STATE OF CHARGE

Executive Summary

Massachusetts Energy Storage Initiative

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

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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

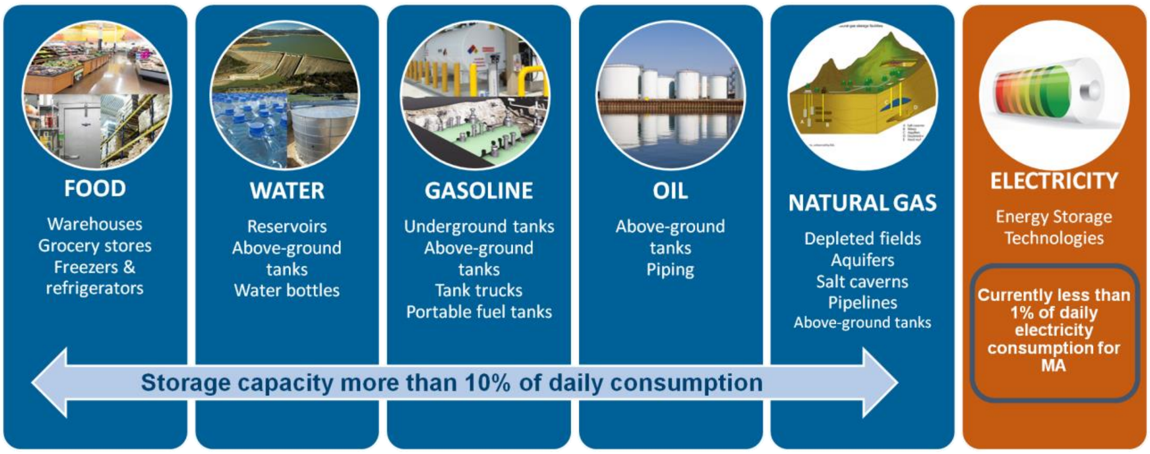

Figure 1: Storage in Commodity Supply Chains

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

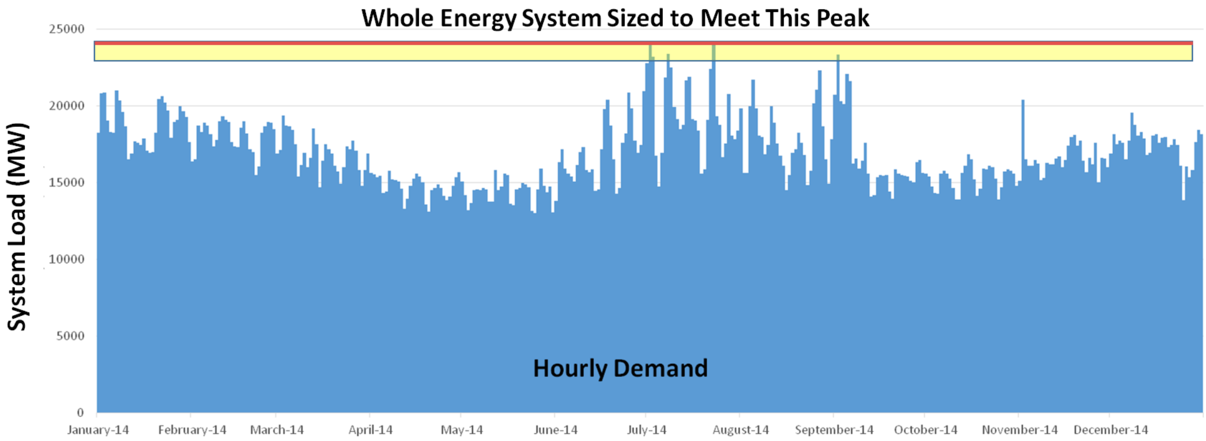

Figure 2: The whole electricity system is sized to meet peak demand

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.

