2021 Power Manager Evaluation Report

Submitted to Duke Energy Carolinas

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1 Executive Summary

This report presents the results and key findings of Resource Innovations' impact and process evaluations of the 2021 Power Manager program in the Duke Energy Carolinas service territory for the event season spanning May 1, 2021, through September 2021, referenced throughout the report as the Summer 2021 program.

1.1 Background

Power Manager is a voluntary demand response program that offers incentives to residential customers who allow Duke Energy to reduce the use of their central air conditioner's outdoor compressor and fan during summer days with high energy usage. Through the program, events may be called to help lessen electricity use during times of high demand. Demand response events are called by Duke Energy on hot summer days between May and September and are designed to reduce loads during times with the greatest system-wide energy demands. Participating customers are provided incentives in the form of monthly utility bill credits. During normal shed events, a remote signal is sent to participating load control devices that reduce customers' air conditioner use. During emergency shed operations, all devices are initiated to quickly shed loads and deliver larger demand reductions.

Beginning in late 2019, Duke Energy introduced a new Power Manager offering to DEC customers that enables them to participate in demand response events through their home's qualifying smart thermostat. By enrolling their thermostats in the Smart Thermostat option (also referred to as Bring-Your-Own-Thermostat (BYOT)), customers agree to let Duke Energy make brief, small adjustments to their thermostat during times of peak electric demand. Participating customers are notified prior to events and provided incentives in the form of pre-paid gift cards. Events called under the BYOT option may vary by duration of the event period, the degree setpoint adjustment implemented during the event period, as well as the duration setpoint adjustment and duration of the pre-cooling period. During the pre-cooling period, the setpoints of participating thermostats are automatically adjusted downward to lower the interior temperature of the home during the period immediately prior to the event in order to help maintain comfort levels during the event period.

1.2 Impact Evaluation Key Findings

The impact analyses – for both the traditional DLC offering and the new BYOT offering – were performed using a randomized control trial (RCT) approach. Prior to the event season, Power Manager program participants within each branch were randomly assigned to one of three groups. During each event, at least one group was withheld as the control group in order to provide an estimated load profile absent curtailment, i.e., the baseline. The average loads among control group customers are used to compare against the average event day loads of the treatment group to calculate the event impacts.

1.2.1 Direct Load Control Analysis Key Findings

Key findings of the Summer 2021 DLC impact analysis include:

- Average demand reductions across all events were 0.76 kW per household
- Emergency shed events produced greater load impacts compared to normal shed events
- The magnitude of demand impacts are larger when temperatures are higher

The table below presents summary results of the 2021 program year.

Table 1-1: Summary of 2021 DLC Event Impacts

Event Date	Start Time	End Time	Event Type	Load w/o DR	Load w/ DR	Impact	% Impact	System Temperature
6/30/2021	5:30 PM	5:58 PM	Full shed	3.28	2.38	0.90	27.5%	86°F
7/16/2021	4:00 PM	4:28 PM	Full shed	3.26	2.19	1.06	32.7%	89°F
7/28/2021	3:55 PM	5:00 PM	64%	3.38	2.68	0.70	20.7%	92°F
8/11/2021	4:00 PM	4:28 PM	Full shed	3.36	2.35	1.01	30.2%	89°F
8/11/2021	4:00 PM	4:28 PM	64%	3.36	2.91	0.45	13.4%	89°F
8/12/2021	4:00 PM	4:28 PM	Full shed	3.42	2.40	1.02	29.8%	91°F
8/13/2021	3:55 PM	5:00 PM	64%	3.57	2.89	0.68	19.0%	94°F
8/23/2021	4:00 PM	4:28 PM	Full shed	3.23	2.27	0.97	29.9%	91°F
8/27/2021	3:55 PM	5:00 PM	50%	3.32	2.74	0.58	17.5%	90°F
8/30/2021	2:55 PM	5:00 PM	64%	3.36	2.68	0.68	20.4%	92°F
8/30/2021	3:55 PM	6:00 PM	64%	3.48	2.81	0.67	19.2%	91°F
9/13/2021	3:55 PM	5:00 PM	50%	2.76	2.37	0.39	14.2%	87°F
Average Full Shed Event				**3.31**	**2.31**	**1.00**	**30.0%**	**89.2°F**
Average 64% Cycling Event				**3.43**	**2.79**	**0.64**	**18.5%**	**91.6°F**
Average 50% Cycling Event				**3.04**	**2.55**	**0.49**	**15.9%**	**88.5°F**
Average Event				**3.31**	**2.56**	**0.76**	**22.8%**	**90.1°F**

