Energy Storage: The New Efficiency

HOW STATES CAN USE ENERGY EFFICIENCY FUNDS TO SUPPORT BATTERY STORAGE AND FLATTEN COSTLY DEMAND PEAKS

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CleanEnergyGroup

ABOUT THIS REPORT

This report, which describes how states can use energy efficiency funds to provide incentives for energy storage, is a publication of Clean Energy Group (CEG), with appendices containing several white papers prepared by the Applied Economics Clinic under contract to CEG. This report explains the steps Massachusetts took to become the first state to integrate energy storage technologies into its energy efficiency plan, including actions to 1) expand the goals and definition of energy efficiency to include peak demand reduction, and 2) show that customer-sited battery storage can pass the required cost-effectiveness test. The report summarizes the economics of battery cost/benefit calculations, examines key elements of incentive design, and shows how battery storage would have been found to be even more cost-effective had the non-energy benefits of batteries been included in the calculations. The report also introduces seven non-energy benefits of batteries, and for the first time, assigns values to them. Finally, the report provides recommendations to other states for how to incentivize energy storage within their own energy efficiency plans. Four appendices provide detailed economics analysis, along with recommendations to Massachusetts on improving its demand reduction incentive program in future iterations of the energy efficiency plan.

The report and accompanying analyses were generously supported by grants from the Barr Foundation and Merck Family Fund. It is available online at *www.cleanegroup.org/ceg-resources/resource/energy-storage-the-new-efficiency*.

ACKNOWLEDGMENTS

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DISCLAIMER

TABLE OF CONTENTS

HOW TO READ THIS REPORT

This report comprises two parts, which may appeal to different audiences.

The main body of this report explains how a groundbreaking new energy efficiency policy came about in Massachusetts; summarizes original economic analyses that supported this policy change; identifies key barriers and issues confronting states in this making this policy change; and makes recommendations for policy and program development in other states. This portion of the report is intended for a general audience and should be of interest to state policymakers and regulators.

Following the main body of the report are three appendices that contain the original white papers prepared for Clean Energy Group by economist Liz Stanton and the staff of the Applied Economics Clinic. These white papers 1) present an independent cost/benefit analysis of customer-sited battery storage, 2) review the economic underpinnings of the new Massachusetts performance-based incentive for battery storage within the efficiency plan, and 3) present new analysis valuing seven non-energy benefits of battery storage. They are intended for readers who wish to delve more deeply into the economics of battery storage and should be of interest to economists and regulators.

The AEC white paper presented here as Appendix 1 was published in July 2018. The two additional white papers from AEC, presented here as Appendix 2 and Appendix 3, are being published and released simultaneously with this report.

A fourth appendix contains recommendations, prepared by Clean Energy Group, for improving the Massachusetts Energy Efficiency Plan, as it pertains to battery storage.

Executive Summary

INTRODUCTION

Energy storage is perhaps the most revolutionary new energy technology since the electric grid was invented over a century ago. It can transport electricity over time, as well as distance; it can act as a generator or as a load; it can integrate renewables into the grid or enable customers to disconnect from the grid entirely.

But states have yet to figure out how to move storage aggressively into various market segments with dedicated incentive programs. Typically, states have supported new clean energy technologies, such as wind and solar, through public benefit funds or utility incentives, which bring down the up-front capital costs and jump-start markets. So far, only a few states have developed incentives that would support energy storage. But that is beginning to change.

This report shows how a new energy storage incentive has been created through the innovative use of state energy efficiency funds. With technical support from Clean Energy Group (CEG), a national nonprofit advocacy organization, Massachusetts, a national leader in energy efficiency, has incorporated energy storage as an active demand reduction measure in its 2019-2021 Three-Year Energy Efficiency Plan.[1] This groundbreaking action was supported with original economic analysis by the Applied Economics Clinic (AEC), under contract to CEG.[2]

This report explains how, for the first time, distributed energy storage has been included in a state energy efficiency plan, and what the implications are for states and the storage industry. It covers the following topics:

- How behind-the-meter battery storage provides efficiencies, both for the customer and for the energy system.
- Why and how Massachusetts included storage in its energy efficiency plan.[3]
- Why this is important to move storage into many markets, including low-income markets where early stage technologies might not otherwise penetrate until years from now.
- Why expanding energy efficiency to include demand reduction measures like energy storage is in keeping with the historical evolution of such funds, to bring new technologies into their programs over time.
- What actions are necessary to enable more states to incorporate storage into their efficiency plans, and to use efficiency funds to jumpstart battery storage markets in those states.
- How to value both energy and non-energy benefits of battery storage, and why this is important if storage is to be incorporated into state policy and programs.

This report shows how a new energy storage incentive has been created through the innovative use of state energy efficiency funds.

KEY FINDINGS

Distributed battery storage can deliver valuable energy efficiencies, both behind the meter and on the grid. This report presents economic analysis showing that peak demand reduction, an emerging energy service for which battery storage is well suited, provides cost savings to both storage customers and the energy system as a whole. Peak demand reduction, or peak shifting, is a valuable efficiency that cannot be effectively achieved with traditional, passive efficiency measures, but it can be cost-effectively achieved with battery storage. As more renewables come onto the electric grid, the ability to shift peak loads becomes more important and valuable.

States can open energy efficiency programs to battery storage with one simple step. As shown in Massachusetts, states can redefine energy efficiency to include the peak demand reduction concept. Electricity demand peaks are costly, leading to huge inefficiencies across the energy system. While some states have demand reduction programs, these are not typically as well funded as are energy efficiency programs. Bringing demand programs under the umbrella of energy efficiency makes more resources available to support battery storage deployment and allows consumption-reduction and demand-reduction measures to be installed together, to achieve optimal results.

Battery storage can pass required cost-effectiveness screens, justifying the investment of public dollars. As shown in the CEG/AEC July 2018 report (Appendix 1), battery storage passes the Total Resource Cost (TRC) test in Massachusetts, meaning it returns savings to consumers that are greater than its cost. This is the threshold requirement for efficiency measures to be eligible for incentives under the Massachusetts Energy Efficiency Plan. Since most state rebate and incentive programs include cost-effectiveness screens, it is important that states develop methods to fairly and thoroughly evaluate the costs and benefits of battery storage.

Battery storage offers more than just energy benefits—and its non-energy benefits are both valuable and important. As shown in the CEG/AEC report on the non-energy benefits of storage (Appendix 3), battery storage offers many non-energy benefits, including resiliency, reduced outages, increased property values, job creation, and reduced land use. The non-energy benefits of storage must be assigned an economic value, or by default they will be valued at zero in cost/benefit analyses. In this report, we present economic analysis showing the value of seven non-energy benefits of battery storage.

Numerous program design issues should be addressed when states contemplate creating battery storage incentives. These include: Incentive design, Financing, Low-income provisions, Defining peak, Duration of discharge, Measuring benefits, Ownership issues, Stacking incentives, and Transparency.

More work is needed to continue to refine and expand the value of battery storage, including the identification and valuation of more non-energy benefits. Establishing a more accurate benefit-cost ratio (BCR) for distributed battery storage will support its inclusion in state energy efficiency programs and other incentive programs (such as rebates) that require measures to pass a cost-effectiveness screen. If this is not done, storage will continue to be at a disadvantage relative to other technologies, and it may not qualify for state incentive programs.

State energy efficiency programs represent an important potential source of incentive funding for distributed battery storage. Most states have energy efficiency programs, and these programs collectively represent an investment of nearly $9 billion in public funds annually. Qualifying energy storage as an efficiency measure in these state programs would make storage eligible for vastly greater incentive support than it currently enjoys in any state—even early adopter states like California, Massachusetts and New York. Bringing new technologies like storage into state energy efficiency programs is in keeping with the history of these programs and is cited as a best practice in EPA guides.[4]

Battery storage offers many non-energy benefits, including resiliency, reduced outages, increased property values, job creation, and reduced land use.

RECOMMENDATIONS

In the main body of this report, we discuss policy issues and present recommendations for a national audience of state policymakers and regulators. Recommendations and discussion directed specifically toward improving the Massachusetts demand reduction program can be found in Appendix 4.

Key Recommendations

- Other states should learn from the experience of Massachusetts and incorporate demand reduction measures, including storage, into their own energy efficiency plans.
- State energy storage incentives, in general, should include three basic elements: an up-front rebate, a performance incentive, and access to financing.
- State energy storage incentives should include adders and/or carve-outs for low-income customers. These customers need the cost savings and other benefits of new clean energy technologies the most but are typically the last to gain access to them.
- Researchers should build on the economics analyses presented here. Specifically, cost/benefit analyses of storage should be conducted using not only the TRC but also other cost-effectiveness tests commonly in use among states, such as the Societal Cost Test and the Utility/PACT test.
- Non-energy benefits of storage should be identified, analyzed, and valued.

How Massachusetts brought energy storage into its efficiency plan

In January 2019, the Massachusetts Department of Public Utilities (DPU) approved the Commonwealth's new Three-Year Energy Efficiency Plan, which for the first time includes incentives that could be used for behind-the-meter energy storage. This DPU order[5] demonstrates a bold new direction for energy storage funding at the state level, while expanding the opportunities for behind-the-meter battery storage applications.

In Massachusetts, two barriers needed to be overcome before energy storage could be included in the efficiency plan:

1. **Redefining efficiency.** In order to include storage within the energy efficiency plan, Massachusetts first had to include *demand reduction*, a major application of battery storage, within the efficiency plan. This underlying expansion of the Commonwealth's efficiency efforts to include demand reduction was formalized as early as 2008 with the Massachusetts *Green Communities Act*.[6]
2. **Showing that storage is cost-effective.** In order for battery storage to qualify for the efficiency plan, it first had to be shown to be *cost-effective*. This meant that batteries had to be able to pass a Total Resource Cost (TRC) test with a benefit-cost ratio (BCR) equal to or greater than 1. This was demonstrated in the CEG/AEC July 2018 white paper, *Massachusetts Battery Storage Measures: Benefits and Costs*, in Appendix 1.

These two barriers will likely be faced by every state that seeks to incorporate energy storage into its energy efficiency plan. We discuss these two barriers, and how they can be overcome, in more detail below.

REDEFINING EFFICIENCY

The first barrier to the inclusion of energy storage in energy efficiency programs is the traditional definition of electrical efficiency as "using fewer electrons." If efficiency is defined solely in terms of reduced electricity consumption, efforts to include battery storage as an efficiency measure will face high barriers due to the round-trip losses associated with battery cycling. Therefore, any effort to incorporate battery storage into an efficiency program first requires that the definition of efficiency be expanded to include energy services other than reduced consumption.

> *Any effort to incorporate battery storage into an efficiency program first requires that the definition of efficiency be expanded to include energy services other than reduced consumption.*

In Massachusetts, the inclusion of energy storage as an efficiency measure was preceded by the recognition that in addition to reducing consumption, there is also value in shifting consumption from times of high electricity demand to times of lower demand. This peak load shifting is an increasingly important application for which batteries are well suited, and which cannot be accomplished with traditional, passive efficiency measures. Massachusetts recognized the high cost of high electricity demand (peak demand) to utility customers and to the grid and, to better address the problem, brought demand reduction measures into its efficiency program, see **Figures 1** and **2** (p. 8).

Massachusetts formally associated demand reduction with energy efficiency in the *Green Communities Act of 2008*.[7] *The Green Communities Act* requires that efficiency program administrators seek ". . . all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply." Demand reduction, in this context, includes the notion of shifting demand from peak to off-peak hours.

FIGURE 1

Traditional Efficiency Reduces Net Consumption, but Does Not Shift Peaks

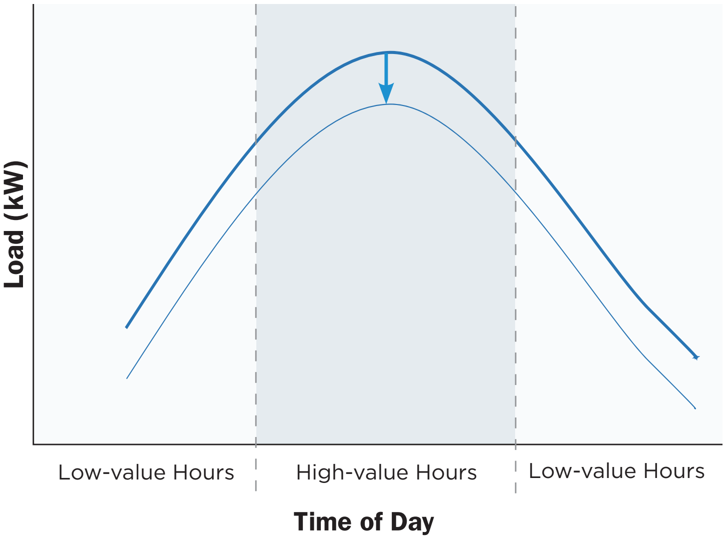
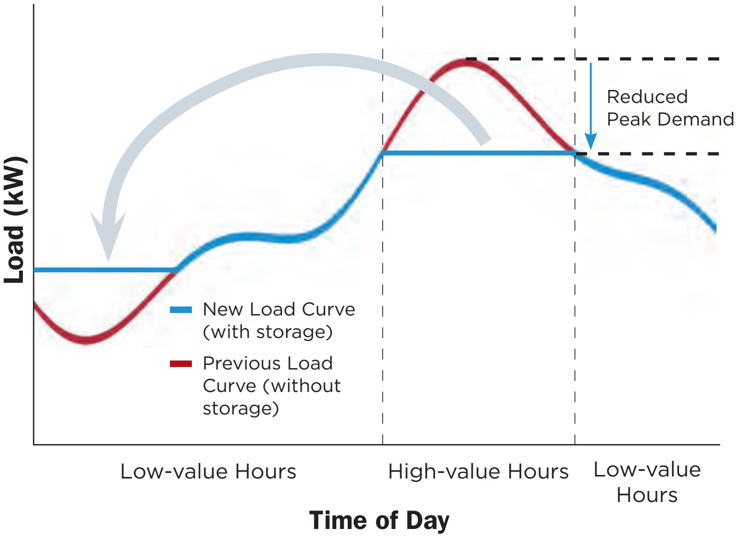


FIGURE 2

Peak Demand Reduction Shifts Peaks, but Does Not Reduce Net Consumption



Redefining efficiency—Not all load hours should be valued the same!

That this was the intent of the *Green Communities Act* was confirmed and reinforced in the *State of Charge* report, published jointly by Massachusetts Clean Energy Center (MA CEC) and Massachusetts Department of Energy Resources (MA DOER) as part of the Massachusetts Energy Storage Initiative in 2016. *State of Charge* (p. xix) notes that "Storage and other measures that shift load are firmly covered by the intent of the [Green Communities] Act" and adds, "The 2016–2018 Statewide Energy Efficiency Investment Plan ("Three Year Plan") identifies peak demand reduction as an area of particular interest in the term sheet and in the EEAC resolution supporting the 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." This was further reinforced by the state legislature in the 2018 "Act to Advance Clean Energy," Section 2, which specifically added active demand management technologies and called out energy storage as an allowable investment in the energy efficiency plan.

Among its many recommendations, the *State of Charge* report called for "Storage as Peak Demand Savings tool in Energy Efficiency Investment Plans" and notes on p. 162, "The [Green Communities] 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)."

Beyond reinforcing the legal basis for storage to be included as an efficiency measure, the *State of Charge* report also took a first step toward assessing the value of storage as a demand reduction technology. The report concluded that 40 percent of the Commonwealth's annual electricity dollars spent was attributable to just 10 percent of the top demand hours. That is, the top 10 percent demand hours in each year cost Massachusetts *nearly half* its overall electricity budget. Shifting load away from these very costly peak hours, while it does not reduce net electricity consumption, can significantly reduce costs to ratepayers and increase efficiencies across the electric system (see **Figure 3)**.

Shifting load away from these very costly peak hours, while it does not reduce net electricity consumption, can significantly reduce costs to ratepayers, and increase efficiencies across the electric system.

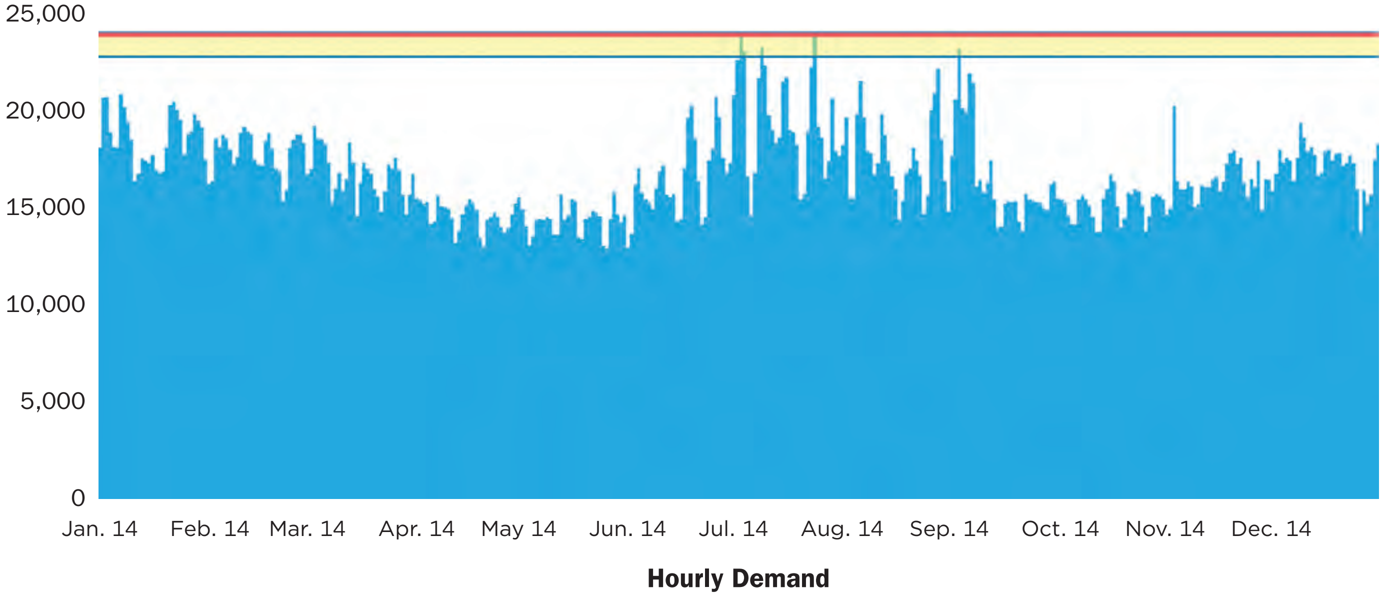
The net value of peak load reduction using behind-the-meter battery storage in Massachusetts was more specifically established in CEG's cost/benefit valuation of storage, with analysis from the Applied Economics Clinic (see Appendix 1) and, subsequently, by the Massachusetts utility program administrators' own BCRs for energy storage.

SHOWING THAT STORAGE IS COST-EFFECTIVE

Once peak demand reduction measures became eligible for inclusion in the energy efficiency plan, it remained to show that battery storage would also pass the Commonwealth's cost effectiveness test, the Total Resource Cost test (TRC).[8]

FIGURE 3

Peak-hour Demand for 2014—Whole Energy System Sized to Meet This Peak



The white area indicates inefficiencies in a system sized to meet occasional peaks.

Source: The Massachusetts *State of Charge* report

In recommending battery storage as an energy efficiency measure, the *State of Charge* report notes the importance of showing that storage can pass the TRC cost-effectiveness test. The report states,

> "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 Guidelines.... 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 [sic] untested for active demand response programs. It is possible that active demand reduction programs might require modification to the current cost effectiveness methodology."[9]

In 2018, CEG contracted with Liz Stanton of the Applied Economics Clinic (AEC) to produce original economic analysis[10] of distributed battery storage, using the same data and methods employed by utility program administrators in the Massachusetts energy efficiency program. AEC's initial white paper, "Massachusetts Battery Storage Measures: Benefits and Costs"[11] showed that battery storage passes the cost/benefit test required by the Commonwealth's energy efficiency program, with BCRs of 2.8 in the low-income category, and 3.4 in the commercial/industrial category. In other words, for every dollar of public money spent on battery storage, the Commonwealth would see benefits in the range of $2.80–$3.40. Therefore, according to the Massachusetts Green Communities Act,[12] battery storage should qualify for inclusion in the Massachusetts Energy Efficiency Plan.[13] These results are shown in **Table 1**. Clean Energy Group presented the findings from AEC's analysis to the DOER, the Massachusetts Energy Efficiency Advisory Council (EEAC), and the utility program administrators. These positive BCRs provided a basis for inclusion of a performance incentive that could be applied to battery storage as a demand reduction measure in the proposed new energy efficiency plan.

TABLE 1

Total Benefits and Costs by Customer Class

Parameter for 2019	Low-Income	C&I
Total Electric Benefits ($)	$36,296	$155,782
Total Resource Costs ($)	$13,163	$46,322
Benefit-Cost Ratio	**2.8**	**3.4**

Source: Applied Economics Clinic calculations

Following the release of the white paper, the utility program administrators revised their draft energy efficiency plan to include a new calculation of the cost/benefits of storage. This final plan was presented by the program administrators in October, and ultimately approved by the DPU. In this version of the energy efficiency plan, the Massachusetts utilities, using only the energy benefits of battery storage, came up with BCRs in the range of 0–6.2, as shown in **Table 2** (p. 10).

Note that the program administrators' calculated BCRs for energy storage are different depending on where storage measures are to be installed and how they are to be dispatched. For example, in **Table 2**, storage in the targeted dispatch program in the Eversource service territory is shown to have a BCR of 3.2 when installed behind a commercial/industrial

TABLE 2

Energy Benefits of Storage by Utility

BCRs	Cape Light			Eversource			National Grid			Unitil		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Residential Advanced Demand Management Program (A2e)												
Program BCRs	1.6	2.4	2.4	1.0	1.4	1.6	1.5	2.4	2.5	0.7	1.1	1.2
Direct Load Control	4.9	6.6	7.4	5.0	5.0	5.0	5.3	5.5	5.3	5.2	9.6	9.6
Behavior DR												
Storage System & Performance		3.0	3.0									
Storage Daily Dispatch				1.5	1.5	1.5	4.9	4.9	5.0			
Storage Targeted Dispatch				0.0	0.0	0.0	0.1	0.1	0.1			
EV Load Management								0.8	0.8			
Income-Eligible Advanced Demand Management Program (B1b)												
Program BCRs		2.3	2.4					2.4	2.4			
Direct Load Control												
Behavior DR												
Storage System & Performance		3.0	3.0									
Storage Daily Dispatch												
Storage Targeted Dispatch												
EV Load Management												
Commercial/Industrial Advanced Demand Management Program (C2c)												
Program BCRs	7.5	4.6	4.7	2.9	2.9	2.8	7.9	4.8	4.9	2.7	2.9	3.1
Interruptible Load	9.7	9.8	9.8	7.9	7.9	7.9	7.5	7.5	7.5	4.2	4.2	4.2
Winter Interruptible Load												
Storage System & Performance		3.0	3.0									
Storage Daily Dispatch				1.7	1.7	1.7	4.9	4.9	5.0	6.2	6.2	6.2
Storage Targeted Dispatch				3.2	3.2	3.2	0.1	0.1	0.1	0.1	0.1	0.1
Custom	8.3	8.3	8.3		2.0	2.0	1.3	1.3	1.3			

Source: AEC

This table shows the BCRs of behind-the-meter energy storage as calculated by the program administrators (i.e., utilities) in Massachusetts. Note that these BCRs are based on energy benefits, which include emissions reductions, but they do not take into account non-energy benefits in their calculations. The circled numbers show how results can vary based on sector.

meter, but a BCR of zero when installed behind a residential meter. However, overall, the program administrators' results were similar the CEG-commissioned analysis performed by AEC, showing that in most cases, battery storage is cost-effective.

The proposed new energy efficiency plan was approved by the Massachusetts DPU in January 2019. The plan is expected to provide approximately $13 million in customer-sited performance incentives for demand reduction, which could result in the installation of approximately 34 MW of new behind-the-meter battery storage over three years.

Following the energy efficiency plan's approval, CEG again contracted with AEC to produce additional analysis of battery storage BCRs, as included in the final energy efficiency plan (attached in Appendix 2 of this report).

The plan is expected to provide approximately $13 million in customer-sited performance incentives for demand reduction, which could result in the installation of approximately 34 MW of new behind-the-meter battery storage over three years.

Valuing the non-energy benefits of storage

Although energy storage passed the required cost/benefit test for most applications in the Massachusetts energy efficiency plan, it did so based solely on its energy benefits. It is important to note that storage also provides non-energy benefits, which were not included in the storage BCRs calculated for the Massachusetts energy efficiency plan. CEG therefore contracted with AEC to conduct new analysis valuing the non-energy benefits of battery storage (attached in Appendix 3 of this report).

Establishing the value of non-energy benefits of battery storage is important because unless dollar values can be assigned to these benefits, their value in state cost/benefit analyses is effectively zero. Had the value of the non-energy benefits been included in the cost/benefit calculations for energy storage in Massachusetts, the resulting BCRs would likely have been higher. When other states conduct their own cost/benefit calculations for energy storage, it is important that the non-energy benefits of storage be included; otherwise, storage may be undervalued and may not qualify for energy efficiency incentive funds.

In the "Non-Energy Benefits of Battery Storage" white paper, AEC has identified seven non-energy benefits of battery storage and calculated their values. Though this is not a comprehensive list, it shows that storage has significant non-energy benefits, which should be included in future BCR calculations.

The seven non-energy benefits of battery storage analyzed in AEC's white paper are the following:

1. Avoided power outages
    a. Energy system reliability benefit (the system-wide benefit of fewer grid outages)
    b. Non-energy reliability benefit to consumers (customer's value of backup power)
2. Higher property values (after storage is installed)
3. Avoided fines to utilities for outages
4. Avoided cost to utilities of collections and terminations
5. Avoided cost to utilities of emergency calls during outages
6. Job creation
7. Reduced land use due to peaker replacement (using distributed storage as a peaking resource to avoid investments in new fossil fueled peaker plants, which require more land)[14]

It is important that the non-energy benefits of storage be included; otherwise, storage may be undervalued and may not qualify for energy efficiency incentive funds.

These non-energy benefits are valued by AEC as shown in **Table 3** (p. 12).

Inclusion of these non-energy benefit values in future storage cost/benefit analyses should result in an even greater BCR for battery storage as a demand reduction measure, and it could justify more aggressive investment goals by the Commonwealth of Massachusetts and its utilities.

TABLE 3

Values for Additional Non-Energy Benefits of Battery Storage

	Non-Energy Benefit (2018$)
Avoided Power Outages	
Battery storage measure participants avoid outages, and all of the costs that come with outages for both families and businesses	• Residential: **$172**/kWh • Commercial/Industrial: **$15.64**/kWh
Higher Property Values	
Installing battery storage in buildings increases property values for storage measure participants by increasing leasable space, increasing thermal comfort, increasing marketability of leasable space, and reducing energy costs.	• **$5,325**/housing unit for low-income single family participants • **$510**/housing unit for owners of multi-family housing
Avoided Fines	
Increasing battery storage will result in fewer power outages and fewer potential fines for utilities	• **$24.8 million** in 2012
Avoided Collections and Terminations	
More battery storage reduces the need for costly new power plants, thereby lowering ratepayer bills, and making it easier for ratepayers to consistently pay their bills on time. This reduces the need for utilities to initiate collections and terminations.	• Terminations and Reconnections: **$1.85**/year/participant • Customer Calls: **$0.77**/year/participant
Avoided Safety-Related Emergency Calls	
Increasing battery storage results in fewer power outages, which reduces the risk of emergencies and the need for utilities to make safety-related emergency calls	• **$10.11**/year/participant
Job Creation	
More battery storage benefits society at large by creating jobs in manufacturing, research and development, engineering, and installation.	• **3.3 jobs**/MW • **$310,000**/MW
Less Land Used for Power Plants	
More battery storage reduces the need for peaker plants, which are more land-intensive than storage installations—benefiting society by allowing more land to be used for other purposes.	• **12.4 acres**/MW

Source: AEC

This table shows the values calculated by AEC for seven non-energy benefits of battery storage. These non-energy benefits should be considered by policy makers when calculating the cost/benefit for battery storage. The non-energy benefits are in addition to the energy benefits.

How the Massachusetts program incentivizes battery storage

It is important to understand that the Massachusetts Active Demand Reduction program within the Energy Efficiency Plan *incentivizes peak demand reduction, not the installation of demand-reducing technologies.* This means that customers can qualify for battery performance incentives, but there is no rebate for installing batteries. Customers must shoulder the initial investment (unless developers offer leasing or power purchase agreement options).[15]

Customers installing batteries or other peak demand reduction devices will be able to sign up for a five-year performance contract with their utility. At the end of each season (twice a year) they will be paid an incentive payment based on how much they reduced their load (use of electricity) *on average* in response to utility signals for that season. This program will be offered both to commercial and to residential customers (although a critical mass of residential customers from each area will have to sign up before the utilities issue contracts).

It is anticipated that the program will be marketed to customers by third-party developers. HEAT loans (zero-interest loans) will be available to Massachusetts customers purchasing storage equipment, but developers may also offer their own financing plans, which may include leasing as well as purchasing options.

At this writing, the program performance incentive rates were still being developed by the program administrators. For the "targeted" dispatch program, the summer rate is anticipated to be $100/kWh average load reduction, and the winter rate is anticipated to be $25/kWh average load reduction. Payouts would be calculated seasonally based on the customer's average load reduction in each season.[16]

For a commercial customer signed up for targeted dispatch, this program could provide a modest but significant incentive. For example, a commercial customer installing a 60-kWh battery system might be able to earn $2,500/year or $12,500 over the five-year contract period (for details on how this is calculated, see *duration of discharge* below).

Utility filings indicate that the Massachusetts utilities anticipate spending approximately $13 million over three years on demand reduction incentives (exclusive of the administrative costs of the program). The incentives are expected to result in about 34 MW of new behind-the-meter battery storage being installed in the Commonwealth. If the program is successful, it is reasonable to assume that these levels of investment and the resulting deployment will increase in future energy efficiency plans.

It is important to understand that the Massachusetts Active Demand Reduction program within the Energy Efficiency Plan incentivizes peak demand reduction, not the installation of demand-reducing technologies.

Only new battery installations would be eligible for an incentive. There is no requirement that batteries be paired with renewable generation, but solar+storage customers could take advantage of both the efficiency incentive and the state's SMART solar program, which includes a storage adder. Commercial customers may also be able to engage in demand charge management behind the meter, for additional savings; and solar customers can net-meter excess solar. Other upcoming state programs, such as a clean peak standard now in development, may present additional revenue opportunities for storage customers.

What this means for other states and for the battery storage industry

Clean Energy Group views the inclusion of battery storage as a demand reduction measure in the Massachusetts energy efficiency program as critically important to the development of a robust and competitive battery storage market in the Commonwealth. But beyond that, we see this as an important precedent for other states across the nation.

The larger context for this work is that battery storage has not, to date, enjoyed the kind of broad support from public clean energy funds that other clean energy technologies, such as wind and solar, have relied on. Only a few early adopter states—California, Massachusetts, New York, New Jersey, and Oregon—have established battery storage procurement mandates or portfolios; and even fewer states offer incentives for behind-the-meter battery storage deployment. Thus, there is very little material support in state policy for distributed storage.

Due to competition for public funds, it is difficult for any emerging clean energy technology to attract new dollars for the creation of a new state incentive program. On the other hand, battery storage may fit into existing incentive programs with dedicated funding. Among such programs, energy efficiency is nearly ubiquitous, and a leader in terms of committed funds. With nearly $9 billion spent nationwide in 2017, state efficiency budgets constitute an enormous resource. Equally important to the size of these budgets is their relative permanence and reliability when compared to one-off grant programs and time-limited bridge incentive funding.

The 2018 ACEEE State Scorecard[17] shows that out of the 50 states and the District of Columbia, only Alaska, Kansas and North Dakota spent no money on electric efficiency in 2017. Top annual spenders included California ($1.4 billion/year), Massachusetts ($620 million/year), and New York ($450 million/year). For the third in a row, Massachusetts is ranked first on the 2018 scorecard, which considers policy and program efforts in terms of performance, best practices, and leadership.

These state energy efficiency budgets constitute a large potential new source of support for behind-the-meter storage deployment going forward. If other states follow Massachusetts' lead, bringing demand reduction technologies like battery storage into their energy efficiency programs, battery storage could gain access to many more state incentive dollars than are currently available to it. Conversely, if peak demand-reducing measures remain segregated from mainstream efficiency measures, they will likely continue to receive a fraction of the support given to efficiency measures.

