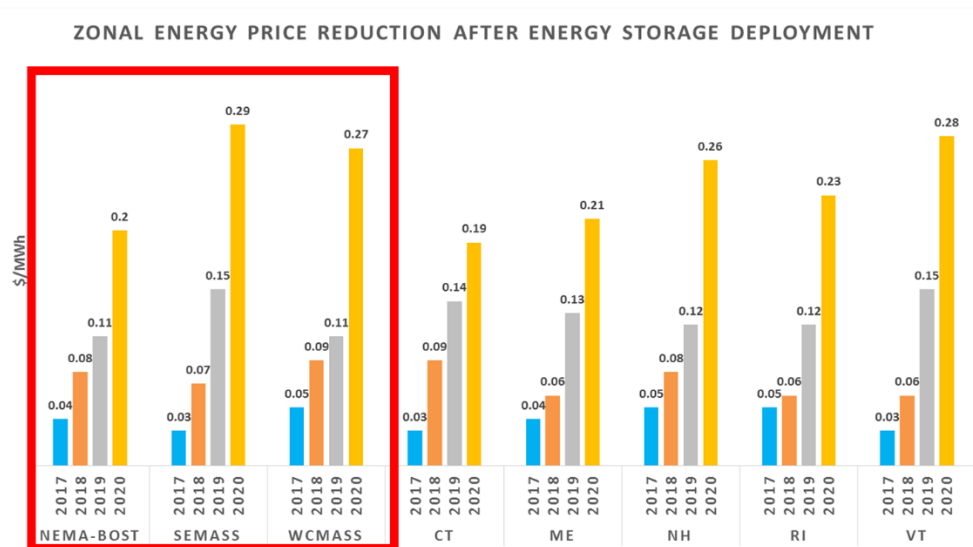


Figure 4-6: Storage Reduces Zonal Energy Price

Figure 4-6 shows the energy price reduction after the deployment of energy storage for the same zones for each year between 2017 and 2020. Including energy storage yields a consistently lower annual average energy price than without energy storage across all ISO-NE zones and years. The most prominent price reduction is in 2020. Paired t-tests¹²⁴ show that this amount of price reduction is statistically significant across all ISO-NE zones for 2020. Table 4.3 shows the mean and maximum of the hourly zonal price reduction in 2020.

¹²⁴ A paired t-test is commonly used to compare a sample group's scores before and after an intervention.

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	NEMA-BOST	SEMA	WCMA	CT	ME	NH	RI	VT
Mean (\$/MWh)	0.20	0.29	0.27	0.19	0.21	0.26	0.23	0.28
Max (\$/MWh)	35.89	27.55	26.34	23.51	103.49	34.95	31.67	26.04

Table 4-3: Mean and Max of the Hourly Zonal Price Reduction in 2020

4.9.1.2 Storage Benefit for Winter Fuel Program

As illustrated in Figure 4-7, the top brown line represents the original system demand without any energy storage. The use of energy storage reduces the system demand at peak, as shown by the flattened dotted blue line. This reduces the strain on natural gas resources during peak times. During times of natural gas constraints many generators must switch to oil and coal fuel sources which can increase energy costs and emissions. A reduction in peak demand means dual fuel generators see less switching to oil and coal, contributing to ratepayer savings and emission reductions.

For example, on a winter day energy storage can be charged at night when the natural gas consumption is relatively low and be discharged during the day time when millions of homes have their heaters on and the natural gas consumption is high. When storage results in an 800 MW peak reduction for 4 hours, there is a 0.02 Bcf of natural gas per day reduction. The regular Henry Hub natural gas price is around \$3/MMBtu. However, during the winter peak time the natural gas price in ISO-NE can reach \$35/MMBtu or even higher for the peak days. The white dotted line in Figure 4-7 shows the reduction in oil and natural gas consumption during peak times of the day from the addition of energy storage.

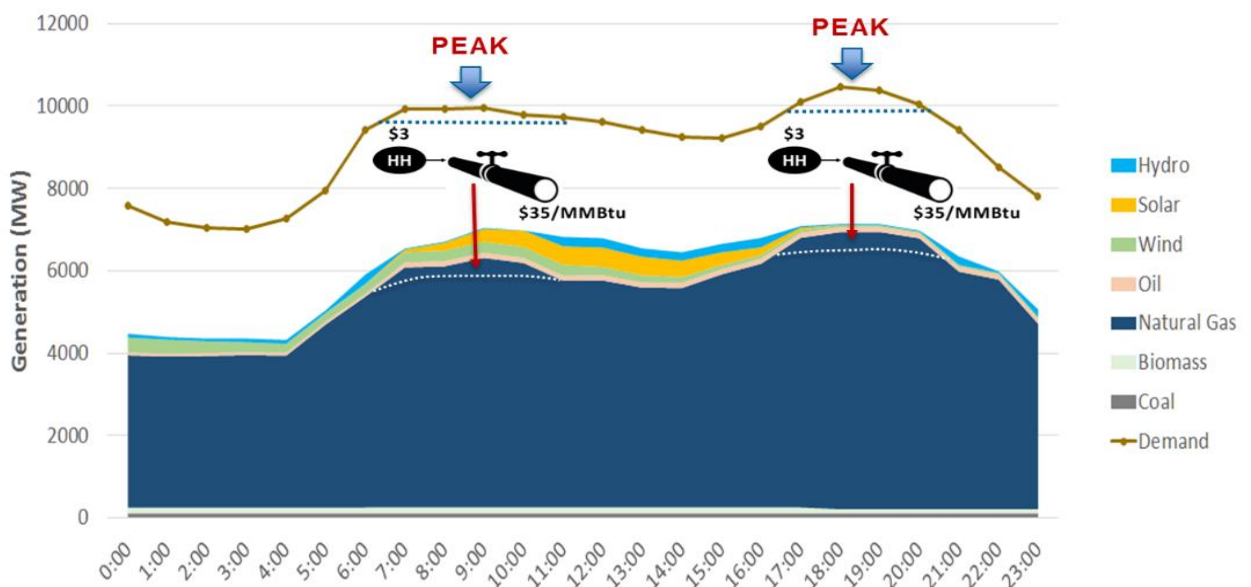


Figure 4-7: Impact of Storage on Winter Fuel Program

4.9.2 Reduced Peak Capacity

Benefit Description	Ratepayer Savings
Reduced Peak Capacity Energy storage can provide peaking capacity to: <ul style="list-style-type: none"> • defer the capital costs peaker plants • reduce cost in the capacity market 	\$1093M

Adding energy storage to the system provides an estimated \$1093 million in avoided peaking plant cost savings.

Figure 4-8 shows the comparison of demand curves between the case without energy storage and then after energy storage is deployed for Massachusetts. Storage can be charged at night when demand is low. During the peak hours, it can be seen that the demand with energy storage (in orange line) is lower than the demand without storage (in blue line) because of storage discharging. This kind of peak reduction (or shaving) can be maximized when energy storage dispatch is coordinated either by the ISO or by utilities on peak days, to fully utilize storage capability for peak reduction.

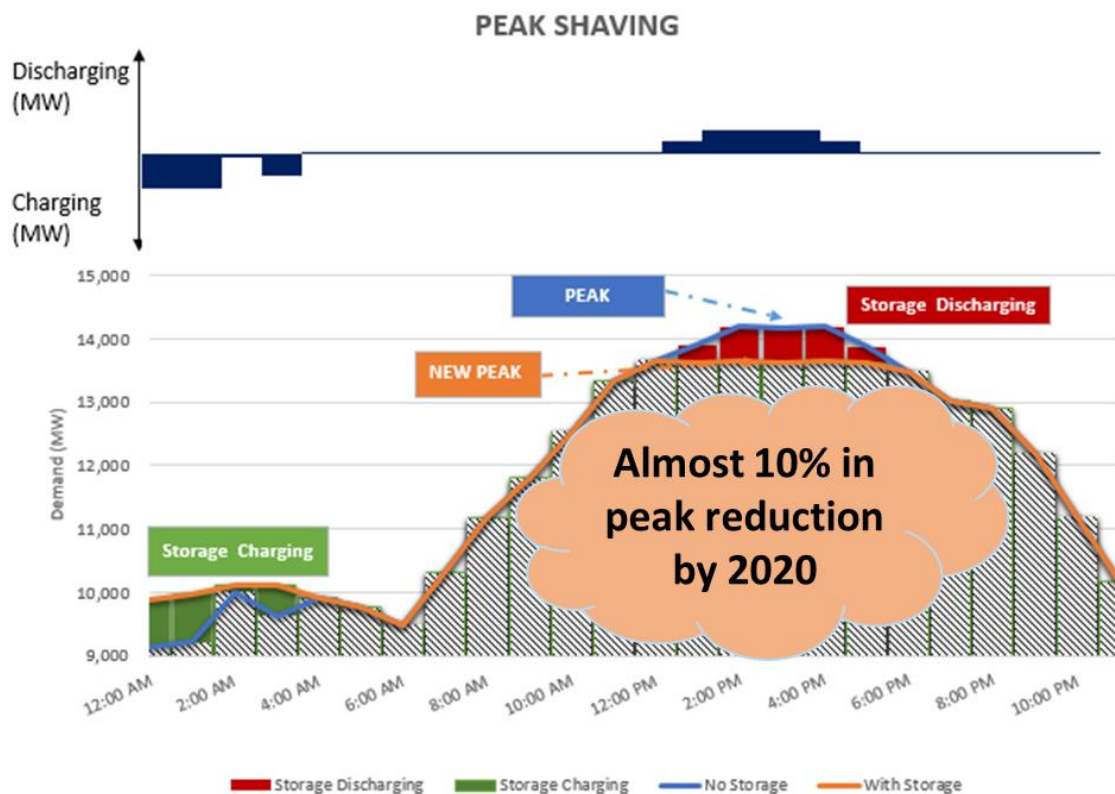


Figure 4-8: MA New Demand Curve after Deployment of Energy Storage

Through such peak demand reduction, energy storage can reduce or eliminate the needs for new peaking resources and thus save the capital costs needed for new peaking plants. Simulation results show a potential of 908 MW of peak demand reduction (for year 2020 as shown in Table 4-4).

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Year	Peak Demand for Base Case (MW)	Peak Demand for Energy Storage Case (MW)	Delta in Peak Demand (MW)	% Reduction in Peak Demand
2019	8,828	8,119	709	8.04%
2020	9,293	8,385	908	9.77%

Table 4-4: Change in Peak Demand with the Addition of Energy Storage

The estimated capital cost for a new natural gas combustion turbine peaking plant based on assumptions adopted from EIA's Annual Energy Outlook (AEO 2015) report is \$973/kW. From capital cost point of view, including all developers' costs and profit, a 908 MW peak reduction in 2020 is equivalent to a \$1093 million investment.

4.9.3 Ancillary Services Cost Reduction

Benefit Description	Ratepayer Savings
Ancillary Services Cost Reduction Energy storage would reduce the overall costs of ancillary services required by the grid system through: <ul style="list-style-type: none">• frequency regulation• spinning reserve• voltage stabilization	\$200M

4.9.3.1 Storage Provide Reserve Services

Including energy storage would reduce the overall cost of ancillary services by \$200 million over a 10 year period.

The ISO-NE forward reserve market provides include: 10 minute spinning reserves, 10 minute non-spinning reserve, and ten minute operational reserve. The ISO-NE Frequency Regulation market encompasses both an upward and downward Regulation service. Currently ISO-NE uses mostly natural gas generators and some pumped hydro storage to provide both reserve and Regulation services.

Through the use of new advanced energy storage, ancillary services can be provided at lower costs. The reduction in the cost of ancillary services is due to the replacement of conventional generating units that provide reserve services by advanced energy storage systems. Due to the nature of reserve services, the generators that are dispatched for spinning reserves must be ready to generate energy in a limited time period. To do this, there is a cost associated with keeping the unit at minimum load so that it can respond within ten minutes when dispatched. Energy storage systems, in contrast, have a fast-response time and relatively lower cost to keep the unit ready for such services. Switching the provision of reserve services from generators to advanced energy storage systems also reduces the ramping costs related to wear and tear of the generators. It is worth noting that to achieve the ancillary services benefits, ISO-NE market rules would need to be updated to be able to dispatch energy storage with other dispatchable generation in the system.

Moreover, there are added efficiencies with using energy storage for the provision of ancillary services. For example, when it is charging to provide a downward service, it can also be collecting low price off peak power for future use. Figure 4-9 and Figure 4-10 show the 1,766 MW of energy storage operations in 2020, including charge and discharge status and ancillary services provisions in a regular day in summer and in winter.

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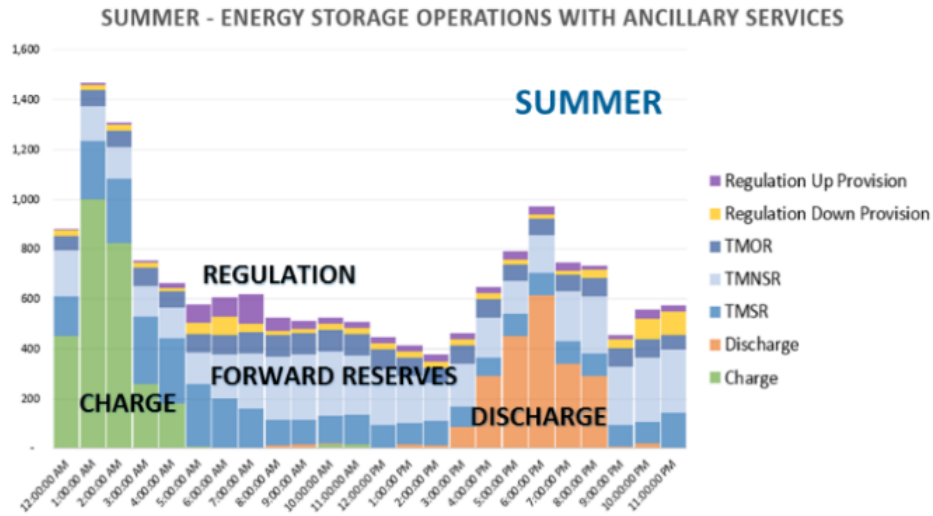


Figure 4-9: Summer-stack Services Provided by Energy Storage Operations

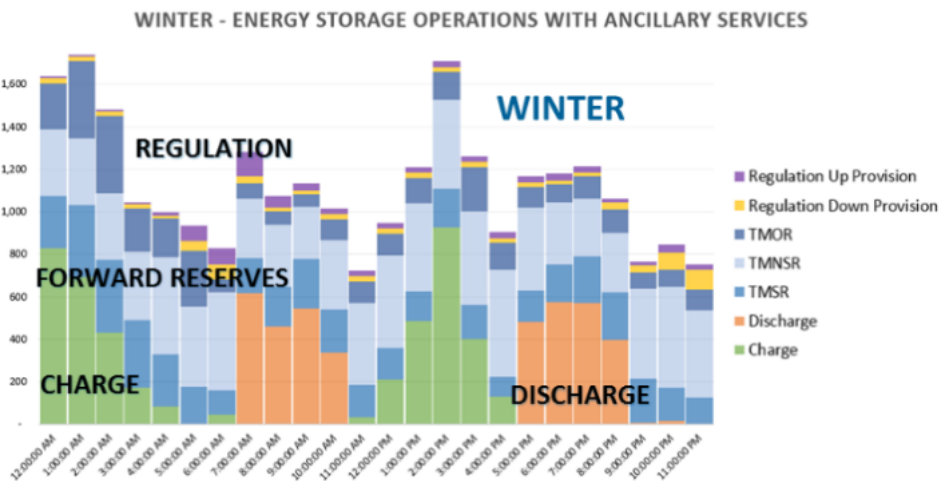


Figure 4-10: Winter-stack Services Provided by Energy Storage Operations

The green portion of chart shows the charging of the energy storage and the orange portion shows the discharge of the energy storage throughout the course of a day. Energy storage is capable of providing more than one service at a time, such as the simultaneous charging and forward reserve service provision as shown in Figure 4-10. Note that these combined value streams are captured separately in the multiple benefit categories and are not double-counted.

4.9.4 Wholesale Market Cost Reduction

Benefit Description	Ratepayer Savings
Wholesale Market Cost Reduction Energy storage provides system flexibility, reducing the need to ramp generators up and down and resulting in: <ul style="list-style-type: none"> • less wear and tear • reduced start up and shut down costs • reduced GHG emissions (lower compliance cost) 	\$197M

4.9.4.1 More Efficient Use of Conventional Generation, Lower Uplift Costs, and Reduction in Generator Variable Operations and Maintenance (O&M) Costs

Integrating energy storage improves the efficiency of the generator fleet by reducing the need for generators to start and stop as well as the need to ramp generation up and down. This results in lower costs from operations at minimum load, and variable O&M, including environmental compliance cost. This amounts to \$197 million over 10 years.

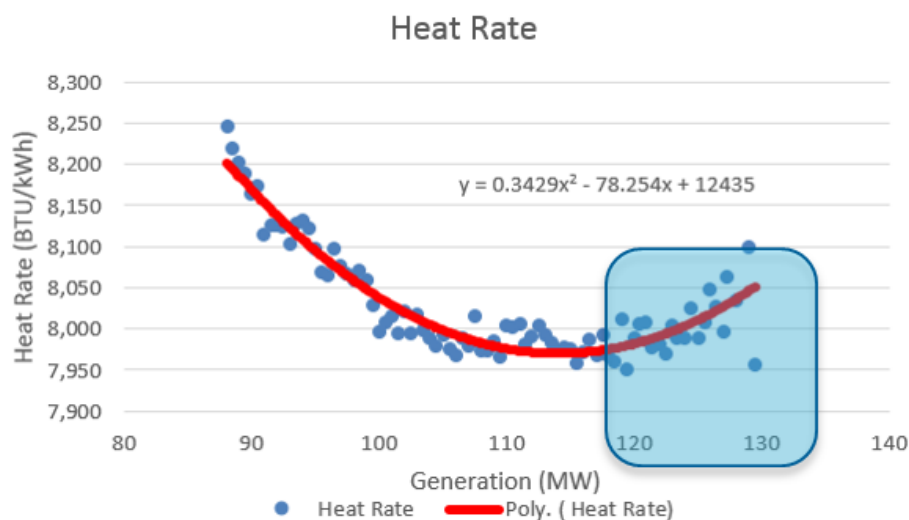


Figure 4-11: Polynomial Heat Rate Curve of a Fossil-Fuel Plant

Energy storage deployment can provide generation support during times of changes in load so that conventional fossil fuel generators can operate at its optimal heat rate.¹²⁵ As shown in Figure 4-11, the fossil fuel generator's heat rate increases when the generator is operated at its top 10% of capacity as shown as a blue box. Anytime a fossil plant cannot operate at its optimal output, efficiency decreases and heat rate increases. Instead of increasing or decreasing their generation, especially during small peaks or with renewable generation output, the generator could instead use energy storage to meet demand changes, as shown in Figure 4-12 below. This would allow result in a

¹²⁵ A common method of quantifying the efficiency at thermal power plants is "heat rate," a measurement of the efficiency of converting fuel to electricity. A higher heat rate indicates less efficient electricity generation and an increase in wasted fuel.

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conventional plant operating at constant generation output, reducing the heat rate, increasing efficiency, and decreasing costs. This is analogous to a car's fuel economy. A car may get 18 miles per gallon driving on city roads but can increase its fuel efficiency up to 30 miles per gallon on the highway with a reduction in starts and stops.

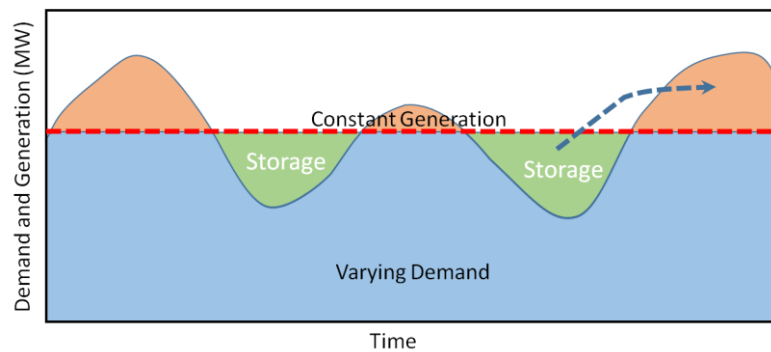
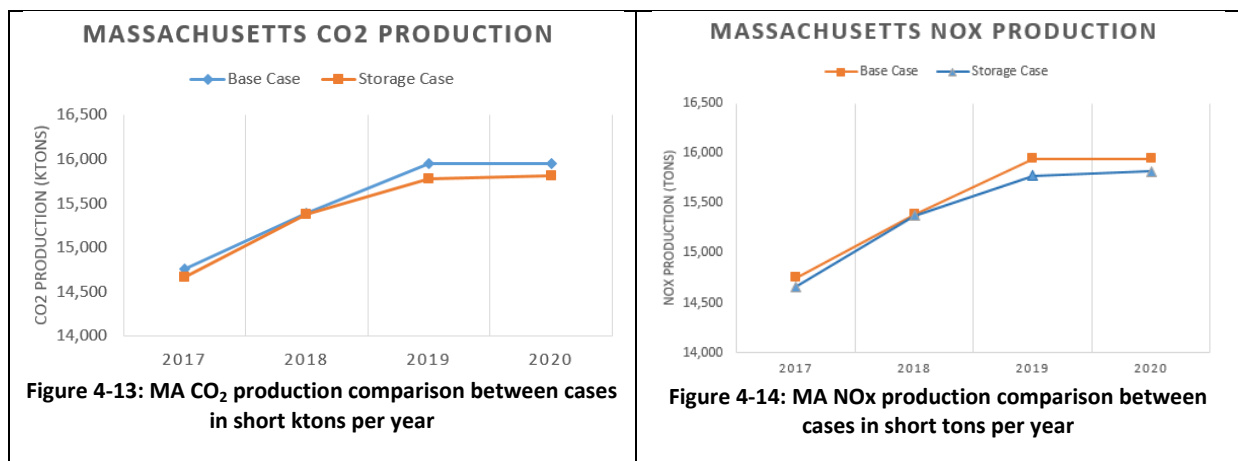


Figure 4-12: Storage used to Reduce Ramping.

4.9.4.2 Emissions Reductions

In Chapter 2 there is a discussion of the fuel mix of energy generating sources in Massachusetts. Natural gas is the primary fuel in ISO-NE, accounting for 48% of the existing generation mix, while oil and coal account for 6%.¹²⁶ Thus, fossil fuels account for approximately 54% of the fuel mix, providing a large opportunity for energy storage to increase the operational efficiency and decrease GHG emissions in Massachusetts.

The model's estimate of CO₂ and NO_x emissions with and without energy storage over the study's 5-year analysis is illustrated in Figure 4-13 and Figure 4-14.



The addition of 1,766 MW of energy storage is estimated to save 1.06 MMT CO₂e over a 10 year period. This estimated 10 year amount of GHG emissions is the equivalent of more than 223,000 cars off the road for one year. The estimated 10 year CO₂ emissions reduction contributed to a portion of the wholesale electricity cost reduction of \$197 million because of lower compliance costs.

¹²⁶ ISO-NE, Resource Mix; <http://www.iso-ne.com/about/key-stats/resource-mix>

4.9.5 T&D Cost Reduction

Benefit Description	Ratepayer Savings
T&D Cost Reduction Energy storage: <ul style="list-style-type: none"> reduces the losses and maintenance of system provides reactive power support increases resilience defers investment 	\$305M

4.9.5.1 Transmission and Distribution Deferral Benefits

In general, energy storage contributes to more efficient operation of transmission and distribution (T&D) assets by transmitting and storing energy closer to the load center at night when the T&D assets are less utilized from lower demand, and releasing this stored energy during times of peak demand when the lines would otherwise be under a lot of stress from moving increased amounts of electricity through the system. This decreased thermal and voltage stressing of the assets extends the life of existing T&D equipment, avoiding the need to upgrade electrical T&D equipment. This benefit also helps to improve resiliency of the system in case of sudden changes in the system conditions.

For example, Figure 4-15 illustrates the annualized hourly flow in 2020 (i.e. hourly flow summed across 2020) for the Boston Imports interface. The blue line shows that the hourly import flow into Boston without energy storage continues to increase up until the peak afternoon/evening hours. The red line shows decreased annualized energy flow into Boston between the peak hours of 3 PM and 9 PM. This increased availability in capacity during peak hours was made possible through the energy storage transmitting electricity into Boston overnight when load was low and the T&D assets were less utilized, and releasing this stored energy during times of peak demand the next day where the blue line peak was previously seen.

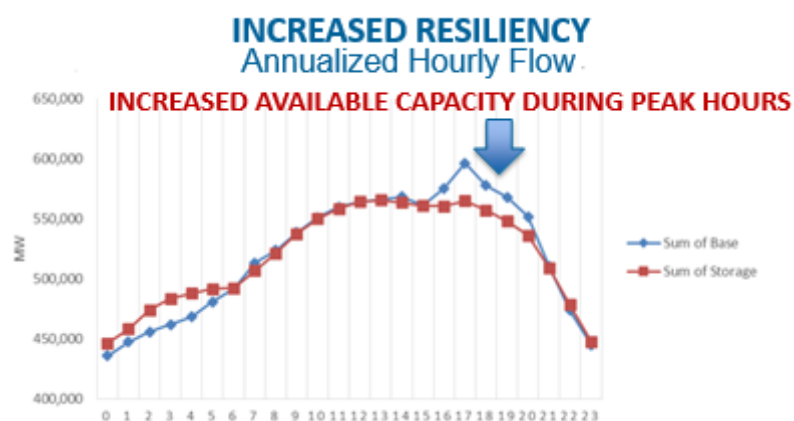


Figure 4-15: Boston Imports with and without Storage

Figure 4-16 shows that one of the energy storage systems considered in this study is located at the anonymized Substation E4Z9. The considered storage power capacity at this substation is 27.76 MW and the maximum power demand at the Substation E4Z9 is 80 MW. The orange line in the figure shows the annual energy passing through the transformer located at the Substation E4Z9 without energy storage and the blue line shows that with the addition of energy storage, the electricity is moved into Boston at night during the hours of midnight to 6 am when there is less load, and released the next day during the peak times of 4 to 9 pm, decreasing the energy passing through the transformer during those peak hours. This shifting and storing of electricity at night when there is low utilization of the transformer reduces the thermal stress on the system, as well as the voltage stress on the T&D equipment.

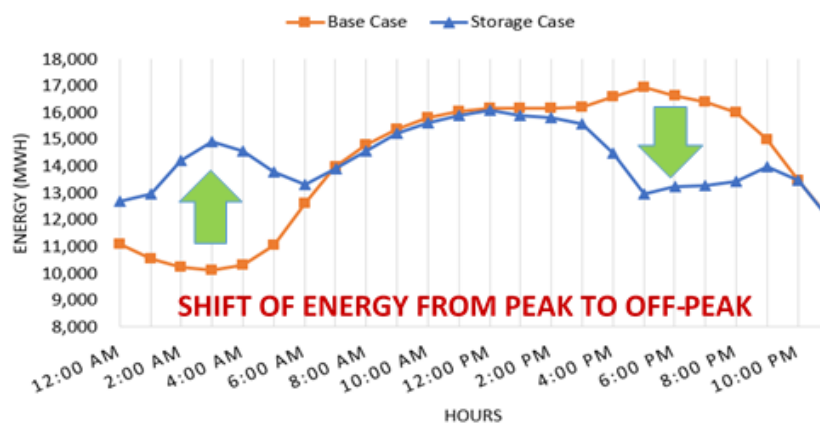


Figure 4-16: Efficient utilization of a transformer by storage systems

Table 4-5 summarizes the change in energy utilization during off-peak and peak hours with the addition of energy storage. The annual peak energy is reduced by 16 GWh and it is shifted to the off-peak time window. Moreover, the peak power is reduced from 80 MW to 72MW by this time shifting of energy.

	Base	Storage	Delta (Storage-Base)
Off-peak Energy (MWh)	75,907	96,426	20,519
Peak Energy (MWh)	127,216	110,389	(16,827)
Max (MW)	80	72	(8)

Table 4-5: Utilization of a transformer after deployment of energy storage

4.9.5.2 Storage Provides Critical Power System Reliability

In ISO-NE's recent needs assessment for zones within Massachusetts, there are time-sensitive transmission needs which include 36 time-sensitive voltage violations on elements at or below 115kV and 12 time-sensitive non-convergence power flow problems, as well as dozens of non-time-sensitive voltage needs. Energy storage can provide real and reactive power support to help eliminate voltage violations and solve power flow non-convergence, which can save millions of dollars from the avoidance of transmission upgrades. Readily available local reactive power source improves the power quality in terms of serving loads within acceptable voltage limits. Poor power

quality, most clearly understood as lights flickering due to voltage fluctuations, can cause serious damage to many household electronics.

Energy storage provides more flexibility in the way the power grid system responds to transmission outage scenarios and conditions. Figure 4-17 shows two scenarios (with and without energy storage) during a transmission outage. The remote power plant has a cheaper electricity price than the local, more expensive power plant, therefore, in the scenario without energy storage, the outage results in all of the electricity transmission being shifted to the remaining transmission line connecting the remote power plant to the load center. This causes that line to become overloaded and be at risk of load shedding.

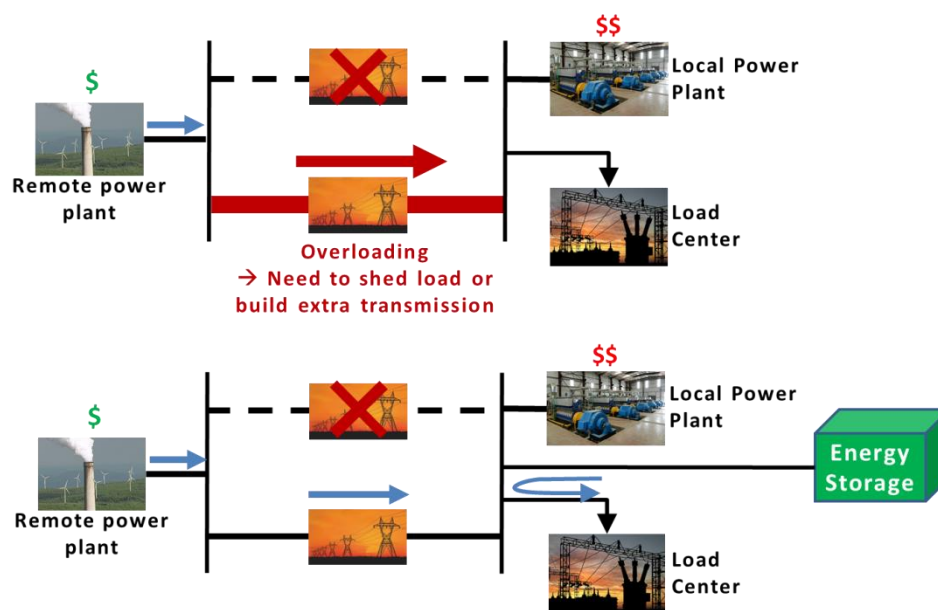


Figure 4-17: System Response to Transmission Outages

The scenario with energy storage shows that, during an outage, the energy storage is able to discharge its stored electricity to the local load center, avoiding the utilization and overloading of the transmission line connecting the remote power plant to the load center as well as avoiding power generation from the local and expensive unit. These benefits reduce the startup cost by avoiding the start of an expensive power plant, the price of electricity by reducing the generation from an expensive source, and the GHG emissions by avoiding the generation from inefficient power plants. The avoided cost of transmission upgrades to improve the power system reliability with the deployment of energy storage systems contributes to the total energy cost reduction of \$305 million.

4.9.6 Distributed Renewable Generation Integration Cost Reduction

Benefit Description	Ratepayer Savings
Integrating Distributed Renewable Generation Cost Reduction Energy storage reduces cost in integrating distributed renewable energy by: <ul style="list-style-type: none"> • addressing reverse power flow at substations • avoiding feeder upgrades at substations 	\$219M

Energy storage contributes to renewable integration in multiple ways which are already captured in the above benefit categories. These are described further in the following sections. This benefit description identifies an incremental benefit of renewable integration at the distributed level that is not already captured, and amounts to \$219 M.

4.9.6.1 Solve Reverse Power Flow Problem Caused by Distributed Generation

Reverse power flow is an excess of power flowing from the solar generator into the grid, which may damage the grid's protective systems. This may occur during times of light load and high solar generation and protection systems are not designed for this overload. Distributed solar is growing in Massachusetts, but the projects seeking interconnection of distributed generation on 13 kV lines with over 3 MW of distributed solar already installed will likely face costly distribution upgrades due to reverse power flow concerns during minimum load periods. Upgrades and system modification to feeders and transformers can substantially increase the costs of deploying a distributed generation (DG) project as well as create delays to fulfill interconnection requirements.

Using energy storage on the distribution side of the system will eliminate reverse power flow concerns by charging with the solar surplus (seen in the green portion of Figure 4-18) and discharging during times of high demand (seen in the red portion of Figure 4-18). Eliminating the reverse power flow concerns will enable more solar to be integrated without expensive distribution system upgrades. Energy storage will also enable additional solar to be added to the distribution system, further reducing the system peak.

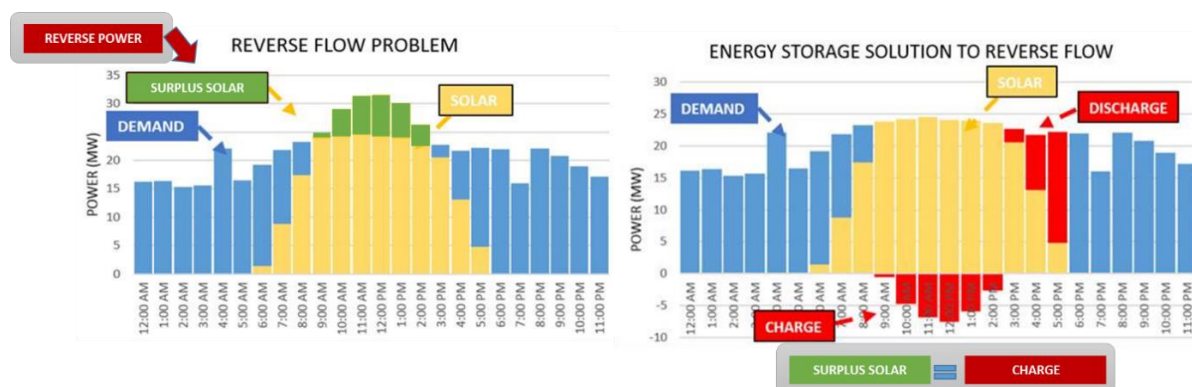


Figure 4-18: Reverse power flow problem solved with storage

4.9.7 Over-Arching Renewable Integration Benefits That Are Captured in Multiple Benefit Categories

Energy storage is an important solution to the reliability challenges associated with renewable integration. Below is a description of some of the over-arching ways that energy storage helps with renewable integration on the power grid. These benefits are already quantified as part of the benefit categories described above.

4.9.7.1 Storage Helps Renewable Integration

Figure 4-19 shows that the renewables generation solar/wind profiles (shown in yellow and blue) often do not line up with the load profile throughout the day. This means that the hours that the sun is shining or the wind is blowing to generate renewable energy are not always the same hours during which people are using the highest amount of electricity.

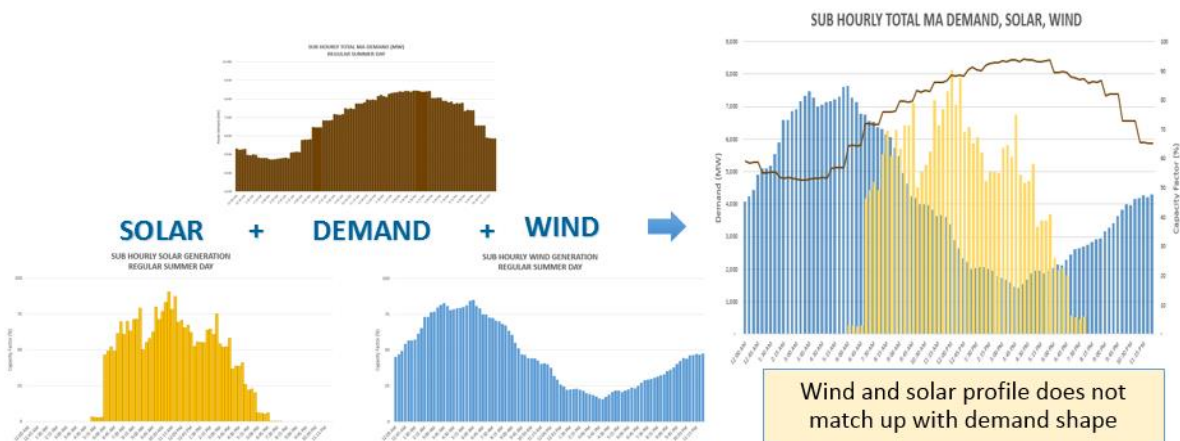


Figure 4-19: Comparison of renewables profiles with the load profile

Energy storage can solve this problem by storing renewable energy at times of low demand and discharging during high demand periods when energy cost is high but there is not necessarily any renewable energy being produced (for solar energy this time period would be during the hours after sunset and for wind energy this time period would be during the daytime when wind speeds are lower).

4.9.7.2 Time Shift of Renewables and Peak Reduction

Figure 4-20 illustrates the ability of storage to create greater peak shaving when coupled with solar versus when solar is used alone. As can be seen from the figure, solar reduced system load from the black curve to the yellow curve, and the yellow area is the capacity of peak reduction contributed by solar generation. Storage can further reduce the peak demand in addition to the solar reduction as shown in the figure from the yellow curve to the red curve by time shifting of energy. Storage can be charged at night and non-peak time during the day as shown in the red area, and be discharged during peak time when the energy price is high to provide peak reduction for most of the hours after sunset. Energy storage can also provide more stable ramping for system operations. In addition to the system operator benefits, the deployment of energy storage will minimize the need to meet the peak with more expensive peaking generation units, which can further reduce the wholesale electricity market costs.

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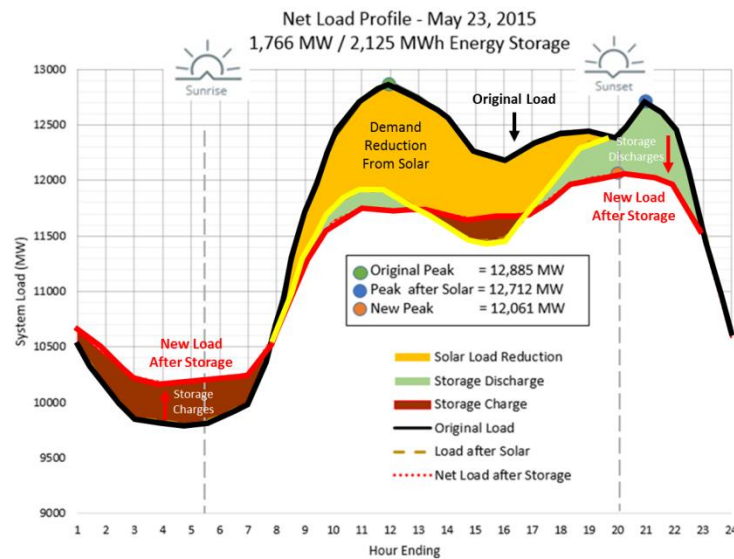


Figure 4-20: Storage enables peak shaving of the load and time-shifting of solar¹²⁷

4.9.7.3 Provide Flexible Capacity to Integrate More Renewable

Day-ahead hourly and real-time sub-hourly simulation results for a regular day in 2020 are shown in Figure 4-21 and Figure 4-22. The red bars indicate the energy storage charge (above the red line) and discharge (below the red line), and the middle dotted yellow line indicates the system demand with the addition of energy storage. It can be seen from the figure that energy storage allows more efficient market operations by charging at a low energy cost and discharging at a high energy cost. Meanwhile, energy storage provides the ability to integrate more renewables into the system with its fast response to intermittency. This means the energy storage can quickly inject energy into the grid when there is a dip in the solar energy generation cause by a passing cloud or a storm.

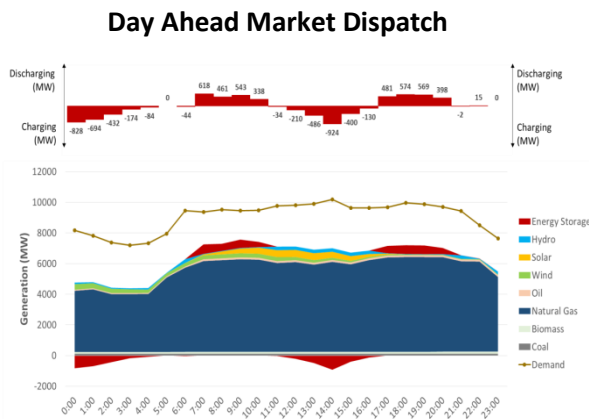


Figure 4-21: Hourly Market Operations with Energy Storage

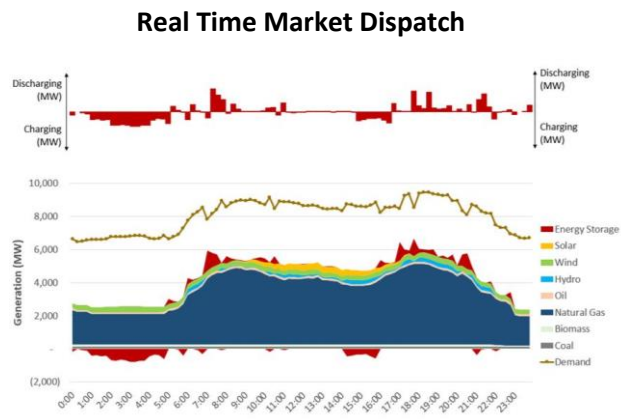


Figure 4-22: Sub-hourly Market Operations with Energy Storage

¹²⁷ Modified from ISO-NE, *State of the Grid - 2016*, January 26, 2016; http://www.iso-ne.com/static-assets/documents/2016/01/20160126_presentation_2016stateofthegrid.pdf

Available storage capacity also gives the system more flexibility to respond to forecast errors for weather, transmission and generation outages, demand, wind and solar generation that would otherwise cause a dip in the amount of energy being generated.

4.9.8 Utilization of Canadian Imports

The deployment of energy storage in Massachusetts will potentially enable a higher line transfer capability within voltage and thermal limits as night-time transfers of power can occur for existing and future intertie assets. This allows for better utilization of existing and future electricity import lines from Canada, which can consequently increase imports during off-peak hours when the price of electricity is low to store electricity in Massachusetts and sell the electricity during peak hours. Storage will also enable better utilization of existing Quebec and New Brunswick lines as shown in Figure 4-23. Due to voltage concerns and transient stability limitations, the allowed maximum capacity of the imports is well below the thermal limit of the lines.