1.2.2 Bring-Your-Own-Thermostat Analysis Key Findings

Key findings of the Summer 2021 BYOT impact analysis include:

- The average load reduction across all BYOT events in 2021 was 1.32 kW
- The magnitude of baseline loads and load impacts tend to increase with temperature
- There does not appear to be any significant difference in program performance due to pre-cooling and event period offset conditions

Table 1-2: Summary of 2021 BYOT Event Impacts

Date	Start Time	End Time	Pre-Cool	Offset	Load w/o DR	Load w/ DR	Impact	% Impact	Temperature
7/1/2021	3:00 PM	5:00 PM	60 min 1°F	3°F	2.95	1.78	1.17	39.5%	88°F
7/30/2021	3:55 PM	5:00 PM	None	3°F	3.34	2.04	1.30	38.8%	91°F
8/11/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.29	1.86	1.43	43.6%	89°F
8/12/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.33	1.94	1.39	41.7%	91°F
8/13/2021	3:55 PM	5:00 PM	60 min 1°F	3°F	3.48	2.14	1.34	38.4%	94°F
8/23/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.10	1.84	1.25	40.5%	91°F
8/24/2021	4:55 PM	6:00 PM	90 min 2°F	4°F	3.54	2.20	1.35	38.0%	93°F
8/30/2021	3:55 PM	5:00 PM	90 min 2°F	3°F	3.33	2.01	1.32	39.7%	92°F
Average BYOT Event					**3.30**	**1.98**	**1.32**	**40.0%**	**91.1°F**

1.3 Demand Reduction Capability

A key objective of the impact evaluation is to quantify the relationship between demand reductions, temperature, hour-of-day, and event settings. This objective is achieved by estimating loads under historical weather conditions and applying observed percent load reductions from the Summer 2021 events. The resulting tool, referred to as the time-temperature matrix, allows users to predict the program's load reduction capability under a wide range of temperature and event conditions.

1.3.1 Direct Load Control Demand Reduction Capability Key Findings

Key findings discovered during the development of the Time-Temperature Matrix include:

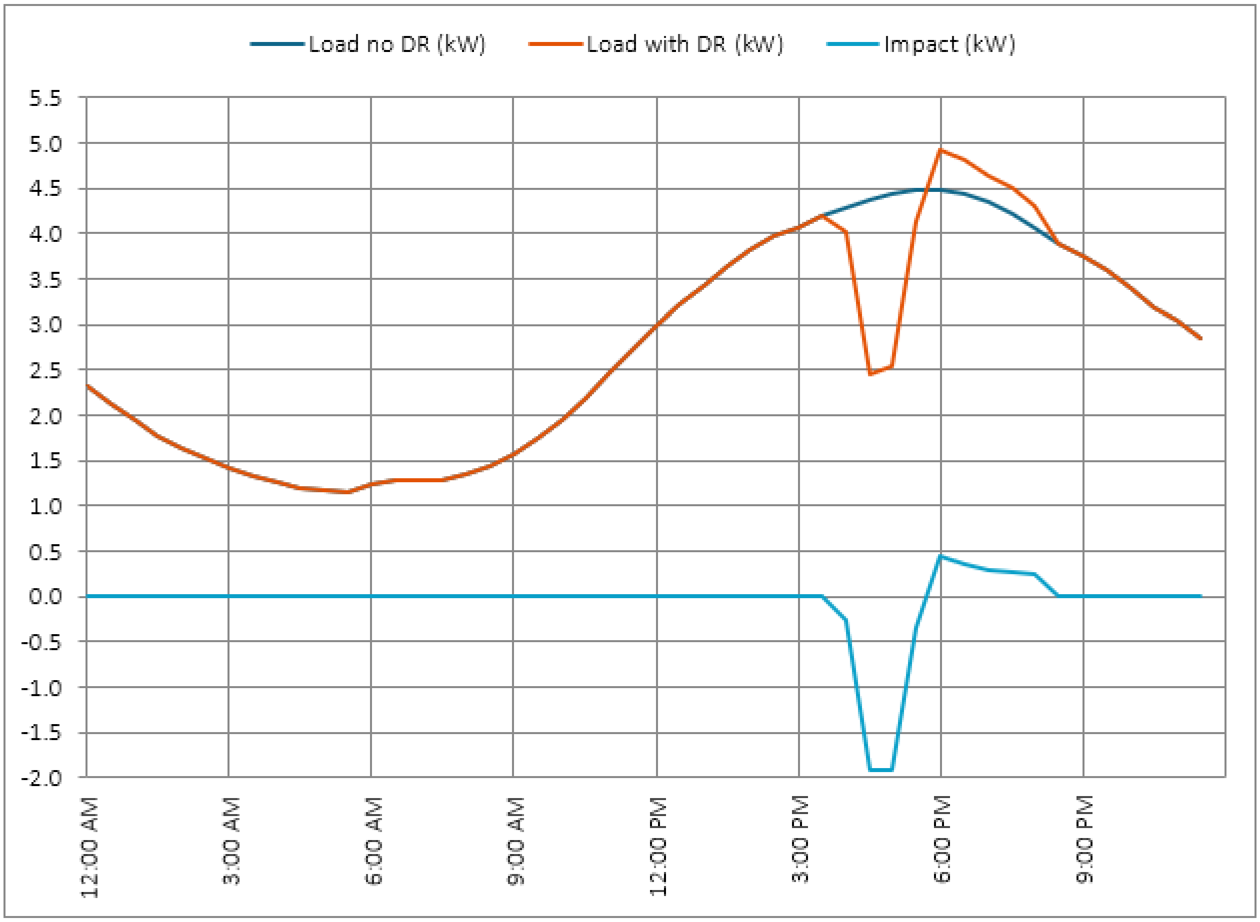
- Impacts increase later in the day and as the temperature goes up
- Estimating reference loads and load impacts under extreme, hypothetical conditions is routinely difficult because such conditions have not occurred since 2012.

- The Time-Temperature Matrix predicted that for a 1-hour event called at 4:00pm under 100° conditions the average impacts would be 1.92 kW per customer, or 431 MW of aggregate impacts across the region

Figure 1-1: Load Reduction Capability for Extreme DLC Event

Inputs	
Dispatch Type	Emergency Dispatch
Event Start Time	4 PM
Event Duration	1
Event Period Max Temp	100
# Customers	239,700

Event Window Average Impacts		
Load without DR	4.41	kW per customer
Load with DR	2.49	kW per customer
Impact per Customer	-1.92	kW per customer
Program Impact	-459.1	MW
% Impact	-43.4	%