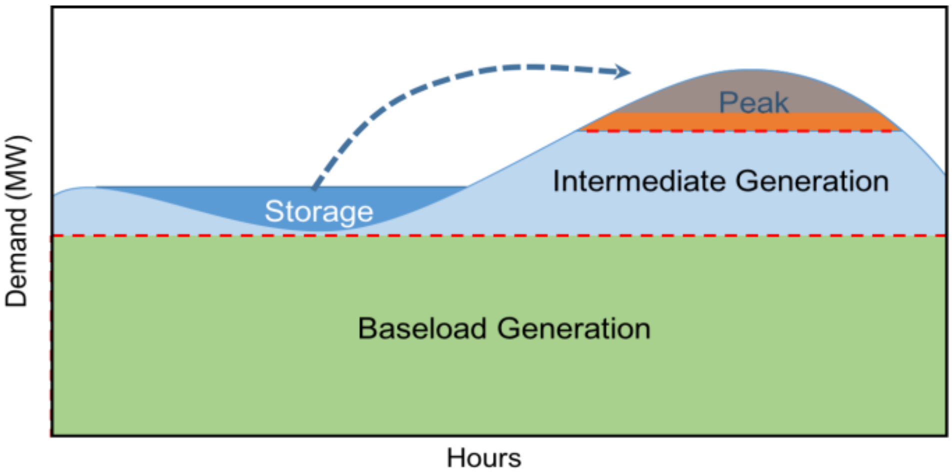

Figure 3: Energy storage can use off peak energy during times of high demand

[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.

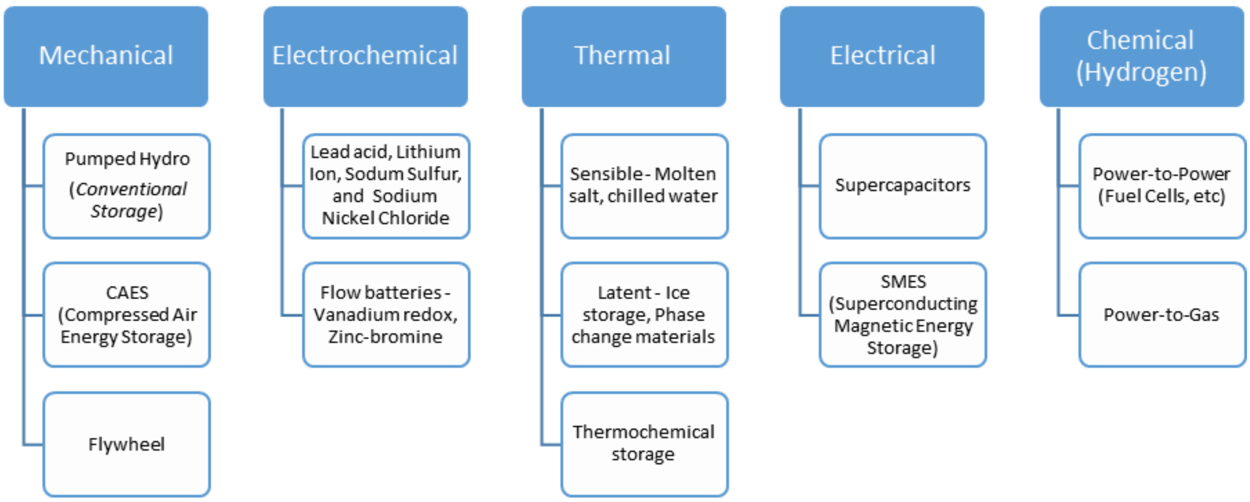

Figure 4: Classification of Energy Storage Technologies

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 2014[2]. 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]