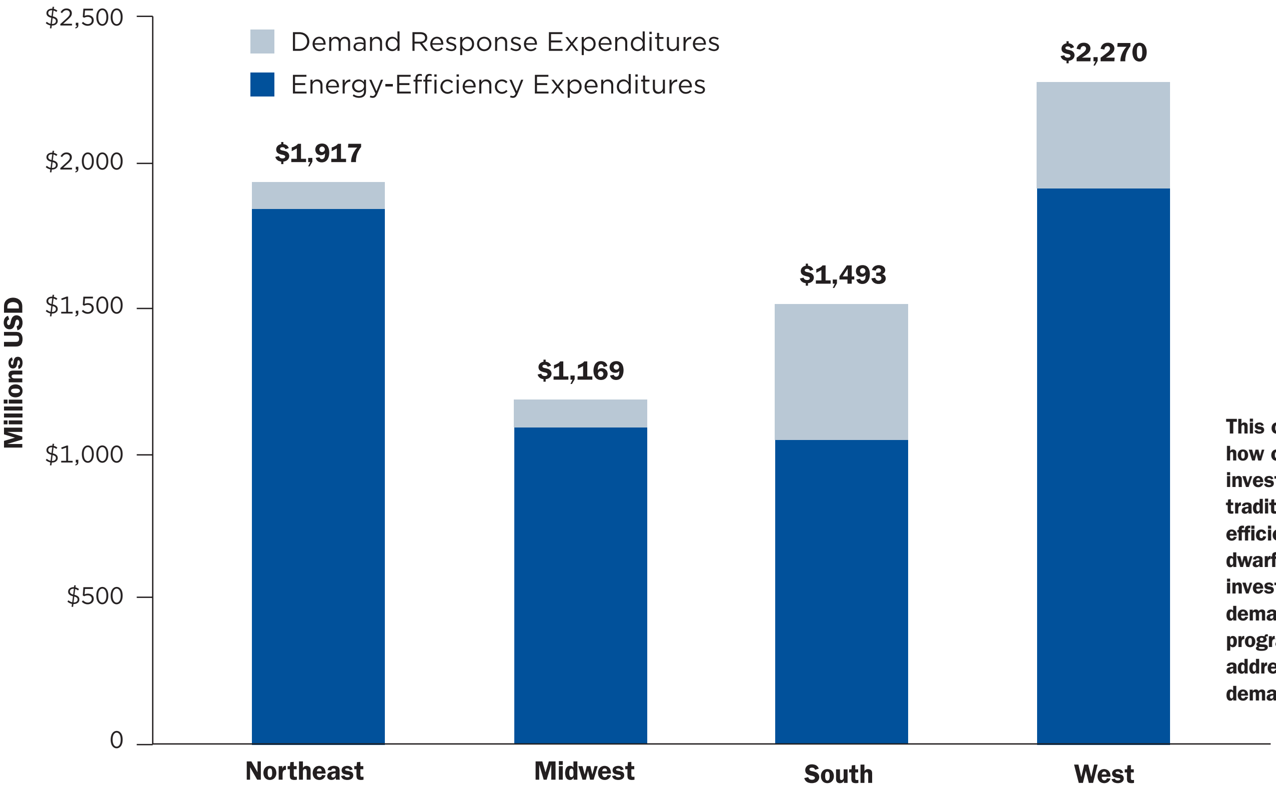
The disparity between public dollars spent on traditional energy efficiency measures versus demand reduction measures is stark. Nationally, demand reduction program budgets account for only about 16 percent of the combined energy efficiency-demand response spend in the US (see **Figure 4**).[18]

Adding battery storage to efficiency programs makes sense for several reasons. First, distributed battery storage is a good fit for efficiency programs. It works well behind the meter, delivers significant cost savings and other benefits to customers, and provides needed services not provided by traditional, passive efficiency measures. Notably, at a time when electricity demand is increasing faster than volumetric electricity sales, battery storage is capable of targeted peak demand reductions—unlike traditional measures, such as low-energy lighting and weatherization measures, which reduce net consumption but do nothing to shift demand peaks.[19] As shown by the "duck curve" phenomenon,[20] which was first noted in California but has now become evident in New England as well, the ability to shift peak loads becomes more important as more solar generation is added to the grid.

Second, it is noteworthy that the rise of battery storage comes at an opportune time, coinciding with the decline of state investment in efficient lighting programs. Long a mainstay of efficiency programs, lighting investments are now declining due to federal standards, which require light bulbs reach higher efficiencies. Unless these federal lighting regulations are rescinded,[21]

FIGURE 4

US Electric Energy Efficiency and Demand Response Expenditures by Region, 2016



This chart shows how current public investment in traditional energy efficiency measures dwarfs public investment in demand response programs, which address peak demand reduction.

Source: Consortium for Energy Efficiency 2017 Annual Industry Report

no incandescent bulb currently on the market will be able to be sold in the US by 2020, and the market will have completed its transition to fluorescent and LED bulbs.[22] Thus, state efficiency dollars currently dedicated to increased lighting efficiency will be freed up, and could be reallocated to support emerging demand reducing resources, including battery storage.

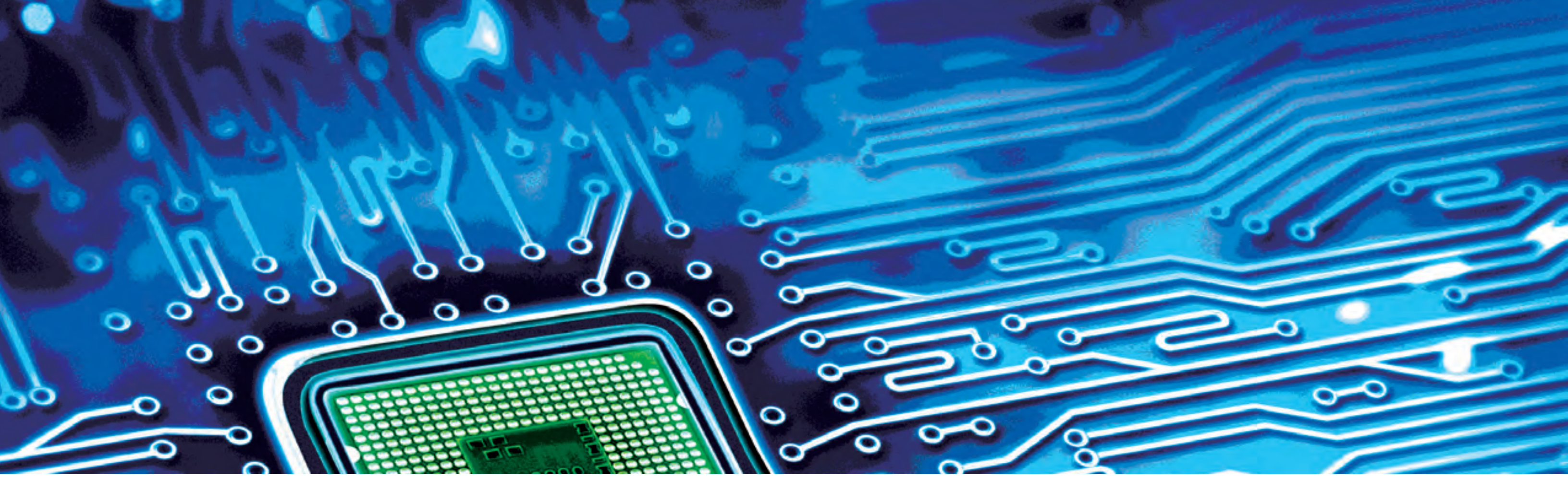
Third, customer and grid benefits are greatest when both kinds of efficiency—consumption reduction and demand reduction—are applied together. For some customers, potential reductions in electricity consumption are limited, and once these limits are reached, only demand management can provide further gains.

Commercial utility customers, in particular, frequently face steep electricity demand charges based on the highest 15-minute demand period each month. These customers need and deserve the ability to reduce demand peaks by employing battery storage behind the meter.[23] Doing so not only saves money for the storage owner—it also saves money across the electric system, by reducing the need to run costly "peaker" power plants and easing congestion on electric lines and substations.

It is also important to recognize that the integration of new technologies like battery storage is well within the history of state energy efficiency programs. In fact, the US EPA cites adding new technologies as a best practice in energy efficiency programs. In its 2008 National Action Plan for Energy Efficiency, EPA explains the importance of introducing new technologies as a best practice for efficiency programs:

> Many of the organizations reviewed have a history of providing programs that change over time to accommodate changes in the market and the introduction of new technologies . . . technology innovation that targets improved energy efficiency and energy management will enable society to advance and sustain energy efficiency in the absence of government-sponsored or regulatory-mandated programs. Robust and competitive consumer-driven markets are needed for energy efficient devices and energy efficiency service. . . . Programs must be able to incorporate new technologies over time. As new technologies are considered, the programs must develop strategies to overcome the barriers specific to these technologies to increase their acceptance.[24]

Massachusetts' groundbreaking inclusion of battery storage in its energy efficiency program is a change that should have significant and far-reaching impacts. Massachusetts is at the cutting edge in the electric efficiency sphere, and the work that has been done to incorporate and value distributed battery storage as an efficiency measure in Massachusetts should inform similar efforts in other states.



Program design considerations

The Massachusetts Three-Year Energy Efficiency Plan was shaped through a collaborative process that included state agencies, utilities, and non-governmental organizations. As the plan evolved, numerous program design considerations arose. We discuss some of these here. States looking to incorporate battery storage into their own efficiency plans will likely need to consider similar program design elements.

INCENTIVE DESIGN

In designing incentives for battery storage deployment, it is important to recognize both the unique operational and economic attributes of batteries, and the barriers they face as an emerging technology.

As discussed above, battery storage operates differently from traditional energy efficiency measures in that it does not usually reduce the net consumption of electricity, but instead, can redistribute consumption to non-peak times. In addition to this peak shifting service, battery storage can often provide other services to both the customer (such as resiliency) and the grid (such as ancillary services).

> *Battery storage operates differently from traditional energy efficiency measures in that it does not usually reduce the net consumption of electricity, but instead, can redistribute consumption to non-peak times.*

Battery storage developers and customers may need to stack several such applications to achieve favorable battery storage project economics (see “Stacking incentives” below). Furthermore, unlike passive efficiency measures, batteries must be discharged at the right times to provide the desired demand reduction benefit; and in some cases must be charged at specific times, or from specific sources, to achieve economies and satisfy regulations and tax rules. These unique attributes should be taken into account when states design battery storage incentives, so that participation in the incentive program does not preclude the use of storage for other revenue-generating or cost-saving applications.

As an emerging technology, battery storage also faces cost and risk barriers. Installed costs of battery storage have declined rapidly in recent years but still present a barrier for customers, especially for low-income customers. Customers also shoulder the burden of economic risk, which is exacerbated when incentives come only in the form of performance incentives. Both these barriers could be addressed by an up-front rebate for battery storage systems.

Massachusetts regulators and efficiency program administrators chose to offer performance incentives for peak demand reduction in response to a utility signal, rather than a straightforward energy storage rebate upon installation. This makes sense from a program administrator’s point of view, because it incentivizes only those uses of storage that achieve the desired load reductions during demand peaks. However, it puts the burden of capital investment entirely on the customer or developer. A more traditional up-front rebate would have shifted this burden in part to the state, but that would not have provided any guarantee that the resulting installed storage capacity would provide the peak load reduction services envisioned in the plan.

Ideally, states would offer both an up-front rebate and performance incentives. This would help to make storage more affordable and accessible, especially to underserved communities, while also incentivizing peak demand reductions.

FINANCING

Another important element of a successful incentive program is financing. The Massachusetts energy efficiency plan makes energy storage eligible for the HEAT loan program, an interest-free loan offered to support the installation of efficiency measures. Unfortunately, the seven-year HEAT loan payback period exceeds the five-year incentive contract the utility program administrators will offer customers.[25] With no assurance that a second five-year contract will be offered after the initial contract period, and with incentive rates subject to change after contracts expire, HEAT loan recipients may have no way to offset the final two years of loan payments. Even during the initial five years, annual incentive payments to battery customers are unlikely to fully offset HEAT loan debt incurred as a result of battery purchases.

In practice, third-party developers may offer their own financing packages when marketing the battery incentive program. This industry financing, if offered, would provide an alternative to some customers. However, customers outside territories targeted by developers may have no recourse other than the Commonwealth's HEAT loan program.

States looking to support customer-owned battery storage deployment should consider providing low- or zero-interest financing with paybacks calibrated to coincide with performance incentive payments. Alternately, a customer rebate would help to offset equipment costs and could reduce the loan burden carried by the customer.

LOW-INCOME PROVISIONS

As noted above, battery storage is a relatively new technology that faces cost and financing barriers. These are particularly problematic when it comes to deploying the technology in low-income communities. To avoid leaving low-income customers behind, it is important that states include provisions for participation by underserved communities in storage incentive programs.

One major shortcoming of the Massachusetts plan is that it lacks any special provisions to support participation by low-income customers, referred to in the Massachusetts energy efficiency plan as "income eligible" customers (see **Table 4**).[26]

TABLE 4

Lack of Income-Eligible Programs by Utility

	Cape Light			Eversource			National Grid			Unitil		
Summer kW Savings	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Residential Advanced Demand Management Program												
Program Summer kW Savings	1,055	2,869	3,400	2,050	3,150	4,250	6,099	8,597	11,033	94	112	135
Direct Load Control	1,055	1,618	1,861	2,000	3,000	4,000	5,156	6,785	8,278	94	112	135
Behavioral DR												
Storage System & Performance		1,250	1,539									
Storage Daily Dispatch				50	150	250	903	1,763	2,696			
Storage Targeted Dispatch												
EV Load Management							39	49	60			
Income-Eligible Advanced Demand Management Program												
Program Summer kW Savings		289	385									
Direct Load Control												
Behavioral DR												
Storage System & Performance		289	385									
Storage Daily Dispatch												
Storage Targeted Dispatch												
EV Load Management												
Commercial/Industrial Advanced Demand Management Program												
Program Summer kW Savings	5,798	6,053	6,080	28,000	57,500	96,000	69,500	79,000	90,000	300	500	500
Interruptible Load	5,395	5,458	5,485	27,000	47,000	75,000	66,000	72,000	79,000	200	400	400
Winter Interruptible Load												
Storage System & Performance		192	192									
Storage Daily Dispatch				500	5,000	10,000	2,500	5,000	7,000	100	100	100
Storage Targeted Dispatch				500	5,000	10,000						
Custom	403	403	403		500	1,000	1,000	2,000	4,000			

Source: Applied Economics Clinic

This table shows the program offerings in the Active Demand Reduction program, including battery storage. Note that none of the Commonwealth's utilities provided an income-eligible offering (the blank space indicated by the red oval). Cape Light Compact did propose income-eligible investment, but Cape Light's proposed program was not approved by the DPU.

The result is that while low-income customers can participate through the commercial and residential offerings, there is no dedicated, additional support targeted to low-income communities.

Typically, it is more difficult to provide clean energy options to low-income communities, which need clean, resilient and low-cost energy the most. States looking to incorporate storage into energy efficiency plans should include specific low-income provisions, such as an added incentive, more favorable financing, a carve-out guaranteeing a certain percentage of low-income participation, an up-front rebate, or (preferably) a combination of these.

DEFINING PEAK

Because the value of peak load shifting is tied to the value of energy at peak demand hours, it is important to ensure that these peak hours are defined in a way that 1) allows for battery storage to meaningfully shift peak loads and 2) allows these shifted peak loads to be appropriately valued.

In Massachusetts, peak hours are defined in "Avoided Energy Supply Components in New England: 2018 Report" (AESC) as being from 9 a.m. to 11 p.m. weekdays, excluding holidays, both summer (four months) and winter (eight months). As noted in AEC's July 2018 report, "This broad definition of 'peak' is not useful in representing the strategic use of batteries to relieve tight energy markets in periods of high energy demand or high energy prices."

TABLE 5

Peak/Off-Peak Hours, 2019

		Highest 10% by	
	Total Count	**Energy Price**	**MWh**
Summer Peak	1,260	0	317
Summer Off-Peak	1,668	1	313
Winter Peak	2,565	502	128
Winter Off-Peak	3,267	373	118

Source: Applied Economics Clinic calculations

From the perspective of a battery storage provider, the problem with such a broad definition of peak is twofold. First, shifting so many hours (1,260 hours in summer and 2,565 hours in winter) is not feasible (see **Table 5**). Second, the average value of any given peak hour is lowered by the sheer number of hours considered to be "peak." In other words, the more hours defined as "peak," the less valuable any given peak hour is, on average. In Massachusetts, for example, the average value of a peak MWh under this overly broad definition falls into a range of $31–$47. These prices would be significantly higher, however, if the definition of "peak" hours were restricted to the top 10 percent of hours in the year, either by price or by volumetric sales, as suggested in the *State of Charge* report.

TABLE 6

Peak/Off-Peak Hours, 2019

		Highest 10% by	
	Total Count	**Energy Price**	**MWh**
Summer Peak	$31	N/A	$37
Summer Off-Peak	$27	$69	$36
Winter Peak	$47	$80	$73
Winter Off-Peak	$42	$78	$75

Source: Applied Economics Clinic calculations

To illustrate the significance of the pricing difference, AEC showed in its July 2018 report that under the AESC definition of peak, the average avoided energy price for a winter peak hour is $47 (see **Table 6**). If defined as the top 10 percent of hours by peak pricing, the same winter peak hour is worth $80. If defined as the top 10 percent of hours by MWh sales, the same hour is worth $73.

States interested in integrating storage into an energy efficiency program should make sure to adopt a definition of "peak" that is narrow enough to allow storage measures to make a meaningful and valuable contribution.

These differences in peak load shifting values are very important for battery storage. Under an extremely broad definition of peak, such as is used in AESC 2018, storage measures represent a net cost to the electric system. Under a more restricted definition of peak as the top 10 percent of hours by price, storage provides a net benefit. Although there are other benefits of storage to be calculated (such as non-energy benefits), this fundamental definition of peak hours provides the basis of the positive BCR for battery storage.

It is important to understand that "peak" may be defined differently for different purposes, and by different entities. For example, ISO-New England recognizes a 2- and 4-hour peaks, while PJM recognizes a 10-hour peak, for their respective demand response programs. These definitions may have a great impact on how battery storage can play in wholesale markets in these regions. However, there is nothing preventing a state from using a different definition of peak within an energy efficiency program.

States interested in integrating storage into an energy efficiency program should make sure to adopt a definition of "peak" that is narrow enough to allow storage measures to make a meaningful and valuable contribution.

DURATION OF DISCHARGE

Related to the above discussion of how peak hours are defined is the issue of the duration of discharge (of the batteries) required for demand reduction measures. Where performance incentives are used, the duration of discharge can have a significant impact on the economic viability of battery storage. The Massachusetts program administrators have indicated that they will call for demand reduction in three-hour blocks. For example, a customer might be called upon to reduce their load from 2 p.m. until 5 p.m. Because the incentive payment is based on the average hourly load reduction across all the hours called in a season, this three-hour signal effectively reduces battery capacity to one-third its nameplate capacity, for purposes of calculating the seasonal incentive payment.[27]

As an example, consider a customer who has a 60-kW battery. When responding to a three-hour call by the utility, the maximum average load reduction possible across those three hours is 20 kW. This average is then multiplied by the incentive rate to arrive at the incentive payment. If the utilities instead employed a two-hour load-reduction call, the same battery would be capable of an average reduction of 30 kW per hour, resulting in a higher incentive payment at season's end. Given a 100/kW incentive rate (the targeted dispatch program's summer rate), the difference in annual incentive payments is significant:

Three-hour call: 20 kW x $100 = $2,000 seasonal payment
Two-hour call: 30 kW x $100 = $3,000 seasonal payment

Note that under the targeted dispatch program, the winter rate is only $25/kWh, so signing up for the winter season does not add much to the customer's annual payout.

Assuming a 60 kW battery (maximum 20 kW load reduction average):

Summer payout = 20 kW x $100 = $2,000
Winter payout = 20 kW x $25 = $500
Annual revenue = $2,500

States that design an incentive based on this average load-reduction model should be aware that the longer the duration of load-reduction calls by the utility, the lower the incentive payment will be to the customer.[28]

MEASURING BENEFITS

The need to show that battery storage passes a cost-effectiveness screen is not unique to Massachusetts. Most states require some sort of cost-effectiveness screening, not only for energy efficiency plans, but also for other types of clean energy incentive programs. Where a benefit/cost test is required, a full accounting of the benefits of battery storage should include both energy benefits and non-energy benefits.

The Massachusetts program administrators' BCR calculations for the 2019–2021 efficiency plan, as shown in **Table 2** (p. 10), are based on the energy benefits of storage, but they do not take into account its many non-energy benefits. These non-energy benefits were omitted despite the fact that they are commonly used in calculating the BCR of traditional efficiency measures in Massachusetts. The current Massachusetts energy efficiency plan describes non-energy benefits, here referred to as non-energy impacts (NEIs), thus:

> "A NEI is a benefit (positive or negative) for participants in energy efficiency beyond the energy savings gained from installing energy efficient measures. NEIs include benefits such as reduced costs for operation and maintenance associated with efficient equipment or practices, or reduced environmental and safety costs. The Department has stated that NEIs are 'a well-established component of the program cost-effectiveness analyses conducted by the Program Administrators' and found that the benefits of the NEIs are quantifiable and flow to Massachusetts ratepayers. 2013-2015 Order at 61. The Department has specifically stated that non-resource benefits (NEIs) should be included in cost-effectiveness. Guidelines at §§ 3.4.4.1, 3.4.4.2."[29]

The plan goes on to state that the program administrators have included benefits associated with NEIs in the current plan's cost-effectiveness calculations for a number of measures, including low-income, health- and safety-related NEIs, C&I new construction NEIs, residential multi-family common area lighting NEIs, residential heat pump NEIs, and others. However, the non-energy benefits of energy storage were not included, meaning that energy storage technologies were likely undervalued compared to other measures included in the plan. A more accurate accounting of the BCR of energy storage would have included its non-energy benefits.

Most states require some sort of cost-effectiveness screening, not only for energy efficiency plans, but also for other types of clean energy incentive programs.

When states omit non-energy benefits from cost/benefit calculations, the value of those non-energy benefits defaults to zero for purposes of finding the BCR of the measure. The result is that the measure being considered will be undervalued, and it may not pass the cost-effectiveness screen. Therefore, it is important for states to begin to assign values to the non-energy benefits of battery storage.

In addition to the omission of non-energy benefits, there are a number of other omissions and errors in the valuation of battery storage in the 2019–2021 Massachusetts energy efficiency plan. The most important of these are discussed in more detail in the Appendices. Future work may focus on further analysis of some of these issues.

It should be noted that calculating the BCR of battery storage is a complicated task that relies on previously established values for services such as avoided emissions and avoided energy demand reduction induced price effects (DRIPE). Many of these underlying values may not be the same for all states. For example, the values associated with avoided emissions and increased capacity will vary from state to state and market to market. Therefore, while the values of various storage benefits presented in this report may serve as a good baseline for other states, additional work may be needed to fully adapt these values to the needs of other states' policymakers.

OWNERSHIP ISSUES

Issues around the ownership and control of battery storage resources are important, and they should be considered carefully when states design storage incentive plans or incorporate storage into existing programs, such as energy efficiency plans. In order to advance battery storage deployment, it is important that customers retain rights of ownership and control of storage resources behind their electric meters.

This is important due to the need to stack benefits, as described below (see "Stacking Incentives").

In order to advance battery storage deployment, it is important that customers retain rights of ownership and control of storage resources behind their electric meters.

Though it does not address issues of battery ownership directly, the Massachusetts energy efficiency plan assumes customer and third-party ownership of battery resources behind the meter. However, Massachusetts law places no restrictions on utility ownership of storage, meaning that utilities could have opted to offer customers utility-owned batteries, as Green Mountain Power has done in Vermont, and Liberty Utilities is doing in New Hampshire.[29] Such a move could have had a negative effect on the nascent distributed, customer-sited battery storage industry in the Commonwealth rather than supporting its development; and future customers could have faced a potential utility monopoly when pursuing battery storage options.

Similar to issues of battery ownership are issues of the ownership and control of battery attributes that have their own market values, such as capacity. This was the subject of a recent Massachusetts DPU docket. In January 2019, the DPU issued a ruling[31] allowing customers to buy back the capacity assets of behind-the-meter, solar+battery storage systems, to which the utilities had previously claimed rights of ownership. This is an important issue not only because battery capacity is a monetizable asset, but also because control over it can determine when and whether customers control the dispatch (use) of their own battery systems. This in turn has significant implications for project economics, particularly for commercial customers who wish to use batteries for demand charge management. If utilities are allowed to own the capacity rights to behind-the-meter battery storage and bid this capacity into markets, as they do in the case of net-metered solar, this can prevent customers from using batteries to reduce demand charges, because the utilities may leave batteries depleted at times when customers need to use them to reduce their own electricity demand.

In the case of the Massachusetts energy efficiency plan, the program administrators will not directly dispatch behind-the-meter storage resources, but instead will compensate customers based on their average load reduction in response to a utility signal. This means customers retain the ability to use their batteries for other purposes if they judge those purposes to be more valuable than the efficiency performance incentive. There is no penalty for failing to respond to a utility dispatch signal, but it does lower the yearly average load reduction, which is used to calculate the customer's incentive payment.

States looking to incorporate batteries into an efficiency program should be aware of this aspect of incentive design. If customers lose control of their battery storage equipment (e.g., utilities can remotely discharge batteries without customer consent), their ability to stack benefits decreases (see "Stacking Incentives," below). In this case, incentive rates may need to be higher to make customer participation worthwhile. The same logic applies to cases where failure to respond to a dispatch call can result in a fine.

STACKING INCENTIVES

Battery storage owners and developers often configure battery systems in such a way as to allow "benefit stacking." This refers to the ability of a single battery system to provide numerous benefits, often generating savings from several incentive or revenue streams. The ability to stack incentives and applications is important, because it gives customers flexibility; and it can help to further defray the cost of investing in a battery system. It follows the principle of allowing battery storage owners to be compensated fairly for all the services that the batteries are able to provide.

For example, a commercial customer who installs a new solar+storage system in Massachusetts may qualify for a SMART solar incentive (rebate) with a storage adder, as well as an energy efficiency demand-reduction incentive.

The customer may be able to net meter solar generation and may also engage in demand charge management (reducing the monthly demand charge that is part of commercial utility bills). Being able to stack values in this way allows the customer greater flexibility and helps to offset the cost of installing the solar+storage system.

Other states interested in developing battery storage policy should consider how various state programs and storage markets may interact, to avoid unduly limiting how the storage resource can be used. Opportunities for combining incentives and market programs should be clearly spelled out to reduce confusion and give consumers and developers a clear understanding of potential project economics, which is important to obtain financing.

TRANSPARENCY

During the development of the Massachusetts energy efficiency plan, numerous stakeholders noted a lack of transparency which made it difficult to provide meaningful stakeholder input. Lack of transparency has also been noted as a shortcoming of the final plan, which leaves significant design elements vague.

For example, the program administrators have stated in docket filings that they intend to offer residential contracts for load reduction performance incentives (for which storage would be eligible) only after a critical mass of applications has been received.[32] However, there is nothing in the plan identifying how many applications are needed to trigger the offer. This creates uncertainty and hinders the efforts of developers in marketing the program to their customers.

Vague, inconsistent, and opaque program language should be avoided when states design battery storage incentive programs.

Similarly, in their white papers, AEC notes that such fundamental terms as “measure” are used to mean different things by different program administrators in different parts of the plan. This kind of internal inconsistency makes it difficult to understand what incentives are available to customers.

Vague, inconsistent, and opaque program language should be avoided when states design battery storage incentive programs. States looking to adapt portions of the Massachusetts energy efficiency plan to support their own policy development for battery storage should be aware of these internal inconsistencies and avoid replicating them. For example, a state could require utilities to agree on the definition of important terms such as “measure,” which are necessary to understand how an efficiency program works and what various incentives are worth to customers.

What states should do to promote battery storage

While Massachusetts' integration of battery storage into its energy efficiency plan as a demand reduction measure is not perfect, it does provide a model for other states to follow, along with some lessons learned as identified below.

Other states that are leaders in clean energy programs and policy should consider following the example of Massachusetts. These states should understand that the changing electricity system presents a need and opportunity to identify new types of efficiency. Among these, peak demand reduction will be increasingly important. It is critical that technologies capable of reducing peak demand, such as battery storage, be incorporated fully into state energy efficiency programs, so that behind-the-meter storage markets can come to scale, with incentives commensurate to those offered other clean energy and efficiency measures.

Other states that are leaders in clean energy programs and policy should consider following the example of Massachusetts.

Here are some lessons learned from Massachusetts for states to consider:

- Expand the definition of energy efficiency to include peak demand reduction. This means that state energy efficiency goals would include peak demand reduction goals, and that peak demand reduction measures would be made eligible for efficiency incentives.
- Fully integrate demand reduction measures, including battery storage, into state energy efficiency plans.
  - In some states with separate demand reduction targets and budgets, this might mean merging the efficiency and demand reduction budgets into a single program that encompasses both energy efficiency and demand reduction goals.
- Establish battery storage or demand reduction incentives within the energy efficiency program.
  - These should, in general, include three basic elements: an up-front rebate, a performance incentive, and access to financing.
  - These should also include adders and/or carve-outs for low-income customers. These customers need the cost savings and other benefits of new clean energy technologies the most but are typically the last to gain access.
  - Utility ownership should be limited, so that some substantial portion of the storage deployed will be owned by customers and/or third parties.
  - Third-party developers should be allowed to market the program to customers, provide private financing, offer lease and PPA models, and aggregate capacity to meet program goals.
- Adopt, adapt and build on the economics analysis presented here.
  - Cost/benefit analyses of storage should be conducted using whatever cost-effectiveness tests states apply to other energy efficiency measures. These might include the Total Resource Cost Test, the Societal Cost Test or the Utility/PACT test.
  - BCRs should be calculated based on both the energy and the non-energy benefits of storage.
  - Additional non-energy benefits of storage should be identified and valued.

Key Findings and Conclusion

Many studies have concluded that battery storage offers immense value to the electric grid as well as to consumers. The benefits of storage include not just renewables integration and peak shifting, but other services such as increased resiliency, reduced transmission and distribution investment, ancillary services provision, arbitrage and black start capability. The challenge has been that markets do not yet exist for most of these services; and without markets, it has been very difficult for policymakers to assign values to these benefits of storage, or for storage providers to sell and be compensated for these benefits.

This market failure is a major finding of the Massachusetts *State of Charge* report, which concludes, "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."[33]

The same problem is discussed in the Massachusetts energy efficiency plan itself, which notes, "There is no beneficial value proposition for individual residential customers to participate in active demand offerings [including battery storage] absent Program Administrator incentives. However, peak demand reductions through active demand management can have a system benefit that reduces overall capacity and temporal-energy costs for all customers."[34]

This basic market failure is a familiar one, and it is one reason why many states invest public funds to support development and deployment of new advanced clean energy resources. However, the investment of public funds, in itself, often requires states to show that this investment will result in a positive return. To do this, it is necessary to attribute dollar values to the many benefits of behind-the-meter battery storage.

This report begins to address the challenges of valuing battery storage by showing that it can and does pass a Total Resource Cost test in Massachusetts; and furthermore, that storage provides many additional non-energy benefits that have definable monetary value in Massachusetts, and that could (and should) be incorporated into future cost/benefit analyses, both in Massachusetts and in other states.

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 report also documents incentive design issues arising from this first-ever inclusion of energy storage in a state energy efficiency plan. These design issues will need to be considered by other policy makers that wish to follow the lead of Massachusetts. The lessons learned from Massachusetts, as discussed in this report, should inform similar efforts in other states.

More work remains to be done to more accurately define the value of storage, including expanding on the non-energy benefits of storage—analyzed for the first time in this report—as well as to further refine program design for storage within state energy efficiency plans. However, this report should provide valuable information to state policymakers and regulators working to incorporate storage in efficiency and other incentive programs.

