Massachusetts Residential Energy Storage Demand Reduction Offering Evaluation

Prepared for
Massachusetts Program Administrators
Study No.: MA23-DR02-E-2023-Res-BS-DR

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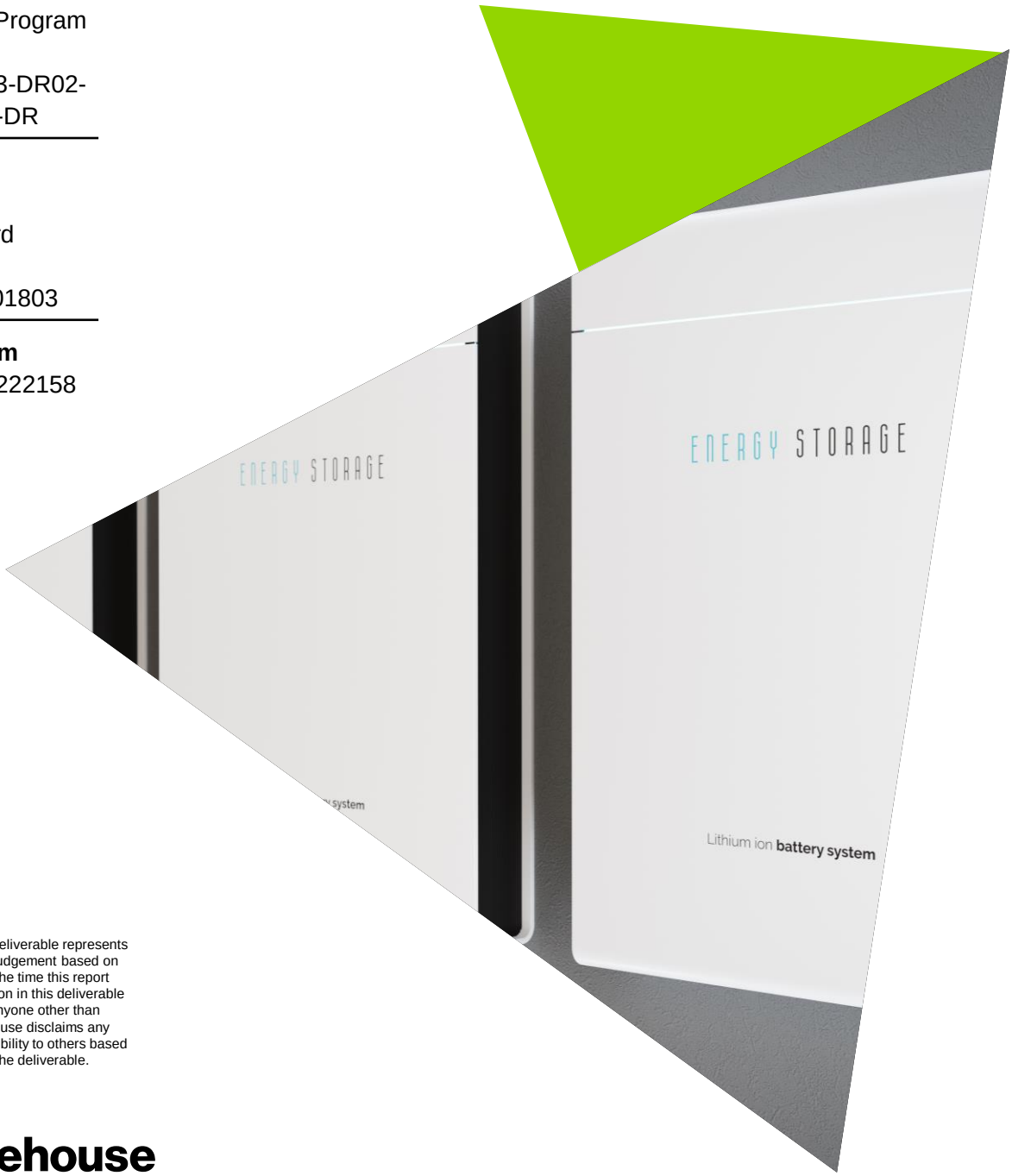

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Offering Overview

Offering Summary

The Massachusetts Residential Energy Storage Demand Reduction Offering (hereinafter referred to as "the offering") aims to reduce peak demand by leveraging residential battery energy storage ("ES").

This offering is part of the Connected Solutions portfolio of programs offered by the electric Massachusetts Program Administrators (PAs) - Cape Light Compact (CLC), Eversource, National Grid, and Unitil. The offering is a "Bring Your Own Battery" or "BYOB" program, targeting residential customers that already have ES installed. The ES system is primarily charged from co-located solar PV (although co-located solar is not a requirement of the program) and is discharged during events called by each PA during summer months. In total, the PAs each called 29 events during the summer 2023 program period, with events varying in length from 1 to 3 hours

The PAs sought to assess the peak demand reduction impacts of the offering as well as participant acceptance and the significance of a five-year incentive-lock on the motivation for purchasing the battery storage system.

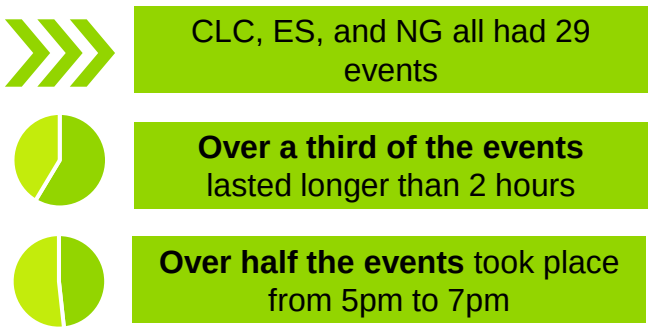
This evaluation report describes Guidehouse's customer research, benchmarking and storage economics review, assessment of event participation, and analysis of impacts. Guidehouse's methodology, data sources used, and key findings are detailed in subsequent sections of this report.

Table 1. Residential Energy Storage Offering Summary Highlights

	Program Attributes	
Program Participants	**State**	Massachusetts
	Customer Segment	Residential customers
	Enrollment as of Sep. 30, 2023	CLC – 211 Eversource – 2,439 National Grid – 2,051
Program Design	**Battery Ownership**	Customer-owned
	Ongoing Incentive	$275/kW
	Event Parameters	Events can take place during June through September on non-holiday weekdays from 3pm-8pm and last 2-3 hours. The maximum number of potential events is 60 per season, with event dispatch criteria varying by PA.
	Charge Profile	If co-located PV, primarily charges from solar PV
	Discharge Profile	Uniform dispatch equal to rated power capacity
	Reserve Margin	20%

Figure 1. Number of Events in Summer 2023

Figure 1 shows the number of events from each PA in summer 2023 along with some notable features of the events that occurred.



Source for figure: Guidehouse analysis of DERMS vendor data

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Evaluation Methods

Residential Energy Storage Demand Reduction Evaluation Methods

PARTICIPANT SURVEYS

Guidehouse developed, fielded, administered, and analyzed an online survey to 2,058 participants to solicit feedback about their reason for purchasing the battery, when they made their battery purchase and thoughts on their participation. The survey asked questions related to pre-program and post summer season benefit/cost (expected versus actual). The survey also ascertained whether participants have an EV, or are preparing for getting an EV, and its influence in getting battery storage.

BENCHMARKING & REVIEW OF STORAGE ECONOMICS

Guidehouse conducted secondary research of four residential storage demand reduction programs offered by program administrators in other jurisdictions to review incentive levels and terms.

Guidehouse compared the economics of storage purchase and ownership in 2019 versus 2023 to understand the simple payback and the importance of program incentives relative to how the state (e.g., Solar Massachusetts Renewable Target (SMART) battery adder) and federal (e.g., Investment Tax Credit (ITC)) incentives have changed.

DATA MANAGEMENT

Prior to the end of the summer offering season, Guidehouse and EnergyHub performed a data transfer test of the 15-minute battery storage telemetry data. Guidehouse reviewed the data to assess whether it contained the fields required for evaluation.

After the season, all data was transferred to Guidehouse for QA/QC and for analysis.

OFFERING'S ENERGY AND DEMAND IMPACTS

Guidehouse examined the telemetry data to determine the extent to which batteries charge/discharge on non-event days. Guidehouse estimated peak demand and energy impacts using three baseline scenarios. A blended baseline was derived from evaluation data, with survey data used to determine proportions of the two possible assumed baselines. The assumption baselines are 1) no battery baseline, and 2) with battery baseline.

Guidehouse reviewed the vendor-estimated demand savings to check for any substantial differences from Guidehouse's estimates. Guidehouse developed realization rates for all three baseline scenarios that can be applied to vendor-estimated demand savings in the future.

REPORTING

Reporting included a draft presentation, a draft report, and a final report. Report contents include findings from the survey, benchmarking & storage economics review, and impact analysis.

Source: Guidehouse

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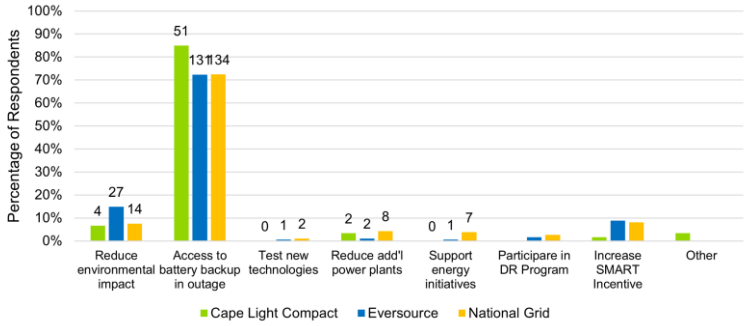
Findings: Customer Experience & Secondary Research

MOTIVATIONS FOR PURCHASE

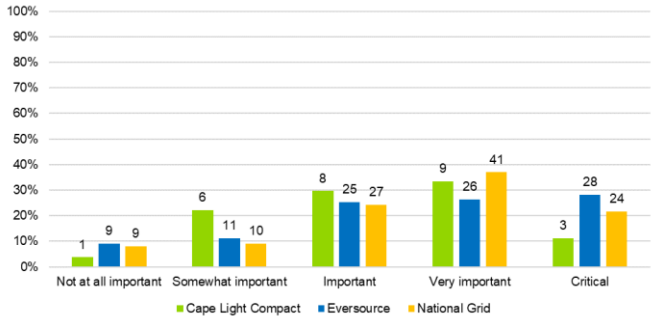
- 74% of respondents selected access to battery backup as their primary motivation in purchasing a battery system.
- Reducing environmental impact, program participation incentives and the 5-year guarantee, ITC, and SMART storage adder were all important secondary motivations in purchasing a battery system.
  - 131 respondents (31% overall, 55% of those who purchased their battery in parallel to enrolling) indicated the incentive lock was “critical” or “very important” to their purchase decision.
- 25% (48) of the 189 batteries purchased prior to enrollment reported using their battery system for daily or near daily prior to enrolling . Following program enrollment, 38% (162) reported using their battery system for daily or near daily dispatch (outside of program events).

Figure 2. Primary Purchase Motivation (n=426)



Source: Guidehouse analysis of participant survey data

Figure 3. Importance of 5-Year Incentive Guarantee on Battery Purchase (n=237)



Source: Guidehouse analysis of participant survey data

PROGRAM EXPERIENCE AND SATISFACTION

- Approximately 80% of respondents indicated that they never opted out of an event.
- 68% (290) were very satisfied or satisfied with the program and 67% (284) were very likely to continue participating in the program.

BENCHMARKING & STORAGE ECONOMICS REVIEW

- Three of four programs benchmarked provide a one-time, upfront incentive to enrollees (only Liberty does not since Liberty’s program involves monthly discounted battery lease cost to participants with free battery installation). Only CT also offers an ongoing performance incentive which varies based on how many years one has been enrolled in the program. CT provides a performance incentive lock of 10 years.
- Simple payback for Massachusetts participants in 2019 was 4.8 years compared to 7.3-8.4 years in 2023, depending on PA and income level category. This suggests that the 5-year incentive guarantee is even more important than it used to be as the cost of batteries continues to rise.

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Findings: Impact Analysis

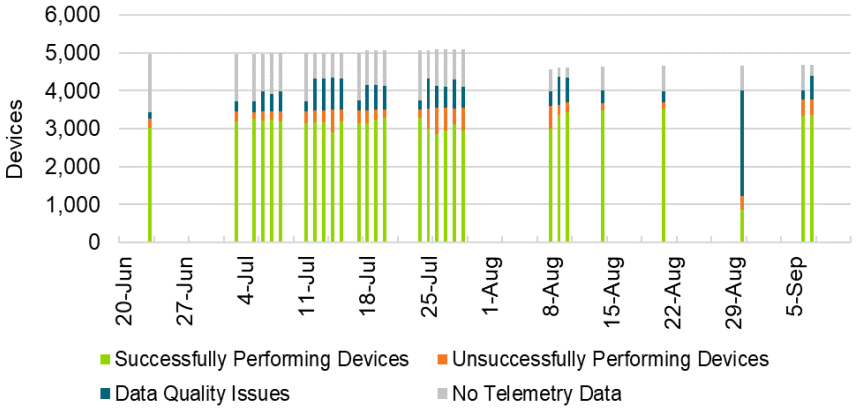
PARTICIPATION METRICS

- The program had 6,760 unique devices enrolled throughout the summer, with an aggregate load reduction potential of 56.5 MW.
- Throughout the summer, the PAs called 29 events with 89% of devices successfully participating in events, on average.

EVENT IMPACTS

- Program batteries discharged at an average rate of 4.8 kW using the evaluation- based blended baseline. Using the Assumed No Battery baseline, the average discharge rate was 5.0 kW. Using the Assumed With Battery baseline, the average discharge rate was 4.7 kW.
- In aggregate, the program reduced load by 24.5 MW per event on average using the blended baseline derived from the program data and participant survey. Using the Assumed No Battery baseline, total program reductions were 25.4 MW per event on average. Using the Assumed With Battery baseline, total program reductions were 24.0 MW per event on average.
- Over the 48 hours inclusive of event days and the following day, program batteries increased their overall energy consumption, with total energy charged exceeding total energy discharged on average.
- The program had an average realization rate of 94.8% across PAs, using the blended baseline. PA-specific realization rates were 93.9% for Cape Light Compact, 94.7% for Eversource, and 95.6% for National Grid. Using the Assumed No Battery baseline, the average realization rate was 99.4%. Using the Assumed With Battery baseline, the average realization rate was 92.1%.

Figure 4. Successful Event Participation by Date



Source: Guidehouse analysis of DERMS vendor data.

Table 2. Event Impact Summary per Device*

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Max 15-min impact (kW)	-7.6	-9.2	-7.4
Blended	Avg 15-min impact (kW)	-4.5	-5.2	-4.3
No Battery	Max 15-min impact (kW)	-7.4	-9.0	-7.3
No Battery	Avg 15-min impact (kW)	-4.8	-5.5	-4.4
With Battery	Max 15-min impact (kW)	-7.7	-9.3	-7.5
With Battery	Avg 15-min impact (kW)	-4.4	-5.1	-4.2

Source: Guidehouse analysis of DERMS vendor data.

Table 3. Comparison to Vendor-Calculated Performance Estimates

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Realization Rate	93.9%	94.7%	95.6%
No battery	Realization Rate	99.0%	99.8%	99.5%
With battery	Realization Rate	91.0%	91.8%	93.4%

Source: Guidehouse analysis of DERMS vendor data.

*Note: In instances when the Assumed With Battery Baseline indicates that a specific device is charging during an event period, the magnitude of calculated impacts is the sum of the full discharge amount and the avoided charge amount. The result is a larger impact using the With Battery Baseline compared to the No Battery Baseline. This scenario applies for some devices when calculating the maximum impact during a single 15-minute interval.

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Final Considerations

Table 4. Key Findings and Recommendations/Considerations

Research Category	Finding	Recommendation / Consideration
Incentive Lock	131 respondents (31% overall, 55% of those who purchased their battery in parallel to enrolling) indicated the incentive lock was “critical” or “very important” to their purchase decision. Additionally, simple payback in 2019 was 4.8 years compared to 7.3-8.4 years in 2023, depending on PA and income level category.	**Recommendation:** Continue to offer the 5-year incentive guarantee.
Program Data	The vendor continued to provide updated telemetry and enrollment data files through January 10, 2024, more than 3 months after the season end date.	**Consideration:** The PAs should consider having the vendor develop a **standardized set of data processing steps** to enable a timely export of data for evaluation, ideally within one month of the season end. Use of a standardized process would also reduce the volume of data corrections and updates required, which impact both evaluation costs & timelines.
	The vendor provided telemetry data in a variety of formats.	**Consideration:** The PAs should consider having the vendor develop a **standardized data export** that contains fields commonly required for evaluations. When data updates are required, use of a standardized data format will reduce the amount of re-work required to process data.
	Some data fields were inconsistent across battery OEMs.	**Consideration:** The PAs should consider encouraging the vendor to work with OEMs to **identify any inconsistencies** in the way data are captured (e.g., sign conventions, timestamps). If the vendor is unable to standardize the data across fields, the vendor should document any inconsistencies in the data and provide this information with the data transfer. Additionally, the vendor should provide a data dictionary that describes each data field.
Future Evaluations	Continue asking survey questions to determine the most accurate blended baseline.	**Consideration**: Future evaluations should consider asking survey questions that specifically are designed to determine how many/proportion of participants are purchasing their batteries prior to enrolling in the program and how many of those who enroll at the same time as purchasing their battery did not consider the program a primary motivator for their purchase.

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Massachusetts Residential Energy Storage Demand Reduction Offering Evaluation (MA23-DR02-E-2023-Res-BS-DR)

Final Report

Prepared for:

Massachusetts Program Administrators

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March 20, 2024

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1. Introduction

The Massachusetts Residential Energy Storage Demand Reduction Offering (hereinafter referred to as "the offering") aims to reduce peak demand by leveraging residential battery energy storage ("ES"). This offering is part of the Connected Solutions portfolio of programs offered by the electric Massachusetts Program Administrators (PAs) - Cape Light Compact (CLC), Eversource, National Grid, and Unitil. The offering is a "Bring Your Own Battery" or "BYOB" program, targeting residential customers that already have ES installed. The ES system is primarily charged from co-located solar PV (although co-located solar is not a requirement of the program) and is discharged during events called by each PA during summer months. The PAs sought to assess the peak demand reduction impacts of the offering as well as participant acceptance and the significance of a five-year incentive-lock on the motivation for purchasing the battery storage system.

This evaluation report describes Guidehouse's customer research, benchmarking and storage economics review, assessment of event participation, identification of baseline, and analysis of impacts. Guidehouse's methodology, data sources used, and key findings are detailed in subsequent sections of this report.

1.1 Offering Summary

Table 1-1 summarizes the characteristics of the ES offering in 2023.

Table 1-1. Residential Energy Storage Offering Characteristics

Offering Attributes	2023
Battery Ownership	Customer-owned
Ongoing Incentive	$275/kW
Season	Jun 1 - Sep 30
Maximum Number of Events	60
Potential Event Days	Non-holiday weekdays
Potential Event Times	3 p.m. – 8 p.m.
Event Dispatch Criteria	Varies by PA
Event Duration	2-3 hours
Charge Profile	If co-located PV, primarily charges from solar PV
Discharge Profile	Uniform dispatch equal to rated power capacity
Reserve Margin	20%

Figure 1-1 shows cumulative enrollment in the program from June 1, 2023, through September 30, 2023. As of September 30, 2023, enrolled device counts were: CLC – 211; Eversource – 2,439; and National Grid – 2,051 (Unitil does not currently have any customers enrolled in the residential offering). A large number of devices were unenrolled in August 2023, which reflects the DERMS vendor undertaking a periodic cleaning to update enrollment data rather than a data issue or actual single day mass unenrollment of devices.

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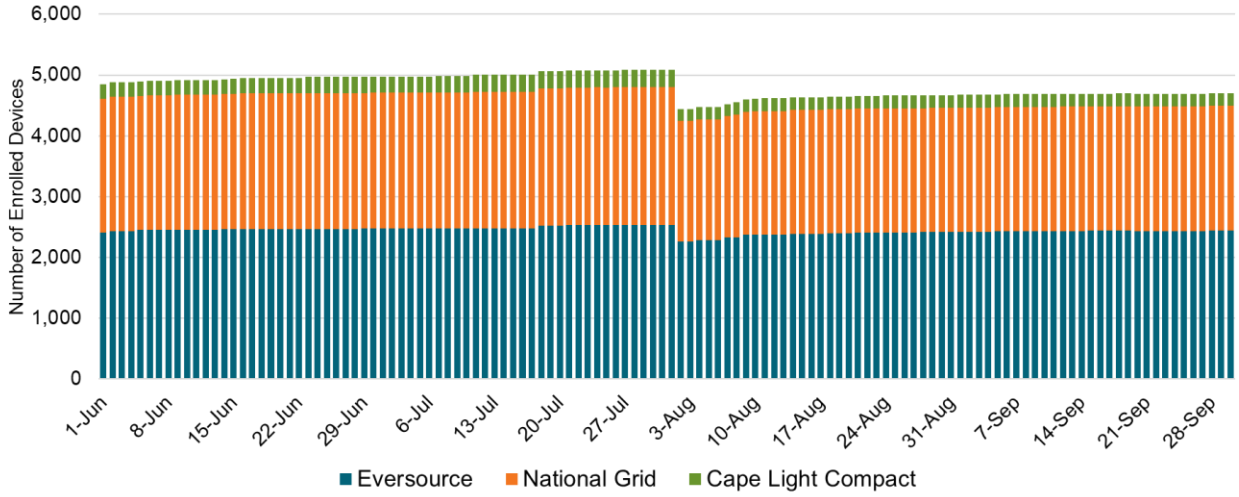
Figure 1-1. Cumulative Enrollment by PA (Devices)



Note: The DERMS vendor undertook its periodic cleaning in August.
Source: Guidehouse analysis of DERMS vendor data.

Figure 1-2 shows the timing of each event by date and PA in summer 2023. In total, CLC, Eversource, and National Grid each called 29 events during the summer 2023 program period, with events varying in length from 1 to 3 hours. Event dates were consistent across PAs, as were event start time and duration with a few exceptions, however. PAs were not obligated to call events on the same day and time.

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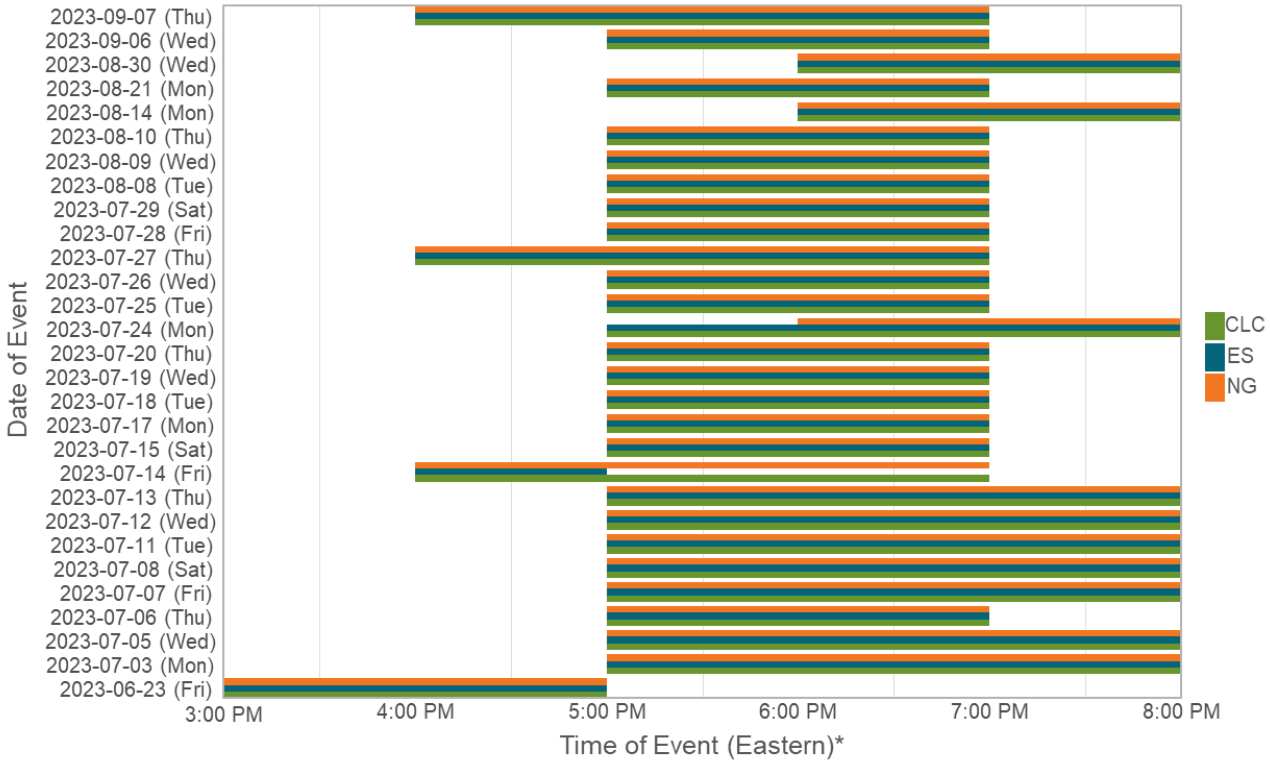
Figure 1-2. Event Timing by Date and PA in Summer 2023



Note: *Guidehouse noted discrepancies between the event data and the telemetry data on Friday, July 14, 2023, and Monday, July 17, 2023 and used the information in the telemetry data for the evaluation. The start and end time provided in Figure 1-2 is based on the telemetry data.

Source: Guidehouse analysis of DERMS vendor data.

1.2 Evaluation Objectives

The goal of this evaluation is to assess the customer acceptance, demand savings, and performance of battery storage as a resource for lowering the system peak demand. The evaluation consisted of process and impact components. The process component assessed customer acceptance and significance of a five-year incentive-lock on the motivation for purchasing the battery storage system, while the impact component measured the demand reduction through the offering and the battery storage system. The specific research questions are included in Table 1-2Table 1-2. These research questions, where appropriate, were answered for each PA.

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Table 1-2. Residential Energy Storage Demand Reduction Offering Evaluation Objectives

Research Category	Research Questions	Evaluation Approach
Customer Motivations & Lessons Learned	• What is the primary motivation for customers to obtain a battery? What is the motivation to then participate in the program? What value streams are most important to them (e.g., Connected Solutions program incentives, HEAT loan financing, state incentives, federal incentives, other non-economic (e.g., reduce peak demand/environmental))? • How important is a 5-year guaranteed incentive for program participation in the decision to purchase a battery and participate in the DR offering? • Would customers continue to allow their PA to control the battery storage system during peak periods in the future and, if so, would there be certain conditions under which they would or would not?	Online Participant Survey Program Benchmarking Review of Storage Economics
Program Impacts	• What is the per participant average battery charge or discharge each hour during called events? • What is the per participant average kW output from batteries during called events? • Is zero battery usage the appropriate baseline, or do customers utilize batteries outside of events? • Are the vendor-estimated demand savings closely aligned with Guidehouse's estimates? If not, what realization rate should be applied to vendor-estimated demand savings?	Telemetry Analysis
Battery Storage System Performance	• What is the average percentage of called event days that each battery storage system successfully discharges? • What is the average battery charge or discharge profile during non-event periods? • How does calling multiple events on consecutive days affect battery performance? Are batteries able to fully recharge between consecutive events?	Telemetry Analysis

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2. Evaluation Tasks and Methods

Guidehouse completed a variety of evaluation activities to address the research questions identified in the previous section. The evaluation approach is summarized Table 2-1.