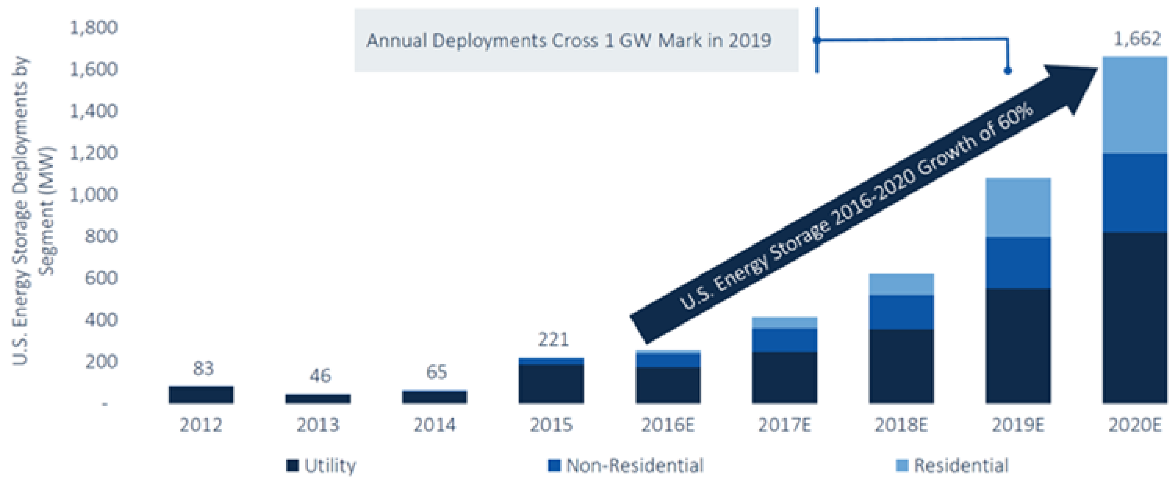

Figure 5: GTM Research Estimate of Energy Storage Growth

[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

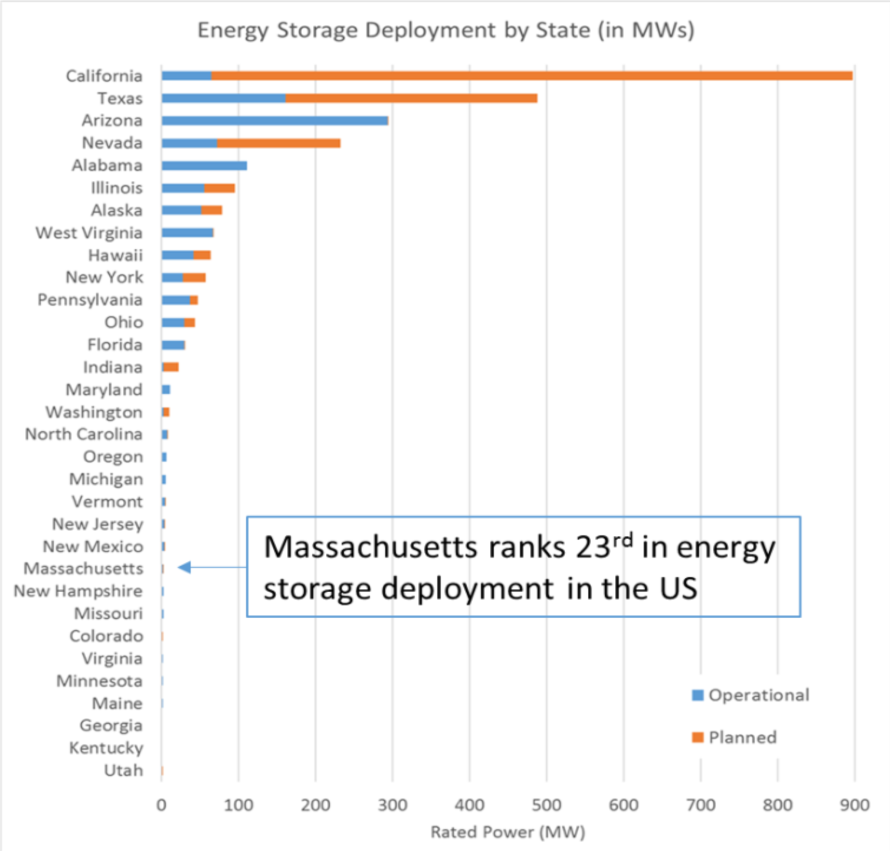

Figure 6: Planned and Operational Energy Storage Deployment by State

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.

