Massachusetts Battery Storage Measures: Benefits and Costs

Updated April 2, 2019 – White Paper

Applied Economics Clinic

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April 2, 2019

[AEC-2019-04-WP-01]

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Acknowledgements

This report was commissioned by Clean Energy Group in support of its efforts to expand the benefits of energy storage and clean energy technologies. The Applied Economics Clinic would like to thank Todd Olinsky-Paul, Project Director at the Clean Energy Group, for comments and input that greatly improved this report.

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

[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.

[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.

[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 plus 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.

[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

[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.

[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).

[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)

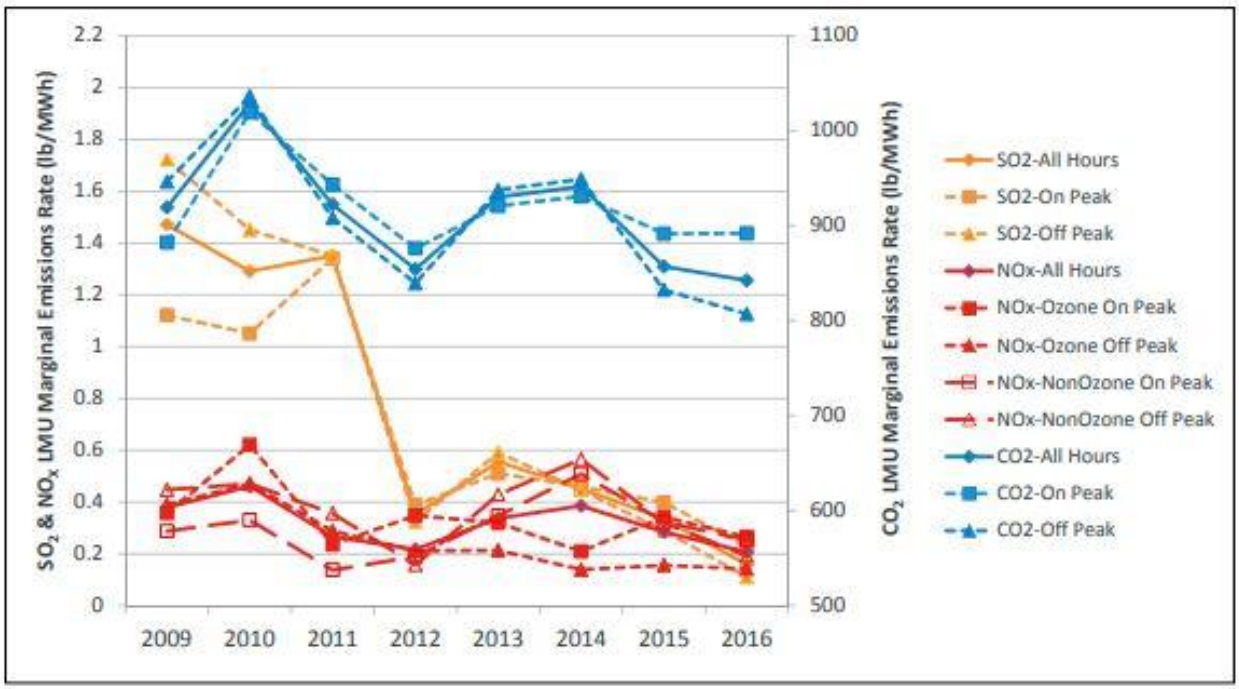
Ozone / Non-Ozone Season Emissions (NOx)					
Air Emission	Ozone Season		Non-Ozone Season		Annual Average (All Hours)
	On-Peak	Off-Peak	On-Peak	Off-Peak	
NO_X	0.26	0.14	0.25	0.19	0.21
Annual Emissions (SO_2 and CO_2)					
Air Emission		Annual			Annual Average (All Hours)
		On-Peak	Off-Peak		
SO_2		0.22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

	Total Count	Highest 10% by	
		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

[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)*