Table 2-1. Residential Energy Storage Demand Reduction Evaluation Approach

Task	Description
Participant Survey	• Guidehouse developed, fielded, administered, and analyzed an online survey to 2,058 participants to solicit feedback about their reason for purchasing the battery, when they made their battery purchase and thoughts on their participation experience. The survey asked questions related to pre-program and post summer season benefit/cost (expected versus actual). The survey also ascertained whether participants have an EV, or are preparing for getting an EV, and its influence in getting battery storage.
Benchmarking & Review of Storage Economics	• Guidehouse conducted secondary research of four residential storage demand reduction programs offered by program administrators in other jurisdictions to review incentive levels and terms. • Guidehouse compared the economics of storage purchase and ownership in 2019 versus 2023 to understand the simple payback and the importance of program incentives relative to how the state (e.g., Solar Massachusetts Renewable Target (SMART) battery adder) and federal (e.g., Investment Tax Credit (ITC)) incentives have changed.
Data Management	• Prior to the end of the summer offering season, Guidehouse and EnergyHub performed a data transfer test of the 15-minute battery storage telemetry data. Guidehouse reviewed the data to assess whether it contained the fields required for evaluation. • After the season, all data was transferred to Guidehouse for QA/QC and for analysis.
Offering's Energy and Demand Impacts	• Guidehouse examined the telemetry data to determine the extent to which batteries charge/discharge on non-event days. Guidehouse estimated peak demand and energy impacts using three baseline scenarios. A blended baseline was derived from evaluation data, with survey data used to determine proportions of the two possible assumed baselines. The assumption baselines are 1) no battery baseline, and 2) with battery baseline. • Guidehouse reviewed the vendor-estimated demand savings to check for any substantial differences from Guidehouse's estimates. Guidehouse developed realization rates for all three baseline scenarios that can be applied to vendor-estimated demand savings in the future.

The remainder of this section provides additional detail on each evaluation task and methods.

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2.1 Participant Survey

Participant survey invitations were sent by email and one round of reminders was sent within a week of the initial invite. Survey was fielded online between October 5, 2023 and October 20, 2023. Respondents were provided $10 for completing the survey.

Table 2-2 summarizes the population and sample sizes by PA, along with response rates. The average response rate across PAs was 21%.

Table 2-2. Participant Survey Summary

PA	Enrollment Status	Population of Enrolled Customers	Population of Enrolled Batteries	Survey Sample Size	Number of Completes	Response Rate
Cape Light Compact	New	83	85	83	27	33%
Cape Light Compact	Returning	125	125	125	33	26%
Eversource	New	391	403	350	82	23%
Eversource	Returning	782	803	350	99	28%
National Grid	New	649	656	575	74	13%
National Grid	Returning	1,264	1,274	575	111	19%
Total		**3,294**	**3,346**	**2,058**	**426**	**21%**

Source: Guidehouse analysis of program and survey data

The survey covered the following topics:

- Motivations – the influence of PAs' offering and 5-year guaranteed incentive on customers' decision to join the offering with existing batteries and to purchase the battery if they did not have a battery already.
- Usage patterns prior to and after program enrollment
- Barriers to full-scale deployment that the participants identify
- Satisfaction with battery and the Connected Solutions offering
- Participant demographics and EV ownership status

Table 2-3 includes Guidehouse's activities for the participant survey. The survey instrument is contained in Appendix A.

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Table 2-3. Participant Survey Activities

Category	Activities
Survey Design and Programming	• Developed draft survey instrument • Finalized survey instrument based on feedback from the PAs and EEAC Evaluation, Measurement, and Verification consultants. • Programmed survey • QA/QC of programmed survey
Sample Preparation	• Received latest enrolled participant information (including contact information) • Prepared sample
Survey Implementation	• Provided the PAs call center with information about the survey effort • Contacted program participants with a link to the online survey • Monitored survey completions • Sent reminder emails • Administered $10 e-gift cards for respondents who completed the survey
Data Cleaning and Analysis	• Cleaned/recoded data in preparation for analysis (including cleaning and coding of verbatim/open-ended responses) • Analyzed data using R

Source: Guidehouse

2.2 Benchmarking & Review of Storage Economics

Guidehouse conducted secondary research on residential storage demand reduction programs offered by program administrators in other jurisdictions to review incentive terms (incl. incentive lock), structures, and levels.

This research included review of the following programs:

- Connecticut's Energy Storage Solutions Program
- Green Mountain Power's Bring Your Own Device Energy Storage Program
- Liberty Utilities (NH) Battery Storage Pilot Program
- Arizona Public Service Residential Battery Pilot

As another approach to assess the need for an incentive lock, we compared the economics of a typical storage purchase and ownership in 2019 versus today to understand how simple payback periods and the importance of program incentives relative to state (e.g., SMART battery adder) and federal (e.g., ITC) incentives have changed. The analysis considered average Massachusetts electric rates based on U.S. Energy Information Administration (EIA) Form 861 data[1] and assumes prior solar PV installation.[2] It compared standard income and low-

[1] Rates are implied from EIA-861 data by dividing total revenues by total sales for each customer type and service type combination for each utility, from the Sales_Ult_Cust dataset. That data is available here: https://www.eia.gov/electricity/data/eia861/.

[2] We assumed these customers will not have time-of-use rates.

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income households for similar sized homes based on average residential household consumption from EIA Form 861.

2.3 Impact Analysis

As part of its analysis of program impact, the Guidehouse team conducted the following evaluation tasks.

2.3.1 Participation Metrics

Guidehouse assessed the number of program participants and associated device characteristics over the course of the season, accounting for devices enrolled, devices online and operational, as well as accounting for exclusions due to data QC issues (Section 3.3). In combination with enrollment data, Guidehouse was able to review event participation data, reporting how many of the enrolled devices were successfully called for each event, including those that opted out or had a dispatch failure. Guidehouse considered successful device participation to be a device recording an average discharge greater than charge for the duration of the event window.

2.3.2 Review Non-Event Battery Behavior

Guidehouse examined the telemetry data to determine the extent to which batteries charge/discharge on non-event days and found persistent non-event day charge/discharge behavior that warranted examination of multiple baselines (Appendix E). Guidehouse derived a blended baseline from evaluation data, with survey data used to determine proportions of the two possible assumed baselines. The assumed baselines are 1) no battery baseline, and 2) with battery baseline. The baselines were used to measure peak demand and energy impacts.

Figure E-1, in Appendix 5.E summarizes non-event load shape behavior and indicates non-event-day battery usage.

2.3.3 Identify Baseline

The impact evaluation measured peak demand reductions using three different baseline scenarios: Assumed No Battery Baseline, Assumed With Battery Baseline, and Blended Baseline.

2.3.3.1 Assumed No Battery Baseline

The “Assumed No Battery Baseline” assumes the program was an important factor in the decision to purchase an ES system. Were it not for the program, these customers would have been unlikely to purchase an ES system. Thus, the baseline in this scenario is 0 kW and impacts are the observed values of battery charge and discharge, as illustrated in Figure 2-1.

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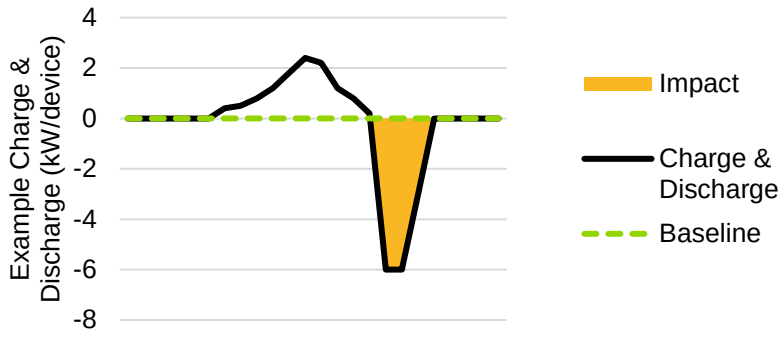
Figure 2-1. Assumed No Battery Baseline (Illustrative)

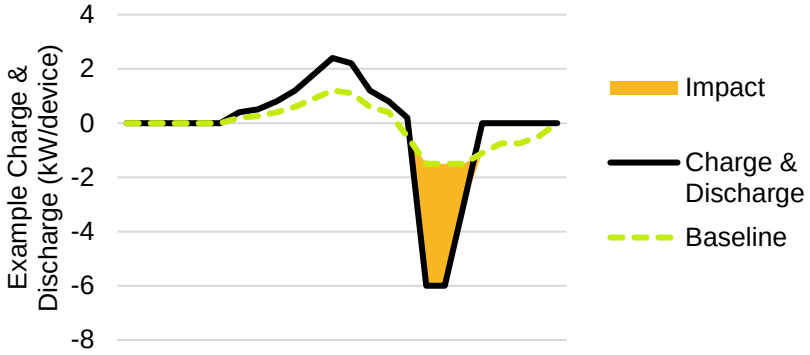


Source: Guidehouse

2.3.3.2 Assumed With Battery Baseline

The "Assumed With Battery Baseline" assumes participants would have purchased the ES system even absent the program. Therefore, the baseline must account for participants' use of the ES system outside of program events. For this scenario, the baseline usage is calculated as the average non-event day usage by month, day-of-week, and hour.[3] Impacts are the difference between the observed ES system usage profile and the baseline.

Figure 2-2. Assumed With Battery Baseline (Illustrative)



Source: Guidehouse

2.3.3.3 Blended Baseline

The "Blended Baseline" was constructed as a weighted average of the "Assumed No Battery Baseline" and "Assumed With Battery Baseline", with the weighting factor derived from evaluation data. In particular, the weighting factor represents the proportion of survey respondents who either owned the ES system prior to enrolling in the program or stated that the program did not influence their decision to purchase an ES system. Based on survey responses, 64% (+/- 3.8%)[4] of respondents met these criteria, whereas 36% did not. As such, for the "Blended Baseline" we apply a 64% weight to the "Assumed With Battery Baseline" and

[3] If a device did not have data for a non-event day for a certain month and day-of-week and hour, Guidehouse set the baseline to the average non-event day usage for the month and day-type (weekday or weekend).

[4] The error bound reported here and throughout the report corresponds to the 90% confidence level.

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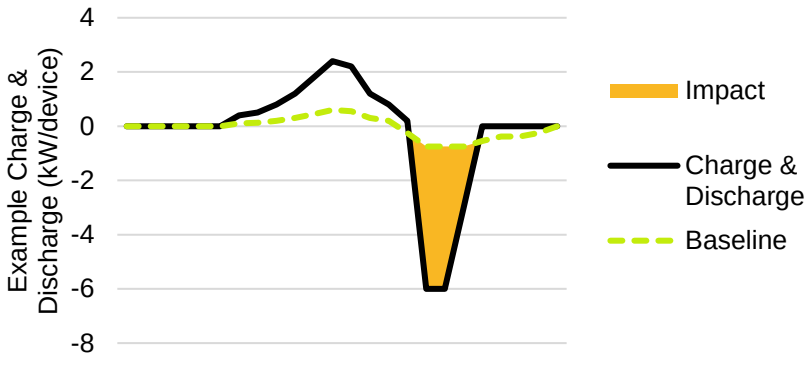
a 36% weight to the "Assumed No Battery Baseline." We apply the weight to the program level impacts, either total or average, rather than at the individual device level.[5]

The Assumed No Battery and Assumed With Battery baselines are based on observed data for all participants and therefore have no associated uncertainty. However, the blended baseline incorporates the weighting factor derived from a sample of participants. At the 90% confidence level, the relative precision on the weighting factor is 6.0%. This uncertainty applies to all impacts derived from the blended baseline.

Figure 2-3. Blended Baseline (Illustrative)



Source: Guidehouse

Table 2-4 shows how the blended baseline weighting factor was derived from the participant survey questions. The survey respondents included customers (57) who purchased a battery prior to the Connected Solutions program being available. As such, over time, the proportion of customers who purchased "before the program" will decrease, which will likely decrease the blended baseline factor. On the other hand, customers could still purchase a battery significantly earlier than deciding to participate, and even do so while having knowledge of the program. This latter group of customers could counterbalance those with reduction from the first group. This should be tested in future evaluations.

Table 2-4. Blended Baseline Weighting Factor

Relevant Survey Q's	Respondent Characteristic(s)	Count of Respondents	Baseline Classification
Q2	• Owned battery before enrolling (Whether purchased battery before or after program was available)	189	With battery baseline
Q2, Q2B	• Purchased battery at same time as enrolling • Program did not influence purchase of battery	82	With battery baseline
Q2, Q4	• Purchased battery at same time as enrolling • Program ranked as 1st reason for battery purchase	8	No battery baseline

[5] The participant survey responses were from a subset of participants, those that responded to the survey. As such, data is not available on an individual ES system or participant level. This then required the weighting factor to be applied at the total or average level.

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Relevant Survey Q's	Respondent Characteristic(s)	Count of Respondents	Baseline Classification
Q2, Q5	• Purchased battery at same time as enrolling • Program incentives AND/OR 5-yr guarantee – Critical	49	No battery baseline
Q2, Q5	• Purchased battery at same time as enrolling • Program incentives AND/OR 5-yr guarantee – Very Important	65	No battery baseline
Q2, Q5	• Purchased battery at same time as enrolling • Program incentives AND/OR 5-yr guarantee – Important	29	No battery baseline
Q2, Q2B, Q5	• Purchased battery at same time as enrolling • Those who indicated program did influence battery purchase AND who are NOT previously accounted for	4	No battery baseline
	Total	**426**	

Q2 Did you own your battery system prior to your enrollment in the offering?
Q2B Did the Connected Solutions program influence your decision to purchase your battery system?
Q4 What was your first and second biggest motivation in purchasing a battery system?
Q5 Please indicate how important each of the following was in your decision to purchase a battery system: (factor list)
Source: Guidehouse analysis of participant survey results

2.3.4 Assess Peak Reduction Impacts of Events

As a key output of the impact analysis, Guidehouse performed several tasks to fully assess the peak reduction from battery storage resulting from called events.

2.3.4.1 Peak Demand Impacts

Guidehouse assessed the peak demand reduction for each participating ES system in each called event and calculated the average demand impacts across the hours of the event and the hours preceding and following the event, per event and by season.

2.3.4.2 Relative Battery Performance

In order to assess theoretical performance potential, Guidehouse reviewed program enrollment files to sum the power rating (kW) and energy rating (kWh) across individual storage systems to calculate the total load reduction potential (MW and MWh) of the program if all batteries were fully discharged during an event of a given length, assuming uniform dispatch during the event.[6] Guidehouse then compared actual performance relative to that theoretical potential.

2.3.4.3 Review of Vendor-Estimated Demand Savings

Guidehouse compared the peak demand impacts with the EnergyHub's event performance estimates (kW) that are used to calculate participant incentives and identify any differences. Assuming that EnergyHub applies the zero-usage baseline, we utilized the Assumed No Battery Baseline for this effort.

Further, Guidehouse developed realization rates for each of the three baseline scenarios that can be applied to vendor-estimated demand savings in future years.

[6] Accounting for a 20% reserve capacity which the program will not discharge a battery below.

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2.3.5 Assess Energy Impacts of Events

In addition to peak reduction impacts, Guidehouse also assessed annual efficiency losses (in kWh) by aggregating the increase in energy consumption from charging as a result of round-trip efficiency (RTE) loss. We do not report energy impacts for each event because each time a battery discharges, it also recharges offsetting any impact from the event or resulting in slight increases in consumption due to RTE loss. Over time, the RTE loss associated with each charge and discharge results in a net increase in energy consumption.

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3. Data Sources and Data Review

This section describes the data sources used for this evaluation and the steps taken to prepare the data for analysis. The data sources used included event summary data from the PAs, and enrollment, telemetry, and vendor-calculated impact data from the DERMS vendor.

3.1 Data from PAs

- **Event summary data:** General event information such as date, start time, and stop time.

3.2 Data from DERMS Vendor

- **Enrollment data:** One row per application to the program, with information on battery characteristics such as the date of enrollment, date of unenrollment (as applicable), battery model and manufacturer, and battery capacity.

- **Telemetry data:** One row per time, date, and unique device ID indicating the battery power, energy, cumulative stored energy, and cumulative stored energy as a share of nameplate capacity. Telemetry data was supplemented with a column indicating if a reading was taken during the day of an event, and/or during an event itself.

- **Vendor-calculated impact data:** One row per unique device ID, with information on device characteristics, such as battery manufacturer and service territory, and assessed impact during each event. Additionally, summary data was presented separately for average and cumulative impact by unique device ID, event ID, battery manufacturer, and service territory.

3.3 Data Review

Guidehouse addressed several discrepancies in the data to prepare it for the analysis including: correcting original equipment manufacturer – specific (OEM) variations in time-zone, removing rows with exact duplicate readings, correcting OEM-specific variations in sign conventions for battery power, aggregating rows with sub-15 minute telemetry readings, removing rows that do not align with enrollment data, removing rows outside of the enrollment range, either before the accepted date or after the unenrolled date, removing rows with a power (kW) reading greater than 125% or less than -125% of nameplate capacity, removing rows for days with less than 90 observations within the day (i.e. – removing rows that are missing more than 6 intervals per day). Completion of the QC steps outlined above reduced the raw data set by 11%, and we were able to pair 84% of cleaned telemetry data with enrollment data by unique battery. Devices are defined by having a unique battery ID and may or may not include multiple “coupled” batteries operating as a collective system.[7]

In total 11% of observations were removed: 4% were missing (i.e., they had less than 90 observations per day), 3% had incorrect timesteps, 1% were removed due to missing enrollment data and data outside the enrollment range, respectively, and less than 1% were removed due to exact duplicates and being outside nameplate capacity range, respectively.

[7] Device count does not take into consideration any potential overlaps in participant ownership.

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4. Analysis and Results

This section summarizes evaluation findings by task.

4.1 Participant Survey

This section summarizes key findings from the participant survey. Additional results are located Appendix B.

4.1.1 Key Findings

- 74% of respondents selected **access to battery backup** as their **primary motivation in purchasing a battery** system.
- **Reducing environmental impact, program participation incentives and the 5-year guarantee**, **ITC**, and **SMART storage adder** were all important **secondary motivations** in purchasing a battery system.
    - 131 respondents (31% overall, 55% of those who purchased their battery in parallel to enrolling) indicated the **incentive lock was "critical" or "very important"** to their purchase decision.
- 25% (48) of the 189 batteries purchased prior to enrollment reported using their battery system for daily or near daily prior to enrolling. Following program enrollment, 38% (162) of all the 426 respondents reported using their battery system for daily or near daily dispatch (outside of program events).
- Approximately 80% of respondents indicated that they never opted out of an event.
- **68% (290) were very satisfied or satisfied with the program** and 67% (284) were very likely to continue participating in the program.

4.1.2 Participant Survey Results

Figure 4-1 shows the results of questions asking respondents to indicate their primary motivation for purchasing a battery system. As shown, 74% of respondents selected access to battery backup as their primary motivation in purchasing a battery system.

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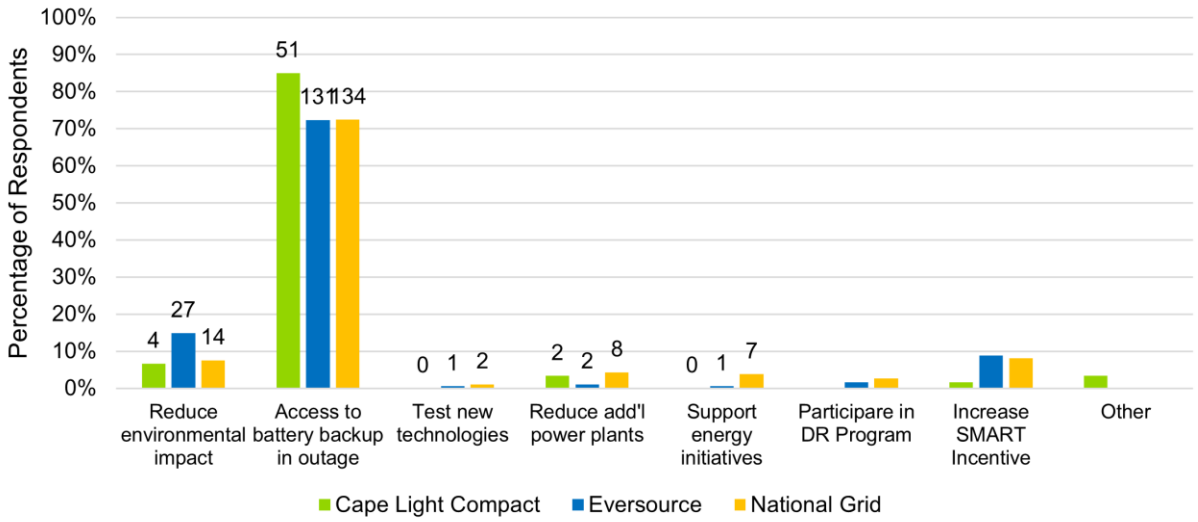
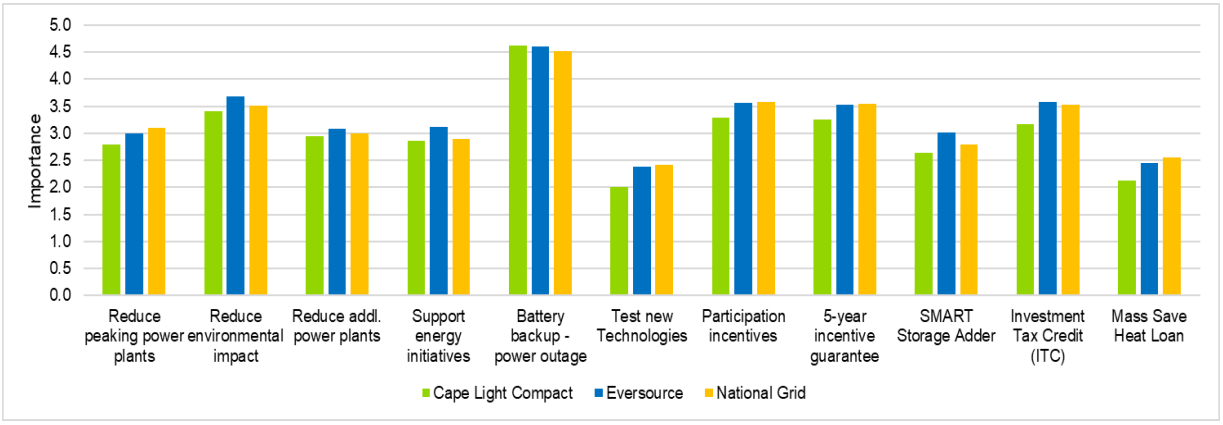
Figure 4-1. Primary Purchase Motivation (n=426)*



Q4. What was your first and second biggest motivation in purchasing a battery system?
*Those who purchased their battery prior to program enrollment were not shown the option "Participate in DR Program".
Source: Guidehouse analysis of participant survey data

Survey respondents were also asked to rate the importance of several different factors in their decision to purchase a battery system. As shown in Figure 4-2**,** reducing environmental impact, program participation incentives and the 5-year guarantee, the ITC, and the SMART storage adder were all important secondary motivations in purchasing a battery system.

Figure 4-2. Importance of Different Factors on Battery Purchase (n=426)



Q5. Please indicate how important each of the following was in your decision to purchase a battery system: (factor list).
*Those who purchased their battery prior to program enrollment were not shown the topics "Participation incentives" or "5-year incentive guarantee".
Source: Guidehouse analysis of participant survey data

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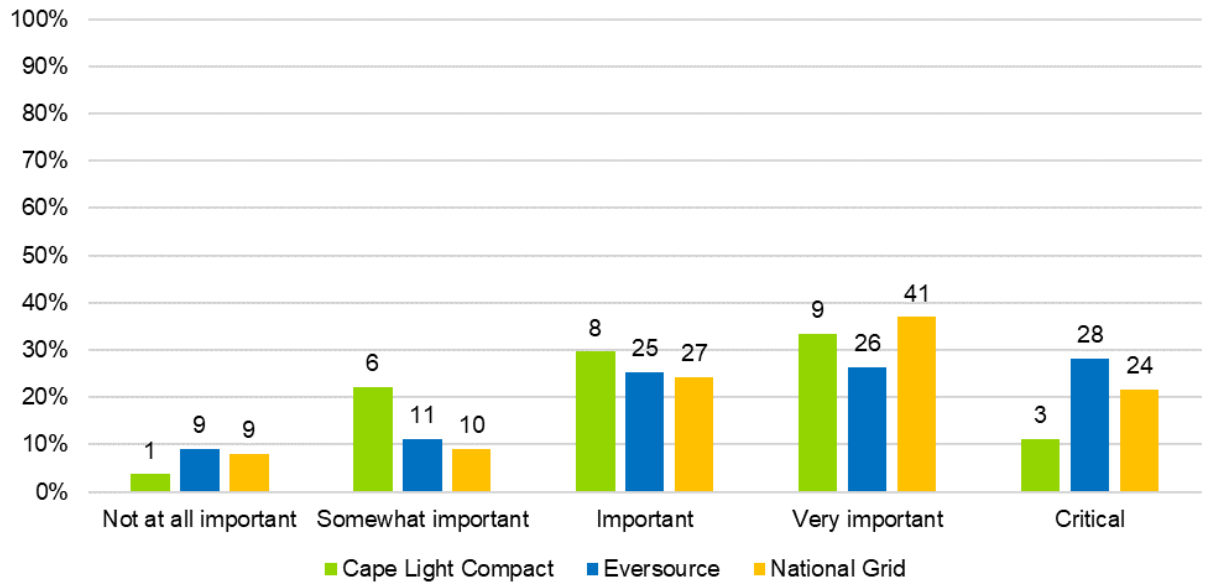
In terms of the importance of the 5-year incentive guarantee in customer decision-making, 55 respondents indicated the incentive lock was “critical” to their purchase decision and another 76 said that it was “very important” (Figure 4-3). In total, for 55% (131) of those who purchased their battery at the same time as enrolling in the program, the 5-year guarantee was critical or very important (this is 31% of all respondents).

Figure 4-3. Importance of 5-Year Incentive Guarantee on Battery Purchase (n=237)



Q5. Please indicate how important each of the following was in your decision to purchase a battery system: **ConnectedSolutions 5-Year Incentive Guarantee**
*Those who purchased their battery prior to program enrollment were not shown this category.
Source: Guidehouse analysis of participant survey data

The survey asked respondents who had purchased their battery system prior to program enrollment about if and how they used their systems before enrolling in the program. 25% (48) of the 189 batteries purchased prior to enrollment reported using their battery system for daily or near daily prior to enrolling (Figure 4-4).

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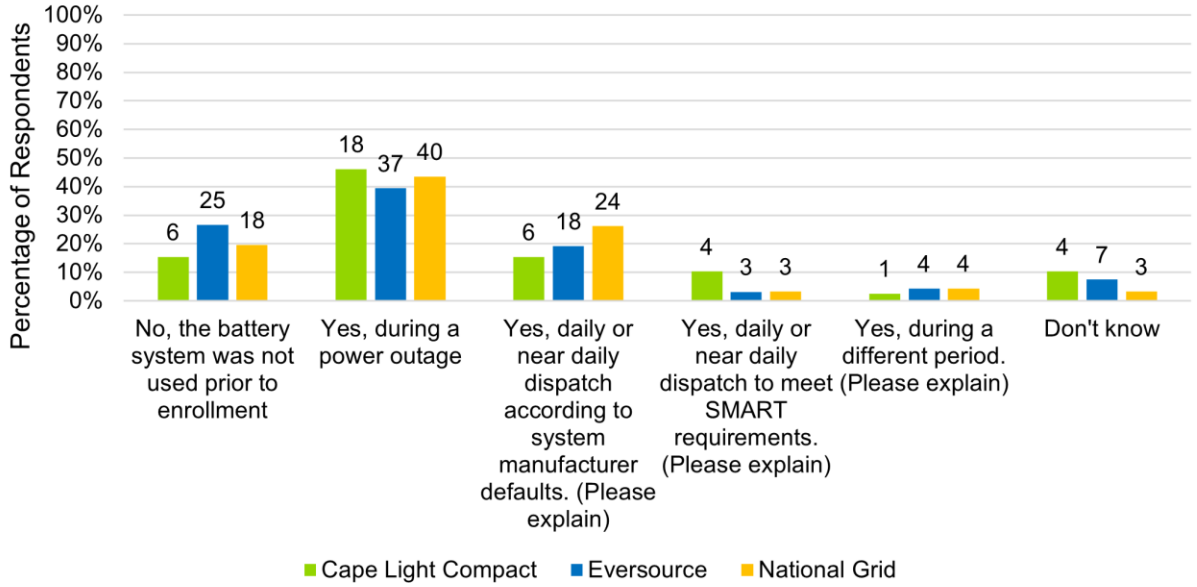
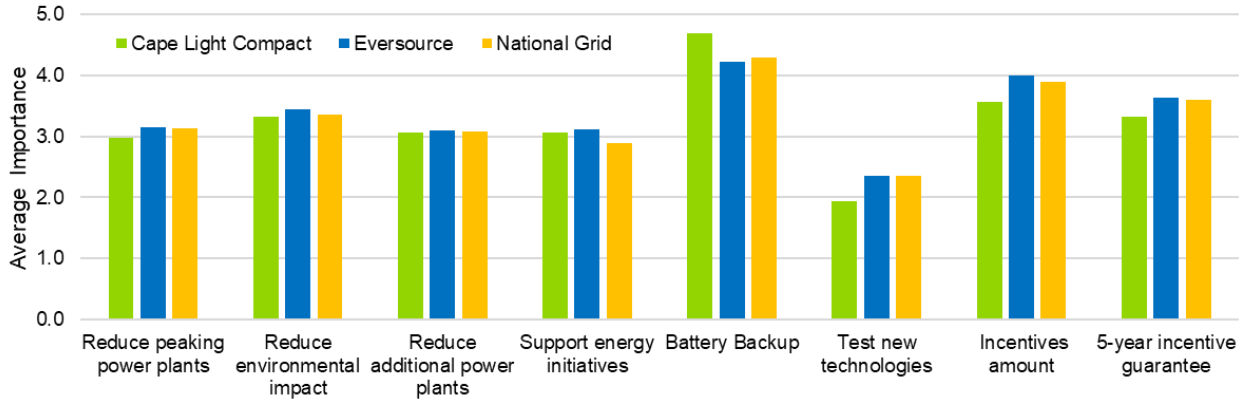
Figure 4-4. Battery System Use Before Enrolling in the Program (n=189)



Q6. Before your enrollment in ConnectedSolutions, did you ever use your battery system? Select all that apply.
*Only those who purchased their battery prior to program enrollment were asked this question.
Source: Guidehouse analysis of participant survey data

Survey respondents were also asked to rate the importance of several different factors in their decision to enroll in the program. As shown in Figure 4-5, battery backup still emerged as the factor with the greatest influence, suggesting that people enrolled in the program to help offset the costs of purchasing a battery for backup. Logically, program incentives and the 5-year incentive lock were also determining factors – ranking as the second and third greatest influence.