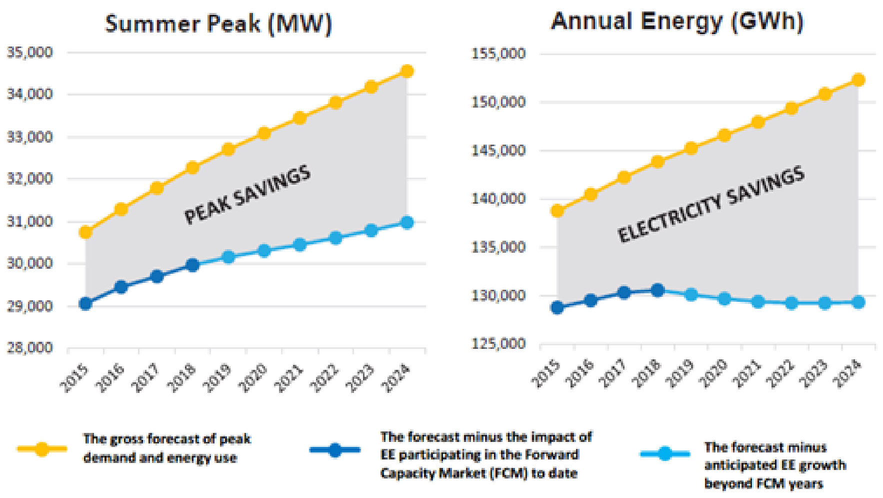

Figure 7: While Energy Efficiency has Decreased Average Energy Consumption, Peak Continues to Grow (1.5% per year)[8]

[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.

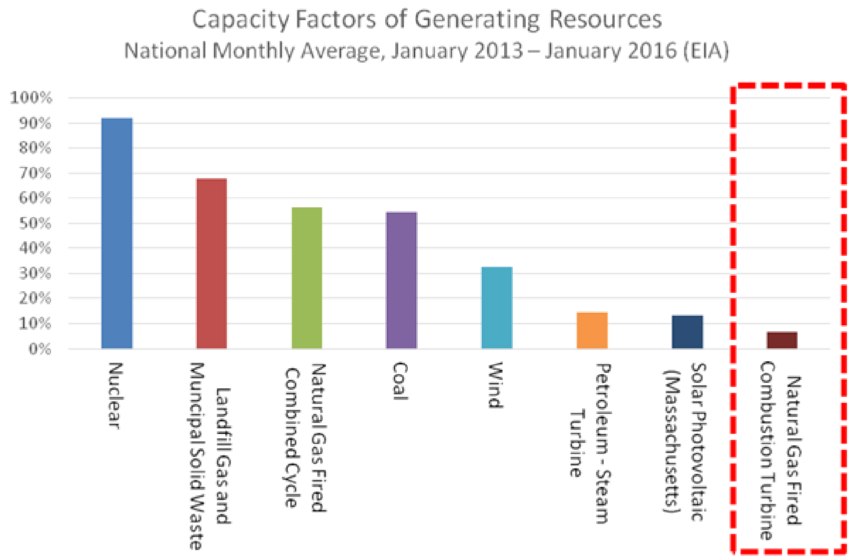

Figure 8: Peaker Plants Only Operate 2-7% of the Time

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).