Key take-aways from this report:

1. At least two major barriers had to be overcome in order to incorporate energy storage into the Massachusetts energy efficiency plan: first, peak demand reduction had to be incorporated into the energy efficiency program; and second, storage had to be shown to pass cost-effectiveness screens. Other states will likely have to confront these barriers when incorporating storage into their own energy efficiency plans.
    a. Peak demand reduction is an important new kind of electric efficiency that offers benefits both to customers and to the grid. Battery storage is a critical technology for shifting peaks when installed behind the customer's meter.
    b. Battery storage passes the Massachusetts cost/benefit test and has been incorporated into the Massachusetts energy efficiency plan for 2019–2021. About 34 MW of behind-the-meter battery storage is expected to be installed in MA over three years under load reduction performance contracts worth about $13 million in customer incentives. Other states should follow the example of Massachusetts and conduct their own cost/benefit analysis of behind-the-meter energy storage.
2. The non-energy benefits of energy storage have significant value and should be included in cost/benefit analyses. This was not done in the 2019–2021 Massachusetts Energy Efficiency Plan but should be included in future iterations of the plan and should be considered by other states when developing energy storage incentives.
3. Numerous program design issues should be addressed when states contemplate creating battery storage incentives, whether within an efficiency plan, or as a free-standing rebate. These include: Incentive design, Defining peak, Dispatch duration, Measuring benefits, Ownership issues, Low-income provisions, Stacking incentives, and Transparency.
4. More work is needed to continue to refine and expand the value of battery storage, including the identification and valuation of more non-energy benefits. Establishing a more accurate BCR for distributed storage will support its inclusion in state energy efficiency programs and other incentive programs (such as rebates) that require measures pass a cost-effectiveness screen. If this is not done, storage will continue to be at a disadvantage relative to other technologies and may not qualify for state incentive programs.
5. State energy efficiency programs represent an important potential source of incentive funding for distributed battery storage. Most states have energy efficiency programs, and these programs collectively represent an investment of nearly $9 billion in public funds annually. Bringing new technologies like storage into state energy efficiency programs is a recommended "best practice."

At least two major barriers had to be overcome in order to incorporate energy storage into the Massachusetts energy efficiency plan: first, peak demand reduction had to be incorporated into the energy efficiency program; and second, storage had to be shown to pass cost-effectiveness screens.

ENDNOTES

1 The Commonwealth of Massachusetts. “Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan 2019–2021.” *Department of Public Utilities.* October 31, 2018. *http://ma-eeac.org/wordpress/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf*.

2 In addition to conducting the economic analysis presented here, CEG advocated for program design elements in the Massachusetts Energy Efficiency plan that would support customer choice, allow the participation of third-party installers and aggregators, provide significant financing and incentives—with an emphasis on the needs of low-income customers and underserved communities—and ensure a competitive and diverse market for behind-the-meter battery storage in Massachusetts.

3 Although it is the first to fully incorporate energy storage into its energy efficiency program, Massachusetts is not the first state to recognize the importance of storage for peak demand reduction. Arizona Corporation Commission (ACC) has included peak demand reduction in its state energy efficiency resource standard, although it caps the contribution of peak demand reductions at 2% (the overall goal is 22% cumulative energy savings by 2020). ACC also ordered Arizona Public Service, the state’s largest utility, to develop a residential demand response or load management program that facilitates energy storage technology. APS developed the Demand Response, Energy Storage and Load Management (DRESLM) initiative, which was approved by the ACC in 2016 and offered to customers in 2017. In 2018 APS expanded the DRESLM initiative to include both residential and non-residential customers. ACC has also ordered all regulated Arizona utilities to include energy storage in their integrated resource plans, or explain why it is omitted. For more information on the APS Demand Side Management plan, see *https://www.aps.com/en/ourcompany/aboutus/energyefficiency/Pages/home.aspx*.

4 United States Environmental Protection Agency. “National Action Plan for Energy Efficiency, Chapter 6: Energy Efficiency Program Best Practices.” 2015. *https://www.epa.gov/energy/energy-efficiency-program-best-practices*.

5 The Commonwealth of Massachusetts, Department of Public Utilities. *Three Year Energy Efficiency Plans Order.* D.P.U. 18-110 through D.P.U. 18–119. January 29, 2019. *https://www.mass.gov/files/documents/2019/01/31/2019-2021%20Three-Year%20Energy%20Efficiency%20Plans%20Order_1.29.19.pdf*.

6 An Act Relative to Green Communities. The Commonwealth of Massachusetts, Chapter 169. July 2, 2008. Retrieved March 13, 2019. *https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169*.

7 The Commonwealth of Massachusetts. M.G.L. c.25, §21. Retrieved March 12, 2019. https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25/Section21.

8 At the time of this analysis, Massachusetts required individual efficiency measures to pass the TRC cost-effectiveness test. The 2018 Act to Advance Clean Energy amended this requirement so that it now applies to entire sectors rather than individual measures. Note that although the total resource cost test (TRC) is the most commonly used, many states use other cost-effectiveness tests such as the participant cost test (PCT), the utility/program administrator cost test (PACT), the ratepayer impact measure test (RIM), and the societal cost test (SCT). This report does not address how battery storage would fare in tests other than the TRC. For more information on the differences between different types of cost-effectiveness tests, see: National Action Plan for Energy Efficiency. “Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers.” *United States Environmental Protection Agency and United States Department of Energy.* November 2018. *https://www.epa.gov/sites/production/files/2015-08/documents/cost-effectiveness.pdf*, and Daykin, Elizabeth et al. “Whose Perspective? The Impact of the Utility Cost Test.” *Cadmus Group.* December 2011. *https://www.cadmusgroup.com/wp-content/uploads/2012/11/TRC_UCT-Paper_12DEC11.pdf*.

9 Massachusetts Department of Energy Resources and Mass Clean Energy Center. “State of Charge: A Comprehensive Study of Energy Storage in Massachusetts.” September 27, 2016. *https://www.mass.gov/service-details/energy-storage-study*.

10 Stanton, Elizabeth A. “Massachusetts Battery Storage Measures: Benefits and Costs.” *Clean Energy Group.* July 2018. *https://www.cleanegroup.org/ceg-resources/resource/massachusetts-battery-storage-measures-benefits-and-costs*.

11 Ibid.

12 An Act Relative to Green Communities. The Commonwealth of Massachusetts, Chapter 169. July 2, 2008. Retrieved March 13, 2019. *https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169*.

13 Ibid. The Green Communities act states that ”Every three years. . . the electric distribution companies and municipal aggregators with certified efficiency plans shall jointly prepare an electric efficiency investment plan.... Each plan shall provide for the acquisition of all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply.”

14 Note that the land use benefit is presented in acres rather than dollars. This is because it is difficult to know the value of the land required for a prospective new peaker plant. However, this benefit could be quite valuable. For example, the average value of land in Boston is $600,000 per acre according to a recent report: Albouy, David et al. “Metropolitan Land Values.” *The Review of Economics and Statistics.* July 2018, 100(3): 454–466. *http://davidalbouy.net/landvalue_index.pdf*. Based on this average, the formula to find the value of land saved through use of distributed storage to replace a peaker plant planned for Boston would be $600,000 x 12.4 x MW capacity of peaker. For example, avoiding development of a 60 MW peaker in Boston could save $446.4 million in avoided land use

value. Of course, all land value is highly locational; and this only provides a very rough estimate, which would be different for different cities.

15 Clean Energy Group (CEG) had originally proposed a stand-alone battery storage rebate plan for Massachusetts. Due to a lack of available funds for such a rebate, this proposal was put on hold temporarily, in favor of incorporating storage into the energy efficiency budget. CEG supported this effort, but also continues to advocate for a battery storage rebate, which could be provided within the Commonwealth's energy efficiency plan or as a stand-alone program.

16 There is also a daily dispatch program, which may offer higher incentive rates in exchange for more frequent battery cycling, but this is being offered initially as a pilot program, and may be expanded to a full program offering in coming years.

17 Berg, Weston, et al. "The 2018 State Energy Efficiency Scorecard." *American Council for an Energy-Efficient Economy.* Research Report U1808. October 2018. *https://aceee.org/research-report/u1808*.

18 Consortium for Energy Efficiency. "State of the Efficiency Program Industry: Budgets, Expenditures, and Impacts 2017." March 2018. *https://www.cee1.org/annual-industry-reports*.

19 In this regard, storage is part of an emerging field of smart and grid interactive energy efficiency measures which address, to varying degrees, load shifting and reduced consumption behind the meter. These include wireless thermostats, remotely controlled HVAC and water heater systems, and the like.

20 Spector, Julian. "Massachusetts Is Staring Down a Duck Curve of Its Own. Storage Could Help." *GTM^2.* April 23, 2018. *https://www.greentechmedia.com/articles/read/massachusetts-is-staring-down-a-duck-curve-of-its-own-storage-could-help#gs.3388ma*.

21 deLaski, Andrew and Steve Nadel. "Rollback of light bulb standards would cost consumers billions—$100 per household each year." *The Appliance Standards Awareness Project (ASAP)* and *The American Council for an Energy-Efficient Economy (ACEEE).* February 6, 2019. *https://aceee.org/press/2019/02/rollback-light-bulb-standards-would*.

22 Granda, Chris. "Impacts of the 2020 Federal Light Bulb Efficiency Standard." *Strategies.* February 2018. *https://appliance-standards.org/sites/default/files/AESP2020LightingStandards.pdf*.

23 Commercial/industrial customers in Massachusetts face some of the highest demand charges in the nation, but a recent study conducted by CEG and NREL shows that high demand charges can be found in many parts of the country. See: McLaren, Joyce and Seth Mullendore. "Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges." *National Renewable Energy Laboratory* and *Clean Energy Group.* August 24, 2017. *https://www.cleanegroup.org/ceg-resources/resource/nrel-demand-charges-storage-market*.

24 Environmental Protection Agency. "National Action Plan for Energy Efficiency, Chapter 6: Energy Efficiency Program Best Practices." August 2015. *https://www.epa.gov/energy/energy-efficiency-program-best-practices*.

25 The Massachusetts energy efficiency plan provides for contractual battery storage performance payments to customers over a five-year term. This is an unusual offering in that the incentive term is longer than the term of the three-year energy efficiency plan.

26 In the efficiency plan proposed by the PAs to the DPU, only Cape Light Compact proposed any batteries for income eligible customers. The Cape Light Compact plan was opposed by Eversource and the DPU did not approve it. At this writing it is uncertain whether the Cape Light Compact plan will eventually go forward as proposed.

27 This is because a battery would not have time to discharge, recharge and discharge again during a period of three consecutive hours.

28 Technically, this type of performance incentive can be considered a "payment for performance," rather than a traditional incentive.

29 The Commonwealth of Massachusetts. "Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan 2019–2021" (page 119–120). *Department of Public Utilities.* October 31, 2018. *http://ma-eeac.org/wordpress/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf*.

30 The Liberty and GMP programs offer residential customers a utility-owned battery in exchange for a monthly fee. The customer can use the battery for backup power in case of a grid outage; during normal operations, the utility draws on the battery to reduce peak demand.

31 The Commonwealth of Massachusetts, Department of Public Utilities. *Net Metering, Smart Provision, And the Forward Capacity Market.* D.P.U. 17-146-B. February 1, 2019. *https://d12v9rtnomnebu.cloudfront.net/library-page/D.P.U._17-146-B_Order_02.01.19.pdf*.

32 The program adminstrators' response to the DPU's Information Request DPU-Electric 2-3, wherein the program administrators state that they "may not offer the statewide storage offerings if they cannot achieve cost-effectiveness, i.e., if there are not enough storage devices already deployed and willing to enroll to be able to overcome any fixed costs necessary to offer the program."

33 Massachusetts Energy Storage Initiative. "State of Charge." *Massachusetts Department of Energy Resources (DOER)* and *Massachusetts Clean Energy Center (MassCEC)* (page xiii). July 2017. *https://www.mass.gov/files/2017-07/state-of-charge-report.pdf*.

34 The Commonwealth of Massachusetts. "Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan 2019–

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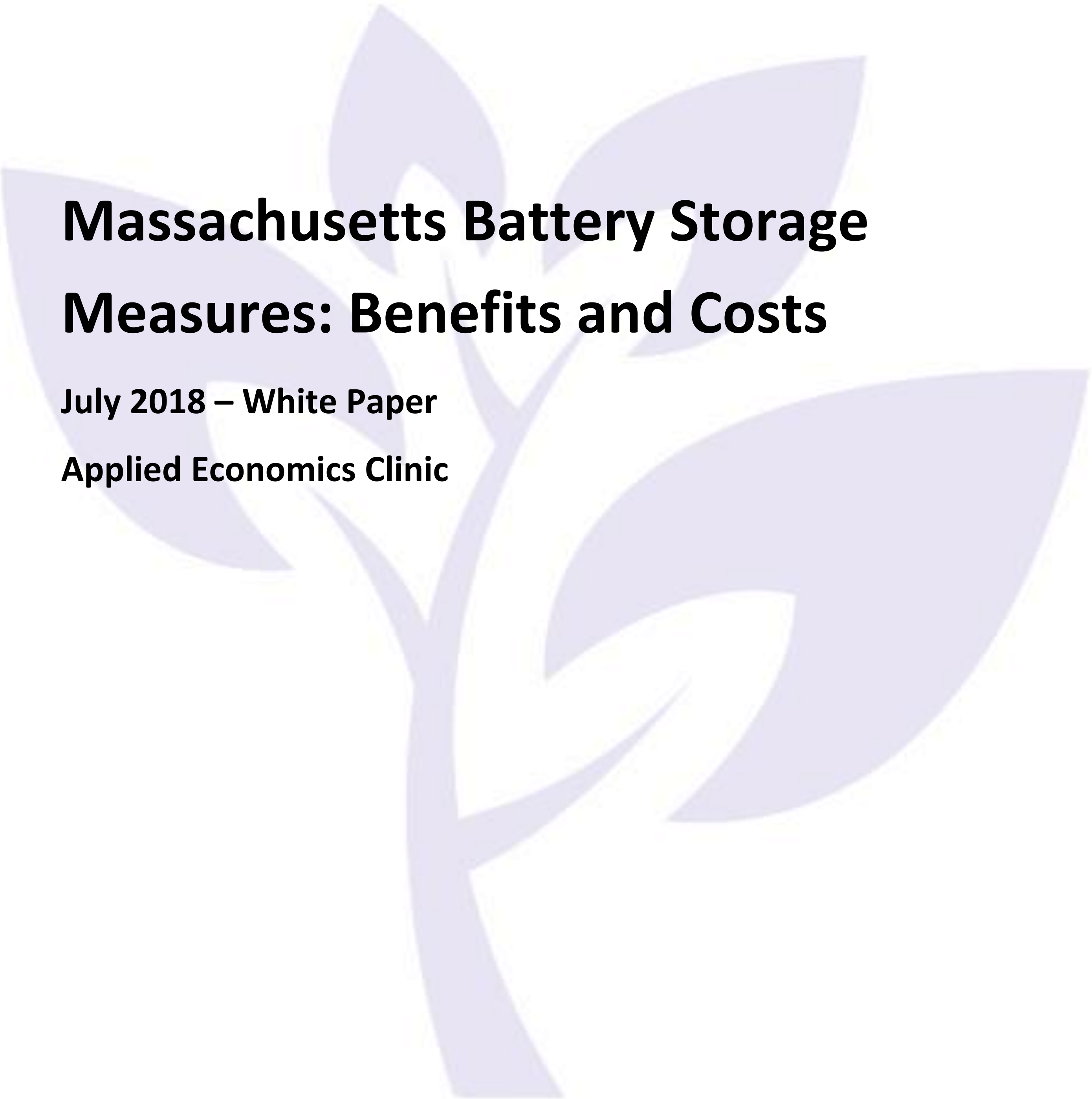
Appendix 1

MASSACHUSETTS BATTERY STORAGE MEASURES: BENEFITS AND COSTS



Massachusetts Battery Storage Measures: Benefits and Costs

July 2018 – White Paper

Applied Economics Clinic

Prepared for:

Clean Energy Group

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www.aeclinic.org

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Table of Contents

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About Clean Energy Group

Clean Energy Group (CEG) is a leading national, nonprofit advocacy organization working on innovative policy, technology, and finance strategies in the areas of clean energy and climate change. CEG promotes effective clean energy policies, develops new finance tools, and fosters public-private partnerships to advance clean energy markets that will benefit all sectors of society for a just transition. CEG assists states and local governments to create and implement innovative practices and public funding programs for clean energy and resilient power technologies. CEG manages the Clean Energy States Alliance (CESA), a national nonprofit consortium of public funders and agencies working together to accelerate clean energy deployment. Learn more at www.cleanegroup.org.

About Applied Economics Clinic

The Applied Economics Clinic is a 501(c)(3) non-profit consulting group housed at Tufts University's Global Development and Environment Institute. The Clinic provides expert testimony, analysis, modeling, policy briefs, and reports for public interest groups on the topics of energy, environment, consumer protection, and equity, while providing on-the-job training to a new generation of technical experts.

1. Introduction

Lithium-ion batteries for electric storage are considered in Massachusetts' energy efficiency program administrator's 2019-2021 draft plan, released April 30, 2018,[1] and addressed, partially, in the "BCR Model" spreadsheets (publicly released in June 2018) used to calculate cost-effectiveness in the April draft plan. Massachusetts' assessment of the cost-effectiveness of electric demand and peak-reducing measures' depends on the "BCRs"—or benefit-cost ratios—estimated in these spreadsheets. For measures to be included in the funding allocation and program implementation described in the 2019-2021 plan they must receive a benefit-cost ratio of 1.0 or higher; that is, a measure's benefits must have a higher value than its costs.

This Applied Economic Clinic white paper provides the calculations and assumptions necessary to estimate complete 2019 benefit-cost ratios for battery storage measures in Massachusetts, using a methodology identical to that of the program administrator's own "BCR Model" spreadsheets for the 2019-2021 and previous three-year efficiency plans. The resulting Massachusetts benefit-cost ratios for battery storage in 2019 are:

- 2.8 for a single-family home battery under the low-income efficiency program
- 3.4 for a multi-family apartment complex battery under the commercial and industrial efficiency programs

The benefits of electric battery storage outweigh their costs, and, therefore, must be offered by Massachusetts electric program administrators to their customers, in accordance with the Green Communities Act.[2] This white paper reviews the calculation of a value for battery storage of the cost and each type of benefit included in Massachusetts' cost-effectiveness assessment: avoided energy, avoided energy demand reduction induced price effects (DRIPE), summer generation capacity, winter generation capacity, electric capacity DRIPE, transmission, distribution, and reliability, non-energy benefits, and non-embedded environmental costs. Of these benefits, avoided capacity costs are by far the most substantial.

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[1] Massachusetts Program Administrators. 2018. "Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan: 2019-2021". http://ma-eeac.org/wordpress/wp-content/uploads/2019-2021-Three-Year-Energy-Efficiency-Plan-April-2018.pdf

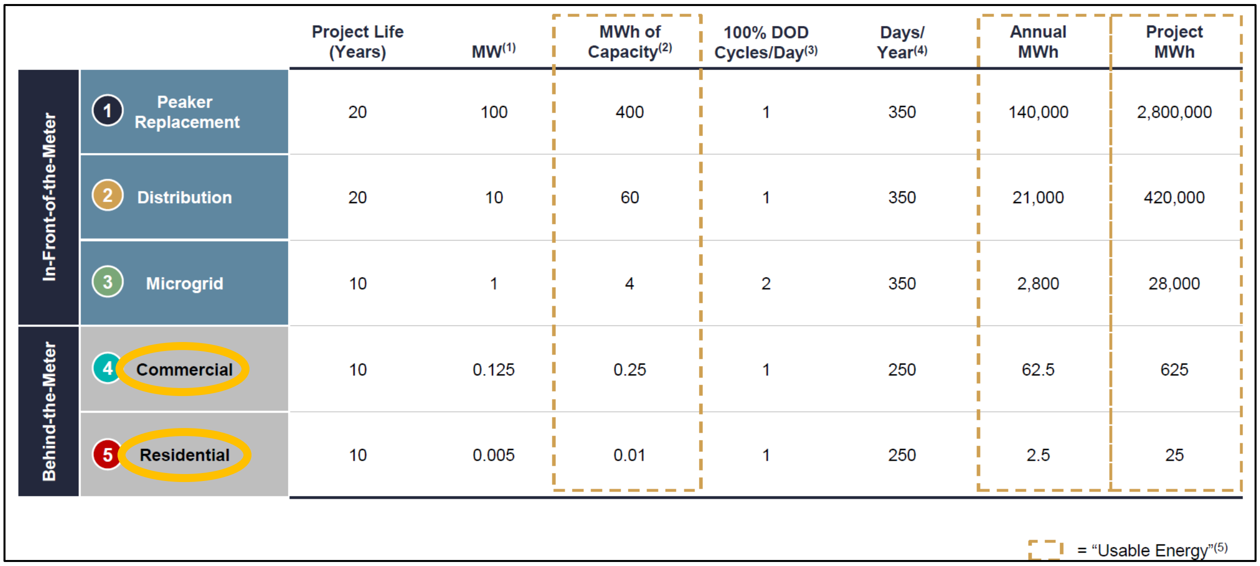
[2] The General Court of the Commonwealth of Massachusetts. 2008. Acts 308-80: An Act Relative to Green Communities. Chapter 169. https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169.

2. Engineering Assumptions

Lazard's *Levelized Cost of Storage 3.0* report outlines two behind-the-meter energy storage use cases: Case 4, commercial, and Case 5, residential.[3] Case 4, commercial, represents storage "designed for behind-the-meter peak shaving and demand charge reduction services for commercial energy users" while Case 5, residential, represents storage "designed for behind-the-meter residential home use," that "provide backup power, power quality improvements and extend the usefulness of self-generation".[4] This analysis adopts the lithium-ion assumptions for both Cases.

Figure 1 presents the technical parameters of all cases, with Cases 4 and 5 highlighted.

Figure 1. Energy storage use cases—operational parameters



		Project Life (Years)	MW(1)	MWh of Capacity(2)	100% DOD Cycles/Day(3)	Days/ Year(4)	Annual MWh	Project MWh
In-Front-of-the-Meter	1 Peaker Replacement	20	100	400	1	350	140,000	2,800,000
	2 Distribution	20	10	60	1	350	21,000	420,000
	3 Microgrid	10	1	4	2	350	2,800	28,000
Behind-the-Meter	4 Commercial	10	0.125	0.25	1	250	62.5	625
	5 Residential	10	0.005	0.01	1	250	2.5	25

⬚ = "Usable Energy"(5)

Source: Reproduced from Lazard's Levelized Cost of Storage Analysis – Version 3.0, page 9. https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf. *Emphasis added by Applied Economics Clinic.*

Figure 2 below presents Lazard's levelized cost of storage for Cases 4 and 5 according to their "high" component costs: capital, operations and maintenance (O&M), charging, taxes and other costs. In the calculations presented in this white paper, the following changes are made to Lazard's treatment of the components:

- Capital costs are de-escalated by 20 percent from the 2017 cost, following Lazard's assumption, to estimate the 2019 capital cost.

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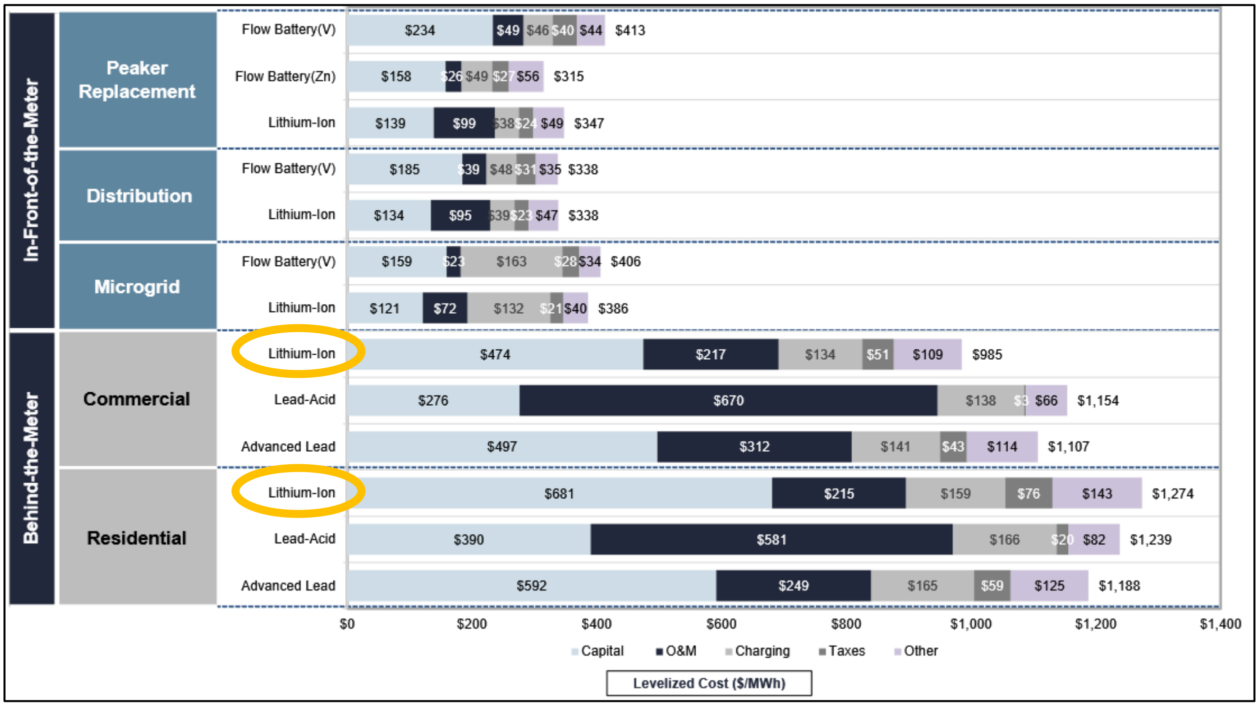
[3] Lazard. November 2017. *Lazard's Levelized Cost of Storage Analysis – Version 3.0*, page 8. https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf

[4] Ibid.

- Capital costs per MWh of battery capacity are adjusted to instead reflect capacity costs per MWh of use based on 52 days of use per year (that is, 52 full cycles per year—on average, one cycle per week) instead of the frequency of use shown in Figure 1.
- Charging costs are removed because, in Massachusetts, costs and savings related to the use of electricity are included in the benefits calculations of benefit-cost ratios. For measures—like storage—where on an annual basis megawatt-hours (MWhs) are lost instead of saved the net costs of charging are considered negative benefits. To include charging in these measures' levelized cost would be double counting.

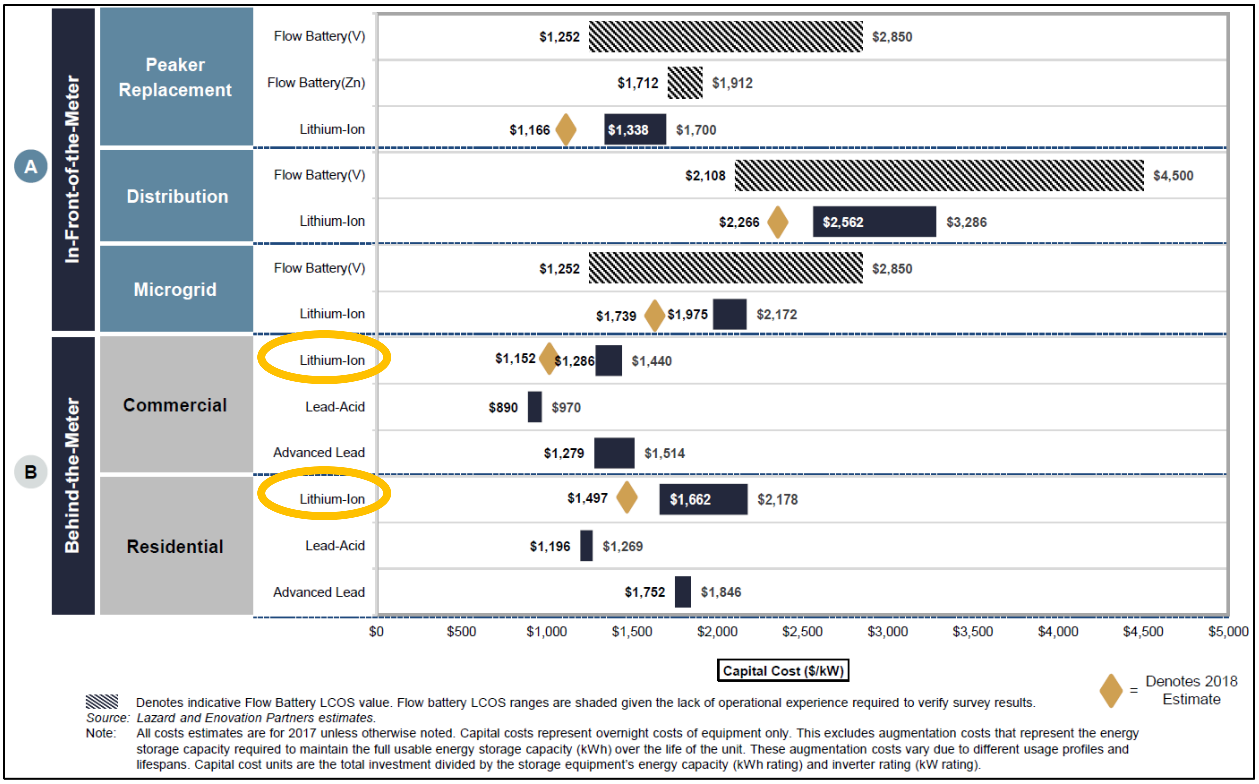
Figure 2. Levelized cost of storage components—high



Source: Reproduced from Lazard's Levelized Cost of Storage Analysis – Version 3.0, page 29. https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf. *Emphasis added by Applied Economics Clinic.*

Figure 2 and Figure 3 together show that Lazard's levelized capital costs of $474/MWh for commercial multi-family and $681/MWh for low-income single-family represent 1,440/kW for commercial and $2,178/kW for residential. When we reduce these costs by 20 percent for 2019, the per kW capital costs are $1,152/kW for multi-family and $1,742/kW for single-family.

Figure 3. Capital cost comparison: $/kW



▨ Denotes indicative Flow Battery LCOS value. Flow battery LCOS ranges are shaded given the lack of operational experience required to verify survey results.

Source: *Lazard and Enovation Partners estimates.*

Note: All costs estimates are for 2017 unless otherwise noted. Capital costs represent overnight costs of equipment only. This excludes augmentation costs that represent the energy storage capacity required to maintain the full usable energy storage capacity (kWh) over the life of the unit. These augmentation costs vary due to different usage profiles and lifespans. Capital cost units are the total investment divided by the storage equipment's energy capacity (kWh rating) and inverter rating (kW rating).

Source: Reproduced from Lazard's Levelized Cost of Storage Analysis – Version 3.0, page 15. https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf. *Emphasis added by Applied Economics Clinic.*

3. Total Resource Cost

The total resource cost is calculated as the product of the measure or system life in years, the annual production in MWh, and the levelized cost in dollars per MWh, scaled proportionately to the kW size of the system being analyzed. These kW system sizes used in this report are: 6 kW for a single-family battery in the low-income efficiency program, and 30 kW for multi-family battery in the commercial and industrial efficiency program. In their "BCR Model" spreadsheets, National Grid assumes 2.5 kW for residential batteries, and Cape Light Compact assumes 5 kW for residential and 5 kW for commercial and industrial batteries. Eversource and Unitil do not include any system size measures in their "BCR Model" spreadsheets. Because technical assumptions regarding battery performance and cost are proportional to system size throughout these calculations, system size does not impact on cost-effectiveness.

For simplicity, a single system of each kind of measure (residential and commercial) is assumed for the calculations presented in this white paper. This should not be interpreted as a recommendation for how many measures the program administrators should strive to provide.

Using this method, total resource costs for each measure are $13,163 for low-income measures and $46,322 for commercial and industrial measures (see Table 1 below). It is important to note that these total resource costs represent levelized costs per MWh of battery discharge, not capital costs, and are estimated for the 10-year lifetime of the measures.