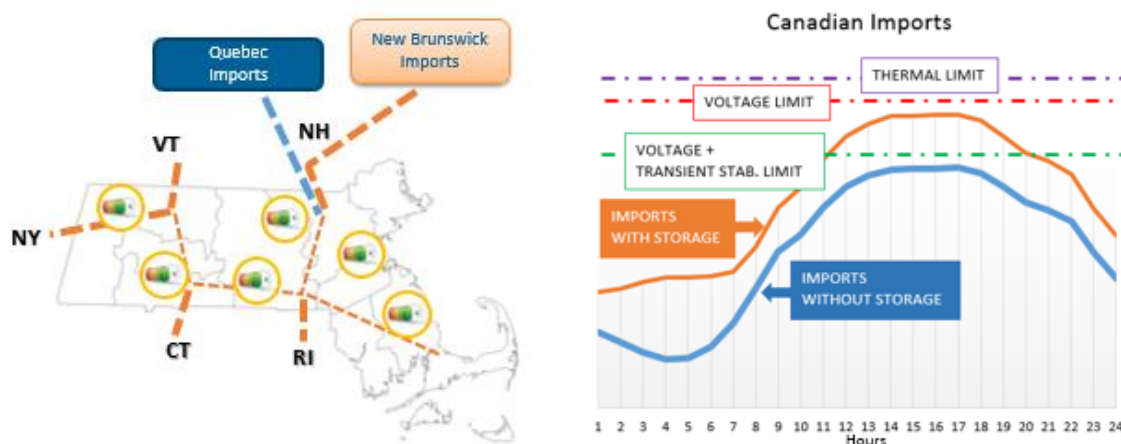


Figure 4-23: MA interconnections and impact of storage on Canadian imports

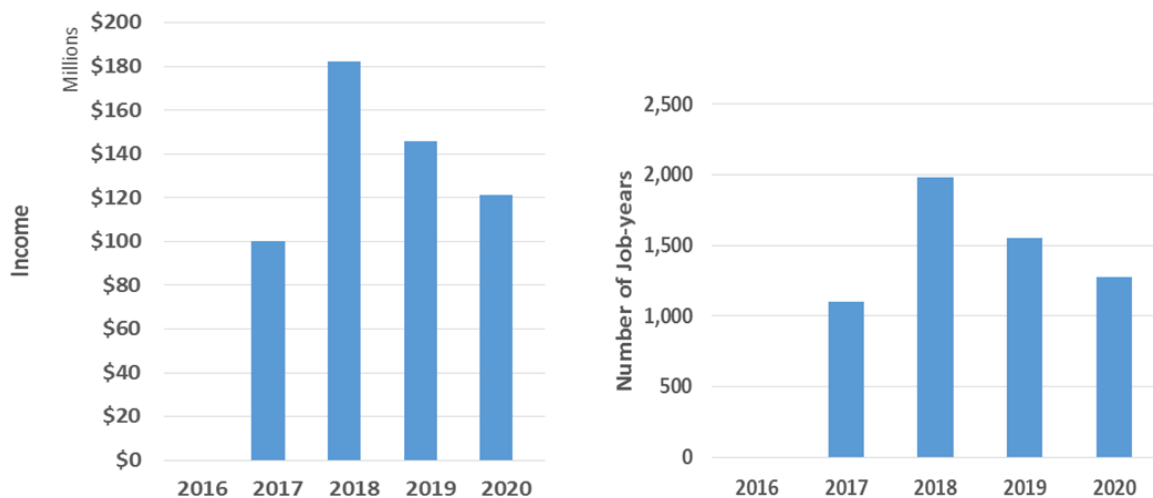
There could be a transient stability benefit to storage by increasing the import capability from any Quebec imports because advance storage can respond within 20 milliseconds. However, a detailed transient and voltage analysis would be required to confirm this. The benefit of increased utilization of energy imports is an example of the unquantified additional benefits that energy storage could provide to MA. These benefits are captured in the model and their quantitative value is already included in the efficiencies described in the above benefit categories.

4.10 Storage Economic Development Impact Study

As part of the current analysis, an economic impact model known as IMPLAN was used to assess the economic impact of incremental investment in energy storage development in Massachusetts. The evaluation entailed examining the components of the energy storage supply chain to identify the particular industries that may be impacted by an expansion of investment in energy storage facilities. Appendix B provides details on the IMPLAN model, the inputs and assumptions used to run the model and the detailed results of the assessment.

Based on the optimal energy storage deployment scenario of 1,766 MW over 5 years (2016-2020) described above, the annual economic development impacts on Massachusetts were analyzed by studying the effects on employment (in terms of “job-years”), income (which is the sum of all forms of employment income, including employee compensation in terms of wages and benefits and proprietor income), and the dollar level of value added (also known as gross state product or “GSP”).

The integration of energy storage has a substantial economic impact in Massachusetts. The economic impact of 1,766 MW of energy storage deployment in the Commonwealth shows the creation of 5,911 job-years (where 1 job year is defined as one job for one year) over the 5-year study period (2016-2020) as shown in Figure 4-24 (b). Figure 4-24 (a) presents the impact on labor income which is approximately \$549.55 million over the 5-year period (2016-2020).



Massachusetts Labor Income Impacts 2015-2020

Figure 4-24: (a) Massachusetts Labor Income Impact, (b) Massachusetts Employment Impacts

4.11 Conclusion

Through this modeling effort, it was found that up to 1,766 MW of energy storage deployed at appropriate locations in the state, and with sizes defined by system requirements at these locations, could optimize the benefit to the electricity system as modeled.¹²⁸ The benefits from deploying 1,766 MW of storage from now through 2020 include:

- A total 10-year storage value of \$3.4 billion to Massachusetts
 - \$2.3 billion in system benefits
 - \$1.1 billion in potential economic value of market sales
- An additional \$250 million in regional system benefits to the other states in ISO-NE, yielding consistently lower annual average energy price across all ISO-NE zones.
- Reduction of Massachusetts' peak demand by almost 10%.
 - This is equivalent to avoiding the need of electricity from 908 MW of peaker plants to serve the peak load in Massachusetts.

¹²⁸ The analysis did not explicitly reflect a likely expansion of solar photovoltaic policy beyond the SREC-II program and resultant increased solar penetration in Massachusetts; a yet-to-be-defined increased solar penetration might benefit from an even higher optimal energy storage deployment.

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- Reduction in CO₂ gas emissions by more than 1.06 million metric tons of carbon dioxide equivalent (MMTCO₂e) in 10-year time span.
 - This CO₂ gas emission reduction is the equivalent of 223,000 cars off the road for one year.

The modeling work described in this chapter clearly demonstrates that energy storage deployment can provide substantial benefit to Massachusetts' ratepayers. The total estimated cost to deploy 1,766 MW storage is \$968M - \$1,355M, and the ten years estimated system benefit of this investment is about \$2.3 billion, resulting in a Benefit-Cost ratio of 1.7 – 2.4. At the projected level, however, revenue mechanisms are not yet available that fully recognize the net system benefits that energy storage can provide. As described in Chapter 6, regulatory and policy initiatives are being advanced in other states that recognize and seek to correct this discrepancy. In subsequent chapters we propose a roadmap for Massachusetts to facilitate the deployment of energy storage within the state to achieve optimal system benefits to the rate payers.

5 Use Cases of Specific Applications in Massachusetts

5.1 Introduction

While the grid optimization modelling described in Chapter 4 shows the benefit of 1,766 MW/ 2,125 MWh of advanced energy storage deployed across the Massachusetts grid over the next five years, there is only a limited amount of advanced storage actually operating in the Commonwealth today. In order to describe the many market opportunities for energy storage in Massachusetts, the Study Team identified multiple Use Cases that provide a diverse range of business opportunities.¹²⁹ These opportunities exist in both wholesale and retail markets, include transmission, distribution, and customer-sited resources, and involve a variety of types of organizations, both utilities and non-utilities. The Use Cases highlight how energy storage can address specific energy needs including managing energy costs, reducing peak demand, increasing reliability, and providing resiliency.

This chapter evaluates the economics for growing storage in Massachusetts by providing cost benefit modeling of ten specific application Use Cases for using advanced energy storage. For each Use Case the Study Team evaluated the economics for making the investment in the storage by assessing:

- (1) The value the storage owner/developer can monetize through existing market mechanisms, and
- (2) The system benefits that would accrue to Massachusetts ratepayers should the investment in storage be made.

By examining both the value the storage resource could earn through market mechanisms, as well as the benefits the storage resource would provide the system through reductions in system costs, a determination can be made as to whether it would be cost-effective to Massachusetts ratepayers to utilize storage for each Use Case.¹³⁰

The economic Use Case evaluation shows that the biggest challenge to achieving more storage deployment in Massachusetts is that there is a lack of clear market mechanisms to transfer some portion of the system benefits (e.g. cost savings to ratepayers) created by having the storage deployed on the electric grid to the storage project developer. Each Use Case was evaluated with techno-economic modelling to comprehensively value the benefits of energy storage in each specific application. While the modeling results clearly show there are substantial net benefits to ratepayers from increasing the amount of storage deployed in Massachusetts, the revenue mechanisms that would encourage investment in storage are, in many cases, either not yet developed and/or there are market and regulatory barriers preventing storage from monetizing the value it creates for the electric grid. Without a means to be compensated for the value the storage

¹²⁹ A Use Case is defined as an integrated set of grid services performed by a technology at a distinct site or location on the grid

¹³⁰ This approach is similar to the methodology used to evaluate investment in energy efficiency in Massachusetts. Massachusetts state law, M.G.L. c.25, §21, the Green Communities Act (the "Act"), requires that investor-owned utilities and approved municipal aggregators ("Program Administrators") seek "...all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply." The DPU Guidelines §3.4.3 provide for Total Resource Cost (TRC) benefit/cost assessment methodology, in which the total program costs are compared to the total benefits attributed to the net energy savings attributable to the programs (avoided electric generation and gas supply costs; avoided transmission and distribution costs, and energy and capacity demand-reduction induced price effects) to determine cost-effectiveness. See Guidelines Order, Jan. 2013; <http://www.mass.gov/eea/docs/dpu/electric/dpu-11-120-a-phase-ii.pdf>

resource provides to the system, investors will simply not invest in building storage projects in Massachusetts even though doing so would result in significant benefits to ratepayers that substantially outweigh the cost of investment. This limit on existing energy storage opportunities prompts a fresh look into how energy storage's complete benefits can be correctly accounted for in the wholesale and retail market electricity markets, as well as by regulators and policy makers.

This chapter is organized by Use Cases, showing how storage developers can capture value from owning, operating, or contracting for services from energy storage resources. The benefits to the electric system are discussed and a cost-benefit analysis presented to inform an understanding of the cost effectiveness of energy storage in each Use Case. Finally, this chapter will briefly discuss current challenges to realizing existing and potential opportunities. More details of the challenges and proposed solutions can be found in Chapters 7 and 8.

5.2 Overview of Use Cases

Based on feedback from stakeholders and research into the existing and potential market opportunities for energy storage, ten Use Cases (Figure 5-1) were selected to analyze how energy storage could provide value in the wholesale market, to utilities, to ratepayers, and to the electric power system. Table 5-1 provides more detailed description of each Use Case.

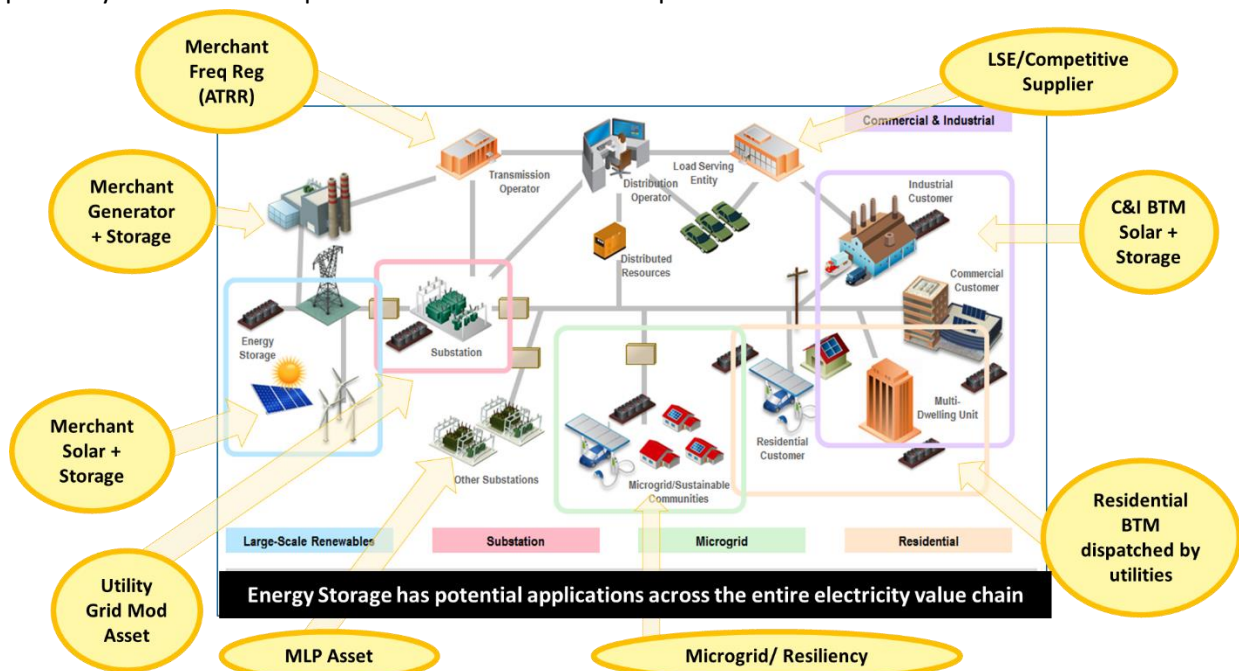


Figure 5-1: Energy Storage Use Cases¹³¹

¹³¹ The graphic highlights nine Use Cases as the Residential Storage and Residential Storage Dispatched by the Utility are the same location in the energy system.

<i>Use Cases</i>		
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		The storage systems would be owned and dispatched by the Investor Owned Utilities, i.e. Unitil, Eversource, and National Grid. The systems would be likely located at distribution substations with the locations selected by the IOUs to address local needs including high demand, reliability conditions, and renewables integration.
Municipal Light Plant (MLP) Asset		The storage systems would be owned and operated by a Massachusetts MLP and located within the municipality. Uses for the systems would be to lower the municipality's peak demand, capacity and transmission costs, as well as to provide local resiliency.
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		In Massachusetts LSE's provide the energy supply portion of a ratepayers IOU electricity bill. LSE's either offer competitive supply direct to consumers or provide IOU's basic service supply. An LSE would utilize storage as a means to hedge energy costs, purchasing low cost energy and providing stored energy during times of high energy cost, and to sell services in the ISO-NE markets.
Behind the Meter	C&I Solar Plus Storage	A commercial or industrial customer with on-site solar would own and operate a storage system to better utilize and firm the energy from the solar installation, allowing the C&I customer to reduce their reliance on grid energy during peak times, decreasing demand charges, and capturing the full value of their solar energy regardless of net-metering structure.
	Residential Storage	A behind the meter residential storage system can be owned by the customer and located within the home for resiliency during grid outages.
	Residential Storage Dispatched by Utility	Similar to the above Use Case, the storage system would be located in the home and provide resiliency but the utility would be able to dispatch the system to capture the grid benefits of peak demand reduction. The system could be owned by either the utility or the customer.
Merchant	Alternative Technology Regulation Resource	A merchant storage developer operates the storage system as an Alternative Technology Regulation Resource (ATRR) to provide frequency regulation in the ISO-NE market.
	Storage + Solar	A solar merchant project developer operates a storage system co-located with the solar resource to better integrate the solar generation into the energy market. The storage system allows the project developer to sell "dispatchable" and firm solar energy better aligned with peak demand, as well as ancillary services.
	Stand-alone Storage or Co-Located with Traditional Generation Plant	A gas or other fossil fuel generator would own and operate a storage system on site to allow the plant to run at optimal heat rate levels, utilizing the storage to provide fast ramping response and ancillary services.
Resiliency/Microgrid		A municipality or another localized energy user such as a university campus or medical center owns and operates the energy storage systems to provide peak demand reduction, reducing capacity or demand charges, while reducing the costs to provide backup power in the event of an outage.

Table 5-1: Use Case Descriptions

5.3 Overview of Cost Benefit Modeling

By examining both the value that the storage resource could earn through market mechanisms, as well as the benefits the storage resource would provide the system through reductions in system costs, a determination can be made as to whether it would be cost-effective to Massachusetts

ratepayers to utilize storage for each Use Case. For each Use Case the Study Team evaluated the economics for making the investment in the storage by assessing:

- (1) The value the storage owner/developer can monetize through existing market mechanisms, and
- (2) The system benefits that would accrue to Massachusetts ratepayers should the investment in storage be made.

For item number 1, the Study Team utilized the Energy Storage Valuation Tool (ESVT)¹³² developed by the Electric Power Research Institute (EPRI) to model the value the storage owner/developer can monetize through existing market mechanisms for each Use Cases under consideration.^{133;134} ESVT is a financial simulation model that evaluates the revenue that can be obtained by technically feasible, grid-connected energy storage applications. However, since the ESVT is a price-taker type of model without a network representation of the Massachusetts electric grid, it does not have the capability to directly measure the additional second-order system level or system benefits for the Massachusetts grid from:

- Reducing the price paid for electricity consumption
- Reducing peak demands
- Deferring capital investments in new capacity
- Reducing greenhouse gas (GHG) emissions (reducing the effective cost of compliance)
- Reducing the cost to integrate renewable generation
- Increasing the grid's overall flexibility, reliability and resiliency

For item 2, the Study Team utilized the Alevo Analytics methodology as presented in Chapter 4 to analyze the system benefits that would accrue to Massachusetts ratepayers should the investment in storage be made.

As an example, consider the use of behind-the-meter storage by a commercial and industrial (C&I) customer that already has on-site solar PV generation. In order to analyze the value of installing the storage resource to the C&I customer, the Study Team used ESVT to model the avoided costs and revenue streams of an energy storage project, targeting time of use tariff management, demand charge reductions, and capturing the full value of the solar generation. The second analysis contains the system benefits identified in Chapter 4 with Alevo Analytics, attributed specifically to this Use Case. The system benefits that are identified in the Alevo Analytics analysis are not captured in the ESVT revenue streams. After considering and removing any potential for overlapping or double counted benefits, the analyses' benefits are then stacked together and compared to the cost of deployment.

This hybrid approach aims at providing the stakeholders with information on the full value of energy storage, with the understanding that not all of the benefits identified can be readily monetized by the project owner. Special attention was given to avoiding double-counting the benefits when

¹³² EPRI, Energy Storage Valuation Tool (ESVT) Version 4.0;
<http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?productId=000000003002003839>.

¹³³ Strategen Consulting, LLC supported the baseline analysis for Customized Energy Solutions, Ltd based on information received from MassCEC/DOER. This analysis includes an application of the Energy Storage Valuation Tool (ESVT) Version 4, with all reliance thereon to be at evaluator's sole risk without any endorsement by the Electric Power Research Institute, Inc.

¹³⁴ While Strategen Consulting, LLC conducted a preliminary cost-benefit analysis in ESVT, the Use Cases presented in Chapter 5 were supplemented with calculations of additional benefits and revenue prepared by Alevo Analytics. All reliance thereon is at the evaluator's risk without any endorsement by Strategen Consulting, LLC.

combining the two sets of data. This was done by carefully examining the benefits categories in both models and reconciling potential overlaps to the greatest extent possible. This hybrid modeling is illustrative of how the full value of energy storage can be counted and should be considered a representative example of the economics of each Use Case given that each Use Case contains multiple assumptions and projections around costs and revenue.

5.3.1 Cost Benefit Analysis

The key findings from the ten Use Cases include the cost of a project, the currently monetizable value to the project owner, additional value that could be captured with market changes, and the expected system benefits. By examining both the value the storage resource could earn through market mechanisms, as well as the benefits the storage resource would provide the system through reductions in system costs, a determination can be made as to whether it would be cost-effective to Massachusetts ratepayers to utilize storage for each Use Case. The benefit to cost ratio (BCR) reflects all the Use Case's benefits, whether currently monetizable or not, compared to the total cost of all the Use Case installations. The analysis resulted in BCRs exceeding one in most Use Cases (Table 5-2) when all benefits are taken into consideration. Residential storage is the only Use Case with a BCR under one because the only achievable benefit is customer resiliency. Because residential customers do not have time of use rates or demand charges, there is no incentive or method for the storage to provide grid benefits such as peak demand reduction. Instead, a second residential Use Case is included to show that when the utilities are given control of the storage system's dispatchability, a residential energy storage system can provide both the resiliency benefits and the grid benefits. This expanded Use Case allows the BCR to exceed one.

Use Case		Estimated Share of 1766 MW Recommendation		Millions \$		Benefit/Cost Ratio
		%	MW	Combined Benefits (Market Revenue + System Benefits)	Cost	
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		40%	707	1301	387	3.36
Municipal Light Plant (MLP) Asset		10%	177	446	97	4.60
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		8%	141	158	77	2.05
Behind the Meter	C&I Solar + Storage	6%	106	103	58	1.78
	Residential Storage	4%	71	19	53	0.49
	Residential Storage Dispatched by Utility	5.5%	96	129	39	2.43
Merchant	Alternative Technology Regulation Resource	1.5%	28	45	15	3.00
	Storage + Solar	10.5%	185	373	102	3.66
	Stand-alone Storage or Co-Located with Traditional Generation Plant	9.5%	168	405	92	4.40
Resiliency/Microgrid		5%	87	133	48	2.77

Table 5-2: Summary of Cost-Benefit Analysis of All Use Cases

However, as discussed in detail below, while the all-in benefits outweigh the cost of investment, in many Use Cases the value that the storage owner/developer can monetize through existing market mechanisms and regulatory constructs is too small for the investment to be made by the storage owner/developer even though doing so would result in net benefits to electric ratepayers. To realize the system benefits modeled, mechanisms are needed to bridge the gap between the cost of energy storage and the revenue captured by the storage owner/developer.

5.4 Cost Benefit Analysis Methodology

5.4.1 Alevo Methodology

As discussed earlier, the final Use Cases presented represent a hybrid approach combining the modeled results from ESVT and those from Alevo Analytics. For a more complete overview of the Alevo Analytics modeling method, please see Chapter 4. The system benefits categories analyzed by the Alevo Analytics model are recapped here in Table 5-3.

Benefit Categories	Benefit Description
Wholesale Market Cost Reduction	Energy storage can be a flexible and rapid tool that helps generators operate more efficiently through: (1) less wear and tear, (2) less start up and shut down costs, and (3) reduced GHG emissions.
Ancillary Services Cost Reduction	Energy storage would reduce the overall costs of ancillary services required by the grid system through: (1) frequency regulation, (2) spinning reserve, and (3) voltage stabilization
Energy Cost Reduction	Energy storage replaces the use of inefficient generators at peak times causing: (1) reduced peak prices which (2) reduces the overall average energy price. This also benefits the natural gas supply infrastructure.
T&D Cost Reduction	Energy storage (1) reduces the losses and maintenance of system, (2) provides reactive power support, (3) increases resilience, and (4) defers investment
Increased Renewable Integration ¹³⁵	Energy storage reduces cost in integrating renewable energy by (1) addressing reverse power flow and (2) avoiding feeder upgrades
Reduced Peak	Energy storage can provide peaking capacity to (1) defer the capital costs of peaker plants and (2) reduced cost in the capacity market

Table 5-3: System Benefits Categories from Alevo Analytics

5.4.2 Key Assumptions in ESVT

The Energy Storage System model assumes a generic 1 MW Lithium Ion battery system¹³⁶ with a 1-hour discharge duration (1MW/1MWh). To streamline/simplify the analysis, and to set up an apples-to-apples comparison across multiple Use Cases, the Study Team selected this single representative technology. This allows the reader to evaluate Use Cases without the added complication of technology choices.

Based on industry experience with Li-Ion energy storage projects, the Use Cases under consideration typically include a 10-year project life for the battery paired with a 10-year end of life (EOL) performance warranty. These general project terms were simulated in the model. The warranty is priced at \$20/kW-yr. These terms remove the need for estimating battery replacements, assigning this financial obligation to the technology/warranty provider. If multiple technologies were included in the analysis, replacement schedules would have to be considered to maintain similar project lives across technologies and Use Cases.

The following assumptions were made about the energy storage system, based on current industry standards.

¹³⁵ As discussed in Chapter 4, Increased Renewable Integration is only the incremental value of renewable integration at the distributed level, and addresses reverse power flow and avoiding feeder upgrades. The more comprehensive benefits of renewable integration are captured in the other benefit categories.

¹³⁶ Lithium Ion battery was assumed since it is the most versatile technology when it comes to participating in different Use Cases. Although other technologies may have the potential to suit the application, they would require adjustments to the inputs. The fact that these technologies were not considered should not prevent their consideration for grid deployment.

Lithium Battery Assumptions¹³⁷	
Maximum Plant Life (Years) ¹³⁸	10
Discharge Duration (Hours) ¹³⁹	1
Depth of Discharge ¹⁴⁰	0.8
Capacity (kW)	1,000
AC-AC Roundtrip Efficiency ¹⁴¹	0.85
Capital Cost (\$/kWh) ¹⁴²	600
Fixed O&M (\$/kW-Year) ¹⁴³	10

Table 5-4: Energy Storage Performance and Cost Assumptions¹⁴⁴

For evaluating the market services and utility applications, the following information was collected for 2015 from ISO-NE¹⁴⁵ market reports, a representative Massachusetts utility, and EPRI research:

- 8760 hourly Day Ahead and Real Time System Energy Prices
- 8760 hourly Regulation and Operating Reserve prices
- G-3 Time-of-Use Rates from National Grid
- ESVT Default Values

For some of the Use Cases, it was assumed that the energy storage systems would be installed by a third party installer or an independent power producer (IPP) and it would be financed through equity and debt. This was done to simplify financial modeling comparisons from one Use Case to another for readers. For federal taxes, a project owner is allowed to depreciate the value of the storage asset over a specified time as defined by the asset type. This IRS Modified Accelerated Cost Recovery System (MACRS) guideline defines a term of 7 years for energy storage projects and, for this analysis, 2015 was assumed to be the depreciation start year.

¹³⁷ Assumed to Discharge at 1000kW/1000kVA for 1MW system.

¹³⁸ Energy storage replacement was not considered since most warranty periods last 10 years which would cover any battery replacements that may take place during its plant life. Further, we are looking only at one technology for the Use Case and not comparing against other technologies.

¹³⁹ ESVT uses the Discharge Duration input to calculate the Energy Capacity of the energy storage system.

¹⁴⁰ Accounts for Minimum State of Charge of 20%.

¹⁴¹ IRENA, Case Study 1: Alaska, U.S., Island/Off-grid Frequency Response;
http://www.irena.org/DocumentDownloads/Publications/IRENA_Battery_Storage_case_studies_2015.pdf

¹⁴² Utility Scale Energy Storage, Energy Research and Development Division FINAL PROJECT REPORT, Feb 2015

¹⁴³ Manuel, W. (2014), Energy Storage Study 2014, Turlock Irrigation District;
http://www.energy.ca.gov/assessments/ab2514_reports/Turlock_Irrigation_District/2014-10-28_Turlock_Irrigation_District_Energy_Storage_Study.pdf

¹⁴⁴ Due to the lack of information on station power and variable costs, they were considered to be 0.

¹⁴⁵ The average Day Ahead Energy price was \$43.65/MWh while the average Real Time Energy price during the same period was \$42.79/MWh. The prices for Frequency Regulation, Spin and Non Spin were collected as well, and their average prices were \$23.49/MWh, \$2.18/MWh and \$1.55/MWh respectively.

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Financing Inputs	
Ownership Type	IPP
% Debt	40%
Debt Interest Rate	7.49%
% Equity	60%
After Tax Nominal WACC	8%
Return on Equity	10.35%
Economic Inputs	
Inflation Rate (%/Year) ¹⁴⁶	2%
Fuel Escalation Rate (%/Year)	1%
Tax Inputs	
Federal Income Tax Rate %	35%
State Income Tax Rate ¹⁴⁷ %	8%
Property Tax Rate %	0%
MACRS Term (Years)	7
% of Capital Cost Eligible for ITC ¹⁴⁸	100%
Non-Tax incentives	
\$/kW State or Local Rebate (\$/kw)	0

Table 5-5: Financial and Economic Assumptions

Single-year, hourly optimization was conducted for modeling each of the Use Cases. The performance of the energy storage technology is simulated for Year 1 using the hourly market price data and then it estimates the revenue and costs for future years using escalation rates for market prices and fuel costs. The sensitivities of certain assumptions were considered in evaluating the cost benefit analysis of each Use Case. To calculate the sensitivity of the system prices on the cost benefit analysis, it was assumed that system price decline would take place and a low and high projection of \$/kWh battery prices were made. Table 5-5 and Table 5-6 show additional cost and value assumptions. The capital cost for a storage project is assumed to be \$600/kWh in 2016, \$450/kWh in 2018, and \$300/kWh in 2020. This cost represents the installation cost for a project based both on the project's capacity and the duration. Because all of the Use Cases are represented with a 1MW/1MWh project, which may not have a long enough duration to realize a capacity payment reduction, a separate calculation was performed to determine capacity payment. To realize the capacity payment, the 1MW/1MWh project would be operated as a 0.33MW/1MWh, or a 3-hour, storage system to coincide with the peak demand period. The capacity payment calculation first takes annual system capacity value for the 1MW/1MWh system, escalates at 2% per year for 10 years, discounts to net present value, and adjusts downward by a factor of 2.2, instead of 3. To assume an equal reduction in capital cost and capacity payment does not adequately take into account the reduced cost to increase the project duration while still realizing the full capacity payment reduction.

¹⁴⁶ Average of inflation rates for US 2011 to 2014: World Bank

¹⁴⁷ Department of Revenue, Massachusetts Tax Rate for Business and Manufacturing Corporations;
<http://www.mass.gov/dor/all-taxes/tax-rate-table.html>

¹⁴⁸ Continuation of the Investment Tax Credit

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System Capacity¹⁴⁹	
System Capacity Value (\$/kW-year) ¹⁵⁰	\$114.6
Frequency Regulation	
Market Type	Combined
AGC Signal Selection	ISO NE Input Data
Distribution Investment Deferral	
Distribution Load Selection	Feeder 2 (5 MW)
Modular Installation	No
Maximum Years of Deferral	15
Distribution Load Growth	1%
Load Target	100%
Calculated Distribution Upgrade Cost ¹⁵¹	1.59M
Power Quality	
Customer Class	Industrial
Voltage Level	Secondary
Momentary Outage Costs (\$/kW)	1.4
Power Reliability	
Storage Location	Customer
Customer Class	Industrial
Retail TOU Energy Time Shift and Demand Charge Reduction	
Customer Load Selection	CEUS 500 kW (8760*10) ¹⁵²
Customer Tariff	G-3 Tariff National Grid

Table 5-6 Assumptions Regarding System Values

5.4.3 Limitations of ESVT

- The ESVT model is used to evaluate the revenue streams available to energy storage projects through market mechanisms, but does not address market saturation. The Study Team recognizes that some of the system benefits, if realized when storage is widely deployed, might change the fundamentals of the wholesale markets that would impact the revenue modeled. For example, if widely-deployed storage reduces the cost of energy by shifting renewable energy production to better align with load, the revenue of selling stored energy in the wholesale market will be reduced. The Use Cases modeled are snapshots of existing market mechanisms and do not take into account such dynamic interactions.
- The model assumed a 10-year continuation of the current market conditions at 2% annual escalation while estimating the cost benefit for each Use Case.

¹⁴⁹ Given the development time for these projects and assuming that these projects would bid into a future capacity, FCM 2018-2019 results were used.

¹⁵⁰ ISO-NE System wide Capacity Values, 2018-2019, based on FCM Results #9

¹⁵¹ Assuming Deferral value to be: 50th Percentile of \$197/kW, 90th Percentile of \$318/kW, Electric Utility Transmission and Distribution Upgrade Deferral Benefits from Modular Electricity Storage, Sandia, 2009

¹⁵² 8760 data was multiplied by 10. This was done to size the load profile to the battery size under consideration. The size of the load was kept consistent for Use Case #10

5.5 Cost Benefit Analysis Results

Presented for each of the Use Cases is (1) a description of how the participant would utilize the energy storage resource, (2) the avoided cost and/or revenue streams to the participant, (3) the benefits to the electric system, (4) the cost-benefit analysis, and (5) a brief discussion on the barriers and recommendations. In the figure accompanying each Use Case, the benefit streams are categorized into system benefits (blue), values that can readily be captured by the storage participant (green), values to the storage participant but currently not realized because of regulatory or market barriers (yellow), and the identified gap between readily-captured-values market mechanism and cost of storage (pink). The revenue gap can be overcome through various mechanisms, such as an Alternative Energy Credit, by including storage in the Alternative Portfolio Standard so it can receive Alternative Energy Credits or can be reduced or removed as the capital cost of projects decrease over time and market price signals change.

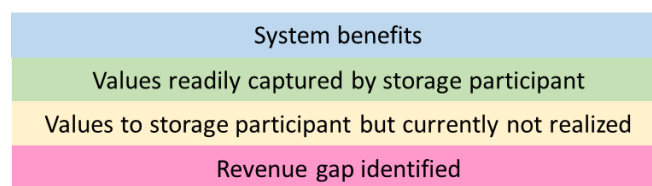


Figure 5-2: Legend for Benefit Streams in Use Cases

5.5.1 Investor-Owned Utilities (IOU) Utilizing Energy Storage as Grid Modernization Asset

Energy storage resources deployed across a utility's system provides the utility with an aggregated and flexible tool to manage peak demand, integrate renewable energy, and mitigate power outages. The IOU Use Case describes an energy storage asset located at an IOU distribution substation that is experiencing incremental load growth and increased penetration of customers with distributed energy resources (DERs). The storage resource can help defer the investment to upgrade the capacity of the distribution system by using the storage to manage load and DERs' reverse power flows at the substation.

As an example, consider a distribution line that is already at its capacity during the early evening hours of the weekday. Additionally, the service territory has an increasing population. The distribution line and the substation therefore need to be upgraded to accommodate the increasing demand especially during the early evening peak hours. Because of the long lead time required with traditional distribution upgrades, the distribution system is often upgraded in large "chunks." This creates excessive capacity in the early years after the upgrade. Energy storage assets on the other hand can be added to the system incrementally to accommodate demand growth. The utility can use the stored energy to serve the demand during peak hours, deferring the need to upgrade the distribution system. The distribution system would still need to be upgraded as demand keeps rising, but such upgrades can be done with more certainty and deferring large investments allows the utility to prioritize its resources.

In June 2014, the Massachusetts Department of Public Utilities (DPU) issued Order 12-76-B¹⁵³ (Order) requiring each investor owned utility¹⁵⁴ to develop Grid Modernization Plans (GMPs) to meet four objectives:

¹⁵³ <http://www.mass.gov/eea/docs/dpu/orders/dpu-12-76-b-order-6-12-2014.pdf>

¹⁵⁴ In Massachusetts the IOUs include Eversource, National Grid, and Unitil.

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- (1) Reduce the effect of outages;
- (2) Optimize demand which includes reducing system and customer costs;
- (3) Integrate distributed resources; and
- (4) Improve workforce and asset management.

The GMPs may include investment in advanced energy storage if supported by a comprehensive business case analysis that includes:

- (1) A detailed description of the proposed investments, including scope and schedule;
- (2) The rationale and business drivers for the proposed investments
- (3) Identification and quantification of all quantifiable benefits and costs associated with the investment; and
- (4) Identification of all difficult to quantify or unquantifiable benefits and costs

The business case summary template instructions included in the Order provides examples on how to map technologies to functions and functions to benefits.¹⁵⁵ Consistent with the benefits described in this report, and the objectives of the Order, the EPRI methodology lists the benefits in Table 5-7 of “stationary electricity storage” to smart grid projects as:

Benefits of “Stationary Electricity Storage” - EPRI Methodology	
Improved Asset Utilization	Optimized Generator Operation
	Deferred Generation Capacity Investments
	Reduced Ancillary Service Cost
	Reduced Congestion Cost
T&D Capital Savings	Deferred Transmission Capacity Investments
	Deferred Distribution Capacity Investments
Electricity Cost Savings	Reduced Electricity Costs
Power Interruptions	Reduced Sustained Outages
Power Quality	Reduced Momentary Outages
	Reduced Sags and Swells
Air Emissions	Reduced CO2 Emissions
	Reduced SOx, NOx, and PM-10 Emissions
Energy Efficiency	Reduced Electricity Losses

Table 5-7: Benefits of “Stationary Electricity Storage”

Further, the Order allows for proposed research, development, and deployment (RD&D) of new and emerging technologies, and specifically lists energy storage as a technology that can be included in “portfolio of projects.” The IOUs may propose “additional funding mechanism to support increased RD&D activities.”

All the IOUs provided energy storage projects as part of their GMPs. Eversource, as part of the Short Term Investment Plan (STIP), proposed a distribution-level Solar Plus Storage project between 3-5 MW. The project would address the integration of 20 MW of existing to 45 MW of existing and

¹⁵⁵ Examples are taken from EPRI’s 2010 report: Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects;

https://www.smartgrid.gov/files/Methodological_Approach_for_Estimating_Benefits_Costs_Smart_201007.pdf

planned of solar PV projects at a substation in the City of New Bedford serving a peak load of 36.7 megavolt amperes (MVA) in 2014. Eversource estimates that a 3-5 MW capacity storage system with 15-30 minute duration is needed to mitigate distribution level impacts of the PV output. National Grid is proposing two pilots as part of research, development, and demonstration (RD&D) budget. Their distributed energy storage proposal would analyze utility-sized battery storage used to complement renewable generation and improve power quality. A High Density Community Energy Storage Pilot proposal would explore benefits of distributed energy storage in areas with a considerable number of distributed small solar installations.

Although the utilities have already filed their GMPs, the grid modernization process is ongoing. In addition to projects already proposed, utilities are allowed to revisit their plans and update projects and budgets. For example, Eversource has notified the DPU of their willingness to revisit their GMP, noting they “may propose to update the energy storage proposal during the term of the STIP.”¹⁵⁶

Given the recent advances in energy storage technology and cost-effectiveness, it is hard to imagine a modern electric distribution system that does not include energy storage.”

- Eversource, Grid Modernization Plan 2015-08-19, p56

Figure 5-3 below models the business case analysis for IOUs to invest in energy storage as a grid modernization asset.

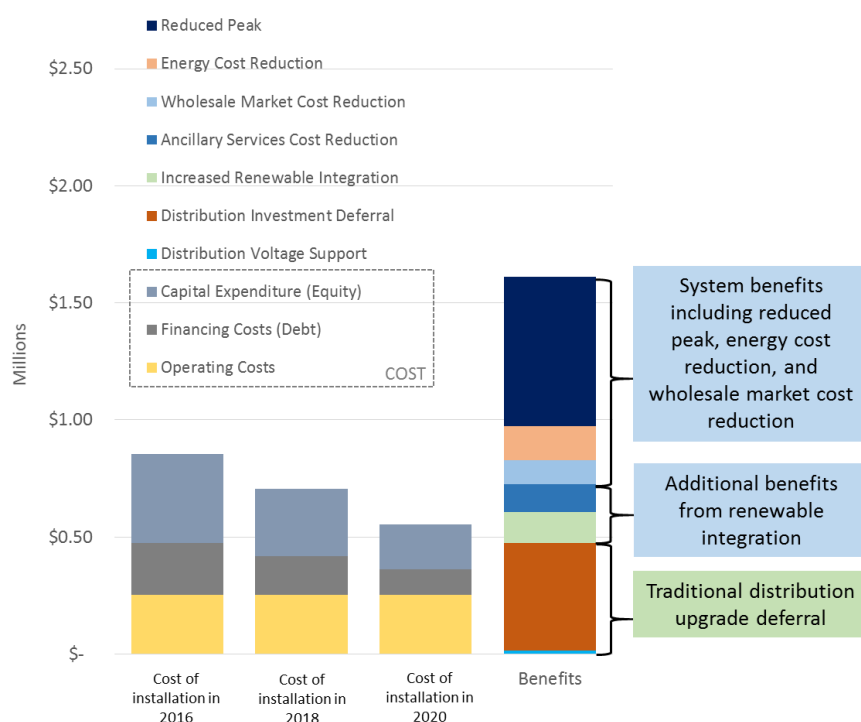


Figure 5-3: Illustrative Example of Cost-Benefit Analysis for a 1MW/1MWh Energy Storage Project in IOU Use Case¹⁵⁷

Although the cost-benefit analysis shows that that all potential benefits from the storage resource, including demand optimization, outage mitigation and DER integration, outweigh the cost, cost-effectiveness requires using the storage for all the multiple grid modernization benefits. As shown in

¹⁵⁶ Eversource, Letter from NSTAR Electric Company d/b/a Eversource, Grid Modernization Plan Update Cover Letter, D.P.U. 15-122, June 16, 2016.

¹⁵⁷ The tax assumptions are not applied to this Use Case to reflect the fact that IOUs recover the full cost of such project through tariff.

Figure 5-3, if a project only accounts for the traditional distribution upgrade deferral and voltage support benefits, these benefits alone do not outweigh the cost. This explains why little investment in storage has occurred to date by Massachusetts utilities. In the 2018 timeframe, storage capital costs are expected to reach \$450/MWh, allowing distribution projects targeting traditional cost deferrals and renewable integration to become cost effective. As storage capital costs decrease and DERs continue to grow, particularly solar PV, the utility can capture additional storage benefits from renewable integration, i.e. managing the intermittent fluctuating output of distributed solar and avoiding reverse power flows at the substation. However, if the utility has multiple storage installations across its distribution system which can then be coordinated and dispatched together as an aggregated demand management tool to provide peak shaving on peak days, then the benefit of storage can far outweigh the cost of storage at today's capital prices. As described earlier, an energy storage asset can be critical in serving the load during the early evening peak hours, eliminating generation from the rarely used peaking generation plants. To obtain maximum system benefits that come from reducing peak capacity the utility must have multiple installations of energy storage distributed across its network instead of a few demonstration projects scattered around the grid, to be used as an aggregated dispatchable asset at peak times.

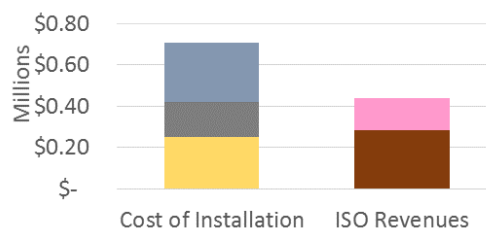


Figure 5-4: Cost of IOU Use Case with Potential ISO Market Revenue

There are additional benefits streams if the energy storage asset at the distribution substation can participate in the ISO-NE wholesale market (Figure 5-4). The energy storage asset can provide capacity in the Forward Capacity Market (FCM) as well as sell its services into the Ancillary Service Market. If such additional revenue could be captured by the utility it reduces the amount of capital investment that needs to be included in the utility's rates from the Grid Modernization plan. This is similar to how revenue captured by the utilities from bidding energy efficiency into the FCM is used to offset the energy efficiency charge on customer bills. The total benefit cost stack for potential ISO market revenues can be seen below in Figure 5-5. Although the IOU would still only be able to recover the cost of the system plus a rate of return at their rate, not the full value of the system to the ratepayers.

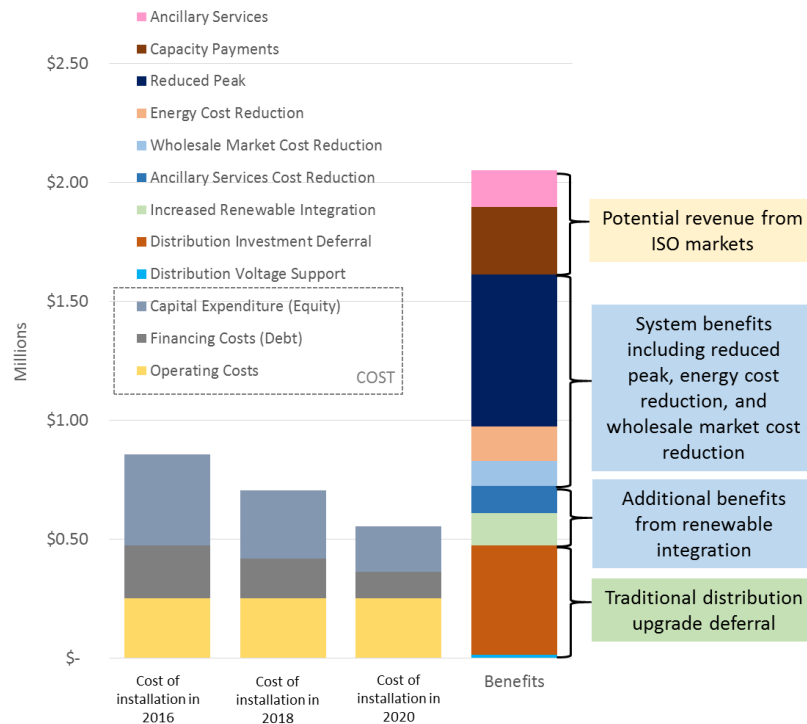


Figure 5-5: Illustrative Example of Cost-Benefit Analysis when Wholesale Market Revenues are Considered

While energy storage assets described in this Use Case are technically capable of participating in the ISO-NE wholesale market, there are existing barriers preventing them from doing so. For example, there are no clear rules guiding resources capable of providing both transmission and distribution benefits and selling services into the wholesale market. Furthermore, the ISO also lacks market rules that fully accommodate the characteristics of advanced energy storage. More discussions on the barriers for energy storage to participate in the ISO-NE wholesale market are presented in Chapter 7.