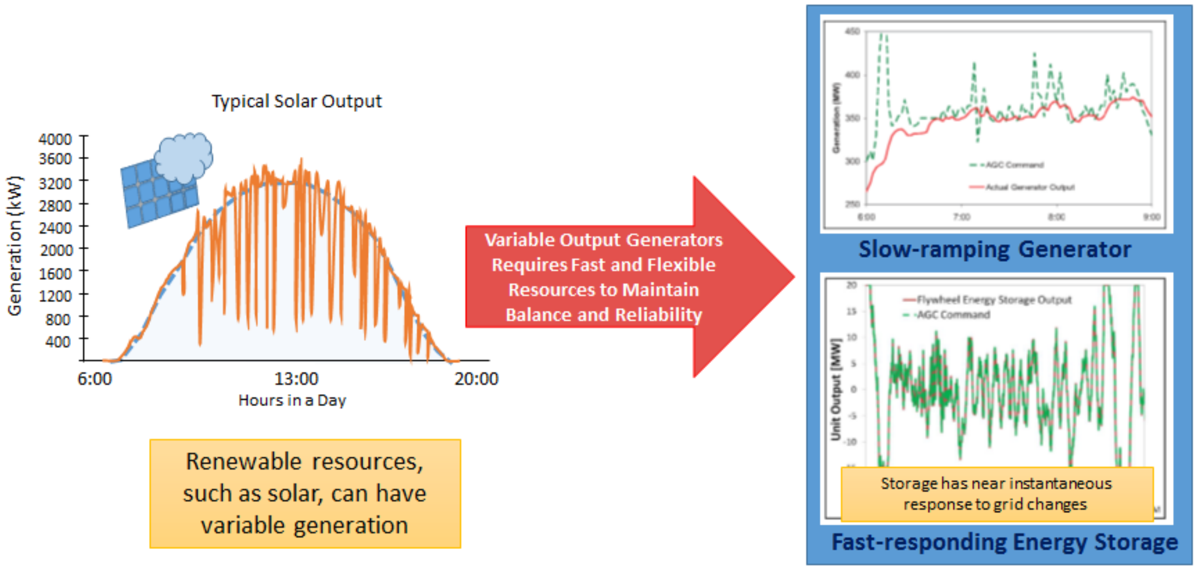

Figure 9: Energy Storage Can Respond Quickly to Variable Output to Smooth Output and Provide Frequency Regulation

Skyrocketing Growth in Distributed Generation

The amount of installed distributed generation, particularly solar photovoltaic (PV) resources, has sky rocketed 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.

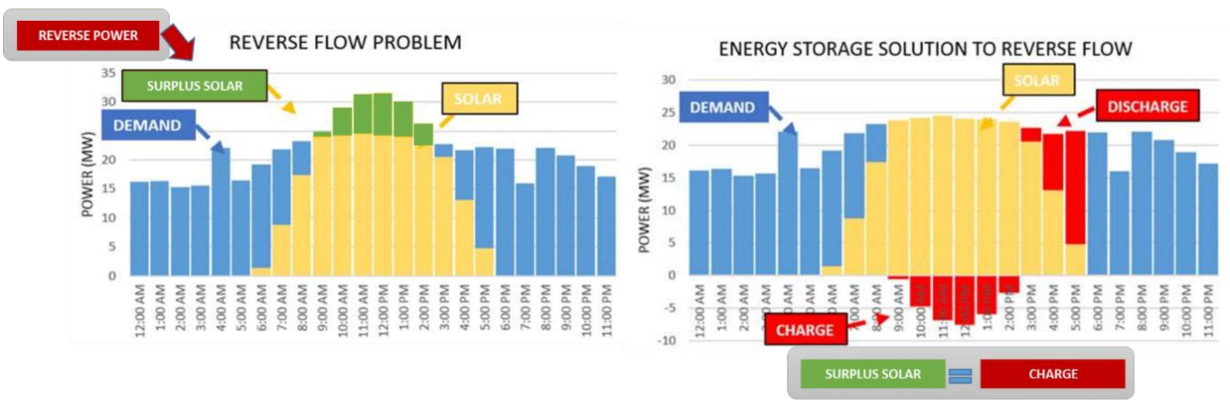

Figure 10: Storage Can Avoid Reverse Power Flows with Solar PV

[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).