Figure 4-5. Importance of Different Factors on Program Enrollment (n=426)



Q8. Please indicate how important each of the following was in your decision to enroll in [PA]'s ConnectedSolutions program: (factor list).
Source: Guidehouse analysis of participant survey data

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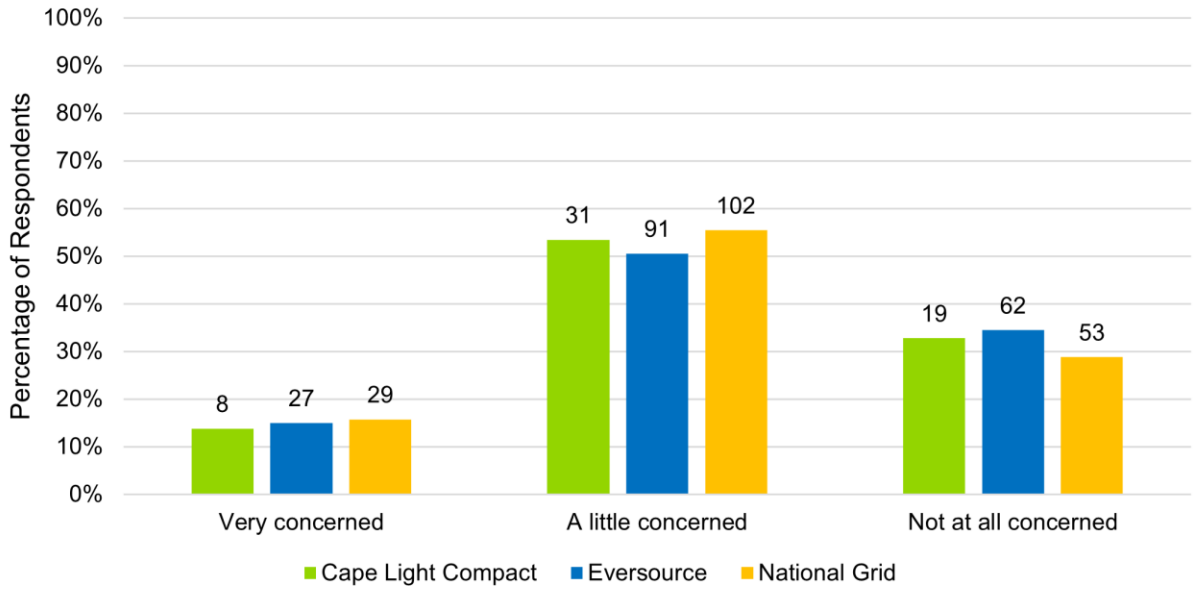
Respondents who indicated that battery backup was an important motivation for their battery purchase were asked if they were concerned about whether the program would interfere with the ability of their battery to provide backup power when needed. The majority of these respondents indicated that they were “a little concerned”.

Figure 4-6. How concerned are you that ConnectedSolutions may discharge your battery when you are counting on it for backup purposes? (n=422)*



Q9. How concerned are you that ConnectedSolutions may have discharged your battery when you are counting on it for backup purposes?
*Note: those asked selected that Battery Backup is important or was a primary/secondary motivation to purchase their battery system.
Source: Guidehouse analysis of participant survey data

The survey asked respondents if and how they used their systems after enrolling in the program. 38% (162) reported using their battery system for daily or near daily dispatch (outside of program events), as shown in Figure 4-7.

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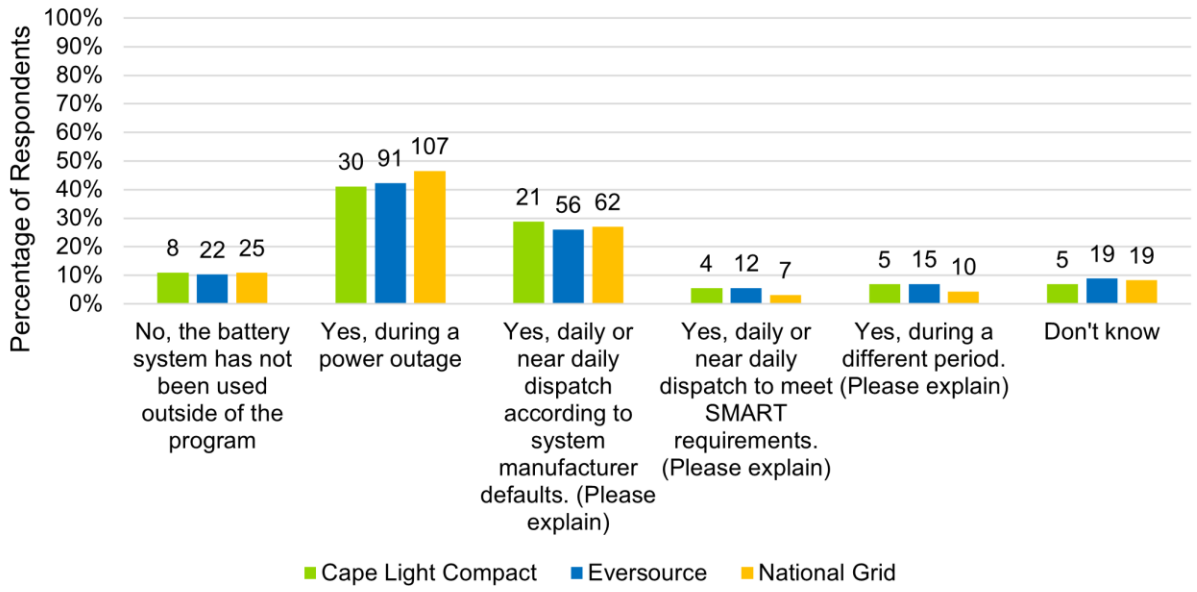
Figure 4-7. Battery System Use Outside of the Program (n=426)



Q10. While enrolled in ConnectedSolutions, have you used (charged or discharged) your battery system outside of when [PA] utilized your battery as part of the program? Select all that apply.
Source: Guidehouse analysis of participant survey data

Overall, 73% of survey respondents believed that their PA had dispatched their battery system during the summer. However, 100 respondents reported not knowing how many times events were called. Of those who provided an estimate for the number of events called since they enrolled, most underestimated the number.

As shown in Figure 4-8, most respondents indicated they had never opted out of an event while enrolled in the program; 77% (37) CLC, 76% (97) Eversource, 81% (112) National Grid.

Those who did opt-out of events mostly indicated they wanted to preserve their battery system for inclement weather or that they wished to use the battery system for personal discharge. Five of those who reported having opted out indicated some confusion about what it means to opt out.

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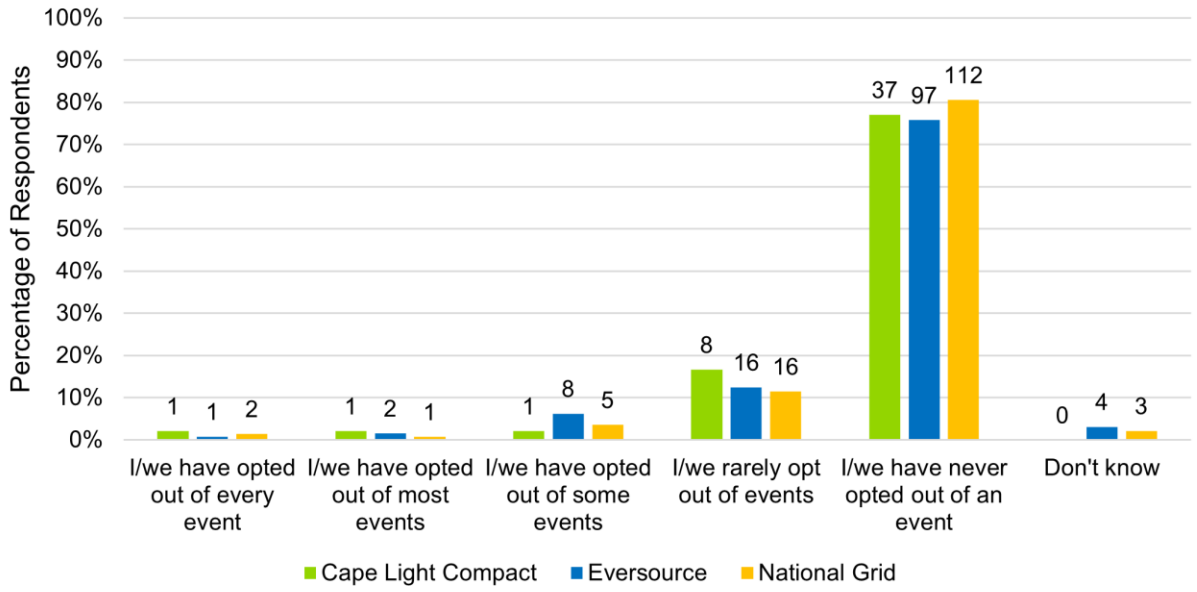
Figure 4-8. Self-Reported Opt-Out Frequency (n=315)



Q14. How often have you chosen to opt-out of events while enrolled in ConnectedSolutions?
Source: Guidehouse analysis of participant survey data

The majority of the 313 respondents who were aware that their PA had dispatched their energy storage system for events (74% or 230) did not change their behaviors during program events. Behavior changes were mostly related to conserving energy by limiting appliance use.

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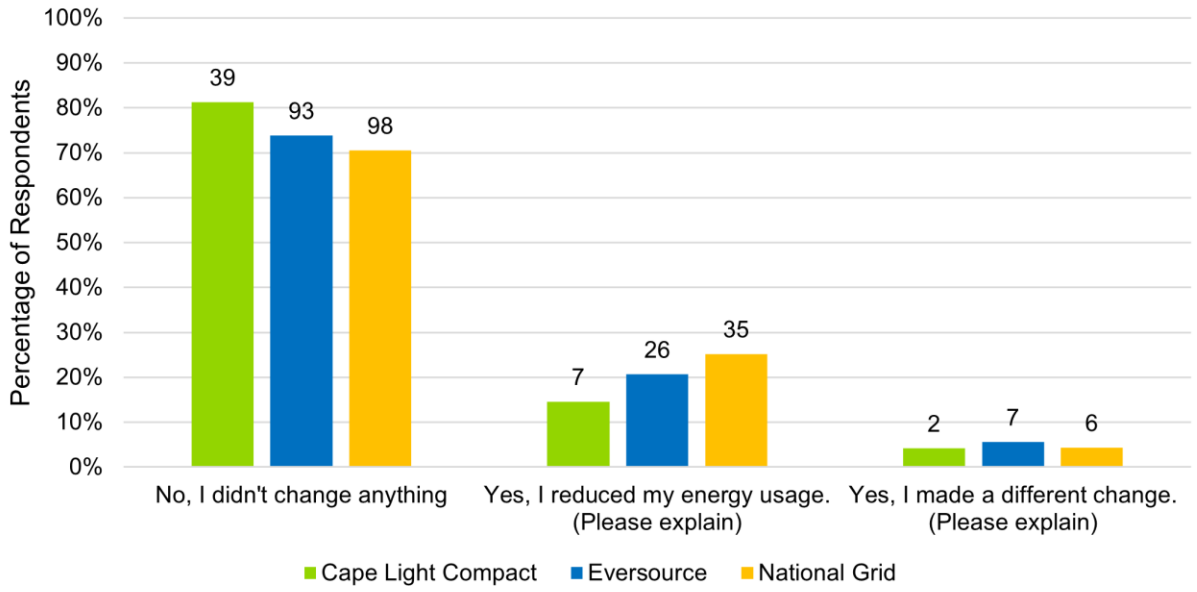
Figure 4-9. Did participation in the program change anything about your daily routine during periods when your battery system was dispatched by [PA]? (n=313)*



Q18. Did participation in the program change anything about your daily routine during periods when your battery system was dispatched by [PA]? For example, did you reduce your energy usage when you knew you were running on battery power?
*Note: those asked selected that their PA dispatched their energy storage system during the program period
Source: Guidehouse analysis of participant survey data

As shown in Figure 4-10, 86% (365) of respondents indicated they would recommend others purchase a battery for home energy storage; 11% (46) noted “Depends”, citing costs and difficulty calculating incentives. Two percent (8) of respondents indicated they would not recommend the system. Some of the reasons stated included:

- *Battery caps net metering credits*
- *The state denied my compensation because something was not filled out correctly I have not been compensated*
- *The SMART incentive has run out*
- *I am not satisfied with the storage capability of the battery and its overall ability to minimize my grid dependence*

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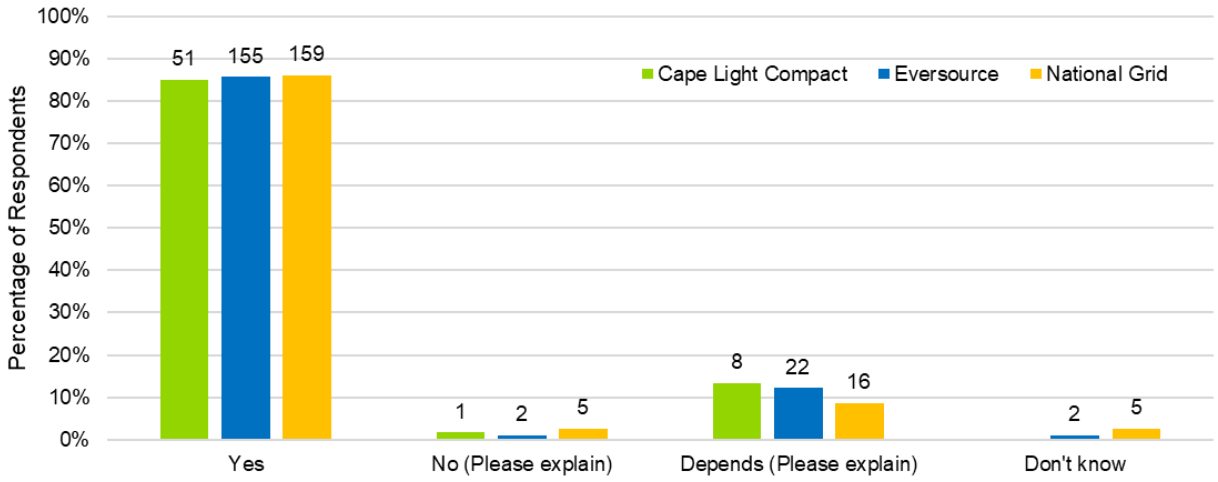
Figure 4-10. Would you recommend purchase of a battery for home energy storage to others? (n=426)



Q19. Would you recommend purchase of a battery for home energy storage to others?
Source: Guidehouse analysis of participant survey data

Figure 4-11 shows results of a question asking participants about their level of satisfaction with the program. 68% (290) were very satisfied or satisfied, 19% (82) neutral, and 7% (29) either not satisfied or very unsatisfied.

Additionally, 67% (284) of respondents indicated they were very likely to continue participating in the program, 19% (81) likely, 6% (24) neutral, and 5% (21) were unlikely or very unlikely to continue participating. Asked to explain their unlikeliness to continue participating, respondents noted they were unable to calculate how much they had earned in rebates, had poor experiences with contractors/installers, or were generally confused about terms/when they would receive rebate.

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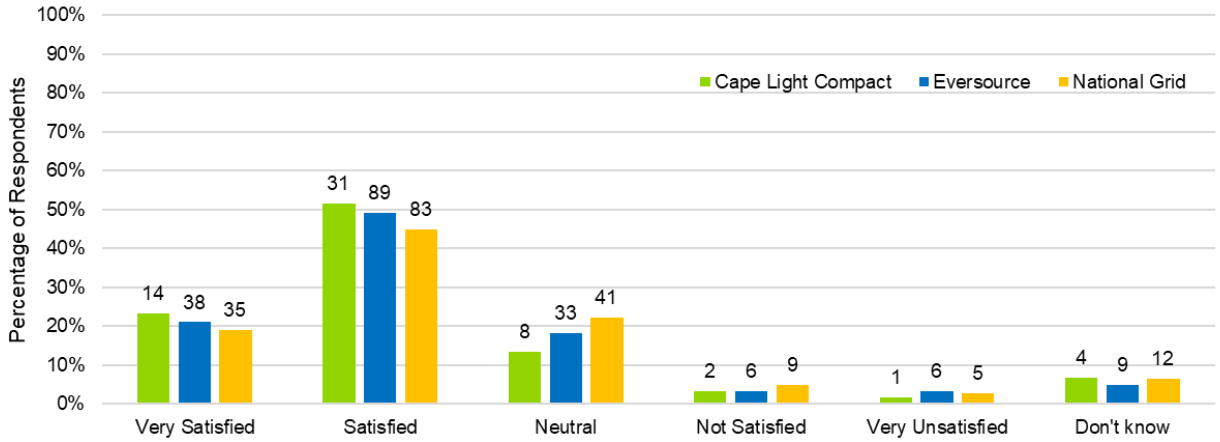
Figure 4-11. How satisfied are you with your participation in the ConnectedSolutions Battery Demand Response Program? (n=426)

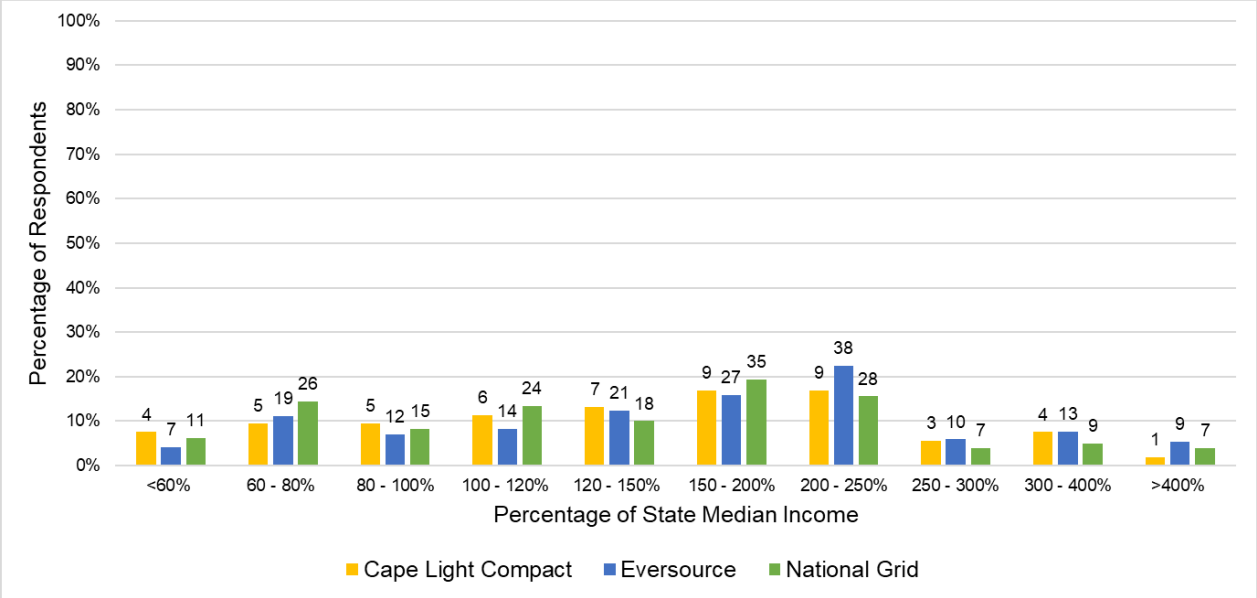


Q21. How satisfied are you with your participation in the ConnectedSolutions Battery Demand Response Program?
Source: Guidehouse analysis of participant survey data

The survey included select demographic questions. Figure 4-12 shows the distribution of respondents' annual household income as a percentage of state median income. Seventy-two respondents (18%) are low or moderate income:

- 6% of respondents (22) are low income (<60% of state median income);
- 12% (50) are moderate income(60% to 80% of state median income).

Figure 4-12. What will be your estimated total annual household income in 2023 before taxes? (n=403)



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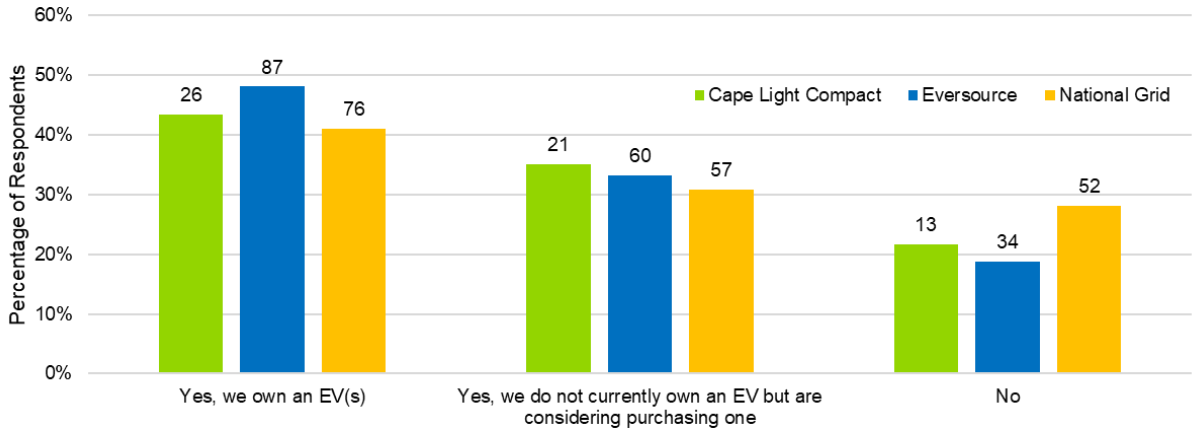
Q28. What will be your estimated total annual household income in 2023 before taxes (in other words, your gross household income)?
*Note: respondents who selected "Prefer not to answer" are not included in the above chart
Source: Guidehouse analysis of participant survey data

Shown in Figure 4-13, 44% (189) of respondents marked that they own an EV, 32% (138) are considering purchasing an EV, and 23% (99) do not own an EV. 73% (239) of respondents mentioned that owning an EV did not influence their decision to purchase a battery system.

For those who responded that owning an EV factored into their battery purchase, these individuals noted that they desired the ability to charge their EV from solar energy stored by the battery system, charge their EV during an outage or similar emergency, and offset electricity costs incurred by charging the EV with their solar plus battery system.

Figure 4-13. Does your household own an EV(s) or considering purchasing one? (n=426)



Q29. Does your household own an EV(s) or considering purchasing one?
Source: Guidehouse analysis of participant survey data

4.2 Benchmarking & Storage Economics Review

This section summarizes findings from the benchmarking & storage economics review task.

4.2.1 Key Findings

- Three of four programs benchmarked provide a one-time, upfront incentive to enrollees (only Liberty does not since Liberty's program involves monthly discounted battery lease cost to participants with free battery installation). Only CT also offers an ongoing performance incentive which varies based on how many years one has been enrolled in the program. CT provides a performance incentive lock of 10 years.
- Simple payback for Massachusetts participants in 2019 was 4.8 years compared to 7.3-8.4 years in 2023, depending on PA and income level category. This suggests that the 5-year incentive guarantee is even more important than it used to be as the cost of batteries continues to rise.

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4.2.2 Benchmarking & Storage Economics Review Results

This research included review of the following programs:

- Connecticut's Energy Storage Solutions Program ("CT ES Solutions")
- Green Mountain Power's Bring Your Own Device Energy Storage Program ("GMP BYOD")
- Liberty Utilities (NH) Battery Storage Pilot Program ("Liberty ES pilot")
- Arizona Public Service Residential Battery Pilot ("APS Res ES Pilot")

The section below provides a summary of information collected through the benchmarking effort. More details on each program are included in Appendix C.

Three of four programs provide a one-time, upfront incentive to enrollees (only Liberty does not since Liberty's program involves monthly discounted battery lease cost to participants with free battery installation). Only CT also offers an ongoing performance incentive which varies based on how many years one has been enrolled in the program. CT provides a performance incentive lock of 10 years. Table 4-1 includes a summary of program characteristics for the programs reviewed in addition to the MA program.

Table 4-1. Program Comparison - 2023

Program	Administrator(s)	Demand Reduction	Incentive Lock	Upfront Incentive	Performance Incentive
MA Res ES DR	Cape Light Compact, Eversource, National Grid, Unitil	Direct load control	Yes – 5 years	N/A	$275 per kW for first 5 summers enrolled
CT ES Solutions	Connecticut Green Bank, Eversource Energy, United Illuminating (UI)	Direct load control	Yes – 10 years	Lower of: ESS kWh * $200/kWh; 50 percent of electric storage system total installed cost; or Maximum per project incentive of $7,500	Years 1-5: Summer $200 /kW, Winter $25 /kW Years 6-10: Summer $15 /kW, Winter $15 /kW
GMP BYOD	Green Mountain Power	Direct load control	No – ongoing payment	Battery (back up only): up to $1050 Battery (self-consumption): up to $950	N/A
Liberty ES Pilot	Liberty Utilities	Time-of-use	Yes – 10 years	N/A	N/A
APS Res ES Pilot	Arizona Public Service	Time-of-use, Direct load control	No – ongoing payment	Performance data-only: $500 /kW up to $2,500.	N/A

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Program	Administrator(s)	Demand Reduction	Incentive Lock	Upfront Incentive	Performance Incentive
				Performance and management: $500 /kW + $1,250, up to $3,750	

Source: Guidehouse

Table 4-2 provides a comparison of the value of program participation assuming a participant has a 5kW by 13.5 kWh battery (additional assumptions are noted in the table). CT has the richest cumulative incentives by year 5, followed by MA. Assuming MA participants receive incentives for 10 years (even though the rate lock is only 5 years), MA has the richest total incentives by year 10. Note that APS participants also benefit from a time-of-use (TOU) rate.