1.3.2 BYOT Demand Reduction Capability Key Findings

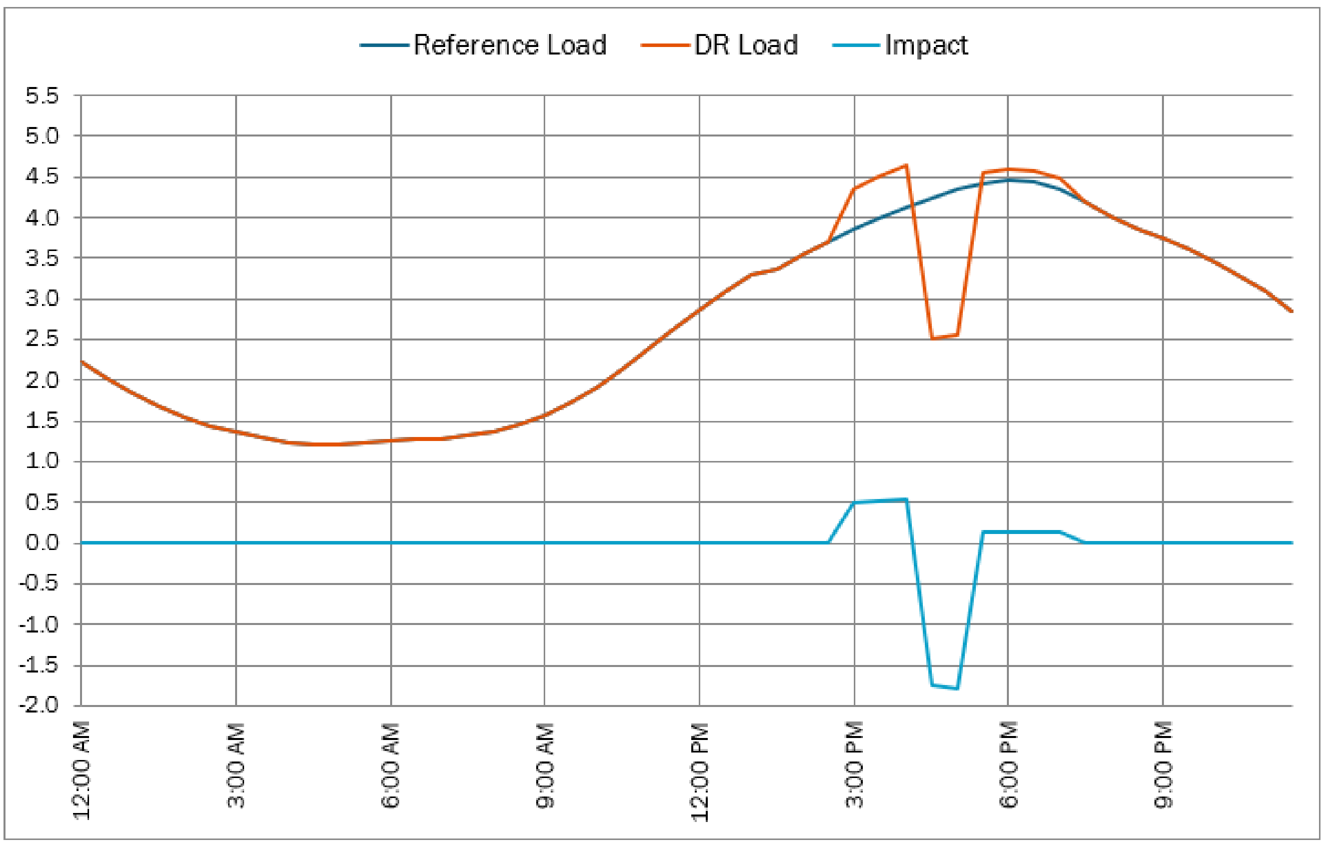
Key findings of the BYOT Time-Temperature Matrix tool include:

- Per household impacts grow larger as the event period temperature offset increases
- The duration and degree of the pre-cooling did not significantly affect event impacts
- Estimating load impacts for extreme, hypothetical conditions is difficult due to the lack of observed data and because such conditions have not occurred since 2012
- The Time-Temperature Matrix predicted that for a 1-hour event called at 4:00pm under 100° conditions, with a 90-minute 2°F pre-cool and a 4°F event offset, the average impacts would be 1.76 kW per household.

Figure 1-2: Load Reduction Capability for Extreme BYOT Event

INPUTS	
Event Start Time	4 PM ▼
Event Duration	1 ▼
Event Option	90 min 2 deg precool / 4 deg offset ▼
Event Temperature	100 ▼
# Customers	33,900

OUTPUTS		
Reference Load	4.29	kW
Curtailed Load	2.53	kW
Impact per Customer	-1.76	kW
Program Impact	-59.7	MW
% Impact	-41.0	%



1.4 Process Evaluation Key Findings

The process evaluation is designed to inform efforts to continuously improve the program by identifying strengths and weaknesses, opportunities to improve program operations, adjustments likely to increase overall effectiveness, and sources of satisfaction or dissatisfaction among participating customers. The process evaluation consisted of telephone interviews with key program managers and implementers, a post-event survey of participants implemented after an event, and a nonevent survey of participants implemented on a nonevent day with similar temperature profile to an event day.