Table 1. Total resource cost

Parameter for 2019	Low-Income	C&I	Source
Quantity	1	1	
Measure Life	10	10	Lazard's Levelized Cost of Storage Analysis v.3.0 November 2017, p.9
Maximum Load Reduction (kW)	6	30	
Annual kWh Production (kWh)	624	3,120	Lazard's Levelized Cost of Storage Analysis v.3.0 November 2017, p.9
2019 Levelized Cost ($/MWh) without capital costs	$434	$377	Lazard's Levelized Cost of Storage Analysis v.3.0 November 2017, p.12, 14, 29; "high" cost of storage components; 2017 total cost per MWh less capital and charging costs
2019 capital cost ($/kW)	$1,742	$1,152	Lazard's Levelized Cost of Storage Analysis v.3.0 November 2017, p.15, "high" cost of storage components; 2017 capital cost less 10% per year per Lazard
Total Resource Cost ($)	**$13,163**	**$46,322**	**Calculation; multiplied by measure life**

Source: Applied Economics Clinic calculation

4. Energy Use by Time Period

The program administrators' "BCR Model" methodology has traditionally been used to estimate the benefits and costs of energy efficiency measures that reduce annual energy demand. While the methodology includes the apparatus and assumptions necessary to estimate benefits from peak shifting measures—such as batteries—that change the pattern of energy demand but do not lower the annual total, this is not the way these spreadsheets have typically been used. For a typical energy efficiency measure, the gross annual kWh savings would be a positive value, but for the battery storage measures shown here, they are negative, due to round-trip efficiency losses inherent in batteries. Batteries are typically charged at times of low demand or low energy price and discharged at times of high demand or high energy prices. If batteries had perfect round-trip efficiency (no energy was lost in storing and discharging the battery), then gross annual kWh savings would equal zero. Energy out would equal energy in. However, Lazard assumes 15 percent efficiency losses for commercial batteries and 14 percent efficiency losses for residential batteries.[5] For this reason, gross annual kWh saved shows a loss, or negative value: negative 87.4 kWh for low-income and negative 468 kWh for commercial and industrial (see Table 2 below).

Table 2. Energy use by time period

Parameter for 2019	Low-Income	C&I	Source
EE: Gross Annual kWh Saved	(87.4)	(468.0)	Assume 15% efficiency loss for commercial; 14% for residential Lazard's Levelized Cost of Storage Analysis v.3.0 November 2017, p.31
Summer Peak Energy (%)	33.3%	33.3%	By assumption: representing a peak shifting measure
Summer Off-Peak Energy (%)	-33.3%	-33.3%	
Winter Peak Energy (%)	66.7%	66.7%	
Winter Off-Peak Energy (%)	-66.7%	-66.7%	
Summer Coincident (%)	100.0%	100.0%	MA PAs assumption
Winter Coincident (%)	100.0%	100.0%	By assumption
Summer Peak Energy MWh Net Lifetime	2.1	10.4	Changed PA calculation to refer to total peak MWh instead of total annual MWh savings/losses
Summer Off-Peak Energy MWh Net Lifetime	-2.4	-12.2	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh savings/losses; off peak calculated as 100%/(1-efficiency rate)
Winter Peak Energy MWh Net Lifetime	4.2	20.8	Changed PA calculation to refer to total peak MWh instead of total annual MWh savings/losses
Winter Off-Peak Energy MWh Net Lifetime	-4.8	-24.5	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh savings/losses; off peak calculated as 100%/(1-efficiency rate)

Source: Applied Economics Clinic calculations

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[5] Lazard. November 2017. *Lazard's Levelized Cost of Storage Analysis – Version 3.0*, page 31. https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf

The program administrators' "BCR Model" takes the annual kWh saved and divides it into four time-periods—summer peak, summer off-peak, winter peak, winter off-peak—totaling 100 percent. For example, National Grid's new residential buildings high-rise lighting measure is assumed to have annual savings allocated as follows: 12.9 percent summer peak, 15.2 percent summer off-peak, 36.3 percent winter peak, and 35.6 percent winter off-peak.

Alternatively, for a storage measure, the assumption used in this white paper is that energy is subtracted from energy demand during summer and winter peak (a negative percentage) and added on to demand during summer and winter off-peak (a positive percentage), adding up to zero across the four time-periods. (Efficiency losses are included in the calculation of gross annual kWh saved and are therefore not included in these shares to avoid double counting.) The values use in these calculations (shown in Table 2) are 33.3 percent summer peak and 66.7 percent winter peak, negative 33.3 percent summer off-peak and negative 66.7 percent winter off-peak, and 100 percent summer and winter coincident.[6] This is equivalent to assumption an equal use of the battery in every month of the year (where summer is assumed to last for four months, and winter for eight months).

Based on these assumptions, the avoided energy over a ten-year system life from a 6 kW low-income single-family battery is: 2.1 MWh of summer peak energy and 4.2 MWh of winter peak energy, and negative 2.4 MWh of summer off-peak energy and negative 4.8 MWh of winter off-peak energy. The avoided energy over a ten-year system life from a 30 kW commercial multi-family battery is: 10.4 MWh of summer peak energy and 20.8 MWh of winter peak energy, and negative 12.2 MWh of summer off-peak energy and negative 24.5 MWh of winter off-peak energy (see Table 2 above).

5. Avoided-Energy Benefits

Avoided-energy benefits are the product of avoided energy (in MWh) and avoided energy prices, as calculated in the *Avoided Energy Supply Components in New England: 2018 Report* (AESC 2018).[7] Avoided energy prices are calculated on an hourly basis in AESC 2018 and then aggregated to summer peak, summer off-peak, winter peak, winter off-peak. The average energy prices for these time periods, by year, are very sensitive to changes in the assignment of hours as peak or off-peak. AESC 2018 follows the definition of peak as 9 am to 11 pm each weekday (excluded holidays) for both summer (four months) and winter (eight months). This broad definition of "peak" is not useful in representing the strategic use of batteries to relieve tight energy markets in periods of high energy demand or high energy prices.

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[6] Program administrators hard-code a winter coincidence to peak of 0 percent (see "BCR Model" spreadsheets, 'ADMYr1 tab, AE4:AE123).

[7] Synapse Energy Economics. June 1, 2018. Avoided Energy Supply Components in New England: 2018 Report. http://www.synapse-energy.com/sites/default/files/AESC-2018-17-080-June-Release.pdf

As shown in Table 3, redefining peak as those hours with the highest energy prices or highest MWh sales results in a very different allocation of hours between summer peak, summer off-peak, winter peak, winter off-peak. By energy price, all but one of the highest priced hours are in the winter months, and 43 percent of these are off-peak. By demand, 28 percent are in winter and 48 percent of these are off-peak.

Table 3. Peak/Off-peak hours for 2019

		Highest 10% by	
	Total Count	**Energy Price**	**MWh**
Summer peak	1,260	0	317
Summer offpeak	1,668	1	313
Winter peak	2,565	502	128
Winter offpeak	3,267	373	118

Source: Applied Economics Clinic calculations

Table 4 demonstrates how average energy prices change based on each of these definitions. The average avoided energy price for winter peak is $47 under the AESC 2018 definition of peak, $80 under the definition of peak as those hours with the highest energy prices, and $73 under the definition of peak as those hours with the highest MWh sales. The average avoided energy price for winter off-peak is $42 under the AESC 2018 definition of peak, $78 under the definition of peak as those hours with the highest energy prices, and $75 under the definition of peak as those hours with the highest MWh sales.

The average avoided energy price for summer peak is $31 under the AESC 2018 definition of peak and $37 under the definition of peak as those hours with the highest MWh sales. The average avoided energy price for summer off-peak is $27 under the AESC 2018 definition of peak, $69 under the definition of peak as those hours with the highest energy prices, and $36 under the definition of peak as those hours with the highest MWh sales.

Table 4. Peak/Off-peak energy prices for 2019

		Highest 10% by	
	Total Count	**Energy Price**	**MWh**
Summer peak	$31	n/a	$37
Summer offpeak	$27	$69	$36
Winter peak	$47	$80	$73
Winter offpeak	$42	$78	$75

Source: Applied Economics Clinic calculation

Table 5 and Table 6 below present avoided-energy benefits using two different definitions.

Table 5 presents avoided-energy benefits using the AESC 2018 definition of peak; benefits are negative for both storage measures, meaning a cost to the electric system: -$22 for low-income single-family and -$138 for commercial multi-family.

Table 5. Avoided energy benefits: AESC 2018 definition of peak

Parameter for 2019	Low-Income	C&I	Source
Summer Peak Energy Benefits ($)	$113	$563	Changed PA calculation to refer to total peak MWh instead of total annual MWh; corrected erroneous cell reference to wrong avoided costs
Summer Off-Peak Energy Benefits ($)	(113.0)	(572.0)	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh; off peak calculated as 100%/(1-efficiency rate); corrected erroneous cell reference to wrong avoided costs
Winter Peak Energy Benefits ($)	$288	$1,440	Changed PA calculation to refer to total peak MWh instead of total annual MWh; corrected erroneous cell reference to wrong avoided costs
Winter Off-Peak Energy Benefits ($)	($310)	($1,569)	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh; off peak calculated as 100%/(1-efficiency rate); corrected erroneous cell reference to wrong avoided costs
Total Avoided Energy Benefits ($)	**($22)**	**($138)**	**Sum**

Source: Applied Economics Clinic calculation; cell references corrected in "BCR Model" spreadsheets, 'ADMStrategies' tab.

Table 6 presents avoided-energy benefits using the percent of hours by energy price definition that is consistent with discharging an average of one time per week: the highest 2.2 percent of hours by energy price in winter and the highest 5.0 percent of hours by energy price in summer. Following this method, batteries would have time to charge in between each discharge. In addition, discharges occur during times of highest energy prices. With just 52 discharges per year, it is possible to select times of very high energy prices, and still have time to charge between each discharge. Using this definition, benefits are positive for both storage measures—meaning a positive benefit to the system: $162 for low-income single-family and $787 for commercial multi-family.

Table 6. Avoided energy benefits: Discharging 52 times per year

Parameter for 2019	Low-Income	C&I	Source
Summer Peak Energy Benefits ($)	$136	$682	With peak definition adjusted to match 52 discharges per year
Summer Off-Peak Energy Benefits ($)	($119)	($602)	
Winter Peak Energy Benefits ($)	$461	$2,305	
Winter Off-Peak Energy Benefits ($)	($316)	($1,598)	
Total Avoided Energy Benefits ($)	**$162**	**$787**	**Sum**

Source: Applied Economics Clinic calculation

6. Avoided-Energy DRIPE Benefits

Demand reduction induced price effects (DRIPE) are defined in AESC 2018 as “the reduction in prices in the wholesale markets for capacity and energy, relative to the prices forecast in the Reference case, resulting from the reduction in quantities of capacity and of energy required from those markets due to the impact of efficiency and/or demand response programs. Thus, DRIPE is a measure of the value of efficiency in terms of the reductions in wholesale prices seen by all retail customers in a given period.”[8] Avoided-energy DRIPE benefits are the product of avoided energy and avoided-energy DRIPE as presented in AESC 2018.

The avoided-energy DRIPE benefits presented in Table 7 have been adapted to the definition of peak as the highest 10 percent by energy price, although this change makes relatively little difference to the resulting benefits. Benefits are positive for both storage measures, meaning a positive benefit to the system: $38 for low-income single-family and $185 for commercial multi-family.

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[8] Synapse Energy Economics. June 1, 2018. "Avoided Energy Supply Components in New England: 2018 Report". Page 13. http://www.synapse-energy.com/sites/default/files/AESC-2018-17-080-June-Release.pdf.

Table 7. Avoided-energy DRIPE benefits

Parameter for 2019	Low-Income	C&I	Source
Summer Peak Energy DRIPE Benefits ($)	$41	$206	Changed PA calculation to refer to total peak MWh instead of total annual MWh saved/lost; corrected erroneous cell reference to wrong avoided costs
Summer Off-Peak Energy DRIPE Benefits ($)	($33)	($165)	Changed PA calulation to refer to total off-peak MWH instead of total annual MWh saved/lost; off-peak calculated as 100$/(1-efficiency rate); corrected erroneous cell reference to wrong avoided costs
Winter Peak Energy DRIPE Benefits ($)	$126	$631	Changed PA calculation to refer to total peak MWH instead of total annual MWh saved/lost; corrected erroneous cell reference to wrong avoided costs
Winter Off-Peak Energy DRIPE Benefits ($)	($85)	($429)	Changed PA calculation to refer to total off-peak MWH instead of total annual MWh saved/lost; off-peak calculated as 100$/(1-efficiency rate); corrected erroneous cell reference to wrong avoided costs
Energy Electric Cross DRIPE Benefits ($)	($11)	($58)	
Total Energy DRIPE Benefits ($)	**$38**	**$185**	**Sum**

Source: Applied Economics Clinic calculations

7. Avoided-Capacity Benefits

The program administrator's "BCR Model" awards measures with benefits based on avoided costs of summer generation capacity, winter generation capacity, electric capacity DRIPE, transmission, distribution, and reliability—together referred to as "avoided-capacity benefits." The benefits shown in Table 8 are calculated following the program administrator's methodology exactly with one important change: the program administrator's assumption of a winter capacity value of $0/kW for storage measure has been adjusted to the AESC 2018 un-cleared capacity value by year.[9] The sum of all avoided-

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[9] Un-cleared capacity chosen as a proxy to replace zero values. Program administrators hard-code a winter capacity value of $0/kW (see "BCR Model" spreadsheets, 'Avoided Cost' tab, O9:O40), which applies to both energy efficiency and advanced demand management measures.

capacity benefits for the two storage measures is positive, $30,861 for low-income single-family and $154,300 for commercial multi-family.

Table 8. Avoided-capacity benefits

Parameter for 2019	Low-Income	C&I	Source
Summer Generation Capacity Benefits ($)	$2,586	$12,928	
Winter Generation Capacity Benefits ($)	$2,586	$12,928	Changed PA calculation to use uncleared capacity value per kW instead of $0. Note that PAs assign winter generation a value of $0/kW for all measures.
Electric Capacity DRIPE Benefits ($)	$14,362	$71,810	
Transmission Benefits ($)	$2,491	$12,454	
Distribution Benefits ($)	$8,342	$41,708	
Reliability Benefits ($)	$494	$2,472	
Total Electric Capacity Benefits ($)	**$30,861**	**$154,300**	**Sum**

Source: Applied Economics Clinic calculations

8. Avoided-Non-Energy Benefits

The program administrators' "BCR Model" assigns non-energy benefits to numerous energy efficiency measures based on the *Massachusetts Program Administrators' Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts Evaluation*.[10] Table 9 lists non-energy benefits for which monetary values were provided in the 2011 Evaluation; marked in green are the subset of these benefits assigned to measures in the program administrator's 2019-2021 April draft plan.

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[10] Massachusetts Program Administrators. 2011. *Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation*. http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf

Table 9. Avoided-non-energy benefits

NEI	Duration
UTILITY PERSPECTIVE	
Arrearages	Annual
Bad debt write-offs	Annual
Terminations and reconnections	Annual
Rate discounts	Annual
Customer calls	Annual
Collections notices	Annual
Safety-related emergency calls	Annual
Insurance savings	—
SOCIETAL PERSPECTIVE	
National Security	Annual
NON-RESOURCE BENEFITS	
Appliance Recycling – Avoided landfill space	One time
Appliance Recycling – Reduced emissions due to recycling plastic and glass, reduced emissions	One time
Appliance Recycling – Reduced emissions due to incineration of insulating foam	One time
PARTICIPANT PERSPECTIVE (OWNERS OF LOW-INCOME RENTAL HOUSING), PER HOUSING UNIT	
Marketability/ease of finding renters	Annual
Reduced tenant turnover	Annual
Property value	One time
Equipment maintenance (heating and cooling systems)	Annual
Reduced maintenance (lighting)	Annual
Durability of property	Annual
Tenant complaints	Annual
PARTICIPANT PESPECTIVE (OCCUPANT)	
Higher comfort levels	Annual
Quieter interior environment	Annual
Lighting quality & lifetime	One time
Increased housing property value	One time (Annual for NLI RNC)
Reduced water usage and sewer costs (dishwashers)	Annual
Reduced water usage and sewer costs (faucet aerators)	Annual
Reduced water usage and sewer costs (low flow showerheads)	Annual
More durable home and less maintenance	Annual
Equipment and appliance maintenance requirements	Annual
Health related NEIs	Annual
Improved safety (heating system, ventilation, carbon monoxide, fires)	Annual
Window AC NEIs	Annual

**** Green cells showing the Benefits in April Draft of 2019-2021 Plan**

Source: Massachusetts Program Administrators. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. *Emphasis added by Applied Economics Clinic.*

While storage may provide many non-energy benefits, our literature review did not turn up any valuations of these benefits (see Table 10).

Table 10. Non-energy benefits sources reviewed

Eichman et al. December 2015. "Operational Benefits of Meeting California's Energy Storage Targets." National Renewable Energy Laboratory.
Edmunds et al. February 2017. "The Value of Energy Storage and Demand Response for Renewable Integration in California." Lawrence Livermore National Laboratory.
Edmunds et al. June 2013. "The Value of Energy Storage and Demand Response for Renewable Integration in California." Prepared for the California Energy Commission by Lawrence Livermore National Laboratory.
Energy Storage Association. 2018. "Incidental and Other Benefits." http://energystorage.org/energy-storage/energy-storage-benefits/benefit-categories/incidental-and-other-benefits
Hledik, et al. 2017. "Stacked Benefits: Comprehensively Valuing Battery Storage in California." Prepared for Eos Energy Storage.
Lazard. 2017. "Lazard's Levelized Cost of Storage Analysis – Version 3.0."
Massachusetts Department of Energy Resources and Massachusetts Clean Energy Center. 2016. "State of Charge: Massachusetts Energy Storage Initiative."
Massachusetts Program Administrators. 2011. "Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation." NMR Group, Inc.
Medina et al. 2014. "Electrical Energy Storage Systems: Technologies' State-of-the-Art, Techo-Economic Benefits and Applications Analysis." 47th Hawaii International Conference on System Sciences.
New York Department of Public Service. July 2015. "Staff White Paper on Benefit-Cost Analysis in the Reforming Energy Vision Proceeding." Paper No. 14-M-0101.
NMR Group, Inc. August 2011. "Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation." Prepared for Massachusetts Program Administrators.
ReOpt Web Tool User Manual. https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf
Stark et al. February 2015. "Renewable Electricity: Insights for the Coming Decade." Prepared by Joint Institute for Strategic Energy Analysis for the National Renewable Energy Laboratory.
U.S. Energy Information Administration. 2018. "U.S. Battery Storage Market Trends." U.S. Department of Energy.
Woolf et al. September 2014. "Benefit-Cost Analysis for Distributed Energy Resources." Advanced Energy Economy Institute and Synapse Energy Economics.

Therefore, the calculations presented in this white paper include only one non-energy benefit: a one-time increase to property values of adding a storage system. These values are calculated using the "low-income" benefit from the 2011 Evaluation for a heating retrofit: which was reported to be $949 in the *Massachusetts Program Administrators' Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts Evaluation*. The sum of all avoided-non-energy benefits for the two storage measures is positive, $5,235 for low-income single-family and $510 for commercial multi-family (see Table 11).

Table 11. Avoided-non-energy benefits

Parameter for 2019	Low-Income	C&I	Source
One time per Unit (Net)	**$5,235**	**$510**	Massachusetts' Program Administrators' Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts Evaluation August 15, 2011; p.1-6, 1-8: Increased housing property value is $949 for LI; for multi-family property owners (marketability/ease of finding renters, property value; equipment maintenance) is $17.03 per unit Electric State-wide Cost and Savings Table for 2011: LI 1-4 family heating retrofit TRC for one measure is $1,895; for multi-family $1,155 Resulting assumption: LI housing property value increase by 1/2 of measure capital cost for single-family and 1% for owners of multi-family

Source: Applied Economics Clinic calculations

Avoided-non-energy benefits are the only benefit category in this cost-effectiveness assessment that would change if these batteries were offered in a residential efficiency program, and not in a "low-income" or means-tested program.

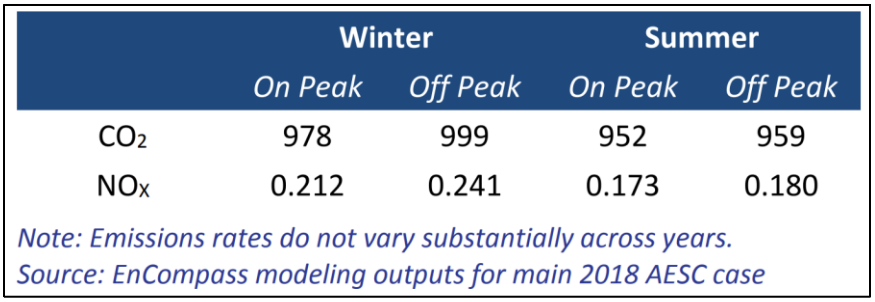
9. Avoided Non-Embedded Environmental Costs

Avoided non-embedded-costs are the product of avoided emissions and the avoided cost of emissions from AESC 2018. These avoided costs are "non-embedded" in the sense that they are externality costs: costs that are not included in market prices but have value to Massachusetts. In the program administrators' "BCR Model" spreadsheets' non-embedded costs are set to zero; the benefit-cost ratios present below adopt this same assumption of zero non-embedded environmental costs.

The section presents the benefits that would occur if non-embedded costs instead included a $100 per metric ton cost of carbon dioxide (CO_2), the lower of two non-embedded CO_2 costs provided in AESC 2018. Here, AESC 2018's definition of peak is important in two ways.

First, AESC 2018 assumes (as a result of its modeling of the hourly dispatch of New England electric generation resources) that CO_2 emissions rates (lbs/MWh) are higher in off-peak hours than they are in peak hours (see Table 12).

Table 12. Electric-sector CO_2 and NO_x emissions rate (lbs/MWh)



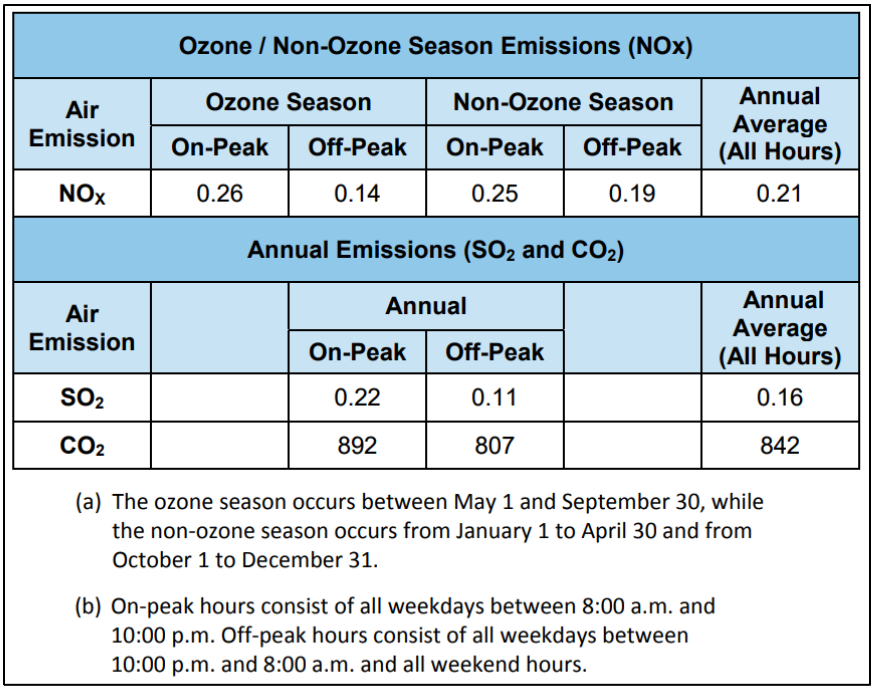
	Winter		Summer	
	On Peak	*Off Peak*	*On Peak*	*Off Peak*
CO_2	978	999	952	959
NO_x	0.212	0.241	0.173	0.180

Note: Emissions rates do not vary substantially across years.
Source: EnCompass modeling outputs for main 2018 AESC case

Source: Avoided Energy Supply Components in New England: 2018 Report by Synapse Energy, Inc. Table 150. *http://www.synapse-energy.com/sites/default/files/AESC-2018-17-080-June-Release.pdf.*

This finding runs counter to the more common assumption that, in New England, CO_2 emissions rates are lower in off-peak hours and higher in peak hours. ISO-New England reported higher peak than off-peak emissions in is its 2016 annual emissions report (see Table 13), which has held true in the last two years (see Figure 4).

Table 13. 2016 LMU Marginal Emission Rates—All LMUs (lb/MWh)



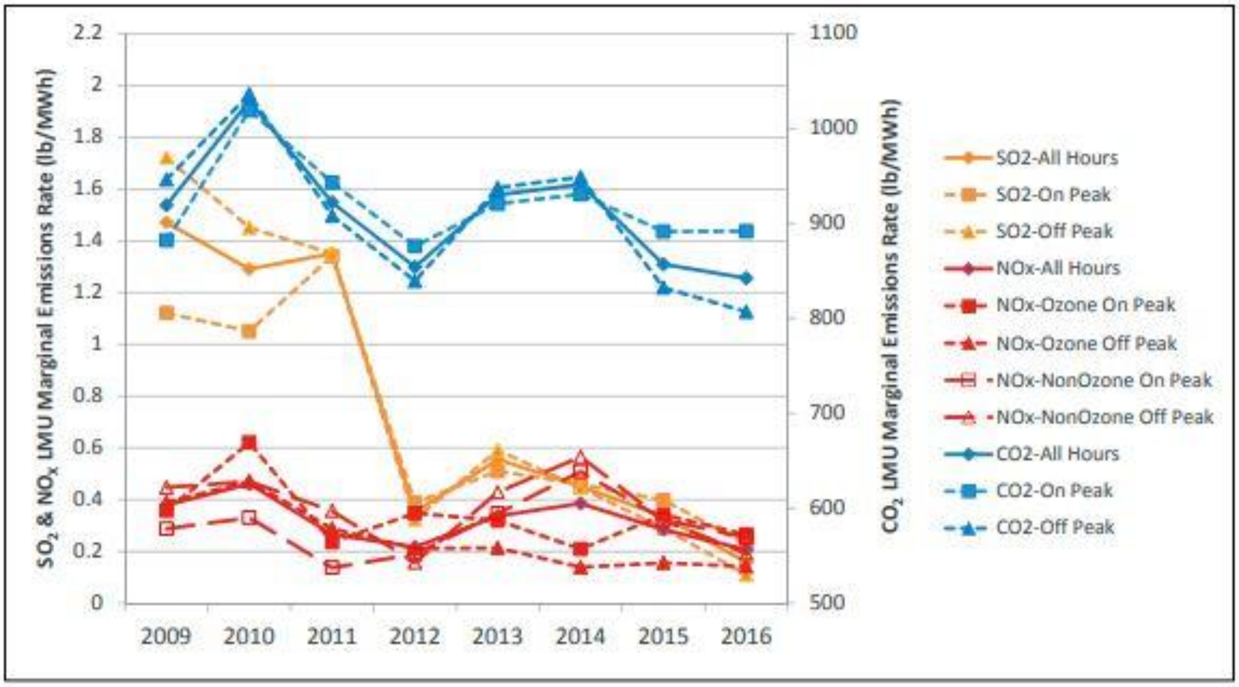
Ozone / Non-Ozone Season Emissions (NOx)					
Air Emission	Ozone Season		Non-Ozone Season		Annual Average (All Hours)
	On-Peak	Off-Peak	On-Peak	Off-Peak	
NO_X	0.26	0.14	0.25	0.19	0.21
Annual Emissions (SO_2 and CO_2)					
Air Emission		Annual			Annual Average (All Hours)
		On-Peak	Off-Peak		
SO_2		0.22	0.11		0.16
CO_2		892	807		842

(a) The ozone season occurs between May 1 and September 30, while the non-ozone season occurs from January 1 to April 30 and from October 1 to December 31.

(b) On-peak hours consist of all weekdays between 8:00 a.m. and 10:00 p.m. Off-peak hours consist of all weekdays between 10:00 p.m. and 8:00 a.m. and all weekend hours.

Source: ISO-NE 2016 Emissions Report, Table 5-3. https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf.

Figure 4. 2009-2016 Marginal Emissions Rates, all LMUs (lb/MWh)



Source: ISO-NE 2016 Emissions Report, Table 5-9. https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf.

Second, the definition of peak impacts not only energy prices (see Table 3 and Table 4 above) but also the average emissions rates for these periods. The calculations presented in this white paper do not include any correction or revised definition with regards to emission rates. The necessary data are not available in the AESC 2018 report or user interface.

Both Table 14 and Table 15 present avoided non-energy-costs using AESC 2018's definition of peak. Table 14 presents avoided non-embedded costs using the AESC 2018 peak and off-peak emission rates; benefits are negative for both storage measures—meaning a cost to the system: -$51 for low-income single-family and -$270 for commercial multi-family.

Table 14. Avoided-non-embedded costs: AESC 2018 peak and off-peak emissions rates

Parameter for 2019	Low-Income	C&I	Source
Summer Peak Energy Benefits ($)	$90	$452	Changed PA calculation to refer to total peak MWh instead of total annual MWh; changed peak and off-peak CO2 emissions rates
Summer Off-Peak Energy Benefits ($)	($106)	($535)	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh; off peak calculated as 100%/(1-efficiency rate); changed peak and off-peak CO2 emissions rates
Winter Peak Energy Benefits ($)	$186	$930	Changed PA calculation to refer to total peak MWh instead of total annual MWh; changed peak and off-peak CO2 emissions rates
Winter Off-Peak Energy Benefits ($)	($221)	($1,117)	Changed PA calculation to refer to total off-peak MWh instead of total annual MWh; off peak calculated as 100%/(1-efficiency rate); changed peak and off-peak CO2 emissions rates
Total Avoided Non-Embedded Benefits ($)	**($51)**	**($270)**	**Sum**

Source: Applied Economics Clinic calculations

Table 15 presents avoided non-energy-costs using the peak and off-peak emission rates for ISO-New England's 2018 emissions report; benefits are negative (but smaller) for both storage measures, meaning a cost to the system: -$12 low-income single-family and -$83 for commercial multi-family.

Table 15. Avoided-non-embedded costs: ISO-New England peak and off-peak emissions rates

Parameter for 2019	Low-Income	C&I	Source
Summer Peak Energy Benefits ($)	$85	$423	With peak / offpeak emission rates changed to 2016 ISO-NE values: 2016 ISO New England Generator Air Emissions Report, January 2018, Table 5-3, https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf
Summer Off-Peak Energy Benefits ($)	($89)	($451)	
Winter Peak Energy Benefits ($)	$170	$848	
Winter Off-Peak Energy Benefits ($)	($178)	($903)	
Total Avoided Non-Embedded Benefits ($)	**($12)**	**($83)**	**Sum**

Source: Applied Economics Clinic calculations

In the total benefits and benefit-cost ratios presented below, non-embedded environmental costs are set to zero, following the program administrators' "BCR Model" assumption.

10. Total Benefits

Table 16 sums up total benefits for these two storage measures assuming the peak definite of highest 10 percent of hours by energy price for energy benefits, non-energy impacts for low-income households, and zero non-embedded environmental costs. For low-income single-family measure, $36,296; for commercial multi-family measure, $155,782.