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Table 4-2. Program Value Comparison - 2023

Program	Demand Reduction	Assumptions	Upfront Incentive	5-year Incentive Total	10-year Incentive Total
MA Res ES DR	Direct load control	- 5kW by 13.5kWh battery - Average performance of 5 kW	N/A	5 (kW) * $275 * 5 = **$6,875**	$6,875 + 5 (kW) * $275 * 5 = **$13,750**
CT ES Solutions	Direct load control	- 5kW by 13.5kWh battery - Incentive step 1 - No Grid edge adder	13.5 (kWh) * $200= **$2,700**	$2,700 + (5 (kW) * $225 * 5) = **$8,325**	$8,325 + 5 (kW) * $130 * 5) = **$11,575**
GMP BYOD	Direct load control	- 5kW by 13.5kWh battery - Four-hour discharge - Not retrofitting existing solar system	Back up only: 5 (kW) * $950 = **$4,750** Self-consumption: **$850**	Back up only: **$4,750** Self-consumption: **$850**	Back up only: **$4,750** Self-consumption: **$850**
APS Res ES Pilot	Data only: Time-of-use Data & management: Direct load control	5kW by 13.5kh battery	Data only: 5 (kW) * $500 = **$2,500** Data & management: (5 (kW) * $500) + $1,250 = **$3,750**	Data only: **$2,500** Data & Management: **$3,750**	Data only: **$2,500** Data & Management: **$3,750**

Source: Guidehouse

This study also included a review of the economics of battery storage ownership in 2019 compared to 2023 to assess the relative impact of program incentives over time. We assessed the economics of battery ownership by estimating simple payback. Table 4-3 includes the inputs used for the calculation of simple payback, along with components of the simple payback calculation (output).

Table 4-3. Simple Payback – Inputs and Outputs

	Metric	Definition
Inputs	Upfront Costs	Non-financed purchase and installation
	Upfront Incentives	Investment Tax Credit
	Annual Incentives	Connected Solutions Incentive, MA SMART incentive

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	Annual Operating Costs	Customer bill impact of round-trip efficiency losses (if no TOU rate)*
Output – Components	Net Upfront Costs	Upfront Costs – Upfront Incentives
	Net Annual Revenues	Annual Incentives – Annual Operating Costs

Source: Guidehouse

We calculated simple payback as Net Upfront Costs / Net Annual Revenues for standard income and low income residential customers in 2019 and 2023.

Table 4-4 contains the assumptions made for standard and low income residential customers. Only rates varied by income category. More details on cost and incentives assumptions are included in Appendix D.

Table 4-4. Storage Economics Review - General Assumptions

	Standard Income Residential	Low Income Residential
Battery System	• Non-financed • 5 kW, 12.5 kWh battery, 90% incentive battery performance • Prior installed 8 kW Solar PV system, 8,760 kWh annual output	• Non-financed • 5 kW, 12.5 kWh battery, 90% incentive battery performance • Prior installed 8 kW Solar PV system, 8,760 kWh annual output
Rates	• Eversource Rates: A1 • National Grid Rates: R-1	• Eversource Rates: A2, 42% discount • National Grid Rates: R-2, 32% discount

Incentives	• MA SMART Incentive:
	  ○ 75% charged by solar and installed within one year of the PV array's completion
	• Investment Tax Credit (ITC):
	  ○ Meets labor requirements, No domestic content bonus
		• MA SMART Incentive:
		  ○ 75% charged by solar and installed within one year of the PV array's completion
		• Investment Tax Credit (ITC):
		  ○ Meets labor requirements, No domestic content bonus

Source: Guidehouse

Table 4-5 and Table 4-6 show the simple payback results for 2019 and 2023, respectively. Simple payback in 2019 was 4.8 years compared to 7.3-8.4 years in 2023, depending on PA and income level category. This suggests that the 5-year incentive guarantee is even more important than it used to be as the cost of batteries continues to rise.

Table 4-5. Simple Payback of Battery System Ownership - 2019

	Standard Income Residential	Low Income Residential
Net Upfront Costs	$8,415	$8,415
Net Annual Revenues – Eversource	$1,746	$1,752
Net Annual Revenues - National Grid	$1,745	$1,750
Simple Payback (years) – Eversource	4.8	4.8
Simple Payback (years) - National Grid	4.8	4.8

Source: Guidehouse

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Table 4-6. Simple Payback of Battery System Ownership - 2023

	Standard Income Residential	Low Income Residential
Net Upfront Costs	$11,710	$11,710
Net Annual Revenues – Eversource	$1,594	$1,603
Net Annual Revenues - National Grid	$1,397	$1,405
Simple Payback (years) – Eversource	7.3	7.3
Simple Payback (years) - National Grid	8.4	8.3

Source: Guidehouse

4.3 Impact Analysis

This section provides the results from Guidehouse's impact evaluation of enrolled battery participation, peak reduction, and seasonal energy impacts.

4.3.1 Key Findings

The following are the key findings from the impact evaluation.

- The program had 6,760 unique devices enrolled throughout the summer, with an aggregate load reduction potential of 56.5 MW.
- Throughout the summer, the PAs called 29 events with 89% of devices successfully participating in events, on average.
- Program batteries discharged at an average rate of 4.8 kW (+/- 0.01 kW)[8] using the evaluation-based blended baseline. Using the Assumed No Battery baseline, the average discharge rate was 5.0 kW. Using the Assumed With Battery baseline, the average discharge rate was 4.7 kW.
- In aggregate, the program reduced load by 24.5 MW (+/- 0.05 MW) per event on average using the blended baseline derived from the program data and participant survey. Using the Assumed No Battery baseline, total program reductions were 25.4 MW per event on average. Using the Assumed With Battery baseline, total program reductions were 24.0 MW per event on average.
- Over the 48 hours inclusive of event days and the following day, program batteries increased their overall energy consumption, with total energy charged exceeding total energy discharged on average.
- The program had an average realization rate of 94.8% across PAs, using the blended baseline. PA-specific realization rates were 93.9% for Cape Light Compact, 94.7% for Eversource, and 95.6% for National Grid. Using the Assumed No Battery baseline, the

[8] The error bound reported here and throughout the report corresponds to the 90% confidence level.

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average realization rate was 99.4%. Using the Assumed With Battery baseline, the average realization rate was 92.1%.

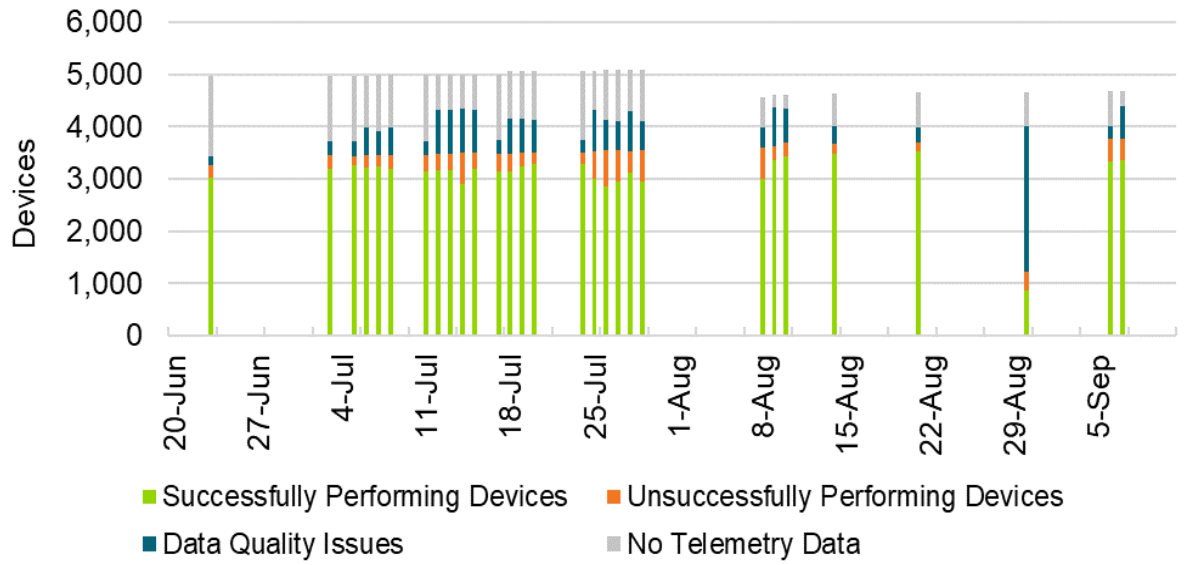
4.3.2 Event Impact Results

Successful event participation ranged between 71% and 95% of analyzed devices, with a seasonal average of 89%. Successfully performing devices are defined as those with an average event load (kW) less than zero (i.e., battery successfully discharged).

Data quality issues were most prevalent for the event occurring on August 29, due to an observed trend in telemetry data completeness in which data was significantly less available during the last two days of each month.

Figure 4-14 summarizes the count of successfully performing devices, unsuccessfully performing devices, and devices not analyzed due to a lack of telemetry data or data quality issues.[9]

Figure 4-14. Successful Event Participation by Date



Source: Guidehouse analysis of DERMS vendor data.

Guidehouse did not observe a pronounced relationship between average event performance and whether events occurred on consecutive days. Events with a lower average performance occurred sporadically, with a potential correlation between poorer performance and inclement weather. Event performance by date is available in more detail within Table F-1 and Table F-2 in Appendix F.

Table 4-7 presents the kW discharge per device averaged over all event windows throughout the event season. On average, devices discharged at a rate of 4.8 kW (+/- 0.01 kW) during

[9] Devices were removed for "Data Quality Issues" for the following reasons: no telemetry data after the device accepted date and before the device unenrollment date, kW readings outside the expected range given by the device nameplate capacity, or fewer than 90 observations within the day.

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events using a blended baseline. This corresponds to 57% of load reduction potential.[10] Average discharge rates varied by PA, with values ranging from 4.3 to 5.2 kW per device. Using the Assumed No Battery baseline, the average discharge rate was 5.0 kW. Using the Assumed With Battery baseline, the average discharge rate was 4.7 kW.

Table 4-7 also presents the maximum battery discharge rate during a single 15-minute period. Battery discharge rates are generally highest at the start of the event and decline toward the end of the event window. On average, the maximum discharge rate varied by PA and ranged from 7.4 to 9.2 kW per device, using a blended baseline.

Table 4-7. Event Impact Summary per Device

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Max 15-min impact (kW)	-7.6	-9.2	-7.4
Blended	Avg 15-min impact (kW)	-4.5	-5.2	-4.3
No Battery	Max 15-min impact (kW)	-7.4	-9.0	-7.3
No Battery	Avg 15-min impact (kW)	-4.8	-5.5	-4.4
With Battery	Max 15-min impact (kW)	-7.7	-9.3	-7.5
With Battery	Avg 15-min impact (kW)	-4.4	-5.1	-4.2

Note: In instances when the Assumed With Battery Baseline indicates that a specific device is charging during an event period, the magnitude of calculated impacts is the sum of the full discharge amount and the avoided charge amount. The result is a larger impact using the With Battery Baseline compared to the No Battery Baseline. This scenario applies for some devices when calculating the maximum impact during a single 15-minute interval.
Source: Guidehouse analysis of DERMS vendor data.

Table 4-8 presents the total kW discharge averaged over all event windows throughout the event season. On average, statewide program-level reductions were 24.5 MW (+/- 0.05 MW) during events using a blended baseline. Using the Assumed No Battery baseline, program-level reductions were 25.4 MW. Using the Assumed With Battery baseline, program-level reductions were 24.0 MW. Eversource participants delivered just over half of those reductions.

The program achieved a maximum load reduction of 31.2 MW (+/- 0.07 MW) during a single 15-minute period using a blended baseline. Using the Assumed No Battery baseline, maximum load reductions were 32.4 MW. Using the Assumed With Battery baseline, maximum load reductions were 30.5 MW. Note that the maximum values shown in Table 4-8 may have occurred during different time periods, and therefore do not sum to the totals stated in this paragraph.

[10] Corresponding load reduction percentage estimates are calculated as the average kW divided by the average per-device enrolled capacity during each event day of the summer season [8.38 kW].

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Table 4-8. Event Impact Summary (Program Level)

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Max 15-min impact (kW)	-1,590	-18,100	-12,700
Blended	Avg 15-min impact (kW)	-1,210	-13,400	-9,660
No Battery	Max 15-min impact (kW)	-1,660	-18,800	-13,000
No Battery	Avg 15-min impact (kW)	-1,280	-14,100	-10,000
With Battery	Max 15-min impact (kW)	-1,560	-17,700	-12,600
With Battery	Avg 15-min impact (kW)	-1,180	-13,000	-9,450

Source: Guidehouse analysis of DERMS vendor data.

Table 4-9 shows the realization rates between Guidehouse's assessed performance estimates and the performance estimates calculated by the DERMS vendor, which are assumed to align with the Assumed No Battery baseline. Guidehouse generally found strong alignment between evaluated impacts using the Assumed No Battery baseline and performance estimates. However, Guidehouse was unable to verify the DERMS vendor's performance estimate in some cases due to missing or low-quality data.[11]

The program had an average realization rate of 94.8% across PAs, using the blended baseline. PA-specific realization rates were 93.9% for Cape Light Compact, 94.7% for Eversource, and 95.6% for National Grid

Table 4-9. Comparison to Vendor-Calculated Performance Estimates

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Realization Rate	93.9%	94.7%	95.6%
No battery	Realization Rate	99.0%	99.8%	99.5%
With battery	Realization Rate	91.0%	91.8%	93.4%

Source: Guidehouse analysis of DERMS vendor data.

[11] There was some discrepancy between the sets of devices analyzed by Guidehouse and the Vendor, resulting in 4% of Guidehouse's analyzed ID & Event combinations and 20% of the vendor's analyzed combinations not being available for comparison. The impact results excluded correspond to 1.7% and 13.1% of the summed assessed impact as analyzed by Guidehouse and the Vendor respectively.

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4.3.3 ISO-NE Peak Reduction Results

Table 4-10 summarizes the average device reduction and program-level reduction by PA and baseline during the ISO-NE system peak which occurred on September 7, 2023, from 5:00-6:00 p.m. ET.[12]

The ISO-NE Annual System peak occurred during the final event called in 2023's summer season, resulting in significant load reduction during the ISO-NE peak hour. In aggregate, reductions were 27.4 MW (+/- 0.08 MW) using a blended baseline. Using the Assumed No Battery baseline, the aggregate load reduction was 28.7 MW. Using the Assumed With Battery baseline, the aggregate load reduction was 26.6 MW.

Table 4-10. Energy Impact During ISO-NE Peak

Baseline	Metric	Cape Light Compact	Eversource	National Grid
Blended	Per device reduction (kW)	-5.9	-6.7	-4.8
Blended	Program-level reduction (MW)	-1.2	-16.3	-9.8
No Battery	Per device reduction (kW)	-6.0	-7.0	-5.0
No Battery	Program-level reduction (MW)	-1.3	-17.1	-10.3
With Battery	Per device reduction (kW)	-5.8	-6.5	-4.7
With Battery	Program-level reduction (kW)	-1.2	-15.9	-9.5

Source: Guidehouse analysis of DERMS vendor data.

[12] ISO-NE System Peak identified at [https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/ann-sys-peak-day-hr-load], on Jan. 18, 2024. As of this time, ISO-NE indicates that this is a preliminary value and subject to change.

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4.3.4 Energy Results

Table 4-11 summarizes the average Round-trip Efficiency (RTE) by PA across the event season. RTE is defined as the ratio between battery discharge load and battery charge load across the entire summer season.[13] RTE values range from 0 to 1 and are less than 1 due to efficiency losses inherent to a battery's operation. As expected, due to RTE losses, we observed an increase in energy consumption, with total energy charged exceeding total energy discharged for each battery and overall. The RTE and overall energy losses over the summer season are provided in Table 4-11.

Table 4-11. Season-Wide Average Round-Trip Efficiency

Metric	Cape Light Compact	Eversource	National Grid
Round-Trip Efficiency (RTE)	0.85	0.87	0.87
Round-Trip Losses (kWh/Device)	118	124	95

Source: Guidehouse analysis of DERMS vendor data.

[13] Note: Calculations for RTE do not depend on a baseline assumption.

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5. Findings and Considerations

Table 5-1 presents key findings from each research activity, along with key considerations for the program.

Table 5-1. Key Findings and Recommendations/Considerations

Category	Finding	Recommendation / Consideration
Incentive Lock	131 respondents (31% overall, 55% of those who purchased their battery in parallel to enrolling) indicated the incentive lock was “critical” or “very important” to their purchase decision. Additionally, simple payback in 2019 was 4.8 years compared to 7.3-8.4 years in 2023, depending on PA and income level category.	**Recommendation:** Continue to offer the 5-year incentive guarantee.
Program Data	The vendor continued to provide updated telemetry and enrollment data files through January 10, 2024, more than 3 months after the season end date.	**Consideration:** The PAs should consider having the vendor develop a **standardized set of data processing steps** to enable a timely export of data for evaluation, ideally within one month of the season end. Use of a standardized process would also reduce the volume of data corrections and updates required, which impact both evaluation costs & timelines.
	The vendor provided telemetry data in a variety of formats.	**Consideration:** The PAs should consider having the vendor develop a **standardized data export** that contains fields commonly required for evaluations. When data updates are required, use of a standardized data format will reduce the amount of re-work required to process data.
	Some data fields were inconsistent across battery OEMs.	**Consideration:** The PAs should consider encouraging the vendor to work with OEMs to **identify any inconsistencies** in the way data are captured (e.g., sign conventions, timestamps). If the vendor is unable to standardize the data across fields, the vendor should document any inconsistencies in the data and provide this information with the data transfer. Additionally, the vendor should provide a data dictionary that describes each data field.

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Category	Finding	Recommendation / Consideration
Future Evaluations	Continue asking survey questions to determine the most accurate bended baseline.	**Consideration:** Future evaluations should consider asking survey questions that specifically are designed to determine how many/proportion of participants are purchasing their batteries prior to enrolling in the program and how many of those who enroll at the same time as purchasing their battery did not consider the program a primary motivator for their purchase.

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A. Participant Survey Instrument

A.1 Landing page

[INCLUDE PA's LOGO IN HEADER THROUGHOUT SURVEY]

Thank you for taking a few moments to answer these questions about [PA]'s **Connected**Solutions Battery Program. This is a 10-minute survey and all responses will remain anonymous.

A.2 Verification

Q1. Do you participate in [PA]'s **Connected**Solutions Battery Demand Response Program?

1. Yes
2. No

[IF Q1=2 >> End survey]
[End text: We thank you for your time spent taking this survey. Your response has been recorded.]

A.3 Motivations for Battery Purchase & Pre-Program Usage

Q2. Did you own your battery system prior to your enrollment in the offering?

1. Yes, I enrolled with a previously purchased battery system
2. No, I bought a battery when I enrolled

[SHOW IF Q2 = 2]
Q2B. Did the **Connected**Solutions program influence your decision to purchase your battery system?

1. Yes. (Please explain) [OPEN END >> FORCE RESPONSE]
2. No (Please explain) [OPEN END >> FORCE RESPONSE]

[SHOW IF Q2 = 1]
Q3. Approximately when did you purchase your battery system? [FORCE MONTH AND YEAR DROP DOWNS, 2010-2023]

Q4. What was your first and second biggest motivation in purchasing a battery system? [RANDOMIZE ALL BUT RESPONSE 8] [SELECT 1st and 2nd]

1. Reduce my environmental impact
2. Access to battery backup in the event of a power outage
3. Ability to test new technologies
4. Reduce the need for additional power plants
5. Support our community and/or state's energy initiatives
6. [SHOW IF Q2=2] To participate in the **Connected**Solutions Battery Demand Response Program
7. To increase the Solar Massachusetts Renewable Target (SMART) offering incentive
8. Other: [TEXT BOX >> FORCE ENTRY]

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Q5. Please indicate how important each of the following was in your decision to purchase a battery system: [RANDOMIZE]

Factor	Not at all important	Somewhat important	Important	Very important	Critical
Reduce the need for peaking power plants					
Reduce my environmental impact					
Reduce the need for additional power plants					
Support my community and/or state's energy initiatives					
Access to battery backup in the event of a power outage					
Ability to test new technologies					
[SHOW IF Q2=2] **Connected**Solutions participation incentives					
[SHOW IF Q2=2] **Connected**Solutions 5-year incentive guarantee					
SMART Storage Adder					
Investment Tax Credit (ITC)					
Mass Save Heat Loan Financing					

[SHOW IF Q2 = 1]

Q6. Before your enrollment in **Connected**Solutions, did you ever use your battery system? Select all that apply.

1. No, the battery system was not used prior to enrollment [MUTUALLY EXCLUSIVE]
2. Yes, during a power outage
3. Yes, daily or near daily dispatch according to system manufacturer defaults. (Please explain) [OPEN END >> FORCE RESPONSE]
4. Yes, daily or near daily dispatch to meet SMART requirements. (Please explain) [OPEN END >> FORCE RESPONSE]
5. Yes, during a different period. (Please explain) [OPEN END >> FORCE RESPONSE]
6. Don't know

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[SHOW IF Q6 = 2 or 5]
Q7. Approximately how many times did you draw energy from your battery prior to participating in [PA]'s **Connected**Solutions program?

1. [OPEN END, ENTER NUMERIC >> FORCE RESPONSE]
2. Don't know

A.4 Motivations for Program Enrollment & Post-Enrollment Usage

Q8. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: [RANDOMIZE]

Factor	Not at all important	Somewhat important	Important	Very important	Critical
Reduce need for peaking power plants					
Reduce my environmental impact					
Reduce the need for additional power plants					
Support my community and/or state's energy initiatives					
[SHOW IF Q2=2] Access to battery backup in the event of a power outage					
Ability to test new technologies					
Participation incentives					
5-year incentive guarantee					

[Show if Q5 OR Q8 Access to Battery Backup is important or greater OR Q4 = 2]
Q9. How concerned are you that **Connected**Solutions may have discharged your battery when you are counting on it for backup purposes?

1. Very concerned
2. A little concerned
3. Not at all concerned

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Q10. While enrolled in **Connected**Solutions, have you used (charged or discharged) your battery system ***outside of*** when [PA] utilized your battery as part of the program? Select all that apply.

1. No, the battery system has not been used outside of the program [MUTUALLY EXCLUSIVE]
2. Yes, during a power outage
3. Yes, daily or near daily dispatch according to system manufacturer defaults. (Please explain) [OPEN END >> FORCE RESPONSE]
4. Yes, daily or near daily dispatch to meet SMART requirements. (Please explain) [OPEN END >> FORCE RESPONSE]
5. Yes, during a different period. (Please explain) [OPEN END >> FORCE RESPONSE]
6. Don't know

[SHOW IF Q10 = 2 or 5]
Q11. Approximately how many times have you drawn energy from your battery while participating in [PA]'s **Connected**Solutions program?

1. [OPEN END, ENTER NUMERIC >> FORCE RESPONSE]
2. Don't know

Q12. Has [PA] dispatched your energy storage this summer?

1. Yes
2. No
3. Don't know

[SHOW IF Q12 = 1]
Q13. Approximately how many times has [PA] dispatched your battery system this summer? [OPEN END >> FORCE NUMERIC RESPONSE lower limit of 0, upper of 100].

Q14. How often have you chosen to opt-out of events while enrolled in **Connected**Solutions?

1. I/we have opted out of **every** event
2. I/we have opted out of **most** events
3. I/we have opted out of **some** events
4. I/we **rarely** opt out of events
5. I/we have **never** opted out of an event
6. Don't know

[SHOW IF Q14 <> 5 or 6]
Q15. Please describe the reason(s) you have chosen to opt-out of event(s). [OPEN END >> FORCE RESPONSE]

Q16. Have you experienced any technical difficulties or malfunctions with your battery system?

1. Yes
2. No
3. Don't know

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[SHOW IF Q16 = 1]
Q17. Please describe the technical difficulties or malfunctions you have experienced. [OPEN END >> FORCE RESPONSE]

[SHOW IF Q12 = 1]
Q18. Did participation in the program change anything about your daily routine during periods when your battery system was dispatched by [PA]? For example, did you reduce your energy usage when you knew you were running on battery power? [Select all that apply]

1. No, I didn't change anything [MUTUALLY EXCLUSIVE]
2. Yes, I reduced my energy usage. (Please explain) [OPEN END >> OPTIONAL]
3. Yes, I made a different change. (Please explain) [OPEN END >> FORCE RESPONSE]

A.5 Satisfaction

Q19. Would you recommend purchase of a battery for home energy storage to others?

1. Yes
2. No (Please explain) [OPEN END >> FORCE RESPONSE]
3. Depends (Please explain) [OPEN END >> FORCE RESPONSE]
4. Don't know

Q20. Based on your experiences to-date, how would you characterize the benefits and costs of battery ownership? [RANDOMIZE]

1. Benefits of ownership have outweighed costs. (Please explain) [OPEN END >> FORCE RESPONSE]
2. Benefits of ownership are about equal to the costs. (Please explain) [OPEN END >> FORCE RESPONSE]
3. Costs of ownership have outweighed benefits. (Please explain) [OPEN END >> FORCE RESPONSE]
4. Don't know

Q21. How satisfied are you with your participation in the **Connected**Solutions Battery Demand Response Program? [RANDOMLY FLIP ORDER FROM 1-5 FOR SOME TO START WITH "Very Unsatisfied"]

1. Very Satisfied
2. Satisfied
3. Neutral
4. Not Satisfied
5. Very Unsatisfied
6. Don't know

Q22. How likely are you to continue participating in the **Connected**Solutions Battery Demand Response Program?

1. Very Unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very Likely
6. Don't know

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[SHOW IF Q22=1, 2, 3, or 6]
Q23. Please explain the reason for your response. [OPEN END >> FORCE RESPONSE]

[SHOW IF Q22=1, 2, 3, or 6]
Q24. What change(s) to **Connected**Solutions would encourage you to continue participating? [OPEN END]

Q25. Would you recommend **Connected**Solutions to others who own or are thinking about purchasing a battery?

1. Yes
2. No (Please explain) [OPEN END >> FORCE RESPONSE]
3. Don't know

A.6 Demographic Questions

Q26. Which of the following best describes the property type where your battery system is located?

1. Single family home
2. Multi-family home (2-4 units)
3. Multi-family home (5+ units)
4. Mobile home
5. Not a residence (business, workshop or other)
6. Other, please specify: _____ [OPEN-ENDED>> FORCE RESPONSE]

Q27. **[RESTRICT RESPONSE OPTIONS TO 2 DIGITS]** How many people occupied your home this summer 2023? Enter zero if appropriate.

Occupant Type	Number
Children, under 18	[RECORD NUMBER]
Adults, 18 to 65	[RECORD NUMBER]
Adults, 65 and older	[RECORD NUMBER]

Q28. **[USE TABLE PROVIDED IN EXCEL FILE TO PROVIDE RANGES BASED ON RESPONSE TO Q27. AS AN EXAMPLE, IF THE SUM OF D27=1 (SINGLE HOUSEHOLD MEMBER), SHOW THE FOLLOWING]** What will be your estimated total annual household income in 2023 before taxes (in other words, your gross household income)?

1. Less than $42,400
2. $42,401- $56,500
3. $56,501- $70,700
4. $70,701- $84,800
5. $84,801- $106,000
6. $106,001- $141,400
7. $141,401- $212,100
8. $212,101- $254,500
9. $254,501- $424,100
10. Greater than $424,100
11. Prefer not to answer

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Q29. Does your household own an EV(s) or considering purchasing one?

1. Yes, we own an EV(s)
2. Yes, we do not currently own an EV but are considering purchasing one
3. No

[SHOW IF Q29 = 1 OR 2]
Q30. Did owning or thinking about owning an EV influence your decision to purchase a battery system?

1. Yes. (Please explain) [OPEN END >> FORCE RESPONSE]
2. No

A.7 Closing

Q31. We have reached the end of the survey. Do you have any additional comments regarding the **Connected**Solutions Battery Demand Response Program?

- [OPEN-ENDED]
- None

Q32. Thank you for taking the time to fill out this survey! Please confirm your email address in order to receive your $10 Tango® e-gift card.

1. Email: [FORCE RESPONSE, valid email verification]
2. Checkbox for "I prefer not to receive the $10 Tango® e-gift card."

[Closing text: We thank you for your time spent taking this survey. Your response has been recorded.]