As an aggregated and flexible energy storage program, utilities can cost-effectively utilize energy storage as a grid modernization asset, optimizing peak demand reduction, reduce the effects outages, and integrate DERs, especially solar PV. When considering all the grid benefits accrued from a widespread storage investment, utilities can currently recover capital costs through rates while providing an even greater benefit to ratepayer with a benefit to cost ratio of over 3.0. Removing ISO-NE market barrier would allow utilities to further capture benefits through market revenue, reducing the amount of investment that would need to be recovered in rates.

5.5.2 Municipal Light Plant

Similar to the above IOU Use Case, energy storage assets provide Municipal Light Plants (MLP) with a flexible tool to manage demand peaks, integrate renewable energy and mitigate power outages. A MLP is a vertically integrated public utility that owns transmission systems and distributes electricity to its customers. Some MLPs manage generation assets within their services territories but most purchase electricity from the wholesale market. Many MLPs are interested in investing in energy storage to provide resiliency to municipal critical facilities. Although resiliency benefits are not monetized here in this Use Case, more discussion on resiliency and microgrids can be found in Section 5.5.6.

The Use Case analyzed describes a MLP using energy storage to manage peak demand with energy storage assets, reducing the costs of serving its customers in several ways. The MLP uses energy storage assets to shift its peak demand on the peak day of the year and at other congested times to reduce both its capacity and transmission payments to ISO-NE. Without the energy storage assets, the ISO charges the MLP with capacity payments based on its peak capacity on the ISO-defined peak day of the year and with transmission payments based on the MLP's monthly peak demand. In addition, the MLP stores lower-cost energy purchased from off-peak hours to serve the load during peak ones, reducing the total cost of energy it purchases. At other times, the MLP sells the capability of the energy storage assets into the ISO-NE wholesale market to provide ancillary services.

Accompanying the benefits of reducing the cost of serving the MLP's customers are significant system benefits. As the analysis shows, a large portion of the system benefits come from the effect peak demand reduction has on the wholesale energy prices and a reduced need for new peak capacity. This is similar to the described IOU Use Case in that energy storage is an alternative for costly peak demand infrastructure. In the cost-benefit analysis shown in Figure 5-6,¹⁵⁸ the total benefits, both the benefits accruing to the MLP as well as those to the system, are stacked together in the middle column. Those benefits that the MLP can monetize – savings on the cost of energy, avoided capacity payments, revenue from selling ancillary services and avoided transmission payments — are sufficient to justify the cost of energy storage in 2018.

However, there are barriers for the MLP to realizing all the monetizable benefits. Under existing ISO-NE rules, MLPs cannot avoid the transmission cost with energy storage. If MLPs utilize generation or demand response to reduce its monthly transmission peak, the ISO reconstitutes such generation and adds back to the transmission charges. This practice is known as load reconstitution and is further discussed in Chapter 8. Additional ISO-NE market rules do not allow for this Use Case to participate in the Ancillary Services market, reducing the projects revenue from possible wholesale market services.

¹⁵⁸ The capacity payment, or avoided capacity cost, is calculated based on the system capacity value at \$/kW-year. However, it takes a 3- to 4-hour storage system to manage the peak demand to receive capacity payment or avoid capacity cost. To be consistent with the 1MW/1MWh assumption, the capacity payment here is adjusted down, assuming the stored energy would be discharged at a lower power level throughout the 3 to 4 hour period.

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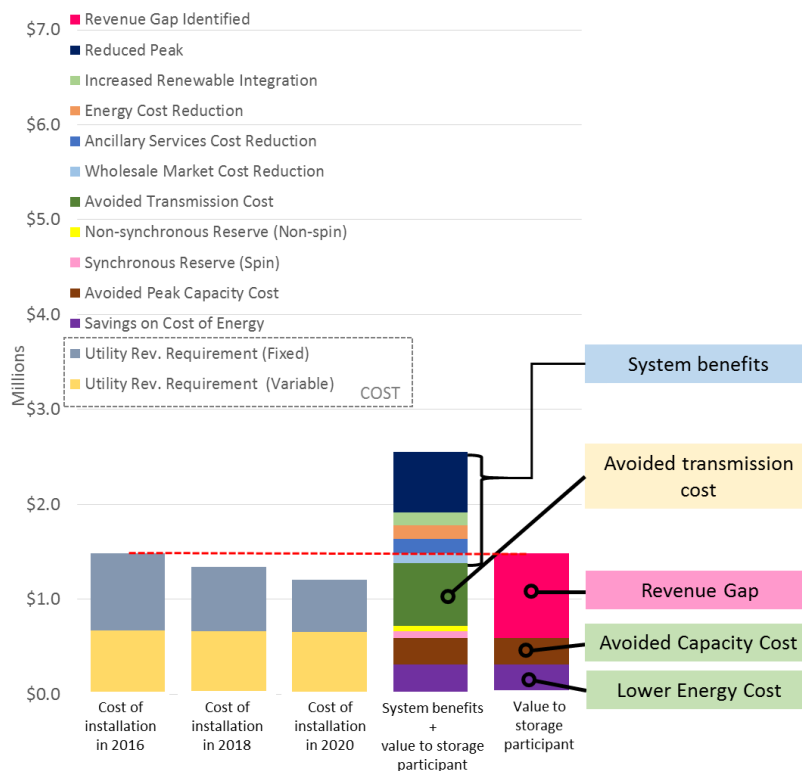


Figure 5-6: Illustrative Example of Cost-Benefit Analysis for a 1MW/1MWh Energy Storage Project in MLP Use Case

Figure 5-6 shows that without the avoided transmission payments and the ISO-NE market revenue from spin and non-spin reserves, the benefits accrued to the MLP are not sufficient to justify the cost of energy storage. To unlock the system benefits associated with this Use Case, mechanisms are needed to close the gap between the cost and the benefits that can be captured by the MLP. Inclusion of energy storage technologies in the Alternative Portfolio Standards (APS) can be such a mechanism; more discussions on APS can be found in Chapter 7. Closing this revenue gap allows the MLP to invest in an energy storage project while capturing the many benefits that project would provide to the large distribution grid, including reduced peak, energy cost reduction, and wholesale market cost reductions.

5.5.3 Load Serving Entities/Competitive Suppliers

Load Serving Entities (LSEs), or competitive suppliers, purchase energy in the wholesale market and compete for business to serve retail loads. LSEs often provide retail electricity directly to either a C&I or residential customer through competitive supply but also provide retail electricity to the utilities for basic service loads and to municipalities through municipal aggregation. LSEs provide this retail electricity through competitive contracts where their offered electricity price provides competitive leverage.

LSE-controlled energy storage assets give an LSE flexibility in serving its load, and in turn reduce the cost of service. An LSE can serve the load during peak hours with lower-cost energy stored during off-peak ones. An LSE can also utilize energy storage to hedge against volatility in the wholesale spot market. For the LSEs that own renewable generation or have customers with solar power generation, energy storage could be deployed to firm the renewable generation and manage power flows.

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Energy storage can be used to hedge against energy price spikes in the spot market. Energy prices in the spot market are usually volatile during winter and summer peak seasons when the grid is stressed. An LSE hedges against such spot market volatility by procuring energy through the forward market, usually one month ahead. Any discrepancies between the actual load and the hedged position would have to be settled through the spot market. As an example (Figure 5-7), on January 23, 2014, despite hedging through the forward market, an LSE still had to purchase from the spot market at \$500 - \$850/MWh during the peak hours to make up for the difference between actual load (blue line) and its hedged position (orange area).

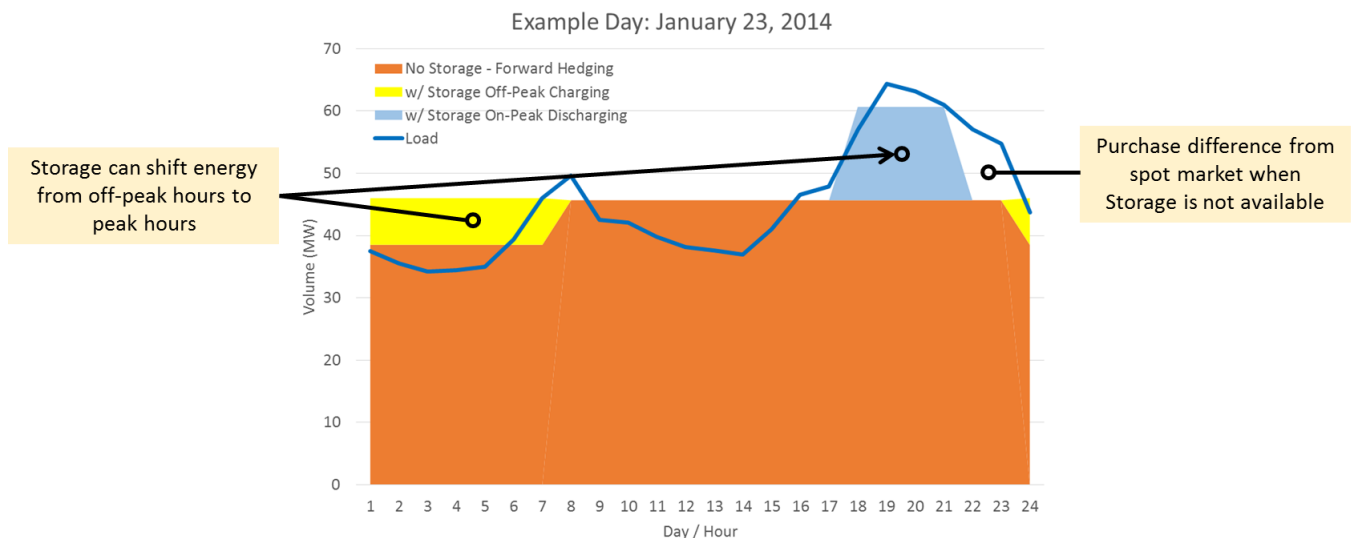


Figure 5-7: Example of Hedging with Energy Storage

If the LSE has control over energy storage assets, either grid connected or located on site, it can charge the storage at off-peak hours (yellow area) with energy procured through the forward market and serve the load during the peak hours (blue area) with the stored energy. Applied to the above example, the LSE can reduce its cost of serving the load from \$171k to \$132k, or a 23% reduction over the 24 hour day. While price spike happens rarely, it can be a significant cost to an LSE.

In this Use Case, a large portion of the system benefits come from reduced peak capacity since LSE uses energy storage to better manage its peak demand. The benefits are two-fold: the LSE reduces its cost of serving the load and the system can reduce the infrastructure needed to meet peak demand. The rest of the system benefits come from more efficient operations of the generation fleet and better integration of renewable energy within the LSE's service area.

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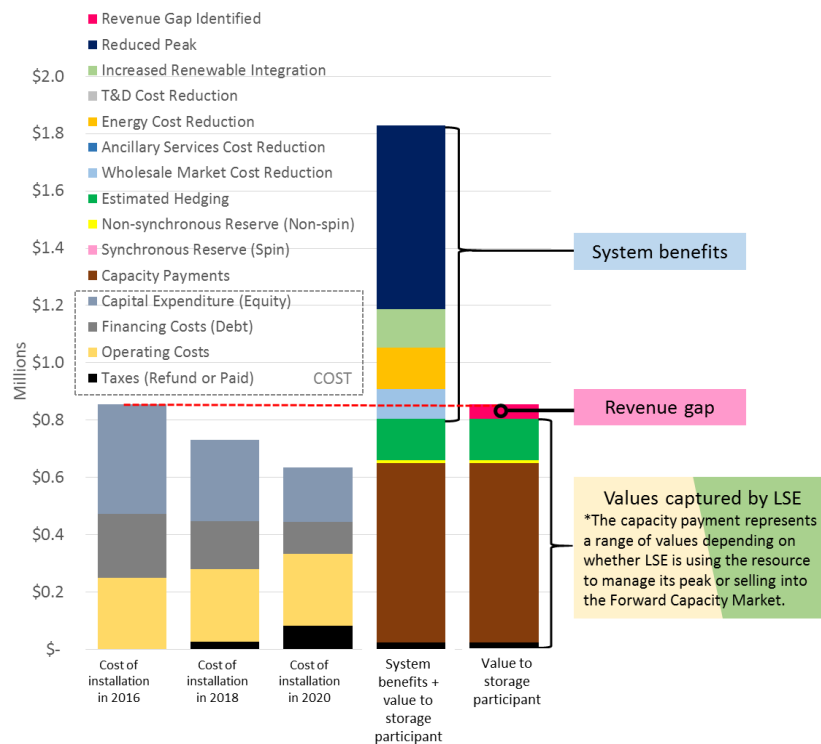


Figure 5-8: Illustrative Example of Cost-Benefit Analysis for 1MW/1MWh Energy Storage Project in LSE Use Case¹⁵⁹

The cost-benefit analysis (Figure 5-8) shows that the benefits captured by the LSE alone cannot justify the cost of energy storage until 2018. The benefits to the project can vary whether the storage is managing peak or selling into the forward capacity market to realize ISO-NE market revenue. However, if the system benefits are considered, such as peak demand reduction and energy cost reduction, the energy storage project is immediately cost-effective. Such results are similar to the previous IOU and MLP Use Cases in that mechanisms are needed to unlock the system benefits described.

The LSE Use Case shows that energy storage can provide significant benefit to the project owner by shielding the LSE from the volatility of energy prices. As an LSE is in the business of selling retail electricity, being able to manage the price of electricity, especially renewable generation, provides a competitive edge. By bridging the revenue gap, LSE energy storage projects can be immediately developed and the system benefits can be realized.

5.5.4 Behind-the-Meter Use Cases

Storage owners can realize significant energy management benefits when they install energy storage on site behind their electricity meter. In addition to providing direct demand reduction customer benefits, these storage systems can also provide significant grid benefits. In order to evaluate behind the meter (BTM) storage projects' benefits, several BTM Use Cases are presented below. These Use Cases highlight energy storage paired with on-site solar power generation for commercial and industrial (C&I) customers and energy storage installed in residential homes, both independently operated and dispatched by local utilities.

¹⁵⁹ Hedging in the benefits stack was estimated using high LMPs during peak hours resulting from extreme weather for 10 days out of a year, escalating over the life of the project (10 years) and discounted to represent net present value.

5.5.4.1 Behind-the-Meter Commercial & Industrial Energy Storage Working with Solar Power Generation

There is considerable interest amongst C&I customers to utilize energy storage to reduce retail demand charges on their utility bill which are set based on the customer's peak usage. Considering current demand charge rates, an energy storage system for a C&I customer could be cost-effective with current capital costs in certain circumstances and utility territories. Additionally, C&I customers can use an energy storage system for price management if they are on a time of use (TOU) rate. Following the basic principal of energy arbitrage, the customer would charge the storage system when rates are low and dispatch the stored energy to offset energy when rates are more expensive. Each of the benefits to the customer are a form of peak demand reduction as the customer is responding to utility price signals set to reduce peak demand.

The C&I customer can also utilize energy storage to help to improve local power quality and serve as back-up power during planned and unplanned outages. Figure 5-9 shows a small revenue gap for a current project based only on power reliability, power quality, time of use rate management and demand charge reductions. The Use Case modeling used a blended demand charge rate but projects can be cost effective when considering higher demand charges which exist in some utility territories.¹⁶⁰

¹⁶⁰ The benefit of retail demand charge management was adjusted from the original ESVT results to reflect distribution demand charge rate from several utilities. For example, National Grid has a demand charge rate of \$3.92/kW (G-3 tariff) whereas Eversource has a rate of \$8.59/kW or \$14.56/kW depending on the season. For the above example a blended rate of \$7.84/kW was used. As demand charges increase, the cost effectiveness for the system owner would increase.

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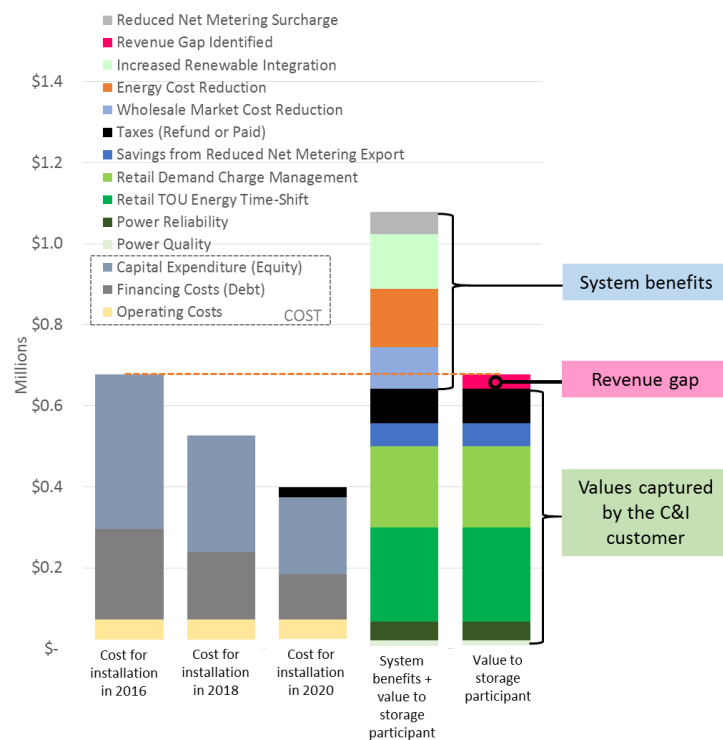


Figure 5-9: Illustrative Example of Cost-Benefit Analysis for Behind-the-Meter C&I Customer, Pairing 1MW/1MWh Energy Storage with On-Site Solar Generation¹⁶¹

In addition to the traditional customer benefits, behind-the-meter C&I customers can realize additional benefits by pairing energy storage with on-site solar power. An example of such a benefit is the ability to utilize storage to better align solar generation and avoid using grid power during periods of peak demand. This allows a customer on TOU rates to avoid paying higher energy costs. Additionally, a customer can utilize storage to reduce their own peak usage, lowering their monthly demand charges in the process. Lastly, if a customer has an on-site solar project that may export power to the grid, storage would allow that customer to avoid exporting the power and being credited at a lower net metering credit rate and use the stored electricity to avoid consumption at the full retail rate when the project is not exporting. This allows the customer to maximize the \$/kWh value of the solar electricity they generate.

In addition to the customer benefits, this Use Case benefits the electricity system from reduced energy cost and peak capacity cost. The customer can utilize the stored energy on peak days, resulting in reduced reverse power flow costs to the utility and reduced net metering costs because electricity generated from solar resource would be consumed locally by an existing load, instead of flowing back to the grid and being sold into the wholesale market at a loss by the utility.

The cost-benefit analysis (Figure 5-9) shows that this Use Case provides system benefits that reduce costs to all ratepayers and that the benefits captured by the C&I customer can only readily justify the cost of energy storage currently when in utilities with high demand charges. As capital costs decrease, energy storage projects become cost-effective under lower demand charge rates meaning some projects may be developed in the future. Policy incentive mechanisms may be used to promote immediate project development in order to monetize the described system benefits. Policy makers should consider adopting a mechanism to monetize their system benefits so investment

¹⁶¹ The refund tax in the benefit stack is based on project installation in 2016.

happens now. Such mechanisms may include Alternative Energy Credits (AECs) through inclusion in the Alternative Portfolio Standard (APS).

5.5.4.2 Behind-the-Meter Residential Energy Storage, Dispatched by the Utility

Similar to the C&I Use Case, residential customers can be interested in energy storage to provide resiliency in the event of a grid outage but, without price signals to reduce peak demand such as TOU rates and demand charge, the project is not cost effective to the resident. This residential BTM Use Case, energy storage installed in homes but not paired with roof-top solar PV, was modeled and showed grid benefits when the system was used to serve demand during peak hours. Consistent with other Use Cases, the electric system creates benefits from reduced energy cost and reduced wholesale market costs. However, benefits to the residential customers are minimal since there are no demand charges and the residential customers do not have time-of-use tariffs. Therefore the cost of the project outweighs the realizable benefits to the project owner. It is worth noting that while power resiliency in emergencies should be a primary benefit in such Use Case, it is difficult to quantify such benefit.

For the storage systems that affect peak demand and therefore more significantly benefit the grid, a second Use Case is investigated where the local utilities can control the residential behind-the-meter energy storage assets. As is evident from the system benefits analysis shown in Figure 5-10, if the local utilities can dispatch the energy storage assets installed in homes behind the meter, additional benefits can be unlocked and the case becomes cost-effective. The energy storage assets behind the meter can be used to manage the peak demand, reducing the cost of energy as well as more effectively utilizing peak generation and T&D equipment. When the assets are dispatched by local utilities, the systems are no longer confined behind the residential meter where they are installed, but can now be leveraged across the utility's system to address renewable integration and distribution upgrade deferral.

There are several pilot projects in Massachusetts and other states in which utilities are experimenting with dispatching energy storage assets installed in homes. As part of a proposed non-wires alternative in Nantucket, National Grid has proposed the use of thermal storage to reduce peak demand.¹⁶² The utility would own and program multiple assets that would use low cost energy at night to freeze liquid around a residential air conditioning unit's condenser. During the day, when air conditioning load contributes to peak demand, the resident's air conditioner uses the stored thermal energy in the frozen condensers instead of grid electricity. This is an example of a utility dispatched behind the meter system because the utility realizes the peak demand reduction and can defer the cost of a transmission line investment.

¹⁶² Massachusetts Electric Company and Nantucket Electric Company, each d/b/a National Grid, D.P.U. 16-06 – Petition of Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid for Approval of Non-Wires Alternative Pilot, and of Non-Wires Alternative Provision; Initial Filing, pg. 2 (January 11, 2016).

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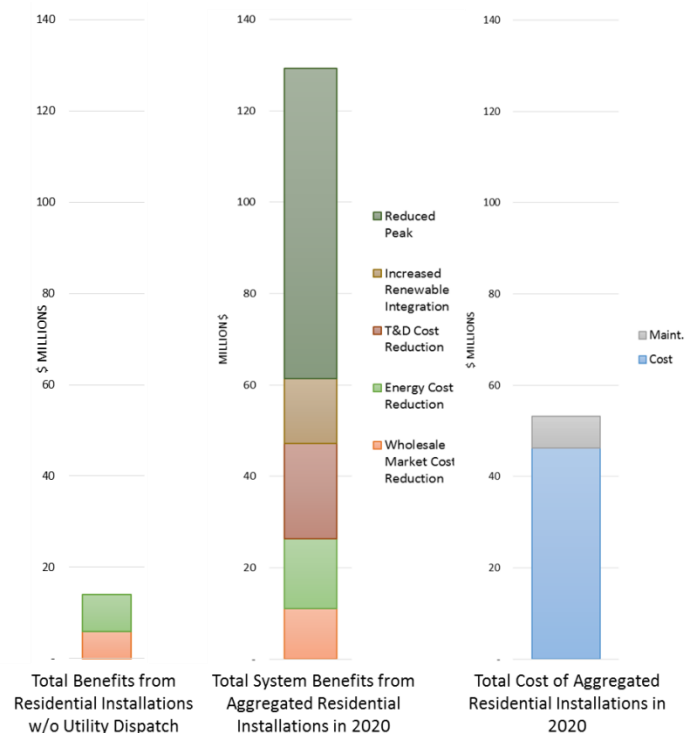


Figure 5-10: System Benefits Analysis for Behind-the-Meter Residential Energy Storage Project Dispatched by Local Utilities

5.5.5 Merchant

While several of the Use Cases previously discussed can be based on bilateral contracts with merchant-owned energy storage facilities, the Use Cases discussed below focus specifically on the wholesale market potential of merchant-owned energy storage facilities and how they could work with other merchant generators.

5.5.5.1 Alternative Technology Regulation Resource

Energy storage resources, with superior speed and accuracy, are significantly more effective at correcting system imbalances. As previously discussed, FERC Order 755 directs the ISOs to take such fast-responding capabilities into consideration in frequency regulation dispatch and settlements. ISO-NE implemented Order 755 in April 2015, and created ATRR, or Alternative Technology Regulation Resource, for short-duration storage to provide frequency regulation only.

Energy storage resources in the ISO-NE Frequency Regulation market can realize greater revenue than other technologies because their fast and accurate performances responding to the ISO's dispatch signals. This market is currently the only commercially viable market in ISO-NE for advanced energy storage. However, with a limited frequency regulation procurement of 70 MW in ISO-NE, there is limited storage development potential.

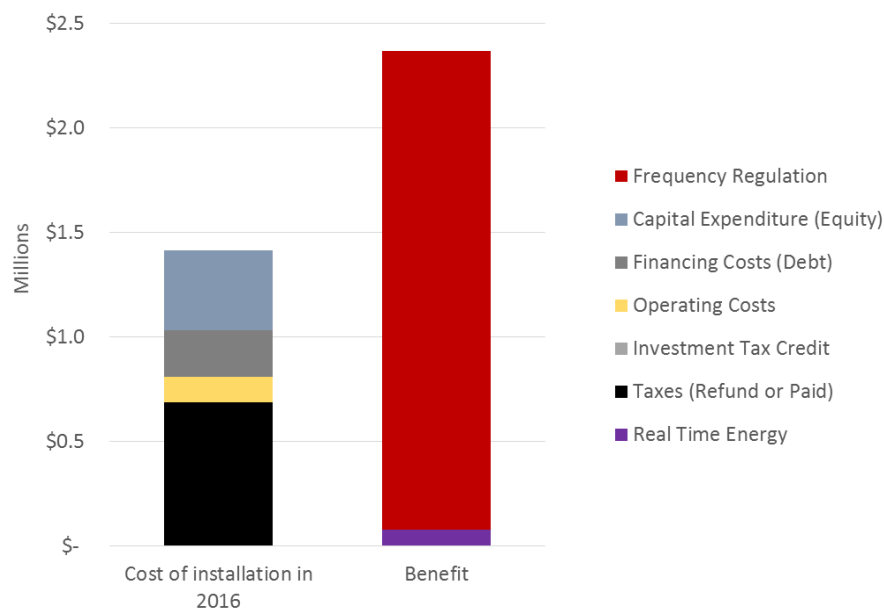


Figure 5-11: Cost-Benefit Analysis for a 1MW/1MWh Merchant ATRR Project

From the cost-benefit analysis (Figure 5-11), it is evident that the cost of an energy storage project selling frequency regulation services into the ISO-NE market can be readily justified by the revenue it generates. This is the only Use Case where energy storage is fully compensated in the market. Most of the system benefits from this Use Case were already considered in the market mechanism through a pay for performance revenue that compensates resources with fast and accurate responses.

5.5.5.2 Energy Storage with Merchant Solar Power Plant

Energy storage, co-located with solar installations, assists with renewable integration by allowing the solar facility to be dispatched according to the system's needs. The electricity generated by the solar facility can be stored and sold to the grid at peak hours rather than exporting in real-time. The facility's owner increases the dollar per kWh value of the solar installation and the electricity system benefits from the renewable generation better aligning with its load, reducing the cost of energy. Energy storage also assists with mitigating solar intermittency and improving local power quality by providing the generator with the ability to store excess generation and rapidly dispatch during times of low generation often created by cloud cover.

There is often a large cost for building transmission and distribution lines to connect generators to customers if necessary. In these circumstances, storage co-located with solar can allow the electricity generation from solar to be used at any time closer to load centers, potentially reducing the need for additional transmission and distribution infrastructure that would otherwise need to be constructed to meet peak demand or manage issues arising from the intermittency of solar. These benefits are included with T&D deferral in the cost benefit analysis below.

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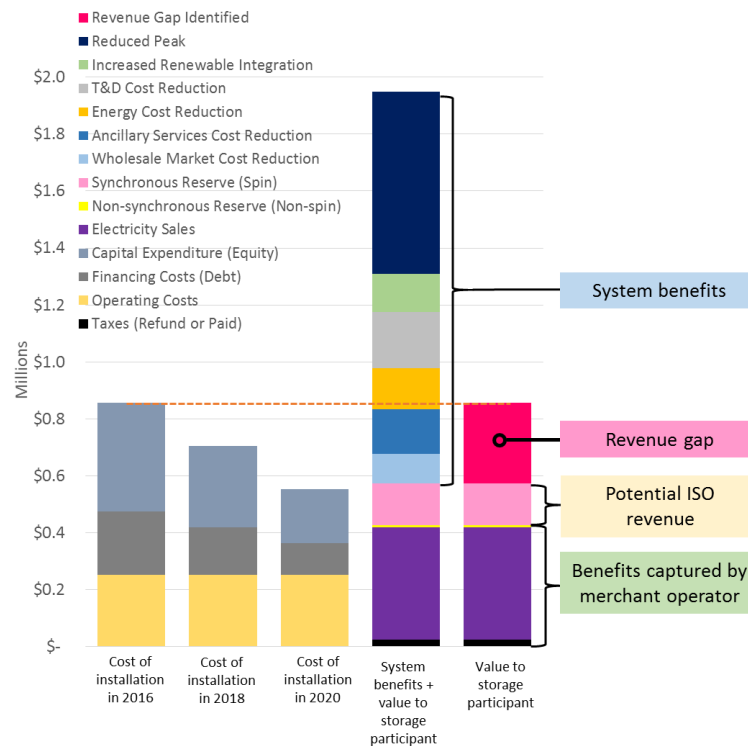


Figure 5-12: Illustrative Example of Cost-Benefit Analysis for 1MW/1MWh Energy Storage Paired with Merchant Solar Plant^{163 164}

The primary use of this type of asset is energy arbitrage, shifting energy generated from the solar facility to be used at a time of greater demand and higher price. The merchant operator receives revenue from selling the electricity in the wholesale market. In addition to the energy arbitrage revenue, the operator can also sell the capabilities of the energy storage device to provide other ancillary services in the wholesale market. As the cost-benefit analysis shows in Figure 5-12, if only these two main benefits to the merchant are considered, the cost of energy storage asset is not cost effective to the project owner. However, the system benefits greatly exceed the cost to the merchant, making the Use Case cost-effective to the Massachusetts energy system. In order to increase this Use Case deployment and capture the system benefits, mechanisms to support this Use Case can be created.

5.5.5.3 Energy Storage with Gas Generator

In this Use Case, an energy storage asset is co-located or coordinated by the system operator or utility with a gas generator to improve the generator's operational efficiency. A generator following load and providing frequency response and regulation often has to back its output down to leave enough "head room" to provide load-following and ancillary services. Therefore, the generator often does not operate at its optimal heat rate, the operating point where the generator realizes the most efficient fuel consumption. If an energy storage asset is dispatched instead of using a generator to load follow and provide frequency response and regulation, a generator can operate at a constant

¹⁶³ The refund tax in the benefit stack is based on project installation in 2016.

¹⁶⁴ It is not yet clear how a combined solar and energy storage project would be treated in the capacity market. It is possible that the energy storage asset can be used to increase the qualified capacity value of the solar generation; it is also possible that the energy storage asset and the solar generating asset would be counted separately. Due to such uncertainty, the capacity payments are not included here as part of the benefits.

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output, reducing the number of starts and stops and the associated maintenance costs and GHG emissions.

The flexibility energy storage provides gas generators, allowing an optimal heat rate, is especially important to the northeast during winter gas shortages. Because the gas generators operate more efficiently when energy storage takes over the load following and ancillary services responsibilities, there will be less fossil fuel consumed by the generators during the time when gas is most needed for heating homes. Often when gas constraints are the most pronounced, generators must use stored oil fuel reserves to maintain reliable generation. Utilizing energy storage to optimize fuel use can also lead to a decrease in the amount of burned oil during the winter months. In addition to the benefits from the flexibility of energy storage described above, the electric system also benefits from lower cost of ancillary services, lower energy price, and reduced cost for peak capacity.

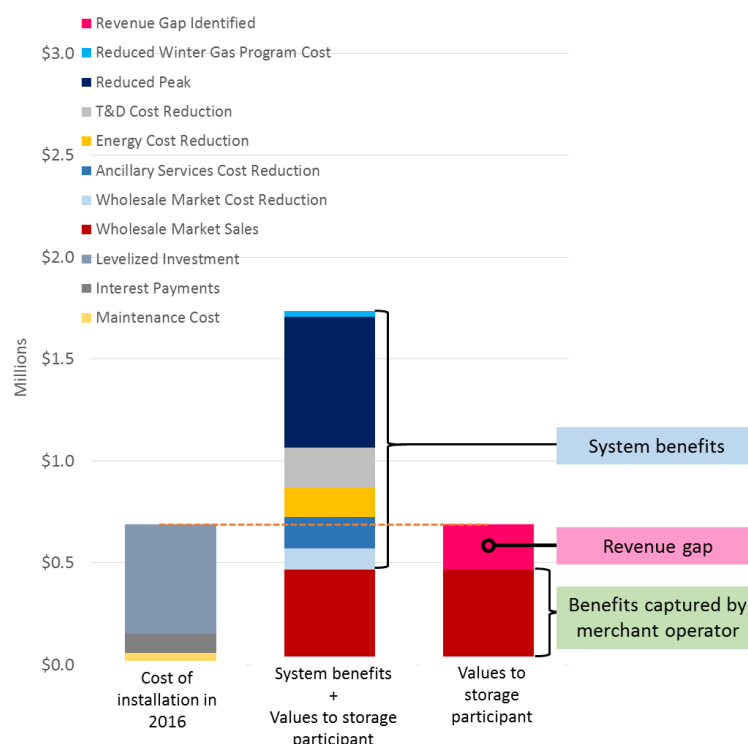


Figure 5-13: Illustrative Example of Cost-Benefit Analysis for 1MW/1MWh Energy Storage Paired with a Gas Generator

For this Use Case to be economical for the developer, barriers for energy storage for participation in ISO-NE energy markets need to be removed or clarified. More discussions on barriers of energy storage participating in the ISO-NE wholesale market can be found in Chapter 8.

As the cost-benefit analysis in Figure 5-13 shows, the only revenue stream that can be captured by the merchant operator in this Use Case is that from selling stored electricity in the wholesale market. This revenue stream alone is not sufficient to justify a merchant investment in an energy storage asset. The project becomes cost-effective when considering the system benefits. Mechanisms are therefore needed to realize the system benefits modeled.

5.5.6 Microgrid

A microgrid is a collection of generation assets and other distributed energy resources and loads within a defined boundary that can operate in grid connected mode or separate, or “island”, from the broader electricity grid. Energy storage can benefit a microgrid by allowing the operator to flexibly manage its generation and load.

Different microgrid business and ownership models are still emerging. Multiple ownership models can be found where a utility, a private developer, or a public private partnership can own and operate the microgrid. For all of these ownership models, storage provides benefits in both grid connected and islanded operating modes that can be monetized in different ways. Importantly, for microgrids that are owned and operated by a private party, a microgrid simultaneously looks like a large load and a generation asset to a utility or the grid operator. Storage is seen the same way to the utility or the grid operator.

The benefits of energy storage in a utility owned grid-connected microgrid are similar to those enumerated in the MLP Use Case including: energy cost reduction, peak demand charge reduction, renewables integration, transmission and distribution cost reduction, and ancillary services revenue. As shown in the MLP cost-benefit analysis in Section 5.5.2, the benefits that can be captured by a microgrid operator might be impacted by the load reconstitution issue; the issue may be a barrier for MLP owned storage, storage in the context of an MLP owned microgrid, or microgrids in general, and should be clarified and addressed by ISO-NE.

Storage provides energy resilience allowing critical facilities and other loads within the microgrid to ride through prolonged grid outages, maximally leverage renewable resources (such as solar PV), and/or extend limited liquid fossil fuel supplies. When the microgrid is not connected to the grid, storage provides critical load balancing, power quality, and renewables integration services. Further, energy storage provides bridging power in times when the microgrid is switching from one generating resource to another.

Resiliency, though not easily quantified, is a key benefit of a microgrid. The estimated cost of a power outage is high (Table 5-8 and Table 5-9), especially to small commercial and industrial customers who are less likely to have on-site back-up power. For specific customers, it might be easier to quantify the value of resilience. Importantly, microgrids can also provide black start services to the broader grid in the event of a widespread outage.

Average Cost per Unserved kWh						
	Duration of Outage					
	Momentary	30 minutes	1 hour	4 hours	8 hours	16 hours
Medium and Large Commercial & Industrial Customers	\$191	\$37	\$22	\$12	\$13	\$13
Small Commercial & Industrial Customers	\$2,255	\$474	\$295	\$214	\$267	\$258
Residential Customers	\$31	\$6	\$3	\$2	\$1	\$1

Table 5-8: Estimated Cost of Unserved Electricity¹⁶⁵

¹⁶⁵ Lawrence Berkeley National Lab (2015), Updated Value of Service Reliability Estimated for Electric Utility Customers in the United States; <https://emp.lbl.gov/sites/all/files/value-of-service-reliability-final.pdf.pdf>

Cost of Power Outage in the Boston Area (thousand dollars)

	Duration of Outage					
	Momentary	30 minutes	1 hour	4 hours	8 hours	16 hours
Medium and Large Commercial & Industrial Customers	\$854	\$5,029	\$5,862	\$13,015	\$27,751	\$54,692
Small Commercial & Industrial Customers	\$10,105	\$63,744	\$79,327	\$230,507	\$575,030	\$1,111,061
Residential Customers	\$138	\$793	\$887	\$1,721	\$3,011	\$5,598
Citywide Cost	\$11,098	\$69,566	\$86,077	\$245,243	\$605,793	\$1,171,351

Table 5-9: Estimated Cost of Outages in the Boston Area¹⁶⁶

DOER provides incentives for microgrid projects as part of the Community Clean Energy Resiliency Initiative. This \$40 million grant program is part of the Commonwealth's broader climate adaptation and mitigation efforts. This grant program is focused on resiliency projects that utilize clean energy technology solutions to protect communities and critical infrastructure from interruptions in energy services due to severe climate events. Projects include:

- \$1,455,000 in funding was awarded to Taunton and Berkley, Massachusetts for community microgrid initiatives utilizing an energy management system, lithium-ion batteries, solar PV (existing), and diesel generators (existing) at the following facilities: the Middle School and Community School which can serve as shelters, the Police and Fire Station, which serve as an emergency services building, a municipal fueling station/pump, and a Police and Fire Radio Repeater.
- \$3,078,960 in funding was awarded to Northampton, Massachusetts for a microgrid project with on-site renewable energy including an island-able solar PV and battery storage system to serve the interconnected facilities during an outage. Facilities include: Smith Vocational and Agricultural High School, Northampton DPW and Cooley Dickinson Hospital.
- \$1,463,194 in funding was awarded to Sterling, Massachusetts for a municipal microgrid in a Police Station and communication facility. This project is utilizing utility-scale battery storage to deliver multiple layers of resiliency benefits to the Sterling community. The battery array is sized to allow for islanding of critical services within the Sterling Police Station and Dispatch Center and the battery array will also be used daily to provide real-time demand response, frequency regulation services, and off-peak to on-peak load shifting to increase the resiliency of Sterling's solar-reliant microgrid.

5.6 Conclusion

While the modeling results clearly show there are substantial net benefits to ratepayers from increasing the amount of storage deployed in Massachusetts, the biggest challenge to achieving more storage deployment in Massachusetts is that there is a lack of clear market mechanisms to transfer some portion of the system benefits created by storage to the storage project developer. Without a means to be compensated for the value the storage resource provides to the system, investors will simply not invest in building storage projects in Massachusetts. The Use Cases

¹⁶⁶ Values calculated based on citywide annual electricity use of 7 billion kWh.

were examined to identify where market barriers exist and what policy and program changes can be made to enable the development of storage in Massachusetts.

In order to capture the full system benefits of energy storage deployment, mechanisms can be created or opened to more diverse Use Cases. These mechanisms can be wholesale market revenues that are directly applied to the capital cost of investments. The Use Cases highlight various ISO-NE market barriers that limit how storage can fully participate in the wholesale markets. Providing additional room for market growth and clarity could increase the realizable benefits to storage owners, whether merchants or behind the meter. Additionally, mechanisms can be realized through state programs and policy, whether existing rate recovery through grid modernization or new grants and rebate programs. These mechanisms to capture energy storage benefits, promote storage asset deployments, and reduce overall costs for Massachusetts rate payers are discussed in more detail in Chapters 7, 8, and 9.

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6 Programs and Policies that Benefit the Storage Industry in Other States

This chapter describes how programs and policies for energy storage are evolving in other states. Specific state-led programs are described. This information will guide consideration of whether adapting the current suite of programs and policies in the Commonwealth to include energy storage would contribute to the goals of the Massachusetts Energy Storage Initiative (ESI).

6.1 State Policies in Support of Energy Storage

Many states are now embracing energy storage as a solution for various reliability challenges that they are facing on the grid. Power plant closures and renewable integration, combined with the high cost, lengthy time, and onerous permitting required to build new generation and transmission, is often making energy storage a viable solution. As Massachusetts considers targets and policies to increase the amount of energy storage development, consideration of how other states are proceeding in this area is pertinent.

To date, the primary drivers for energy storage development have been a direct result of FERC order 755 Pay-for-Performance (primarily in PJM)¹⁶⁷ or state initiatives, such as the California Small Generator Incentive Program (SGIP)¹⁶⁸, the California storage mandates, and the NYSEDA GreenBank¹⁶⁹ initiatives, each of which is discussed below along with similar drivers.

State	Driver	Driver Category	Start Year	Funds ¹⁷⁰ (\$M)	Total Storage ¹⁷¹ (MW/MWh)
AZ	All Source RFP Solicitation Storage Requirement (10% of traditional generation capacity and 3-hour duration) ¹⁷²	Legislative/Regulatory Policy	2014	-	-
CA	Self-Generation Incentive Program (SGIP) ¹⁷³	Incentive	2001	188	106.5 / -
	California Energy Commission: Public Interest Energy Research (PIER) ¹⁷⁴	Legislative/RD&D	2006	779	10.8 / 55.8 ¹⁷⁵

¹⁶⁷ FERC Order 755 Pay-For-Performance (<https://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf>)

¹⁶⁸ Small Generator Incentive Program (SGIP) (<http://www.cpuc.ca.gov/PUC/energy/DistGen/sgip/>)

¹⁶⁹ NYSEDA GreenBank <http://www.nyserda.ny.gov/All-Programs/Programs/NY-Green-Bank>

¹⁷⁰ Reflects total funding allocation expected over the program life, and note that not all funding is strictly for energy storage. SGIP is an exception, though, as funds are \$ amount paid or reserved to date for storage only (per CSE). Funding often only covers a percentage of the project (or storage component) cost and is combined with 3rd party funds, so a direct correlation of funding \$ to storage MW is not possible in the majority of programs.

¹⁷¹ In some cases, this reflects storage installed, 'planned', or de-commissioned as of December 2015 for the program (e.g. SGIP, REIP, DEEP, EPIC, and wholesale markets), whereas in other cases it is total expected storage over the program lifetime (e.g. CA AB 2514 and OR HB 2193). Data comes from either 1) cited program website, or 2) DOE Global Energy Storage Database. Some storage may overlap from one category/driver to another, such as AB 2514 procurement that participates in CAISO's Frequency Regulation market. CAISO figures do not include PG&E's proposed CAES project (300 MW/3 GWh).