Key findings from the process evaluation include:

- Participants of Duke Energy Carolinas Power Manager program for both DLC and BYOT technologies do not experience a statistically significant increases in thermal discomfort during events, as evidenced by similar responses across post-event and nonevent surveys.
- Power Manager is a well-received program, with most participants willing to stay in the program, recommend it to others and reporting the program is easy to enroll in.
- Program areas with the lowest participant satisfaction include communications from Duke Energy, and incentive amounts (bill credits for DLC and e-gift cards for BYOT). Participants most frequently suggested increase in transparency and communication from Duke Energy and increased program incentives.
- Duke Energy leads and manages three partner vendors to operate and maintain the DLC option of Power Manager as a reliable resource for the Carolinas electric system.
- In-depth interviews reveal two areas of process improvement for the DLC option. First, that EM&V programming each year should be kept as simple and should reflect as few changes as possible from the prior year to mitigate risks of programming errors. Second, Duke Energy should resume normal QA inspections as soon as possible following the completion of the enrollment database reconciliation.
- In-depth interviews with BYOT option stakeholders show that Duke Energy's implementer EnergyHub delivers value by managing the BYOT implementation, which relieves Duke Energy program staff of much of the effort that is expended in managing the DLC option.
- The typical BYOT option participant is in a higher-than-average income bracket. EnergyHub recommends that the Duke Energy Online Savings Store would be an effective way to get smart thermostats into lower income households and enrolled in Power Manager through discounts and promotional messaging.

1.5 Recommendations

The 2021 Summer season Power Manager evaluation provided insights into program performance from both a load impact and a customer experience perspective for the DLC and BYOT program offerings. The following recommendations have been developed based on the key findings from the evaluation.

- Continue to promote both the DLC and BYOT Power Manager program options to DEC residential customers who exhibit high peak load consumption. Customers with higher-than-average peak loads remain the best candidates for program participation and have the greatest potential to contribute to demand savings.
- Revisit the time-temperature matrix requirements and consider developing a model of program capabilities across a relatively modest band of temperatures, reflecting the current dispatch strategy. For example, reporting estimated impacts under a range of temperatures regularly observed during most event seasons for a 1-hour event starting at 4:00PM.
- For planning purposes, apply more extreme event offsets for BYOT curtailment strategies to generate greater load impacts during events.
- Continue to prioritize participant comfort and satisfaction during BYOT and DLC events. Overall, customers experiencing BYOT and DLC events do not report feeling uncomfortable during Power Manager events any more than they do on comparable non-event days.
- Increase engagement and communication with Power Manager participants through notifications on the program website and emails to participants that request them.
- Return to AMI data analysis-based QA inspections as soon as possible; consider increasing the number of inspections scheduled given the 2021 hiatus.
- Continue to prioritize inter-organizational communications with Spring Trainings, weekly and monthly calls, and other existing approaches.
- Test locational dispatch capabilities in 2022 or 2023 once the final upgrades to the Yukon system Assets module are complete.
- Drive enrollment of households from income brackets lower than that of the current typical BYOT customer by continuing to offer discounted BYOT-eligible thermostats on the Duke Energy-sponsored online storefront.

2 Introduction

This report presents the results the Summer 2021 Power Manager program impact and process evaluations for the Duke Energy Carolinas (DEC) jurisdiction. Power Manager is a voluntary demand response program that provides incentives to residential customers who allow Duke Energy to reduce their electricity usage on summer or winter days with high energy usage. In 2021, the DEC Power Manager program includes two offerings: traditional direct load control (DLC) and a new option for homes with qualifying smart thermostats. Customers participating in the DLC option agree to allow Duke Energy to remotely cycle their air conditioner's outdoor compressor on and off during periods of peak load demand. Participants in the thermostat option – referred to as the Bring Your Own Thermostat or "BYOT" option – allow Duke Energy to remotely adjust their thermostat setpoints during and prior to events in order to reduce household cooling or heating loads. Events called under the DLC and BYOT options are separate and distinct from one another; however, they may be called at the same time.