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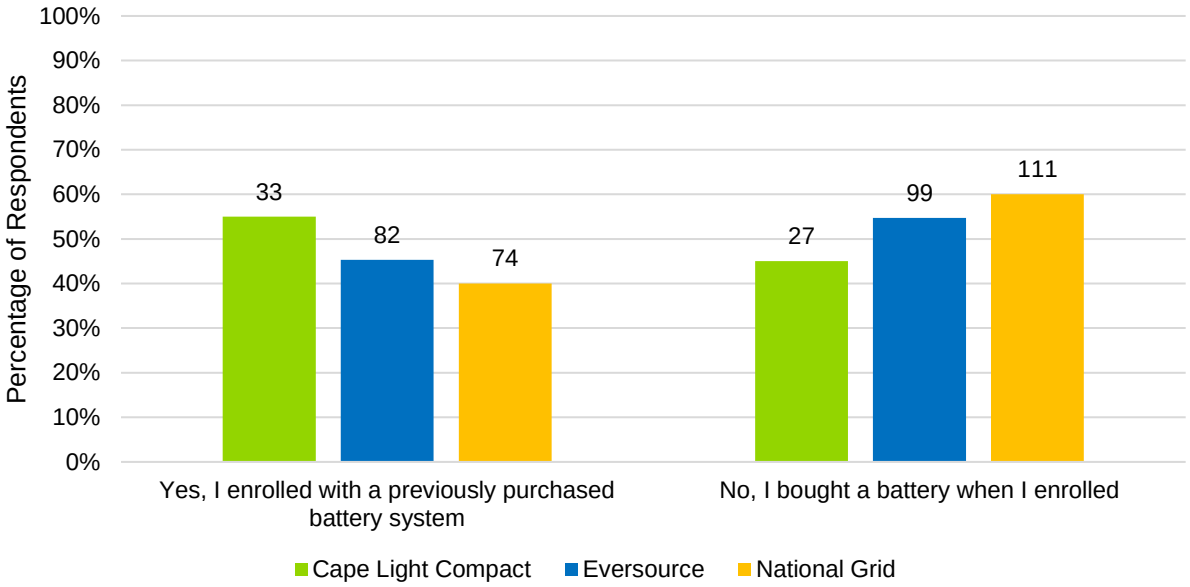
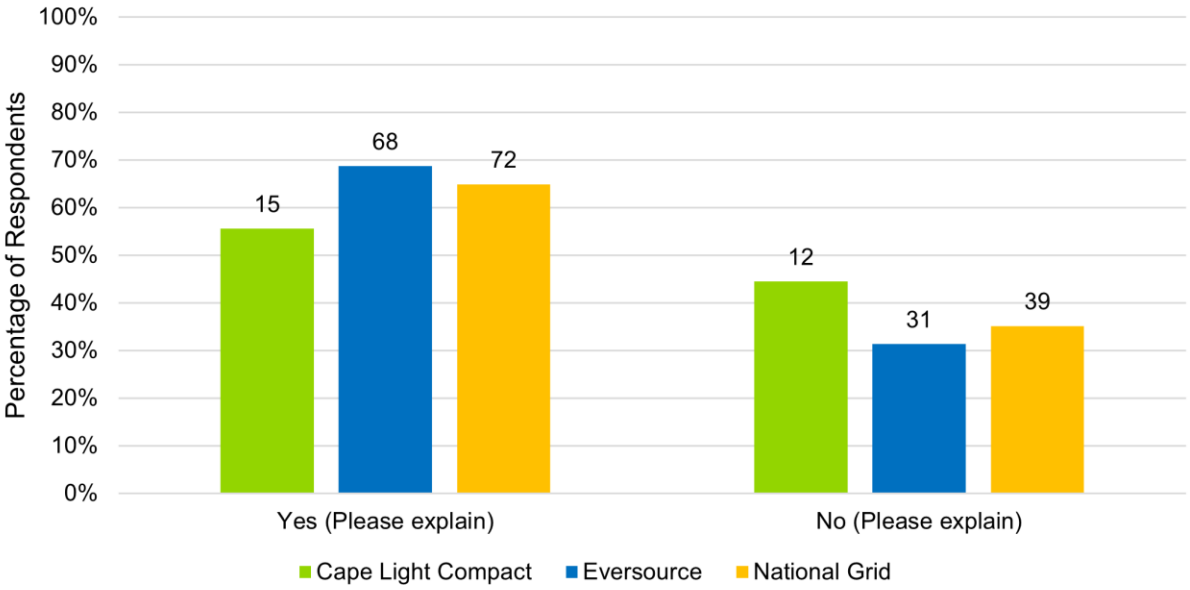
B. Participant Survey Output

Q2. Did you own your battery system prior to your enrollment in the offering? (n=426)



Source: Guidehouse analysis of participant survey data

Q2B. Did the **Connected**Solutions program influence your decision to purchase your battery system? (n=237, those who purchased the battery at the same time as enrolling)



Source: Guidehouse analysis of participant survey data

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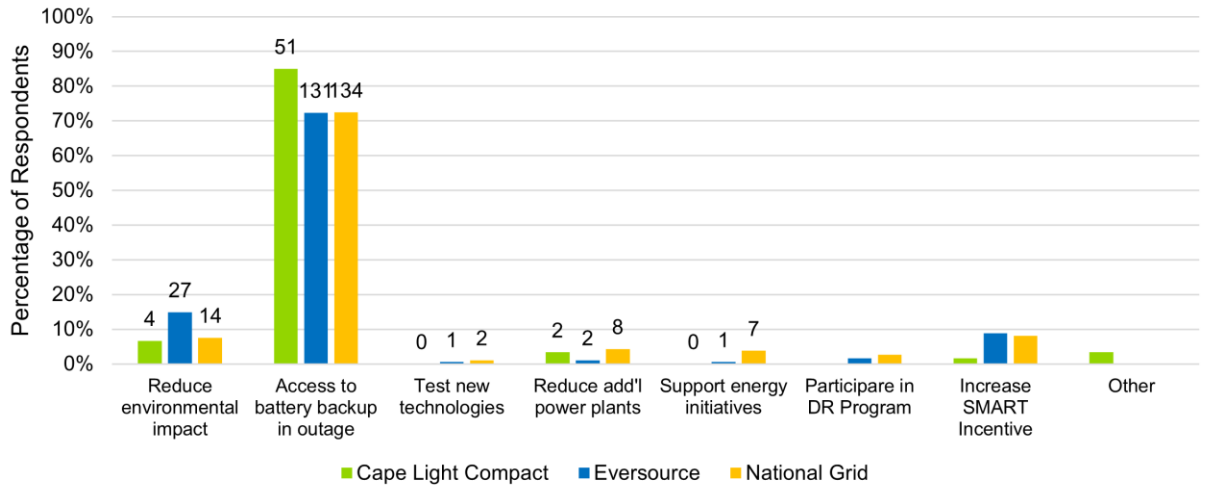
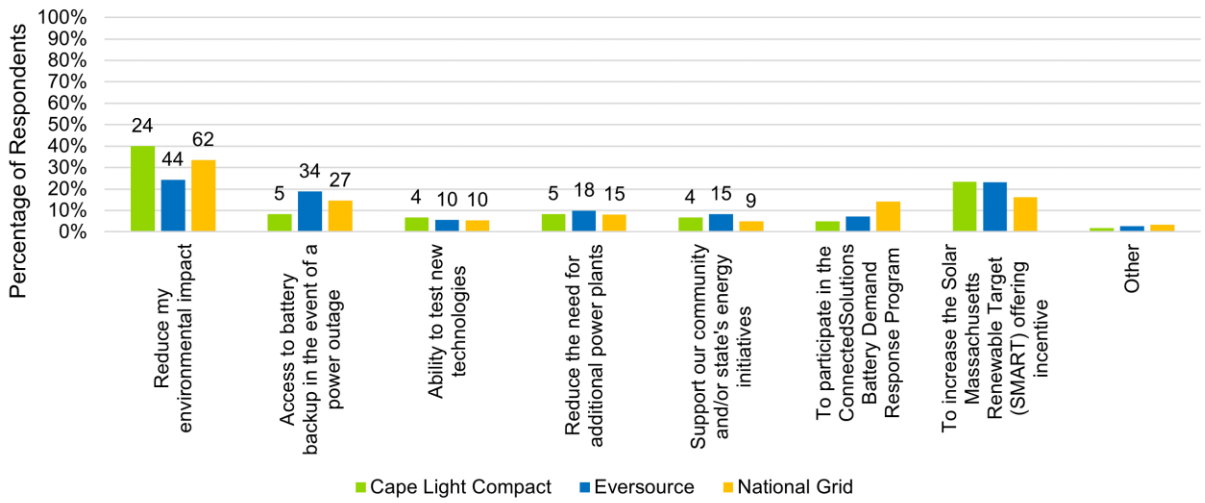
Q4A. What was your first and second biggest motivation in purchasing a battery system? **First Motivation** [RANDOMIZE ALL BUT RESPONSE 8] [SELECT 1st and 2nd] (n=426)



Source: Guidehouse analysis of participant survey data

Q4B. What was your first and second biggest motivation in purchasing a battery system? **Second Biggest Motivation** [RANDOMIZE ALL BUT RESPONSE 8] [SELECT 1st and 2nd] (n=426)



Source: Guidehouse analysis of participant survey data

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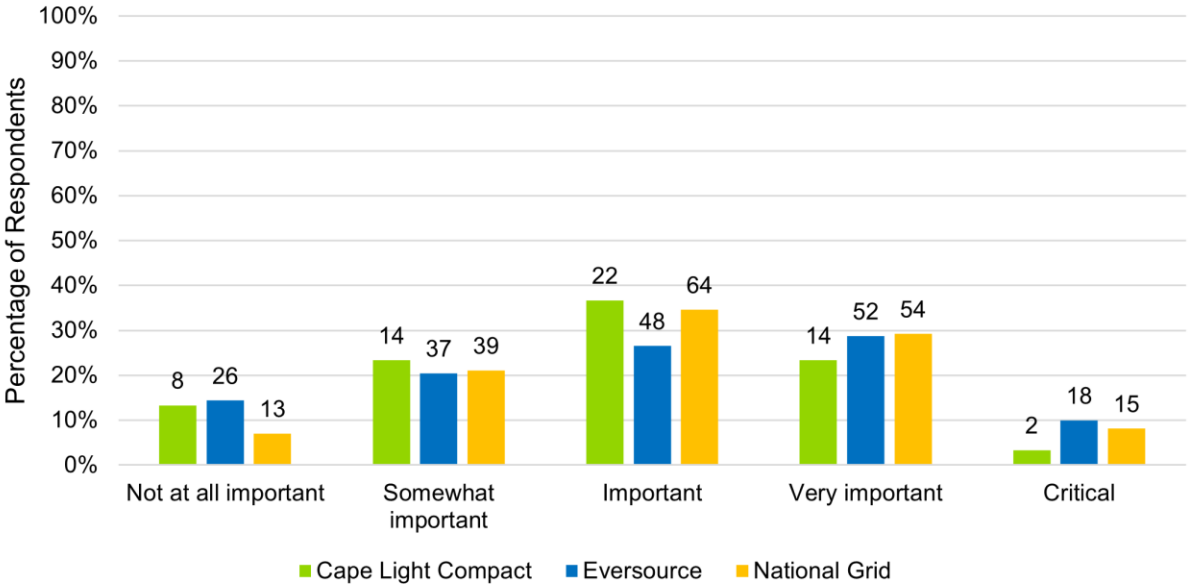
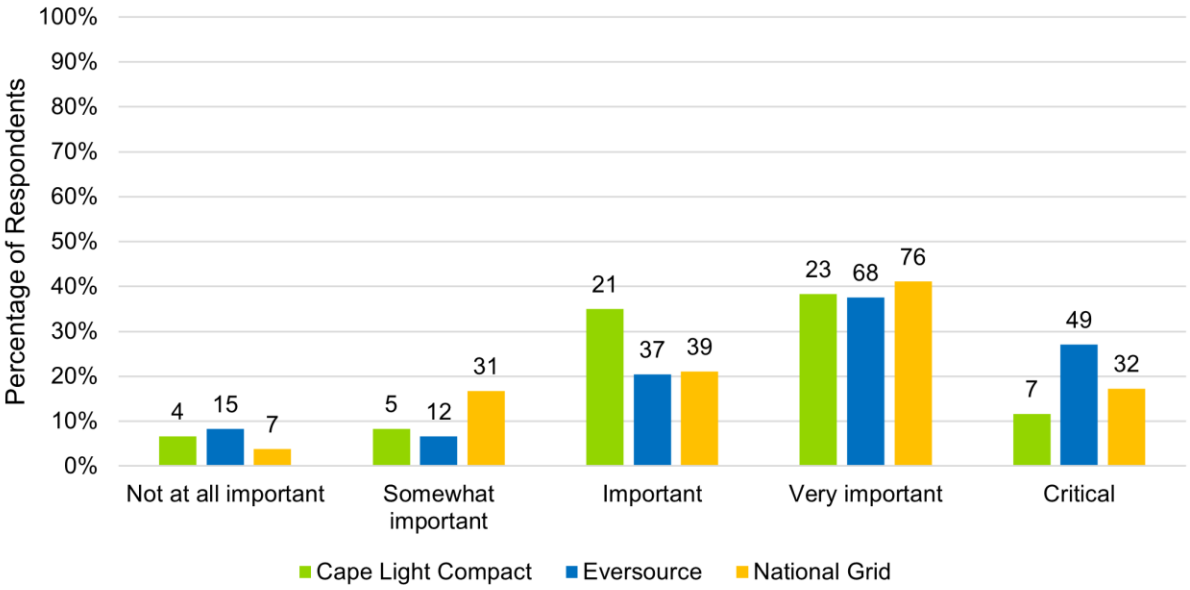
Q5_1. Please indicate how important each of the following was in your decision to purchase a battery system: Reduce the need for peaking power plants (n=426)



Source: Guidehouse analysis of participant survey data

Q5_2. Please indicate how important each of the following was in your decision to purchase a battery system: Reduce my environmental impacts (n=426)



Source: Guidehouse analysis of participant survey data

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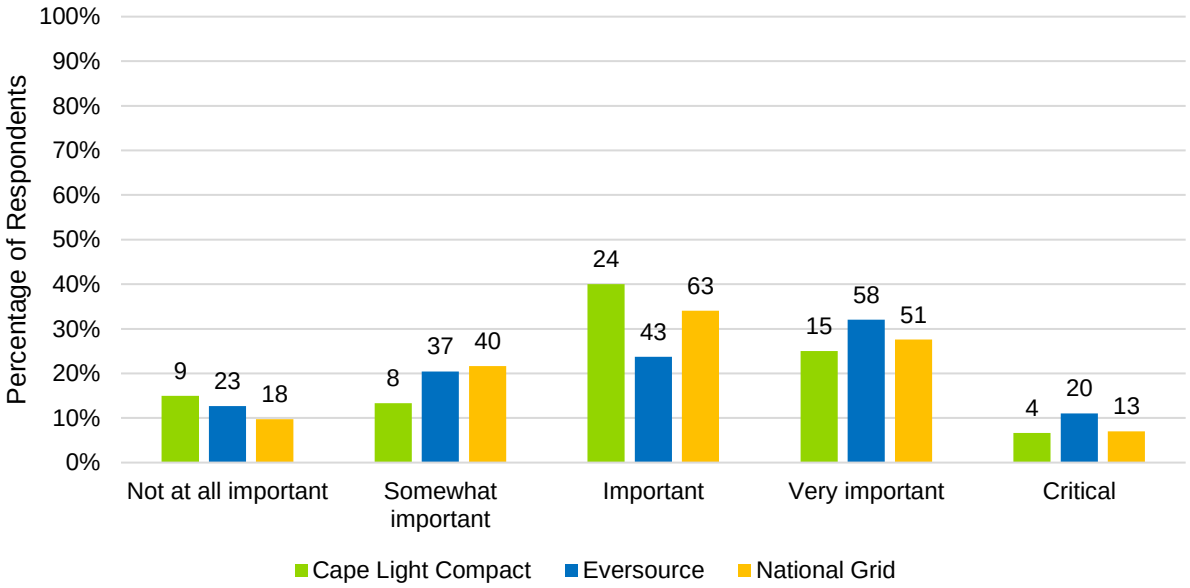
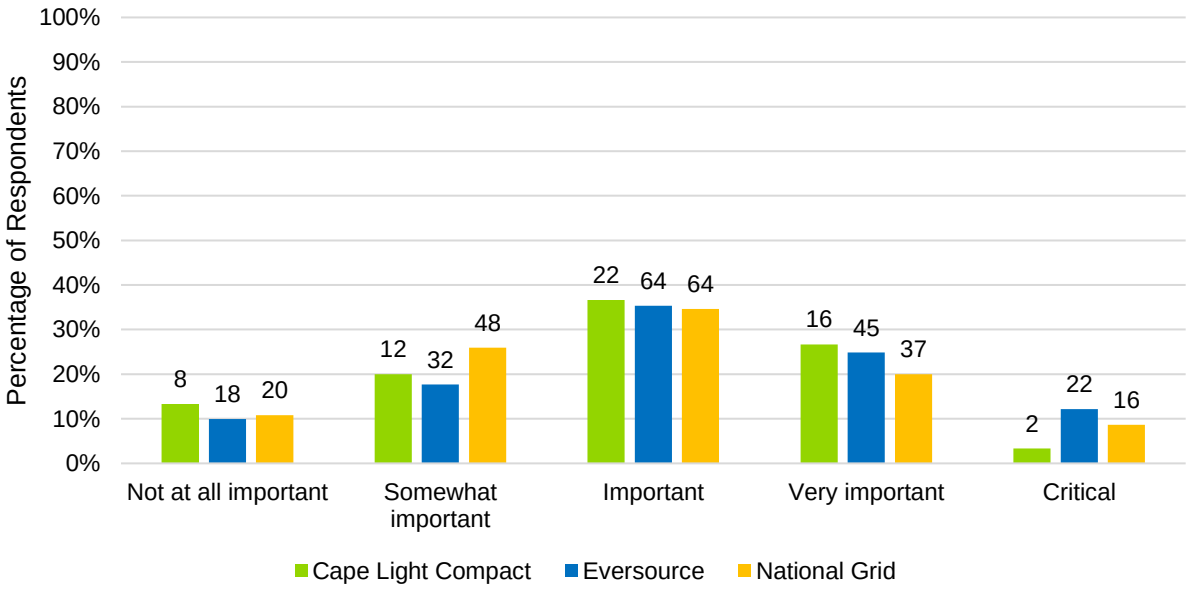
Q5_3. Please indicate how important each of the following was in your decision to purchase a battery system: Reduce the need for additional power plants (n=426)



Source: Guidehouse analysis of participant survey data

Q5_4. Please indicate how important each of the following was in your decision to purchase a battery system: Support my community and/or state's energy initiatives (n=426)



Source: Guidehouse analysis of participant survey data

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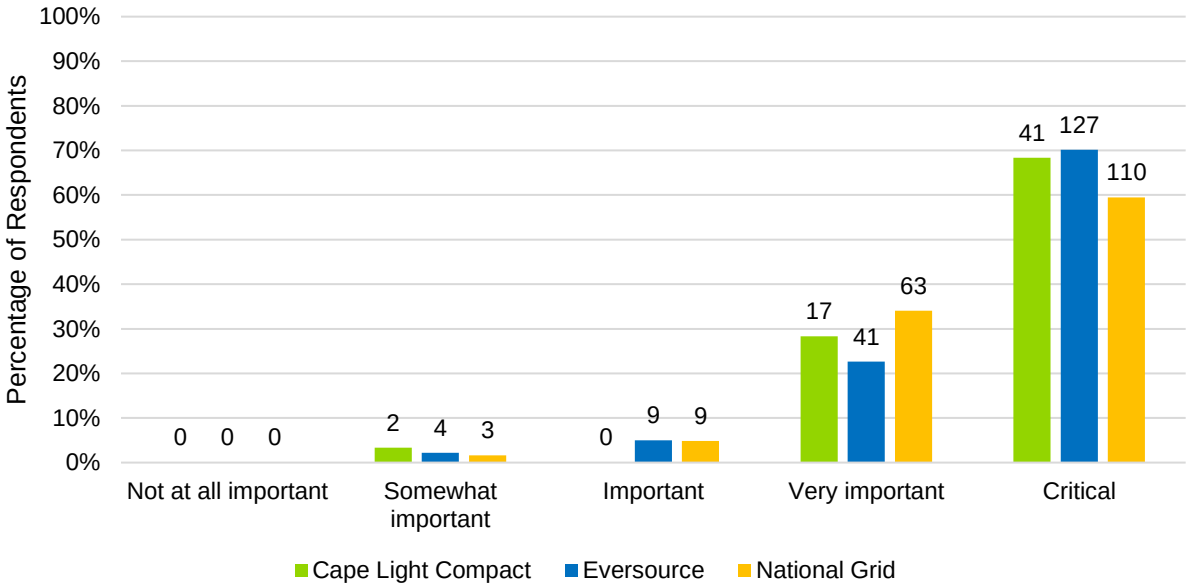
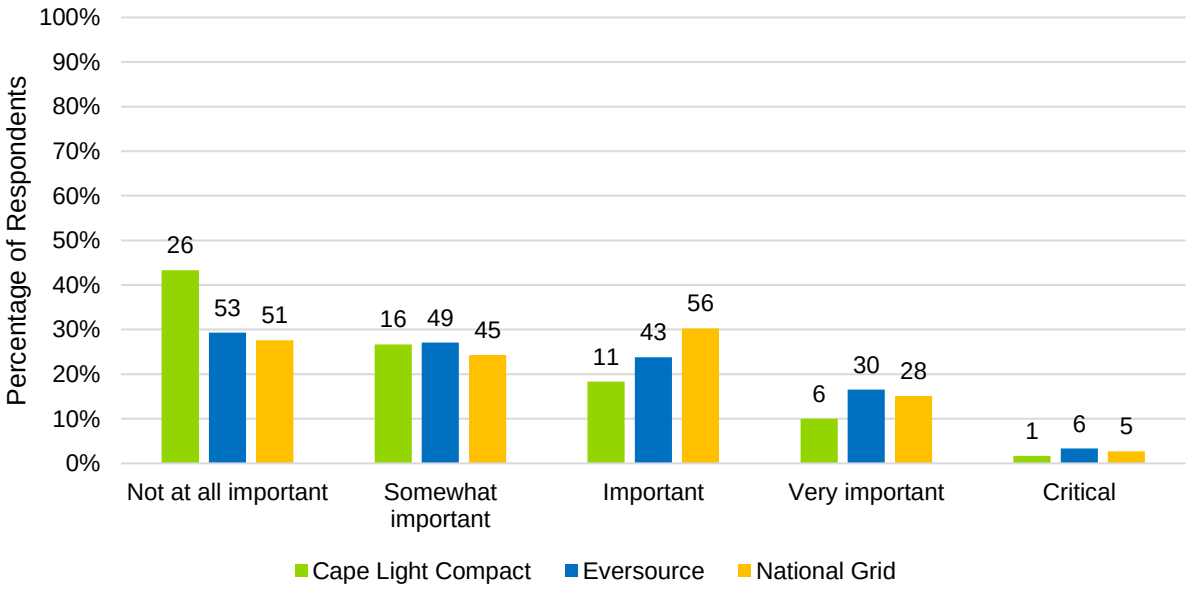
Q5_5. Please indicate how important each of the following was in your decision to purchase a battery system: Access to battery backup in the event of a power outage (n=426)



Source: Guidehouse analysis of participant survey data

Q5_6. Please indicate how important each of the following was in your decision to purchase a battery system: Ability to test new technologies (n=426)



Source: Guidehouse analysis of participant survey data

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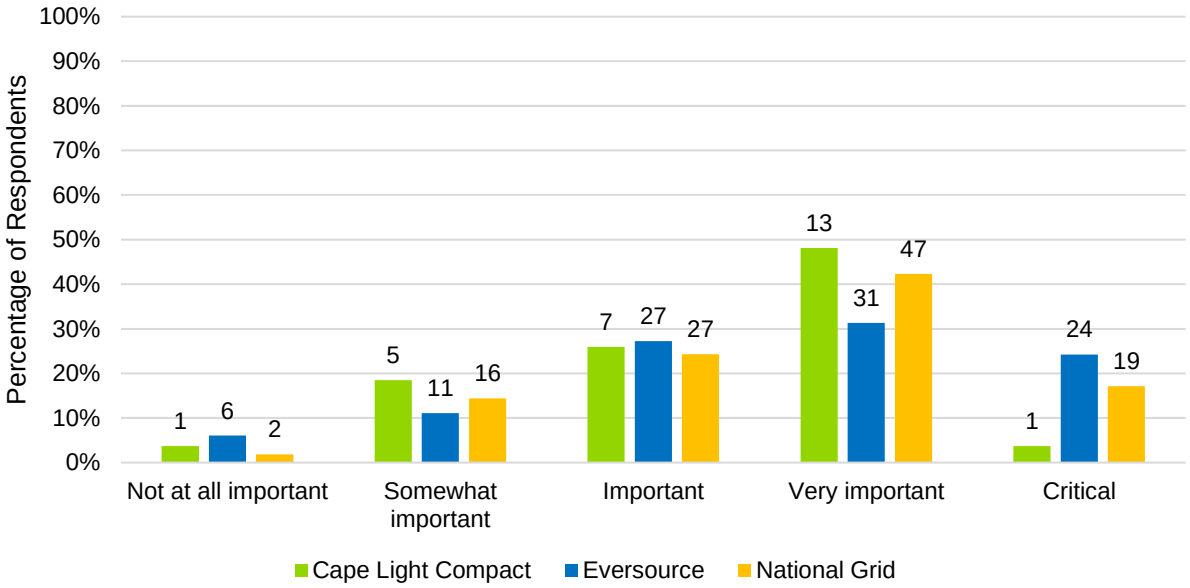
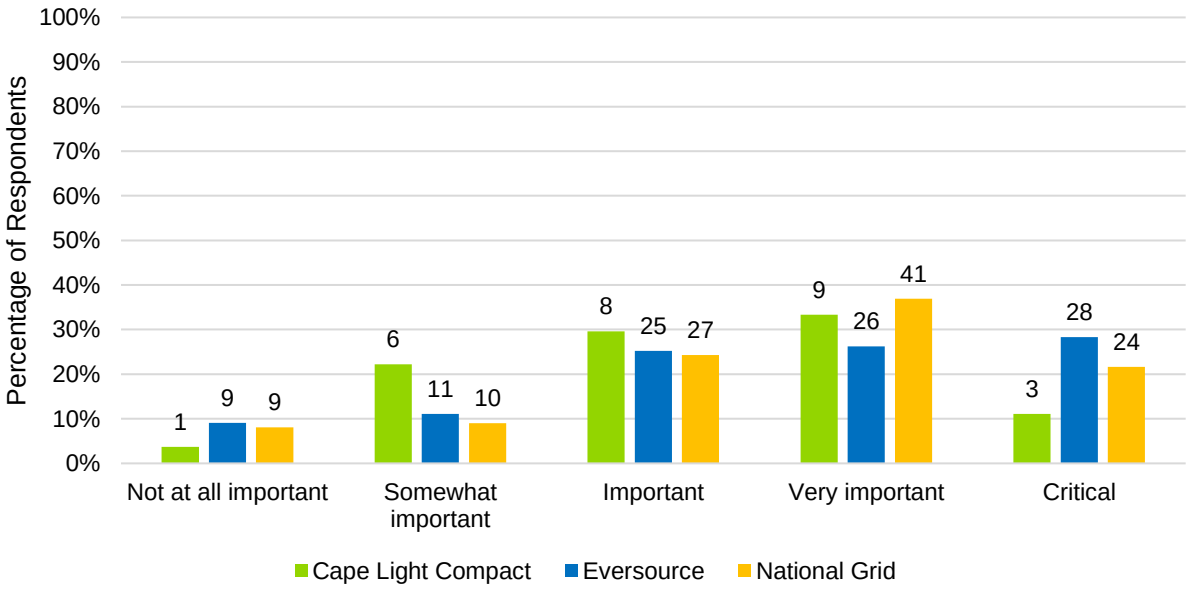
Q5_7. Please indicate how important each of the following was in your decision to purchase a battery system: [SHOW IF Q2=2] **Connected**Solutions participation incentives (n=426)



Source: Guidehouse analysis of participant survey data

Q5_8. Please indicate how important each of the following was in your decision to purchase a battery system: [SHOW IF Q2=2] **Connected**Solutions 5-year incentive guarantee (n=426)