Table 16. Total benefits

Parameter for 2019	Low-Income	C&I
Total Avoided Energy Benefits ($)	$162	$787
Total Energy DRIPE Benefits ($)	$38	$185
Total Electric Capacity Benefits ($)	$30,861	$154,300
Total Non-Energy Impacts ($)	$5,235	$510
Total Avoided Non-Embedded Benefits ($)	$0	$0
Total Electric Benefits ($)	**$36,296**	**$155,782**

Source: Applied Economics Clinic calculations

11. Benefit-Cost Ratio

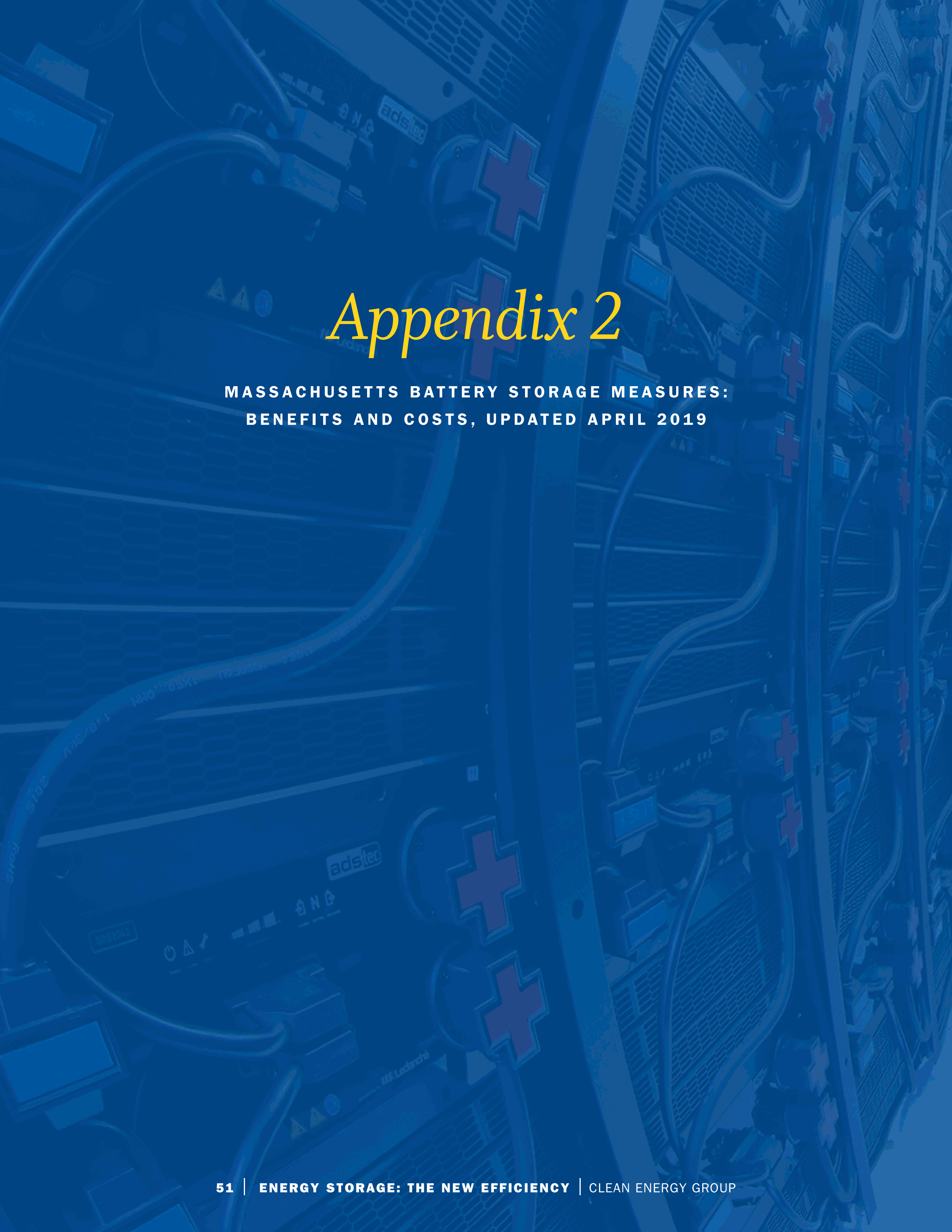
Based on the assumptions and methodology presented in this white paper, the benefit-cost ratio for the low-income single-family measure is 2.8 (that is, the value of benefits is nearly three times that of the costs, see Table 17) and the benefit-cost ratio for the commercial multi-family measure is 3.4. Both measures pass the cost-effectiveness test for Massachusetts.

Table 17. Total benefits and costs

Parameter for 2019	Low-Income	C&I
Total Electric Benefits ($)	$36,296	$155,782
Total Resource Cost ($)	$13,163	$46,322
Benefit-Cost Ratio	**2.8**	**3.4**

Source: Applied Economics Clinic calculations

If avoided-non-energy benefits were removed from these calculations, their benefit-cost ratios would be reduced to 2.4 for the single-family battery and 3.4 for the multi-family battery.



Appendix 2

MASSACHUSETTS BATTERY STORAGE MEASURES: BENEFITS AND COSTS, UPDATED APRIL 2019

Massachusetts Battery Storage Measures: Benefits and Costs

Updated April 2, 2018 – White Paper

Applied Economics Clinic

Prepared for:

Clean Energy Group

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April 2, 2019

[AEC-2019-04-WP-01]

Table of Contents

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Executive Summary

On January 29, 2019, the Massachusetts Department of Public Utilities (DPU) approved—with some exceptions and limitations—program administrators' 2019-2021 three-year energy efficiency plan. The program administrators' plan includes incentives for battery storage along with cost-effectiveness assessment of these storage measures. This Applied Economics Clinic white paper updates the July 2018 white paper[1] of the same name: The July 2018 white paper reviewed the program administrators' April 2018 cost-effectiveness assessment and provided an independent cost-effectiveness analysis whereas this white paper reviews program administrators' final assessment submitted October 31, 2018. The October assessment of battery storage measures' specifications, associated programs, and related costs differ substantially from the plans submitted in April.[2]

This white paper reviews the methodology, assumptions, and results of the cost-effectiveness assessment of storage measures presented in the approved 2019-2021 plan and the assessment of battery measures that was submitted to DPU by Cape Light Compact but not approved, including discussion of:

- ***Measure specification:*** Program administrators' storage measures differ, and these differences impact on cost-effectiveness. Nonetheless, almost all of the included active demand response programs are cost effective.
- ***Inclusion of measures in the final plan:*** Program administrators' way of presenting storage measure adoption is inconsistent and sometimes difficult to interpret. With that limitation in mind, the approved 2019-2021 plan appears to include battery storage equivalent to 0.1 to 0.5 percent of peak load, depending on electric distributor (for a total of about 34 megawatts of storage statewide).
- ***Improvements to April draft plan:*** Corrections to program administrators' April draft cost-effectiveness assessments include the treatment of storage measures' charging and discharging periods, and the inclusion of a Massachusetts-specific cost of Global Warming Solutions Act compliance. These needed corrections were discussed in the July 2018 white paper.
- ***Critical omissions:*** Despite improvements and corrections, the final plan still includes several critical omissions in the program administrators' calculations of the benefit-cost ratios of

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[1] Stanton, E.A. July 2018. *Massachusetts Battery Storage Measures: Benefits and Costs*. Applied Economics Clinic White Paper. AEC-2018-07-WP-02. https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs

[2] The July 2018 white paper does not apply to the final (October 31, 2018) version of Massachusetts' program administrator efficiency and storage plan.

storage, including the omission of any value related to non-energy benefits, the omission of any value related to winter reliability, and the undervaluing of summer capacity benefits.

The findings of this white paper are limited by the extent of information made available by the program administrators at the time of this writing.[3]While several of these issues likely have the effect of undervaluing benefits in storage measures' cost-effectiveness analysis, all program administrators have assessed the programs that include storage measures as cost-effective in all years (with the exception of Unitil in 2019).

The total Massachusetts summer peak capacity addition three-year plan offering for behind-the-meter storage was 34 MW, or two-fifths of the Commonwealth's assessed storage potential (84 MW). Nevertheless, these omissions should be corrected in future energy efficiency planning, to more completely and fairly evaluate the cost-effectiveness of behind-the-meter energy storage.

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[3] Somewhat more detailed descriptions of Massachusetts' storage measures have been made available in two March 2019 presentations to the Energy Efficiency Advisory Council: Schlegel, J. March 20, 2019. *Active Demand Management: Where Are We Now Plus A Look Ahead.* Slide presentation by the EEAC Consultant Team to the Massachusetts Energy Efficiency Advisory Council. Available at: http://ma-eeac.org/march-20-eeac-meeting/; Massachusetts Energy Efficiency Program Administrators. March 20, 2019. *Active Demand Reduction Demonstration & Initiative Update.* Slide presentation by the EEAC Consultant Team to the Massachusetts Energy Efficiency Advisory Council. Available at: http://ma-eeac.org/march-20-eeac-meeting/;

1. Introduction

Lithium-ion batteries for electric storage are considered in Massachusetts' energy efficiency program administrator's 2019-2021 plan, last updated October 31, 2018,[4] and addressed in the "BCR Model" spreadsheets (provided in November 2018) used to calculate the values in the approved plan and in the assessment of battery measures submitted by Cape Light Compact but not approved. Massachusetts' assessment of electric demand and peak-reducing measures' cost-effectiveness depends on the "BCRs"—or benefit-cost ratios—estimated in these spreadsheets. For measures to be included in the funding allocation and program implementation described in the 2019-2021 plan, they must receive a benefit-cost ratio of 1.0 or higher; that is, a measure's benefits must have a higher value than its costs.[5]

This Applied Economic Clinic white paper reviews the calculations and assumptions used by program administrators to estimate complete 2019-2021 benefit-cost ratios for battery storage measures in Massachusetts, according to the methodology shown in program administrator's own "BCR Model" spreadsheets for the October 31, 2018 plan.[6]

Massachusetts program administrators' benefit-cost ratios for 2019 range from 0.0 to 6.2 for individual storage measures (benefit-cost ratios of 1.0 and higher indicate cost-effectiveness) and from 0.7 to 7.9 for the advanced demand management programs (called "active demand reduction" or ADR in the approved three-year plan) that include storage measures. Only one ADR program (that is, the group of measures considered jointly) for one utility in one year (Unitil's residential ADR program for 2019) failed to achieve cost-effectiveness. All other utility storage-related programs for all years were found to be cost effective.

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[4] Massachusetts Department of Public Utilities. Docket Nos. 18-116, 18-117, 18-118, 18-119. *Three Year Energy Efficiency Plan for 2019 through 2021.* October 31, 2018. "Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan: 2019-2021". Available at: http://ma-eeac.org/wordpress/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf

[5] The General Court of the Commonwealth of Massachusetts. 2008. Acts 308-80: *An Act Relative to Green Communities.* Chapter 169. https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169.

[6] This February 2019 AEC white paper updates a July 2018 white paper of the same name: Stanton. July 2018. *Massachusetts Battery Storage Measures: Benefits and Costs.* Applied Economics Clinic White Paper. AEC-2018-07-WP-02. https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs

Because the benefits of electric battery storage outweigh their costs, as shown in this report, these cost-effective measures must be offered by Massachusetts electric distributors to their customers, in accordance with the Green Communities Act.[7]

Each program administrator may offer three ADR programs—residential, income-eligible, and commercial/industrial. The Massachusetts program administrators have developed different battery measures (along with other ADR measures) to offer to their customers: System and Performance, Daily Dispatch, and Targeted Performance (discussed below). Storage cost effectiveness depends on measure specification.

Massachusetts energy efficiency program administrators' benefit-cost ratios for the ADR programs that include battery storage show cost-effectiveness (i.e., are greater than 1.0), with the exception of Unitil's residential program in 2019. Cost-effectiveness can be measured either at the program or the measure level. Massachusetts program administrators have three storage-related programs in parallel to the three programs offered for energy efficiency: residential, income-eligible, and commercial and industrial ADR (see Table 1). Each of these three programs can include three types of measures (described in more detail below): storage system and performance, storage daily dispatch, and storage targeted performance. Not every program administrator offers every measure type.

Table 1. MA program administrators' storage-related programs and measures

Programs	Measures
Residential Advanced Demand Management Program (A2e)	**A2e Storage System and Performance**
	A2e Storage Daily Dispatch
	A2e Storage Targeted Dispatch
Income-Eligible Advanced Demand Management Program (B1b)	**B1b Storage System and Performance**
	B1b Storage Daily Dispatch
	B1b Storage Targeted Dispatch
Commercial/Industrial Advanced Demand Management Program (C2c)	**C2c Storage System and Performance**
	C2c Storage Daily Dispatch
	C2c Storage Targeted Dispatch

Program cost-effectiveness is calculated as the summed benefits of measures in the program divided by the summed costs of these measures <u>plus</u> the costs of the program's administration. Storage program cost-effectiveness depends, therefore, on three factors: (1) the cost-effectiveness of the measures in the programs; (2) the composition of those measures (how many of each measure is included); and (3) the expected costs to administer the program.

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[7] The General Court of the Commonwealth of Massachusetts. 2008. Acts 308-80: *An Act Relative to Green Communities*. Chapter 169. https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169

Storage ***measure*** cost-effectiveness depends on the specification of these measures, and Massachusetts' program administrators have designed very different storage measures for inclusion in their final 2019-2021 plan.

Programs and measures not achieving cost-effectiveness are shown in orange text in Table 2.

Table 2. MA program administrators' benefit-cost ratios for ADR measures

BCRs	Cape Light			Eversource			National Grid			Unitil		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Residential Advanced Demand Management Program (A2e)												
Program BCRs	*1.6*	*2.4*	*2.4*	*1.0*	*1.4*	*1.6*	*1.5*	*2.4*	*2.5*	*0.7*	*1.1*	*1.2*
Direct Load Control	4.9	6.6	7.4	5.0	5.0	5.0	5.3	5.5	5.3	5.2	9.6	9.6
Behavioral DR												
Storage System and Performance		3.0	3.0									
Storage Daily Dispatch				1.5	1.5	1.5	4.9	4.9	5.0			
Storage Targeted Dispatch				0.0	0.0	0.0	0.1	0.1	0.1			
EV Load Management								0.8	0.8			
Income-Eligible Advanced Demand Management Program (B1b)												
Program BCRs		*2.3*	*2.4*					*2.4*	*2.4*			
Direct Load Control												
Behavioral DR												
Storage System and Performance		3.0	3.0									
Storage Daily Dispatch												
Storage Targeted Dispatch												
EV Load Management												
Commercial/Industrial Advanced Demand Management Program (C2c)												
Program BCRs	*7.5*	*4.6*	*4.7*	*2.9*	*2.9*	*2.8*	*7.9*	*4.8*	*4.9*	*2.7*	*2.9*	*3.1*
Interruptible Load	9.7	9.8	9.8	7.9	7.9	7.9	7.5	7.5	7.5	4.2	4.2	4.2
Winter Interruptible Load												
Storage System and Performance		3.0	3.0									
Storage Daily Dispatch				1.7	1.7	1.7	4.9	4.9	5.0	6.2	6.2	6.2
Storage Targeted Dispatch				3.2	3.2	3.2	0.1	0.1	0.1	0.1	0.1	0.1
Custom	8.3	8.3	8.3		2.0	2.0	1.3	1.3	1.3			

Note: Blank cells indicate that no measures were offered.

Among the battery storage measures offered by program administrators in their final 2019-2021 plan, only Eversource and National Grid's residential Storage Targeted Dispatch measures, and National Grid's commercial and industrial Storage Targeted Dispatch measure do not meet cost-effectiveness in all three years.

"Storage System and Performance" measures: Cape Light Compact's proposed storage measures differ from those of other program administrators and from the description of storage measures approved in the 2019-2021 plan. The Cape Light Compact proposed storage measures would provide 1,000 participants with free 4-kilowatt (kW) batteries and then manage the batteries' charging and discharge to reduce system peak demand without an additional incentive. (In contrast, the other program administrators' approved storage measures do not provide batteries to participants.) Cape Light Compact's proposed measures have a 10-year measure life.

"Storage Daily and Targeted Dispatch" measures: Eversource, National Grid, and Unitil's proposed storage measures use a "bring your own battery" structure: participants provide their own batteries and receive financial incentives for allowing the program administrators to send dispatch signals (to which either the customer or a third-party aggregator then respond):

> *The 2019-2021 Plan includes new statewide Active Demand Reduction Offerings for residential and commercial and industrial sectors designed to reduce summer and winter peak demand. Customers will earn an incentive for verifiably shedding load in response to events called by Program Administrators…The Program Administrators will offer a technology agnostic approach in order to encourage innovations and capture all cost-effective demand reductions. (2019-2021 3YP, p.9)*
>
> *[A] new bring-your-own device active demand reduction initiative that allows residential and income eligible customers to expand the use of controllable efficiency equipment that can provide demand reduction during peak hours;…a new specialized storage performance offering will provide enhanced incentives to customers to dispatch energy storage during daily peak hours in the summer and winter months. (2019-2021 3YP, p.14)*

The Eversource, National Grid, and Unitil "measures" are an incentive, not a battery. These incentives have a 1-year measure life.

While the System and Performance, and Daily Dispatch measures are cost-effective in all years, some Targeted Dispatch measures are not. Of program administrators' residential (Eversource and National Grid) and commercial and industrial (Eversource, National Grid, and Unitil) Targeted Dispatch measures, only one—Eversource's commercial and industrial measure—is cost-effective. Among Targeted Dispatch measures, Eversource's cost-effective commercial and industrial measure differs from the measures that are not cost-effective in one important regard: The cost-effective measure includes summer discharge and benefits, the others do not. The absence of summer discharge for certain measures raises questions regarding measure design that cannot be answer given current public materials. Greater transparency in providing detailed descriptions of each storage measure would facilitate third-party reviewers in offering useful critique and analysis, and could lead to improvements in measure design and selection.

The Targeted Dispatch measures, which (according to program administrators' BCR spreadsheets) are not dispatched in summer months, are assigned no benefit for their kW savings and cannot achieve cost-effectiveness.

2. Storage is included only minimally for some program administrators

The number of storage measures included in the final 2019-2021 plan is difficult to interpret and is not comparable among the program administrators (see Table 3).

Table 3. MA program administrators' number of measures for ADR measures

Number of Measrues	Cape Light			Eversource			National Grid			Unitil		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Residential Advanced Demand Management Program (A2e)												
Program Number of Measures	*1,918*	*4,242*	*4,984*	*5*	*5*	*5*	*10,609*	*14,464*	*18,154*	*170*	*204*	*245*
Direct Load Control	1,918	2,942	3,384	1	1	1	9,375	12,336	15,050	170	204	245
Behavioral DR												
Storage System and Performance		1,300	1,600									
Storage Daily Dispatch				2	2	2	420	820	1,254			
Storage Targeted Dispatch				2	2	2	420	820	1,254			
EV Load Management							393	488	596			
Income-Eligible Advanced Demand Management Program (B1b)												
Program Number of Measures		*300*	*400*									
Direct Load Control												
Behavioral DR												
Storage System and Performance		300	400									
Storage Daily Dispatch												
Storage Targeted Dispatch												
EV Load Management												
Commercial/Industrial Advanced Demand Management Program (C2c)												
Program Number of Measures	*215*	*529*	*578*	*8*	*9*	*9*	*7*	*7*	*7*	*6*	*8*	*8*
Interruptible Load	214	328	377	1	1	1	1	1	1	1	2	2
Winter Interruptible Load				1	1	1	1	1	1	1	2	2
Storage System and Performance		200	200									
Storage Daily Dispatch				2	2	2	2	2	2	2	2	2
Storage Targeted Dispatch				4	4	4	2	2	2	2	2	2
Custom	1	1	1		1	1	1	1	1			

Different program administrators appear to be using different definitions of a "storage measure" and may even be defining a "measure" differently for different sectors. Cape Light Compact's System and Performance measure is a single 4-kW battery provided to a participant together with the Compact's managed discharge of that battery. For Eversource, National Grid, and Unitil's commercial and industrial Daily and Targeted Dispatch measures, and for Eversource's residential Daily and Targeted Dispatch measures, the measure appears to be the aggregated managed discharge of all batteries signed up with the program. For National Grid and Unitil's residential Daily and Targeted Dispatch measures, however, the measure appears to be each battery signed up for the program (see Table 4). (That there is a difference between Cape Light Compact and National Grid's residential storage measures can be observed in their measures lives: 10 years for Cape Light Compact's battery provision measure and 1 year for National Grid's bring-your-own battery measure.)

Table 4. Definition of measure

	Cape Light	Eversource	National Grid	Unitil
Residential Advanced Demand Management Program (A2e)	Single battery provided	Aggregate of BYO batteries	Single BYO battery	Single BYO battery
Income-Eligible Advanced Demand Management Program (B1b)	Single battery provided	N/A	N/A	N/A
Commercial/Industrial Advanced Demand Management Program (C2c)	Single battery provided	Aggregate of BYO batteries	Aggregate of BYO batteries	Aggregate of BYO batteries

The Massachusetts Energy Efficiency Advisory Council's consultant team identified the potential for including 84.3 megawatts (MW) of summer peak behind-the-meter storage capacity in the 2019-2021 plan, and a total of 250 MW for all ADR programs. Table 5 presents the programs administrators' ADR offering in summer peak kW, from their October 31, 2018 filing. (Massachusetts' program administrators' winter storage offering is not the same as that for summer.) Here, again, the information provided is difficult to interpret and is not comparable among the program administrators. Eversource, National Grid, and Unitil's Daily and Targeted Dispatch measures have a one-year measure life and therefore the capacity additions do not accumulate. Cape Light Compact's System and Performance measures have a 10-year measure life and the summer peak capacity presented likely refers to annual incremental additions to storage capacity (i.e. new batteries given to participants in each year). Assuming that Cape Light Compact's summer capacity accumulates but the other program administrators' does not, the total Massachusetts summer peak capacity addition offering for behind-the-meter storage was 33.9 MW, or two-fifths of the consulting team's estimate of storage potential.

Table 5. MA program administrators' summer kW savings for ADR measures

Summer kW Savings	Cape Light			Eversource			National Grid			Unitil		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Residential Advanced Demand Management Program												
Program Summer kW Savings	*1,055*	*2,869*	*3,400*	*2,050*	*3,150*	*4,250*	*6,099*	*8,597*	*11,033*	*94*	*112*	*135*
Direct Load Control	1,055	1,618	1,861	2,000	3,000	4,000	5,156	6,785	8,278	94	112	135
Behavioral DR												
Storage System and Performance		1,250	1,539									
Storage Daily Dispatch				50	150	250	903	1,763	2,696			
Storage Targeted Dispatch												
EV Load Management							39	49	60			
Income-Eligible Advanced Demand Management Program												
Program Summer kW Savings		*289*	*385*									
Direct Load Control												
Behavioral DR												
Storage System and Performance		289	385									
Storage Daily Dispatch												
Storage Targeted Dispatch												
EV Load Management												
Commercial/Industrial Advanced Demand Management Program												
Program Summer kW Savings	*5,798*	*6,053*	*6,080*	*28,000*	*57,500*	*96,000*	*69,500*	*79,000*	*90,000*	*300*	*500*	*500*
Interruptible Load	5,395	5,458	5,485	27,000	47,000	75,000	66,000	72,000	79,000	200	400	400
Winter Interruptible Load												
Storage System and Performance		192	192									
Storage Daily Dispatch				500	5,000	10,000	2,500	5,000	7,000	100	100	100
Storage Targeted Dispatch				500	5,000	10,000						
Custom	403	403	403		500	1,000	1,000	2,000	4,000			

By program administrator, total summer capacity for storage measures is as follows:

- Cape Light Compact (adding together 2020 and 2021 as discussed above): 3.8 MW (not approved)
- Eversource: 20.3 MW
- National Grid: 9.7 MW
- Unitil: 0.1 MW
- **Total: 33.9 MW including Cape Light Compact; 30.1 MW without Cape Light Compact**

Eversource and Cape Light Compact's combined proposed storage measures amounted to 0.5 percent of Eversource's peak load (or 0.4 percent after removing Cape Light Compact's peak savings), National Grid's measures amount to 0.2 percent of its peak load, and Unitil's measures amount to 0.1 percent of its peak load.[8] For comparison, the Energy Efficiency Advisory Council's consultant team's estimated

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[8] ISO-NE Regional Network Load data. August 2018. https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/reg-net-load-costs

potential storage capacity of 84.3 MW is 0.9 percent of Eversource, National Grid, and Unitil's combined summer peak load.

3. Improvements from the April draft storage benefit-cost analysis

Massachusetts' program administrators' approved cost-effectiveness analysis of storage measures offered in their final 2019-2021 plan includes several improvements over their April 2018 draft.[9]

Peak shifting

The April draft represented peak shifting by allocating peak energy (MWh) savings across four seasons (summer peak and off-peak, winter peak and off-peak), rather than explicitly showing charging and discharging in its calculations. The approved 2019-2021 plan instead treats both winter and summer, and charging and discharging as separate "measures."[10] This new method allows for a clearer accounting of what is and is not valued. It should be noted, however, that storage measures' benefit-cost ratios only have meaning for the aggregate of these four "measures" (summer charging, summer discharging, winter charging, winter discharging). The four "measures" together make up the storage measure as one would normally understand it.

Avoided non-embedded costs

The April draft assumes a $0 per metric ton non-embedded cost of carbon dioxide (CO_2). The final 2019-2021 plan includes the Massachusetts-specific avoid cost of Global Warming Solutions Act compliance as developed in the August 2018 supplement[11] to the *Avoided Energy Supply Components in New England: 2018 Report* (AESC 2018)[12]: $35 per short ton of CO_2. This adds to the measured benefits of storage.

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[9] For a complete review of Massachusetts program administrators April 2018 draft 2019-2021 benefit-cost analysis for storage measures see: Stanton. July 2018. Massachusetts Battery Storage Measures: Benefits and Costs. Applied Economics Clinic White Paper. AEC-2018-07-WP-02. https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs

[10] Some program administrators' storage programs do not have savings in every season. The framework for calculating benefits reported in the three-year plans, however, is consistent across program administators.

[11] Knight, Pat, et al. August 2018. *Analysis of the Avoided Costs of Compliance of the Massachusetts Global Warming Solutions Act: Supplement to 2018 AESC Study*. Prepared for Massachusetts Department of Energy Resources and Massachusetts Department of Environmental Protection. http://ma-eeac.org/wordpress/wp-content/uploads/MA-GWSA-Supplement-to-2018-AESC-Study.pdf

[12] Synapse. June 2018. *Avoided Energy Supply Components in New England: 2018 Report.* http://www.synapse-energy.com/sites/default/files/AESC-2018-17-080-June-Release.pdf

4. Remaining concerns from the April draft storage benefit-cost analysis

Some other issues presented in the July 2018 version[13] of this critique have not been addressed and remain concerns in the approved 2019-2021 plan:

Non-energy benefits are omitted

Program administrators did not include non-energy benefits (such as avoided utility costs, national security, benefits to landlords, increased property values, improved comfort levels, safety, and health, and reduced home maintenance) in their cost-effectiveness assessment of battery measures, although non-energy benefits such as these are included in the cost-effectiveness assessments of energy efficiency measures. This omission is discussed in Section 6.

Summer capacity values are undervalued

Program administrators include only one-tenth of the capacity prices associated with summer peak reductions from batteries in their cost-effectiveness assessment. This largely unexplained assumption is discussed in Section 6.

Winter reliability values are omitted

Program administrators assign a value of $0 to the reliability of Massachusetts' winter electric service in their cost-effectiveness assessment of battery measures. This omission is discussed in Section 6.

Peak versus off-peak emissions

Avoided non-embedded-costs are the product of avoided emissions and the avoided cost of emissions from AESC 2018. These avoided costs are "non-embedded" in the sense that they are externality costs: costs are that are not included in market prices but have value to Massachusetts. AESC 2018 assumes (as a result of its modeling of the hourly dispatch of New England electric generation resources) that CO_2 emissions rates (lbs/MWh) are higher in off-peak hours than they are in peak hours (see Table 6).

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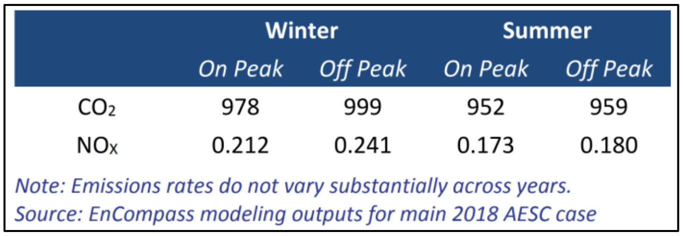
[13] Stanton. July 2018. Massachusetts Battery Storage Measures: Benefits and Costs. Applied Economics Clinic White Paper. AEC-2018-07-WP-02. https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs

Table 6. Electric-sector CO_2 and NO_x emissions rate (lbs/MWh)



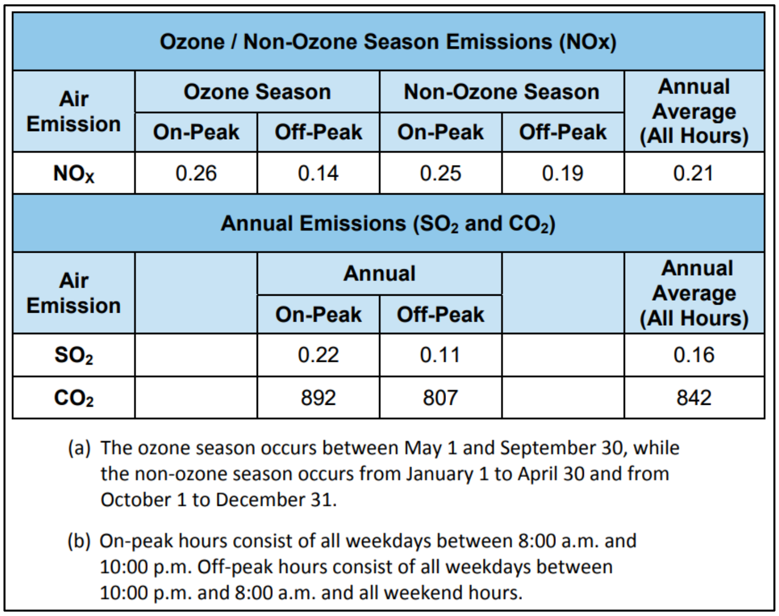
	Winter		Summer	
	On Peak	*Off Peak*	*On Peak*	*Off Peak*
CO_2	978	999	952	959
NO_X	0.212	0.241	0.173	0.180

Note: Emissions rates do not vary substantially across years.
Source: EnCompass modeling outputs for main 2018 AESC case

Source: Avoided Energy Supply Components in New England: 2018 Report by Synapse Energy, Inc. Table 150. Available online at http://www.synapse-energy.com/sites/default/files/AESC-2018-17-080-June-Release.pdf.

This assumption runs counter to the more commonly used assumption that, in New England, CO_2 emissions rates are lower in off-peak hours, and higher in peak hours. Higher peak emissions are reported by ISO-New England is its 2016 annual emissions report (see Table 7) and have been so in the last two years as shown in Figure 1. The definition of peak impacts not only on energy prices but also on the average emissions rates for these periods.

Table 7. 2016 LMU Marginal Emission Rates—All LMUs (lb/MWh)



Ozone / Non-Ozone Season Emissions (NOx)					
Air Emission	**Ozone Season**		**Non-Ozone Season**		**Annual Average (All Hours)**
	On-Peak	**Off-Peak**	**On-Peak**	**Off-Peak**	
NO_X	0.26	0.14	0.25	0.19	0.21

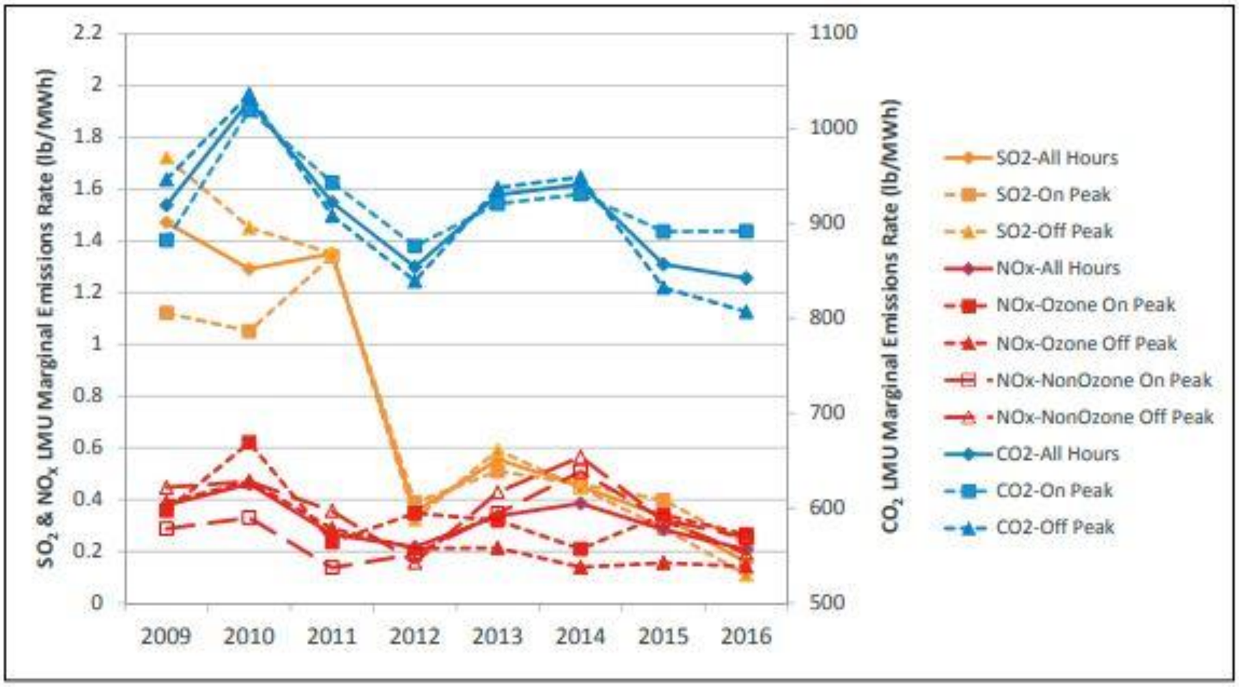
Annual Emissions (SO_2 and CO_2)					
Air Emission		**Annual**			**Annual Average (All Hours)**
		On-Peak	**Off-Peak**		
SO_2		0.22	0.11		0.16
CO_2		892	807		842

(a) The ozone season occurs between May 1 and September 30, while the non-ozone season occurs from January 1 to April 30 and from October 1 to December 31.