¹⁷² See <http://images.edocket.azcc.gov/docketpdf/0000156123.pdf>

¹⁷³ See <https://energycenter.org/programs/self-generation-incentive-program>

¹⁷⁴ See http://www.energy.ca.gov/business_meetings/2015_packets/2015-03-11/Item_14_2014_PIER_Electric_Annual_Report_3-6-15_BM_FINAL.pdf

¹⁷⁵ Totals do not include two proposed projects: PG&E CAES (300 MW/3 GWh) & MID/Primus EnergyFarm (28 MW/112 MWh)

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	Electric Program Investment Charge (EPIC) (Ratepayer-funded) ¹⁷⁶	Legislative/ RD&D	2011	1,296	1.1 / 1.1
	AB 2514 & CPUC (D.)13-10-040 - Energy Storage System Procurement Targets ¹⁷⁷	Legislative/ Regulatory Policy	2013	-	1,325 / -
CT	DEEP Microgrid Pilot Program ¹⁷⁸	Incentive/ RD&D	2012	48	0.1 / 0.2
	Connecticut Green Bank ¹⁷⁹	Loan	2011	-	-
IL	PJM – Frequency Regulation ¹⁸⁰	Wholesale Market	2001	-	116 / 36
IN	MISO – Capacity ¹⁸¹	Wholesale Market	2001	-	20 / 20
MA	ISO-NE – Alternative Technologies Regulation Pilot Program ¹⁸²	Wholesale Market/ RD&D	2008	-	0.5 / 0.125
	Community Clean Energy Resiliency Initiative ¹⁸³	Incentive/ RD&D	2014	40	-
	Energy Storage Initiative (ESI) ¹⁸⁴	Incentive/ RD&D	2014	10	-
MD	Game Changer Competitive Grant Program ¹⁸⁵	Incentive/ RD&D	2013	1	0.53 / 0.28
	PJM - Frequency Regulation	Wholesale Market	2001	-	10/ -
ME	Boothbay Transmission Deferral Pilot ¹⁸⁶	Regulatory Policy	2014	-	0.5 / 3
MN	Renewable Development Fund Grant (Ratepayer-funded) – Wind-to-Battery Project ¹⁸⁷	Incentive/ RD&D / Wholesale Market	2008	1	1 / 7.2
NJ	Renewable Energy Incentive Program (REIP): Renewable Electric Storage Incentive ¹⁸⁸	Incentive/ RD&D	2014	9	8.75 / -
	Energy Resiliency Bank (ERB) ¹⁸⁹	Loan	2014	200	-

¹⁷⁶ See <http://www.energy.ca.gov/research/epic/>

¹⁷⁷ See <http://www.cpuc.ca.gov/PUC/energy/storage.htm>

¹⁷⁸ See <http://www.ct.gov/deep/cwp/view.asp?a=4405&Q=508780>

¹⁷⁹ See <http://www.spark.ctgreenbank.com/>

¹⁸⁰ See <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>

¹⁸¹ See <https://www.misoenergy.org/Planning/ResourceAdequacy/Pages/ResourceAdequacy.aspx>

¹⁸² See

https://www1.eere.energy.gov/analysis/pdfs/iso_ne_3_results_of_ancillary_service_pilots_programs_jon_lowell_and_henry_yoshimura.pdf

¹⁸³ See <http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/resiliency/resiliency-initiative.html>

¹⁸⁴ See <http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/>

¹⁸⁵ See <http://energy.maryland.gov/business/Pages/incentives/gamechanger.aspx>

¹⁸⁶ See <http://www.pressherald.com/2015/06/08/grid-feeding-battery-system-of-the-future-humming-in-boothbay/>

¹⁸⁷ See

<https://www.xcelenergy.com/staticfiles/xcel/Corporate/Renewable%20Energy%20Grants/Milestone%20Final%20Report%20PUBLIC.pdf>

¹⁸⁸ See <http://www.njcleanenergy.com/renewable-energy/programs/energy-storage>

¹⁸⁹ See [http://www.njeda.com/erb/erb-\(1\)](http://www.njeda.com/erb/erb-(1))

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	PJM – Frequency Regulation ¹⁹⁰	Wholesale Market	2001	-	3.8 / 1.5
NY	Con Edison Brooklyn Queens Demand Management Program (BDQM) ¹⁹¹	Incentive	2014	200	2 / 12
	NY Prize ¹⁹²	Incentive/ RD&D	2015	40	-
	New York Green Bank ¹⁹³	Loan	2013	1000	-
OH	PJM - Frequency Regulation	Wholesale Market	2001	-	40/ -
OR	HB 2193-B Energy Storage Guidelines ¹⁹⁴	Legislative/ Regulatory Policy	2015	-	- / 5+
	State RFP Storage Solicitation ¹⁹⁵	Legislative/ Regulatory Policy	2015	0.045	0.5+ / 0.5+
PA	PJM – Advanced Technology Pilot Program ¹⁹⁶	Wholesale Market/ RD&D	2013	-	1 / 0.25
	PJM – Frequency Regulation ¹⁹⁷	Wholesale Market	2001	-	50.4 / -
PR	New Renewable Generator + Storage Requirement (30% of generator capacity) ¹⁹⁸	Legislative/ Regulatory Policy	2013	-	-
WA	Washington Department of Commerce: Clean Energy Fund Smart Grid Grants ¹⁹⁹	Incentive/ RD&D	2014	14.3	6 / 14.5
WV	PJM – Frequency Regulation ²⁰⁰	Wholesale Market	2001	-	63.5 / 12.1
VT	Clean Energy Development Fund: Electrical Energy Storage Demonstration Program ²⁰¹	Incentive/ RD&D	2013	0.05	4 / 4

Table 6-1: Energy Storage Drivers and Related Deployments

¹⁹⁰ See <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>

¹⁹¹ See <http://www.coned.com/energyefficiency/pdf/BQDM-program-update-briefing-08-27-2015-final.pdf>. Energy storage is listed as a 12 MWh battery capable of 1 MW for 12 hour or 2 MW for 6 hours.

¹⁹² See <http://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize>

¹⁹³ See <http://greenbank.ny.gov/>

¹⁹⁴ See <http://gov.oregonlive.com/bill/2015/HB2193/>

¹⁹⁵ See <http://www.oregon.gov/energy/Pages/energy-storage.aspx>

¹⁹⁶ See <http://www.pjm.com/markets-and-operations/advanced-tech-pilots.aspx>

¹⁹⁷ See <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>

¹⁹⁸ See <http://www.greentechmedia.com/articles/read/puerto-rico-mandates-energy-storage-in-green-power-mix>

¹⁹⁹ See <http://www.governor.wa.gov/news-media/state-pursues-new-smart-grid-projects-capture-store-more-solar-and-wind-power>

²⁰⁰ See <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>

²⁰¹ See http://www.vermontbusinessregistry.com/bidAttachments/10128/CEDF_Storage_RFP_Final.pdf

6.2 Characteristics of Energy Storage State Policies

6.2.1 Grants and Loans

Several states including California, Washington, Minnesota and Oregon use grant programs to support energy storage. This study also examined other states' policies and program mechanisms on energy storage to facilitate a broader understanding of advanced storage development efforts. The California Energy Commission's Electric Program Investment Charge (EPIC) is a program with goals similar to those of the InnovateMass program.

California Energy Commission's Electric Program Investment Charge (EPIC): In May 2012, the CA Public Utilities Commission (CPUC) established the purpose of the EPIC which is to provide funding for investments in applied research and development, technology demonstration and deployment, and market facilitation of clean energy technologies and approaches.²⁰² The CPUC designated the CA Energy Commission as one of the program administrators. Through this mechanism, the early R&D programs are known for successfully aiding in the development of several early stage energy storage companies. Demonstration programs have been leveraged to obtain project financing or venture funds. They also supported efforts to assist the CA investor owned utilities (IOUs) in gaining direct operational experience of energy storage.

EPIC is designed to assist the development of non-commercialized new and emerging clean energy technologies in California while providing assistance to commercially viable projects. EPIC consists of three program areas:

- (1) Applied research and development (\$55 M/year);
- (2) Technology demonstration and deployment (\$75 M/year);
- (3) Market facilitation, consisting of market research, regulatory permitting and streamlining, and workforce development activities (\$15 M/year).

Funding for EPIC is collected from IOUs, and is currently at an approved level of \$162 million per year beginning January 1, 2013 and ending December 31, 2020. The Triennial Investment Plan²⁰³ explicitly identifies energy storage as an essential element for meeting the investment plan's strategic objectives.

Examples of EPIC's recent solicitations related to energy storage include:

- A Request for Proposal (RFP) for (1) developing computer models for the CPUC's energy storage Use Cases to determine which storage technologies and systems are optimal; and (2) developing advanced energy storage technologies and systems that can be demonstrated and deployed by the IOUs. The maximum funding available for each category is \$1,000,000 and \$5,000,000 respectively.
- An RFP for improving and advancing large-scale electric generation through enabling technologies. The RFP included a solicitation for new and enhanced tools and technologies that improve the cost and efficiency of thermal energy storage (TES), leading to the increased capacity and dispatchability of concentrating solar power (CSP). This solicitation underscored the broader acceptance of the role storage can and will play in managing utility-scale renewable assets.

²⁰² A description of the strategic objectives are on pages 3 and 4 of the Triennial Plan:

<http://www.energy.ca.gov/2014publications/CEC-500-2014-038/CEC-500-2014-038-CMF.pdf>

²⁰³ The link to the plan is at: <http://www.energy.ca.gov/2014publications/CEC-500-2014-038/CEC-500-2014-038-CMF.pdf>

The California Energy Commission (CEC) also approved the 2014-2015 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program that will help reduce greenhouse gas emissions from the transportation sector. This program funds use and demonstration of electric vehicle (EV) battery technologies and hydrogen storage. The program includes an emphasis on vehicle to grid technologies.

The justification for including energy storage in the EPIC plans is that development and deployment of energy storage complements and further facilitates the state's goals for the RPS targets, grid reliability and resiliency, better integration of renewable generation and peak load management. A thorough examination of the EPIC plan can provide insights into how energy storage is contemplated for research, development, and industry growth.

Washington Department of Commerce: Clean Energy Fund Smart Grid Grants²⁰⁴: In July 2014, the Washington State Governor and the Washington State Department of Commerce announced more than \$14 million in smart grid matching grants from the Governor's Clean Energy Fund, which received \$40 million from the Legislature to grow Washington's clean energy economy. The total cost for the three smart grid projects is \$35.3 million, which includes more than \$21 million in non-state funds. The state-funded grant allotments were as follows: Snohomish County PUD \$7.3 million, Puget Sound Energy \$3.8 million, and Avista Corporation \$3.2 million.

The funds were allocated to three smart grid demonstration projects in the state that utilize energy storage technologies. The utility-led projects will develop and validate "Use Cases" combining energy storage and information technology solutions. The goal is to promote widespread deployment of advanced energy technologies and create a power grid that is more efficient, resilient, and cleaner from generation to consumer.

Oregon Energy Storage Demonstration Pilot (RFGA #15-013)²⁰⁵: The Oregon Department of Energy issued a Request for Grant Applications ("RFGA") for utility-scale, electrical energy storage demonstration projects to be installed and operated in Oregon. In this grant request, the Oregon Department of Energy partnered with the U.S. DOE Office of Electricity's Energy Storage Program, and Sandia National Laboratories, to offer funds for energy storage demonstration projects.

The Oregon Department of Energy has awarded \$295,000 in state and federal funds to the Eugene Water & Electric Board (EWEB) for a pilot project that demonstrates how energy storage in a microgrid can improve community resiliency and response in emergency situations. EWEB has also launched solar microgrid test projects at three sites that will all be connected to EWEB's grid. The sites are as follows: EWEB's Roosevelt Operations Center, Blanton Heights communications tower, and a central water pumping station.

Minnesota Renewable Development Fund Grant (Ratepayer-funded) – Wind-to-Battery Project²⁰⁶: Xcel Energy conducted a Wind-to-Battery (W2B) Project to evaluate the overall effectiveness of battery technology in its ability to facilitate the integration of wind energy onto the grid. The energy storage system is a 1 MW, 7.2 MWh battery that was installed near the 11.5 MW Minwind Energy

²⁰⁴ <http://www.governor.wa.gov/news-media/state-pursues-new-smart-grid-projects-capture-store-more-solar-and-wind-power>

²⁰⁵ <http://www.oregon.gov/energy/Pages/energy-storage.aspx>

²⁰⁶ <https://www.xcelenergy.com/staticfiles/xcel/Corporate/Renewable%20Energy%20Grants/Milestone%206%20Final%20Report%20PUBLIC.pdf>

LLC (MWD) wind facility in Luverne, MN. Xcel Energy is investigating the ability of energy storage to provide system benefits, the cost-effectiveness of the storage device, and methods to evaluate other types of energy storage technologies in the future.

Through this small-scale demonstration project, Xcel Energy can evaluate energy storage technology at a modest level of investment and customer impact. By doing so, the company will promote the future deployment only of proven technologies that meet or exceed cost, reliability, and environmental requirements.

The demonstration project proved that this type of storage technology can perform functions that can help utilities manage the variability of wind energy on an operating system. This project also contributed significant knowledge and insights into the value of energy storage as a wind integration tool for the grid.

6.2.2 Rebates and Incentives

As described previously, several of the existing MassCEC and DOER programs offer financial incentives such as rebates to entities offering clean energy solutions. For example, the Commonwealth Solar II Rebate program (which ended in early 2015) provided rebates for over 13,000 solar systems across the state.

The following information about major rebate and loan programs in other states can inform stakeholders in the Commonwealth about the technical parameters and concepts that have been vetted by stakeholders and subsequently implemented to foster the energy storage industry.

NJ Solar Rebate Program: New Jersey expanded its solar rebate program to also fund energy storage projects. The objective of including storage was to (1) combine solar with other technologies to help mitigate the impact of solar on the distribution system; and (2) to develop feasible solutions to provide enhanced reliability during prolonged outages. In 2015, New Jersey's Renewable Electric Storage Incentive Solicitation²⁰⁷ committed \$3.0 million to support New Jersey's Renewable Energy goals. By leveraging the solar program and funding 9 MW of energy storage, NJ has created a vehicle for development of grid resiliency projects in case of natural disaster and interruptions to the grid. Resiliency enhanced through energy storage helps in disaster preparation and also helps create in-state expertise in installing and managing energy storage. Ultimately, this solution will foster broader business and economic development in NJ. After the extensive interest in the 2015 solicitation, the New Jersey Board of Public Utilities (BPU) approved an additional \$6 million of funding for the storage program. The first \$3 million round of funding opened on March 1, 2016, with another \$3 million round of funding expected later in 2016.

NY Green Bank: New York State Energy Research and Development Authority (NYSERDA) manages the NY Green Bank, a financial entity that leverages public and private capital to finance clean energy. The Green Bank invests in projects that utilize a wide range of technologies, including renewable and clean energy resources, as well as efficiency and demand reduction technologies such as energy storage. The Bank receives seed funding from state funds, but also requires capitalization from the private sector. Ultimately, the bank hopes to promote an expansion of clean-energy financing in New York in a way that reduces the need for government support and accelerates the deployment of clean energy while increasing customer energy choices and promoting economic development.

²⁰⁷ <http://www.njcleanenergy.com/storage>

By leveraging state dollars to attract private investment, the Bank is attempting to use market-oriented strategies to jump-start a sustainable stream of financing to support state goals of promoting clean energy technologies, decreasing energy costs while stimulating employment, and adding further energy resiliency. According to economic models, the Bank could double the amount of private capital available for clean energy investment in five years and could ultimately promote a 10-fold increase in private capital over a 20-year period.

The New York Public Services Commission approved \$165.6 million of reallocated clean energy ratepayer funds toward a December 2013 initial capitalization, which also included about \$52.9 million from Regional Greenhouse Gas Initiative allowance sales. The next major capitalization came in July 2015, when NY PSC approved another \$150 million. In January 2016, NY PSC approved the full \$1 billion capitalization goal for the Bank. By June 30, 2016, the NY Green Bank had received over \$1.4 billion in investment proposals, but had only distributed \$121 million to ten initiatives.

NY Con Ed Brooklyn/Queens Demand Management Program (BQDM): These initiatives offer special opportunities for storage to offset demand spikes in portions of New York City's Brooklyn and Queens Boroughs. The BQDM program is currently supporting non-traditional utility- and customer-sited demand reduction projects that include energy storage technologies, among other qualifying resources and systems, to aid in load reduction on sub-transmission feeders serving substations in Brooklyn. Traditional infrastructure upgrades would have been more expensive for the utility—estimates were as high as \$1 billion—than the approximately \$200 million worth of novel resources that the BQDM program seeks to procure plus the additional \$500 million worth of traditional transmission upgrades still required.

Con Ed issued an RFI for various resource types to provide demand reduction in July 2014, and NY PSC officially approved the BQDM program—and stated that it aligned with the goals of the state's Reforming the Energy Vision initiative—in December 2014. The program is targeting a total of 41 MW of customer-side solutions and additional utility-side solutions by its completion in 2018. Con Ed has begun acquiring storage through the BQDM program and, in August 2015, it signed a contract with a storage vendor for Distributed Energy Storage Systems that will offer 12 MWh of storage and provide 1 MW over 12 hours or 2 MW over 6 hours. Con Ed also expects to install utility-side fuel cell generation systems, as well as customer-side distributed fuel cells as part of the program and will explore ways to utilize its Mobile Power Interface, or "DC-link", to connect mobile energy resources such as fuel cells, solar power, and storage to the grid.

The NY Prize: Also managed by NYSERDA, this is a \$40 million initiative that provides support for new microgrids that will promote energy resiliency in the event of grid outages and reduce costs while also promoting clean energy. Potential projects can be sited anywhere in the state, but NYSERDA specifically identified a number of Opportunity Zones where local utilities have suggested microgrids could reduce grid constraints and defer infrastructure upgrades. NYSERDA is aiming to foster innovation and build partnerships by encouraging communities to work with utilities, local government, and private companies to develop projects. Projects are encouraged to utilize a variety of technologies, such as renewable generation, combined heat-and-power, smart controls, and energy storage. New York Governor Andrew M. Cuomo launched NY Prize in February 2015 as part of the sweeping Reforming the Energy Vision initiative the state is pursuing to modernize its electricity distribution system by emphasizing distributed energy resources, efficiency, resiliency, clean energy resources and increased customer engagement, among other measures. In July 2015, Stage 1 of the NY Prize awarded funding for 83 feasibility studies it selected from an applicant pool of over 130 entries, providing up to \$100,000 for the full cost of these studies, which were

completed by February 2016. Subsequent stages, however, require cost-sharing. In Stage 2, NYSERDA will utilize a pool of \$8 million to award up to \$1 million per project to go towards detailed engineering plans, selecting finalists from the candidates that respond to an RFP by October 12, 2016. Entrants in Stage 2 may include designs based on studies from Stage 1 but can also include new designs. Stage 3 will award up to \$5 million per project for actual construction of approximately 7 projects. These final projects will be selected from responses to a RFP expected to be released in fall 2017 and due in March 2018.

California - The Self Generation Incentive Program (SGIP) in California: Beginning in 2001, the Self Generation Incentive Program (SGIP) initially provided financial incentives for the installation of clean and efficient distributed generation technologies. SGIP is a ratepayer-funded rebate program, overseen by the California Public Utilities Commission (CPUC) and available to retail electric and gas customers of the four California investor-owned utilities (Pacific Gas & Electric, Southern California Edison, Southern California Gas and San Diego Gas & Electric). The initial intent was to help create distributed, clean energy generation by providing rebates for fuel cells, small solar and wind, and combined heat and power systems. The annual state-wide incentive budget for 2015 was \$74.7 million. Unused funds from previous years get rolled over into the next year. The program's expiration date is currently January 1, 2021.

Since energy storage enhances the operational ability of the existing distributed generation fleet, either in combination or by stand-alone installations at the distribution level, energy storage became eligible for the SGIP rebates in 2011. Detailed technical parameters for round trip efficiency and other eligibility criteria such as the minimum greenhouse gas (GHG) reduction have been established and recently updated.

The incentives for energy storage started at \$2.00 per watt but are reduced by 10 percent in each subsequent year. An energy storage project can only claim rebate for up to 3 MW, and each additional tranche of MW up to 3 MW has a diminishing rebate rate.

The weighted average of incentives for the systems of various energy storage sizes is as follows:

- Incentive for a 1 MW storage system = \$1,620 / kW
- Incentive for a 2 MW storage system = \$ 1,215 / kW
- Incentive for a 3 MW storage system = \$ 945 / kW

The bulk of energy storage applications have focused on a particular application/market - ranging from peak load shifting, to demand reduction, backup power, and electric vehicle charging. The average energy storage system size is between 5 to 25 kW, which is relatively small compared to the average size of other participating SGIP technologies.

The modified SGIP program furthered its goal of reducing electricity demand and greenhouse gas emissions by supporting distributed generation technologies and has played a critical role in creating the energy storage industry (and employment) in California. The inclusion of storage was justified based on the multiple benefits its deployment provided to the overall distribution level reliability, peak load management, solar photovoltaic integration, and GHG reduction. The additional tax base and creation of employment is an added bonus. A result of the SGIP program expansion to include energy storage has resulted in 106.5 MW of funded energy storage and has leveraged additional private capital in energy storage systems. The program successfully evolved

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from a program targeting Solar PV and internal combustion technology to a more diverse program as illustrated in Figure 6-1 and Figure 6-2.

	Projects	Capacity (MW)	% of Total Capacity (%)	Incentive Amount (\$)
Installed	Fuel Cell Electric	1	0.11%	1,000,000
	Wind Turbine	4	0.63%	3,088,671
	Gas Turbine	11	8.30%	7,164,285
	Microturbine	143	6.73%	22,117,026
	Fuel Cell CHP	28	3.77%	42,632,173
	Internal Combustion	253	41.65%	93,219,411
	Photovoltaic	920	38.81%	478,052,658

Figure 6-1: CA SGIP Funding Allocation by technology from 2001 to 2008 (pre-energy storage inclusion)²⁰⁸

	Projects	Capacity (MW)	% of Total Capacity (%)	Incentive Amount (\$)
Installed	Pressure Reduction T..	2	0.51%	1,312,500
	Gas Turbine	2	6.84%	2,112,000
	Microturbine	8	2.80%	4,859,600
	Wind Turbine	20	12.09%	29,150,862
	Internal Combustion	21	9.42%	32,201,478
	Fuel Cell CHP	63	9.98%	65,056,750
	Energy Storage	330	10.06%	36,696,521
	Fuel Cell Electric	215	48.30%	317,040,905
Reserved	Waste Heat to Power	2	0.93%	1,793,270
	Pressure Reduction T..	7	1.05%	2,132,050
	Gas Turbine	4	8.61%	6,848,000
	Microturbine	8	2.87%	5,945,208
	Wind Turbine	3	2.57%	5,128,200
	Internal Combustion	21	11.47%	19,793,894
	Fuel Cell CHP	7	4.40%	15,564,320
	Energy Storage	876	47.71%	152,552,458
	Fuel Cell Electric	117	20.38%	75,927,950

Figure 6-2: CA SGIP Funding Allocation by technology from 2009 to 2016

6.2.3 Procurement Authorizations by State Commission

A different approach for expanding energy storage that has been implemented in other states involves long-term procurement authorizations.

²⁰⁸ Center for Sustainable Energy (2016). Accessed January 4th 2016. <https://energycenter.org/programs/self-generation-incentive-program/program-statistics>

CA Long Term Procurement Process (LTPP): The CA Long Term Procurement Process (LTPP) is a program to integrate all procurement policies with the adoption of long-term procurement plans by the Investor Owned Utilities (IOUs) over a ten-year duration. Drivers for long-term procurement include CA's preferred loading order,²⁰⁹ GHG emission reduction measures, RPS goals, intra-zonal congestion, and system and local Resource Adequacy requirements. As part of the procurement process, the CPUC designates how much procurement must come from various types of resources (including renewables, Demand Response (DR), Energy Efficiency, Conventional, etc.). This list now specifies energy storage. To date, more than 250 MW of energy storage have been procured via the LTPP authorizations.

Arizona: All Source Request for Proposal (RFP) Solicitation Storage Requirement²¹⁰: Arizona Public Service (APS) planned to install over 500 MW of new generation within the bounds of the existing Ocotillo Power Plant in Tempe, Arizona. The ratepayer advocate, Residential Utility Consumer Office (RUCO), intervened in order to encourage a full analysis of all available resources (including energy storage), associated costs, and potential environmental benefits. APS agreed that if a new simple-cycle combustion turbine is proposed to be in service before 2021, at least 10% of the capacity will be competitively procured energy storage. APS will also use a competitive RFP process for a single or multiple storage projects totaling 10 MWhs to be in service by the end of 2018. The duration of the storage will be no less than 3 hours daily.

6.2.4 Mandates/Targets

Another example of how the energy storage industry is being advanced is via mandated goals analogous to the Renewable Portfolio Standard (RPS). Once a mandate is created, procurement authorizations and contracting mechanisms are then developed.

California Target: In 2010, California enacted legislation, known as Assembly Bill (AB) 2514. AB 2514 encouraged California utilities to incorporate energy storage into the electricity grid. The legislation defined an energy storage system as commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy. It also stated that an energy storage system may be centralized or distributed and accomplish one or more of the following:

- Reduce emissions of greenhouse gases.
- Reduce demand for peak electrical generation.
- Defer or substitute for an investment in generation, transmission, or distribution assets.
- Improve the reliable operation of the electrical transmission or distribution grid.

The legislation required the CPUC to open a proceeding to determine appropriate targets for the state's investor-owned utilities to procure viable and cost-effective energy storage systems and, by October 1, 2013, to adopt an energy storage system procurement target to be achieved by each load-serving entity by December 31, 2020.²¹¹

The legislation ultimately transitioned into a comprehensive state program that provides incentives to both private and publicly owned utilities for integrating energy storage. It also requires new

²⁰⁹ The loading order consists of decreasing electricity demand by increasing energy efficiency and demand response, and meeting new generation needs first with renewable and distributed generation resources, and second with clean fossil-fueled generation. The loading order was adopted in the 2003 *Energy Action Plan* prepared by the energy agencies and the Energy Commission's 2003 *Integrated Energy Policy Report* (2003 *Energy Report*) used the loading order as the foundation for its recommended energy policies and decisions.

²¹⁰ <http://images.edocket.azcc.gov/docketpdf/0000156123.pdf>

²¹¹ More information on that proceeding can be found on the CPUC's web site: [Energy Storage Proceeding](#).

approaches to lower regulatory barriers to greater energy storage deployment and to integrate energy storage with other state programs, including Long Term Procurement Plans (LTPP), Resource Adequacy (RA) and the RPS. In its Storage Rulemaking (R.10-12-007) the CPUC issued a decision in October 2013 directing the California's investor owned utilities (IOUs) to procure 1,325 MW of energy storage by the year 2020. The utilities have subsequently filed plans and begun biennial solicitations to procure the requisite amount of energy storage.

*Oregon - HB 2193-B Energy Storage Guidelines*²¹²: HB 2193-B directs energy companies to submit to the Oregon Public Utility Commission (PUC), no later than January 1, 2018, proposals for developing energy storage projects. Furthermore, the bill specifies that, subject to authorization by the Public Utility Commission, electric companies are directed to procure one or more qualifying energy storage system with capacity to store at least five megawatt hours of electricity on or before January 1, 2020.

6.2.5 Distributed Energy Resource Programs

New York Reforming the Energy Vision (REV) Distributed Resource Plans: New York State's REV initiative is an ambitious effort to remake the state's utility landscape into one that emphasizes Distributed Energy Resources (DERs) and uses utilities as distribution system platforms and service providers that facilitate energy transfer between many clean and resilient sources. As part of the REV initiative, the NY PSC has directed its utilities to file Distributed System Implementation Plans. These are 5 year investment plans to include alternative demand and supply resource portfolios being considered, proposed resource portfolios, and proposals of how to procure needed distributed energy resources.

California Distributed Resource Plans: On August 14, 2014, the CPUC issued an Order Instituting Rulemaking ("Order") to establish policies, procedures, and rules to guide California investor-owned electric utilities ("IOUs") in developing their Distribution Resources Plan Proposals ("DRPs"). The rulemaking will evaluate the IOUs' existing and future electric distribution infrastructures and planning procedures with respect to incorporating DERs into the planning and operation of their electric distribution systems. DERs include distributed renewable generation resources, energy efficiency, energy storage, electric vehicles, and demand response technologies. Plans were submitted in mid-2015. Ultimately, this proceeding will further refine how distributed resources are integrated into the grid, including creation of new tariff and contracting mechanisms.

Hawaii Distributed Energy Resource (DER) Programs: In Hawaii, net metered PV systems have increased to the point that program capacity can run as high as 30% to 53% of system peak load depending on the utility. Almost a fifth of all customers in Oahu (HECO) and Maui (MECO) territories are utilizing net metering.²¹³ As a result of this very high penetration of solar onto the grid net metering has been replaced with new customer Distributed Energy Resource (DER) programs.²¹⁴ This change will make energy storage more attractive economically.

Under the new programs, customers integrating DERs into the grid will need to choose between:

- **Customer Grid Supply (CGS)**: customers receive a PUC-approved credit for electricity sent to the grid and are billed at the retail rate for electricity they use from the grid.

²¹² <http://gov.oregonlive.com/bill/2015/HB2193/>

²¹³ <http://www.utilitydive.com/news/what-comes-after-net-metering-hawaii-latest-postcard-from-the-future/407753/>

²¹⁴ Hawaii PUC – Docket No. 2014-0192 - The Hawaii Public Services Commission (PUC) is currently in Phase 2 of Docket No. 2014-0192. Phase 1 of this proceeding ended net metering and led to a re-designed, market-based structure for interconnecting new distributed energy resources to the grid (including both solar and storage).

- Customer Self Supply (CSS): is intended only for solar PV installations that are designed to not export any electricity to the grid. Customers are not compensated for any export of energy.²¹⁵

In order to reach its 100% renewable energy goal by 2045, Hawaii will likely need to implement a large amount of energy storage onto its grid.

Many states offer net energy metering as an incentive for interconnecting distributed solar resources. Pronounced solar penetration can result in operational and reliability challenges for the utility and the grid operator. Therefore many states are re-evaluating the concept of net energy metering (NEM). Without NEM, energy storage combined with solar can be a more economical solution.

6.3 Energy Storage Initiatives and Programs in Other ISO-NE States

Energy storage initiatives are blossoming in New England. Following are key developments happening in the neighboring states:

Regional

The Massachusetts Department of Energy Resources, the Connecticut Department of Energy and Environmental Protection, Eversource Energy, National Grid and Unitil developed a Final Clean Energy RFP²¹⁶ in order to identify projects that will advance the clean energy goals of Connecticut, Massachusetts and Rhode Island. Public versions of the bids in response to this RFP were made available on February 1, 2016. Of note, Nextera's bid includes energy storage (2 x 25 MW storage facilities integrated with wind).

Connecticut

The Connecticut Department of Energy and Environmental Protection (DEEP) is pursuing the following activities related to energy storage:

Demonstration Project – An initiative for demonstration projects for grid-side system enhancements to integrate distributed energy resources, with one of the goals of the project being to include energy storage. Proposals were due on February 8, 2016. More information is in the project notice.²¹⁷

Microgrid Grant – A Microgrid grant program with \$30 million total available funding in the most recent round, more information is available in the docket for this latest round²¹⁸ and on the program website²¹⁹, which details past rounds of funding.

²¹⁵ <http://www.hawaiianelectric.com/heco/Clean-Energy/Renewables-and-Customer-Generation/Customer-Grid-Supply-and-Self-Supply-Programs>

²¹⁶ CT DEEP, Notice of Request for Proposals from Private Developers for Clean Energy and Transmission, November 12, 2015; <https://cleanenergyrfpdotcom.files.wordpress.com/2015/11/clean-energy-rfp-final-111215.pdf>

²¹⁷ CT DEEP, Notice of Stakeholder Meeting and Opportunity for Public Comment, January 6, 2016; http://www.seadvantage.com/Documents/Eyes_and_ears_Library/CT/Sec103_DER_Integration_Demonstration_Project_Notice.pdf

²¹⁸ <http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/69dc4ebaa1ebe96285257ed70064d53c?OpenDocument>

²¹⁹ <http://www.ct.gov/deep/cwp/view.asp?a=4405&Q=508780>

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Information Gathering for Storage – Docket 15-11-34²²⁰ is aimed at collecting information about energy storage from industry stakeholders and interested parties.

DEEP Issued RFP – DEEP issued a Request for Proposals (RFP)²²¹ for small-scale clean energy under PA 15-107 on March 9, 2016 which explicitly included energy storage resources as an eligible technology.

Rhode Island

Vision Document - The Office of Energy Resources (OER), the Energy Efficiency and Resource Management Council (EERMC), the Distributed Generation Board (DG Board), and National Grid have assembled a Systems Integration Rhode Island (SIRI)²²² working group to identify significant issues with respect to the future of Rhode Island's electric grid and thereafter develop recommendations. A final "vision document" was released in January 2016. This effort mentions storage as a "non-wires alternative" (NWA) factor in distribution planning and system reliability procurement; recommendations include promotion of cost-effective, comprehensive NWA distribution planning, and acceleration of EV use.

State Energy Plan - The State Energy Plan²²³ was recently completed. The October 2015 final plan²²⁴ includes consideration of energy storage as a means for increasing energy security/resiliency, grid modernization, and interstate coordination to reduce high and volatile regional energy costs. The plan includes a modeled deployment of 200 and 150 MW of storage. The report does acknowledge the need for modifications to rate and regulatory regimes to accelerate deployment.

Maine

BoothBay Smart Grid Project - The Maine Public Utility Commission (PUC) has been overseeing GridSolar's Boothbay Smart Grid Reliability Pilot Project (Maine PUC Docket 2011-00138),²²⁵ which includes solar PV systems, battery storage, and ice banking storage as parts of the overall non-transmission alternative project. The final report was recently issued in the docket, which provides more details on the project and recommendations based on findings during the pilot term.

Transmission Alternatives - The PUC also initiated an inquiry into designating a non-transmission alternative (NTA) coordinator for the state, but the docket was closed due to significant issues remaining to be resolved. The Commission staff have been directed to draft a Notice of Investigation to identify issues to be resolved before defining the role of an NTA coordinator.

Vermont

Energy Plan - Energy storage has been included in the recently issued 2016 Vermont Comprehensive Energy Plan²²⁶, developed by the Department of Public Service Commission and issued in January 2016. Section 10.4 is devoted to storage and includes recommendations. Of note, the report recognizes price decreases as a result of federal policies and market maturation.

Pilot Program - Green Mountain Power (GMP) is in the early stages of a pilot program offering 7 kWh Tesla Powerwall batteries²²⁷ for in-home energy storage for customers to both supplement solar

²²⁰ [http://www.dpuc.state.ct.us/dockcurr.nsf/\(Web+Main+View/All+Dockets\)?OpenView&StartKey=15-11-34](http://www.dpuc.state.ct.us/dockcurr.nsf/(Web+Main+View/All+Dockets)?OpenView&StartKey=15-11-34)

²²¹ [http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/ffee9c54378d404a85257f710054fb32/\\$FILE/RFP_03-09-16_CLEAN.pdf](http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/ffee9c54378d404a85257f710054fb32/$FILE/RFP_03-09-16_CLEAN.pdf)

²²² <http://www.energy.ri.gov/siri/>

²²³ <http://www.energy.ri.gov/energyplan/>

²²⁴ <http://www.planning.ri.gov/documents/LU/energy/energy15.pdf>

²²⁵ <https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2011-00138>

²²⁶ http://publicservice.vermont.gov/publications-resources/publications/energy_plan/2015_plan

²²⁷ <http://products.greenmountainpower.com/product/tesla-powerwall/>

power systems and provide backup power. The two purchase options for the GMP Tesla PowerWall offering are for \$6,501. A separate option allows the customer to lease the system for \$1.25 per day. Dynapower of Burlington VT is the supplier for the inverter technology of the larger 100 kWh Powerpack (which, unlike the Powerwall, is not marketed directly to residential and small commercial customers) is priced point below the threshold that many analysts predicted would be necessary for batteries to be cost-competitive with new peaking plants for electricity. GMP estimates that the cost of installing two proposed Powerwalls at a state park will take the park off grid and cost 20% of what it would have to spend to rebuild the distribution line.

Demonstration Project - In 2013, the Department of Public Service (DPS) partnered with the DOE's Office of Electricity (DOE-OE) and the Clean Energy States Alliance (CESA) to encourage a utility-scale energy storage demonstration project. The DPS's Clean Energy Development Fund issued a \$50,000 solicitation, and the DOE-OE agreed to contribute \$235,000 in funding to the selected project. The Stafford Hill energy storage project was chosen to receive funding, and became operational in 2015. This 4 MW, 3.4 MWh electric energy storage system was installed in conjunction with a 2 MW solar photovoltaic project in Rutland by Green Mountain Power, with controls supplied by Dynapower.

New Hampshire

Grid Modernization Plan - The PUC is investigating the issue of grid modernization in Docket IR 15-296.²²⁸ Public comments were accepted in the fall of 2015. The NH PSC has directed its utilities to file *Distributed System Implementation Plans*. The five-year investment plans are to include alternative demand and supply resource portfolios, proposed resource portfolios, and proposals of how to procure needed distributed energy resources.

6.4 Conclusion

The Commonwealth's framework of public policy, invention, innovation, and increased adoption of clean energy technologies is well underway. The Massachusetts framework involves governmental research, development, and demonstration (RD&D) funding, establishment of consensus and industry standards, incentive programs, and industry programs and initiatives, all operating within the context of a competitive energy market place.

As energy storage is already a part of the existing landscape, broadening existing programs is a logical step. Furthermore, lessons learned from other states and regions can be considered and applied to the Massachusetts context to ensure successful development of energy storage in the state. This is explored in greater depth in following chapters.

²²⁸ <https://www.puc.nh.gov/Regulatory/Docketbk/2015/15-296.html>

7 Policy Recommendations to Grow the Deployment of Advanced Energy Storage in Massachusetts

7.1 Introduction

A roadmap is proposed for Massachusetts to facilitate the deployment of energy storage within the state to achieve optimal system benefits to rate payers. The Study Team identified where market barriers exist and what policy and program changes can be made to enable the development of more storage in Massachusetts.

Chapter 7 provides a comprehensive suite of recommendations for Massachusetts policy and programs to help realize energy storage system benefits through the procurement of **600 MW of new energy storage** on the Massachusetts grid by 2025. These regulatory and policy recommendations seek to maximize the system benefits of energy storage via long-term ratepayer cost reductions, increased grid resilience and reliability and decreased GHG emissions. Recommendations support a diverse range of Use Cases, and include recommendations to develop a sustainable and cost competitive energy storage market in the Commonwealth. The recommendations can unlock the game-changing potential of energy storage on the Massachusetts electric grid.

Recommendations include:

- Grant and rebate programs
- Storage in state portfolio standards
- Establishing/clarifying regulatory treatment of utility storage
- Options that include statutory change
- Other changes: easing interconnection, safety and performance codes and standards, and customer marketing and education

Table 7-1 below shows which policies and programs, further described in Chapters 7 and 8, would jumpstart specific Use Cases and begin wider deployment.

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Use Cases		Policies & Programs								ISO-NE Market Rule Changes	
		Grant and Rebates				State Portfolio Standard		Regulatory Treatment			
		ESI Funding for Storage Demonstrations	MOR-Storage Rebates for MA Businesses	Resiliency Grants	Make Storage Eligible for Green Communities Grants	Add Storage to Alternative Portfolio Standard	Storage + Solar Option in Next Solar Incentive Program	DPU Grid Modernization	Energy Efficiency Programs for Peak Demand Savings		Statutory Change: Storage in Future Renewable Procurements
Investor Owned Utility (IOU) Grid Mod Asset: Distributed Storage at Utility Substations		•				•	•	•	•		•
Municipal Light Plant (MLP) Asset		•				•	•				•
Load Serving Entity (LSE)/Competitive Electricity Supplier Portfolio Optimization		•				•	•				•
Behind the Meter	Commercial & Industrial Solar Plus Storage	•	•		•	•	•		•		•
	Residential Storage Dispatched by Utility	•				•	•		•		•
Merchant	Alternative Technology Regulation Resource	•				•					•
	Storage + Renewable	•				•	•			•	•
	Stand-alone Storage or Co-Located with Traditional Generation Plant	•				•					•
Resiliency/Microgrid		•		•	•	•	•				•

Table 7-1: Policies and Programs Recommendations

7.2 The DOER & MassCEC Grant and Rebate Programs

7.2.1 Energy Storage Initiative (ESI): RFP for Project Demonstrations

Summary	Grant funding to demonstrate the diverse Use Case applications of storage
Duration of the program	One-time competitive grant opportunity
Funding	Part of \$10 million of ESI funding, recommend increasing to \$20 million given storage stakeholder interest and study results.
Targeted Use Cases	All cost-effective Use Cases
Implementation requires	Develop and issue an RFP to spend existing funding

Description

As planned under the existing Energy Storage Initiative (which includes completion of this report), project demonstration funds will serve as an initial catalyst to jump start implementation of storage projects in Massachusetts. There is no substitute for “learning by doing” as a means for overcoming barriers and motivating market actors. Under the banner of the Massachusetts Energy Storage Initiative or ESI, this program is intended to quickly spur the market to deploy projects. Through demonstration grants, the objective of the pilots is to engage private sector investment, validate Use Cases, facilitate development experience, and identify and solve hurdles to storage deployment through stakeholder collaboration on actual projects.

Requirements

The ESI funding would prioritize fast deployment of the high value Use Cases identified in Chapter 5. Projects with simpler implementation would hopefully provide early success to build upon; however, more complex project implementation will serve to uncover unforeseen regulatory and other market barriers. Demonstration projects will enable the testing of various ownership and procurement models for storage projects.

7.2.2 Massachusetts Offers Rebates for Storage (“MOR-Storage”) Program

Summary	Rebate Program for Behind the Meter Storage Projects (customer-sited)
Duration of the program	Rolling grant opportunity
Funding	\$20 million of ACP funds
Targeted Use Cases	Storage located on-site (either paired with on-site solar generation or stand-alone) at commercial and industrial businesses
Implementation requires	Development of program scope and incentives

Description

Incentive buy down programs have been very successful in rapidly accelerating new technology development. This program would be modeled after the DOER’s successful MOR-EV Rebate program that provides funding to Massachusetts residents who purchase electric vehicles. The goal of the MOR-Storage program is to encourage Massachusetts commercial and industrial businesses to invest in storage that will 1) assist the business in lowering their electricity bills, 2) integrate any on-site

generation, and 3) provide benefits to the grid by reducing peak demand. Funding would be from the DOER Alternative Compliance Payment (ACP) funds.

Key best practices from similar programs include establishing clarity of program goals and objectives, requiring customer or third-party cost share, and providing sufficient funding so the program can help achieve market transformation. Utilizing performance based incentives and ensuring program certainty over time, both in terms of per project incentive amounts and program funding and duration are also recommended. The program, which could be administered by the DOER and/or MassCEC, could award rebate incentives on a first come first served basis, with a portion of the incentive funding provided up front upon project commissioning and the remaining incentives to be provided over time.

Other State Examples

A similar program in California called the Self-Generation Incentive Program (SGIP) provides incentives to support existing, new, and emerging distributed energy resources. SGIP is a ratepayer-funded rebate program, overseen by the California Public Utilities Commission, and available to retail electric and gas customers of the four California investor-owned utilities. The program is currently funded at \$83 million annually through 2019 and supports the deployment of distributed generation projects and the reduction of onsite electric demand and greenhouse gas emissions.

Another example is the New Jersey's Renewable Electric Storage Program that provides financial incentives for electric energy storage systems that are integrated with Class 1 renewable energy projects installed behind-the-meter at non-residential customer sites. It seeks to benefit New Jersey ratepayers by supporting the installation of renewable electric storage systems in government, commercial, institutional and industrial entities for the purpose of providing emergency back-up power for essential services, offsetting peak loads by shifting electricity to hours of higher demand and/or helping to stabilize the electric distribution system through the provision of frequency regulation services.

A program was also launched by the state of Maryland through its Game Changer competitive grant program in 2015. The program awards grants ranging from \$25,000 to \$250,000 per award. Applicants are expected to provide at least 70% of the project costs. One area of interest in the program is commercial, customer-sited electric storage systems that are integrated with a Tier 1 renewable energy source. Maryland will only consider systems that provide a quantifiable reliability or resiliency benefit, demonstrate an innovative Use Case for storage, and drive economic development opportunities. Examples of innovative Use Cases may include the potential for storage to mitigate intermittency from on-site renewable generation, to manage on-site demand during times of highest need, or to provide another benefit to the host customer or electric system more generally, including utility distribution systems and wholesale markets.