Source: Guidehouse analysis of participant survey data

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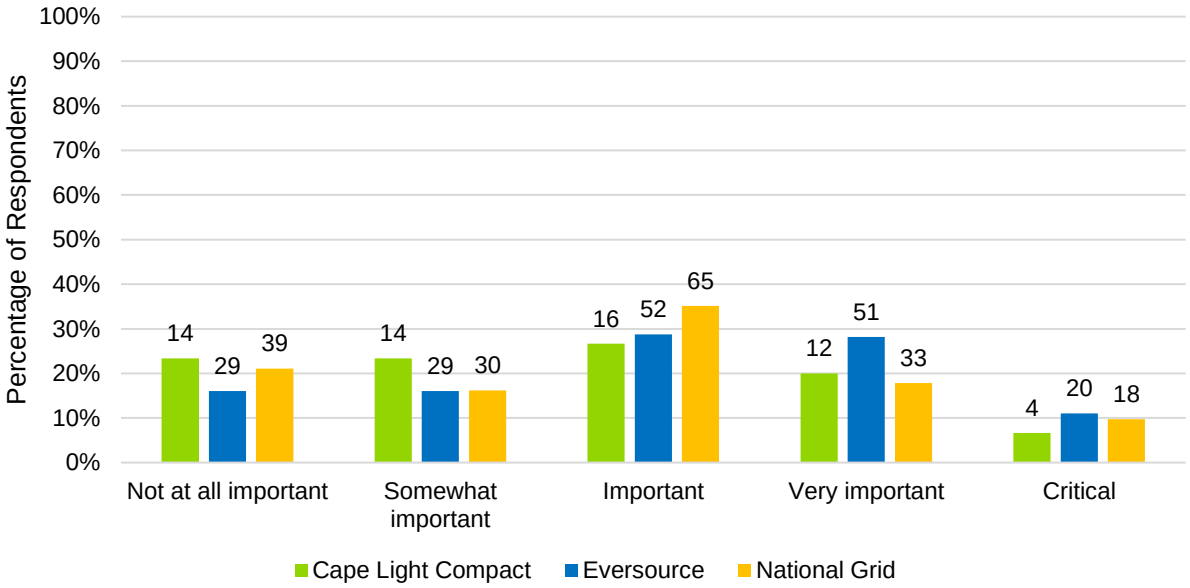
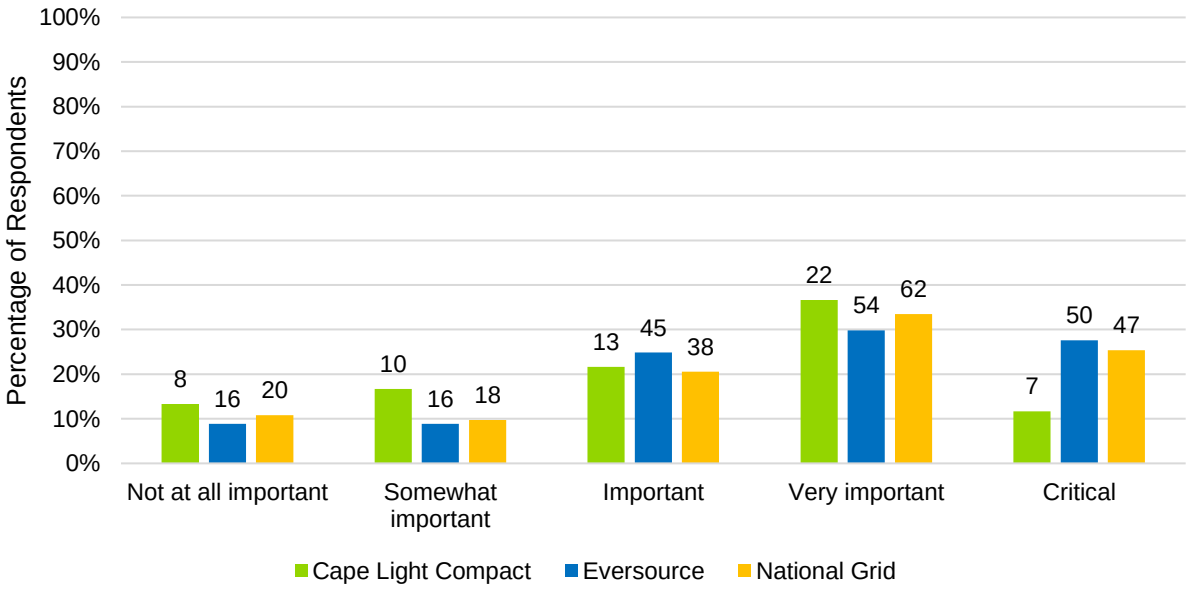
Q5_9. Please indicate how important each of the following was in your decision to purchase a battery system: SMART Storage Adder (n=426)



Source: Guidehouse analysis of participant survey data

Q5_10. Please indicate how important each of the following was in your decision to purchase a battery system: Investment Tax Credit (ITC) (n=426)



Source: Guidehouse analysis of participant survey data

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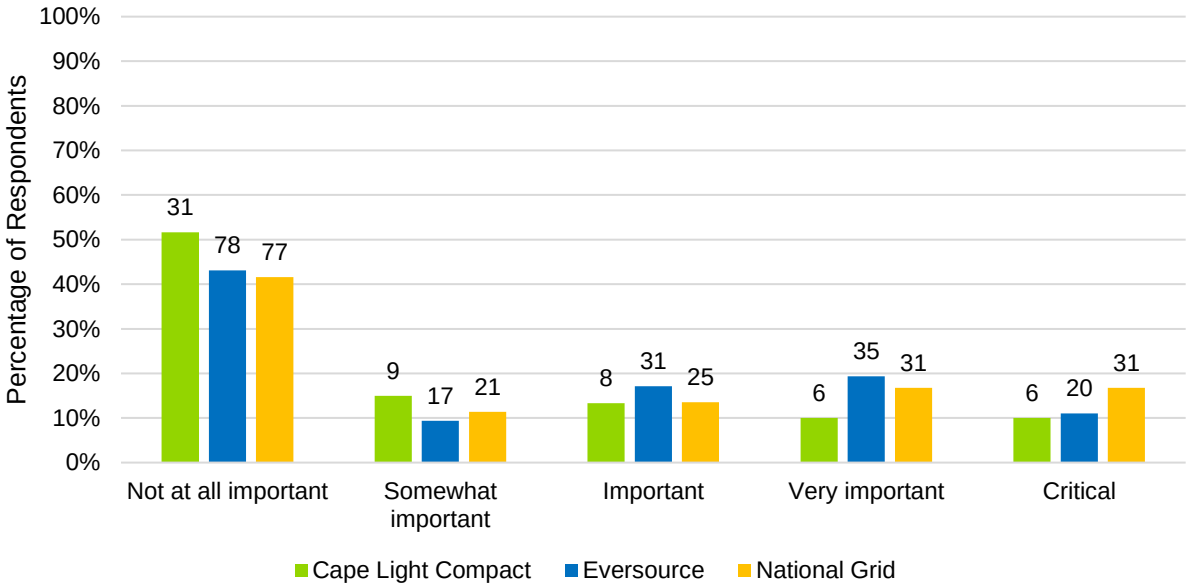
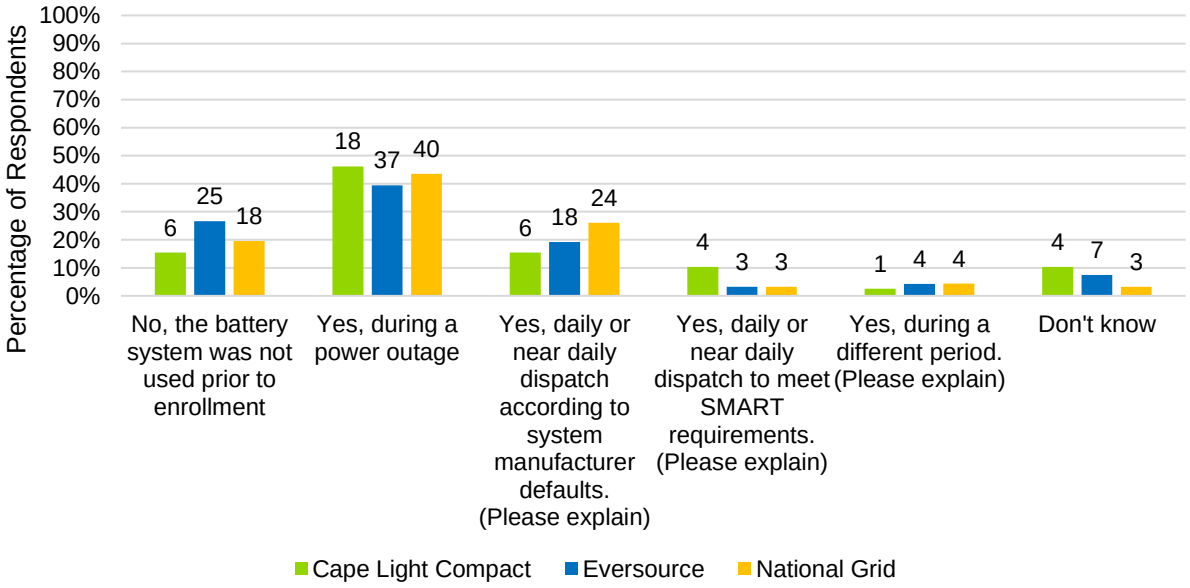
Q5_11. Please indicate how important each of the following was in your decision to purchase a battery system: Mass Save Heat Loan Financing (n=426)



Source: Guidehouse analysis of participant survey data

Q6. Before your enrollment in **Connected**Solutions, did you ever use your battery system? Select all that apply. (n=189)



Source: Guidehouse analysis of participant survey data

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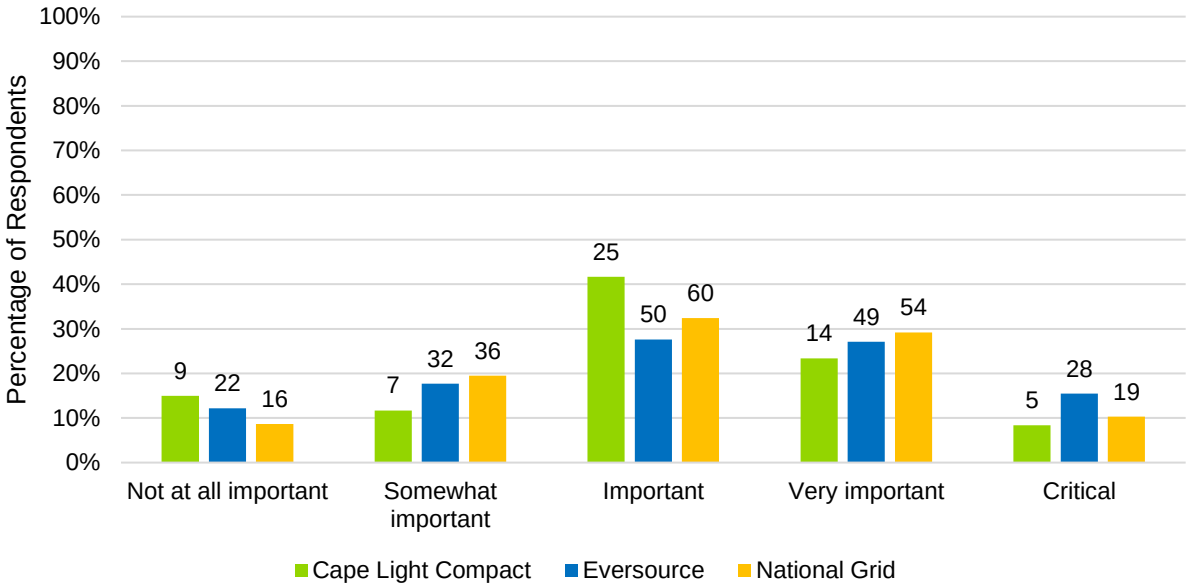
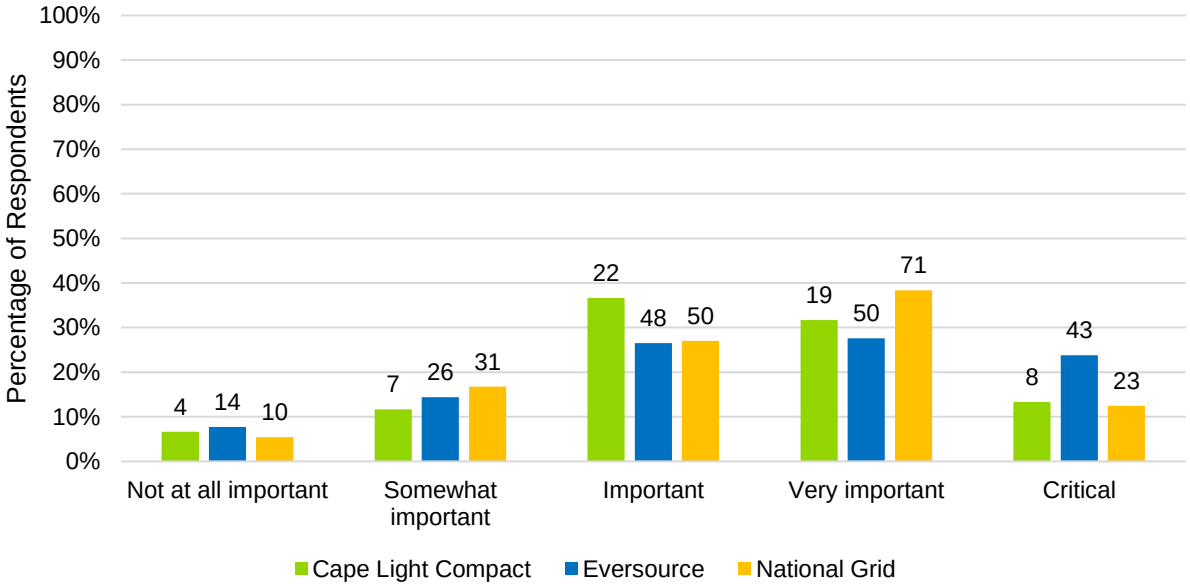
Q8_1. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Reduce need for peaking power plants (n=426)



Source: Guidehouse analysis of participant survey data

Q8_2. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Reduce my environmental impact (n=426)



Source: Guidehouse analysis of participant survey data

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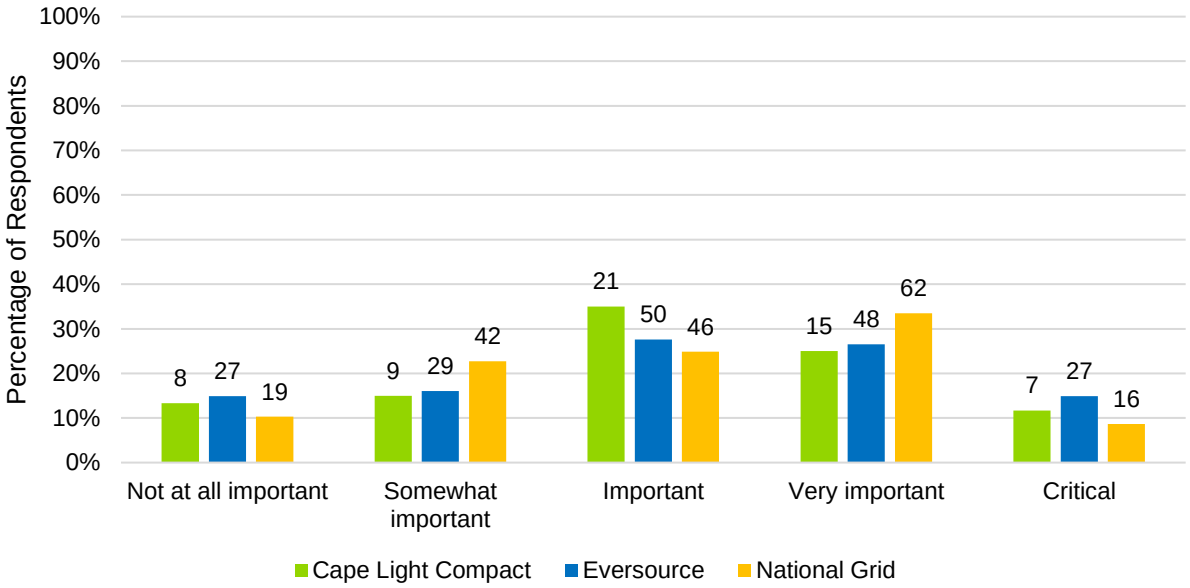
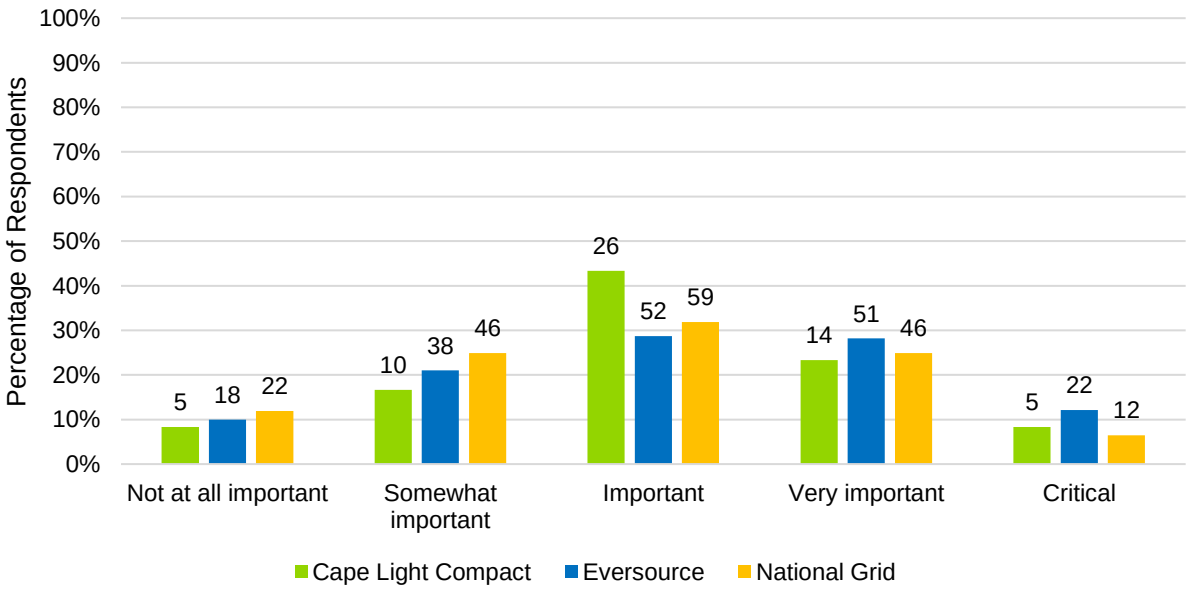
Q8_3. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Reduce the need for additional power plants (n=426)



Source: Guidehouse analysis of participant survey data

Q8_4. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Support my community and/or state's energy initiatives (n=426)



Source: Guidehouse analysis of participant survey data

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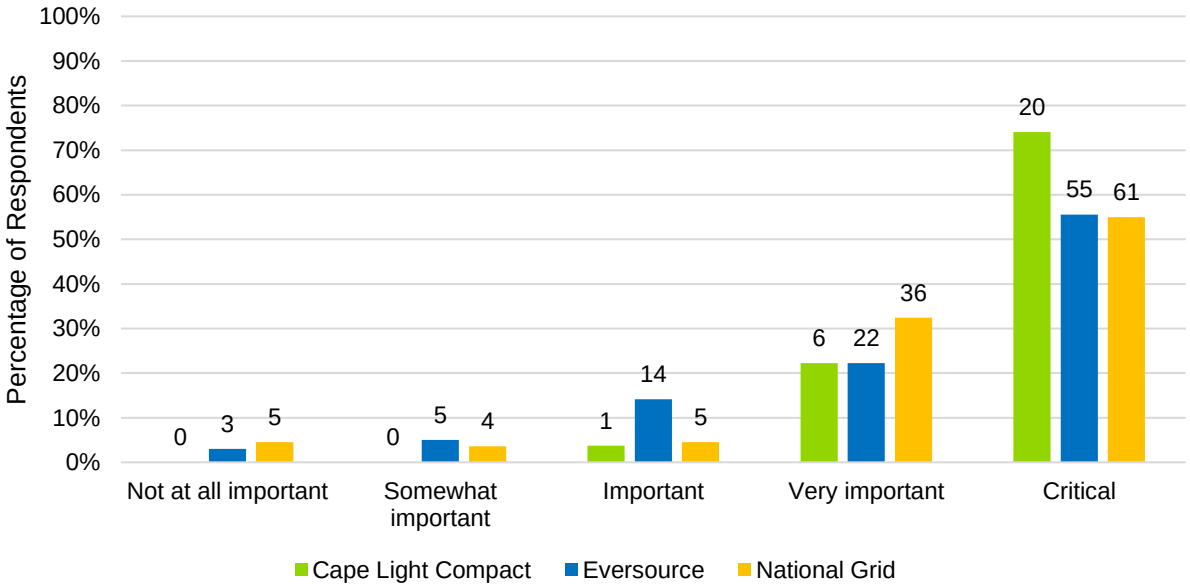
Q8_5. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: [SHOW IF Q2=2] Access to battery backup in the event of a power outage (n=426)



Source: Guidehouse analysis of participant survey data

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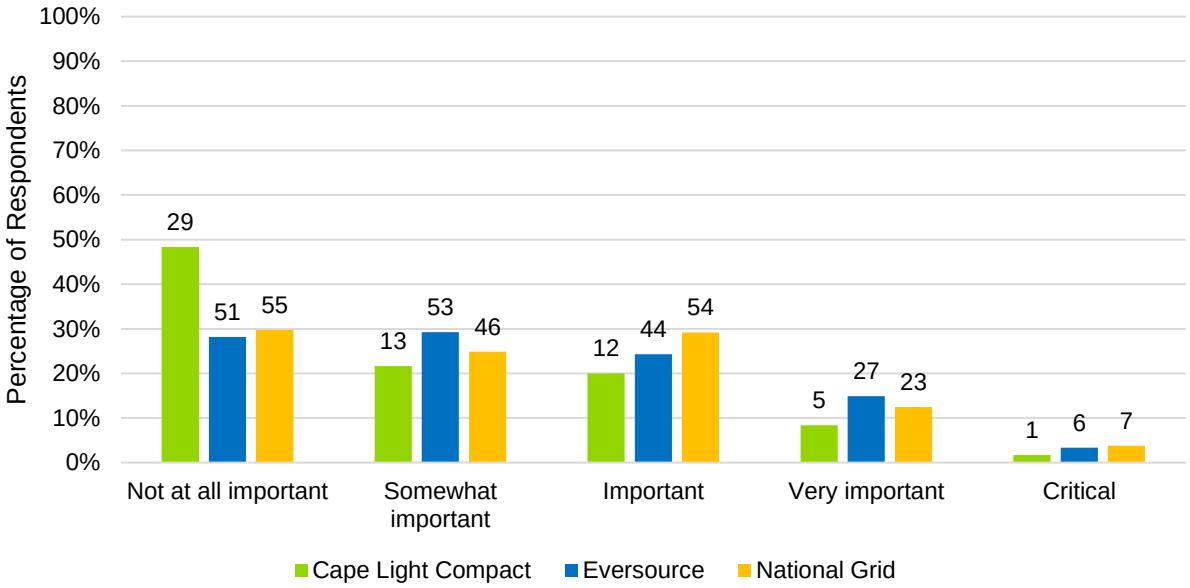
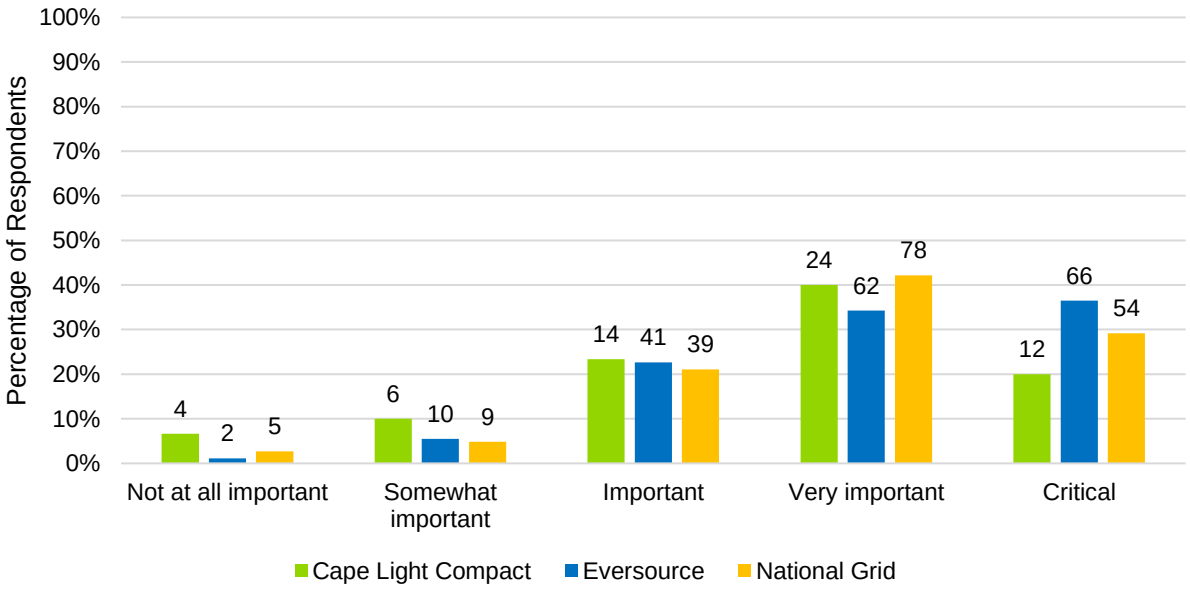
Q8_6. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Ability to test new technologies (n=426)



Source: Guidehouse analysis of participant survey data

Q8_7. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: Participation incentives (n=426)