(b) On-peak hours consist of all weekdays between 8:00 a.m. and 10:00 p.m. Off-peak hours consist of all weekdays between 10:00 p.m. and 8:00 a.m. and all weekend hours.

Source: ISO-NE 2016 Emissions Report. Table 5-3. Available online at: https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf.

Figure 1. 2009-2016 Marginal Emissions Rates, all LMUs (lb/MWh)



Source: ISO-NE 2016 Emissions Report, Table 5-9. Available online at: https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf.

Program administrators' final plan continues to follow the AESC 2018 assumption that (contrary to ISO-New England historical data) New England generator's CO_2 emission rates are higher off-peak than on. The adoption of this unfounded assumption in program administrators' plan means that storage energy benefits, which include emissions benefits, are likely lower than they would otherwise be.

Average energy price by time period

Battery measures' avoided-energy benefits are the product of avoided energy (in MWh) and avoided energy prices, as calculated in AESC 2018. Avoided energy prices are calculated on an hourly basis in AESC 2018 and then aggregated to summer peak, summer off-peak, winter peak, winter off-peak. The average energy prices for these time periods, by year, are very sensitive to changes in the assignment of hours as peak or off-peak. AESC 2018 follows the definition of peak as from 9 am to 11 pm each weekday (excluded holidays) for both summer (four months) and winter (eight months).

As shown in

Table 8, redefining peak as those hours with the highest energy prices or highest MWh sales results in a very different allocation of hours between summer peak, summer off-peak, winter peak, winter off-peak. By energy price, all but one of the highest priced hours are in the winter months, and 43 percent of these are off peak. By demand, 28 percent are in winter and 50 percent of these are off peak.

Table 8. Peak/Off-peak hours for 2019

		Highest 10% by	
	Total Count	Energy Price	MWh
Summer peak	1,260	0	317
Summer offpeak	1,668	1	313
Winter peak	2,565	502	128
Winter offpeak	3,267	373	118

Source: Stanton. July 2018. Massachusetts Battery Storage Measures: Benefits and Costs. Applied Economics Clinic White Paper. AEC-2018-07-WP-02. https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs

The program administrators continue to assume average summer and winter, peak and off-peak, energy prices instead of using hourly data from AESC 2018 modeling to better identify energy prices during expected periods of charging and discharging for storage measures. The approved 2019-2021 plan continues this practice with the likely result that energy prices during periods of discharge are being undervalued in storage measures' cost-effectiveness assessments.

5. Critical omissions in October methodology

Three key methodological choices stand out as areas of particular concern in the cost-effectiveness assessments for storage measures presented in the final 2019-2021 plans: no value is assigned to non-energy benefits, summer capacity is undervalued, and no value is assigned to winter reliability.

Non-energy benefits valued at $0

In addition to energy benefits (avoided cost of: energy, generation capacity, transmission and distribution infrastructure, and emission permits), storage-related measures also provide non-energy benefits to both consumers and utilities. The program administrators' "BCR Model" assigns non-energy benefits to numerous energy efficiency measures based on the *Massachusetts Program Administrators' Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts Evaluation*[14], including: avoided utility costs, national security, benefits to landlords, increased property values, improved comfort levels, safety, and health, and reduced home maintenance.

The Massachusetts' program administrators have omitted the value of the non-energy benefits of storage in their 2018 cost-effectiveness assessments. A March 2019 Applied Economics Clinic white paper, *Massachusetts Non-Energy Benefits of Battery Storage*, addresses this issue in detail and provides evidence of the following benefits: avoided power outages, higher property values, avoided fines, avoided collections and terminations, avoided safety-related emergency calls, job creation, and reduced

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[14] Massachusetts Program Administrators. 2011. *Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation*. http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf

power plant land usage.[15] The program administrators' failure to include these non-energy benefit values in their benefit-cost ratio calculations for energy storage likely resulted in their undervaluing storage in the three-year energy efficiency plan.

Summer capacity is undervalued

Program administrators' approved cost-effectiveness assessments reduce the summer capacity and electric capacity price sensitivity (called "DRIPE") to 10 percent of its calculated value for almost all storage measures. The BCR spreadsheets refer to this 90 percent reduction as the "Limited Demand Response Scaling Factor," but neither explain nor cite the source of this modeling choice. AESC 2018 includes two oblique references that may refer to this benefit reduction:

> *The PJM load forecasters ran sensitivities on their generally similar regression-based forecasts at the request of the Maryland Office of Peoples Counsel. Those sensitivities showed that an equal-percentage load reduction on all hours for three years resulted in a reduction in the forecast by 10 to 30 percent of the load reduction starting by the seventh year (four years after the end of the modeled load reduction).* (p.104)
>
> *The PJM load forecasters ran sensitivities on their econometric forecasting model and found that load reductions on a few high-load days each summer would reduce the load forecast by only about 10 percent of that from an energy efficiency reduction in all hours. Program administrators should model the effect of selective high-hour reductions on the ISO New England load forecast before claiming any avoided capacity costs from those resources. For initial screening, program administrators may wish to credit those measures with 10 percent of the values in Table 41.*[107] *(Footnote 107: On the other hand, a PA may theoretically claim additional savings if it can demonstrate that its summer DR program reduces load every day during the July/August summer peak forecast period.)* (p.105)

Massachusetts' program administrators appear to have chosen to take a sensitivity analysis conducted for Maryland on electric peak demand forecasts for the PJM region as evidence that not only demand response but most advanced demand or storage measures only operate during 10 percent of peak hours. With this assumption in place, storage BCRs are approximately one-third lower than they would otherwise be (e.g. a BCR of 0.5 with this scaling factor would otherwise be 1.5 without it). Only 10 percent of peak hours are assigned a value, and the value assigned is that of the average across all peak hours defined as 9am to 11pm on weekdays. This method neither captures the high value of avoiding the small number of hours with very high energy costs, nor the smaller per hour value of other "peak hours" (as defined by the program administrators).

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[15] Woods, B. and Stanton, E.A. March 2019. *Massachusetts Non-Energy Benefits of Battery Storage*. Applied Economics Clinic White Paper. AEC-2019-03-WP-01. Available online: https://aeclinic.org/publicationpages/2019/3/15/massachusetts-non-energy-benefits-of-battery-storage.

Winter reliability values at $0

Because New England's peak times for electric consumption occur in summer months, it is this "summer peak" that is used to calibrate markets for generation capacity. Avoided capacity costs are, therefore, the savings from reduced needs to capacity investments vis-à-vis summer peak.

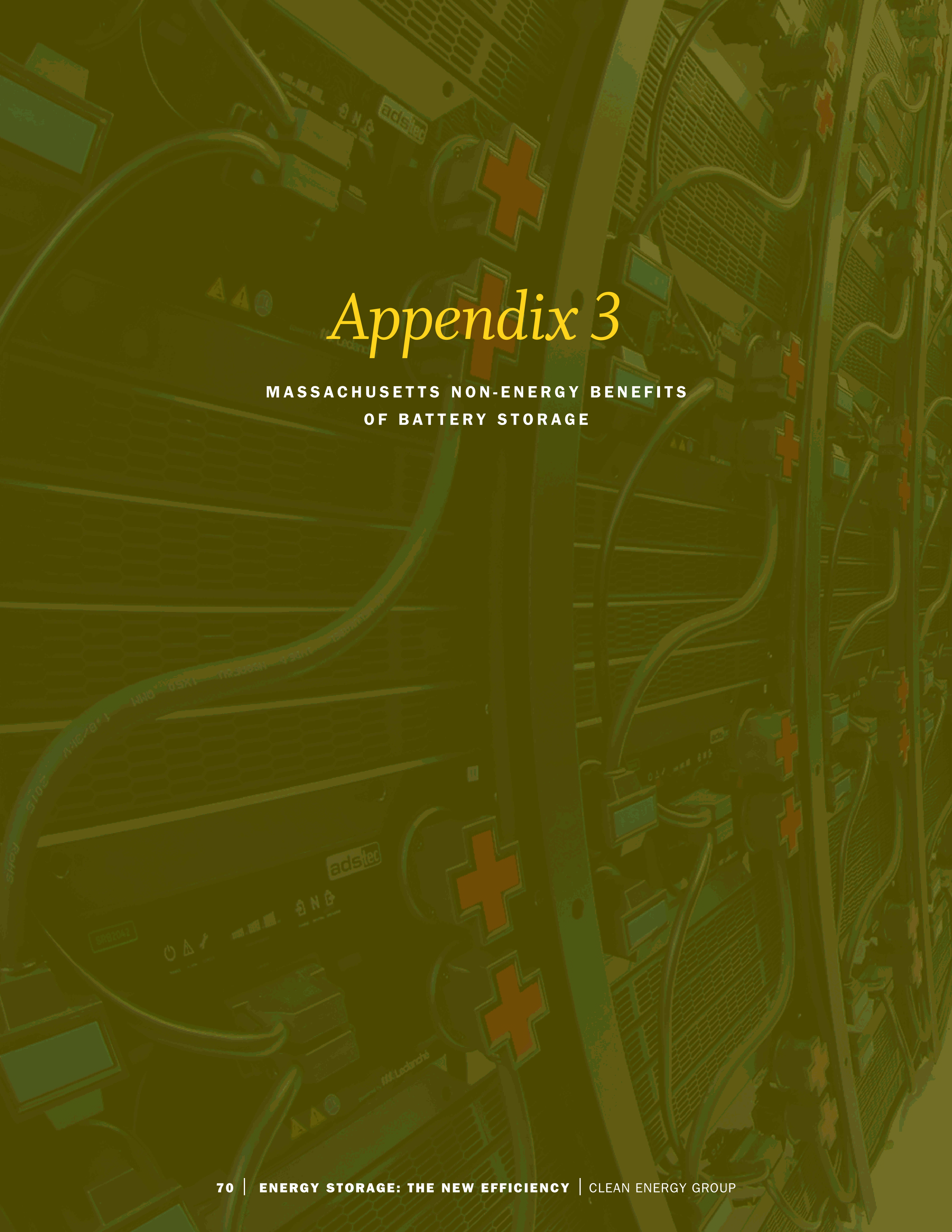
Reduced demand for peak generation capacity in winter does not avoid New England capacity market purchases and is called "winter reliability" in reference to this difference. Nonetheless, reduced winter peak capacity demands (increased winter reliability) holds a substantial value for Massachusetts as the Commonwealth works to balance coincident demands for natural gas used for heating and for electric generation.

Program administrators' final 2019-2021 plan acknowledges storage measures' impact on winter reliability:

> *The innovations in this Plan include new active demand reduction efforts that will have an impact on summer peak demand and winter reliability, while strongly supporting the Commonwealth's greenhouse gas reduction goals. (p.29-30)*

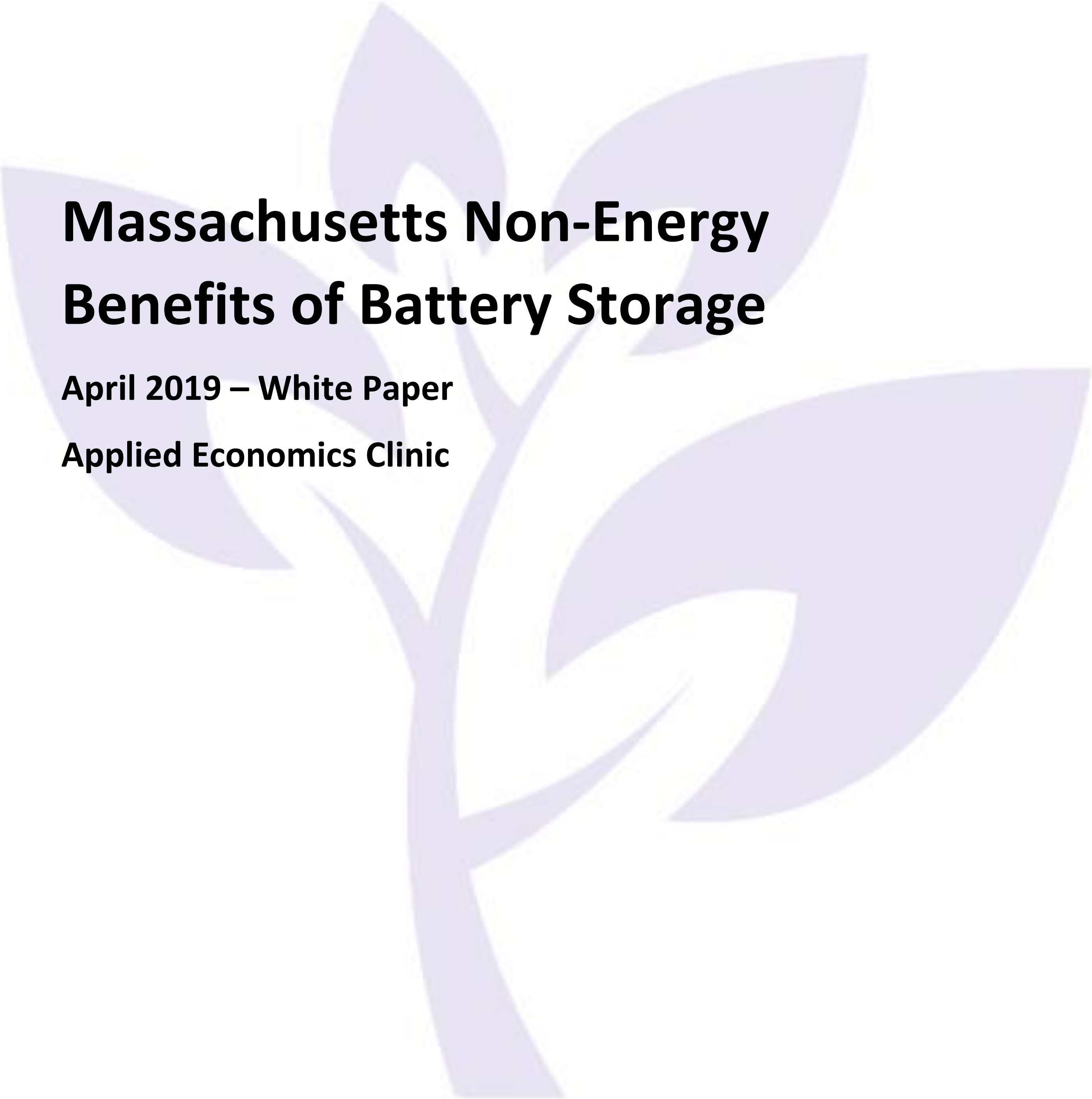
but omits a value for winter reliability. The approved 2019-2021 plan explains that a winter reliability benefit is under development:

> *The Program Administrators have agreed with DOER and the Attorney General to conduct a study to be commenced in Q1 of 2019 to quantify any benefits associated with winter peak capacity reduction. The PAs will issue an RFP and conduct this study in collaboration with the DOER, the Attorney General and the Council consultants. Study results will be aligned with and compatible with the 2018 AESC. If new benefits are identified as a result of this study, the Program Administrators will apply those benefits to reported values. (p.169)*



Appendix 3

MASSACHUSETTS NON-ENERGY BENEFITS OF BATTERY STORAGE



Massachusetts Non-Energy Benefits of Battery Storage

April 2019 – White Paper

Applied Economics Clinic

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Table of Contents

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Executive Summary

Behind the meter battery storage in Massachusetts benefits the energy system itself—lowering costs—and also affords “non-energy benefits” to the participants of storage programs, to electric distributors, and to society. To date, these non-energy benefits have not been included in efforts by utility program administrators to calculate energy storage benefit-cost ratios. For an energy efficiency measure to be included in a program administrator’s energy efficiency program, that measure must have a benefit-cost ratio that is greater than 1—that is, the benefits must be found to outweigh the costs. Leaving non-energy benefits out of cost-benefit calculations may lead to energy efficiency programs that are not offering all the cost-effective efficiency measures that are available. Some of non-energy benefits may be more difficult to quantify than energy system benefits, but leaving non-energy benefits out of programmatic cost-effectiveness assessments has the same effect as assuming they have no value. Omitting these important values may lead to decisions regarding battery investments that are not strategic or economic for the Commonwealth, and puts battery storage measures at a disadvantage vis-à-vis demand response measures and efficiency measures that do include non-energy benefits in their cost-benefit calculations. In this white paper, we present the results of a preliminary assessment of seven non-energy benefits of battery storage, as summarized in Table ES-1.

Table ES-1. Non-energy benefits of battery storage in Massachusetts

	Non-Energy Benefit (2018$)
1) Avoided power outages	
Battery storage helps avoid outages, and all of the costs that come with outages for families, businesses, generators and distribution companies	Residential: **$1.72**/kWh Commercial/Industrial: **$15.64**/kWh
2) Higher property values	
Installing battery storage in buildings increases property values for storage measure participants by: (1) increasing leasable space; (2) increasing thermal comfort; (3) increasing marketability of leasable space; and (4) reducing energy costs	**$5,325/**housing unit for low-income single family participants **$510/**housing unit for owners of multi-family housing
3) Avoided fines	
Increasing battery storage will result in fewer power outages and fewer potential fines for utilities	**$24.8 million** in 2012
4) Avoided collections and terminations	
More battery storage reduces the need for costly new power plants, thereby lowering ratepayer bills, and making it easier for ratepayers to consistently pay their bills on time. This reduces the need for utilities to initiate collections and terminations	Terminations and Reconnections: **$1.85**/year/participant Customer calls: **$0.77**/year/participant
5) Avoided safety-related emergency calls	
Increasing battery storage results in fewer power outages, which reduces the risk of emergencies and the need for utilities to make safety-related	**$10.11**/year/participant
6) Job creation	
More battery storage benefits society at large by creating jobs in manufacturing, research and development, engineering, and installation	**3.3 jobs**/MW **$310,000**/MW
7) Less land used for power plants	
More battery storage reduces the need for peaker plants, which are more land-intensive than storage installations—benefitting society by allowing more land to be used for other purposes	**12.4 acres**/MW

Background

Battery storage accounts for a small but growing share of U.S. electric capacity.[1] According to the U.S. Energy Information Administration (EIA), as of July 2018, the United States has a total electric capacity of 1.2 million megawatts (MW), of which 763 MW is battery storage, accounting for 0.06 percent of all electric capacity in the nation. Massachusetts' 4 MW of battery storage capacity amounts to just 0.03 percent of electric capacity in the Commonwealth.

In 2008, Massachusetts passed into law the Green Communities Act (GCA)[2] and the Global Warming Solutions Act (GWSA)[3]. GCA required electric distributors to pursue all cost-effective energy efficiency opportunities for their customers, created the state's Energy Efficiency Advisory Council, increased the state's renewable energy portfolio requirements, and set aside $10 million per year to assist municipalities seeking to build renewable and alternative energy facilities. GWSA set statewide greenhouse gas emission reduction requirements, including an 80 percent reduction by 2050 (from a 1990 baseline).[4]

GCA and GWSA laid the groundwork for the Baker Administration, in 2015, to set aside $10 million—a figure that doubled to $20 million in 2017[5]—to explore and promote energy storage technology, develop the state's storage market, and recommend policy for the adoption of energy storage to help the state meet its clean energy and climate goals. Following this initiative, the *State of Charge* report, published by the Massachusetts Clean Energy Center (CEC) and Department of Energy Resources (DOER), found that "[t]here 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."[6] The study found that the electric grid in Massachusetts could cost effectively utilize 1,766 MW of battery storage by 2020.[7] In 2018, Massachusetts passed *An*

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[1] U.S. Department of Energy. February 22, 2012. *Energy Storage: The Key to a Reliable, Clean Electricity Supply*. Available online: https://www.energy.gov/articles/energy-storage-key-reliable-clean-electricity-supply.

[2] The 190th General Court of the Commonwealth of Massachusetts. 2008. Chapter 169: An Act Relative to Green Communities. Available online: https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169.

[3] The 190th General Court of the Commonwealth of Massachusetts. 2008. Chapter 298: An Act Establishing the Global Warming Solutions Act. Available online: https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter298.

[4] For a fuller accounting of the GCA, GWSA, and Massachusetts' clean energy policy history, see: Woods, Schlegel and Stanton. May 2018. *Massachusetts' Clean Energy Policy Overview*. Available online: https://aeclinic.org/publicationpages/2018/6/18/history-of-ma-energy-sector-policy-brief.

[5] Mass.gov. December 7, 2017. Baker-Polito Administration Awards $20 Million for Energy Storage Projects. Available online: https://www.mass.gov/news/baker-polito-administration-awards-20-million-for-energy-storage-projects.

[6] Massachusetts Clean Energy Center and Department of Energy Resources. 2017. *State of Charge: Massachusetts Energy Storage Initiative Study*. Available online: https://www.mass.gov/files/2017-07/state-of-charge-report.pdf. p.i.

[7] MA CEC/DOER 2017. *State of Charge.* p. 77.

Act to Advance Clean Energy, which sets an target of 1,000 megawatt-hours of energy storage in service by 2026.[8]

Massachusetts' 2019-2021 energy efficiency plans, approved January 29, 2019,[9] include a proposed new active demand management program with electric battery storage measures. Active demand management is a comprehensive set of actions intended to shift energy demand away from peak times to avoid building new, expensive generating plants, and includes: battery storage, exploiting flexibility on both the supply-side and demand-side, and coordinating demand-side measures with energy efficiency opportunities to more cheaply and efficiently supply energy. For battery storage to receive funding under GCA—in the same way that energy efficiency measures have historically—each program administrator's active demand management program offering for the three-year plan must be found to be cost effective. (Each electric distribution company or utility has a "program administrator" responsible for running their energy efficiency program.) The 2018 *Act to Advance Clean Energy* states:

> *There shall be an energy storage target of 1,000 megawatt hours to be achieved by December 31, 2025. To achieve this target, the department of energy resources may consider a variety of policies to encourage the cost-effective deployment of energy storage systems, including the refinement of existing procurement methods to properly value energy storage systems, inclusion in energy portfolio standards, the use of alternative compliance payments to develop pilot programs and the use of energy efficiency funds under section 19 of chapter 25 of the General Laws if the department determines that the energy storage system installed at a customer's premises provides sustainable peak load reductions on either the electric or gas distribution systems and is otherwise consistent with section 11G of chapter 25A of the General Laws.*[10]

For storage measures to be included in the funding allocation and program implementation described in the Massachusetts' program administrators 2019-2021 plans,[11] each group of measures' benefits must have a higher value than that group's costs.[12] Although the program administrators did find storage measures to be cost effective, their benefit-cost calculations were based only on the energy benefits of storage, not taking into account the non-energy benefits explored in this paper. This likely resulted in an undervaluing of energy storage, and therefore a lower benefit-cost ratio than would have been calculated had all benefits of storage measures been evaluated. As noted in CEC/DOER's *State of Charge*

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[8] The 190th General Court of the Commonwealth of Massachusetts. 2018. Chapter 227: An Act to Advance Clean Energy. Available online: https://malegislature.gov/Bills/190/H4857/BillHistory. Lines 148-9.

[9] MA DPU 18-116, 18-117, 18-118, 18-119. *Three Year Energy Efficiency Plan for 2019 through 2021.*

[10] An Act to Advance Clean Energy. Lines 148-157.

[11] Massachusetts Department of Public Utilities. Docket Nos. 18-116, 18-117, 18-118, 18-119. *Three Year Energy Efficiency Plan for 2019 through 2021.* Available online: http://ma-eeac.org/wordpress/wp-content/uploads/2019-2021-Three-YearEnergy-Efficiency-Plan-April-2018.pdf.

[12] Cost-effectiveness is currently assessed at the program level in Massachusetts.

report, while the ability to monetize all the benefits associated with increased battery storage deployment may be limited, non-monetizable benefits have value nonetheless.[13]

In Massachusetts' 2019-2021 energy efficiency plans include a new active demand management program with electric battery storage measures. Massachusetts program administrators' assessment of energy efficiency measures' cost effectiveness includes two main categories of benefits: 1) energy system benefits (or energy avoided costs), and 2) non-energy benefits (see text box below for a brief explanation of energy versus non-energy benefits). In the 2019-2021 plan, active demand management measures have been assigned values for the former category but not the latter: In other words, non-energy benefits of storage are given no value in assessing these measures' cost effectiveness.

	Benefits of Battery Storage	
	Energy Benefits	**Non-Energy Benefits**
Who benefits?	Benefits to the energy system	Benefits to participants in battery storage programs, electric distribution companies and/or society at large
How does benefit manifest?	Benefit conferred through reductions in the cost of supplying energy	Benefit conferred directly to beneficiary
Examples	▪ Reduced peak energy demand ▪ Reduced need for new generating capacity ▪ Transmission and distribution cost reductions ▪ Increased grid resiliency ▪ Facilitates renewable energy integration	▪ Avoided value losses to cusomters and utilities from power outages ▪ Enhanced value to customers from reduced incidence of power outages ▪ Enhanced property values ▪ Enhanced ability to pay less expensive electric bills ▪ Job creation

While many states use cost-benefit analyses to determine which traditional energy efficiency measures to pursue, Massachusetts is the first state in the country to apply a similar methodological approach for battery storage. To achieve the best decision making, it is critical that Massachusetts recognize the full value of these benefits. To this end, this white paper explores the non-energy benefits of electric storage measures in Massachusetts.

What are the benefits of battery storage?

GCA requires that all cost-effective actions be taken regarding energy efficiency and renewable energy. Massachusetts program administrators perform benefit-cost analyses to determine which energy efficiency and active demand management programs to include in their three-year plans. Capturing a full range of benefits and costs is essential to ensure the most strategic program implementation in the

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[13] MA CEC/DOER 2017. *State of Charge.*

Commonwealth.[14] CEC/DOER's *State of Charge* report found that installing 1,766 MW of advanced energy storage in Massachusetts could save electric consumers $2.3 billion through 2020 (see Table 1 below).

Table 1. *State of Charge* total system benefits from Massachusetts energy storage

Benefit	Ratepayer Savings (billions $)
Energy Cost Reduction	$0.3
Reduced Peak Capacity	$1.1
Ancillary Services Cost Reduction	$0.2
Wholesale Market Cost Reduction	$0.2
Transmission and Distribution Cost Reduction	$0.3
Integrating Distributed Renewable Generation Cost Reduction	$0.2
Total System Benefits	**$2.3**

Source: MA CEC/DOER 2017. State of Charge. p.xii.

State of Charge highlights many commonly discussed energy system benefits from battery storage. An electric grid that has built-in backup in the form of storage can more reliably supply energy on demand and is more resilient to disruptions. Improving the grid's ability to store energy produced at one time and dispatch it at another time would facilitate the increased use of intermittent renewable energy sources. Increasing the grid's share of renewable energy would also result in fewer greenhouse gas emissions from fossil fuel energy generation and associated environmental disruptions like gas leaks or pipeline spills. Increasing the share of renewable energy in New England's electric grid will boost the economy by increasing the value of those resources and by creating jobs associated with an increased need to produce, transport, install and maintain new energy infrastructure.[15]

Perhaps battery storage's most critical energy system benefit, however, is its use in reducing New England's peak energy demand and the substantial costs associated with peak. As battery storage reduces the need for generation at peak, it lowers costs by shrinking the amount of capacity that electric distributors must possess to meet peak demand, and lowers required capacity reserve margins as well. For example, for every 1 MW of reduced peak demand in New England, there is an associated reduced capacity need of approximately 1.15 MW.[16]

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[14] Stanton, E.A. July 2018. *Massachusetts Battery Storage Measures: Benefits and Costs.* Applied Economics Clinic White Paper. AEC-2018-07-WP-02. Available online: https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs; and Stanton, E.A. March 2019. *Updated Massachusetts Battery Storage Measures: Benefits and Costs.* Applied Economics Clinic White Paper. AEC-2019-03-WP-02. Available online: https://aeclinic.org/publicationpages/2019/3/15/updated-massachusetts-battery-storage-measures-benefits-and-costs.

[15] Accounts for 15 percent operating reserve margin. Source: MA CEC/DOER 2017. *State of Charge*.

[16] Kotha, M. June 13, 2018. *Future Representative Installed Capacity Requirements for CCP 2023-2024 through CCP 2027-2028*. Slide 8. Available online: https://www.iso-ne.com/static-assets/documents/2018/06/a9_representative_icr_values_for_ccp_2023_2024_through_2027_2028.pdf.

These types of energy system benefits (often referred to as avoided energy costs) are estimated in more detail by the *Avoided Energy Supply Components in New England* (AESC) reports, most recently released in March 2018 and updated in June 2018 (hereafter referred to as AESC 2018).[17] The energy system benefits estimated in that report include avoided fuel costs, avoided electric generating capacity costs, and avoided costs of complying with GWSA.

In addition to energy system benefits, however, storage measures confer several "non-energy benefits" that are separate from those directly applicable to the cost of energy supply. Battery storage provides benefits to electric distributors and to ratepayers, including both families and businesses, and to society at large. These non-energy benefits of storage are the topic of this white paper.

What are non-energy benefits?

Non-energy benefits of battery storage are conferred not through changes to the cost of electric services (energy system benefits), but directly to participants in storage programs, the electric distribution companies themselves, or to society as a whole. For example, during a power outage, storage systems can enable businesses to stay open, residents to stay in their homes, and hospitals to continue to operate—resulting in clear benefits that are unrelated to the cost of electricity, such as: avoided loss of customers and revenue; avoided equipment damage; avoided loss of perishable materials and goods; and avoided data losses. Some of these non-energy benefits may be more difficult to quantify than energy system benefits, or may require new and different measurement tools.[18] To leave these critical benefits unmeasured, however, is equivalent to assuming that they have no value in a benefit-cost analysis, which has the result of lowering benefit-cost metrics and reducing the likelihood that storage measures and programs will achieve cost effectiveness and be included in program administrators' three-year energy efficiency plans.

Massachusetts energy efficiency program administrators have a long history of assigning values to the non-energy benefits of weatherization, insulation, heating and cooling upgrades, retrofits, lighting and appliance upgrades and other efficiency measures. Program administrators prepare—and periodically update and expand upon—*Non-Energy Impact (NEI) Evaluation* studies that estimate the non-energy benefits of energy efficiency measures for residential and low-income ratepayers in the state, including, for example: reduced asthma, reduced thermal stress on occupants, fewer missed days of work, reduced risk of fire, and reduced noise. The MA NEI Evaluation 2011 study considered utility and societal non-energy impacts in addition to residential and low-income ratepayer non-energy impacts.[19] The MA

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[17] Synapse Energy Economics. June 1, 2018. *Avoided Energy Supply Components in New England: 2018 Report* . Prepared for AESC 2018 Study Group. Available online: https://www.ct.gov/deep/lib/deep/energy/aesc-2018-17-080-june-1-release.pdf.

[18] Energy Storage Association (ESA). November 2017. *35x25: A Vision for Energy Storage*. Available online: http://energystorage.org/system/files/attachments/esa_vision_2025_final.pdf.

[19] Massachusetts Program Administrators. August 15, 2011. *Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation*. Prepared by NMR. Available online: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf.

NEI Evaluation 2016 study focused exclusively on residential and low-income ratepayer non-energy impacts.[20] Table 2 (on the following page) lists the non-energy benefits for which monetary values were provided in the MA NEI Evaluation 2011; rows marked in green indicate the subset of these benefits assigned to measures in the program administrator's 2019-2021 plan.

Currently, the non-energy benefits of battery storage are not included in Massachusetts active demand management program planning. Omitting these non-energy benefits introduces a downward bias on storage measures' benefit-cost assessments. Without a full consideration of all benefits, Massachusetts is unlikely to make the best strategic decisions regarding these important cost-saving measures.

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[20] Massachusetts Program Administrators. August 5, 2016. *Massachusetts Special and Cross-Cutting Research Area: Low-Income Single-Family Health-and Safety-Related Non-Energy Impacts (NEIs) Study*. Prepared by Three, Inc. and NMR. Available online: http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-Non-Energy-Impacts-Study.pdf.