Because Duke Energy has full deployment of smart meters in DEC territory and has access to Power Manager customers' interval meter data, the impact evaluation is predominantly based on a randomized control trial involving the random assignment of customers into three different groups each for the DLC and BYOT options prior to the 2021 event season. During each event, at least one of the groups is withheld to serve as a control group and to provide an estimate of customer's load usage profiles absent a Power Manager event. The randomized control trial approach was applied to all Power Manager operations where a valid control group was available, as well as to test events designed to address a set of specific research questions. The RCT approach is consistent across both program offerings (DLC and BYOT).

In addition to estimating load impacts during 2021 events, this study enables the estimation of the program's demand reduction capability under a range of weather and dispatch conditions. Average customer load reductions, as well as aggregate system capacity, is estimated as a function of event type, event start time, event duration, and event temperature. Program-level load reduction capability is estimated similarly, but independently, for each program offering (DLC and BYOT).

The process evaluation uses survey data from both treatment and control customers, as assigned for impact analysis, gathered during a non-emergency event and similar nonevent day for control customers. As in the impact analysis, responses from control group customers served as a baseline from which treatment effects on the customer experience may be measured. In addition, the evaluation uses interview data and analyses of program documentation and the program database to offer analytic context for evaluating survey results, as well as to offer insight into program operations.

2.1 Key Research Questions

The data collection and analysis activities are designed to address the following research questions and objectives.

2.1.1 Impact Evaluation Research Questions

- What demand reductions were achieved during each event called in 2021?
- Do impacts vary based on the hours of dispatch?
- Do impacts vary based on temperature conditions?
- For the DLC option, do impacts differ for full shed events compared to normal cycling events?
- For the BYOT option, do event conditions, such as pre-cooling duration, pre-cooling offset, event period offset, result in different impacts?
- What is the magnitude of the program's aggregate load reduction capability during extreme conditions?

2.1.2 Process Evaluation Research Questions

- What is the extent to which participants are aware of events, program incentives, and other key program features?
- What is the participant experience during events, particularly relating to thermal comfort?
- What actions do participants take in response to events?
- What are the motivations and potential barriers for participation?
- What are the processes associated with operations and program delivery?
- What are the program's strengths and areas for potential improvement?

2.2 Program Description

Power Manager is a voluntary demand response program that provides incentives to residential customers who allow Duke Energy to reduce their cooling and/or heating energy use on days with high energy usage.

All Power Manager DLC participants have a load control device installed on the outdoor unit of their qualifying air conditioner. If customers have more than one air conditioner, all units must be equipped with a load control device. The device enables the customer's air conditioner compressor to be cycled off and on to reduce load when a Power Manager event is called or turned off completely in the case of a grid emergency. Duke Energy initiates DLC events by sending a signal to participating devices through the Duke Energy paging network, which instructs the DLC devices to reduce air conditioner runtime during events.

All customers participating in the BYOT option must have a qualifying smart thermostat installed in their home. Duke Energy initiates summer BYOT events by remotely adjusting participating thermostats upward, thereby reducing the cooling load required. To help maintain comfort levels during the event period, BYOT events may also involve a pre-cooling period, when thermostats are remotely adjusted downward during the period immediately preceding the event, lowering the interior temperature of the home before the event begins.

Power Manager events typically occur from June through September in DEC territory but are not limited to these months. DLC participants receive financial incentives for their participation in the form of $8 credits applied to their July through October electric bills ($32 in annual credits). BYOT participants receive financial incentives for their participation in the form of pre-paid gift cards.

In DEC territory, Duke Energy uses a cycling algorithm known as TrueCycle to reduce DLC customers' system runtimes during events. The algorithm uses stored data on the air conditioner's runtime to calculate the off and on cycle times to achieve a specific percentage of reduced runtime during each event. In general, DLC events fall into two categories: regular shed events, during which customers are cycled at 64% or the less frequently used 50%, and emergency full-shed events, during which customers are shed at 100%. For purposes of regulatory reporting, emergency full-shed is used to estimate program capability.