Source: Guidehouse analysis of participant survey data

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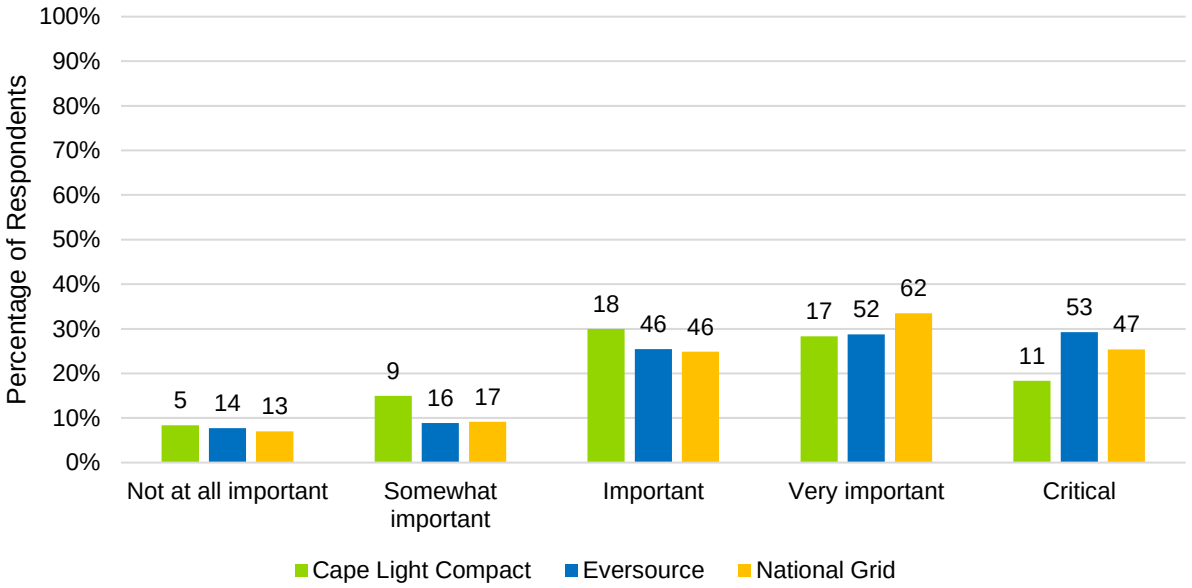
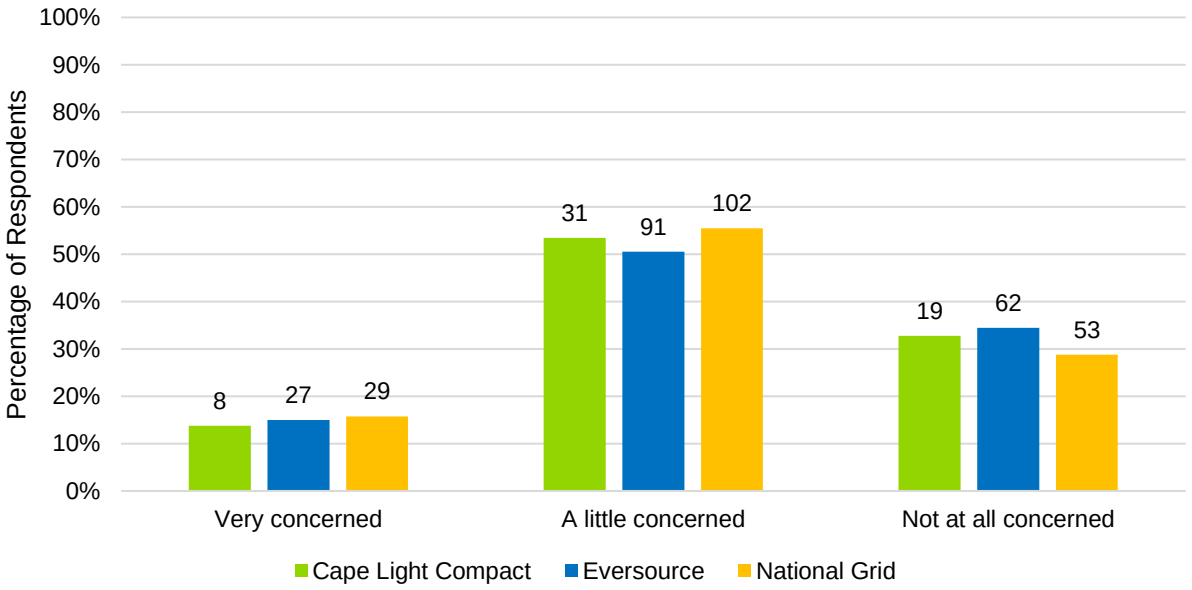
Q8_8. Please indicate how important each of the following was in your decision to enroll in [PA]'s **Connected**Solutions program: 5-year incentive guarantee (n=426)



Source: Guidehouse analysis of participant survey data

Q9. How concerned are you that **Connected**Solutions may have discharged your battery when you are counting on it for backup purposes? (n=422)



Source: Guidehouse analysis of participant survey data

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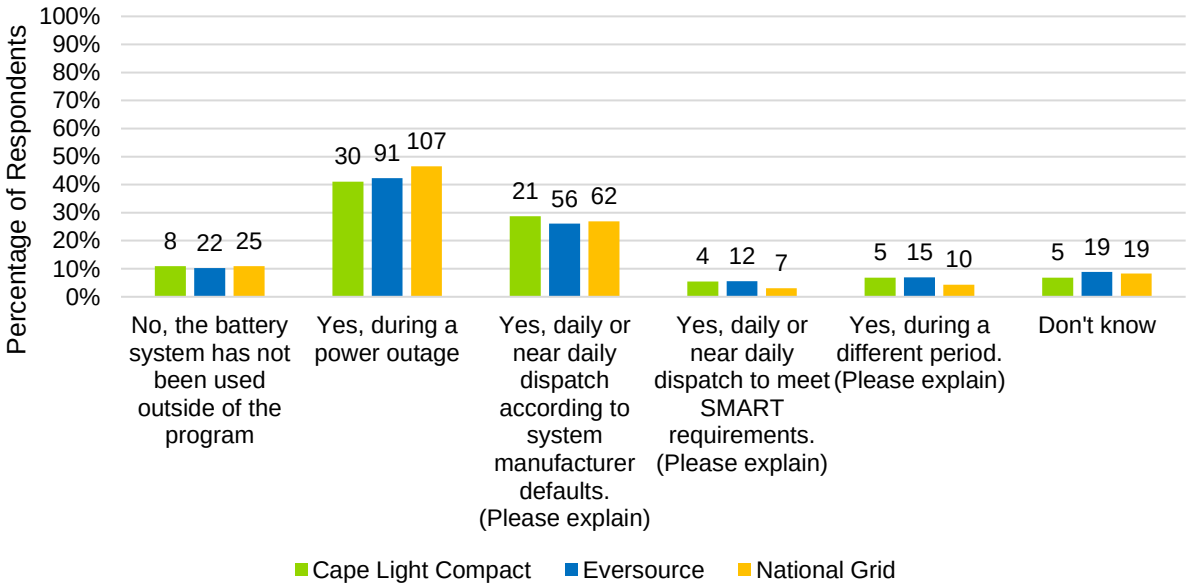
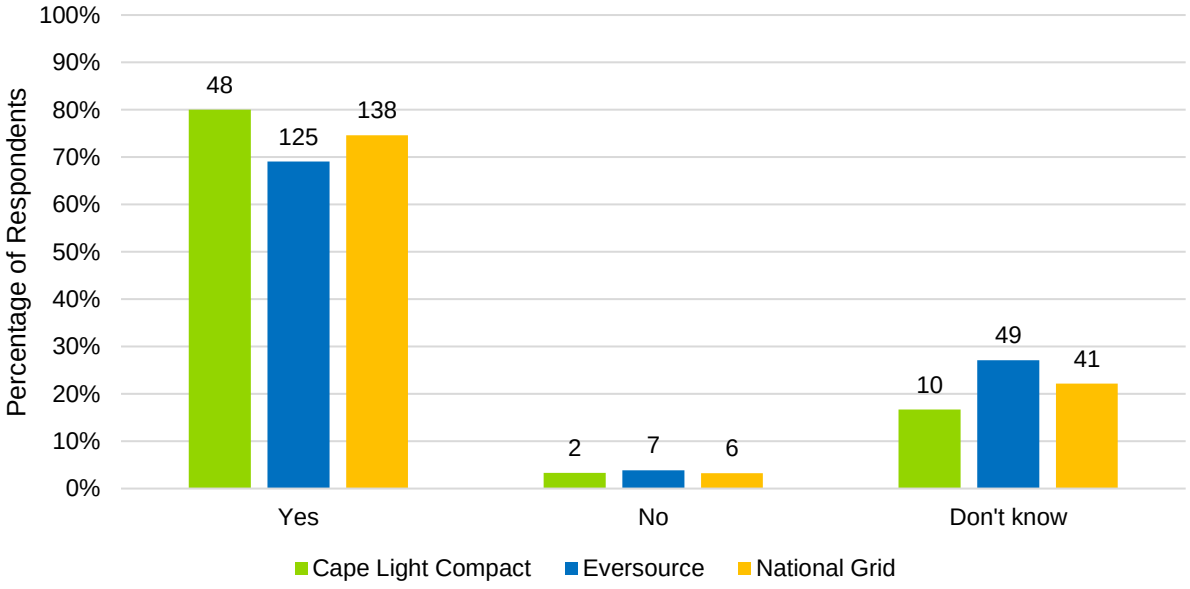
Q10. While enrolled in **Connected**Solutions, have you used (charged or discharged) your battery system ***outside of*** when [PA] utilized your battery as part of the program? Select all that apply. (n=426)



Source: Guidehouse analysis of participant survey data

Q12. Has [PA] dispatched your energy storage this summer? (n=426)



Source: Guidehouse analysis of participant survey data

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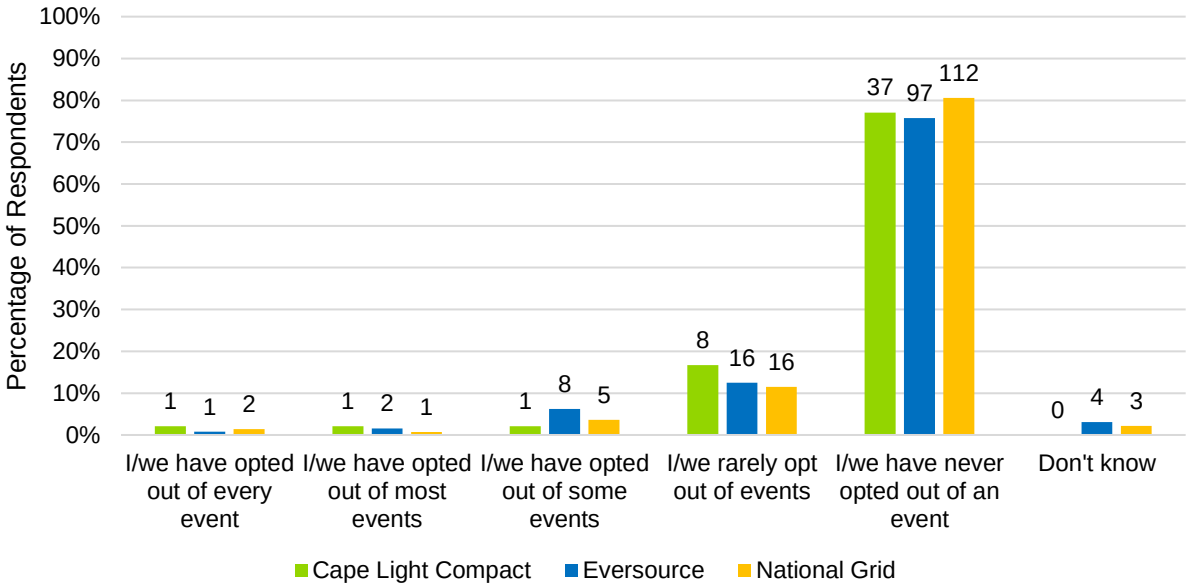
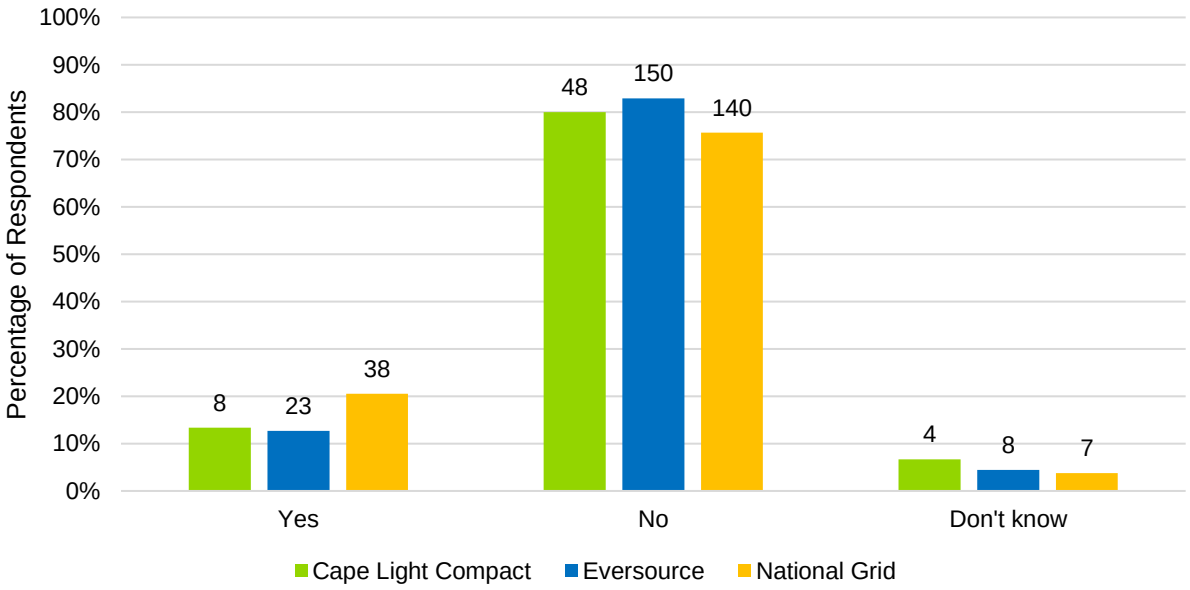
Q14. How often have you chosen to opt-out of events while enrolled in **Connected**Solutions? (n=426)



Source: Guidehouse analysis of participant survey data

Q16. Have you experienced any technical difficulties or malfunctions with your battery system? (n=426)



Source: Guidehouse analysis of participant survey data

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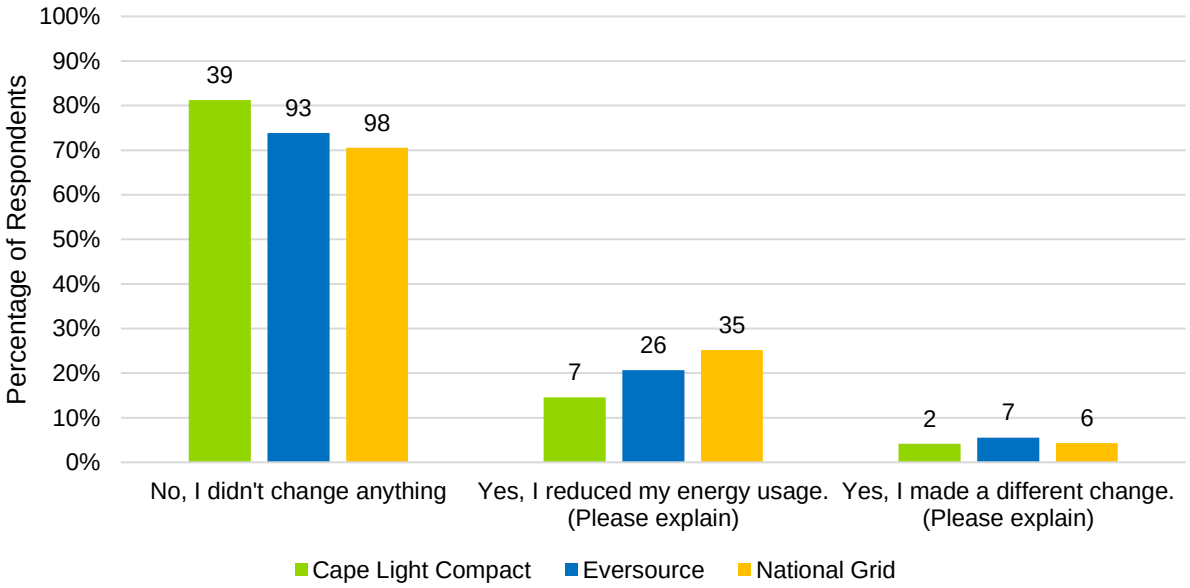
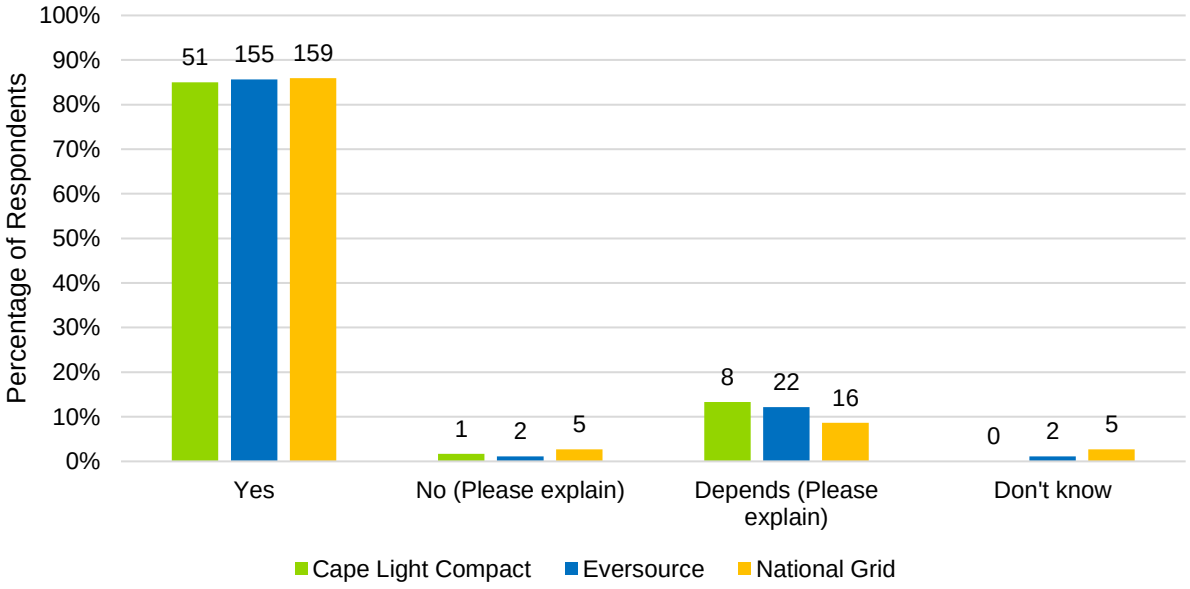
Q18. Did participation in the program change anything about your daily routine during periods when your battery system was dispatched by [PA]? For example, did you reduce your energy usage when you knew you were running on battery power? [Select all that apply] (n=426)



Source: Guidehouse analysis of participant survey data

Q19. Would you recommend purchase of a battery for home energy storage to others? (n=426)



Source: Guidehouse analysis of participant survey data

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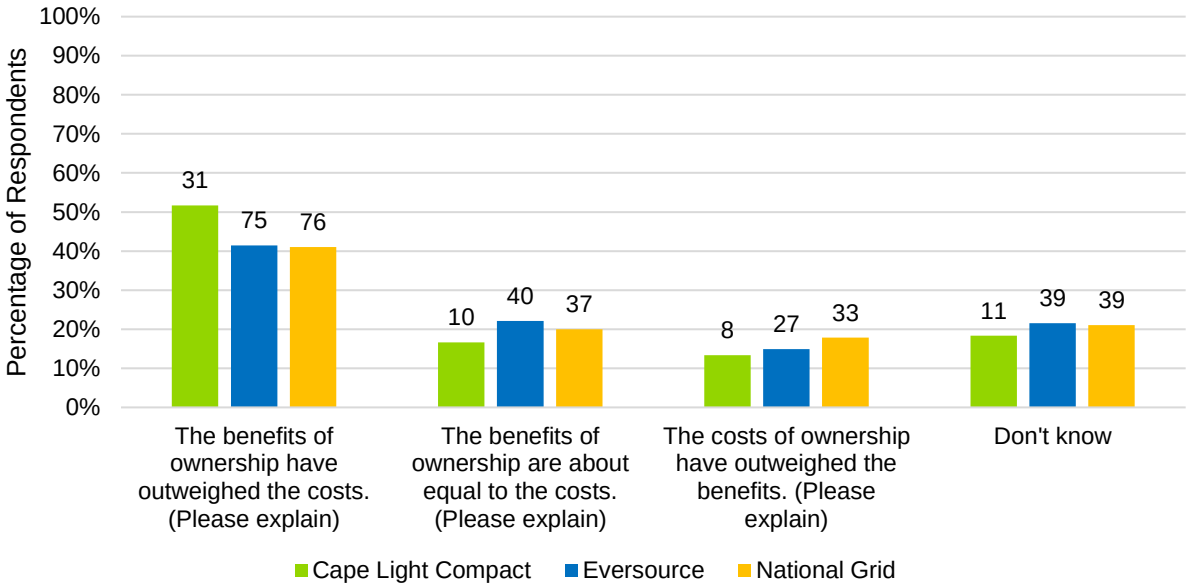
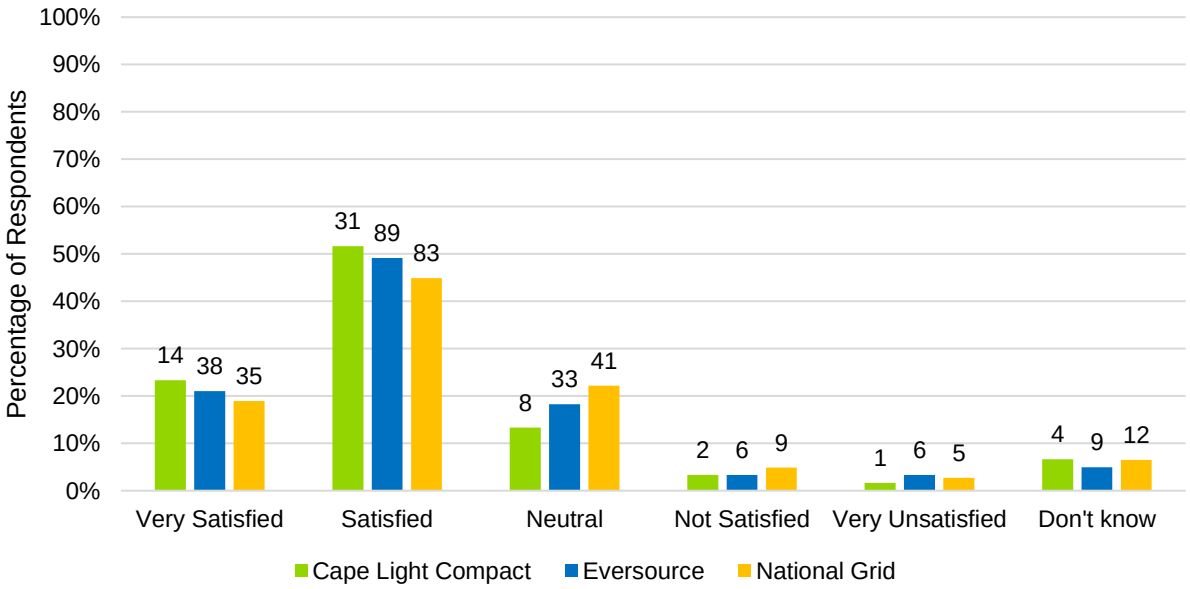
Q20. Based on your experiences to-date, how would you characterize the benefits and costs of battery ownership? [RANDOMIZE] (n=426)



Source: Guidehouse analysis of participant survey data

Q21. How satisfied are you with your participation in the **Connected**Solutions Battery Demand Response Program? [RANDOMLY FLIP ORDER FROM 1-5 FOR SOME TO START WITH "Very Unsatisfied"] (n=426)



Source: Guidehouse analysis of participant survey data

Q22. How likely are you to continue participating in the **Connected**Solutions Battery Demand Response Program? (n=426)

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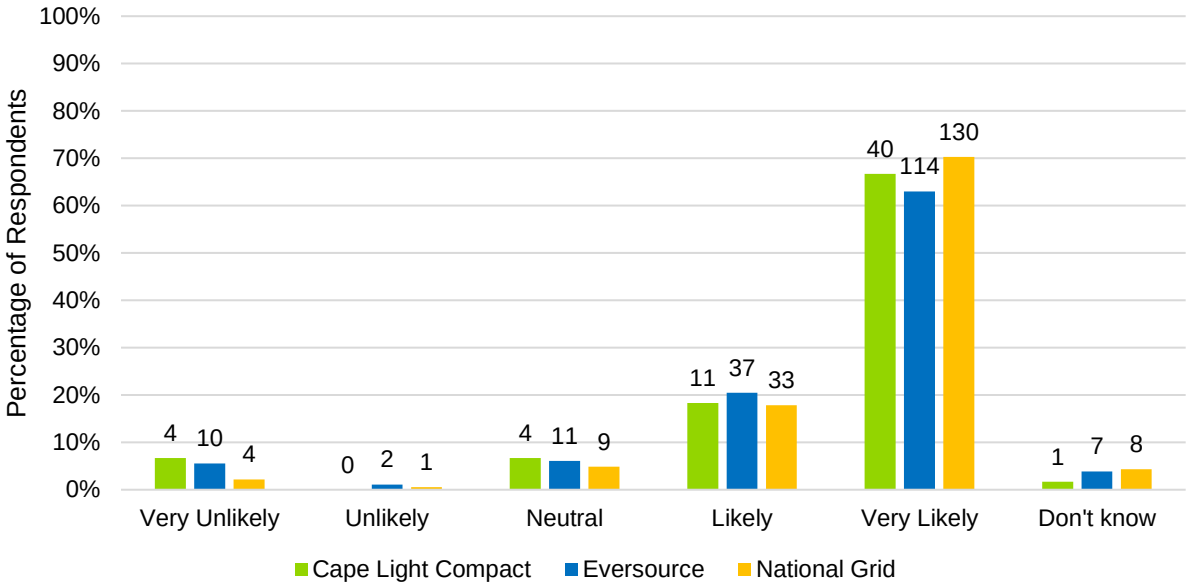
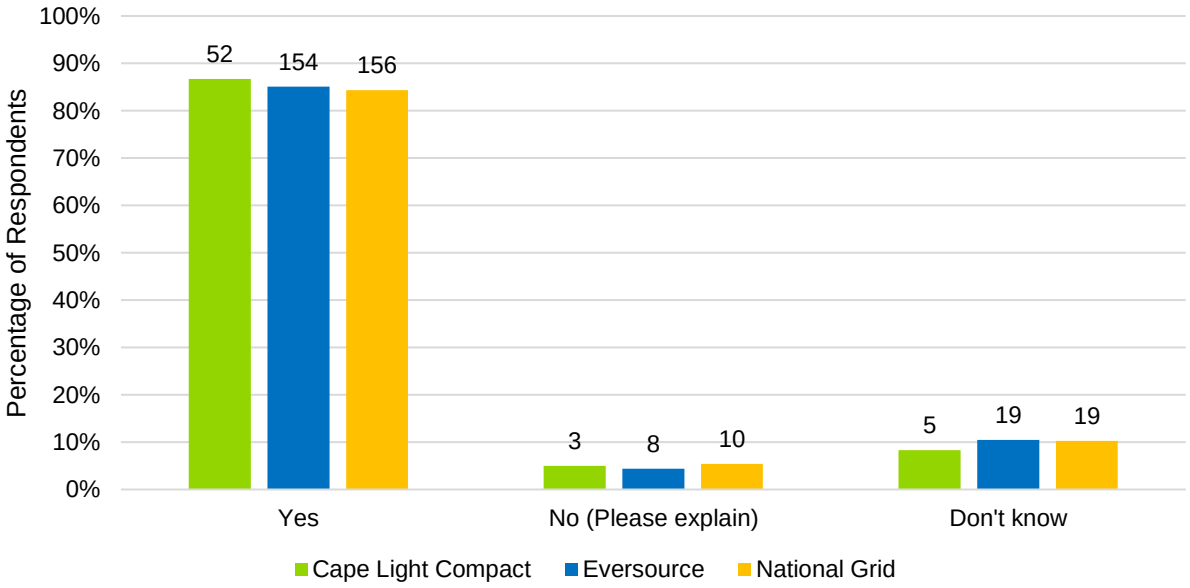


Source: Guidehouse analysis of participant survey data

Q25. Would you recommend **Connected**Solutions to others who own or are thinking about purchasing a battery? (n=426)