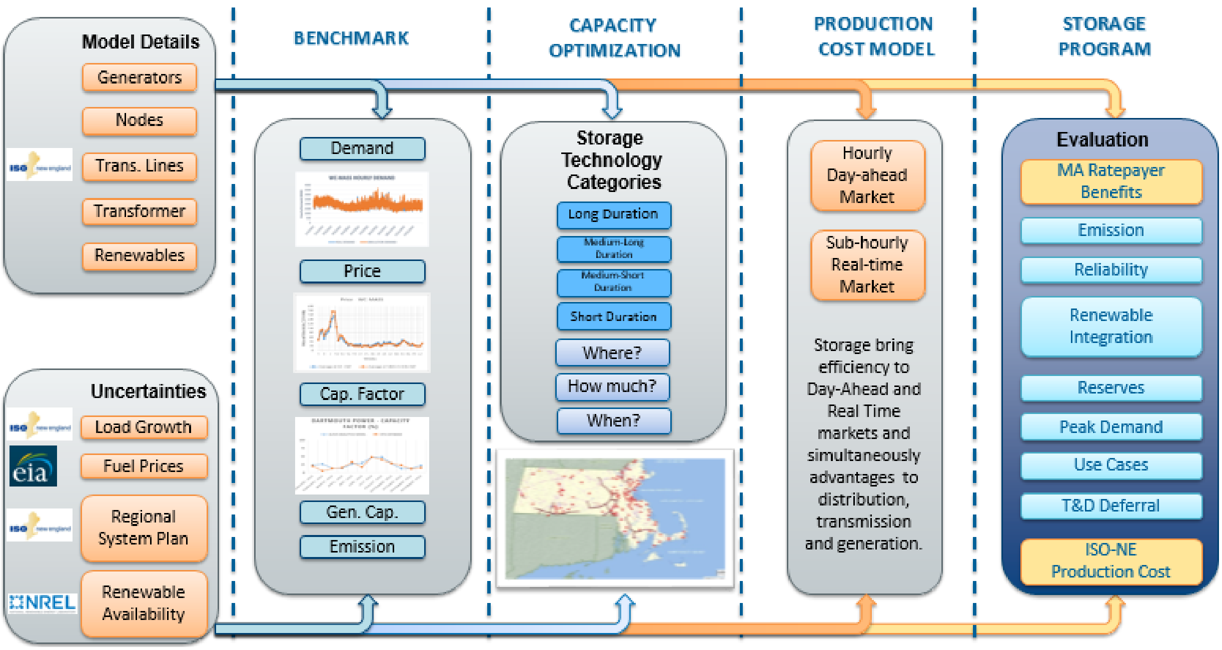

Figure 11: Advanced Storage Optimization Model/Process

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 CO_2e 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.

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: • reduced peak prices • reduced overall average energy price	**$275M**
Reduced Peak Capacity Energy storage can provide peaking capacity to: • 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: • 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: • less wear and tear • reduced start up and shut down costs • reduced GHG emissions (lower compliance cost)	**$197M**
T&D Cost Reduction Energy storage: • 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: • 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.