Table 2. Massachusetts non-energy benefits of energy efficiency

NEI	Duration
UTILITY PERSPECTIVE	
Arrearages	Annual
Bad debt write-offs	Annual
Terminations and reconnections	Annual
Rate discounts	Annual
Customer calls	Annual
Collections notices	Annual
Safety-related emergency calls	Annual
Insurance savings	—
SOCIETAL PERSPECTIVE	
National Security	Annual
NON-RESOURCE BENEFITS	
Appliance Recycling – Avoided landfill space	One time
Appliance Recycling – Reduced emissions due to recycling plastic and glass, reduced emissions	One time
Appliance Recycling – Reduced emissions due to incineration of insulating foam	One time
NEI	**Duration**
PARTICIPANT PERSPECTIVE (OWNERS OF LOW-INCOME RENTAL HOUSING), PER HOUSING UNIT	
Marketability/ease of finding renters	Annual
Reduced tenant turnover	Annual
Property value	One time
Equipment maintenance (heating and cooling systems)	Annual
Reduced maintenance (lighting)	Annual
Durability of property	Annual
Tenant complaints	Annual
PARTICIPANT PESPECTIVE (OCCUPANT)	
Higher comfort levels	Annual
Quieter interior environment	Annual
Lighting quality & lifetime	One time
Increased housing property value	One time (Annual for NLI RNC)
Reduced water usage and sewer costs (dishwashers)	Annual
Reduced water usage and sewer costs (faucet aerators)	Annual
Reduced water usage and sewer costs (low flow showerheads)	Annual
More durable home and less maintenance	Annual
Equipment and appliance maintenance requirements	Annual
Health related NEIs	Annual
Improved safety (heating system, ventilation, carbon monoxide, fires)	Annual
Window AC NEIs	Annual
**** Green cells showing the Benefits in April Draft of 2019-2021 Plan**	

Source: MA NEI Evaluation 2011. Reproduced from: Stanton, E.A. July 2018. Massachusetts Battery Storage Measures: Benefits and Costs. Applied Economics Clinic White Paper. AEC-2018-07-WP-02. Available online: https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs.

Non-Energy Benefits of Battery Storage

This white paper presents seven non-energy benefits of electric storage measures in Massachusetts: 1) avoided power outages; 2) higher property values; 3) avoided fines; 4) avoided collections and terminations; 5) avoided safety-related emergency calls; 6) job creation; and 7) less land used for power plants. In the following sections, we discuss each non-energy benefit in terms of how it works, how it is valued, and how and why it applies to Massachusetts. (Energy and emission-reduction benefits of storage are evaluated in AESC 2018 and, therefore, including in battery measures' cost-effectiveness assessment.)

The seven storage non-energy benefits presented here do not represent a comprehensive set of all such benefits. Rather, this list and the monetized benefits that we have assembled are a starting point for a discussion of how best to fully measure the advantages to Massachusetts of battery storage. The measures selected for inclusion in this white paper are drawn from our review of the literature and are recurring benefits, with one exception: an increase in property value is a one-time benefit.

1. Avoided power outages

Power outages entail costs to generators, distribution companies, and consumers. Battery storage, if charged and discharged at appropriate times, reduces peak load, thereby increasing reserve margins and enhancing grid reliability; it also reduces the incidence and duration of power outages. Avoiding power outages is beneficial for electric distributors and for ratepayers. From an energy system point of view, the benefit of avoided power outages is lower total system costs. From the storage measure participants' point of view, the benefit of avoided power outages is the reduction of costly—and potentially dangerous—disruptions to life and work.

AESC 2018 introduces estimation of a new energy system reliability benefit: the avoided costs of power outages to the electric system. As we describe in this section, this energy system reliability benefit is distinct from the non-energy benefits to consumers of avoided outages. Some understandable confusion between these two kinds of benefits may, nonetheless, arise: the non-energy benefits of avoided outages to families and businesses is often called the "value of lost load" (VoLL). AESC 2018 follows—but does not explain—the common practice of using ratepayers' VoLL as a proxy to estimate the energy system costs of outages. This use of ratepayers' VoLL as a proxy for system costs should not, however, suggest that system costs are in fact the VoLL.

1. ***Energy system reliability benefit:*** Greater reliability lowers system costs. This avoided cost is typically measured indirectly by assuming—based on economic theory—that system reliability costs are equal to the benefits to consumers of avoided outages. AESC 2018 uses ratepayers' VoLL as a proxy to estimate the avoided system costs of enhanced reliability.

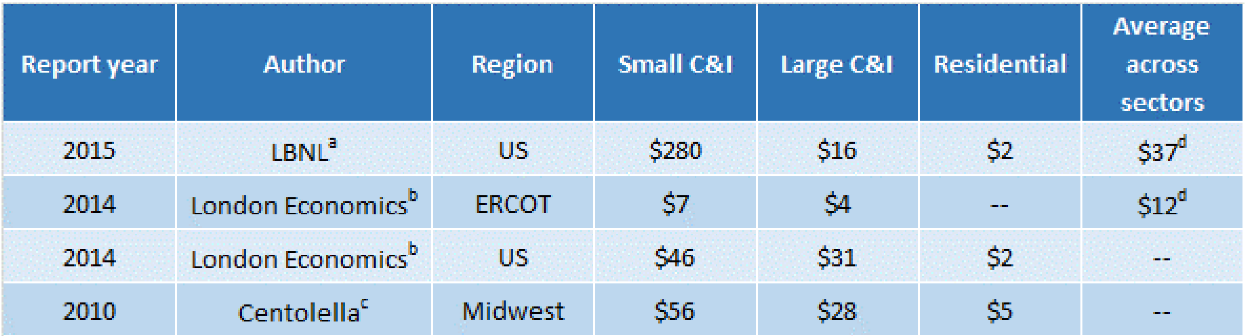
2. ***Non-energy reliability benefit to consumers:*** VoLL is a measure of the value to families and businesses of lost load (outages). Storage measure participants' non-energy VoLL benefit is distinct from the energy system reliability benefit estimated by AESC 2018.

Energy system reliability benefit

Reliable electric service is a benefit for both electric distributors and consumers, but valuing the benefit is made difficult by the fact that there is no market for the reliability of energy, or for energy interruptions. As a result, most valuation exercises seek to determine the reverse; according to an overview of VoLL studies and their use: “It proves often easier to estimate the costs of the effects of supply interruptions for energy consumers.”[21] VoLL accomplishes that by expressing what a *Frontiers in Energy Research* article called the “monetary evaluation of uninterruptedness of power supply.”[22] VoLL estimates the cost per kilowatt-hour (kWh) of a power outage. According to economic theory, energy system reliability can be assumed to have a value equal to the costs to customers in the event of power outages. (Power suppliers would pay up to, but not beyond, this value in order to avoid losses.[23])

AESC 2018 follows the practice of using VoLL as a proxy for energy system reliability benefits, and presents four values for U.S. VoLL taken from the literature (see Table 3).

Table 3. AESC 2018 results of reported values of lost load literature review (2018$/kWh)



Report year	Author	Region	Small C&I	Large C&I	Residential	Average across sectors
2015	LBNL[a]	US	$280	$16	$2	$37[d]
2014	London Economics[b]	ERCOT	$7	$4	--	$12[d]
2014	London Economics[b]	US	$46	$31	$2	--
2010	Centolella[c]	Midwest	$56	$28	$5	--

[a] Sullivan et al. 2015. Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States. Prepared for Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy. Lawrence Berkeley National Laboratory (LBNL). [b] London Economics International LLC. 2013. Estimating the Value of Lost Load. Prepared for the Electric Reliability Council of Texas, Inc. [c] Centolella, P. 2010. Estimates of the Value of Uninterrupted Service for The Mid-West Independent System Operator. Harvard Electricity Policy Group. [d] AESC 2018.

AESC 2018 presents $25 per kWh—the average of the first two U.S. VoLL estimates from Table 3—as the New England VoLL and, by proxy, as the New England system reliability avoided cost. The other two VoLL results in Table 3 were not included in AESC 2018’s VoLL estimate. The second London Economics result (Row 3 in Table 3) is taken from the same study as the ERCOT VoLL and reports the results of an

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[21] van der Welle, A. and van der Zwaan, B. 2007*. An Overview of Selected Studies on the Value of Lost Load (VoLL).* Energy Research Centre of the Netherlands. p.2.

[22] Schröder and Kuckshinrichs. December 24, 2015. “Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A Literature Review”, *Frontiers in Energy Research*. Available online: https://www.frontiersin.org/articles/10.3389/fenrg.2015.00055/full. p.2

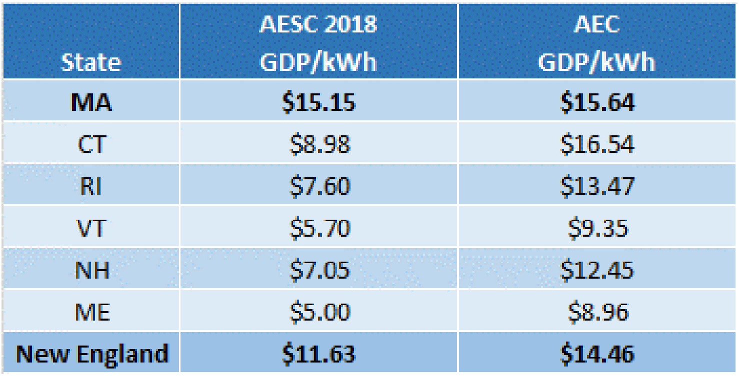
[23] “In the optimum cases, the level of supply security should be defined in such a way that the marginal damage costs, expressed by VoLL, are equal to the marginal costs for ensuring uninterrupted electricity supply. Accordingly, the calculation of the economic indicator VoLL represents, on the one hand, an opportunity to determine the level of damage caused by a power interruption, the results of which, on the other hand, describes the value of power supply security.” Schröder and Kuckshinrichs, 2015. p.4.

older version of the Centolella 2010 study[24] (Row 4 in Table 3). In the Centolella 2010 study, Paul Centolella and coauthors, on behalf of SAIC, estimate U.S. Midwest VoLL, based on the methodology and data used in an earlier version of the LBNL 2015 study[25] (Row 1 in Table 3).

AESC 2018 accepts the LBNL 2015's "willingness-to-pay" survey results as presented, changing only their dollar year and calculating an average value appropriate to the relevant distribution of outage durations in New England. For the London Economics 2014 study, however, AESC 2018 re-calculates New England-specific results following London Economics' production function methodology, citing a U.S. AID study on the Republic of Georgia[26] in substantiating this methodology.

Cleveland State University's 2017 report on valuing resiliency from microgrids describes the VoLL production function methodology in detail and provides U.S.-wide results, with results ranging up to $110 per kWh across different industries.[27] We replicated the production function methodology used in AESC 2018 for New England states but got somewhat different results, as shown in Table 4.

Table 4. Ratio of 2016 GDP to energy usage: AESC 2018 and AEC (2018$/kWh)



State	AESC 2018 GDP/kWh	AEC GDP/kWh
MA	**$15.15**	**$15.64**
CT	$8.98	$16.54
RI	$7.60	$13.47
VT	$5.70	$9.35
NH	$7.05	$12.45
ME	$5.00	$8.96
New England	**$11.63**	**$14.46**

Source: AESC 2018, Table 95, p.224. Data for AEC calculations: GDP—Bureau of Economic Analysis, Regional Data, Gross Domestic Product by State, NACIS All GDP components, available online: https://apps.bea.gov/regional/downloadzip.cfm. Energy usage—EIA-861, Retail Sales of Electricity by State by Sector by Provider, available online: https://www.eia.gov/electricity/data/state/. GDP and sales values originally provided in 2016 dollars have been updated to 2018 dollars using the CPI-U index.

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[24] Centolella et al. (2006). *Estimates of the Value of Uninterrupted Service for The Midwest Independent System Operator*. Science Applications International Corporation (SAIC).

[25] Sullivan et al. (2009). *Estimated Value of Service Reliability for Electric Utility Customers in the United States. Prepared for Office of Electricity Delivery and Energy Reliability*. U.S. Department of Energy. Lawrence Berkeley National Laboratory (LBNL). Available online: http://eta-publications.lbl.gov/sites/default/files/lbnl-2132e.pdf.

[26] Khujadze, S. May 2014. *A Study of the Value of Lost Load (VoLL) for Georgia*. Prepared by Deloitte Consulting for the United States Agency for International Development's Hydro Power and Energy Planning Project (USAID-HPEP).

[27] Thomas, A.R. and Henning, M. December 1, 2017. *Valuing Resiliency from Microgrids: How End Users can Estimate the Marginal Value of Resilient Power*. Cleveland State University, Urban Publications. Available online: https://engagedscholarship.csuohio.edu/urban_facpub/1516/. Values originally provided in 2012 dollars have been updated to 2018 dollars using the CPI-U index.

While our Massachusetts production function-based VoLL matched that of AESC 2018 very closely, results for the other New England states differ. Our New England average, using this method, was $14 per kWh, compared to $12 per kWh reported in AESC 2018. Replacing AESC 2018 with our correction raises the final cross-methodology average VoLL only slightly: from $25 per kWh to $26 per kWh.

Non-energy reliability benefit to consumers

Whereas AESC 2018's estimate of energy system reliability benefits uses ratepayer VoLL only as a proxy for avoided system costs, our estimate of Massachusetts' non-energy reliability benefit to storage measure participants is the VoLL itself. Reliability can and does provide many distinct benefits and it is important to note that VoLL accounts for some, but not all of these benefits. For example, more resilient power enables providers of safety and health services—like hospitals or community health centers—to continue to provide services that are highly valuable to society during outages associated with natural disasters, a distinct non-energy benefit that may not be adequately accounted for in VoLL. There is additional value of avoided power outages for customers who are elderly, disabled or have serious health conditions and rely on electronic devices and are more vulnerable to power outages than the average customer. Research has found that in the United States—among the 175 million people covered by employer-sponsored health insurance—approximately 218 per 100,000 people are "electricity-dependent residing at home".[28] Investor-owned utilities in Massachusetts and other states are required to maintain lists of health critical customers (called "life support customers" in Massachusetts) who cannot have their power shut off, and are prioritized in power restoration efforts, because they are reliant on electrical medical devices, and to be without power would be harmful or life threatening.[29]

Including multiple benefits from increased reliability does not represent double counting. Increased reliability is a benefit to *both* to the energy system as a whole and to ratepayers participating in storage programs. A 2015 study in the journal *Frontiers in Energy Research* (see Figure 1 below) provides an overview of multiple, distinct benefits from battery storage including both "investments in grid construction via charges (network tariffs)" (or energy system benefits) and various non-energy ratepayer benefits discussed in this white paper, including the value of lost load to residential, commercial and industrial ratepayers, and effects on property values.

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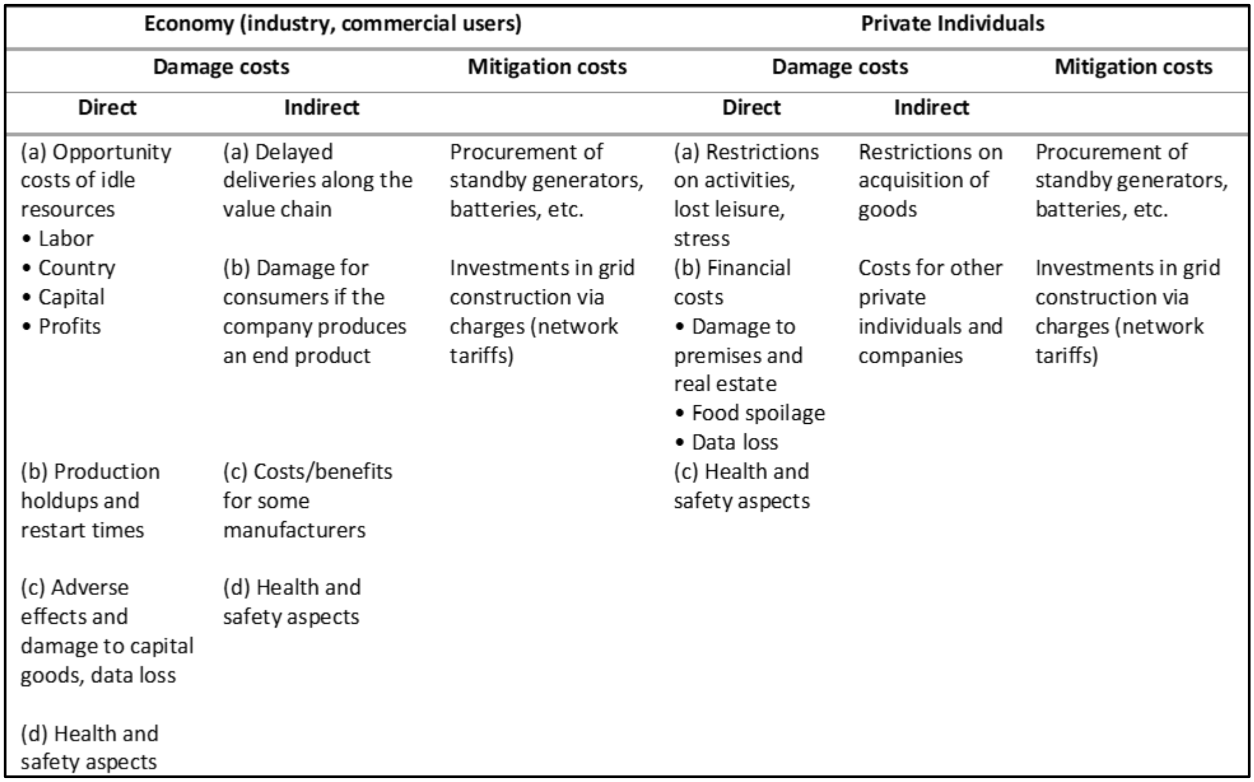
[28] Molinari, N.A.M., Chen, B., Krishna, N., and Morris, T. March 2017. "Who's at Risk When the Power Goes Out? The At-home Electricity-Dependent Population in the United States, 2012." *Journal of Public Health Management and Practice*, 23(2), 152-159. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5007208/.

[29] See: Code of Massachusetts Regulations Title 220. January 27, 2017. 220 CMR 19.00: Standards of Performance for Emergency Preparation and Restoration of Service for Electric Distribution and Gas Companies. Available online: https://www.mass.gov/files/documents/2016/08/rr/220cmr1900.pdf for Massachusetts law governing utility responsibilities towards health-critical customers.

Figure 1. Avoided costs from battery storage

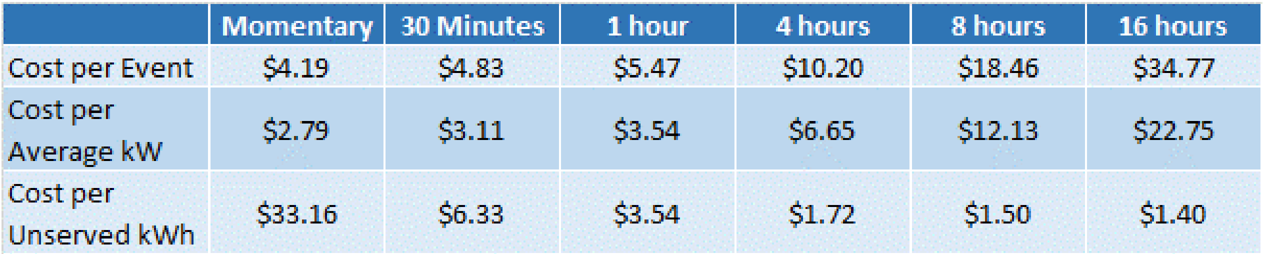


Economy (industry, commercial users)			Private Individuals		
Damage costs		Mitigation costs	Damage costs		Mitigation costs
Direct	Indirect		Direct	Indirect	
(a) Opportunity costs of idle resources • Labor • Country • Capital • Profits	(a) Delayed deliveries along the value chain (b) Damage for consumers if the company produces an end product	Procurement of standby generators, batteries, etc. Investments in grid construction via charges (network tariffs)	(a) Restrictions on activities, lost leisure, stress (b) Financial costs • Damage to premises and real estate • Food spoilage • Data loss	Restrictions on acquisition of goods Costs for other private individuals and companies	Procurement of standby generators, batteries, etc. Investments in grid construction via charges (network tariffs)
(b) Production holdups and restart times	(c) Costs/benefits for some manufacturers		(c) Health and safety aspects		
(c) Adverse effects and damage to capital goods, data loss	(d) Health and safety aspects				
(d) Health and safety aspects					

Source: Reproduced from Schröder and Kuckshinrichs, 2015. Table 2, p. 3.

For use in Massachusetts non-energy benefits of storage, residential VoLL can be estimated using the LBNL 2015 willingness-to-pay survey results for residential customers as cited in AESC 2018. EIA data indicates that 4 hours is the average duration of power outages in the United States across all utility types.[30] LBLN's 4-hour outage VoLL estimate for residential customers is $1.72 per kWh.[31]

Table 5. Estimated cost per event, average kW and unserved kWh, residential (2018$)



	Momentary	30 Minutes	1 hour	4 hours	8 hours	16 hours
Cost per Event	$4.19	$4.83	$5.47	$10.20	$18.46	$34.77
Cost per Average kW	$2.79	$3.11	$3.54	$6.65	$12.13	$22.75
Cost per Unserved kWh	$33.16	$6.33	$3.54	$1.72	$1.50	$1.40

Source: LNBL, 2015. Values originally provided in 2013 dollars have been updated to 2018 dollars using the CPI-U index. Cost per event refers to the "cost for an individual interruption for a typical customer". Cost per average kW refers to the "cost per event

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[30] U.S. Energy Information Administration. April 5, 2018. *Average frequency and duration of electric distribution outages vary by states*. Available online: https://www.eia.gov/todayinenergy/detail.php?id=35652.

[31] Clean Energy Group and Greenlink have a series of forthcoming publications that presents outage estimates for the Southeast: Clean Energy Group, "Resilient Southeast Report Series", pending publication, 2019.

normalized by average demand". Cost per unserved kWh refers to the "cost per event normalized by the expected amount of unserved kWh for each interruption duration".

While the cost of power outages to residential customers may seem small on a per kWh basis, power outages are highly disruptive. As the Energy Storage Association points out in their *Vision for Energy* Storage report:

> *For a homeowner, the economic cost may seem minimal, but the cost to quality of life is high: medication and food refrigeration, shelter and access to water are among those critical losses.*[32]

Power outages also have the potential to cause disruptions for commercial and industrial customers:

> *As enhanced connectivity drives increases in computing capability and economic value in the same footprint, every server that loses power will only have a greater economic cost to it—rippling even further throughout society. The higher VOLL extends to almost all commercial enterprises. Grocers lose perishable products, stores are unable to sell their wares, and credit card systems lose capability to process payments at data centers and points of sale.*[33]

For commercial and industrial non-energy benefits of storage, AESC 2018's Massachusetts-specific production function-based VoLL is $15.64 per kWh. However, it should be noted that the Cleveland State University 2017 analysis of U.S. VoLL suggests a very wide range of values by business sector (see Figure 2). The VoLL values in Figure 2 are not Massachusetts-specific (and are, therefore, not included in this analysis); the wide range of U.S. VoLL values points to a need for additional analysis in New England to fully capture variation in VoLL by industry.

The application of these per kWh non-energy benefits values should follow that of current non-energy benefits for energy efficiency measures. To this end, moving forward, it will be important to consider the extent to which battery storage measures can prevent power outages and the total kWhs of expected outages (absent these measures) in a given year.

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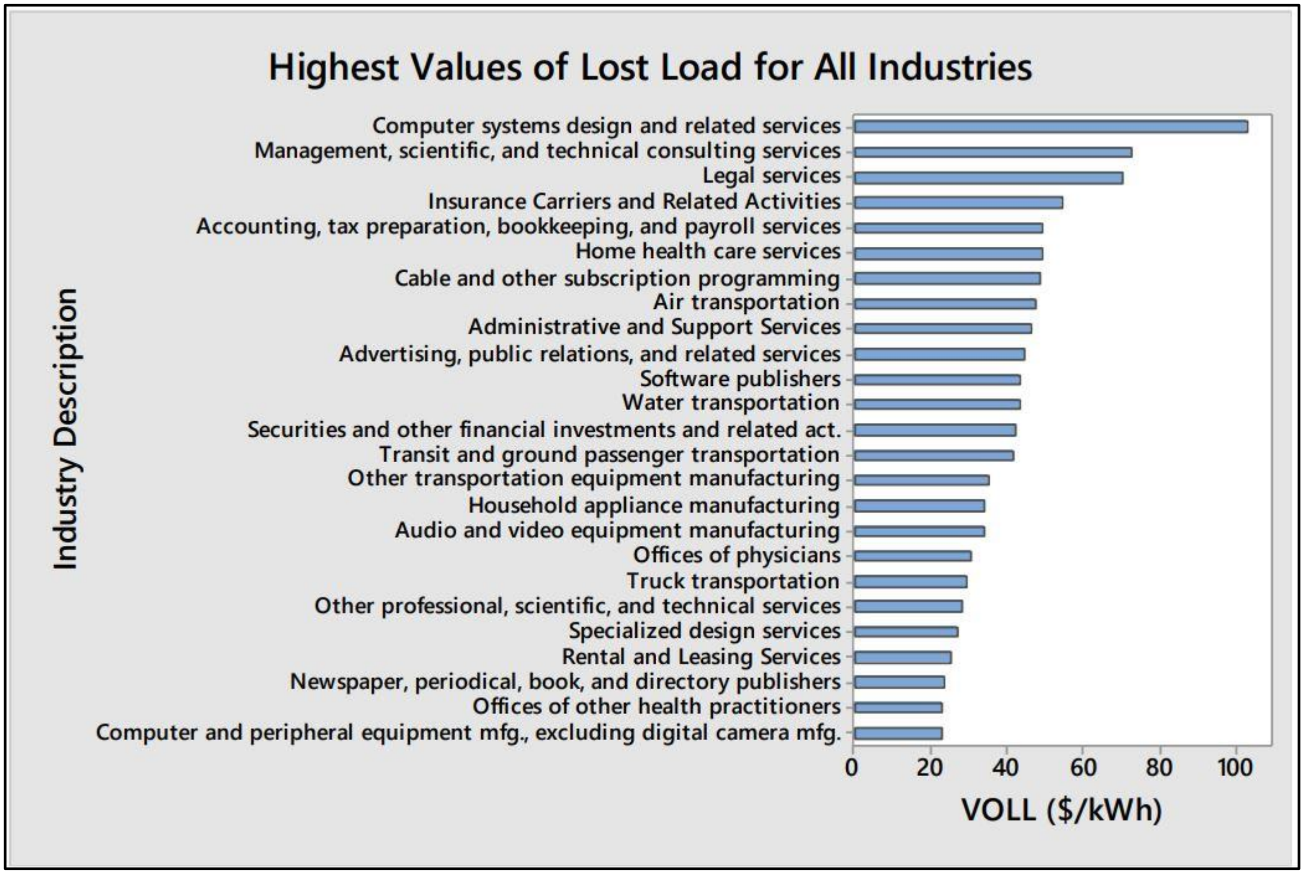
[32] ESA 2017. p.4.

[33] ESA 2017. p.4.

Figure 2. Cleveland State University (2017) VoLL per kWh by industry



Source: Reproduced from Thomas and Henning, 2017. Figure 2, p. 13.

2. *Higher property values*

Installing storage in buildings can increase property values in several ways. Battery storage systems can keep heating and cooling systems running during a power outage, contributing to the increased thermal comfort of buildings and increasing their value.[34] Energy backup systems also serve to increase the marketability of units for landlords, again, increasing the value of the property.[35] Battery storage systems can also reduce maintenance costs by providing energy use data that allows building operators to assess and optimize real-time energy usage.

This non-energy benefit has a value to ratepayers as a one-time increase to property values from adding a storage system. These values can be calculated using the “low-income” single and multi-families benefits for a heating retrofit from the MA NEI Evaluation 2011: one-half of measure capital cost for single family, and 1 percent of measure capital cost for owners of multi-family housing. The Applied Economic Clinic’s July 2018 White Paper, *Massachusetts Battery Storage Measures: Benefit and Costs*,

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[34] ACEEE. 2012. *Measuring Participant Perspective Non-Energy Impacts (NEIs)*. Available online: https://aceee.org/files/proceedings/2012/data/papers/0193-000046.pdf.

[35] MA NEI Evaluation 2011.

assigned values of $5,325 per housing unit for low-income single-family participants and $510 per unit for owners of multi-family housing based on the MA NEI Evaluation 2011 benefit to capital cost ratios.[36,37] An increase in property values would also accrue to residential storage-measure participants who are not income eligible, and to commercial and industrial storage-measure participants.

It is important to note that installing solar arrays can increase a building's value. Evidence shows that home buyers across the United States are willing to pay a premium of about $15,000 for a home with solar panels.[38] Massachusetts offers solar property tax exemptions for both residential and non-residential solar customers; under current law (M.G.L. c. 59, sec. 59) "[a] solar or wind powered system or device which is being utilized as a primary or auxiliary power system for the purpose of heating or otherwise supplying the energy needs of property taxable under this chapter; provided, however, that the exemption under this clause shall be allowed only for a period of twenty years from the date of the installation of such system or device."[39] That means, even when the value of a building increases after a solar system is installed, property taxes still reflect the pre-solar value of the building. While such policies do not currently exist for battery storage in the Commonwealth, tax exemptions are an important tool to incentivize the uptake of storage in homes and businesses.

3. *Avoided outage fines*

As installed battery storage increases, the risk of power outages falls[40]—which means that utilities may avoid costly fines associated with severe power outage events.

In 2012, the Massachusetts Department of Public Utilities (DPU) levied penalties totaling $24.8 million against National Grid, NSTAR, and Western Massachusetts Electric Company (WEMCO) related to their response to power outages caused by Tropical Storm Irene and the Halloween Blizzard of 2011.The fines were levied after customer complaints prompted state officials to launch an investigation into the utilities' preparedness and response to the 2011 storms. The investigation was extensive with 16 public hearings, a dozen evidentiary hearings, and over one thousand exhibits. National Grid, NSTAR and WEMCO were required submit their plans to pay the fines to the DPU within 30 days. The penalties were applied as a credit for ratepayers per a law passed in 2012 that made it illegal for utilities to change rates in order to pay fines for subpar performance.[41] The constitutionality of this law was challenged in

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[36] Stanton, E.A. July 31, 2018. Massachusetts Battery Storage Measures: Benefits and Costs. Prepared for Clean Energy Group. AEC-2018-07-WP-02. Available online: https://aeclinic.org/publicationpages/2018/7/30/massachusetts-battery-storage-measures-benefits-and-costs. p.17.

[37] Note that these values do not include any associated increase in property taxes.

[38] Energy.gov. No Date. Solar Homes Sell for a Premium. Available online: https://www.energy.gov/eere/solar/downloads/solar-homes-sell-premium.

[39] The 191st General Court of the Commonwealth of Massachusetts. General Laws, Chapter 59, Section 59. Available online: https://malegislature.gov/Laws/GeneralLaws/PartI/TitleIX/Chapter59.

[40] Zhang, T., Cialdea, S., Orr, J.A., and Emanuel, A.E. 2014. Outage Avoidance and Amelioration using Battery Energy Storage Systems. *IEEE*. Available online: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6808127.

[41] Howard, Z. December 11, 2012. *Massachusetts slaps utilities with record fines for 2011 outages*. Reuters. Available online: https://www.reuters.com/article/us-usa-massachusetts-power/massachusetts-slaps-utilities-with-

Fitchburg Gas and Electric Light Company v. DPU, but was ultimately upheld by the Massachusetts Supreme Judicial Court.[42]

Together, National Grid, NSTAR, and WEMCO were fined a total of $24.8 million[43] for violating various storm response obligations from their respective emergency response plans, such as: failing to adequately communicate with customers and municipalities; failing to provide damage assessments in a timely fashion; failing to respond to public safety calls; failing to effectively assess the severity of the storms; and failing to directly contact customers with medical needs.[44] Costs paid in fines do not include the legal and procedural expenses from fighting the fines. While the fines were levied due to the inadequate response of various utilities to power outages rather than due to the outages themselves, it is important to reiterate that increased deployment of battery storage makes power outages—and, by extension, the fines that may accompany them—less likely.[45]

With detailed outage data—outage duration, number of affected customers and total lost load—it would be possible to calculate a dollar per kWh estimate of fines and legal costs that Massachusetts utilities could avoid through battery storage programs and avoided severe power outages.

4. Avoided collections and terminations

Battery storage provides electric supply during times of peak demand, reducing the need for costly new peaker plants and the resulting capacity costs that are passed on to ratepayers through their rates and bills. When ratepayers face lower costs they are better able to pay their bills. Electric distributors benefit by avoiding costs associated with collections and terminations.

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record-fines-for-2011-outages-idUSBRE8BA19420121211. Ring, D. December 11, 2012. Massachusetts utility regulators: National Grid and Western Massachusetts Electric Company face multimillion dollar fines for Irene, October snowstorm responses. MassLive. Available online: https://www.masslive.com/news/index.ssf/2012/12/national_grid_to_be_fined_1872.html.

[42] Supreme Judicial Court and Appeals Court of Massachusetts. April 14, 2014. Fitchburg Gas and Electric Light Company vs. Department of Public Utilities. Case Docket SJC-11397. Online: http://www.ma-appellatecourts.org/display_docket.php?dno=SJC-11397.

[43] National Grid was fined $18.7 million, NSTAR $4.1 million and WEMCO $2 million.