Funding

MOR-Storage could make use of a step down \$/Watt incentive that declines each year and may need to be adjusted as rates and tariffs evolve. For example, the California Self Generation Incentive Program (SGIP) initially offered \$2/Watt and is reduced by 10% each year.

This funding mechanism would promote accelerated development by bridging the need for traditional financing that may not be realizable prior to additional market design changes or a decline in cost sufficient to create positive cash flows.

Requirements

MOR-Storage funded projects should require validation that the storage selected is actually providing a service that ultimately benefits all consumers, such as reducing on-site peak demand which results in lower peak electricity prices. There should be a size cap on the total funding that can go to a single project so that no single project absorbs too much of the overall funding pool. They should meet certain minimum viability thresholds established based on stakeholder feedback. Minimum viability thresholds could include minimum customer/third party investment requirements (cost share), and other items such as signed customer letters of intent, preliminary design completed, interconnection request filed, etc.

Other Anticipated Program Elements:

- Clarity on total funding for the incentive program, so as to encourage debt/equity investment in new projects
- Leverage investment/cost share of the private sector
- Ensuring storage is capable of dispatch to respond to local and system needs

7.2.3 Grant Funding for Feasibility Studies at C&I Businesses

Summary	The Solar Plus Storage pilot program will fund site assessments that qualify the technical and financial feasibility of storage only, or solar plus storage systems at C&I businesses
Duration of the program	1 year
Funding	\$150,000 of MassCEC funds
Targeted Use Cases	On-site storage at C&I businesses
Implementation requires	Launch of RFP for feasibility study program

Description

Small to medium sized commercial and industrial customers, particularly Massachusetts manufacturers, often struggle with high and volatile energy costs, which can dramatically impact their competitiveness. At the same time, these customers rarely have the time, nor the in-house expertise to evaluate potentially cost saving storage, or solar plus storage, options for their facilities.

The Solar Plus Storage pilot program will fund a limited number of site assessments that qualify the technical and financial feasibility of storage only, or solar plus storage systems at participating manufacturing facilities. Individual assessments will be provided to manufacturers – free of charge – and a pilot wide, aggregated and anonymized report will be provided to MassCEC and DOER to help inform program and policy decision making.

Funding

MassCEC has allocated \$150,000 to fund 15-30 feasibility assessments. Staff will retain 2-3 qualified firms to conduct assessments, in order to obtain a range of market perspectives. Additionally, MassCEC anticipates making grants and/or financing available to participating facilities to help enable adoption of recommended energy storage systems.

Requirements

The feasibility assessments will include, at a minimum, a description of the optimal system configuration (e.g. energy storage system size, necessary controls hardware, etc.), estimated year 1

benefits for each system, including all applicable state and federal incentives, expected lifetime benefits for each system, and an estimation of the additional incentive, where applicable, that would be necessary to make such a system financially viable and attractive to the customer.

7.2.4 Community Resiliency Grants – Part III

Summary	DOER’s “Community Clean Energy Resiliency Initiative” is a grant program that is part of the Administration’s comprehensive climate change preparedness effort. Round III of the grant program will be focused on C&I and municipal resilience projects using clean energy plus storage solutions to protect from service interruptions.
Duration of the program	One-time grant opportunity
Funding	\$14.2 million remaining of an existing \$40 million ACP funded initiative
Targeted Use Cases	C&I Solar Plus Storage; Microgrid; C&I CHP + Storage
Implementation requires	Development and issuance of an RFP by DOER/MassCEC

Description

DOER’s “Community Clean Energy Resiliency Initiative” is part of the Administration’s comprehensive climate change preparedness effort. Round III of the grant program will be focused on C&I and municipal resilience projects using clean energy plus storage solutions to protect from service interruptions. Resiliency grants fund critical C&I (e.g. hospitals) and municipal facilities. Projects funded through the Community Resiliency Initiative grants will protect critical facilities (hospitals, shelters, gas stations, transportation, schools, etc.) by implementing clean energy technologies to keep facilities operable in times of power outages due to severe climate events or other emergency situations. The initiative also provides technical assistance support for potential project sites and critical facilities, and develops recommendations for resilient clean energy solutions. Knowledge gained from projects funded under the program can be utilized to enhance future resiliency programs and expand on Use Cases. Targeted Use Cases include C&I Solar Plus Storage, Microgrid, and Storage + CHP.

The state of New York launched a similar program through its NY PRIZE program to promote the development clean energy, reduce costs, and build reliability and resiliency into the grid. The New York State Energy Research and Development Authority (NYSERDA), in partnership with the Governor’s Office of Storm Recovery (GOSR) announced the availability of up to \$40,000,000, under the three-stage NY Prize Community Grid Competition (NY Prize), to support the development of community microgrids. The objective of NY Prize is to promote the design and build of community grids that improve local electrical distribution system performance and resiliency in both a normal operating configuration as well as during times of electrical grid outages.

Funding

The initiative is funded by \$40 million in Alternative Compliance Payments (ACP), with a remaining \$14.2 million available for Round III. Funding is awarded to facilities where the loss of electrical service would result in the disruption of a critical public safety or life sustaining function in communities.

Requirements

DOER may fund projects that incorporate eligible clean energy technologies at critical facilities and integrate these technologies with energy storage options such as batteries, flywheels, electric

vehicles with vehicle to grid capabilities, thermal storage including hot/cold water, ice, and other phase change storage. Eligible applicants include private sector entities, municipalities (individual or joint), public/private partnerships, regional school districts, regional water districts, regional sewerage districts, and regional planning agencies (RPAs). Grant funding will prioritize critical facilities including life safety resources, lifeline resources and community resources. Applications may consist of a project at a single building, multiple independent buildings, or multiple interconnected buildings (a microgrid).

7.2.5 Green Communities Designation and Grants

Summary	Green Communities Designation and Competitive Grants
Duration of the program	Permanent
Funding	DOER (\$10 million per year)
Targeted Use Cases	Municipalities
Implementation requires	Adding storage as an eligible technology to existing grant program

Description

The Green Communities Division strives to help all 351 Massachusetts cities and towns find clean energy solutions that reduce long-term energy costs and strengthen local economies. The division provides technical assistance and financial support for municipal initiatives to improve energy efficiency and increase the use of renewable energy in public buildings, facilities and schools.

Municipalities in Massachusetts can become a Green Community by meeting the five criteria required. Along with the designation of Green Community comes an initial grant award to fund identified clean energy projects in the community. Once these initial projects are completed, the designated Green Communities are able to apply annually for additional grant opportunities to further improve energy efficiency, energy management, and renewable energy in the municipality.

While no energy storage projects have been funded through the Green Communities program to date, it could be added as an eligible technology in future grant opportunities. Energy storage has the ability to meet objectives of the program through prioritizing demand reduction and the integration of renewables into communities. Storage can respond to peak load reduction or peak load shifting objectives to meet the Green Communities Act's call for cost effective energy efficiency and demand response. Storage could potentially also be deployed as a component of broader municipal building energy efficiency projects using the existing Mass Save® custom incentives.

Funding

DOER reimburses communities that receive awards for project costs. Total expenditure is limited by the enabling legislation to \$10 million per calendar year.

7.2.6 Grant Program to Demonstrate Peak Demand Savings

Summary	DOER will be funding demonstration grants where utility and market actors can directly address the technical, regulatory, and market challenges of peak demand management in our state-wide Energy Efficiency programs.
Duration of the program	3 years
Funding	\$4.5 million DOER funds
Targeted Use Cases	Storage located at customer-sites, residential, and C&I
Implementation requires	DOER procurement process

Description

The 2016-2018 Statewide Energy Efficiency Investment Plan (“Three Year Plan”), supported by the Energy Efficiency Advisory Council (“EEAC”) and approved by the Department of Public Utilities (“DPU”), identifies peak demand reduction as an area of particular interest in the term sheet and in the EEAC resolution supporting the Three Year Plan. DOER will be funding demonstration grants where utility and market actors can directly address the technical, regulatory, and market challenges of peak demand management in our state-wide Energy Efficiency programs. The goal of the grant program is to test a variety of program designs against Massachusetts market conditions to gain a better understanding of how peak demand management can be a viable system resource moving forward.

Both electric and thermal storage are expected to be among the technologies tested in this grant program. This will enable testing not only of the delivery mechanisms for peak demand management strategies, but also the efficacy of storage technology when used in an active peak demand management program.

Funding

The \$4.5 million in grants will come from ACP funds and be distributed over the course of three calendar years (2016-2018).

Requirements

Grant recipients will be required to develop proof of concept active demand response demonstration projects, and show how the projects could successfully expand under Massachusetts energy efficiency framework and ISO-NE market rules. Specific details will be determined in the forthcoming RFP process.

7.3 Storage in State Portfolio Standards

7.3.1 Amend Alternative Portfolio Standard (APS) to Include All Types of Advanced Energy Storage

Summary	Amending the APS would help close the revenue gap for storage project developers by creating an additional revenue stream to monetize the system benefits not readily captured by storage developers, but which ultimately flow to all ratepayers in the form of lower electricity prices.
Duration of the program	Indefinite (existing program targets increase indefinitely)
Funding	Payments made by Retail Electricity Suppliers for Alternative Energy Certificates (AECs), with program costs embedded in the price paid by electricity end-users for generation supply
Targeted Use Cases	All
Implementation Requires	Regulatory change to the list of eligible technologies under the Alternative Energy Portfolio Standard. ²²⁹ Massachusetts APS currently supports flywheel storage.

Description

The APS requires Retail Electricity Suppliers to include a minimum percentage of electrical energy sales to Massachusetts end-use customers by procuring APS Alternative Energy Certificates (AECs), per 225 CMR 16.00. The proposed change would expand the list of eligible resources established by statute, from the existing combined heat and power, flywheel storage, and renewable thermal energy eligible resources, to all advanced energy storage technology.

Inclusion of a broader range of energy storage systems (beyond the currently-eligible flywheel systems) in the Alternative Energy Portfolio Standard (APS) would expand an existing financial mechanism to encourage increased deployment of energy storage. The market-based nature of the program requires competition against other resource types eligible to supply the APS, thus minimizing the cost of AECs. This approach also caps expenditures by virtue of the size of the APS market and the level of the Alternative Compliance Payment (ACP) Rate. An increased supply base for APS would reduce the likelihood of ACPs by suppliers, thereby reducing ratepayer costs. While not required to be associated with a generation facility, when co-located with an RPS-eligible variable energy resource (solar or wind) installation, the APS revenue would be additive to Class I REC revenue. This is comparable to an RPS-eligible biomass combined heat and power system that can currently earn Class I RECs for electric output and AECs for thermal output. The expected deployment of energy storage as a result of such a program is difficult to estimate without a thorough competitive market analysis, but could be very significant.

This would help close the revenue gap for storage project developers by creating an additional revenue stream to monetize the system benefits not readily captured by storage developers, but which ultimately flow to all ratepayers in the form of lower electricity prices. Since the AECs are paid by ratepayers, as long as the AEC value is lower than the system benefits created this is a win/win for ratepayers of the electric system because it reduces the max electric costs.

²²⁹ The Alternative Energy Portfolio Standard (APS) was established as of January 1st 2009, under the Green Communities Act of 2008, which amended M.G.L. Chapter 25A by adding Section 11F1/2.
<https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169>

Unlike the Class I or Class II RPS where 1 MWh always produces 1 REC, each eligible storage resource type should have a unique method for determining the quantity of AECs produced. For example, for flywheels, the existing method is energy output of a Flywheel Storage Unit, calculated each quarter of the Compliance Year as 65% of the electrical energy discharged from the Flywheel Storage Unit during the quarter.”²³⁰

Requirements

To implement this APS modification, DOER would begin a rulemaking targeted at answering design and implementation questions such as:

- What is the mechanism for determining the amount of AECs granted to different types of energy storage?
- What should the APS annual percentage targets be if energy storage is added to the list of eligible technologies contributing to supply?

The rulemaking would likely begin no earlier than the fall of 2016, immediately following an earlier rulemaking to incorporate thermal renewable energy into the APS. DOER staff would develop the proposed draft APS regulations to incorporate energy storage in parallel with the rulemaking on renewable thermal.

It is recommended that storage resources qualifying under the APS would need to be interconnected to the electric grid in Massachusetts.²³¹ Eligibility should ensure that there is a minimum and material energy storage capacity. It may be appropriate to require a commitment from the energy storage resource to dispatch during peak demand or be subject to utility dispatch. It would also be necessary to define a method for determining the quantity of Alternative Energy Attributes produced. If eligibility were to be expanded to thermal energy storage, a quantifiable volumetric metric with which to associate and distribute AECs would need to be developed.

7.3.2 Consideration of Storage in Next Generation Solar Incentive Program

Summary	Tailor new incentive program design to encourage Solar Plus Storage applications
Duration of the program	Approximately 2017-2023, with payments to generators for 10-20 years from commercial operation date.
Funding	Payments by EDCs and/or Retail Electricity Suppliers for RECs or SRECs (as applicable), with costs embedded in price paid by electricity end-users for generation supply
Targeted Use Cases	Merchant: Solar Plus Storage for Grid Benefit; Behind the Meter C&I Solar Plus Storage; Load-serving Entity;
Implementation Requires	The recently enacted Chapter 75 of Session Laws of 2016 provides DOER with sufficient authority to develop a new solar incentive program, which could include a targeted incentive for solar plus storage within the policy design.

Description

Incorporating solar with behind-the-meter energy storage within the Commonwealth’s future solar incentive would create a reliable long-term revenue stream for energy storage owners. While

²³⁰ 225 CMR 16.05(1)(a)3.b.

²³¹ Per 225 CMR 16.05(1)(d)

incentives would ultimately be paid for by retail electricity customers, the deployed systems would help these same Massachusetts ratepayers capture all of the system benefits of energy storage, including its ability to lower electric costs. In addition, using energy storage in concert with customer-sited solar would allow deployment of solar's intermittent production to reliably match load, driving both greater value to the owner and increased benefits to the system. The goal of this program would be to deploy solar plus storage systems to deliver clean renewable energy to serve local load and provide grid benefits. By aggregating resources to maximize the value of the Solar Plus Storage combination, storage could be used to maximize grid benefits to all ratepayers while also serving a power reliability and backup function to the host. The storage could also be remotely dispatched by the local distribution utility or a third party aggregator to help maximize system benefits.

Energy storage co-deployed and co-located with solar can allow the reshaping of solar production to better support system needs in the wholesale market (energy arbitrage, capacity value), reduce energy and demand charges for host customers, and better support the distribution system (minimizing back flow, better matching generation and load on distribution feeders, etc.). The benefit and attractiveness to C&I solar hosts increases as the level of net metering compensation declines as established by Chapter 75 of Session Laws of 2016.

Lastly, the incentive program could be used to reduce reliance on net metering for both behind-the-meter (BTM) and merchant Solar Plus Storage projects. In a BTM scenario, the storage owner benefits by storing and using the energy locally, avoiding electricity costs at the full retail rate as opposed to being credited for exported power at a lower net metering credit rate. This is beneficial to both ratepayers and the owner as it reduces net metering costs that must be recovered from ratepayers and increases the value of each kWh generated by the PV system for the owner.

In a merchant Solar Plus Storage scenario, the incentive could be structured to encourage co-location of storage resources with solar. Through the use of the incentive structure, it's possible that co-locating Solar Plus Storage could provide more value to both the system owner and all ratepayers than a net metered solar facility would provide.

DOER's current solar incentive, the Solar Carve-out II (SREC-II) program, was recently extended through at least January 8, 2017 (for projects that can be constructed on or before that date). DOER is required by statute²³² to establish a solar policy to succeed the current SREC-II program. The form of the program, and its targets, are still to be determined, but could take the form of either long-term contracts or tariffs issued as a result of either a declining block incentive or a competitive solicitation (in either case offered via electric distribution company tariff), or a modified solar renewable energy credit (SREC) program similar to SREC-II administered by DOER. The specific mechanism for the proposed incentive would differ depending on the structure and details of the future solar program.

Requirements

Following the conclusion of the recently opened rulemaking to implement SREC-II Solar Carve-out emergency regulations, DOER will open a rulemaking on a new solar incentive program. This rulemaking will likely begin sometime in fall 2016, following the development of a straw proposal and stakeholder engagement that should occur over the course of the summer and early fall. Within this rulemaking, DOER would establish the incentive for solar plus storage installations. Based on this schedule, the new solar program would be expected to go into effect in early 2017.

²³² On April 11, 2016, Governor Baker signed into law Chapter 75 of Session Laws of 2016.

7.4 Establish/Clarify Regulatory Treatment of Utility Storage

7.4.1 Storage as Grid Modernization Asset

Summary	Today, Investor Owned Utility (IOU) grid modernization plan filings include limited amounts of energy storage. Based upon the findings of this report, IOUs could update their Grid Modernization plans to augment their investment in storage. In addition, the Commonwealth may benefit from a further DPU investigation into energy storage based upon the findings and recommendations of this report.
Duration of the program	Filings include 5-year short-term investment plans
Funding	Costs of approved investments are pre-authorized for cost recovery through a capital tracker
Targeted Use Cases	Investor Owned Utility Grid Mod Asset: Distributed Storage at Utility Substations
Implementation Requires	IOUs use findings of report to update and subsequently amend their grid modernization plans. DOER may petition DPU to open an investigation into issues unique to energy storage including, but not limited to, DPU guidelines to evaluate energy storage proposals and to examine the business model of IOUs contracting with third-parties for operating storage to enable sales to ISO-NE.
Examples in other States	Grid modernization dockets are open in several states

Description

In June 2014, the Massachusetts Department of Public Utilities (DPU) issued Order 12-76-B (Order) requiring each electric distribution company (EDC) to develop Grid Modernization Plans (GMPs) to meet four objectives: (1) reduce the effect of outages; (2) optimize demand which includes reducing system and customer costs; (3) integrate distributed resources; and (4) improve workforce and asset management. This report has described numerous Use Cases of energy storage that would successfully address the objectives of the Order particularly optimizing demand, integrating distributed resources, and mitigating outages.

The Order requires each IOU to submit a ten-year overall GMP that includes a detailed five-year investment plan of specific grid technologies and costs termed the “Short-Term Investment Plan” or STIP. The IOUs must justify the investments detailed in the STIP with a business case.²³³ All those investments in the STIP that receive approval by the DPU can be considered “pre-authorized” and, therefore can be recovered through a capital tracker typically a formula-based tariff. In other words, the IOU can go forward with the investments approved in their STIP and file annually for reconciliation against the actual costs incurred, and recover these costs in rates according to an approved formula-based tariff.

The business case filing requirements specified in attachments to a subsequent companion DPU Order (DPU 12-76-C) provide a list of technologies and functions that can be included in the STIP. “Energy Storage Technologies” is one of the categories listed and is defined as:

²³³ The business case analysis should include: (1) a detailed description of the proposed investments, including scope and schedule; (2) the rationale and business drivers for the proposed investments; (3) identification and quantification of all quantifiable benefits and costs associated with the STIP; and (4) identification of all difficult to quantify or unquantifiable benefits and costs. D.P.U. 12-76-B, p 17.

Technologies that can store electricity to be used at a later time. These devices require a mechanism to convert AC electricity into another form for storage, and then back to AC electricity. Common forms of electricity storage include batteries, flywheels, and pumped hydro. Electricity storage can provide backup power, peaking power, and ancillary services, and can store excess electricity produced by renewable energy resources when available.

The business case requirements define possible functions of grid mod technologies. Examples of listed functions that are particularly relevant to energy storage include: (1) customer electricity use and optimization, (2) demand response, (3) distributed energy resource monitoring and control, and (4) distribution-sited grid storage integration and control. The business case summary template instructions include a reference, which provides examples on how to map technologies to functions and functions to benefits.²³⁴

Consistent with the benefits described in this report, and the objectives of the Order, Table 7-2 lists the benefits of “stationary electricity storage” to smart grid projects using the EPRI methodology included in the DPU Order:

Benefits of “stationary electricity storage” Taken from EPRI Methodology	
Improved Asset Utilization	Optimized Generator Operation
	Deferred Generation Capacity Investments
	Reduced Ancillary Service Cost
	Reduced Congestion Cost
T&D Capital Savings	Deferred Transmission Capacity Investments
	Deferred Distribution Capacity Investments
Electricity Cost Savings	Reduced Electricity Costs
Power Interruptions	Reduced Sustained Outages
Power Quality	Reduced Momentary Outages
	Reduced Sags and Swells
Air Emissions	Reduced CO ₂ Emissions
	Reduced SO _x , NO _x , and PM-10 Emissions
Energy Efficiency	Reduced Electricity Losses

Table 7-2: EPRI Smart Grid Technology Benefits: Energy Storage²³⁵

Further, the Order allows for proposed research, development, and deployment (RD&D) of new and emerging technologies, and specifically lists energy storage as a technology that can be included in an RD&D “portfolio of projects.” The IOUs may propose “additional funding mechanism to support increased RD&D activities.”

²³⁴ Examples are taken from EPRI’s 2010 report: Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects;

<https://www.smartgrid.gov/files/Methodological Approach for Estimating Benefits Costs Smart 201007.pdf>

²³⁵ Ibid.

Description

Pursuant to DPU's 12-76 Orders, IOUs have the ability to include various technologies in their grid modernization plans so long as these technologies are oriented towards the four grid modernization objectives or part of the IOU's RD&D proposals which are: Energy storage technologies align with several of DPU's proposed examples of grid modernization technologies, and some IOU's grid modernization plans do include storage projects already. Based on the findings in this report, IOU's could amend their grid modernization plans to include more energy storage, as appropriate. DPU's grid modernization proceedings are on-going; however, the DPU's Orders permit an EDC to amend its grid modernization filing in between rate case filings. Amendments to the IOU's grid modernization plans are at the IOU's discretion. Further, as highlighted with several Use Cases, the Commonwealth may benefit from a new DPU investigation on storage.

Energy Storage is a contemporary technology, which has not received thorough assessment and clarification from Massachusetts' regulatory bodies. DOER may petition DPU to open an investigation into issues unique to energy storage. Opening a DPU investigation specifically assigned to storage would assist with the creation of guidelines for methods and procedures for the evaluation and approval of energy storage. Additionally, investigating a business model where IOU's could contract with third parties for operating storage to enable sales to ISO could provide for an additional opportunity for energy storage to make an impact in Massachusetts' energy sector. Clarification of energy storage's role in Massachusetts' energy markets has the potential to allow IOU's the ability to capture the many benefits of energy storage as outlined in this report.

7.4.2 Storage as Peak Demand Savings tool in Energy Efficiency Investment Plans

Summary	Support Demand Reduction demonstration programs in the 2016-2018 Energy Efficiency Investment Plan, with a view to broader long-term integration of demand reduction investments, including energy storage, into the statewide energy efficiency plans.
Duration of the program	2016-2018 Energy Efficiency Investment Plan, to be followed by additional Plans
Funding	DPU has approved two ratepayer-funded demand reduction demonstration projects. Additional projects from Program Administrators would need DPU approval.
Targeted Use Cases	BTM Residential and C&I
Implementation requires	Additional projects developed by the Program Administrators will be submitted to the EEAC for budget review and approved by the DPU.

Description

Massachusetts state law, M.G.L. c.25, §21, the Green Communities Act (the "Act"), requires that investor-owned utilities and approved municipal aggregators ("Program Administrators") seek "...all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply."²³⁶ The Act establishes the framework for developing, implementing and funding energy efficiency and demand side management programs. The Act treats demand management (either peak load reduction or peak load shifting) the same way as energy efficiency (load reduction), with the same potential funding streams and requirements for planning and implementing

²³⁶ G.L. c. 25, § 21(b)(1)

programs. The Act broadly defines what kind of programs can be used to meet the goals of the Act, including (but not limited to),²³⁷ efficiency and load management programs, demand response programs, R&D and market development programs, programs providing commercial, industrial and institutional customers with greater flexibility and control over demand side investments funded by the programs at their facilities and programs for public education regarding energy efficiency and demand management.

Storage and other measures that shift load are firmly covered by the intent of the Act and the successful framework for energy efficiency that has developed since 2008. The 2016-2018 Statewide Energy Efficiency Investment Plan (“Three Year Plan”), supported by the Energy Efficiency Advisory Council (“EEAC”) and approved by the Department of Public Utilities (“DPU”), identifies peak demand reduction as an area of particular interest in the term sheet and in the EEAC resolution supporting the Three Year Plan. The DPU-approved Three Year Plan also includes peak demand reduction demonstration projects from National Grid and the Cape Light Compact, as well as a commitment from all Program Administrators to develop specific demand reduction demonstrations and assess them for cost-effectiveness for full program development in the 2019-2021 Three Year Plan. Energy storage, used to shift and manage load as part of peak demand reduction programs, can be deployed through this existing process.

Requirements

The Program Administrators have committed to proposing peak demand reduction demonstration programs in the 2016-2018 Three Year Plan. These programs would be funded through additional budget supported by the EEAC in a mid-term modification process, and would have to be approved by the DPU. The Program Administrators will also be assessing the demonstration programs for cost-effectiveness.

In order to incorporate storage and demand reduction as full-scale programs in future Three Year Plans, the DPU must approve them as cost-effective as defined in the DPU Guidelines²³⁸ which lay out the methodology to determine the cost-effectiveness of energy efficiency programs. This cost effectiveness test relies on years of precedent and has been rigorously defined to support robust energy efficiency and passive demand reduction programs, but are untested for active demand response programs.²³⁹ It is possible that active demand reduction programs might require modification to the current cost effectiveness methodology. Under the Act, the cost effectiveness test can be reviewed by the EEAC and revised by the DPU periodically. These guidelines could be reviewed and amended to provide clarity and certainty of cost effectiveness analysis for active demand response programs.

The Act gives the EEAC and the DPU the ability to set specific goals in the Three Year Plan that align with policy priorities and tie Program Administrator incentives to those goals. In order to further prioritize active demand response programs, including the use of energy storage, the EEAC could

²³⁷ G.L. c. 25, § 21(b)(2)

²³⁸ The Guidelines use the Total Resource Cost (“TRC”) benefit/cost assessment methodology, in which the total program costs are compared to the total benefits attributed to the net energy savings attributable to the programs (avoided electric generation and gas supply costs; avoided transmission and distribution costs, and energy and capacity demand-reduction induced price effects) to determine cost-effectiveness. Furthermore, the TRC test relies on a technical reference manual (“TRM”) to determine critical data about specific program measures, such as measure life. <http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=08-50%2F102609dpuord.pdf> (pp 49-53)

²³⁹ The PAs noted some challenges with the cost-effectiveness framework, including measure life/persistence, time lag of costs to benefits, etc. (See Demand Savings Working Group 3/31/16 report)

propose specific performance metrics that align with policy goals, such as a quantity of peak load reduction or quantifiably reducing grid congestion as part of the 2019-2021 Three Year Plan development process. These goals could be negotiated in the Term Sheet and, with the approval of the DPU, tied to Program Administrator Performance Incentives.

7.5 Options that Require Statutory Change

7.5.1 Allow Storage to be Considered in Any Possible Future Procurements

Summary	Allow storage to be a part of all future long-term renewable energy procurements. This option does the following: (1) monetizes the ratepayer system benefits of co-locating renewable energy and storage; (2) creates long-term revenue streams to support financing of energy storage; (3) enables generation to be better matched with peak demand; (4) manages congestion on the transmission system; and (5) increases FCM value to generators and reduces FCM costs to ratepayers.
Duration of the program	TBD
Targeted Use Cases	Merchant Solar Plus Storage, Merchant Renewable + Storage projects
Implementation Requires	Statutory change; development of RFP and standard contract by utilities and DOER; DPU approval of RFP; procurement process and standard contract. If this option is pursued, it is recommended that a clear definition of what constitutes a qualifying “Energy Storage System” be included within the statutory framework.
Examples in other States	Other states, including California and Connecticut have adopted statutory definitions for Energy Storage Systems.

Description

Energy storage should be a component of Massachusetts’ long-term renewable energy procurements. Currently, Massachusetts statutes do not provide clarity on the ability to include storage as part of a renewable project bidding into a clean energy RFPs. For example, procurements under the Massachusetts Acts of 2012, Chapter 209, Section 36 require, among other things, that the clean energy be qualified as Renewable Portfolio Standard Class I, and does not specify how energy storage is treated. Eliminating the ambiguities surrounding energy storage systems and including them into future long-term renewable energy procurements will enable the projects to utilize the benefits of storage to firm the renewable portion of the project by: monetizing the ratepayer system benefits of co-locating renewable energy and storage, and creating long-term revenue stream to support financing of energy storage.

A definition of “Energy Storage System” is not codified in Massachusetts laws or regulations. Ambiguity over what qualifies as an energy storage system has the potential to hinder the RFP process. The absence of a clarifying definition and regulation hinders the beneficial impact storage could have towards clean energy programs.

Requirements

In order for Massachusetts to allow bids that have energy storage components in future long-term energy procurements, it is imperative that Massachusetts develops a clear statutory definition of “Energy Storage Systems.” Establishing a definition of an “energy storage system” would create a predictable regulatory environment for interested parties. Two other states, Connecticut and California, have adopted statutory definitions for Energy Storage Systems.

Connecticut’s legislation, passed in 2015, provides a broad definition of an energy storage system:

‘Energy storage system’ means any commercially available technology that is capable of absorbing energy, storing it for a period of time and thereafter dispatching the energy, and that is capable of either: (A) Using mechanical, chemical or thermal processes to store electricity that is generated at one time for use at a later time; (B) storing thermal energy for direct use for heating or cooling at a later time in a manner that avoids the need to use electricity at a later time; (C) using mechanical, chemical or thermal processes to store electricity generated from renewable energy sources for use at a later time; or (D) using mechanical, chemical or thermal processes to capture or harness waste electricity and to store such electricity generated from mechanical processes for delivery at a later time.

California has a more detailed definition of energy storage systems that the legislature passed in 2010. Under California’s statute, “‘Energy storage system’ means commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy.” The statute further assigns characteristics and purposes that the technology must meet in order to be considered an “energy storage system.” Both of these statutes may serve as useful frameworks for a Massachusetts definition.

7.6 Other Changes

7.6.1 Enable Storage Readiness in Building Codes and Standards

Summary	Coordinate and facilitate the adoption of safety and performance codes and standards for energy storage systems.
Supporting Agency	DOER, the Department of Public Safety, MassCEC
Authority	Local fire and codes authorities
Targeted Use Cases	All Use Cases
Implementation	Collaborate with national and global entities like Department of Energy (DOE), Sandia National Laboratories, National Fire Protection Association (“NFPA”) and the International Electrochemical Commission (“IEC”) to develop and adopt codes and standards for safe deployment of energy storage; Support demonstration projects for safety of storage systems

Description

Safety is critical for the development of a robust energy storage market in the Commonwealth and a large scale deployment. Codes and standards are intended to address design, construction, performance and safety features of a product. Codes and standards can be challenging for advanced energy storage in terms of adapting to the newer technology, potentially varied applications and collecting sufficient stakeholder input for arriving at an acceptable set of codes and standards. While codes and standards exist for certain components of energy storage systems and perhaps even certain applications, there is widespread recognition that they are not comprehensive for all technologies and all applications.

Stakeholders identified the limited guidance in building and fire codes that address energy storage and the disparity in jurisdictional adoption of those that do exist. Moreover, there is a lack of common understanding of performance and interoperability standards for distribution-connected equipment and devices among utilities, technology providers, and developers. There is also limited information on back-up lead acid systems that reflect standards developed more than a decade ago. Further, since these fall within the purview of local authorities, there is likely disparity in jurisdictional adoption of those that exist.

The goal of this effort would be to facilitate the adoption of codes and standards for the safe and reliable deployment of energy storage systems by local authorities. Given that standards development organizations are typically national or international bodies, state agencies can provide support in the local adoption of CSR by acting as a facilitator and coordinator of these efforts. It is recommended that the appropriate state agency(ies) (e.g., DOER, the Department of Public Safety, and MassCEC) disseminate information from DOE’s efforts to local authorities, enable local authorities to participate in relevant CSR Working Groups and facilitate the adoption of codes, standards and regulations as they develop. Also, the state agency can work with local authorities to facilitate safety testing of these systems to help the authorities better understand the nature of these systems within their applications. Finally, the state agency can act as a convener of stakeholders to discuss emerging issues and topics of common interest to all stakeholders.

DOE has recently invested efforts, in collaboration with Sandia National Laboratories and Pacific Northwest National Laboratories, to develop an overview of the codes and standards for energy storage and catalog existing codes and standards.²⁴⁰ Their efforts are in partnership with the National Fire Protection Association (“NFPA”) and the International Electrochemical Commission (“IEC”).

Requirements:

State agencies should collaborate with national and global entities like DOE, Sandia National Laboratories, NFPA and IEC to develop and adopt codes and standards for safe deployment of energy storage. The appropriate state agency (e.g. MassCEC) could develop a Memorandum of Understanding with DOE to receive technical assistance on the code and standards efforts. State agencies can also work with local authorities to support demonstration projects for safety of storage systems.

7.6.2 Consider Clarifying and Streamlining Interconnection Requirements for Storage

Summary	Explore with the utilities the proper process for interconnecting electricity storage
Supporting Agency	DOER
Authority	Utility engineers determine the technical standards for interconnection requirements not specified in the tariff (through the TSRG). MA-DPU has authority over the IOU Interconnection Tariffs and ISO-NE has the authority over certain projects over 5 MW.
Targeted Use Cases	All Use Cases
Implementation	Address storage in the existing quarterly MA Technical Standards and Review Group meetings. Collaborate with utility engineers and ISO-NE between meetings for clear and streamlined state and regional processes. If necessary, seek tariff changes through DPU.

Description

The interconnection review and approval process for distributed energy resources has been mentioned by multiple parties as being less streamlined than it should be. It would be helpful to have previously agreed upon technical standards for projects that include storage, whether operating only in backup power mode, where it will not operate in parallel with grid power, or to support the building or the grid in parallel.²⁴¹ By streamlining the review for storage systems, applicants would have greater certainty of interconnection time and cost, while the IOUs and ISO-NE will have greater reassurance that the interconnecting systems will have minimal impact on the grid and will not cause reliability issues or be less likely to trigger overly conservative distribution upgrades.

A potential starting point would be for DOER to address storage in the existing quarterly MA Technical Standards and Review Group (TSRG) meetings where utility engineer requirements are reviewed with non-utility representatives. DOER should collaborate with utility engineers and ISO-NE

²⁴⁰ <http://www.sandia.gov/ess/resources/energy-storage-safety/ess-safety-plan-overview/csr-overview/>

²⁴¹ It is a generally accepted principal that emergency backup power is not required to go through the interconnection process if configured to only operate during grid outages. In such cases, even though approval is not required, notifying the utility is recommended.

between TSRG meetings for clear and streamlined state and regional (NE) interconnection processes. If necessary, DOER should seek interconnection tariff changes through DPU. The next step would be to explore with ISO-NE opportunities to streamline the process to review and interconnect energy storage when done at the wholesale level.

7.6.3 Market and Education

Summary	Accelerate market adoption of energy storage with consumer education, awareness and marketing
Supporting Agency	MassCEC
Authority	Program Administrators, MassCEC
Targeted Use Cases	IOU, MLPs, Behind-the-Meter
Implementation	Collaborate with utilities, National Laboratories, the Department of Energy Office of Electricity and Reliability, and other institutions to leverage existing resources or develop new mechanisms to market the value of energy storage.

Description

Throughout the ESI, stakeholders agreed that regional sharing of models, knowledge and approaches was very valuable and currently lacking. Beyond existing resources like the DOE Global Energy Storage Database,²⁴² the group highlighted the lack of access to information on energy storage applications, technologies and existing Use Cases in Massachusetts. Building off the work that was started in *State of Charge*, this program, piloted by MassCEC, would accelerate knowledge sharing and market adoption of energy storage with customer education and sharing.

For example, a series of stakeholder meetings, including workshops and webinars could be developed to share best practices on the following themes:

- Utility planning requirements, successful contracting mechanisms, and operational best practices. This workshop could involve working with utilities that have already organized successful RFPs and operate energy storage to serve load.
- Relevant state planning approaches to energy storage. These workshops could be geared towards sharing best practices and discussing regulatory or policy issues.
- High value distributed customer-sited applications for end customers. This workshop could convene city, county, college and C&I facilities' energy managers to share best practices in mitigating the impacts of demand charges and TOU rates using energy storage.

Several states are working with the United States Department of Energy, Office of Electricity Delivery and Reliability and National Laboratories (Sandia, PNNL, and others) on similar initiatives that focus on how energy storage technologies and applications can address the unique challenges of each region.

Requirements

²⁴² www.energystorageexchange.org

STATE OF CHARGE

Massachusetts Energy Storage Initiative Study

The next steps would include:

- Work in partnership with DOE/OE, national laboratories, and other local organizations to develop or leverage an existing program focused on sharing resources and best practices on energy storage.
- Leverage existing websites and resources to market the benefits of energy storage to different customer classes.
- Conduct outreach to different customer classes to promote the use of energy storage, educate them on the benefits and point them to relevant resources.
- Encourage new energy storage project developers to enter the details of their projects (locations, technology, size, and services/Use Cases) in the DOE Global Energy Storage Database to continue to build a central hub for free, up-to-date information on energy storage projects and policies.

7.6.4 Application Specific Load Data

Summary	Facilitate load data collection and energy storage system specification development for different classes of consumers towards driving down transaction costs
Supporting Agency	MassCEC
Targeted Use Cases	Behind-the-meter Use Cases and distribution level Use Cases
Implementation	Co-operation from utilities and different classes of consumers. Help from DPU.
Barriers addressed	Energy Storage developers do not have access to load profile data for various customer classes, as needed to identify optimum locations for storage to maximize system benefits as well as revenue opportunity.

Description

The unavailability of users' energy consumption data is often cited by energy storage technology and project developers as a barrier to successfully identifying value-added energy storage demonstration and siting opportunities, and for developing suitable product designs. Often utilities claim such data as proprietary information that they do not want to share, and cite customer privacy issues as a reason for not disclosing the data. Many utility program designs for energy efficiency use such data, but the data is not available to third parties, including energy storage developers who would be able to customize energy storage products and services for specific load profiles. Sometimes, such data is given to regulators or even to academic institutions for research. Similarly, storage technology and project developers who may want to add energy storage to solar at the distribution level would like to have a better understanding of transformer loading at electrical substations. Enabling access to such data will help storage project developers identify highest value energy storage applications by expediting access to energy use data at minimal cost. This also has the potential to reduce transaction costs by developing energy storage system specifications for common uses within specific customer classes.

In California, state regulators are holding proceedings to find a solution to the above problem. PG&E and SCE have published such data along with distribution substation location and sizes to enable

energy storage deployment. This data is then used by prospective developers to size their storage systems. Massachusetts can undertake a similar program, in collaboration with third parties such as academic and research institutions or national labs, which can obtain the information, sanitize it for names and other identifying markers and then pass it on to storage technology developers or service providers. Utilities themselves may undertake similar activities.

Another approach to solve this problem is to convene customer classes that have similar requirements to create a common usable, yet customizable, specification. This will help the developers bid and deliver to fairly standardized specifications, which in turn will help lower transaction costs and increase deployment of storage. This effort will also help customers understand their energy usage and the benefits of energy storage in that context. Raising awareness is key to customer adoption of energy storage. For example, the MLP in Sterling, MA has developed a specification for an energy storage project with technical assistance from DOE and Sandia National Laboratory. It is conceivable that such a specification (or a similar template) would be useful to other MLPs that are considering procuring storage projects.

MassCEC convenes different segments of clean energy stakeholders for its programs. MassCEC could run a stakeholder driven process to understand the requirements for different customer classes. The results of this process could inform the development of a specification for energy storage systems that multiple customers can benefit from. Involving utilities in this process would help the distribution level Use Cases as well as the interconnection requirement for behind-the-meter storage.

Requirements

The next steps would include:

- Create standardized specifications/proforma and data exchange formats for different Use Cases in consultation with the storage industry and utilities.
- Collaboration with university or national lab to serve as the repository of data.
- Convene different customer classes to understand their energy usage and collaboratively create a system specification template for each class.

8 Recommendations for ISO-NE to Facilitate Energy Storage Growth

For energy storage development to grow in MA, it is essential that clear rules are in place at ISO-NE to enable full participation in the energy, capacity and ancillary services markets. Advanced energy storage resources should be treated on a level playing field and afforded access to the same opportunities as other resources. Energy storage resources are flexible and dispatchable, meaning that they can respond to changes quickly to help the grid operator keep the system in balance. With longer durations, they can also fulfill capacity market requirements. Storage can also play an important role in the transmission planning arena.

The market rules that were developed at ISO-NE are based on a traditional generation fleet, and do not yet recognize the unique operating characteristics of advanced energy storage, such as batteries, flywheels and compressed air storage. This chapter describes the current treatment of energy storage at ISO-NE, barriers, and recommendations for full participation by the diverse range of new energy storage technologies in the ISO-NE wholesale market.

8.1 How Energy Storage Can Participate Today at ISO-NE

To date, energy storage has been limited to pumped hydro and a very small amount of fast responding resources in the ISO-NE's Regulation pilot program.

8.1.1 Pumped Storage

Pumped storage resources can participate in the ISO-NE energy, capacity, and ancillary services. When the pumped hydro resource is providing electricity to the grid, ISO-NE views the resource as a generator. When it is consuming energy from the grid to pump, it is considered a demand-side resource. While the pump storage resource is the same physical resource, the ISO's energy management system treats the resource as two separate and distinct resources. In 2015, ISO-NE conducted a stakeholder process to add functionality to their systems to dispatch pumped storage in a way that better acknowledges the resource's inter-temporal constraints, such as the transition period from moving from the pumping mode to the electricity production mode. While this is important for pumped storage, the approach is not directly applicable to advanced energy storage resources which have very different operating characteristics. This is explained in the following section of this chapter.

Furthermore, while some pumped hydro is included in the ISO-NE resource mix, as shown in the Figure 8-1 below, it is still only a small percentage of the amount compared to the other types of resources.

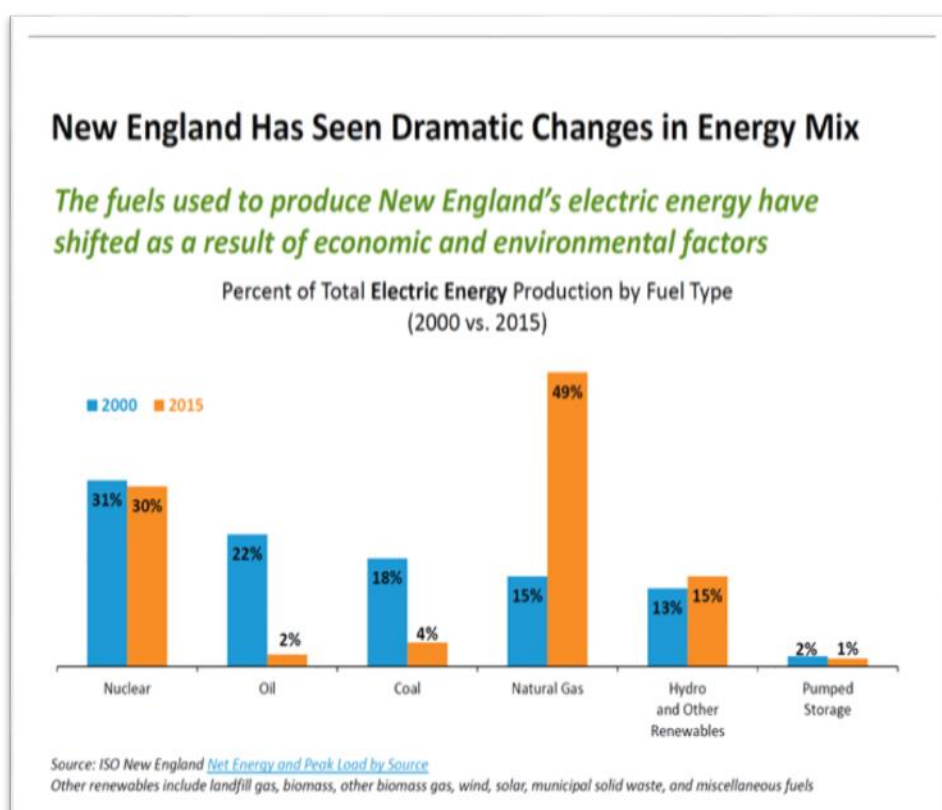


Figure 8-1: Change in energy mix of New England

The above chart²⁴³ shows the relative size of pumped hydro, and also displays that there is no other type of energy storage operating in the ISO-NE markets. In other regions of the country new advanced storage resources are participating in the ISO wholesale markets. For example there are currently 265 MW of advanced storage (primarily batteries) operating in the PJM²⁴⁴ wholesale market. Over 300 MW of advanced storage either operate or are under contract to come online in the California ISO (CAISO), with thousands of MW in the CAISO interconnection queue.