Source: Guidehouse analysis of participant survey data

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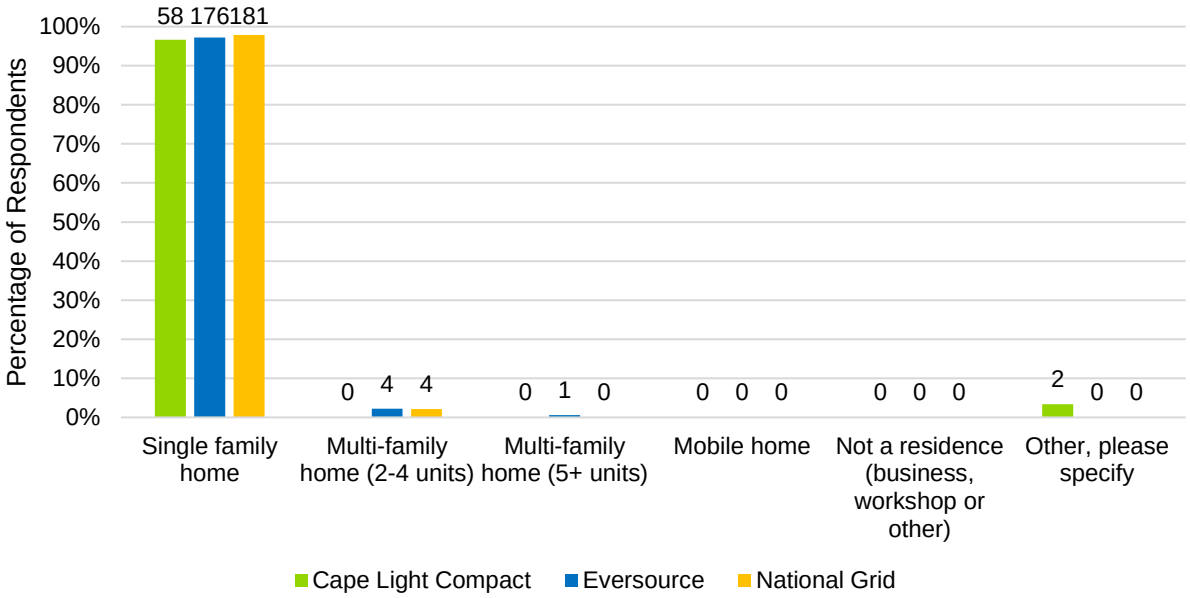
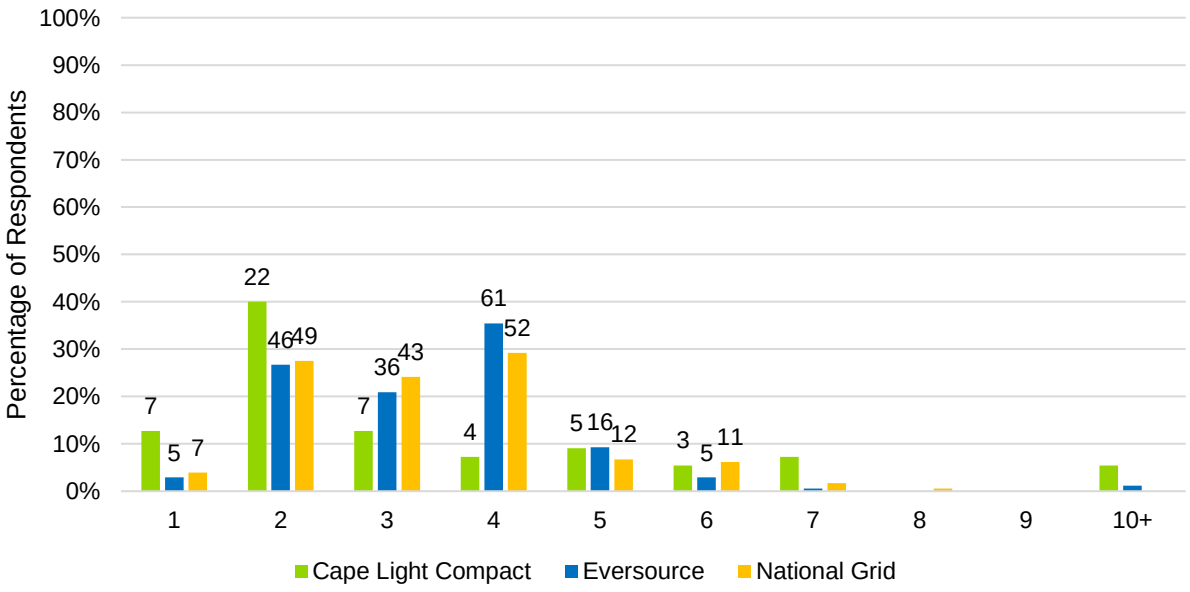
Q26. Which of the following best describes the property type where your battery system is located? (n=426)



Source: Guidehouse analysis of participant survey data

Q27. **[RESTRICT RESPONSE OPTIONS TO 2 DIGITS]** How many people occupied your home this summer 2023? Enter zero if appropriate. (n=426)



Source: Guidehouse analysis of participant survey data

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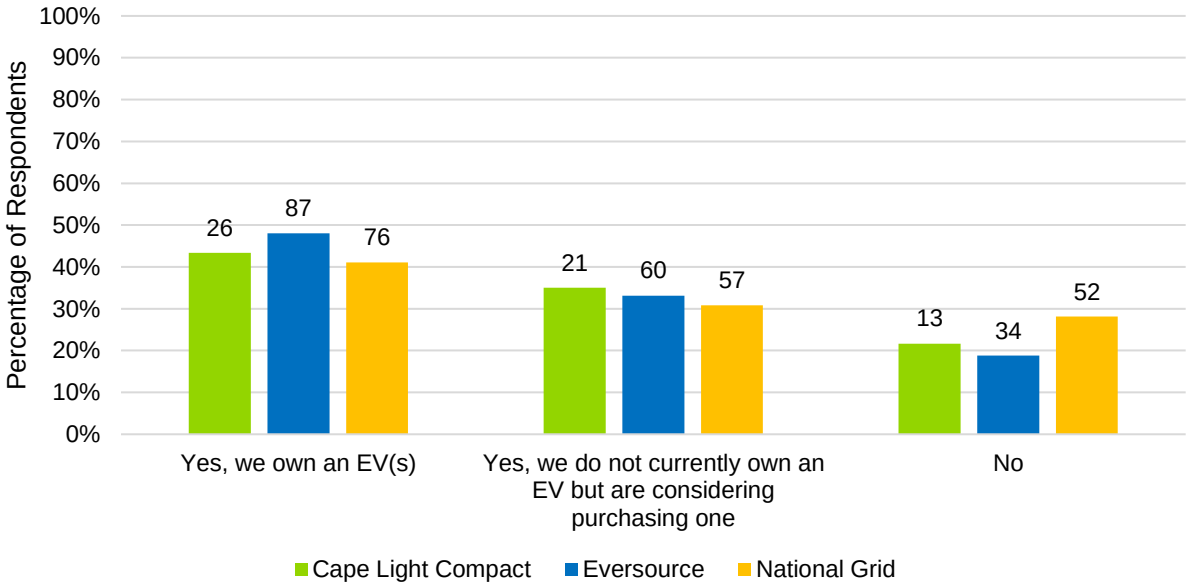
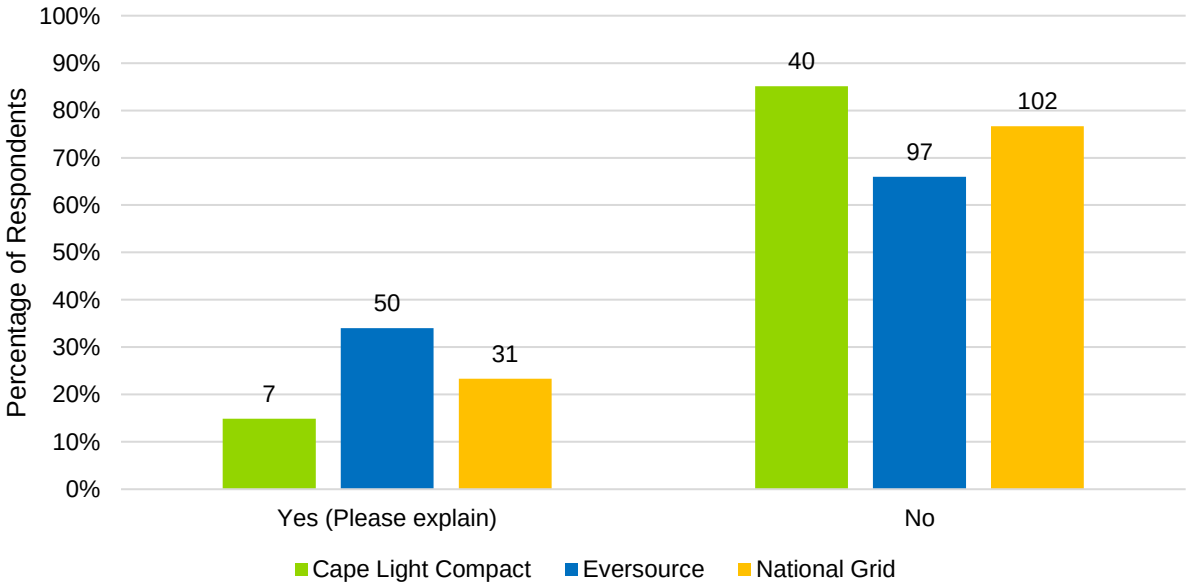
Q29. Does your household own an EV(s) or considering purchasing one? (n=426)



Source: Guidehouse analysis of participant survey data

Q30. Did owning or thinking about owning an EV influence your decision to purchase a battery system? (n=426)



Source: Guidehouse analysis of participant survey data

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C. Benchmarking – Supplemental Results

MA Residential Energy Storage Demand Reduction Program

Overview

MA PAs operate a demand response program during the summer to enable d irect load control. Customers may participate by installing a battery storage system controlled by an approved inverter. When necessary, the PA automatically sends a signal directly to the customers' inverter to dispatch the battery.

Characteristics

- **Administrators** : Cape Light Compact, Eversource, National Grid
- **Deployment target:** Cape Light Compact – 200 customers by 2024; Eversource – 1,750 customers by 2024; National Grid - 4,668 customers by 2024.*
- **Demand reduction approach**: Direct load control
- **Requirements**: Customers must discharge June -September, 3pm -8pm for no more than 60 times a maximum of three hours per event
- **Unenrollment terms:** Customer must stay enrolled for the entire season to receive the incentiveIn the event of a sale, new customer would have to sign up for the program for the battery to continue being enrolled.

Incentives

- **Incentive lock**: Yes, a performance incentive rate is locked in place for the first five summers enrolled
- **Program Incentive:** Performance incentive rate of $275 per kW
- **Other:** 0% financing is available through the Mass Save HEAT loan

ConnectedSolutions

*MA– 1,000 MWhMassachusetts energy storage goal by December 31, 2025

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6

Connecticut Energy Storage Solutions Program (1/3)

Overview

Energy Storage Solutions is a nine -year program designed to help Eversource Energy and United Illuminating customers install energy storage at their home or business and participate in d irect load control. Energy storage backup is aimed at helping customers across Connecticut, including homeowners, small businesses, industrial manufacturers, and critical infrastructure facilities be more energy secure in the face of a changing climate.

Characteristics

- **Administrators** : Connecticut Green Bank, Eversource Energy, United Illuminating
- **Deployment target:** CT PURA – 580 MW of new behind -the-meter (residential + C&I) electric storage by 2030; 27.9 MW program enrollment forecast by 2024 with 20% and 80% project enrolled capacity within United Illuminating and Eversource Energy service territory, respectively
- **Demand reduction approach**: Direct load control
- **Requirements**: Customers must participate in demand response discharge from 12:00 pm -9:00 pm for one to three hours for 30 -60 events between June -September and for one to five events between November -March

energy storage SOLUTIONS

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Connecticut Energy Storage Solutions Program (2/3)

Incentives

- **Incentive lock**: Yes, performance-based incentives are paid at the end of each summer and winter season for ten years based on average energy contributions to the grid; additionally, participating customers receive an upfront incentive to reduce the battery's cost

The upfront residential incentive is calculated using the lower of the following formulas:

1. Electric storage system usable (nameplate) energy capacity (kWh) multiplied by incentive rate (see table below);
2. 50 percent of electric storage system total installed cost;or
3. Maximum per project incentive of $7,500

Residential Customer Upfront Incentive Rates (2023 -2024)

Incentive Step*	Installed Capacity (MW)	Baseline ($/kWh)	Underserved Community ($/kWh)	Low-Income ($/kWh)
1	10	$200	$300	$400
2	15	$175	$255	$340
3	25	$130	$195	$260
Grid Edge Adder		+ 50%	+ 50%	+ 50%
Total	50			

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Connecticut Energy Storage Solutions Program (3/3)

Performance-based Incentives

Years 1-5		Years 6-10	
Summer ($/kW)	Winter ($/kW)	Summer ($/kW)	Winter ($/kW)
$200	$25	$115	$15
$225 annual		$130 annual	

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Green Mountain Power's Bring Your Own Device Energy Storage Program (1/2)

Overview

Customers may receive up to $10,500 to assist GMP in direct load control. Customers enrolled in the 'BYOD' program receive incentives based on the amount of energy storage they have enrolled.

Characteristics

- **Administrator**: Green Mountain Power
- **Deployment target:** Green Mountain Power - 8% of GMP residential customers have battery system by2030
- **Demand reduction approach**: Direct load control
- **Requirements**: Ten-year enrollment period during which customers must discharge to reduce peak demand an average of five to eight times per month for an average of three to six hours
- **Unenrollment terms:** If customers unenroll, they pay GMP a pro-rated one-time payment based on the number of months participated and incentive received. In the event of a sale, customer may choose to unenroll or new owner may assume the agreement with GMP in writing.

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Green Mountain Power's Bring Your Own Device Energy Storage Program (2/2)

Incentives

- **Incentive Lock**: No, both incentives are paid one-time and upfront to customers
- **Battery Back Up Only Incentives:** Customer batteries enrolled for 10 years and receive an upfront payment of $850/kW of storage enrolled for three hour discharge up to 10kW or $950 per kW for four hour discharge up to 10kW. If retrofitting an existing solar system, customers receive an extra $100/kW up to 10kW
- **Battery Self-Consumption Incentives:** Customer required to self-supply from the Equipment for the duration of each Peak events, Customer receives one-time upfront $850 incentive payment. If retrofitting an existing solar system, customers receive extra $100

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Liberty Utilities (NH) Battery Storage Pilot Program

Overview

Monthly discounted battery lease cost to participants with free installation. Liberty Utilities pre -programs its batteries to discharge at certain times. Customers are eligible for net metering. Phase One will be limited to 200 Tesla Powerwall 2s (100 customers). Once Phase One is proven successful, the pilot will move to Phase Two, where Liberty will install up to an additional 300 batteries (150 customers).

Characteristics

- **Administrator** : Liberty Utilities
- **Deployment target:** Phase I - 100 customers; Phase II – 150 additional customers
- **Demand reduction approach:** Time-of-use
- **Requirements:** Customers must agree to time of use rates and install two batteries for grid peak management

Financing Model

- **Financing Lock**: Yes, discount on battery system financing is locked for ten years
- **Customers payment model** : Participate by paying $25 per battery per month ($50 total), for ten years. Additionally, customers may pay $4,866 upfront rather than pay over a period of ten years. The installation, service and maintenance will be provided at no additional cost to customers

Liberty

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Arizona Public Service Residential Battery Pilot (1/2)

Overview

The residential battery pilot is designed to allow Arizona Public Service (APS) to study the performance of a battery system when charged by the grid in the off -peak periods and used by the customer to reduce energy use and demand during on -peak hours when energy prices are higher. The pilot pays incentives for participating in either the Data Only or Data and Battery Management options. Customers may withdraw from the Residential Battery Pilot for any reason, at any time.

Characteristics

- **Administrator** : Arizona Public Service
- **Deployment target:** Arizona Public Service – 3,000 MW of energy storage by 2030
- **Demand reduction approach:** Time-of-use, Direct load control
- **Requirements:** Only new battery systems connected to APS grid for the first time and provided by a participating battery partner are eligible. Customers must be enrolled in time -of-use (TOU) service plan or a grandfathered service plan with a solar rate rider
- **Unenrollment terms:** Customers may withdraw for any reason at any time by contacting EnergyHub . Those that withdraw will not receive the program incentive and cannot participate in the Pilot in the future.

aps

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Arizona Public Service Residential Battery Pilot (2/2)

Incentives

- **Incentive Lock**: No, both incentives are paid one -time and upfront to customers when their battery systems are approved by APS for interconnection and receive Permission to Operate
- **Program Incentive Option 1**: Customers who choose the Data Only option agree to share their battery system performance data with APS and are eligible for an incentive of $500 /kW of battery capacity with a maximum incentive of $2,500 per home
- **Program Incentive Option 2**: Data and Battery Management: With the Data and Battery Management option, the customer agrees to give APS access to data associated with the battery system and share up to 80% of the battery system's capacity for a maximum of100 events a year. The customer is eligible for an incentive of $500 /kW (up to $2,500 per home) for installed battery capacity plus an additional $1,250, with a maximum incentive of $3,750 per home

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aps

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D. Storage Economics – Cost & Incentive Assumptions

The table below shows upfront cost assumptions for 2019 and 2023, which did not vary by income category. Total costs assumed for both standard and low-income customers were $12,021.25 and $16,728.14 for 2019 and 2023, respectively.

D-1. Upfront Cost Inputs – 2019 and 2023

	2019	2023
Residential Installed Cost /kWh	961.70	1,338.25
Energy Storage (kWh)	12.50	12.50

Source: Installed costs are from Guidehouse Insights report "Global Energy Storage Pricing Trends" published 2Q 2023

The table below shows upfront incentives' assumptions for 2019 and 2023, which did not vary by income category. Total upfront incentives were $3,606.38 and $5,018.44, respectively for 2019 and 2023.

D-2. Upfront Incentives Inputs– 2019 and 2023

	2019	2023
Investment Tax Credit (ITC) – 30%	0.30	0.30

Tables D-3 below shows assumptions related to annual incentives from Connected Solutions and SMART. D-4 contains the resulting total annual incentives assumed in 2019 and 2023.

D-3. Annual Incentives Inputs – 2019 and 2023

	2019	2023
Connected Solutions Incentive / kW (June – September)	$225.00	$275.00
Connected Solutions Incentive / kW (December - March)	$50.00	N/A
Eversource (East, West) MA SMART Incentive Incremental ES Value, (Block 2,4) /kWh	$0.05	N/A
National Grid MA SMART Incentive Incremental ES Value, (Block 3) /kWh	$0.05	N/A
Eversource MA SMART Incremental ES Value, (Block 9) /kWh	N/A	$0.04
National Grid MA SMART Incremental ES Value, (Block 10) /kWh	N/A	$0.02
Battery Performance Factor (%)	0.90	0.90
Solar PV	8.00	8.00
Annual PV Capacity Factor	0.15	0.15
Annual PV Production (hours/year)	8,760.00	8,760.00

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D-4. Total Annual Incentives – 2019 and 2023

	2019	2023
Connected Solutions Incentive	$1,237.50	$1,237.50
Eversource (East, West) MA SMART Annual Incentive Total (Block 2,4)	$523.78	N/A
National Grid MA SMART Annual Incentive Total (Block 3)	$523.78	N/A
Eversource MA SMART Annual Incentive Total (Block 9)	N/A	$377.53
National Grid MA SMART Annual Incentive Total (Block 10)	N/A	$184.62

Tables D-5 below shows inputs by PA to annual operating costs, which represent the customer bill impact of round-trip efficiency losses (given no TOU rate).[14] D-6 and D-7 contain the resulting total annual operating costs for 2019 and 2023, respectively, broken out by income category.

D-5. Annual Operating Cost Inputs – 2019 and 2023

	2019	2023
National Grid (R-1) /kWh	0.24	0.37
National Grid (R-2) /kWh	0.24	0.37
National Grid (R-2) Discount (%)	0.32	0.32
Eversource (A1) /kWh	0.23	0.30
Eversource (A2) /kWh	0.23	0.30
Eversource (A2) Discount (%)	0.42	0.42
ES cycles during Summer program period (June - September)	40.00	40.00
ES cycles during Winter program period (December - March)	15.00	15.00

Source: Rate information is from EIA 861

[14] Does not capture other operating costs (e.g., maintenance).

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D-6. Total Operating Costs – 2019

Operating Costs – Standard Income		Operating Costs – Low Income	
Annual Efficiency Loss – Eversource (A1)	$15.49	Annual Efficiency Loss - Eversource (A2)	$8.98
Annual Efficiency Loss - National Grid (R-1)	$16.39	Annual Efficiency Loss - National Grid (R-2)	$11.14

D-7. Total Operating Costs – 2023

Operating Costs – Standard Income		Operating Costs – Low Income	
Annual Efficiency Loss – Eversource (A1)	$20.53	Annual Efficiency Loss - Eversource (A2)	$11.90
Annual Efficiency Loss - National Grid (R-1)	$25.43	Annual Efficiency Loss - National Grid (R-2)	$17.29

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E. Non-Event Day Load Shapes

Table E-1 summarizes the average power charged or discharged by all devices averaged across all non-event days in the season, in 15-minute intervals. 45% of devices charged and/or discharged 25% or greater of their nameplate capacity on average across non-event days, excluding the days directly following event days. Table E-1 indicates consistent non-event day behavior by a significant subset of devices, with approximately a quarter of devices charging and/or discharging greater than 50% of their nameplate capacity on average, and supports the calculation and consideration of a Blended Baseline.

Table E-1: Average Non-Event Day Charge and Discharge as a Share of Capacity

Metric	Less than 25%	More than 25%	More than 50%	More than 75%
Proportion of customers with average daily charging as a share of capacity	55%	45%	27%	13%
Proportion of customers with average daily discharging as a share of capacity	55%	45%	25%	10%

Source: Guidehouse analysis of DERMS vendor data.

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F. Impact Analysis – Supplemental Results

Table F-1 shows the average, per device, event impact by event date and PA for all 29 event dates in the summer season calculated using the blended baseline. All events reduced demand (had a negative event impact) across all PAs, with the largest average event impact occurring on Monday, August 21, 2023 within Eversource's service territory.

Table F-1. Average Event Impact (kW) per Device by Date with the Blended Baseline

No.	Event Date	Cape Light Compact	Eversource	National Grid
1	Friday, June 23, 2023	-5.80	-6.92	-5.52
2	Monday, July 3, 2023	-3.52	-3.61	-3.21
3	Wednesday, July 5, 2023	-4.10	-4.82	-3.96
4	Thursday, July 6, 2023	-5.90	-6.75	-5.67
5	Friday, July 7, 2023	-4.10	-4.69	-3.93
6	Saturday, July 8, 2023	-3.85	-4.32	-3.62
7	Tuesday, July 11, 2023	-3.95	-4.30	-3.87
8	Wednesday, July 12, 2023	-3.86	-4.44	-3.86
9	Thursday, July 13, 2023	-3.79	-4.37	-3.83
10	Friday, July 14, 2023	-2.18	-3.26	-2.43
11	Saturday, July 15, 2023	-5.26	-6.40	-5.44
12	Monday, July 17, 2023	-5.64	-6.26	-5.59
13	Tuesday, July 18, 2023	-5.23	-6.20	-5.49
14	Wednesday, July 19, 2023	-5.31	-6.45	-5.60
15	Thursday, July 20, 2023	-5.52	-4.26	-5.62
16	Monday, July 24, 2023	-3.74	-4.62	-3.36
17	Tuesday, July 25, 2023	-5.44	-4.94	-4.50
18	Wednesday, July 26, 2023	-5.35	-6.49	-4.76
19	Thursday, July 27, 2023	-3.60	-2.87	-2.82
20	Friday, July 28, 2023	-5.33	-6.41	-5.28
21	Saturday, July 29, 2023	-5.14	-5.41	-4.15
22	Tuesday, August 8, 2023	-1.11	-5.26	-2.93
23	Wednesday, August 9, 2023	-5.98	-7.36	-5.37
24	Thursday, August 10, 2023	-5.78	-6.33	-5.36
25	Monday, August 14, 2023	-5.89	-7.29	-5.63
26	Monday, August 21, 2023	-6.07	-7.52	-5.78
27	Wednesday, August 30, 2023	-5.69	-4.18	-2.16
28	Wednesday, September 6, 2023	-6.34	-7.39	-4.56
29	Thursday, September 7, 2023	-4.27	-4.82	-3.49

Source: Guidehouse analysis of DERMS vendor data.

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Table F-2 shows the average, per device, event impact by event date and PA for all 29 event dates in the summer season, calculated with the Assumed No Battery baseline. Again, all events had a negative energy impact across all PAs, with the largest average energy impact occurring on Monday, August 21, 2023 within Eversource's service territory.

Table F-2. Average Event Impact (kW) per Device by Date Assuming a No-Battery-Baseline

No.	Event Date	Cape Light Compact	Eversource	National Grid
1	Friday, June 23, 2023	-5.84	-7.12	-5.64
2	Monday, July 3, 2023	-3.80	-3.93	-3.38
3	Wednesday, July 5, 2023	-4.39	-5.14	-4.13
4	Thursday, July 6, 2023	-6.16	-7.01	-5.80
5	Friday, July 7, 2023	-4.39	-5.01	-4.09
6	Saturday, July 8, 2023	-4.24	-4.76	-3.92
7	Tuesday, July 11, 2023	-4.24	-4.63	-4.03
8	Wednesday, July 12, 2023	-4.15	-4.76	-4.01
9	Thursday, July 13, 2023	-4.08	-4.68	-3.98
10	Friday, July 14, 2023	-2.39	-3.45	-2.52
11	Saturday, July 15, 2023	-5.61	-6.76	-5.70
12	Monday, July 17, 2023	-5.91	-6.52	-5.71
13	Tuesday, July 18, 2023	-5.50	-6.45	-5.61
14	Wednesday, July 19, 2023	-5.58	-6.64	-5.72
15	Thursday, July 20, 2023	-5.79	-4.53	-5.74
16	Monday, July 24, 2023	-4.03	-4.88	-3.54
17	Tuesday, July 25, 2023	-5.71	-5.14	-4.62
18	Wednesday, July 26, 2023	-5.61	-6.67	-4.88
19	Thursday, July 27, 2023	-3.82	-3.01	-2.91
20	Friday, July 28, 2023	-5.59	-6.59	-5.40
21	Saturday, July 29, 2023	-5.43	-5.77	-4.41
22	Tuesday, August 8, 2023	-1.39	-5.68	-3.23
23	Wednesday, August 9, 2023	-6.28	-7.67	-5.59
24	Thursday, August 10, 2023	-6.05	-6.62	-5.63
25	Monday, August 14, 2023	-6.17	-7.68	-5.94
26	Monday, August 21, 2023	-6.24	-7.82	-6.02
27	Wednesday, August 30, 2023	-6.07	-4.39	-2.33
28	Wednesday, September 6, 2023	-6.31	-7.74	-4.77
29	Thursday, September 7, 2023	-4.40	-5.13	-3.73

Source: Guidehouse analysis of DERMS vendor data

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Table F-3 shows the average, per device, event impact by event date and PA for all 29 event dates in the summer season, calculated with the Assumed With Battery baseline. Again, all events had a negative energy impact across all PAs, with the largest average energy impact occurring on Monday, August 21, 2023 within Eversource's service territory.

Table F-3. Average Event Impact (kW) per Device by Date Assuming a With-Battery-Baseline

No.	Event Date	Cape Light Compact	Eversource	National Grid
1	Friday, June 23, 2023	-5.78	-6.81	-5.45
2	Monday, July 3, 2023	-3.36	-3.43	-3.12
3	Wednesday, July 5, 2023	-3.94	-4.64	-3.87
4	Thursday, July 6, 2023	-5.75	-6.60	-5.59
5	Friday, July 7, 2023	-3.94	-4.51	-3.84
6	Saturday, July 8, 2023	-3.63	-4.08	-3.45
7	Tuesday, July 11, 2023	-3.79	-4.12	-3.78
8	Wednesday, July 12, 2023	-3.70	-4.26	-3.77
9	Thursday, July 13, 2023	-3.63	-4.19	-3.75
10	Friday, July 14, 2023	-2.06	-3.16	-2.38
11	Saturday, July 15, 2023	-5.07	-6.20	-5.30
12	Monday, July 17, 2023	-5.49	-6.12	-5.53
13	Tuesday, July 18, 2023	-5.08	-6.06	-5.42
14	Wednesday, July 19, 2023	-5.16	-6.35	-5.53
15	Thursday, July 20, 2023	-5.37	-4.11	-5.56
16	Monday, July 24, 2023	-3.57	-4.47	-3.26
17	Tuesday, July 25, 2023	-5.29	-4.82	-4.44
18	Wednesday, July 26, 2023	-5.20	-6.39	-4.69
19	Thursday, July 27, 2023	-3.48	-2.79	-2.77
20	Friday, July 28, 2023	-5.18	-6.31	-5.21
21	Saturday, July 29, 2023	-4.98	-5.20	-4.01
22	Tuesday, August 8, 2023	-0.95	-5.03	-2.76
23	Wednesday, August 9, 2023	-5.81	-7.19	-5.24
24	Thursday, August 10, 2023	-5.63	-6.16	-5.21
25	Monday, August 14, 2023	-5.74	-7.07	-5.46
26	Monday, August 21, 2023	-5.97	-7.35	-5.65
27	Wednesday, August 30, 2023	-5.47	-4.06	-2.07
28	Wednesday, September 6, 2023	-6.36	-7.20	-4.44
29	Thursday, September 7, 2023	-4.19	-4.64	-3.36

Source: Guidehouse analysis of DERMS vendor data

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