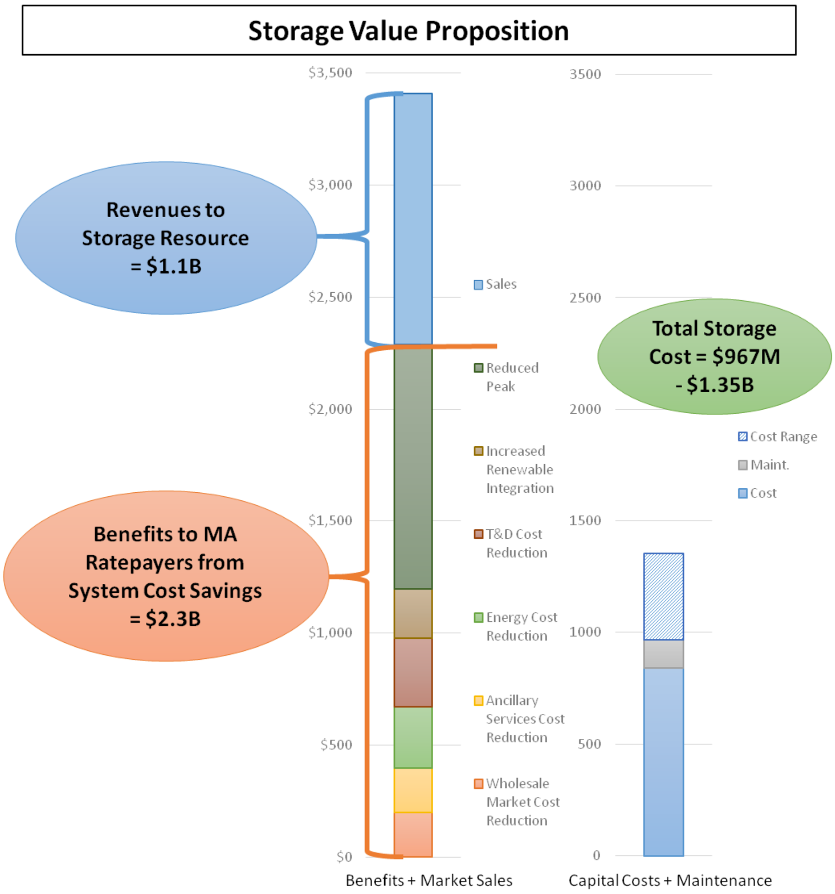

Figure 12: Storage Value Proposition

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.

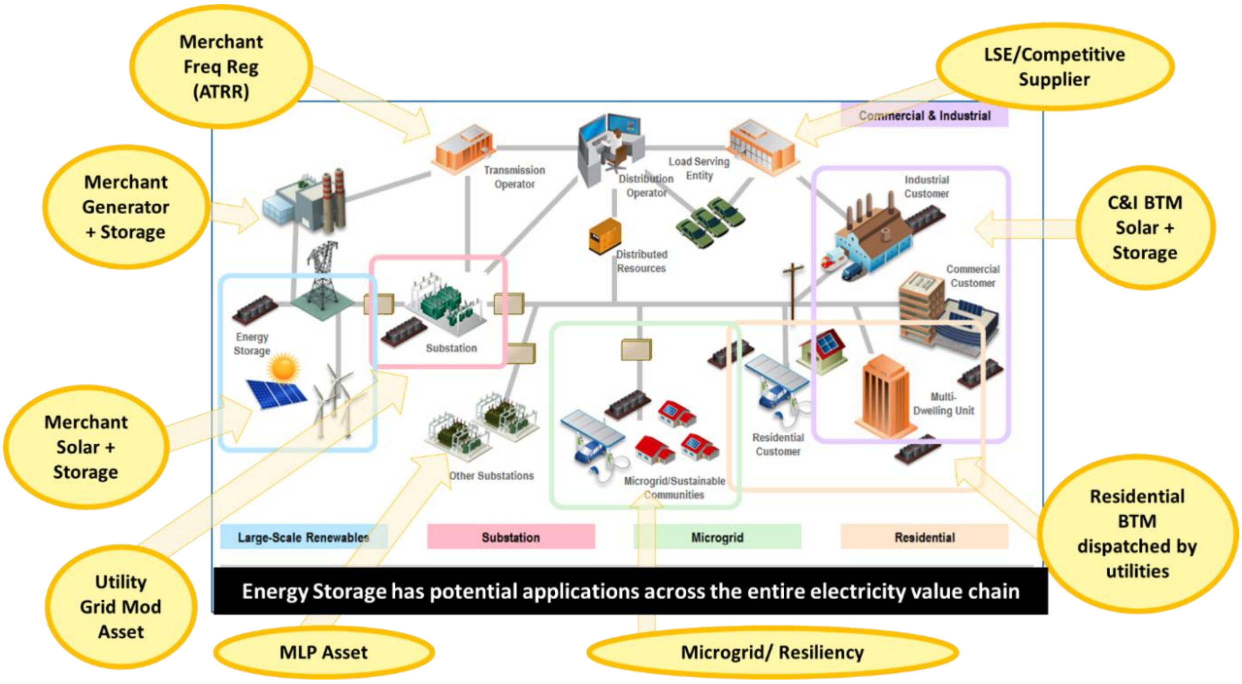

Figure 13: Energy Storage Application across Electricity Enterprise Value Chain

Use Cases		
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.

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.

Use Cases		Policies & Programs									
		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	ISO-NE Market Rule Changes
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.

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.