8.1.2 Frequency Regulation

The ISO-NE rules do allow for new advanced energy storage resources to provide Frequency Regulation. In 2008, ISO-NE began a pilot program called the “Alternative Technology Regulation Pilot Program” (ATRR Pilot Program). This program ran for seven years to March 2015. When the pilot first began, it was seen as a creative way to integrate the advantages of advanced energy storage into the ISO’s dispatch and settlements platforms for the provision of Frequency Regulation. Initially several projects participated, including flywheel, battery and thermal storage resources

Frequency Regulation is the moment-by-moment energy dispatch required to keep generation and load in perfect balance in order to maintain the grid at frequency of 60 Hz. If the frequency deviates too far from 60 Hz the grid can become unstable and outages can occur. Because of this, ISO-NE sends signals to resources providing Regulation every four seconds to adjust their output to follow changes in load. With renewable resources growing in New England, and the associated variability

²⁴³ <http://www.iso-ne.com/static-assets/documents/2016/04/20160404-01-wem101-electricity-prod.pdf>

²⁴⁴ PJM is the wholesale market grid operator in the Mid-Atlantic region of the country and includes 13 states plus the District of Columbia.

caused by their intermittent output increasing, ISO-NE's Frequency Regulation market has grown by about 15% in the last year.

Across the country advanced storage has been seen as an ideal technology to provide Frequency Regulation because it is the only technology that can adjust its full MW output in less than one second. Other resources respond more slowly. Pumped storage typically responds within 30 seconds to one minute to the ISO's requested change in MW output and fossil generators typically take up to five minutes to fully respond to the ISO's dispatch signal to change their output. Because of this, ISOs need to commit more generating resources to provide Frequency Regulation to obtain enough total MW of movement within four seconds to keep the grid in balance.²⁴⁵

On October 20, 2011, FERC issued Order No. 755 "Frequency Regulation Compensation in the Organized Wholesale Power Markets" which found that the organized wholesale market tariffs failed to compensate faster-ramping resources, such as advanced storage, for their superior ability to respond to the grid operator's dispatch signals. FERC found that new storage technologies, such as batteries and flywheels, were being penalized by existing market rules. Thus, FERC mandated that each grid operator change their tariffs to pay resources based on the actual amount of Regulation movement that each resource provides to the grid, i.e. "pay-for-performance."

In its Pilot Program, ISO-NE modified its regulation dispatch signal to accommodate short duration storage resources and created a special dispatch signal to fully utilize the very fast response capability of advanced energy storage. It recognized that storage can quickly change from "charging" (negative output) to "discharging" (positive output) and vice versa, and thus storage resources needed an energy neutral signal to maintain its state-of-charge.

Ultimately, seven years later, the ATRR design was incorporated into the ISO-NE tariff in 2015 and ISO-NE was in compliance with FERC Order 755. Other than the Southwest Power Pool (SPP), which was in the early phase of becoming an ISO market, ISO-NE was the last FERC jurisdictional ISO to comply with FERC Order 755.

However, when ISO-NE transitioned from a pilot program to an updated market tariff, it changed the size requirements for advanced storage to participate in the frequency regulation market. In the Pilot Program resources greater than 0.1 MW could provide service. Now market resources must be at least 1.0 MW in size. All of the pilot projects, some of which provided service for over seven years, were smaller than 1.0 MW and suddenly were out of the market.²⁴⁶

Since the start of the ISO-NE's pilot, advanced energy storage technologies have evolved into commercially viable resources throughout the country and world-wide. Other ISOs and RTOs have successfully integrated energy storage in their markets. Advanced energy storage is no longer envisioned as only providing frequency regulation as it was a decade ago. The evolution and diversity of energy storage technologies, applications, and grid locations has gone well beyond the limits of ISO-NE's pumped hydro storage and ATRR frameworks.

8.2 Challenges for Advanced Energy Storage at ISO-NE

Stakeholders are eager to understand how to integrate storage resources at ISO-NE, and they have been approaching ISO-NE staff to help clarify the requirements for storage resources in its markets.

²⁴⁵ For example in PJM, 40% of the frequency regulation market is now served by advanced storage. Since enabling advanced storage in its market, PJM has been able to reduce the size of its regulation market by 30% resulting in significant savings for ratepayers.

²⁴⁶ Other ISO markets allow resources under 1.0 MW to provide regulation.

In response, in December 2015, ISO-NE posted a paper, *How Energy Storage Can Participate in New England's Wholesale Electricity Markets*, outlining the asset classifications and size requirements for energy storage. This paper was revised in March 2016.²⁴⁷

8.2.1 Advanced Energy Storage Is Not Yet Modeled in ISO-NE Systems beyond Frequency Regulation

According to the paper, ISO-NE does not explicitly prohibit the participation of storage resources in the various markets. On the contrary, ISO-NE suggests that energy storage can indeed participate in the various markets – energy, capacity, and all ancillary services – by utilizing the existing market design. The ISO paper states that it “currently models a storage facility as both a generator asset and a load asset; each asset must be dispatched separately and not at the same time.”

This is a similar concept that is currently being used for pumped-storage hydro. The resource is “modeled as (1) a load for when it pumps water up into the reservoir (i.e., a dispatchable asset-related demand pump), and (2) a generator for when it releases water through the turbines to produce electricity.”

Application of this approach for advanced energy storage, however, is fraught with operational challenges. In actuality, advanced energy storage is a distinct resource type with its own characteristics, and it cannot simply be force-fit into the existing ISO-NE requirements for pumped storage. Unlike pumped storage, advanced energy storage can move seamlessly to respond to dispatches for the portion of its output that is negative (charging) to positive (discharging). The concept of modeling the load and generation portions as two separate resources, therefore, does not take advantage of the resources’ dispatchable capabilities, including its flexibility to quickly respond to changes on the grid.

Unlike pumped storage, advanced energy storage operates in a way that is similar to a conventional generator, except that its dispatch range can go both above and below zero. The below picture from the California ISO shows how a Non Generator Resource (NGR) is represented within their systems. NGRs are “Resources that operate as either Generation or Load and that can be dispatched to any operating level within their entire capacity range but are also constrained by an MWh limit to (1) generate Energy, (2) curtail the consumption of Energy in the case of demand response, or (3) consume Energy.”

The first bar on the far left shows the complete dispatch range as going from positive energy (discharging) to negative energy (charging).

²⁴⁷ http://www.iso-ne.com/static-assets/documents/2016/01/final_storage_letter_cover_paper.pdf

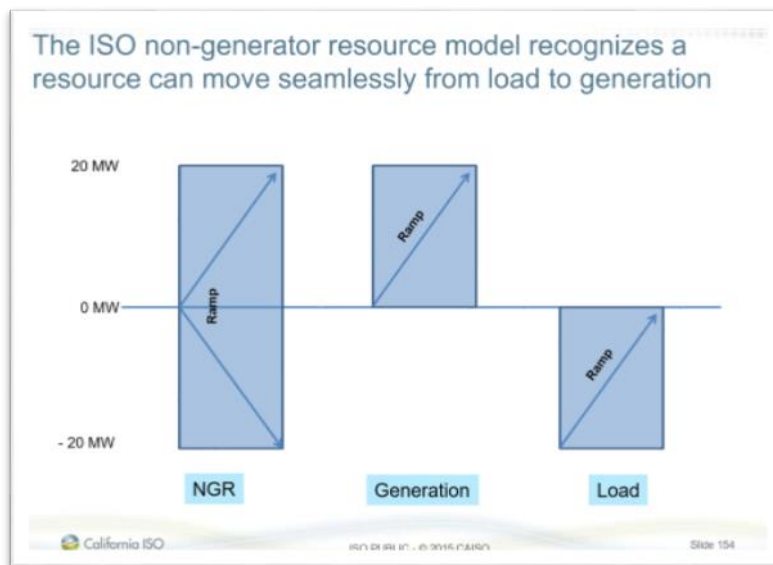


Figure 8-2: A Non-Generator Resource Is Modeled with Both Positive and Negative Output
(Source: CAISO Training Materials 2015)

A generator would be depicted by the second bar. It can produce a positive generation output and can be dispatched in the range above zero. A load is represented in the third bar showing the negative output.

ISO-NE's representation of how energy storage can participate (beyond the ATRR design that is in place for Frequency Regulation) infers that it can dispatch and settle the advanced energy storage resource as two separate resources (the second and third bar in the above chart, not the first bar). ISO-NE has not yet provided any information about how this could actually be done in practice.

Without more detail, this approach does not appear to be achievable. For example, if the resource is modeled as a generator, ISO-NE would only be accessing the positive (discharging portion) of the resource for dispatch. In reality, advanced energy storage may go into the negative (charging) portion of its dispatch range. By only dispatching the positive portion, the resource may be given an infeasible dispatch and therefore could be subject to non-performance settlements charges (an infeasible dispatch is when the ISO-NE dispatches a resource in a way that it cannot respond). The amount and direction of the dispatch are dependent on the resource's State of Charge, its ramp rate, and its MW output range, which are currently not contemplated in the ISO-NE design.

Furthermore, it is not evident from the ISO-NE's paper how the separately modeled load resource would be married with the generation resource in ISO-NE's bidding, optimization, dispatch or settlements systems. Without definitive rules about how the resource is modeled and dispatched, the resource owner will not know how to bid the resource's energy, capacity, and ancillary services. It will not know when to charge and discharge, whether it is in compliance with dispatch instructions, or how it will be settled.

Using the same example as in the above bar chart, if one were to assume the generator resource has a day ahead energy award of 10 MW, and it is dispatched in Real Time to 15MW, and then down to 5 MW in another interval, the ISO-NE would not model the generator resource as two separate resources – one above 10 MW and one below 10 MW – to optimize, dispatch, and settle the same resource's output.

Furthermore, ISO-NE's requirements do not specify how the same resource that would be dispatched for energy would also offer ancillary services. The ATRR design applies to storage resources that are *only* providing Regulation, and no other services such as Energy.

Finally, ISO-NE does not state whether and how storage resources can provide Spinning Reserve. The Northeast Power Coordinating Council (NPCC) rules may prohibit inverter-based resources including storage from providing spinning reserves. Clarification on this point is required, as the provision of spin by advanced energy storage in other markets that adhere to North American Electric Reliability Corporation (NERC) requirements is allowed.

Without more information, the approach as described in ISO-NE's paper does not appear feasible to implement, nor does it allow the ISO-NE to benefit from the very flexible dispatchability (seamlessly moving from positive output to consumption [negative] and vice versa) of advanced energy storage resources.

8.2.2 Dispatchable Resources – Why It Matters

Without considering the energy storage resource's capabilities in its systems, ISO-NE will not be able to utilize the storage resource to its advantage as a dispatchable resource. With a changing resource mix at ISO-NE, flexible resources such as energy storage are growing in importance. Over time, as more solar and wind energy are added to the grid, the "net load"²⁴⁸ requirements are growing.

What is now commonly being referred to as "the Duck Curve" – even beyond California – is a depiction of this emerging change that has become commonly recognized throughout the electric power sector. The period in the duck's belly is when solar generation is highest and there can be too much generation on-line. Larger ramps are now occurring between the midafternoon, and the early evening after the sun goes down and solar comes off line. With renewable integration, the transition between the two periods becomes more severe (the neck).

²⁴⁸ Net load is the difference between forecasted load and expected electricity production from variable generation resources. In certain times of the year, these curves produce a "belly" appearance in the mid-afternoon that quickly ramps up to produce an "arch" similar to the neck of a duck—hence the industry moniker of "The Duck Chart":
http://www.aiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

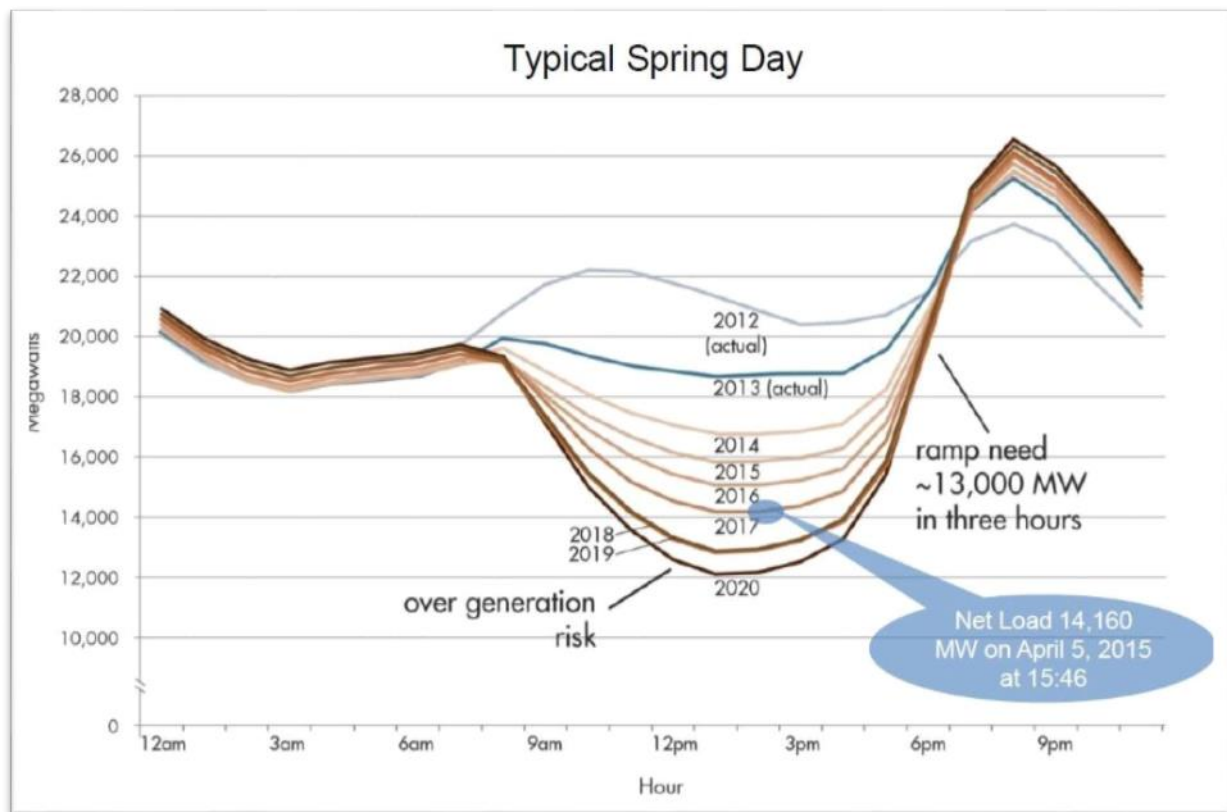


Figure 8-3: California ISO "Duck Curve"²⁴⁹

Dispatchable resources such as advanced energy storage are needed to address new periods of the day when solar and wind generation are producing. Energy storage can be used to help to reduce curtailments of renewable resources and also help to reduce the amount of gas generation that is brought on line to provide the dispatchability needed to address the net load challenges.

The below illustrative graphic²⁵⁰ shows what can happen when there are not enough flexible resources on the grid to address increased renewable penetration, and too many gas resources are brought on line.

²⁴⁹ Source: CAISO Fast Facts: http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

²⁵⁰ Union of Concerned Scientists Graphic: <http://www.ucsusa.org/renewables-and-reliability-grid-management-solutions-support-californias-clean-energy-future#.VyDJN2wm7Zs>

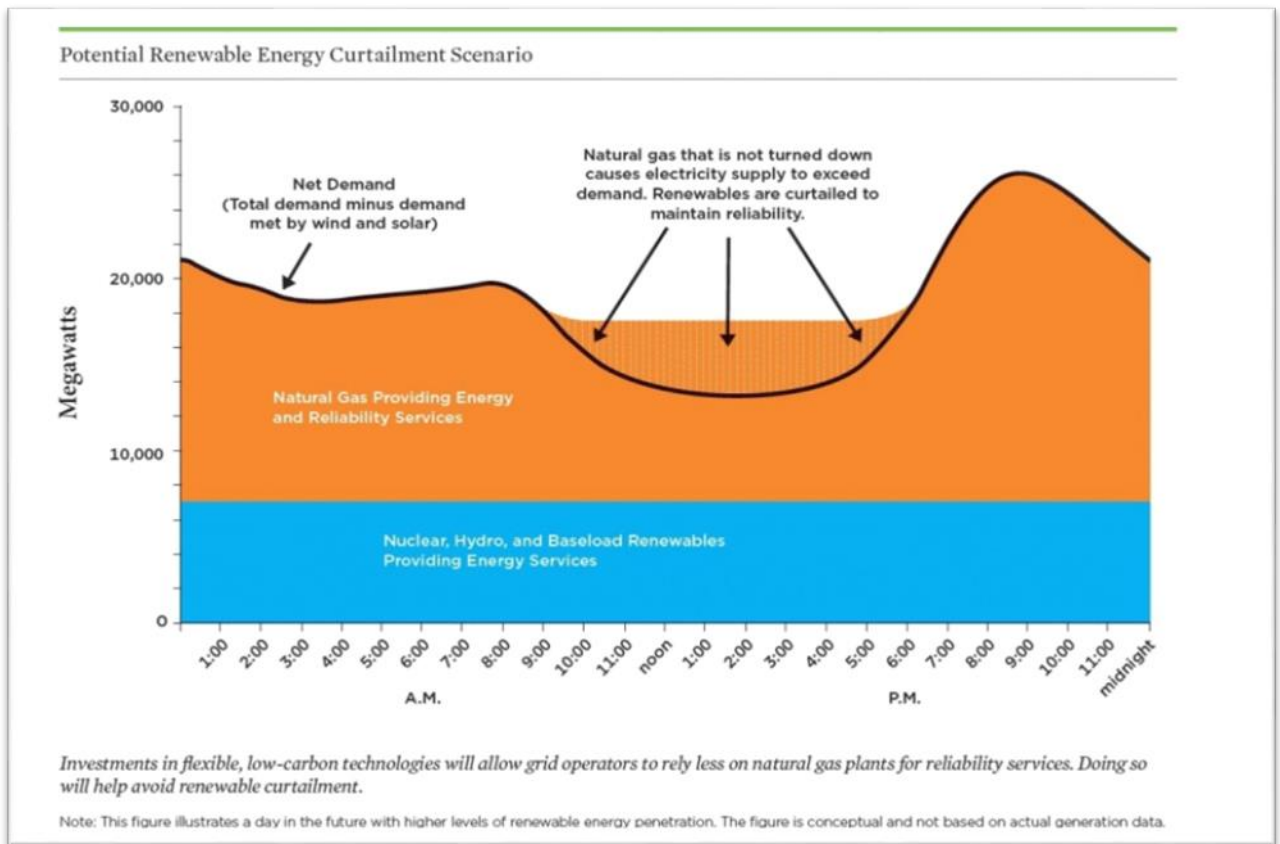


Figure 8-4: The Changing Power Grid with Renewable Curtailments and Over-Generation

This situation results in renewable curtailments and over production by gas generation because the gas generation cannot be turned down due to operational constraints.

8.3 Dispatchable Storage beyond Frequency Regulation in Other Markets

8.3.1 California ISO – Energy Storage Energy and Ancillary Services

In California, the CAISO realized that advanced energy storage has unique operating characteristics and that it can behave as a flexible resource. Since 2012, the ISO has classified energy storage as NGRs. NGRs can participate in all of the CAISO wholesale markets – Energy, Regulation, and Operating Reserves (Spin and Non-Spin).

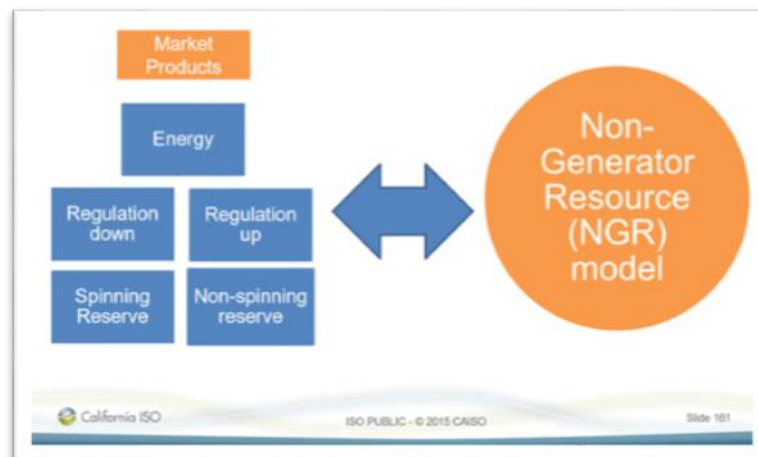


Figure 8-5: Description of How NGR can participate at CAISO²⁵¹

The CAISO models the advanced energy storage capacity parameters to allow for the resources to bid, be co-optimized, dispatched and settled in the various markets. These include:

- The Maximum Capacity represents the resource's maximum potential to inject or withdraw energy at a sustainable rate, and the minimum Capacity (MW) represents the resource's minimum potential to inject or withdraw energy at a sustainable rate.
- The energy (MWh) parameters are used to keep ISO market dispatches and regulation control signals within the resource's energy capability range. The CAISO also includes the instantaneous State Of Charge (MWh) so that the energy (MWh) is considered.
- The CAISO also uses energy limits and State of Charge values to co-optimize the NGR resource over multiple intervals in the ISO markets. It then determines the best utilization of the resource based on its submitted energy schedules or ancillary services ranges. The CAISO can use SOC values in its optimization to prevent infeasible dispatches or control signals. The CAISO is also working with stakeholders on alternative solutions where the resource owner can manage its own SOC.

This approach is a very different concept than the pumped hydro design which involves transition times between discharging and charging, thus making it look more like a combination of two types of resources: a generator and a load. Unlike pumped hydro resources, advanced energy storage does not have minimum load operating points, state configurations, forbidden operating regions, startup, shutdown, minimum load, or transition costs. In short, new storage technologies have significantly more flexibility than traditional pumped storage resources. This capability will be lost to the grid operator if ISO-NE forces new storage resources to be modeled like 1970s pumped storage technology.

The minimum size requirement for NGRs (and all resources) that are in front of the meter is 0.5 MW. However, CAISO also allows for aggregations of smaller resources and there are defined metering

²⁵¹ CAISO Energy Storage and Distributed Resource Educational Forum April 2015, <http://www.caiso.com/Documents/Presentation-EnergyStorageandAggregatedDistributedEnergyResource-EducationalForum.pdf>

and telemetry requirements for aggregations. Energy storage resources can also participate in the Wholesale DR market from Behind the Meter. A Proxy Demand Resource (PDR) can be 0.1 MW.

8.3.2 PJM – Energy and Ancillary Services

PJM has also included an asset class called Energy Storage Resource (ESR) since 2010. The definition per the PJM tariff is: “flywheel or battery storage facility solely used for short term storage and injection of energy at a later time to participate in the PJM energy and/or Ancillary Services markets as a Market Seller.” ESRs, therefore, can participate in all of the PJM wholesale markets – Energy, Regulation, and Operating Reserves. The minimum size requirement is only 0.1 MW.

Additionally, in 2010 PJM changed its tariff to allow ESRs, like pumped storage resources, to be explicitly exempt from station power charges and pay wholesale rates for charging energy.

PJM understands the different operating characteristics for energy storage resources and, while storage resources participate under similar rules as other Market Sellers, PJM operations respects the characteristics of new advanced storage resources. As of the end of 2015, there were slightly over 260 MW of advanced, grid-connected storage resources operating in the PJM market, and about 5 MW operating behind customer meters. These resources have been focused on providing fast-response Frequency Regulation. As the PJM Frequency Regulation market is about 660 MW, advanced storage resources currently provide about 40% of the requirement.

8.4 Other Market Design Issues

8.4.1 ISO-NE Capacity Market and Energy Storage

ISO-NE administers a forward market for capacity, the Forward Capacity Market (FCM), in which resources compete in an annual Forward Capacity Auction (FCA) that is conducted three years in advance of a Capacity Commitment Period. Resources whose capacity clears the FCA acquire capacity supply obligations, which they must fulfill three years later.

ISO-NE states in its white paper that energy storage can participate in the capacity market. However, there do not appear to be specific references to advanced energy storage in the ISO-NE capacity market rules. Without specified market rules, advanced energy storage resources struggle to understand how or even if they can qualify to participate in the FCM.

Examples of rules that would be needed for advanced energy storage to participate in the FCM include:

- **Qualifying Capacity Requirements** - ISO-NE does not specify how advanced energy storage resources’ qualifying capacity value would be determined.
- **Trigger Price for Energy Storage** - ISO-NE calculates a benchmark price, known as an offer review trigger price (ORTP), for each resource technology type (e.g. combustion turbine) based on certain revenue and cost assumptions. ISO-NE compares capacity supply offers from new resources to these ORTPs in order to protect against market power that could inappropriately suppress capacity prices – for example, offer prices well below that necessary for the resource to be operated profitably for the purpose of suppressing capacity clearing prices to be paid to all resources. There is not a calculated ORTP for energy storage.

- Offer Obligations - ISO-NE does not define offer obligations that are specific to advanced energy storage resources. (As described above, there are not clear rules for how a storage resource would bid, be dispatched, or settle in the energy market.)
- Performance - ISO-NE performance rules surmise that the resource would have to provide energy during any reserve shortage events, regardless of the duration of such events. This open-ended performance period and high non-performance penalties could be prohibitive to participation by energy storage resources that have to charge. Other ISO markets have created clear market rules to enable storage to be used as a peak capacity resource (see below).
- Rules for pairing of Energy Storage with Renewables for participation in the FCM are not defined. For example, a renewable generator could add storage to its project in order to increase its ability to firm its output and improve its capacity factor; however in ISO-NE there are no rules to allow for this type of paired offering into the FCM. Other markets have rules that enable this type of offer.

8.4.2 Other RTOs/ISOs and Energy Storage and the Capacity Market

In other markets, such as in California, the rules for the Resource Adequacy (RA) capacity market include details about how energy storage can participate. There are specific rules to determine the qualifying capacity value for energy storage, as well as the offer obligations that are specific to energy storage.

California has multiple categories of RA capacity to ensure there are enough resources to meet system, local and flexible RA needs. There are specified duration requirements for energy storage resources. For the System and Local RA, the energy storage requirement is for four hours. For Flexible Capacity, the energy storage resource can have a shorter duration of three hours which can include a portion of charging, and a portion of discharging.²⁵² There are also rules specific to combining energy storage and renewable resources.

PJM added an asset class called Capacity Storage Resource (CSR) in 2015, which is defined as “any hydroelectric power plant, flywheel, battery storage or other such facility solely used for short term storage and injection of energy at a later time to participate in the PJM energy and/or Ancillary Services markets and which participates in the Reliability Pricing Model.” In the PJM capacity market rules, the CSR can combine with Renewable resources, Demand Response resources, and Energy Efficiency resources as a single offer in a Capacity auction to increase the capacity offer MW and/or to improve the chances of meeting PJM’s performance requirements.

8.5 ISO-NE Demand Response and Energy Storage

While storage resources should be able to participate in the existing construct, it is not evident how the existing rules for DR apply to energy storage. Furthermore, as the market design evolves to allow for demand-reduction offers into the energy and ancillary services markets, whether and how energy storage will be able to participate is not defined.²⁵³

²⁵² Details for Qualifying capacity rules are provided at:

<http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M097/K619/97619935.PDF>

²⁵³ Participation by DR in the ISO-NE energy and ancillary services markets is being implemented in a staged approach. Full integration of demand-response resources is planned for June 1, 2018.

As with in-front-of the meter resources, the rules also seem to prohibit behind-the-meter storage resources from providing spinning reserves.

8.5.1 Other RTOs/ISOs and DR

In California, many storage projects are being used to reduce customers' peak demand and peak demand charges, and have the added benefit of supporting the CAISO grid. Currently these types of projects are providing services in the CAISO's wholesale demand response program which includes the provision of Day Ahead and Real Time energy and ancillary services.²⁵⁴ DR resources, comprised of energy storage, can also sell Resource Adequacy capacity.

PJM also has active participation by energy storage resources that are behind the meter in their DR programs. PJM uses sub-metering for measuring the amount of Frequency Regulation, and also uses a conventional baseline method to determine the DR participation.

Stakeholder initiatives are currently being pursued in both markets addressing topics such as the rules for the baseline calculations, distribution-level interconnection, sub-metering, exporting to the grid, and retail versus wholesale rate treatment.

8.6 Transmission Planning and Energy Storage

Rules to consider energy storage as a transmission solution in the ISO-NE transmission planning process do not exist. In other parts of the country, such as at the CAISO, energy storage solutions are explicitly considered in the reliability studies and are integrated into the transmission planning process.

8.6.1 Other Markets and Transmission Planning

At the CAISO, the increased opportunity for non-transmission alternatives, including advanced energy storage, continues to be a key focus of the CAISO transmission planning analysis. The focus on a cleaner lower emission future governs not only policy-driven transmission, but the path on meeting other electric system needs as well.

²⁵⁴ The CAISO does not yet allow for Behind-the-Meter resources to provide Regulation Up or Regulation Down. The CAISO is working with stakeholders in a current stakeholder initiative.

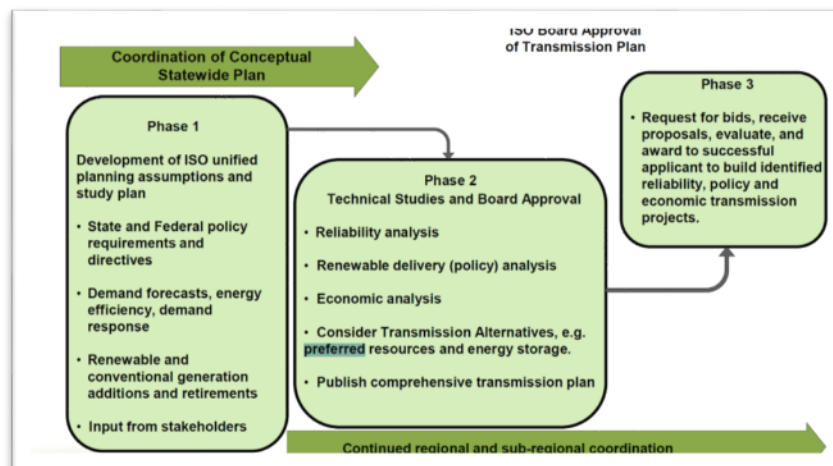


Figure 8-6: Energy Storage is Included in the CAISO Transmission Planning Process (CAISO's Presentation to the Board in March 2016)

The CAISO considers whether energy storage resources are a possible solution to identified reliability needs. The CAISO identifies the most effective buses for potential development of preferred resources,²⁵⁵ which specifically includes energy storage, after reliability concerns have been identified. The CAISO includes the storage resource's energy limitations (duration) in their analysis. To increase awareness of the CAISO's reliance on preferred resources, the CAISO summarizes the preferred resource solutions in addition to being discussed throughout the plan on an area-by-area study basis.

8.7 ISO-NE Interconnection and Energy Storage

ISO-NE's approach to interconnecting storage resources at the transmission and distribution level need further definition for how energy storage resources are modeled and can interconnect. The current process for generation interconnection is not updated to incorporate different operating characteristics of energy storage.

8.7.1 Interconnection – Energy Storage in Other Markets

In California, the interconnection processes at the distribution and CAISO levels all incorporate specific rules that apply to energy storage. Storage resources interconnect using the Generation Interconnection process. However the reliability studies specifically consider both the discharge and charge modes to provide information regarding potential overload issues under assumed conditions.

The CAISO has also clarified how they identify network upgrade and reliability mitigations for storage resources, which apply to the discharging mode. The CAISO interconnection processes also provide for the collection of data that is specific to energy storage resources in the application process. It also includes a deliverability analysis to qualify the resource for Resource Adequacy capacity.

In PJM, energy storage can also interconnect using the same process as a generator. As with conventional generation, there are different types of interconnection study requirements that are applicable to energy storage resources, depending on the resource size. Energy storage can also

²⁵⁵ Preferred resources include demand response, energy efficiency and energy storage.

request Capacity Injection Rights in the Interconnection Process, which would subject the analysis to an additional Deliverability Analysis.

8.8 ISO-NE Issue of “Load Reconstitution”

The rules for whether behind-the-meter generation including storage can contribute to reduced transmission costs differ between ISO-NE and the utilities. ISO-NE’s policy of load reconstitution states “The Network Customer’s Regional Network Load shall include all load designated by the Network Customer (including losses) and shall not be credited or reduced for any behind-the-meter generation.” This implies that load reductions—either intentional or unintentional—from behind-the-meter supply resources are added back to determine the transmission charges for the network customer. Utility tariffs, in contrast, state that the transmission charge is based on the monthly registered peak demand and do not specifically state that an adjustment will be made for behind-the-meter supply resources that offset what would have otherwise been the monthly peak.

The definition of Regional Network Load (RNL) under *Section I: General Terms & Conditions of the ISO-NE Transmission, Markets & Services Tariff* (page 84) includes the following sentence:

“The Network Customer’s Regional Network Load shall include all load designated by the Network Customer (including losses) and shall not be credited or reduced for any behind-the-meter generation.”

This sentence would effectively require anything that is considered “behind-the-meter generation” to be reconstituted for the purposes of determining Transmission payments pursuant to the Open Access Transmission Tariff (OATT) (Section II of the Transmission, Markets & Services Tariff). Furthermore, “behind-the-meter generation” is not defined anywhere in the Transmission, Markets & Services Tariff (or by ISO-NE or FERC).

While the ISO-NE Tariff is explicit on its requirement that behind-the-meter generation be added back to the calculation of RNL (also known as load reconstitution), it is the Network Customer, not ISO-NE that calculates its own RNL values. Each transmission owner memorializes its customized methodology for calculating *Local* Network Load vis-à-vis its local network Schedule 21 of the ISO OATT.²⁵⁶

The ISO expects that transmission owners will provide *Regional* Network Load values inclusive of “all load” excluding behind-the-meter generation. In contrast, the transmission owner’s Schedule 21 defines the methodology for calculating *Local* Network Load. Green Mountain Power²⁵⁷ and New England Power,²⁵⁸ for example, define the local network load differently.

²⁵⁶ Schedule 21 is a sub-component of ISO’s OATT and represents each individual transmission owner’s terms and conditions for its provision of local service.

²⁵⁷ E.g., Green Mountain Power’s Schedule 21 language specifies that it will “treat as internal generation all behind-the-meter generation units with a capacity greater than or equal to 1 MW....” While instructing that “any such generation occurring at the time of the transmission peak will be added to the metered load of the Network Customer for purposes of calculating the Network Customer’s Local Network Load.” http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_2/sch21/sch_21_gmp.pdf

²⁵⁸ New England Power’s Schedule 21 defines Network Load as the “load interconnected (not reduced for any generation behind the meter) to the PTF, Non-PTF or Distribution Facilities of NEP or its New England Affiliates either directly or through Distribution Facilities or Non-PTF Facilities of other entities that a Network Customer designates to receive Local

In Massachusetts, this method impacts the ability of Municipal Light Plants (MLPs) and competitive suppliers to use energy storage (or other peak reduction methods) to reduce transmission related costs. In stakeholder discussions, MLPs ranked Capacity and Transmission Payment Reduction as a high priority application that has one of the most substantial potential value streams for energy storage systems, but stakeholders noted that Load Reconstitution is a significant regulatory barrier for full monetization of this beneficial application. The MLPs considered the lack of clarity around the treatment of load reconstitution for capacity and transmission payment calculations as a significant barrier for energy storage.

8.9 New Products in Other Markets

As we compare ISO-NE to other markets and how energy storage can play a part, it is worthwhile to discuss how new products that integrate flexibility and fast responding resources are developing in other areas.

Frequency Response

Frequency response is the automatic monitoring and response by an operator to ensure system frequency is maintained—at 60 Hertz (Hz) in the US—on an instantaneous basis. Known as “primary frequency control” or “primary reserve,” generating resources, including energy storage, can provide frequency response. Since energy storage has such a rapid response time, it is well suited to provide this service. Frequency response is a standard product in European electricity markets.

There is currently a FERC proceeding which is aimed at collecting more information about Frequency Response, including perspectives about creating a new market product for this service. Separately, the Electric Reliability Council of Texas (ERCOT) is also proposing to develop a new frequency response market. ERCOT has already created a fast frequency response product oriented specifically for fast responding energy storage resources. The CAISO is also conducting a stakeholder process to evaluate whether and how to develop a frequency response market.

Ramping

With more renewable penetration, enough resources need to be available to meet intra-hour ramping needs. In the U.S., the CAISO and the Midcontinent Independent System Operator (MISO) are working to implement new market-based ramping products in 2016 and the Southwest Power Pool (SPP) is also considering one as well. ISO-NE has discussed its desire to implement some form of ramping algorithm or product into its dispatch systems with a goal of implementation sometime in 2017.²⁵⁹ As discussed above, advanced storage resources can ramp very quickly across their full range (from negative to positive) making them an ideal resource to manage ramping constraints. Any new ramping product created by ISO-NE should include the ability for advanced storage to participate.

Flexible Capacity

Network Service under Schedule 21 and this Schedule. http://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_2/sch21/sch_21_nep.pdf

²⁵⁹ ISO-NE, April 8, 2015: Technical Session - Real-Time Price Formation: Pre-ramping, available at: http://www.iso-ne.com/static-assets/documents/2015/04/price_information_technical_session10.pdf.

Growing demand, environmental restrictions, and high penetration of variable energy resources in the market are expected to create a need for other resources in order to reliably maintain the electric system. The California ISO has found that among the challenges for integrating 33% renewable resources is ensuring that there is sufficient flexible capacity to address the added variability and uncertainty of variable energy resources. The specific flexibility attributes the ISO requires include, at a minimum, multi-hour ramping needs, load following, and regulation.²⁶⁰ Because of this need the CAISO is proposing adding flexible capacity procurement targets to the CPUC's Resource Adequacy (RA) program. Likewise, FERC should consider capacity market measures that value flexibility in order to encourage investment today in resources that provide flexible capacity in order to avoid reliability issues in the future.

Furthermore, CAISO has begun a "Flexible Resource Adequacy" initiative, working with local regulatory authorities to ensure flexible capacity resources are available to reliably operate the grid while fulfilling state energy mandates.²⁶¹ The latest straw proposal from the CAISO specifically includes energy storage as an eligible resource for providing Flexible RA, acknowledging the flexibility and reliability benefits of storage resources.

8.10 Recommendations

8.10.1 Create an Advanced Storage Working Group at ISO-NE

The creation of an ISO-NE Advanced Storage Working Group would support a level playing field for the inclusion of advanced energy storage resources in all ISO-NE markets and could recommend market rule changes to remove barriers to new storage technologies participation. Opening additional ISO-NE markets to advanced energy storage through the creation of an Advanced Energy Storage Working Group at ISO-NE would increase advanced storage deployment.

As Massachusetts investigates the benefits of integrating energy storage at the wholesale level, lessons learned from other wholesale markets such as CAISO and PJM can be considered. Given the number and complexity of barriers to full participation of advanced energy storage in the ISO-NE markets, ideally a new ISO-NE stakeholder working group should be created to prioritize the changes needed for complete integration of energy storage in the ISO-NE markets and to put energy storage on a level playing field with other resources. The working group could address the following topics:

- (A) Develop market rules for Energy Storage – Force-fitting advanced energy storage into existing categories does not recognize the flexible operating characteristics of energy storage. Modifications should be made to the co-optimization, dispatch, bidding, optimization, and settlements to allow for energy storage resources to operate seamlessly from their negative to positive range, so that they can fully participate in the energy, and ancillary services markets, consistent with conventional generation. This can enable ISO-NE to realize the dispatchable benefits that energy storage can offer.

ISO-NE should also pursue changes to allow Energy Storage resources to offer spinning reserve as is done in other RTOs/ISOs.

²⁶⁰ For a more detailed discussion of these studies, see

<http://www.caiso.com/Documents/SecondRevisedDraftFinalProposal-FlexibleCapacityProcurement.pdf>.

²⁶¹ For a more detailed discussion of this effort, see

<http://www.caiso.com/informed/Pages/StakeholderProcesses/FlexibleResourceAdequacyCriteria-MustOfferObligations.aspx>

Specific rules for energy storage to participate in the FCM should be developed. Realistic duration requirements should be established, as well as rules to couple energy storage and Renewable resources.

Minimum Size requirements should be reevaluated so that smaller resources – down to 0.1 MW – can participate.

- (B) Interconnection – The generation interconnection process should be updated to address energy storage specific needs in the study process. Furthermore, processes should be put in place that allow energy storage systems to advance through interconnection study processes that cross the jurisdictional divide between wholesale and retail. Differences between the multiple interconnection processes should be coordinated with the establishment of clear rules that apply to energy storage.
- (C) Transmission Planning – ISO-NE should specify the reliability needs where energy storage can mitigate problems. Other markets, such as CAISO, identify where energy storage resources can mitigate reliability problems, such as congestion and voltage issues.
- (D) Reactive Power – ISO-NE should consider enabling energy storage to qualify to provide voltage support, since it is technically capable of doing so.
- (E) Behind the Meter Participation (DR) – The ISO-NE should provide detailed examples to show how and if energy storage resources can fit into the existing wholesale DR framework. ISO-NE should develop rules to further consider energy storage participation behind the meter, including baselines, sub-metering, multiple use applications, and retail versus wholesale rate treatment.
- (F) Load Reconstitution – The ISO definition of Regional Network Load includes the term behind the meter generation (as a significant component of the definition) yet it does not elsewhere define behind the meter generation. The ISO should define that term.

Further, the treatment of the network load at the local level under Schedule 21 is inconsistent from Transmission Owner to Transmission Owner creating inconsistencies and a disconnect between Schedule 9 RNS and Schedule 21. The inconsistent treatment discriminates arbitrarily – and perhaps unfairly – based on interconnection to the Local Network System and based on the ability to participate in the certain market benefits from distributed resources.

When state and federal policies promoting energy storage are in play, and more resources are ready to enter the queue, ideally the grid operator will be driven to further evaluate how the market design will need to be enhanced to fully integrate and benefit from the specific characteristics of energy storage.

STATE OF CHARGE

Massachusetts Energy Storage Initiative Study

9 Policy and Program Recommendations to Grow the Advanced Energy Storage Industry in Massachusetts

The Massachusetts Clean Energy Center (MassCEC), with the support of the Baker-Polito Administration and the DOER, is committed to accelerating the success of clean energy technologies, companies and projects in the Commonwealth, while creating high-quality jobs and long-term economic growth for the people of Massachusetts. MassCEC already has a broad suite of programs that support clean energy technology development and industry growth within the Commonwealth.

MassCEC's role in enhancing the growth of the energy storage industry in Massachusetts encompasses the following:

- Leveraging existing expertise and experience in creating programs for growth and development in clean energy markets;
- Administering programs that cover a range of market development funding gaps unmet by the private sector;
- Providing both financial and non-financial support to technology developers and start-up companies;
- Creating new initiatives to meet the specific needs of the energy storage industry to supplement existing programs.

This chapter suggests mechanisms to create a thriving energy storage industry in the state. In addition to recommending continuation and expansion of existing technology development and commercialization acceleration programs that can support energy storage companies, the sections below propose new initiatives to meet specific industry and stakeholder needs identified in this report. The following strategies for both new and existing energy storage programs will support existing companies, assist local entrepreneurs to grow their businesses, and attract entrepreneurs from other regions to establish their businesses in Massachusetts. In addition to these programs, a supportive policy environment will help attract and retain energy storage companies.