[44] Mass.gov. July 26, 2012. AG Seeks More Than $16 Million in Penalties for Inadequate Storm Response by National Grid. Available online: http://www.mass.gov/ago/news-and-updates/press-releases/2012/2012-07-26-natl-grid-dpu.html?_ga=2.175198242.1077349657.1539625103-207293685.1523300621. Mass.gov. July 12, 2012. AG Seeks $4 Million in Penalties for Inadequate Storm Response by Western Massachusetts Electric Company. Available online: http://www.mass.gov/ago/news-and-updates/press-releases/2012/2012-07-12-wmeco-dpu-recommendation.html. Mass.gov. August 7, 2012. AG Seeks Close to $10 Million in Penalties for Inadequate Storm Response by NSTAR. Available online: http://www.mass.gov/ago/news-and-updates/press-releases/2012/2012-08-07-nstar-dpu.html.

[45] Zhang, T., Cialdea, S., Orr, J.A., and Emanuel, A.E. 2014. Outage Avoidance and Amelioration using Battery Energy Storage Systems. *IEEE*. Available online: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6808127.

MA NEI Evaluation 2011 presents non-energy benefits of avoided collections and terminations for energy efficiency measures, explaining that:

> *Utilities can realize a number of NEIs from their energy efficiency programs in the form of financial savings. Energy-efficient technologies installed by PA programs often result in reduced energy bills for participants, which can decrease the likelihood that customers experience difficulties with paying their utility bills. In turn, utilities realize financial savings through reduced costs associated with arrearages and late payments, uncollectible bills and bad debt write-offs, service terminations and reconnections, bill-related customer calls, and the bill collections process.*[46]

Battery storage—like energy efficiency—can reduce the need for expensive peaker plants and provide electricity at peak more cheaply (assuming that battery storage is appropriately charged at times of inexpensive supply and discharged at times of peak, expensive demand). When rates and bills are lowered and customers are better able to consistently pay their bills, electric distributors need to make fewer collection calls, terminations and reconnections.[47]

Table 6 presents the MA NEI Evaluation 2011 values recommended for these avoided collections and terminations costs for energy efficiency. Because battery storage also lowers peak energy use and ratepayer costs, with the same result—that customers are better able to pay their bills on time—these same benefits are equally applicable to battery storage program participants. The program administrator-recommended value for these avoided costs for terminations and reconnections and customer calls are, respectively: $1.85 and $0.77 per year per participant.

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[46] MA NEI Evaluation 2011. p. 1-2.

[47] Woolf et al. September 22, 2014. *Benefit-Cost Analysis for Distributed Energy Resources: A Framework for Accounting for All Relevant Costs and Benefits*. Prepared for the Advanced Energy Economy Institute. Synapse Energy Economics. Available online: http://www.synapse-energy.com/sites/default/files/Final%20Report.pdf. p.25.

Table 6. Benefits of avoided terminations, reconnections, and customer calls

Study	$/year/participant (Adjusted 2018$)
Terminations and Reconnections	
WI Low-Income Weatherization (Skumatz and Gardner, 2005)	$0.17
National Low-Income Weatherization NEBs Study (Schweitzer and Tonn, 2002)	$0.75
CT Low-Income Weatherization (Skumatz and Nordeen, 2002)	$0.14
CA Low-Income Public Purpose Test (TecMarket Works, Skumatz Economic Research Inc., and Megdal Associates, 2001)	$0.10
VT Low-Income Weatherization (Riggert et al., 1999)	$10.33
CA Low-Income Weatherization (Skumatz and Dickerson, 1999)	$0.48
Venture Partners Pilot Program (Skumatz and Dickerson, 1997)	$0.97
Average of 2018$ Adjusted Values	**$1.85**
Customer Calls	
WI Low-Income Weatherization (Skumatz and Gardner, 2005)	$0.55
MA Low-Income Weatherization (Skumatz Economic Research Associates, 2002)	$0.81
CT Low-Income Weatherization (Skumatz and Nordeen, 2002)	$0.75
CA Low-Income Public Purpose Test (TecMarket Works, Skumatz Economic Research Inc., and Megdal Associates, 2001)	$2.22
CA Low-Income Weatherization (Skumatz and Dickerson, 1999)	$0.10
Venture Partners Pilot Program (Skumatz and Dickerson, 1997)	$0.19
Average of 2018$ Adjusted Values	**$0.77**

Source: MA NEI Evaluation 2011. p. D-5 and D-6. MA NEI Evaluation provided values in 2010$. Values originally provided in 2010 dollars have been updated to 2018 dollars using the CPI-U index.

5. Avoided safety-related emergency calls

As the amount of battery storage connected to the electric grid increases, the frequency and duration of power outages is reduced.[48] Power outages entail risks and can and do result in safety-related emergency calls to customers. When families and businesses experience fewer power outages, electric distributors avoid making some safety-related emergency calls and the expenses associated with those calls.

MA NEI Evaluation 2011 presents non-energy benefits of avoided safety related emergency calls, and describes the related savings to electric distributors: as electric load during peak periods is reduced, “utilities may realize financial savings due to a reduction in safety-related emergency calls and insurance

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[48] (1) Nexight Group. December 2010. *Electric Power Industry Needs for Grid-Scale Storage Applications*. Prepared on behalf of the U.S. Department of Energy’s (DOE) Office of Electricity Delivery and Energy Reliability and the DOE’s Office of Energy Efficiency and Renewable Energy Solar Technologies Program. Available online: https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Utility_12-30-10_FINAL_lowres.pdf. (2) Zhang, T., Cialdea, S., Orr, J.A., and Emanuel, A.E. 2014. Outage Avoidance and Amelioration using Battery Energy Storage Systems. *IEEE*. Available online: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6808127.

costs, due to reduced fires and other emergencies."[49] This benefit may be particularly applicable for electric distributors that offer efficiency programs that repair or replace appliances to low-income households, who may be more likely to have old or damaged space and water heating appliances, gas appliances, and gas connectors.[50]

Non-energy benefits of battery storage reducing emergency calls may exist as well, to the extent that outages and related safety risks are avoided. Table 7 shows the program administrator-recommended value for this avoided cost in the context of energy efficiency: $10.11 per year per participant.

Table 7. Benefits of avoided safety-related emergency calls

Study	$/year/participant (Adjusted 2018$)
Safety-Related Emergency Calls	
National Low-Income Weatherization NEBs Study (Schweitzer and Tonn, 2002)	$9.48
MA Low-Income Weatherization (Skumatz Economic Research Associates, 2002)	$0.55
CT Low-Income Weatherization (Skumatz and Nordeen, 2002)	$0.29
CA Low-Income Public Purpose Test (TecMarket Works, Skumatz Economic Research Inc., and Megdal Associates, 2001)	$0.10
VT Low-Income Weatherization (Riggert et al., 1999)	$25.38
CA Low-Income Weatherization (Skumatz and Dickerson, 1999)	$11.67
Venture Partners Pilot Program (Skumatz and Dickerson, 1997)	$23.27
Average of 2018$ Adjusted Values	**$10.11**

Source: Adapted from MA NEI Evaluation 2011. p. D-8. MA NEI Evaluation provided values in 2010$. Values originally provided in 2010 dollars have been updated to 2018 dollars using the CPI-U index.

6. Job Creation

As investment in storage grows in Massachusetts, related jobs will be created along the entire supply chain, including in: battery manufacturing, research and development, engineering, construction, operations and maintenance, sales, marketing, management, and administration. While job creation is not considered in Massachusetts program administrators benefit-cost ratios for energy efficiency, increasing employment is clearly a benefit to the Commonwealth.

CEC/DOER's 2017 *State of Charge* report addresses job creation as a non-energy benefit of increased investment in energy storage, noting that "growing [the] energy storage industry can expand on the success of the clean energy industry, bringing in new business to Massachusetts and creating new jobs."[51] The report found that deploying 1,766 MW of energy storage in the Commonwealth could create 6,322 job-years (where 1 job-year is defined as one job for one year) and $591 million in labor

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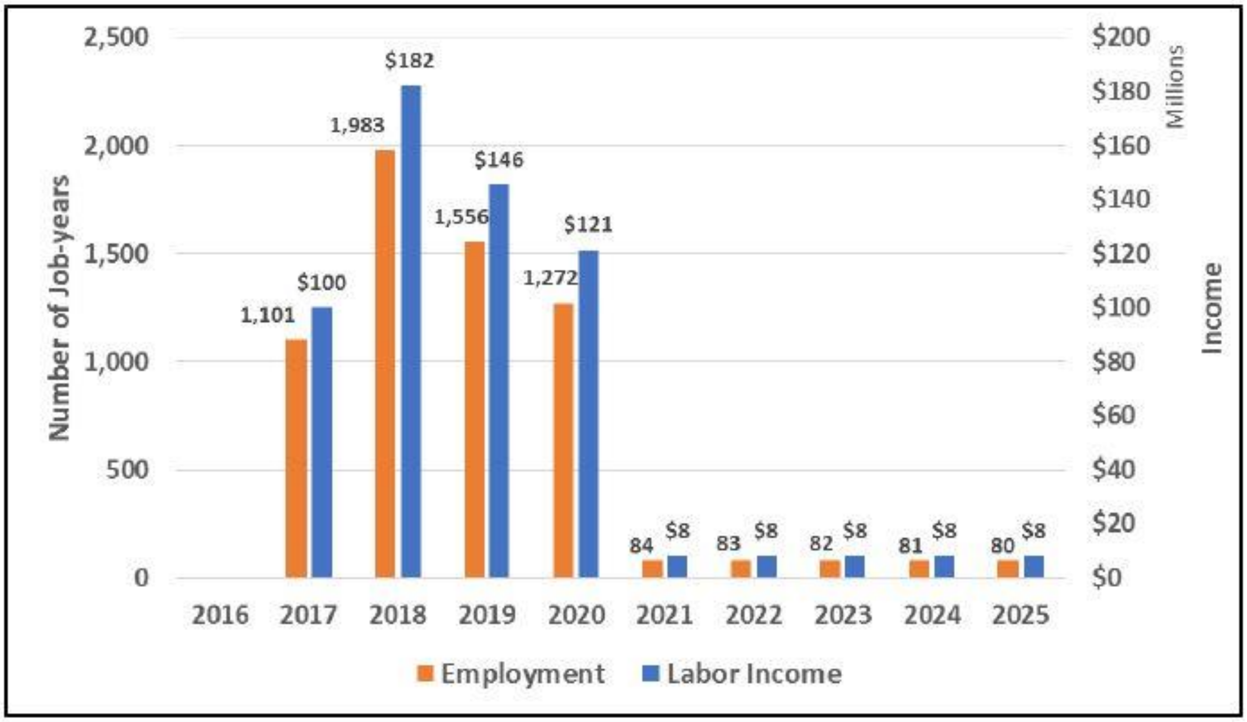
[49] MA NEI Evaluation 2011. p. 1-4.

[50] MA NEI Evaluation 2011. p. 4-16; Woolf et al., 2014. p.25

[51] MA CEC/DOER 2017. *State of Charge*. p.23.

income over the ten-year study period (2016-2025) (see Figure 3 below).[52] Per year, these benefits are equivalent to an average of approximately 700 jobs and $66 million; equivalent to 3.3 jobs per MW and $310,000 per MW over the battery storage deployment period (2017-2020) and 0.05 jobs per MW and $4,500 per MW over the storage maintenance period (2021-2025).[53] For context, according to a Massachusetts Clean Energy Center employment report, in 2017, clean energy industry employment in the Commonwealth grew by 4,014 jobs.[54]

Figure 3. *State of Charge* Massachusetts employment and labor income impacts, 2016-2025



Source: Reproduced from MA CEC/DOER 2017, State of Charge. Available online: https://www.mass.gov/files/2017-07/state-of-charge-report.pdf. Figure Appendix B-3, p.222.

CEC and DOER note that the employment and labor income impacts shown in Figure 3 are the result of anticipated levels of spending. Currently, Massachusetts has allocated $10 million in spending on energy storage initiatives from 2017 through 2020 only, resulting in a sharp decrease in employment and labor income impacts in 2021. In order for employment and labor income impacts in 2021 and beyond to be at the levels expected between 2017 and 2020, more spending would need to be allocated to additional storage deployment in those years.[55]

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[52] MA CEC/DOER 2017. *State of Charge*. p.103.

[53] MA CEC/DOER 2017. *State of Charge.* p.222-3.

[54] Massachusetts Clean Energy Center (CEC). 2017. *Massachusetts Clean Energy Industry Report*. Available online: https://www.masscec.com/2017-massachusetts-clean-energy-industry-report.

[55] MA CEC/DOER 2017. *State of Charge.* p.223.

The *State of Charge* report finds that investing in energy storage systems in Massachusetts will provide: 1) direct benefits from employment created from activities such as planning, developing, constructing, installing and maintaining battery storage;[56] 2) indirect benefits created in industries that support battery storage, such as necessary inputs to manufacture batteries—like lithium ion—or facilities needed to facilitate the manufacture, maintenance or operation of battery storage;[57] and 3) induced benefits (that is, ripple effects through the economy) from, for example, battery storage employees spending money near their place of work in restaurants and shops, signing up for health care services, signing up for retirement accounts, etc.[58]

To estimate a value to this non-energy benefit, we used the results of the *State of Charge* report, presented in Figure 3 above, calculating the number of job years created per MW of battery storage and the associated labor income generation per MW. During the construction period between 2017 and 2020, for each MW of installed battery storage capacity, CEC and DOER expect approximately 3.3 job years and $310,000 of labor income. *State of Charge* projects an average annual income plus benefits of approximately $93,000 per job year.

Increasing battery storage in Massachusetts holds the promise of job creation, which will serve to strengthen local communities by providing Massachusetts families will valuable sources of family income.

7. Less land used for power plants

More battery storage reduces capacity reserve margins and the need for power plants that supply energy exclusively at times of peak demand. Reducing the number of peaker plants needed to maintain reliability (which is an energy system benefit) results in an additional non-energy benefit for society as a whole: less land need be devoted to power plants and instead could be used for other purposes such as recreation, conservation, commercial or residential buildings, cropland or pasture.

State of Charge explains, "[A]dvanced energy storage projects require a much smaller footprint than conventional power plants."[59] The report goes on to discuss the comparative land requirements of storage measures and new 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.* [60]

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[56] MA CEC/DOER 2017. *State of Charge.* p.223.
[57] MA CEC/DOER 2017. *State of Charge.* p.223.
[58] MA CEC/DOER 2017. *State of Charge.* p.223-4.
[59] MA CEC/DOER 2017. *State of Charge.* p. 9.
[60] MA CEC/DOER 2017. *State of Charge.* p. 9.

According to a report commissioned by the U.S. Department of Energy's Storage Systems Program, "society at large has a significant stake in the storage opportunity because some of the key benefits accrue, in part or in whole, to society at large (e.g., reduced air emissions and reduced land use impacts from reduced need for new infrastructure)".[61] Increasing battery storage capacity in Massachusetts provides benefits beyond those directly experienced by electric distributors or ratepayers; there are broader societal benefits including making more land available for alternative uses.

Neither the MA NEI Evaluation 2011[62] nor the MA NEI Evaluation 2016 address reduced land use as a non-energy benefit, although many energy efficiency measures lessen the need for new power plants in the same way that battery storage does, shrinking the electric sector's land use footprint.

As a preliminary estimate of this non-energy benefit based we compare the land use footprints of conventional natural gas combustion turbines and utility-scale battery storage (see Table 8). The vast majority of storage measures offered to ratepayers by the program administrators, however, can be expected to have much smaller per MW land footprints than would a utility-scale battery storage facility. Many behind-the-meter battery storage installations have no land-use footprint whatsoever. (For example, Tesla's Powerwall 2 battery is 45"x30"x6" and is typically installed within an existing building.[63])

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[61] Eyer, J. and Corey, G. February 2010. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide: A Study for the DOE Energy Storage Systems Program*. Prepared by Sandia National Laboratories, SAND2010-0815. Available online: https://www.smartgrid.gov/files/sandia_energy_storage_report_sand2010-0815.pdf. p. 152.

[62] MA NEI Evaluation 2011 does include a consideration of a related non-energy benefit, namely, avoided landfill space due to appliance recycling programs.

[63] Energy Matters. "Buy Tesla Powerwall 2 Home Battery." Available online: https://www.energymatters.com.au/residential-solar/tesla-powerwall-battery/.

Table 8. Average land use of U.S. natural gas plants and utility-scale battery storage installations

Energy Type	Land Use Footprint (Acres/MW)	Location	Source
Natural gas	**12.4**	U.S.-wide estimate	Eyer, J. and Corey, G. February 2010. Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide: A Study for the DOE Energy Storage Systems Program. Prepared by Sandia National Laboratories, SAND2010-0815. Available online: https://www.smartgrid.gov/files/sandia_energy_storage_report_sand2010-0815.pdf.
Utility-scale battery storage	**0.017**	Average of three cases provided below	AEC calculation
Utility-scale battery storage	0.004	Duke Energy wind and battery storage project (TX)	International Renewable Energy Agency (IRENA). 2015. Case Studies: Battery Storage. Available online: http://www.irena.org/documentdownloads/publications/irena_battery_storage_case_studies_2015.pdf
Utility-scale battery storage	0.007	Solar Grid Storage solar and battery storage project (MD)	International Renewable Energy Agency (IRENA). 2015. Case Studies: Battery Storage. Available online: http://www.irena.org/documentdownloads/publications/irena_battery_storage_case_studies_2015.pdf
Utility-scale battery storage	0.04	AES Energy Storage 50 MW lithium-ion configuration	Leslie, P. 2014. Battery Storage Projects. Puget Sound Energy Presentation. UW Energy and Environment Seminar. Available online: https://class.ece.uw.edu/500/2014aut-e/11-13-14%20Pres%20(PSE%20Storage).pdf

While natural gas plants use a substantial amount of land, residential battery storage typically involves little or no additional use of land. The difference between the land use footprint of a typical natural gas combustion turbine and behind-the-meter battery storage is approximately 12.4 acres per MW of capacity—meaning that for each MW of battery storage installed, 12.4 acres of land is available to be utilized for non-energy purposes. While we do not have access to data on the land value of existing gas plants, nor are we able to predict the land value of plants yet to be built, recent research has found that the average value of urban land in Boston is $600,000 per acre.[64] If, for example, a 60 MW gas peaker plant in urban Boston were avoided by installing battery storage instead—the total value of land available for other uses would be approximately $446 million. It is important to conclude with a caveat: land values are highly location-dependent, and the numbers presented above should be interpreted with care as an illustration only.

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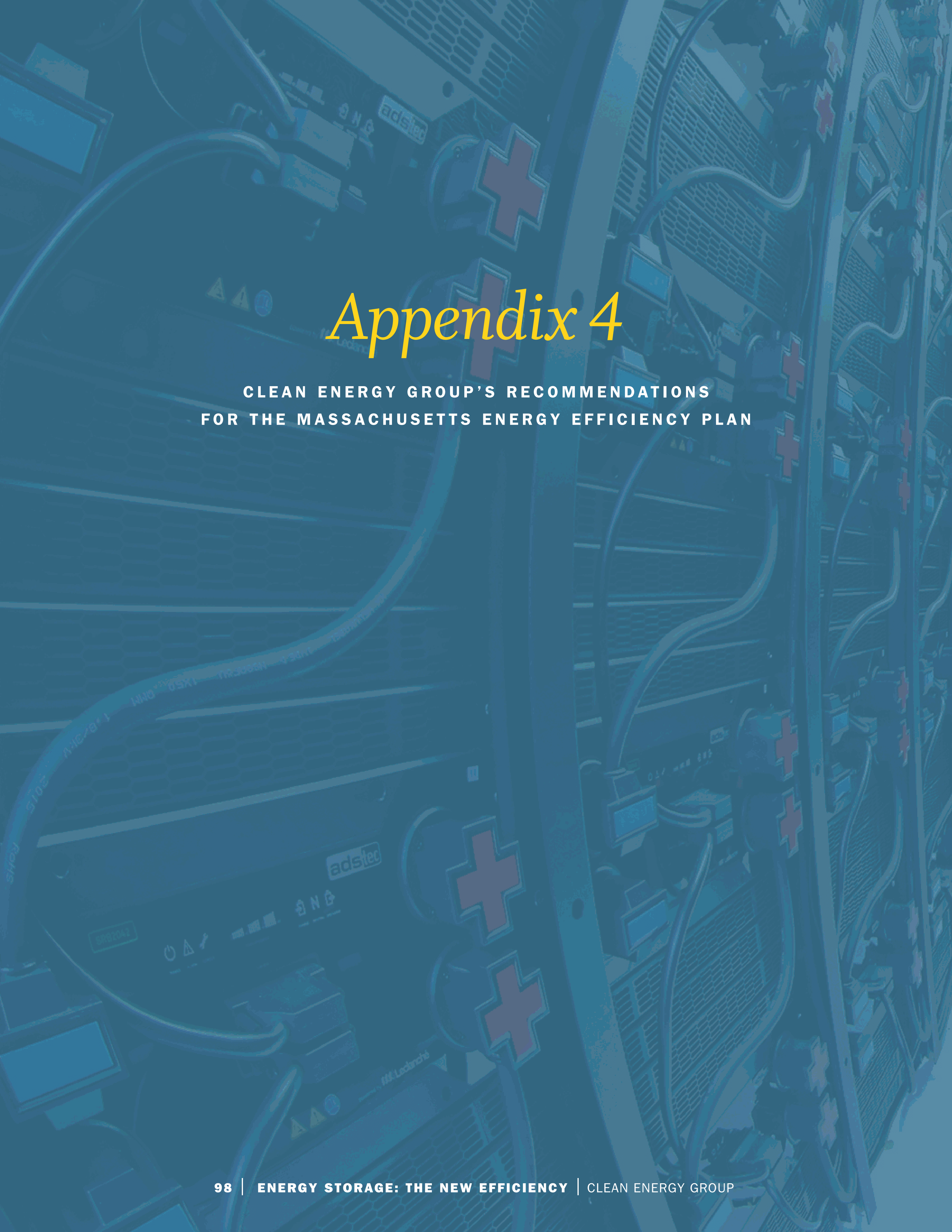
[64] Albouy, D., Ehrlich, G. and Shin, M. 2018. Metropolitan Land Values. *The Review of Economics and Statistics, MIT Press*, 100(3), 454-466. Available online: http://davidalbouy.net/landvalue_index.pdf. p.460.

Full valuation of an energy project that was 12 acres of land per MW more efficient than its alternative would include benefits to the utility—for example, reduced operations, maintenance, and property taxes—as well as benefits to society—for example, land that might have been designated for a power plant could be used for mixed-use development instead.



Appendix 4

CLEAN ENERGY GROUP'S RECOMMENDATIONS FOR THE MASSACHUSETTS ENERGY EFFICIENCY PLAN

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CLEAN ENERGY GROUP'S RECOMMENDATIONS FOR THE MASSACHUSETTS ENERGY EFFICIENCY PLAN

The Massachusetts 2019–2021 Energy Efficiency Plan included some important advances in the inclusion of energy storage as a peak demand reducing technology. However, there are several ways to improve the plan to make it more proactive in supporting energy storage and clean energy equity. We offer the following suggested improvements for Massachusetts' 2022–2024 Three-Year Energy Efficiency Plan:

- **Low-income provisions.** Typically, it is more difficult to provide clean energy options to low-income communities, which need clean, resilient and low-cost energy the most. This is why the Commonwealth of Massachusetts has established a multi-agency initiative to ensure that low-income communities do receive clean energy services and programs.[1] The Commonwealth's energy efficiency plan includes "income-eligible" measures for these underserved communities, however, the program administrators did not include any storage incentives in the income-eligible category for the 2019–2021 plan. To correct this omission, Massachusetts should focus on developing specific low-income provisions as it begins the process to develop the next three-year energy efficiency plan, which will commence in 2022. These could include an added low-income incentive, more favorable financing, a carve-out guaranteeing a certain percentage of low-income participation, an up-front rebate, or (preferably) a combination of these.

- **Lack of transparency.** Numerous stakeholders have noted a lack of transparency in the way the energy efficiency plan was developed, as well as in the resulting plan. The plan as approved by the DPU still includes vague and undefined elements that make it difficult to understand exactly what is being offered to storage customers by the program administrators. Improved transparency is essential, both to enable stakeholder participation in the process, and to enable developers to effectively market the plan.

- **Stacking incentives/applications.** Stacking applications and incentives (such as net metering, SMART incentives, and efficiency incentives) can be important to allow customers to defray battery storage system costs. Because the Massachusetts energy efficiency plan does not prohibit the stacking of incentives and applications, it is assumed that this practice will be allowed. However, it would be preferable to make this clear in the language of the energy efficiency plan itself.

- **Size of investment.** The investment in incentives that could be applied to energy storage is small ($13 million/34 MW) relative to both the size of the state's peak load, and to the size of the efficiency budget. Future plans should expand the energy storage offering.

- **Daily Dispatch program.** The Massachusetts Department of Public Utilities (DPU) should allow the utilities to go forward with their proposed Daily Dispatch energy storage incentive as a full program offering, rather than a pilot program.

- **Energy Storage System and Performance program.** The MA DPU should allow Cape Light Compact (CLC) to go forward with its proposed Storage System and Performance program, which would, if approved, provide free batteries to 1,000 residential and commercial customers of CLC, including low-income customers. CLC's proposed program was the only part of the plan that included income-eligible customers in any way. It also set forth a different approach to incentivizing battery deployment, that would have provided the state with an alternative model to compare with the statewide offering.

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[1] The MA governor announced the Affordable Access to Clean and Efficient Energy Initiative in 2016. For more information, see *https://www.mass.gov/service-details/affordable-access-to-clean-and-efficient-energy-initiative*.

- **Energy storage benefits omitted/undervalued.** Due to numerous omissions, notably the absence of any consideration of non-energy benefits, energy storage was likely undervalued in the utility program administrators' benefit/cost ratios (BCRs). In addition to the omission of non-energy benefits, there are a number of other omissions and errors in the valuation of energy storage in the 2019–2021 Massachusetts energy efficiency plan. The most important of these are listed below (these issues are discussed in more detail in Applied Economics Clinic's reports in Appendices 1–3):
    - Non-energy benefits valued at zero
    - Summer discharge generally not included in targeted discharge
    - Winter reliability benefits valued at zero. The MA Energy Efficiency Advisory Council (EEAC) and the program administrators should together work to value the winter reliability benefits of energy storage, as called for by the EEAC and DOER.
    - Emissions benefit under-counted (CO_2 emissions assumed higher in off-peak hours than on-peak hours, contrary to ISO-New England data)
    - Energy prices use assumed averages rather than actual, granular prices by time period
    - Summer capacity undervalued—assumption that storage only operates during 10 percent of peak hours (based on Maryland study)

In addressing the above issues, additional analytical work may be needed. Recommended future analytical work in Massachusetts includes:

- Analysis of additional non-energy benefits of energy storage (beyond the seven included in this report)
- Evaluation of the value of winter reliability benefits of energy storage (as called for by DOER and the EEAC)
- Analysis of assumptions that New England generators' CO_2 emission rates are higher during off-peak than peak hours (contrary to ISO-New England historical data), and the impact of this on storage BCRs Revision of storage BCRs using hourly price data rather than average seasonal on- and off-peak prices, as the program administrators did for the 2019 MA energy efficiency plan
- Analysis of the value of shaving peak demand in New England
- Analysis of the value of health benefits resulting from replacing fossil fuel generation with renewables and energy storage

ABOUT THE AUTHOR

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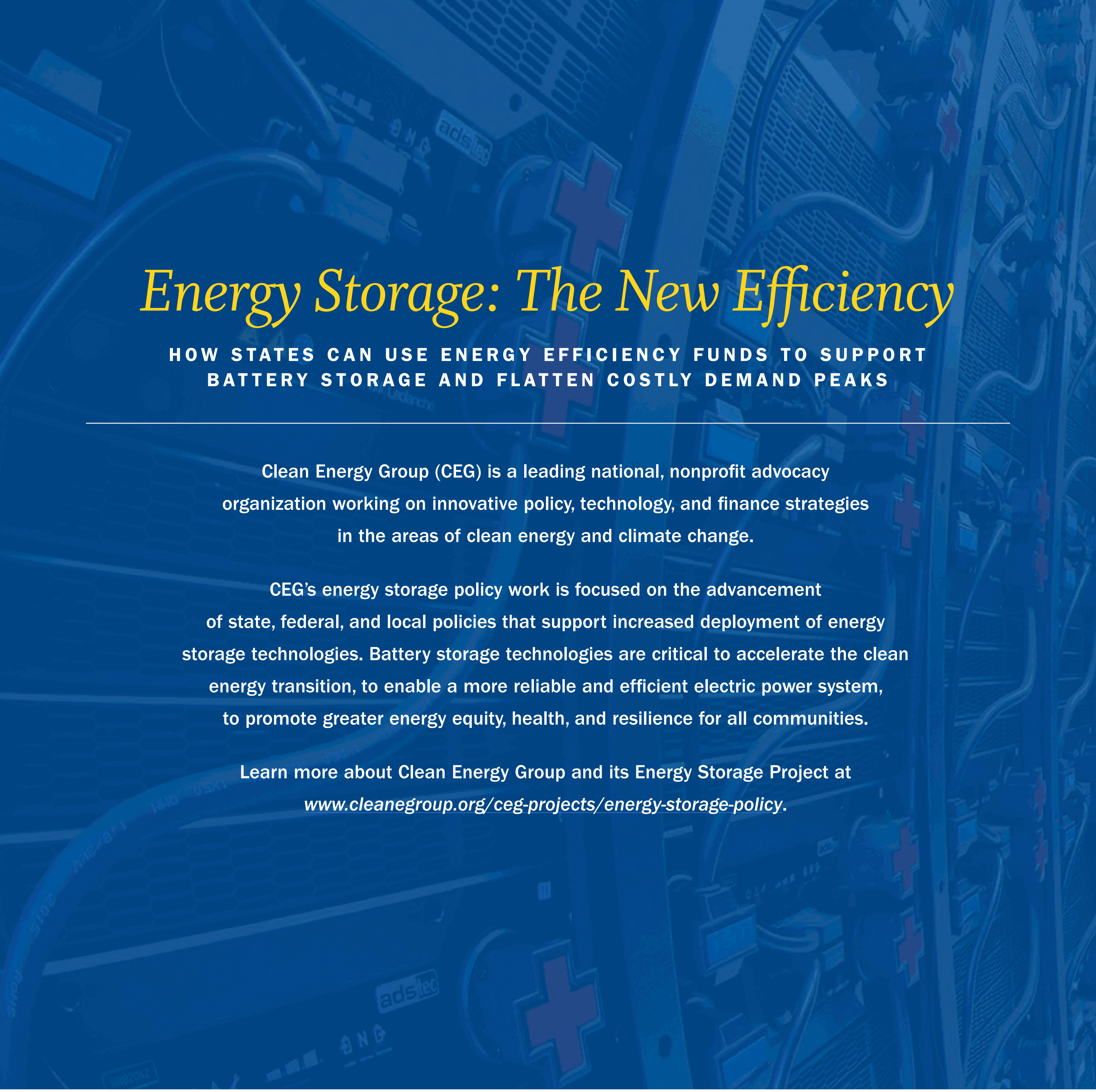
ABOUT CLEAN ENERGY GROUP

Clean Energy Group (CEG) is a national, nonprofit organization that promotes effective clean energy policies, develops low-carbon technology innovation strategies, and works on new financial tools to advance clean energy markets that will benefit all sectors of society for a just transition. CEG works at the state, national, and international levels with stakeholders from government, the private sector, and nonprofit organizations. CEG promotes clean energy technologies in several different market segments, including resilient power, energy storage, solar, and offshore wind. CEG created and now manages a sister organization, the Clean Energy States Alliance, a national nonprofit coalition of public agencies and organizations working together to advance clean energy through public funding initiatives. Neither organization accepts corporate contributions. *www.cleanegroup.org*



Energy Storage: The New Efficiency

HOW STATES CAN USE ENERGY EFFICIENCY FUNDS TO SUPPORT BATTERY STORAGE AND FLATTEN COSTLY DEMAND PEAKS

Clean Energy Group (CEG) is a leading national, nonprofit advocacy organization working on innovative policy, technology, and finance strategies in the areas of clean energy and climate change.

CEG's energy storage policy work is focused on the advancement of state, federal, and local policies that support increased deployment of energy storage technologies. Battery storage technologies are critical to accelerate the clean energy transition, to enable a more reliable and efficient electric power system, to promote greater energy equity, health, and resilience for all communities.

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