9.1 Promoting Energy Storage Company Growth in Massachusetts

A variety of business climate factors impact the growth rate and commercial viability of energy storage companies. Figure 9.1 provides a high level overview of the factors that will impact industry growth in Massachusetts, and the enablers that will foster that growth.

STATE OF CHARGE

Massachusetts Energy Storage Initiative Study

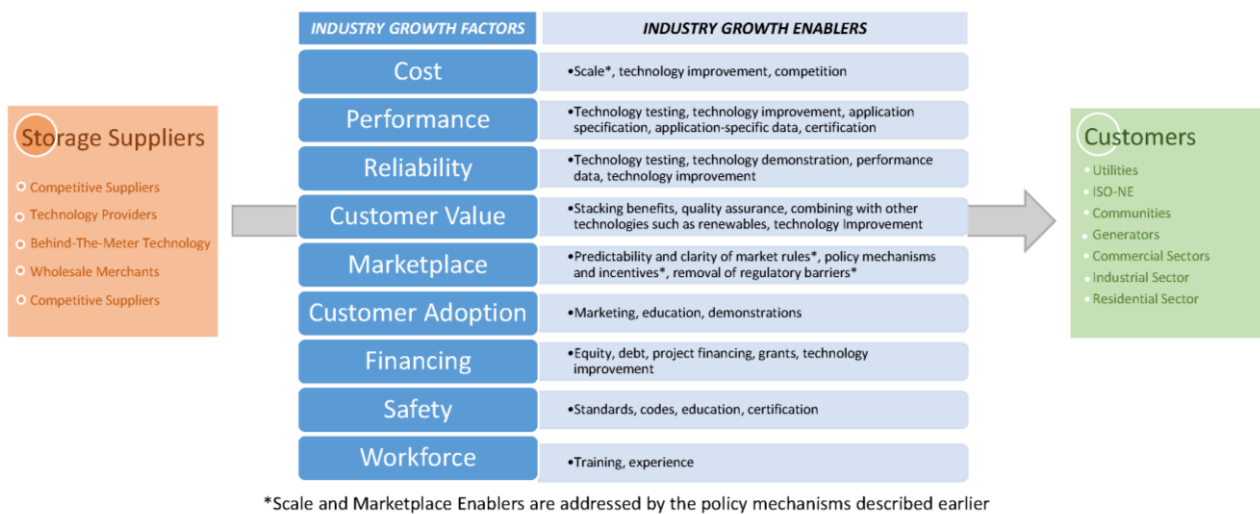


Figure 9-1: Factors Affecting Energy Storage Industry Growth

Policies and regulatory changes that create conditions for sustained market opportunities for energy storage systems and stimulate demand for existing and new energy storage technologies are critical for industry growth. Thus, market development policies, such as those discussed in Chapter 7, are integral to developing a robust energy storage industry in Massachusetts. Other industry growth factors listed in Figure 9.1 are supported by the programs discussed below.

9.2 Supporting Energy Storage Technology Development in Massachusetts

As discussed in Chapter 1, a variety of advanced energy storage technologies are available in the market today. However, no single technology serves all applications in a cost-effective manner and while energy storage costs have decreased dramatically, cost continues to be a barrier across many storage applications and in many markets. Continued public and private investment in energy storage technology will help identify new storage technologies and accelerate the performance improvement and cost reduction of emerging and existing advanced storage technologies.

An energy storage developer or entrepreneur has varying needs to accelerate the growth and development of storage technologies, depending on the stage of technology development. Support mechanisms should be designed and structured to meet the varying needs of storage technology developers and entrepreneurs. For example, in the early stages of technology development, the priority is to provide proof of the technology's performance and to reduce technology risk, often by building a prototype and establishing some baseline performance in a lab environment. Later, companies will often seek to demonstrate the commercial viability of their technology in an operational environment. Finally, as companies seek to scale their technology, market and regulatory risk become key concerns that must also be addressed. While market and regulatory risk factors underpin the programs and recommendations described in Chapters 7 and 8, the proposed initiatives described in this section primarily concentrate on addressing technology risk factors.

As discussed in Chapter 3, the stakeholder engagement process helped to identify some of the key issues and barriers for earlier stage technology developers who hope to bring their technologies to a level where they can move to the next stages of commercialization. In order to move forward, developers may seek to partner with (or sell their demonstrated product or process to) a system

integrator or to an established manufacturer. For their part, these upstream suppliers of products and services need to be convinced of the technical capabilities of otherwise unproven early stage technologies.

The programs described below address a number of areas in support of advanced energy storage technology development in Massachusetts, in large part based on stakeholder concerns. These include:

- Tailored funding programs for energy storage research, development and demonstration;
- Access to dedicated specialized technology testing facilities for storage technology developers;
- Facilitating access to suitable demonstration sites for emerging energy storage technologies; and
- Identifying and addressing priorities in the manufacturing of energy storage products.

9.2.1 New Technology Development and Technology Improvement

Summary	Tailor funding programs to support energy storage technology research, development and demonstration (RD&D).
Duration of the program	Program duration is a function of budget and policy support. It should straddle multiple years depending on the budget and pace of technology development. The program duration should integrate exit ramps and pre-determined effectiveness assessment points to allow for budget and eligibility criteria review.
Funding options	Supported by MassCEC R&D funding programs (e.g. Catalyst, Leveraging Funding Opportunities, AmplifyMass, University Research, etc).
Targeted Use Cases	All
Implementation requirements	Expand energy storage component in existing programs that support clean energy technology development; potentially add energy storage to the legal definition of clean energy; ²⁶² expand the funding level if warranted, leverage financial resources of non-state agencies and federal government, and provide access to non-financial resources (e.g. making introductions to other investors).
Barriers addressed	Addresses lack of financial and non-financial resources that are in shortage for early stage technology developers.
Examples in other States	California's and New York's state programs that support energy storage RD&D. These programs have been very effective in providing pipelines for energy storage growth in both states, particularly in California (e.g. EPIC Program).

Goals and Impacts

Goals: The goals of these funding programs are: 1) to accelerate the pace of new energy storage technology development within the Commonwealth, 2) to keep promising storage technology ideas generated within the state rather than migrating elsewhere for lack of financial support, and 3) to attract companies from other states to be part of an energy storage cluster in the Commonwealth.

Impact: Technologies developing in Massachusetts universities and by entrepreneurs are likely to stay and grow in the state as they move through various stages of commercial development if they are anchored in and supported by local expertise and funds. Creation of new companies, and their contribution to the state's economy and employment, is the expected impact of the MassCEC programs that support energy storage RD&D.

²⁶² Massachusetts General Law, MGL c. 23J s. 1

Description

Funding support for energy storage RD&D from government programs is intended to enable early stage technology developers to bring their concept to a working prototype that can then be tested for its capability to serve specific energy storage applications. Access to both financial and non-financial resources has been identified as a major barrier by stakeholders. MassCEC can help fill this gap by using existing programs for which energy storage may be eligible or modifying these programs to support energy storage RD&D. MassCEC programs that provide funding and non-financial support for energy storage RD&D are listed below. This is not an exhaustive list but is indicative of the type of support that can be provided.

Funding Mechanisms

MassCEC's Catalyst Program:

The MassCEC Catalyst Program provides grants to researchers and early-stage companies looking to demonstrate initial prototypes of their clean energy and water technologies. The Catalyst Program's primary goal is to stimulate the commercialization of clean energy innovative technologies developed in the Commonwealth. Funds are used to demonstrate the feasibility of technologies in specific industry applications in order to obtain increased industry and investor interest.

Recipients must use funding for projects that move their technologies towards commercialization. This can include gathering initial data to demonstrate proof of concept, demonstrating how the technology compares to existing technologies and what competitive advantages the technology may have, and developing a prototype for the technology.

Leveraging Funding Opportunities:

This is a resource to support Massachusetts companies on federal and non-federal funding applications. This program seeks to: promote and advance technologically innovative research and development, and support economic analysis on the impacts of clean energy technologies; support the commercialization of technological innovations, including infrastructure development and pilot projects; and ensure a trained workforce for Massachusetts' clean energy industry. MassCEC may provide qualified businesses with support such as cost share funding, letters of support, and facilitating connections throughout the clean energy ecosystem.

AmplifyMass:

This program offers cost-share funding to Massachusetts-based awardees of ARPA-E (Advanced Research Projects Agency - Energy), an agency of the United States Department of Energy. The program makes awards to companies in the form of grants up to \$300,000, and awards to universities in the form of grants up to \$100,000.

Support for Clean Energy in Academia:

Massachusetts' academic and affiliated research institutions are a source of new and innovative ideas for advanced energy storage technologies and have a history of incubating and growing energy storage companies in the Commonwealth. These institutions provide a competitive advantage for Massachusetts that few other states can match. *Support for Clean Energy in Academia* is intended to support clean energy and water technology efforts in Massachusetts' academic institutions. This program seeks to: promote and advance technologically innovative research and development and support economic analysis on the impacts of clean energy technologies; support the commercialization of technological innovations, including infrastructure development pilot projects;

ensure a trained workforce for Massachusetts' clean energy industry; and support clean energy adoption and promotion.

Implementation

To support energy storage RD&D, some of the available programs, which are currently technology agnostic, may require adjustment or improvement. An increase in funding for these programs, with a specific carve-out for energy storage, may merit consideration.

It should also be noted that the Massachusetts Department of Revenue has both a corporate and a personal income tax deduction known as the Alternative Energy and Energy Conservation Patent Income Tax Deduction,²⁶³ whereby it offers a corporate income tax deduction for (1) any income — including royalty income — received from the sale or lease of a U.S. patent deemed beneficial for energy conservation or alternative energy development by the Massachusetts DOER, and (2) any income received from the sale or lease of personal or real property or materials manufactured in Massachusetts and subject to the approved patent. The deduction is effective for up to five years from the date of issuance of the U.S. patent or the date of approval by the DOER, whichever expires first. Energy storage is not listed as an eligible technology for this tax deduction.²⁶⁴

²⁶³ Massachusetts General Law MGL ch. 62, § 2(a)(2)(G); <http://programs.dsireusa.org/system/program/detail/229>; <http://programs.dsireusa.org/system/program/detail/149>

²⁶⁴ Eligible technologies include: Solar - Passive, Solar Water Heat, Solar Space Heat, Geothermal Electric, Solar Thermal Electric, Solar Thermal Process Heat, Solar Photovoltaics, Wind (All), Biomass, Hydroelectric, Geothermal Heat Pumps, Municipal Solid Waste, Fuel Cells using Non-Renewable Fuels, Wind (Small), Fuel Cells using Renewable Fuels.

9.2.2 Technology Testing

Summary	Support energy storage technology developer access to dedicated technology testing facilities.
Duration of the program	Program duration is a function of budget and policy support. It should straddle multiple years depending on the budget and pace of technology development. The program duration should integrate exit ramps and pre-determined effectiveness assessment points to allow for budget and eligibility criteria review.
Funding options	Public-private partnerships
Targeted Use Cases	All
Implementation requirements	Collaborate with the U.S. DOE and National Labs, which currently have testing facilities; assess the needs and benefits to collaborating with similar facilities such as those in NY; and leverage the technical capabilities and facilities at MA academic and research institutions.
Barriers addressed	The lack of facilities to test new storage technologies' performance standards for the desired application, the high cost of testing, the challenges of testing a new technology with evolving industry specifications and regulations, and the lack of funds to use out-of-state test sites.
Examples in other States	Federal government funded sites at National Labs in NM, IL, WA and CO. State funded testing program in NY.

Goals and Impacts

Goals: The goals of a Technology Testing program are to: 1) help technology developers cost-effectively assess how far a technology has progressed against the performance benchmarks set by the industry and markets, 2) provide an independent performance verification platform on which investors and potential users can base their decisions, and 3) attract energy storage technology developers from other states so that they may wish to establish their businesses in Massachusetts.

Impacts: The expected impact would be to promote an accelerated pace and reduced cost of technology development and commercialization for emerging Massachusetts-based energy storage companies.

Description

Beyond prototype development, energy storage technology developers must also convince potential manufacturers, system integrators, and utilities that their energy storage system can perform to certain specifications. There are basic characteristics such as round trip efficiency, C-rate, product life and stand-by losses, etc. that must be measured and calibrated for a potential user to assess the financial feasibility of a storage technology. National labs such as Sandia in Albuquerque, New

Mexico or Argonne National Laboratory in Illinois can provide this help through rigorous testing, but there are costs associated with these laboratories not being local and sometimes having a waiting list for access to the testing resources.

A testing facility in Massachusetts to provide similar service would be of help not only for Massachusetts-based technology developers but could also become an incentive to companies that may want to relocate to the state from adjoining regions. Massachusetts' educational institutions and the Lincoln Laboratory have the necessary technical experts who can lend their time and possibly resources to set up a test facility. The Battery Prototyping Center (BPC) in New York is one possible model. The BPC at the Rochester Institute of Technology (RIT) focuses on the development of emerging energy storage technologies through a partnership between RIT and NY-BEST Consortium. BPC is made possible by financial support from NYSERDA, Empire State Development, and SoLith (a battery-production equipment manufacturer). Such a testing facility could also be located at one of the incubators as well. Organizations such as the Clean Energy State Alliance (CESA) from Vermont, which already has a DOE contract to help states, may be a good organization to coordinate such efforts with.

A variation of this laboratory configuration is the testing of storage technologies in simulated real-life (e.g. utility connected) environments. This requires an ability to do dynamic testing with simulated grid interaction. This type of testing goes beyond just benchtop testing for parameters and characteristics and is more expensive and space intensive. Although the Sandia Laboratory, and to some extent the NY facility, may provide this sort of help, the distance and costs for early stage Massachusetts-based companies could be prohibitive. Thus, developing a small test site, jointly shared by utilities and educational institutions, is an option that merits serious consideration. When done jointly with utilities, which usually have space and possibly their own testing protocols, this is helpful.

The Emerging Technologies Coordination Council (ETCC) in California is one such program. Utilities agree on what technologies to test and then each utility takes turn based on their capabilities and expertise, and the findings are shared. This, of course, benefits the technology developer. The technology application and integration are tested to utilities' performance and safety standards. Other utilities trust the reports from a sister utility more than someone who is not linked to the utility industry. Also, since utilities will have developed experience while testing the technology, they will be better able to calibrate the technology's impact on their operations and its value. In Massachusetts, the Massachusetts Technical Assessment Committee (MTAC) is an example of new technology collaboration between utilities, in this case to assess energy efficiency technologies.²⁶⁵ Currently, MTAC only considers commercially available technologies. Expanding consideration to nearly commercial technologies would result in increased understanding for both the utilities and the developers about the application and benefits of emerging technologies.

Funding Mechanisms

Assistance for funding technology testing is often folded into the RD&D grants to technology developers. However, successful technology development efforts soon outgrow testing within the confines of standard laboratories or benchtop tests. Completed storage systems or sub-assemblies need different types and scale of testing, simulating real life situations that exist at grid or customer sites. Lack of such testing capabilities within easy access adds to the cost of technology

²⁶⁵ <http://www.masssave.com/en/professionals/business-opportunities/assessment-of-new-efficiency-technologies>

development. State government funding, potentially in collaboration with other states, the federal government, major research institutions, or national laboratories, may be a viable mechanism to develop a dedicated testing facility for energy storage developers and manufacturers. The Wind Technology Testing Center in Charlestown is an example of this model.

An alternative mechanism could be state-allocated funds to Massachusetts academic/research institutions to support the development of capabilities to conduct testing for technology developers. This is an example of indirect (non-financial) support to a technology developer. The Commonwealth could undertake this program as a potential new effort to support energy storage testing, in collaboration with universities/incubators and neighboring resources (e.g. NY-BEST testing facility) with possible federal support. This approach could have the additional benefits of further developing energy storage expertise in one or more of the Commonwealth's academic institutions as well as providing an unparalleled opportunity for student education and hands-on training to help develop the specialized workforce needed to support a growing energy storage industry in Massachusetts. The Water Innovation Network for Sustainable Small Systems (WINSSS) at University of Massachusetts, Amherst, is a model for such a facility.

Another means of funding this need is to offer funds for testing at other facilities in the country, either independently or as an expanded activity of an existing RD&D funding program, once a certain level of technology maturity has been achieved. The advantage of this approach is that local companies can be supported without incurring the capital costs of establishing a testing infrastructure. However, this limits the overall benefit to Massachusetts institutions and reduces the potential for establishing a collaborative network of energy storage technology expertise and innovation within the Commonwealth.

Implementation

- Work with MA-based national lab (Lincoln) and institutions to develop dedicated facilities to perform certain tests to industry standards. (Note: test facilities may not be able to serve all types of storage technologies);
- Collaborate with NY Best and share some program budget with set-aside time and expertise for testing products from MA-based storage technology developers; and
- Allocate funding support through existing RD&D funding programs, to help defray costs for testing at out-of-state facilities for MA-based energy storage technology developers.

9.2.3 Support for Early Stage Technology Demonstration

Summary	Support for Early Stage Technology Demonstration
Duration of the program	Program duration is a function of budget and policy support. It should straddle multiple years depending on the budget and pace of technology development. The program duration should integrate exit ramps and pre-determined effectiveness assessment points to allow for budget and eligibility criteria review.
Funding options	Public-private partnerships
Targeted Use Cases	All
Implementation requirements	Engage partners in finding suitable sites for demonstration; facilitate use of state or public facilities to provide demonstration sites that simulate energy storage deployment conditions; and collaborate with U.S. DOE and National Labs for funds and technical assistance on demonstration projects.
Barriers addressed	Difficulties in accessing demonstration sites for de-risking new energy storage technologies, due to 1) high costs, 2) perceived risks, and 3) permitting costs and delays.
Examples in other States	State-funded programs that fund utilities to test and demonstrate at substations and other applications. Utility-funded and managed programs in CA, NY, OR, WA, NC, OH. CA provide funds for PG&E and SCE to test large scale batteries, sometimes in collaboration with DOE.

Goals and Impacts

Goals: The goal is to demonstrate the functionality, and possibly the economics, of early stage energy storage technologies developed in Massachusetts to reduce perceived technology risk.

Impacts: The demonstrations will allow promising storage technologies developed in Massachusetts to move to the next stages of commercial viability. This would result in follow-on funding for 1) scaling up, 2) encourage in-state manufacturing, or 3) help utilities incorporate the new technologies in their operations.

Description

The demonstration programs and initiatives described in Chapter 7 are expected to involve proven, commercial energy storage technologies where technology risk is perceived to be relatively low. Conversely, it is unlikely that earlier stage technologies will be selected by project developers and/or site owners in pursuing these new initiatives.

Support for demonstration of earlier stage energy storage technologies is an essential step in their path to successful commercialization. The increased financing need, and a lack of suitable or willing sites for demonstration, often leaves a promising technology languishing until the fledgling company runs out of funds to continue operation (commonly referred to as a “commercialization valley of

death”). Unanticipated expenses such as permit costs, insurance, and indemnity from damages add to the need for funds or equivalent resources (whereas, for proven technologies, these items would typically be funded by “project finance” or through outright purchase by the user).

MassCEC’s InnovateMass program is specifically designed to provide targeted, strategic support to companies facing the commercialization valley of death, a widely-recognized funding gap that exists between early-stage support offered by angel investors and later-stage support historically provided by venture capital and strategic investors. Demonstrations discussed here are for energy storage systems between Technology Readiness Levels of 5 and 7.²⁶⁶ The intent of these demonstrations is to show how a specific energy storage system would function in an operational (non-lab) environment, across its applications (e.g. peak demand reduction, solar integration, frequency regulation, etc.) and possibly calibrate operational and economic benefits. The InnovateMass program could allocate funding specifically geared toward advanced energy storage technology demonstrations.

Various agencies in the federal government support energy storage demonstration to advance their respective mission. Two notable examples are U.S. Department of Energy (DOE) and U.S. Department of Defense (DoD).

The Commonwealth can also provide valuable non-financial support by facilitating access to public institutions for demonstration sites. For example, the Massachusetts Water Resource Authority’s Deer Island waste water treatment facility provided space for an experimental wind turbine developed by the Massachusetts based company Flo Design. MassCEC’s DeployMass program helps facilitate public sector adoption of Massachusetts based clean energy technologies by vetting technologies and de-risking public sector customer sales with targeted grant funding. This program could be tailored to help accelerate public sector adoption of Massachusetts based early stage energy storage technologies. Many other states have used state or local government owned facilities to successfully demonstrate energy storage. For example, the campuses of University of California’s San Diego and Irvine campuses have housed several energy storage demonstrations. Besides meeting some on-site energy and reliability needs, this particular nature of demonstration also provide a hands-on opportunity for students to learn about new technologies.

Funding Mechanism

InnovateMass funding is made available once a year. While most InnovateMass funding rounds accept applications covering a wide array of clean energy technologies, the program may issue specific energy challenges to foster innovation within particular sectors that are priority areas for the MassCEC and the Commonwealth of Massachusetts. Energy storage is included in the list of currently eligible technology and the program had issued a RFP. However, given the limit on the funds, large scale demonstrations are often beyond the program’s budget.

As part of the American Recovery and Reinvestment Act of 2009 (ARRA) (Pub.L. 111–5), commonly referred to as the Stimulus or The Recovery Act, the federal government made available several million dollars for suitably sized demonstrations of energy storage. Many of the successfully demonstrated projects contributed to developing viable companies after the demonstrations. Even those that failed were useful in advancing industry knowledge and utility acceptance. While it is unlikely that the program will again be funded to the multi-million dollar level any time in the near future, the U.S. DOE does provide technical assistance on specific large scale projects.

²⁶⁶ <https://github.com/SAF2/documentation/wiki/Technology-Readiness-Level-%28TRL%29>

Looking at other funding sources, the state can also leverage funding from the DOE's Energy Storage Program, housed in the Office of Electricity and Energy Reliability, as well as local government funds to facilitate large demonstrations. The DOE Program collaborates with utilities and state energy organizations to field major pioneering storage installations that are several megawatts in size. DOE has provided support for a project under National Grid's Distributed Energy Storage Systems Demonstration program in Worcester, MA. This project demonstrates competitively-priced, grid scale, long-duration advanced flow batteries for utility grid applications. The project incorporates engineering of fleet control, manufacturing, and installation of two 500 kW/6-hour energy storage systems in Massachusetts to lower peak energy demand and reduce the costs of power interruptions. One system will be installed next to a 605 kW photovoltaic (PV) array in Everett, MA. A second system will be installed next to a 600 kW wind turbine located on a customer site in Worcester, MA. Another mechanism is for the Northeast states to pool their resources (financial and other) and issue energy storage technology development and demonstration RFPs. Organizations like CESA could help coordinate this effort.

The US DoD also believes that energy storage systems are integral to providing resiliency to its mission critical activities and operations. Consequently, it has budgets to demonstrate energy storage technologies and has often collaborated with states by matching funds for storage demonstrations at bases located in the host states. The Office of Naval Research (ONR) has funded research and demonstrations projects under its "Power & Energy" category, including an Energy Storage demonstration project at Ft. Devens, MA. The project supports the DoD's goal to reduce fuel use and logistics, and increase energy security. The project is built around the commercial GTIB-100 Inverter with 82 kWh of lithium-ion batteries and control equipment, all built into one weatherproof enclosure.

9.2.4 Support for Energy Storage Manufacturers

Summary	Early stage support for Energy Storage Manufacturers
Duration of the program	Program duration is a function of budget and policy support. It should straddle multiple years limited only by the budget and pace of technology development. Must have exit ramps and pre-determined effectiveness assessment points to allow for budget and eligibility criteria review.
Funding options	Initial non-financial assistance, with some funds needed to organize events and for information transfer. Potential to leverage funding support for establishing shared specialized resources.
Targeted Use Cases	All
Implementation requirements	Convene a workshop of those already in manufacturing or planning and facilitate a workshop to identify non-financial barriers for manufacturing and capacity growth.
Estimated impact	Development of shared specialized resources particularly useful for manufacturers.
Barriers addressed	Bottleneck to starting manufacturing and expanding capacity.
Examples in other States	California Stakeholder Forum for potential and current manufacturers (see next page).

Goals and Impacts

Goals: The goal of this effort is to lower pre-commercial costs for energy storage manufacturers by identifying and providing pre-competitive shared resources. These include: lowering the cost of first products and improving quality without scaling up for full-fledged manufacturing set-up; creating a framework to enable more effective collaboration and to help secure resources for the identified priorities in manufacturing energy storage products; identifying shared resources for manufacturing used by early stage storage technology developers; and providing resources (calibrating equipment, testing machines, design software, etc.) that could expedite the manufacturing of first products (not prototype) for testing and scaling up.

Impacts: Increase the number of companies that could expeditiously transition into manufacturing without incurring heavy capital equipment costs very early in the development cycle.

Description

To foster a growing energy storage industry in Massachusetts, the Commonwealth seeks to offer resources that technology developers cannot easily find elsewhere, such as facilities for testing as well as achieving competitive manufacturing of components and commercial products. In 2013, the Berkeley National Laboratory in California convened a stakeholder forum of technology developers who were exploring options for help in manufacturing. The findings from the forum (see Sidebar, next page) provide specifics on what the potential energy storage manufacturers were seeking in order to take their companies to the next level. The prospective manufacturers' comments are

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useful input in the context of attracting companies and growing an energy storage industry in Massachusetts.

As summarized in the CalCharge Advanced Manufacturing Roadmap:²⁶⁷ *“While focused on technical issues, a repeated theme during the discussion was the importance of creating a framework to enable more effective collaboration and to help secure resources to address the identified priorities. Participants also repeatedly identified workforce training, and standards and certification issues, as critical to ensuring the development of a US advanced manufacturing capacity. The consistent interweaving of technical, workforce, and ecosystem issues also occurred throughout the two-year market analysis process. As a result, it is apparent that any solutions to address the issues that surfaced require the creation of an institutional framework that engages the entire value chain across the full product development cycle, from “innovation to installation”.*

²⁶⁷ CalCharge Advanced Manufacturing Roadmap. <http://calcharge.org/programs/pre-commercialization-support/>

SIDEBAR: California Energy Storage Technology Developer Stakeholder Session²⁶⁸

In late 2013, over 20 senior energy storage company executives and other stakeholders gathered at the Lawrence Berkeley National Laboratory in California to participate in a stakeholder engagement exercise to assess the needs of early-stage energy storage technology developers. Pre-commercial technical challenges were identified in six broad topic areas:

- **A common user facility to test ideas and to standardize processes**
Examples of the types of equipment and services desired include:
 - Shared process, analytical, and testing equipment to reduce capital equipment investment costs,
 - A library of testing protocols, and
 - Standard components and formulations for non-core process steps.
- **New modeling techniques**
Currently available analytical models are generally a poor predictor of manufacturing costs and product performance. New modeling techniques that better bridge between the “art” and science of manufacturing would:
 - Enable the modeling of process flow and costs,
 - Create and validate accelerated life testing protocols,
 - Reduce prototype development costs by developing credible applications for computer based battery designs, and
 - Better link design to ultimate performance earlier in the product development cycle.
- **New cell designs and associated standardized processes**
Participants identified the need for:
 - Module level innovation to increase safety of batteries,
 - Enhanced internal sensing capability in individual cells,
 - Standardized pouch packaging forming equipment and processes,
 - Alternative techniques to stamping of battery plates, and
 - Less expensive and short-free high power large format batteries.
- **Refined metrology to ensure quality and high yield**
Current battery manufacturing metrology fails to ensure consistency between inputs and outputs. This has resulted in unacceptably low yields in the manufacturing line. Participants advocated for new metrology standards that would better link source materials to the quality of the final product.
- **Application of modern manufacturing techniques from other industries**
Battery manufacturing is still largely based on a 60-year-old process that is labor and time intensive, resource inefficient, and requires large plant footprints. Participants advocated for further exploration of:
 - Standardized six sigma and lean manufacturing processes leveraged from the experience of other industries,
 - Three dimensional uses of space in manufacturing processes that could dramatically reduce manufacturing plant footprints, and
 - Modular manufacturing design that could drive towards energy density product improvement goals (Higher MWh per 40 foot containers).
- **Reduction in manufacturing process steps**
 - Identifying and increasing the yield of bottleneck process steps,
 - Formation of a battery is a particularly slow and expensive process,
 - Need to move away from slot die coating to make electrodes, and
 - More efficient use and re-use of the energy required for formation.

²⁶⁸ CalCharge Advanced Manufacturing Roadmap. <http://calcharge.org/programs/pre-commercialization-support/>

Many of the issues and possible solutions discussed in this 2013 stakeholder engagement have been captured elsewhere and are embedded in the suggestions for expanding or creating the categories of programs discussed elsewhere in this chapter and in Chapter 7. However, the above discussion puts an emphasis on specific help Massachusetts might be able to provide that is attractive to energy storage manufacturers. Massachusetts has many organizations and in-state manufacturing expertise that could be leveraged to provide help in moving along the pathway of “innovation to installation,” taking a company from prototype to successful commercial scale production.

Implementation

- Seek consensus from Massachusetts companies to assess the usefulness of such a facility. Include those that are currently manufacturing or planning to do so;
- Conduct facilitated workshops to identify barriers to manufacturing and capacity growth (non-financial);
- Identify specific equipment or technical expertise that would be of value to the workshop participants; and
- Develop a plan to assemble and then offer the services to Massachusetts storage technology developers.

9.3 Support Energy Storage Company Growth

Capital investment and financial support are critical to company growth in any industry. Investment in energy storage companies have had mixed trends in past years — long sales cycles, uncertain markets that depend often on slow regulatory change, and capital intensive technologies are a few reasons for this. As the policy and regulatory barriers are addressed and markets open up, investments in energy storage companies is likely to become more attractive.

MassCEC offers programs that invest in early stage companies in order to help them advance in their commercialization path and attract external capital from both public and private sources. To help in-state energy storage companies grow and to attract other companies to relocate into the state, Massachusetts can build or expand on existing investments or venture debt programs. Some of these programs could be adjusted to meet the unique needs of the energy storage industry.

9.3.1 Equity

Summary	Equity Funding program
Duration of the program	Duration is determined by availability of budgets. Support is reduced or eliminated if private sector financing is available, market barriers are eliminated, and depends on the level of market and technology maturity.
Funding options	Equity under “Investments in the Advancement of Technology” Program.
Targeted Use Cases	All
Implementation requirements	Develop in-house expertise in analyzing energy storage market opportunities; assess management’s ability to manage a company in energy sector, team experience, the product or technology’s value proposition and defensibility; develop business model viability; and assess the magnitude of company/technology employment prospects.
Estimated impact	Enable promising technologies with good market potential and job prospects by providing a cushion for survival until they find more investors for growth.
Barriers addressed	Paucity of venture & angel capital investment in early stage energy storage technologies/companies.
Examples in other States	Not aware of any states other than MA that have similar programs.

Goals and Impacts

Goals: The goal of this is to help early-stage companies advance their technologies through the commercialization cycle. Further, the invested capital should leverage outside capital by being part of an established funding round, thereby having the potential to create sustainable jobs and generate a financial return.

Impact: Provide financial cushion to promising companies with potential for growth and job creation until they find adequate investment for complete commercialization and financial viability.

Description

MassCEC’s Investment program aims to support the progression of clean energy technologies, including energy storage, to drive down costs to the ratepayer as well as reduce the volatility of energy costs over the course of time. The program invests in Massachusetts-based companies that support and create sustainable, quality green jobs in the Commonwealth as they expand. The program also seeks to leverage outside capital to support clean technologies, projects, and companies through all stages of growth, from both private and public sources. This serves as risk and reward mechanism, both financial and programmatic, to invest in promising companies with reasonable expectation of financial return, which can then be used to continue to support the cleantech industry.

Funding Mechanism***MassCEC Equity Investments:***

The direct equity investment in early stage clean energy companies is approximately \$500,000 in a Seed, Series A, or Series B financing round. MassCEC also considers leading rounds where it can play a significant role and act as a catalyst for other investors to participate. The Equity Investments program was launched in 2009 and to date has invested over \$10M. Applications for the program are accepted on a rolling basis.

Implementation

Expand investment in energy storage companies through MassCEC Equity Investment.

In addition:

- Organize events to link venture capital and other investors with the companies to which MassCEC Investment has provided equity;
- Develop or access expert advice on the viability of the specific storage technology and potential markets before investments are made. There is expertise in the national labs on the technical side although market potential will have to be obtained through experienced consultants; and
- Apply investment due diligence experience with other technologies to analyzing energy storage equity investments.

9.3.2 Debt

Summary	MassCEC Venture Debt
Duration of the program	Duration is determined by availability of budgets. Support is reduced or eliminated if private sector financing is available, market barriers are eliminated, and depends on the level of market and technology maturity.
Funding options	MassCEC Venture Debt Program
Targeted Use Cases	All
Implementation requirements	Develop in-house expertise in analyzing energy storage market opportunities; assess management's ability to manage a company in energy sector, team experience, the product or technology's value proposition and defensibility; develop business model viability; and assess the magnitude of company/technology employment prospects.
Estimated impact	Enable promising technologies with good market potential and job prospects by providing a cushion for survival until they find more investors for growth. Reduce the cost of debt financing for companies perceived as high risk.
Barriers addressed	Lack of debt financing. If available, it is at a very high rate due to perceived risks and against high collateral or with a co-signer.
Examples in other States	Not aware of any states other than MA that have similar programs.

Goals and Impacts

Goals: The goal is to assist companies in reaching major expansion milestones in Massachusetts (may include manufacturing build-out, major sales force expansion, or other growth) and to address funding gaps by offering loans to early-stage companies at competitive rates while creating new, sustainable green jobs in Massachusetts.

Impact: Provide financial cushion to promising companies with potential for growth and job creation until they find adequate investments for complete commercialization and financial viability.

Description

Debt financing is often reserved for established businesses with good credit rating. Many energy storage companies in this nascent industry rarely qualify for debt from banks or any other financial institution. Given the high risk, when and if available, venture capital often becomes the only option. To preserve their ownership, debt financing may be desired by early stage storage companies but is almost impossible to get without collateral or a co-signer. Many entrepreneurs resort to mortgaging their homes or other assets. Consequently a debt program of the type described below would be highly desirable for Massachusetts based companies.

Funding Mechanism

MassCEC Venture Debt:

MassCEC's Venture Debt Program was created to fill funding gaps for clean tech companies that are looking for venture debt, but may have trouble attracting private resources. From a company's perspective, a debt (unless it is a junior debt) affects its balance sheet somewhat negatively and may not be as attractive an option as that provided by an Equity Investment (described above). However, although provided at the conventional market rates, the Venture Debt is "patient capital" and thus may not be as burdensome on the balance sheet as other bank loans. Also, both the flexibility allowed to a company in the use of proceeds and the Program's ability to provide up to \$1 million bode well for energy storage companies that cannot otherwise get sufficient financing (if at all) at more favorable terms.

The limit of \$1 million is large enough to provide financing for medium size (5 MW) storage projects, and thus could act as an instrument for project finance as well, which is often hard to come by. Venture Debt is particularly suitable for financing demonstrations that may have uncertain revenue and may not have access to non-recourse project financing. The Venture Debt Program and its cap of \$1 million are unique among the states that actively support energy storage and thus can be used not only to grow storage businesses but to attract out of state businesses as well.

Implementation

Increase MassCEC Venture Debt program funding as it addresses a major barrier to energy storage company growth.

In addition:

- Advertise this as a recruiting tool for out-of-state companies that are willing to re-locate to Massachusetts and can meet a minimum set of Program conditions.
- Plan an outreach at out-of-state energy storage events to inform prospective companies about Venture Debt and explain how potential migrant companies can avail of this program.

9.4 Workforce Development Initiatives

Summary	Develop a skilled workforce to build, install, operate and maintain energy storage systems.
Duration of the program	5 years, matching the horizon of the deployment of energy storage; phased out when the storage industry no longer identifies lack of trained personnel as a barrier.
Funding options	MassCEC, including its Clean Energy Internship Program; leveraging DOE's Science Undergraduate Laboratory Internships (SULI); and facilitating access to the Workforce Training Fund Programs (WTFP).
Targeted Use Cases	All; particular attention to Solar Plus Storage installation/servicing.
Implementation requirements	Storage industry labor force needs assessment – different needs for 1) manufacturing /technology development/software/operation, and 2) storage as an installation/service industry.
Estimated impact	Increase in-state availability of trained personnel to meet the highly technical skills required for developing and manufacturing energy storage technologies. Ready availability of installation and service technicians for the deployment of energy storage, including the fast emerging solar plus storage industry for behind-the-meter application.
Barriers addressed	Shortage of highly skilled workforce required for storage advanced manufacturing and technology development; recruiting and retaining workforce that meets standards and certification requirements to install/service storage systems.

Goals and Impacts

Goals: The goal is to create a pipeline for establishing a trained workforce that can meet the needs of the emerging energy storage industry, both driven by and facilitating the expected rapid deployment of energy storage in Massachusetts over the next five years. This includes: 1) highly skilled and experienced individuals for technology development and manufacturing, and 2) workforce to install and service storage installations, particularly behind-the-meter (e.g. Solar Plus Storage).

Impact: Enable the energy storage industry in Massachusetts to grow as forecasted and strengthen Massachusetts as a national energy storage industry leader.

Description

Energy storage can readily be described as a “high tech” industry. From the earliest stages of technology development and energy storage systems manufacturing, a highly educated workforce is required, with advanced degrees in material sciences, chemistry, electronics, engineering, mathematics and computer sciences. With its existing high tech industry and world renowned

educational institutions, Massachusetts is ideally positioned to develop such a workforce for the energy storage sector. The challenge for new start-ups is that they may not be able to pay the market salaries that such individuals command nor offer the full time employment with benefits comparable to established companies. Also, small companies are not familiar with the recruitment and training processes as they themselves are learning by doing. The state has an important role in overcoming the barrier of workforce shortage for the fledgling energy storage industry.

A second category of workforce that will be needed in order to grow the energy storage industry in Massachusetts relates to system installation and servicing. The increasing role of storage in managing on-site photovoltaic output is creating a particular need and opportunity for installing and servicing energy storage systems, either stand-alone or when combined with new solar systems. In 2015, Massachusetts installed 286 MW of solar electric capacity (ranking fourth nationally), with more than \$800 million invested on solar installations. All these homes are potential users of add-on energy storage systems. Companies such as Solar City are already offering solar plus storage systems to home owners, and, given the need for resiliency from storms and potential for cost savings by storing energy for use during times of peak demand, this market is likely to grow. Consequently, this segment of the storage industry will need to add more installers or retrain those installing solar to add storage installation skills. The state can provide help in retraining the current solar installers and also train individuals who have not yet contemplated this career. Jobs at this level do require some technical skills and training and salaries are often substantially higher than minimum wage.

Program Mechanisms

MassCEC's *Workforce Development Division* offers programs and funding for creating a well-trained, educated workforce that meets industry needs. These programs could be augmented to serve the energy storage industry.

In particular, MassCEC provides grants for clean energy workforce development programs at secondary and vocational/technical high schools, colleges and universities, and community-based non-profit groups. This program can help develop a curriculum for the anticipated increase of installation/service jobs in the energy storage industry.

The *Massachusetts Clean Energy Internship Program*: Since its inception in 2011, has placed more than 1500 students and recent graduates at clean energy companies across the Commonwealth, with hundreds of those interns going on to receive full-time job opportunities at their host companies. The program helps provide Massachusetts' clean energy businesses with a talented pool of young professionals, with MassCEC providing stipends for interns during fall, spring and summer sessions.

The *Workforce Capacity Building Program* is designed to develop replicable models that address systemic deficiencies and enhance working models in clean energy training and education programs of the Commonwealth's education, non-profit, and workforce ecosystem. The Program consists of two components: (1) a workforce capacity building component and (2) a youth pipeline opportunities component. This program could serve as a means to train individuals, especially youth, in the emerging field of storage technology. As a result, they would be better equipped to enter a competitive renewable energy industry with this specialized and valuable knowledge.

The *Pathways Out of Poverty Program* provides funding for green collar job training programs to low- and moderate-income individuals, offered by clean energy companies, community-based non-profit groups, educational institutions and labor organizations throughout Massachusetts. This program can help recruit and train individuals for the storage industry service sector.

Implementation

The MassCEC programs, and in particular the Clean Energy Internship Program, can serve as a natural home for developing a skilled energy storage workforce. Certain programs may need modification to incorporate an energy storage component into program plans. For example, the MassCEC Internship Program may not be available to some entities (e.g. MLPs) which are likely to be active in energy storage implementation. Thus, programmatic/regulatory changes may be needed to enable maximum participation in the program.

Collaboration should be considered with the following programs to leverage resources outside MassCEC:

The *Center for Manufacturing Technology (CMT)* and *Massachusetts Manufacturing Extension Partnership* can collaborate with MassCEC in developing tailored programs aimed at storage industry companies ready to undertake manufacturing. This also supports the objectives of Section 9.3.4, above.

The U.S. DOE's Office of Science offers the *Science Undergraduate Laboratory Internships (SULI)* program which provides access to technical expertise or facilities to train people for new technologies. This program could also be utilized to recruit interns or train them for work in the storage technology development and manufacturing companies.

A program for workforce training could be launched in collaboration with Massachusetts universities and research institutions. Participants in MassCEC's *Support for Clean Energy in Academia* program may be leveraged, or act as a conduit, to secure trained personnel for the energy storage industry. Additionally, some academic institutions in Massachusetts have *Corporate & Professional Education* programs. For example, one institution states: "Professional Education addresses corporate education needs and strategic goals through custom educational programs. The staff works with your managers to help define needs and then coordinate with the faculty to design a targeted, needs-based learning experience." Such programs provide training to those already employed but want to expand their knowledge/skills or transition into new industries. MassCEC could develop joint programs to specifically retrain individuals for the energy storage industry.

9.5 Other Resources for Energy Storage Companies

The U.S. Department of Energy (DOE) Energy Storage Program, housed in the Office Electricity and Energy Reliability, supports analytical studies on the technical and economic performance of storage technologies, in addition to supporting demonstrations. The national laboratories and the Clean Energy State Alliance (CESA) have provided support for projects in various states. The Program also seeks to improve various sub components of energy storage systems by providing funds and technical assistance through national laboratories including Sandia National Laboratory and Pacific Northwest National Laboratory.

In addition, there are other national organizations that also indirectly support energy storage. Following are two examples:

- *USDA Rural Development Electric Infrastructure Loan & Loan Guarantee Program:*
The USDA Rural Development Electric program makes insured loans and loan guarantees to nonprofit and cooperative associations, public bodies, and other utilities. Insured loans primarily finance the construction of electric distribution facilities in rural areas.

The guaranteed loan program has been expanded and is now available to finance generation, transmission, and distribution facilities.

- *National Rural Electric Co-op Financing Corporation:*
The National Rural Electric Cooperative Association (NRECA) recently published a report, “The Hidden Battery: Opportunities in Electric Water Heating”,²⁶⁹ that examined the economic and grid impacts of controlling three different types of water heaters (80-gallon electric resistance, 50-gallon electric resistance, and heat pump models) for peak shaving, thermal energy storage, and real-time response to supply fluctuations using 2014 data from PJM. A subgroup of NRECA called the National Rural Utilities Cooperative Finance Corporation provides funds for energy efficiency and reliability, and can help energy storage technology developers. These funds may possibly help fund energy storage demonstrations that directly help NRECA members.

9.6 Conclusion

The recommended program development and expansion presented, building on the suite of MassCEC programs currently offered, could nurture and create a thriving advanced energy storage industry in Massachusetts. The mechanisms, initiatives, and program expansion outlined in this Chapter seek to 1) promote energy storage company growth through equity investment and venture debt programs; 2) support storage technology development through technology testing and technology demonstration; 3) provide early stage support for manufacturers; and 4) train and develop a skilled workforce able to meet the expanding energy storage industry needs. These strategies have the potential to accelerate the success of energy storage technologies, companies and projects in the Commonwealth and establish Massachusetts as an energy storage leader.

²⁶⁹ <http://www.nreca.coop/wp-content/uploads/2016/02/The-Hidden-Battery-01-25-2016.pdf>

A. Appendix A - Technical Overview of Alevo Analytics Model

The following sections describe the technology assumptions that define how the model assigns both cost and benefit values as presented in Chapter 4.

System Data

ISO New England is the operator of the region's bulk power system and wholesale electricity markets.

The operation zones in ISO-NE are created based on geographical location of the states; however, the state of Massachusetts is divided into three zones. The following abbreviations will be used hereinafter for zonal representation as shown in Figure Appendix A-1.

- NEMA-BOST, SE-MASS, WC-MASS, CT, RI, VT, NH, ME

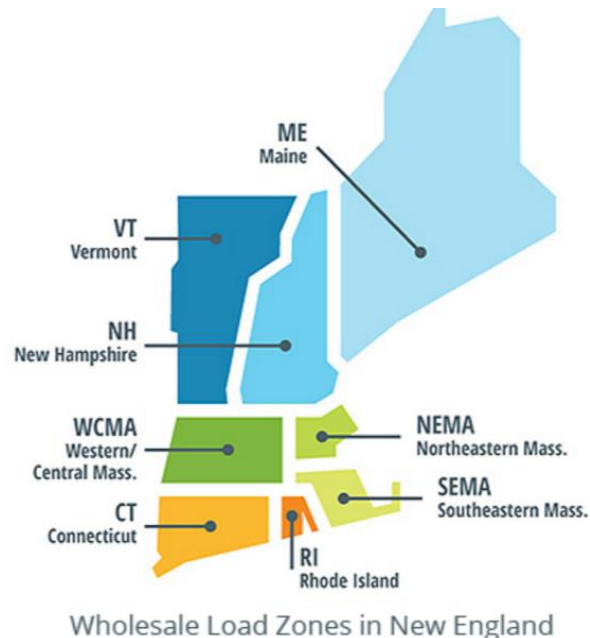


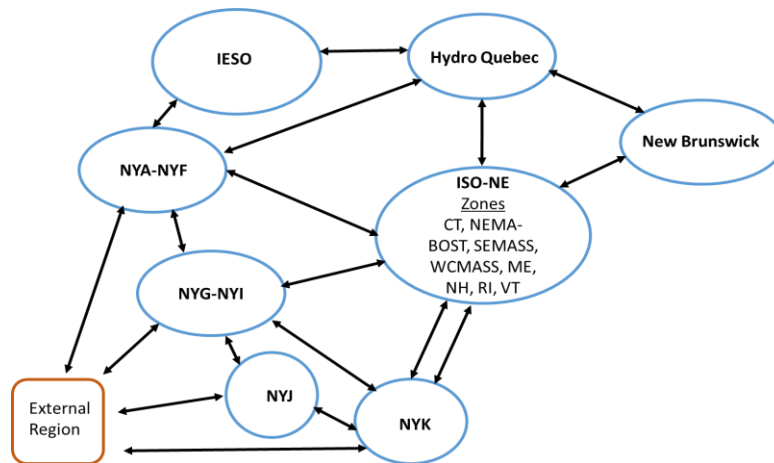
Figure Appendix A-1: ISO-NE Zones

The study used a simulation ready database of ISO-NE competitive markets that co-optimizes energy and ancillary services subject to transmission thermal constraints with detailed Massachusetts specific generation, transmission and distribution data. The database has sufficient nodal details in ISO-NE market, which includes 710 Generators, 66 aggregated solar interconnection station, 2,043 transmission lines, and 2,265 transformers. There are 1,494 nodes or primary substations and a peak load of 12,771 MW in 2015 in Massachusetts. The ISO-New England model interfaces with NYISO, IESO, Hydro Quebec and New Brunswick Power as shown in

Figure Appendix A-2 with imports and exports flow model.

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Data Sources

- [1] ISO-NE website
- [2] MA Interconnection and
- [3] Distributed Generation Website
- [4] NERC Reports
- [5] EPA CEMS database
- [6] EIA database
- [7] ISO-NE CELT demand forecast
- [8] ISO-NE Seasonal Claimed Capability Report
- [9] MMWG transmission model
- [10] NYMEX/CME fuel price forward curves.

Figure Appendix A-2: MA imports and exports flow model

The electric system and its associated costs are intricate, including regional, zonal, nodal, and interface conditions. In addition to system variables, the model includes generator, emissions, and storage metrics.

Regional (ISO NE)	Zonal (MA)	Generator	Emission
<ul style="list-style-type: none"> Ramp up/down cost Fuel cost VO&M cost Energy Cost Startup & shutdown cost Emission cost Forward reserve cost Regulation cost Average LMP Peak load Generation by fuel type 	<ul style="list-style-type: none"> Zonal energy Cost Zonal emission cost Zonal average LMP Zonal peak load Zonal fuel cost Zonal generation by fuel type Zonal ramp up/down cost Zonal VO&M cost Zonal startup & shutdown cost 	<ul style="list-style-type: none"> Generation Emission Capacity factors Fuel Cost Ramp up/down cost Startup & shutdown cost VO&M cost 	<ul style="list-style-type: none"> Production CO2 SO2 NOx Emission by state Emission by fuel type Emission rates
			Storage
			<ul style="list-style-type: none"> Costs Lifetime Cycles Power capacity Energy capacity ROI time
Network Metrics		Production Metrics	

Table Appendix A-1: Input data

The simulation ready database was updated with the latest available information for the purpose of this study for the following data inputs:

- 1) Load forecast for the New England states
- 2) Planned generation capacity
- 3) MA Distributed Solar Integration
- 4) Planned investment in generation additions

- 5) Planned generation retirements
- 6) Planned investment in transmission and distribution
- 7) Fuel costs
- 8) Energy Storage Costs
- 9) Generation Parameters Derived from the Alevo Analytics IQ Database
- 10) Incremental Heat Rates
- 11) Sub-Hourly Data
- 12) Emissions Data

The Alevo Analytics team has also refined the database with sub-hourly demand and renewable profiles to run production cost optimization in sub-hourly intervals. The simulation ready database has also been updated with the New England and Massachusetts specific heat rate inputs and emission rates derived from the current EPA's CEMS database of measured power and air emissions for New England fossil fuel burning power plants.

Energy Storage Costs

The cost of energy storage varies based on the maturity of the technology, round trip efficiency, and life cycle. The mature storage technologies are lead-acid and pumped hydro systems. However, the emerging technologies are lithium ion, flow batteries, and flywheel. The general cost range covering all types of energy storage is between \$100/kWh and \$4,000/kWh. The efficiency of mature technologies is around 75%; but lithium-ion batteries can reach up to 95% round trip efficiency. See Figure 1-3: Forecast of Estimated Capital Costs by Storage Technology and Type in Chapter 1 for more information on declining capital cost trends.

While the costs in the figure above are indicative of storage costs and storage cost decline trends, this study assumed that there could be regional cost differences of storage for installations in Massachusetts and there could be uncertainty in the magnitude of future cost declines. This study uses the above costs but also uses a range of an additional 40% higher cost from the figures above.

The model considered characteristics of several different technologies in the modeling effort. Each technology has different costs. The costs in Table Appendix A-2: Energy storage capital cost

from 2016 through 2020 were used by the capacity optimization model to find the optimal size of storage (for both power and energy).

Capital Cost (\$/kW)	2016	2017	2018	2019	2020
Long Duration	300	298	295	293	290
Medium-Long Duration	325	315	305	295	285
Medium-Short Duration	500	420	340	260	180
Short Duration	875	748	623	468	315

Table Appendix A-2: Energy storage capital cost

*NOTE: this study includes a range of costs of up to 40% higher than those in Table Appendix A-2.

Base Case and Benchmarking

A base case model of the ISO-NE power system was created and this model was validated against metrics for Generation, LMP, Demand and Capacity Factors. The model was modified to include future systems updates including Generation additions and retirements, Transmission Upgrades and

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Fuel Price forecast. The following parameters are considered in order to validate the accuracy of power systems model:

- Demand
- Price
- Available Generation Capacity
- Monthly Capacity Factor
- Emissions

Alevo Analytics' Demand Forecast Tool built a demand forecast for future years based on a historical hourly demand curve. In order to validate the accuracy of Demand Forecast Tool, a demand curve for 2015 is created and compared with the real demand data gathered from ISO-NE.

The following zones are compared and the results are shown in Figure Appendix A-3 below:

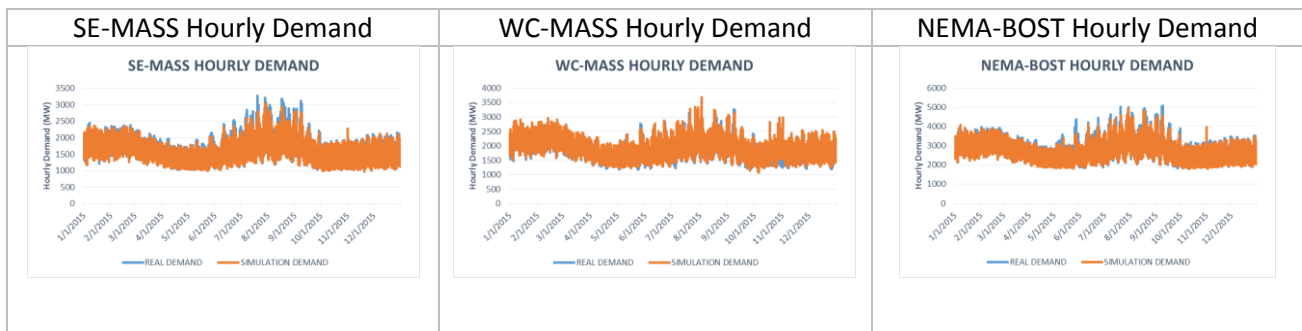


Figure Appendix A-3: Validation of hourly demand

The peak demand in MW and Average Demand in MW are reported in Table Appendix A-3. Three zones in Massachusetts including SE-MASS, WC-MASS, and NEMA-BOST are considered. Day Ahead and Real Time values are gathered from the ISO-NE website stated in the beginning of this section. Simulation values are the forecasted demand from Alevo Analytics Demand Forecast Tool.

2015	SE-MASS		WC-MASS		NEMA-BOST	
	PEAK (MW)	AVERAGE DEMAND (MW)	PEAK (MW)	AVERAGE DEMAND (MW)	PEAK (MW)	AVERAGE DEMAND (MW)
DAY AHEAD	3,044	1,649	3,309	1,979	4,909	2,838
REAL TIME	3,278	1,691	3,260	1,947	5,079	2,897
SIMULATION	3,044	1,649	3,689	1,997	4,909	2,838

Table Appendix A-3: Peak and average demand for three zones in MA

The model validation also considers the price of electricity. In order to validate the accuracy of the model, Alevo Analytics ran the base case simulation for ISO-NE model for 2015. The simulation is based on a production cost optimization model and it mimics the day-ahead energy market. The time horizon is selected to be 2015 and the simulation is executed as a daily optimization with an hour interval. This model covers 8,760 hours in a year. Then the energy price from day-ahead market of ISO-NE is collected. The weekly price chart comparing energy price from simulation and from ISO-NE for 2015 is shown Figure Appendix A-4.

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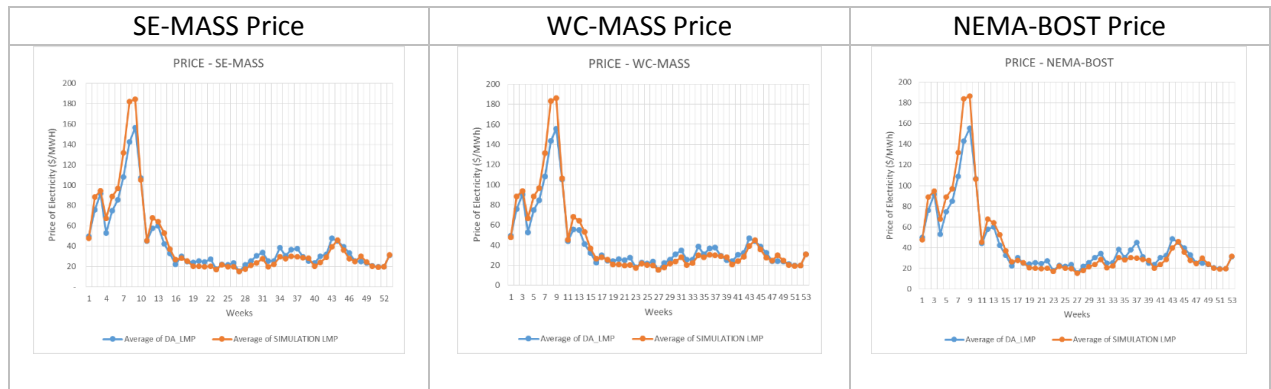


Figure Appendix A-4: Validation of price

In order to validate the accuracy of Maintenance and Forced Outage Forecast Tool, a daily available generation capacity for 2015 was created using Alevo Analytics' Maintenance and Forced Outage Forecast Tool and compared with the real available generation capacity gathered from ISO-NE. The comparison is shown in Figure Appendix A-5.

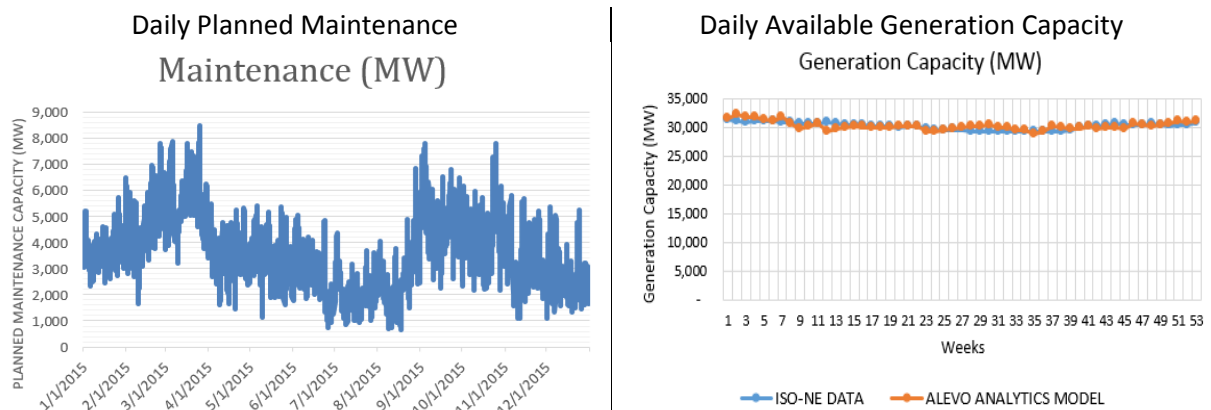


Figure Appendix A-5: Validation of available generation capacity in ISO-NE

The CO₂, SO₂, and NO_x emissions productions in tons for Massachusetts and ISO NE was determined in the Alevo Analytics Emissions Simulation Base Cases using generator-specific emission production rates for each primary fuel type from the EPA database. These simulation results are compared with the 2014 ISO NE Emissions Report emissions productions in Table Appendix A-4.

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		ISO-NE Emission Report	Production Cost Model
MA	CO ₂ Production (tons)	15,229,000	15,289,707
	SO ₂ Production (tons)	5,660	4,219
	NO _x Production (tons)	8,750	8,130
ISO NE	CO ₂ Production (tons)	39,317,000	39,471,108
	SO ₂ Production (tons)	11,680	10,268
	NO _x Production (tons)	20,490	19,902

Table Appendix A-4: Emission Productions Comparison

B. Appendix B - Overview of Daymark Economic Impact Study

Economic Impact of Investment in Energy Storage

The energy storage industry's supply chain includes equipment and software providers, project developers, financing institutions, Engineering Procurement and Construction (EPC) providers, Operations and Maintenance providers, and market participants as shown in Figure Appendix B-1 below. Evaluation of the economic impacts of additional energy storage market development in Massachusetts entails examining the components of the energy storage supply chain to identify the particular industries that may be impacted (and will be modeled) by an expansion of investment in energy storage facilities.

Equipment	Software	Project Development	Financing	Engineering Procurement Construction	Operation & Maintenance	Market Participants
Storage Technology	Profit Optimization/Analysis	Marketing	Debt	Project Engineering and Design	Site Visits	System Aggregation
Power Electronics	Tariff Database	Project Oversight	Equity	Procurement	Customer Service	Metering Equipment
Packaging	Size Optimization Algorithm	Site Audit and Selection	Packaging & Accounting	Project Management	Monitoring	Telemetry Equipment
Grid Periphery Equipment	Bill Management Dispatch	Regulation and Policy	Special Purpose Entity (if required)	Construction (multiple categories)	Reporting	Interconnection
Standard Electrical Components	Sales Interface	Program Management (SGIP)		Commissioning	Maintenance	SC Setup/Registration
Warranty Administration	Financing Model	Permitting		Interconnection	Billing	Telemetry Setup/Installation
	Project Pro Forma	Sales			Warranty Servicing	Market Results
	PV Project Valuation				De-Commissioning	Scheduling
	ESS Cost Model				Recycling and Disposal	Dispatching Service
	PV Cost Model					Outage Reporting
						Settlements
						Meter Data
						Resource Data Submittal
						Compliance Requirements
						FERC EQR Filings

Figure Appendix B-1: Energy Storage Supply Chain

Model, Assumptions, and Methodology

The IMPLAN model was used to assess the economic impact of incremental investment in energy storage development in Massachusetts. IMPLAN is an input-output model that measures the impact on economies—users can define the particular geographic detail (ranging from county to national levels)—from demand-side stimulus actions, such as increased sales to local industries or firms. IMPLAN assumes fixed technology over time, thus a single representation of industries' purchases and sales was used over the entire study period. IMPLAN is a single-year model, thus the model was run for each year in the study period. In terms of general model limitations, the IMPLAN model is a

deterministic model, not a probabilistic model, so there is no measurable margin of error. IMPLAN relies on supporting data and general assumptions of an input-output model.²⁷⁰

The IMPLAN model was used to run a Massachusetts-specific model with statewide detail.²⁷¹ IMPLAN combines databases that contain economic factors, multipliers, and demographic statistics with modeling software that allows the user to develop input-output models for estimating economic impacts in a selected region. IMPLAN identifies direct impacts by sector and then develops a set of indirect and induced impacts by sector using industry-specific multipliers, local purchase coefficients, income-to-output ratios, and other relationships.²⁷²

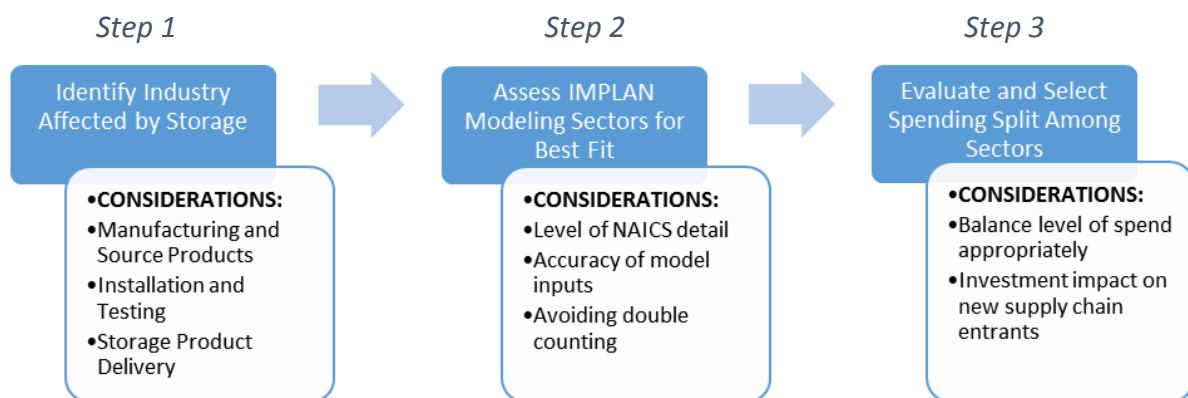


Figure Appendix B-2: IMPLAN NAICS Codes Assumptions

A key input to the IMPLAN model are the industries associated with the products and services of Figure Appendix B-1. Federal statistical agencies (e.g., U.S. Bureau of the Census) use the North American Industry Classification System (“NAICS²⁷³”) codes to classify business establishments for reporting and statistical analysis. Figure Appendix B-1 shows the process used to identify the NAICS codes for the largest and most well-known players in the industry based on the supply chain of Figure Appendix B-1. First, energy storage projects were reviewed from the Department of Energy (DOE) Global Energy Storage Database to identify industry sectors impacted by energy storage markets; this database provides the names of the energy storage technology providers, power electronics providers, integrator companies, O&M contractors, and developers. The NAICS codes of the identified industry sectors were analyzed and compared to the sectors in IMPLAN that best fit the energy storage supply chain components. Unfortunately, the IMPLAN sectors did not more accurately reflect all the details of the energy storage supply chain.²⁷⁴ Consequently, in Step 2 of Figure Appendix B-2, the major pieces of the supply chain needed to be simplified into overarching

²⁷⁰ For documentation of the input data, see here: http://implan.com/index.php?option=com_content&view=article&id=414&Itemid=1878. For documentation about input-output models in general, see here: http://implan.com/index.php?option=com_content&view=article&id=377:377&catid=222:222.

²⁷¹ County level detail is also available but would require further development of inputs at this level of detail.

²⁷² <http://cier.umd.edu/RGGI/documents/IMPLAN.pdf>

²⁷³ NAICS replaced the national “Standard Industrial Classification” or “SIC” codes. Its development was led by the Office of Management and Budget (OMB) and coordinated with agencies in Canada and Mexico in order to permit North-American-wide reporting and analysis. The latest coding system was developed in 2012 and changes as new products and services are developed and retired due to technological changes, consumer preferences, and other changes.

²⁷⁴ Models that use NAICS codes rely on industry provided information for NAICS code assignment, which does not necessarily accurately place companies in the industrial sectors that best fit what they do. This is not a model issue as much as it is a data availability and reliability issue.

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components that were determined using a NAICS code analysis (discussed in detail in the Appendix).²⁷⁵ The following aggregated components of the storage supply chain process were used in the IMPLAN analysis: Power Medium (Storage battery manufacturing), the power conversion system (all other miscellaneous electrical equipment and component manufacturing) and balance of plant (electric power transmission and distribution) that includes the rest of the chain (interconnection, housing, any construction and installation, etc.).

Another input into the IMPLAN model is the investment or spend projection for the three IMPLAN sector described above. For Step 3 of Figure Appendix B-2, the investment or spend projection relative to energy storage was split into the three IMPLAN codes²⁷⁶ as shown in the table below. The associated incremental investment was entered as different events in each year in the IMPLAN model based on a percent split of 40/40/20, respectively, for the 2017-2025 study period. The rationale for using the percentage split into each of the NAICS codes in the Table Appendix B-1 below is due to the strengths of Massachusetts in these industries relative to other states, expected business creation in response to anticipated market investment, and general industry knowledge.²⁷⁷

IMPLAN Code	IMPLAN Industry Name	Proportion
336	Storage Battery Manufacturing	40%
342	All Other Miscellaneous Electrical Equipment and Load Manufacturing	40%
49	Electric Power Transmission and Distribution	20%

Table Appendix B-1: IMPLAN Energy Storage Run NAICS Codes and Proportions

The third input for the IMPLAN model was the cost input supplied by the Alevo Analytics model for 2017 through 2025. The Alevo Analytics model supplied energy storage MW installation numbers for 2017 through 2020. These MW amounts had corresponding dollars spent to construct the storage facilities (capital costs) and Operations and Maintenance (O&M) costs per year as shown in Table Appendix B-2. All of these amounts were assumed to be sales to Massachusetts companies—and modeled as increased “output” to the Massachusetts sectors described earlier. Table Appendix B-2 shows the deployment scheduled and the amount of spending per year over the study period.

	2017	2018	2019	2020	2021	2022	2023	2024	2025
New Storage Capacity (MW)	205	400	500	661					
Capital Costs (\$M)	158.0	285.0	221.0	178.0	0.0	0.0	0.0	0.0	0.0
O&M Costs (\$M)	2.4	6.6	10.0	12.6	12.6	12.6	12.6	12.6	12.6
Total Cost (\$M)	160.4	291.6	231.0	190.6	12.6	12.6	12.6	12.6	12.6

Table Appendix B-2: Storage Buildout and Total Spend

The model assumes that all direct effects of the events occur only in Massachusetts since user input values are for events occurring in Massachusetts. Direct effects represent the initial change in the

²⁷⁵ The Appendix discusses the mapping of the detailed NAICS codes to IMPLAN sectors.

²⁷⁶ An additional number of NAICS codes could have been used to provide a more detailed construct of the industries involved in manufacture, installation, and operation of the storage facilities, but would not have changed the results shown below appreciably. Economic impacts for the sectors described earlier differed based on the amount of in-state inputs would be utilized, but these differences were not extreme.

²⁷⁷ The Appendix discusses how regional specialization was used as a determinate for the NAICS codes used in the IMPLAN analysis and why the percentage allocations of each were used in the analysis.

industries being modeled, such as increased storage medium production. Since the model is a Massachusetts-specific model, the modeled results for indirect and induced effects are also entirely in Massachusetts. Indirect effects, like impacts from non-wage expenditures, represent changes due to inter-industry transactions from supplying industries that respond to increased demands from the industries that are directly affected. Indirect effects lead to employment in industries that supply and support battery storage. Induced effects, like impacts from wage expenditures, represent local spending changes due to income changes in the industry sectors that are directly and indirectly affected.²⁷⁸ Examples for all three effects are provided as part of the results of the analysis later in this section.

Economic Summary Results

The annual economic impacts on Massachusetts were analyzed by studying the effects on employment (in terms of “job-years”)²⁷⁹, income (which is sum of all forms of employment income, including employee compensation in terms of wages and benefits and proprietor income), and the dollar level of value added (also known as gross state product or “GSP”). Figure Appendix B-3 shows the employment and labor income impacts of the deployment and spending upon which this study is based.

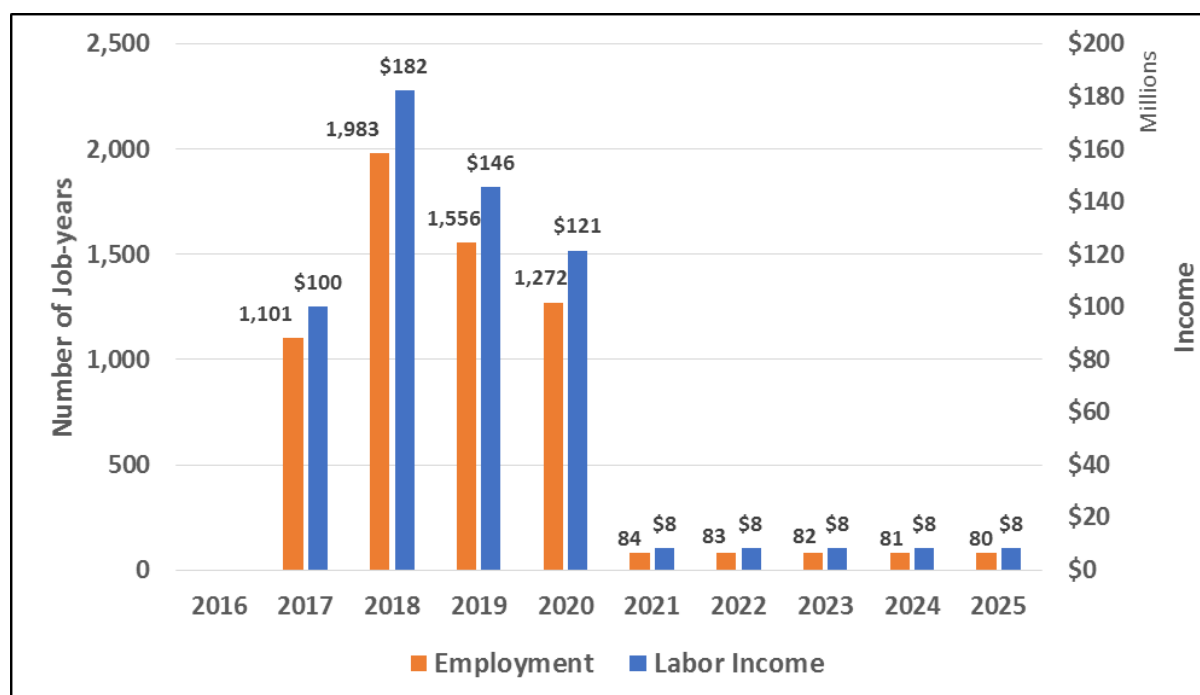


Figure Appendix B-3: Massachusetts Employment and Labor Income Impacts 2016-2025

In total, almost 6,321 job-years are created over the ten-year study period, which averages to about 700 jobs per year over the ten year period. To put these numbers in perspective, the reported employment of solar workers in 2015 was about 16,145 jobs.²⁸⁰ The main reason for the differences in the level of job creation is the fact that the solar industry is more established in Massachusetts compared to the smaller, emerging energy storage industry. Over time, as the energy storage

²⁷⁸ For more information: http://www.implan.com/index.php?option=com_content&view=article&id=330&Itemid=1747.

²⁷⁹ Job-years is defined as jobs created in each specific year related to spending and is not a cumulative number of jobs in each successive year from the preceding years.

²⁸⁰ 2015 Massachusetts Clean Energy Industry Report.
<http://www.masscec.com/node/3371/done?sid=4907&token=8a007413c03d08a2cbb0a43b9907e460>.

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industry grows in the state, jobs will increase, along with more advanced storage technology. In total, almost \$591.5 million in labor income is created over the ten-year study period, which average to about \$65.7 million per year for the ten year period. The employment and labor income impacts show an increase in job creation and labor income as greater amounts of storage are deployed during 2017-2020. The employment data are shown in job-years, thus should not be considered as “permanent” jobs. Economic activity generated in each year is directly related to the level of spending in that year; for the jobs to be permanent (and at the levels shown in the 2017-2020 time frame) additional storage deployment would have to be made subsequent to 2020 to maintain those jobs. Starting in 2021, spending levels will fall to only include O&M spending and less economic and employment activity will ensue, in comparison to earlier years. The purpose of this particular kind of analysis is to demonstrate the economic impact of the investment in energy storage consistent with the benefits captured by the Alevo Analytics modeling.

The economic impact of increased energy storage development represents a maximum amount of impact flowing from the assumption that Massachusetts firms would be used to provide 100% of the goods and services used to deploy the storage. Use of different assumptions relative to the percentage of Massachusetts firms being used to provide goods and services necessary to deploy the storage futures would cause reductions in the economic impacts shown here.

In Figure Appendix B-4 below, the total economic yearly impacts are broken out as percentages of direct, indirect, and induced impacts for employment, labor income, and valued added. Consistently over the study period, direct effects represent roughly 33% of employment, 47% of labor income, and 38% of value added. Indirect effects represent roughly 22% of employment, 23% of labor income, and 29% of value added. Induced effects represent roughly 45% of employment, 30% of labor income, and 33% of value added. The actual total effects for the study period on employment and labor income can be seen in Figure 3 and the actual total effects on value added can be seen in Figure Appendix B-4.

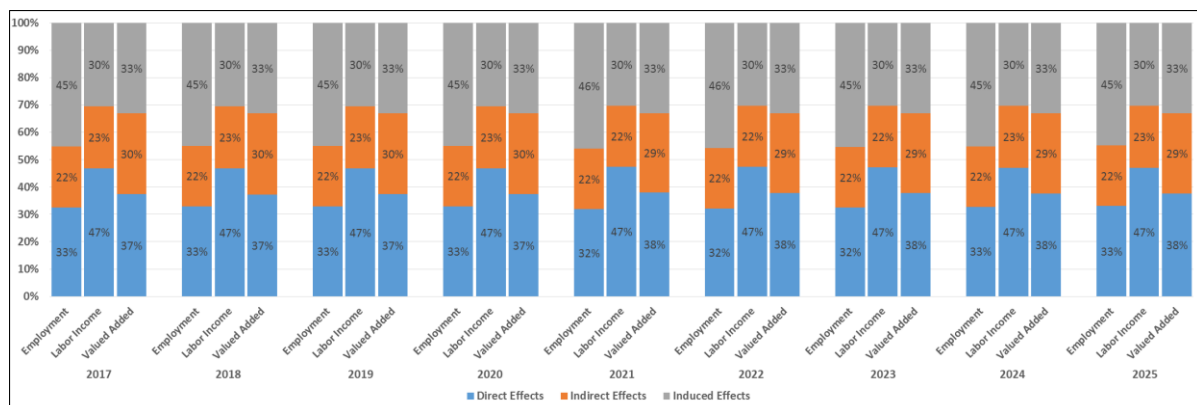


Figure Appendix B-4: Total Economic Yearly Effects for Employment, Labor Income, and Value Added as percentages of Direct, Indirect, and Induced Effects

Investment of energy storage in Massachusetts will directly impact the battery storage industry because of employment caused by planning, developing, managing, manufacturing, constructing, installing, and operating and maintaining different components of battery storage technology. Battery storage investment will indirectly lead to employment in industries that supply and support battery storage, which will include demand for inputs for battery storage manufacturing plants, equipment, facilities, or maintenance and operation. These same supply and support industries will also serve other renewable technologies and therefore will get a boost from the increased financing and buildout of battery storage. Battery storage investment will also have induced effects on employment and spending in Massachusetts in industries not related to battery storage through

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spending by employees of the battery storage industry for example, including retail, financial, and health care industries, which will result in more investments in all other industries and services.

Figure Appendix B-5 shows the economic impacts of value added or Gross State Product (GSP), which is the total value added to the state in terms of employment compensation, proprietor income, other property type income, and taxes on production and imports. Value added also includes local and state tax impacts for Massachusetts, which total to about \$62.5 million over the ten-year study period, which averages to about \$6.9 million per year in the years shown. To put these numbers in perspective, the reported gross state product of the clean energy industry as a whole in 2015 was about \$11 billion.²⁸¹ As discussed above, the energy storage industry is a small, emerging industry that will continue to grow both in technology advances and job creation, which in turn will lead to greater value added to Massachusetts over time. The economic impacts shown in Figure Appendix B-5 only include the impacts on the economy of the demand-side stimulus from increased sales to support the deployment of storage. The other benefits of storage—such as impacts on electricity prices or reliability—were not modeled due to the inability of IMPLAN to capture those impacts. In addition, the model did not include the possible use of Massachusetts ratepayer funds or other forms of assistance (such as tax subsidies), which would serve to reduce the economic impacts shown above under certain conditions.

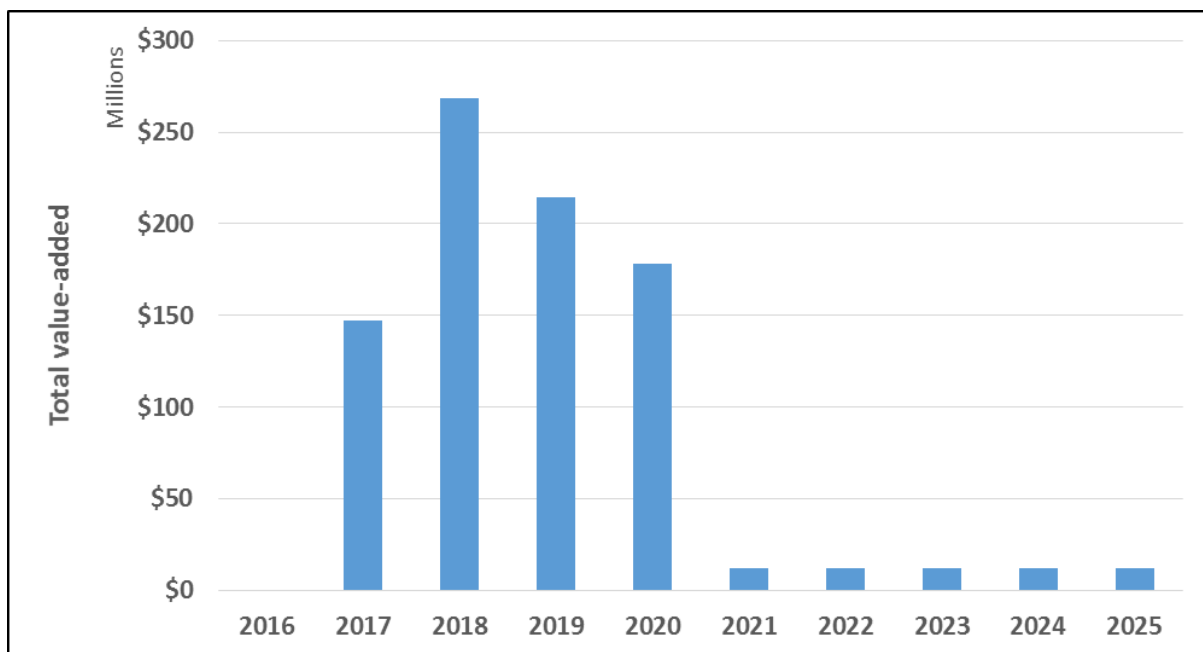


Figure Appendix B-5: Massachusetts Value Added (or Gross State Product)

²⁸¹ 2015 Massachusetts Clean Energy Industry Report.

<http://www.masscec.com/node/3371/done?sid=4907&token=8a007413c03d08a2cbb0a43b9907e460>.

Supplementary Information

Choice of NAICS Codes in IMPLAN Model

NAICS codes are defined for various levels of industry detail and numbered up to a 6-digit level.²⁸² Each digit adds further product or service specificity to the NAICS code. Table Appendix B-3 below provides the final list of the three-digit and detailed (six-digit) NAICS codes included as relevant to energy storage and each NAICS code's respective linkage to the energy storage supply chain. Industries (and supply chain components) that provide base or requisite services to support any industry expansion were not included (e.g. finance sector).

3-Digit NAICS Code	IMPLAN Code	Industry Name	Industry Description (with 6-digit NAICS)	Supply Chain
221	49	Electric Power Generation, Transmission and Distribution	> Electric power transmission and distribution (221121, 221122)	Project Development / Operations and Maintenance
237		Heavy and Civil Engineering Construction	> Construction of new power and communication structures (237130) > Construction of other new nonresidential structures (237990)	EPC
238		Specialty Trade Contractors	> Electrical contractors and other wiring installation contractors (238210)	EPC
331		Primary Metal Manufacturing	> Copper rolling, drawing, extruding and alloying (331420)	Equipment
333		Machinery Manufacturing	> Turbine and turbine generator set units manufacturing (333611)	Equipment
334		Computer and Electronic Product Manufacturing	> Computer storage device manufacturing (334112) > Electronic computer manufacturing (334119) > Computer terminals and other computer peripheral equipment manufacturing (334118) > Electronic Computer Manufacturing (334111) > Telephone apparatus manufacturing (334210) > Broadcast and wireless communications equipment manufacturing (334220) > Other communications equipment manufacturing (334290) > Semiconductor and related device manufacturing	Equipment

²⁸² See <http://www.census.gov/eos/www/naics/> for the full NAICS code listing.

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3-Digit NAICS Code	IMPLAN Code	Industry Name	Industry Description (with 6-digit NAICS)	Supply Chain
			(334413) > Other electronic component manufacturing (334419) > Industrial process variable instruments manufacturing (334513) > Totalizing fluid meter and counting device manufacturing (334514) > Watch, clock, and other measuring and controlling device manufacturing (334519)	
335	336 342	Electrical Equipment, Appliance, and Component Manufacturing	> Power, distribution, and specialty transformer manufacturing (335311) > Switchgear and switchboard apparatus manufacturing (335313) > All other miscellaneous electrical equipment and component manufacturing (335999) > Storage battery manufacturing (335911) > Primary battery manufacturing (335912) > Fiber optic cable manufacturing (335921) > Wiring device manufacturing (335931/335932)	Equipment
423		Merchant Wholesalers, Durable Goods	> Electrical apparatus and equipment, wiring supplies, and related equipment merchant wholesalers (423610) > Other Electronic Parts and Equipment Merchant Wholesalers (423690)	Equipment
517		Telecommunications	> Telecommunications Resellers (517911) > All Other Telecommunications (517919)	Operations and Maintenance
518		Data Processing, Hosting, and Related Services	> Data processing, hosting, and related services (518210)	Software / Operations and Maintenance
541		Professional, Scientific, and Technical Services	> Architectural Services (541310) > Landscape Architectural Services (541320) > Testing Laboratories (541380) > Surveying and Mapping (except Geophysical)	Project development

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3-Digit NAICS Code	IMPLAN Code	Industry Name	Industry Description (with 6-digit NAICS)	Supply Chain
			Services (541370) > Building Inspection Services (541350) > Drafting Services (541340) > Engineering Services (541330) > Computer systems design services (541512)	

Table Appendix B-3: NAICS Codes for Energy Storage Industries in Supply Chain

Location Quotient Analysis

Identification of the energy storage industries and NAICS codes allows analysis of industry data, such as the industry's size (in employment or revenues) and the level of concentration in Massachusetts compared to the rest of the country. The Bureau of Labor Statistics (BLS) publishes a number of statistics by NAICS codes down to the three-digit level by state and for the nation based on a compilation of six-digit data from the County Business Patterns (CBP), which are published by the U.S. Census Bureau. Among a myriad of employment and wage statistics, the BLS publishes location quotients. The BLS defines location quotients as "ratios that allow an area's distribution of employment by industry to be compared to a reference or base area's distribution."²⁸³

A location quotient (LQ) is a metric that is frequently used to determine "export" vs. "base" industries, with higher values for location quotients indicating local or regional specialization or industry "clusters" that have developed for exporting to other regions. LQs were used to understand Massachusetts' current industry structure in terms of the presence of firms that could directly support an expansion of energy storage in the Commonwealth. A location quotient greater than one means that the industry represents a larger portion of the Massachusetts economy than its representation nationwide and thus is more concentrated in the Commonwealth than the nation as a whole. Industries with high LQs (greater than 1.5) may show a competitive advantage for the region or state. Using LQs, the list of NAICS codes above was analyzed to understand the Massachusetts concentration levels of each component of the supply chain, which ultimately led to using the NAICS codes for storage battery manufacturing, all other miscellaneous electrical equipment and component manufacturing, and electric power transmission and distribution.

Examination of more detailed industries within the NAICS system leads one to believe that there is more concentration of Massachusetts battery storage than in the nation. For example, though NAICS 335 showed lower concentration in Massachusetts compared to the nation, NAICS 3359, which also includes 335911, energy storage manufacturing, shows a relatively high concentration. LQs are simply one metric that provides insights to industrial structure of a state or region, but they do provide some guidance about where Massachusetts firms are more or less likely to provide goods and services to support increased storage deployment in the Commonwealth.

The LQ analysis showed that Massachusetts continued to specialize in computer and electric product manufacturing between the 2001 and 2014 time period. During that same time period, battery storage manufacturing showed a decline in concentration in the state. Massachusetts is also concentrated in professional and technical services, which is involved heavily in the development and EPC components of the storage supply chain. Further LQ analysis was done to understand those

²⁸³ http://www.bls.gov/help/def/lq.htm#location_quotient

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NAICS codes that have the highest and lowest concentrations in Massachusetts relative to the U.S. along with the total employment figures for that industry.

Table Appendix B-4 below shows how the six-digit NAICS codes used by the BLS are used in IMPLAN. The rows actually used in the IMPLAN analysis are highlighted. Note that the electric power transmission and distribution six-digit NAICS codes are combined into one in IMPLAN.

<i>NAICS Codes</i>	<i>IMPLAN CODE</i>	<i>IMPLAN Industry Name</i>
<i>221121, 221122</i>	<i>49</i>	<i>Electric power transmission and distribution</i>
<i>334419</i>	<i>313</i>	<i>Other electronic component manufacturing</i>
<i>334513</i>	<i>317</i>	<i>Industrial process variable instruments manufacturing</i>
<i>334519</i>	<i>322</i>	<i>Watch, clock, and other measuring and controlling device manufacturing</i>
<i>335911</i>	<i>336</i>	<i>Storage battery manufacturing</i>
<i>335912</i>	<i>337</i>	<i>Primary battery manufacturing</i>
<i>335921</i>	<i>338</i>	<i>Fiber optic cable manufacturing</i>
<i>335999</i>	<i>342</i>	<i>All other miscellaneous electrical equipment and component manufacturing</i>
<i>335931, 335932</i>	<i>340</i>	<i>Wiring device manufacturing</i>

Table Appendix B-4: NAICS and IMPLAN Sector Comparison