During BYOT events, Duke Energy may remotely adjust customers' home thermostats by up to 4°F for up to four hours. Event pre-cooling ranges from 0°F to 2°F for up to 90 minutes. Duke Energy may apply different combinations of pre-cooling and event period offsets that may result in varying changes in load demanded during each phase of the event. For purposes of regulatory reporting, a 90-minute pre-cool of 2°F, followed by a 4°F offset for one hour is used to estimate program capability.

2.3 Participant Characteristics

Duke Energy serves approximately 2.25 million residential customers in its DEC service territory, which spans a large portion of the western half of North Carolina and northwestern South Carolina. During the 2021 summer season, approximately 239,700 customers were enrolled in the DLC option of Power Manager and approximately 33,900 customers were enrolled in the BYOT option. Figure 2-1 and Figure 2-2 show the program enrollment growth by number of households and number of devices installed for the DLC and BYOT programs, respectively. In 2021, the number of devices per household are approximately 1.2 devices per household for DLC and approximately 1.3 thermostats per household for BYOT.

Figure 2-1: DLC Participation Growth (2010-2021)

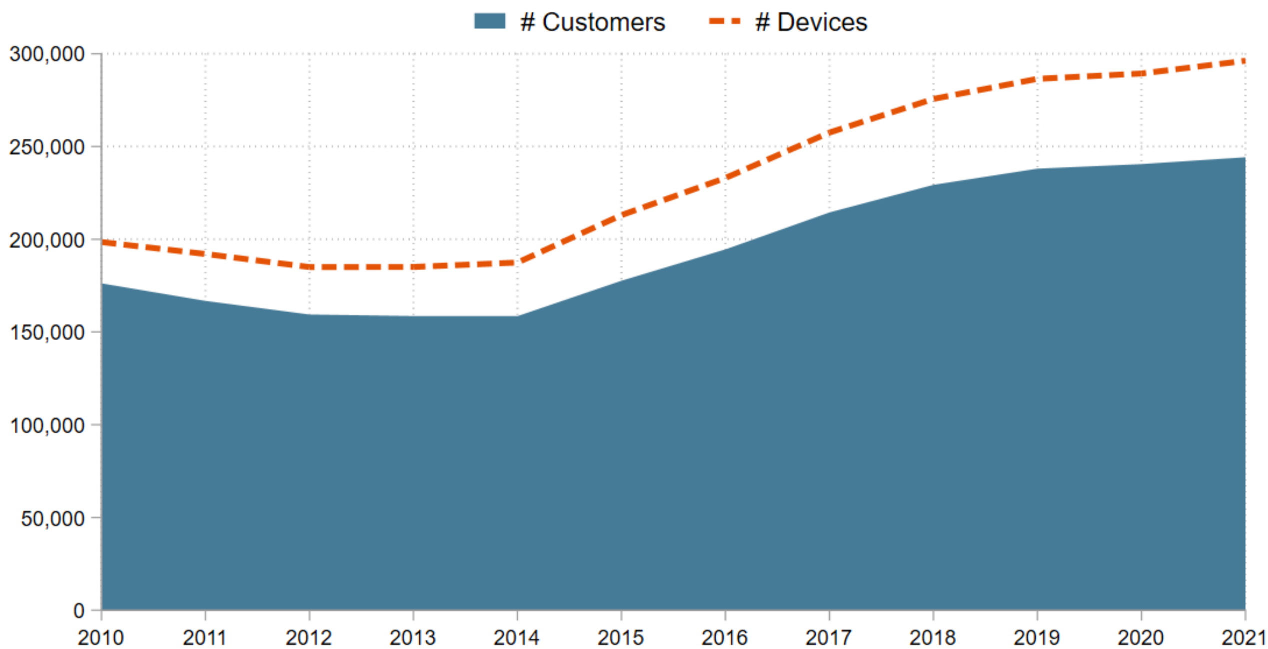
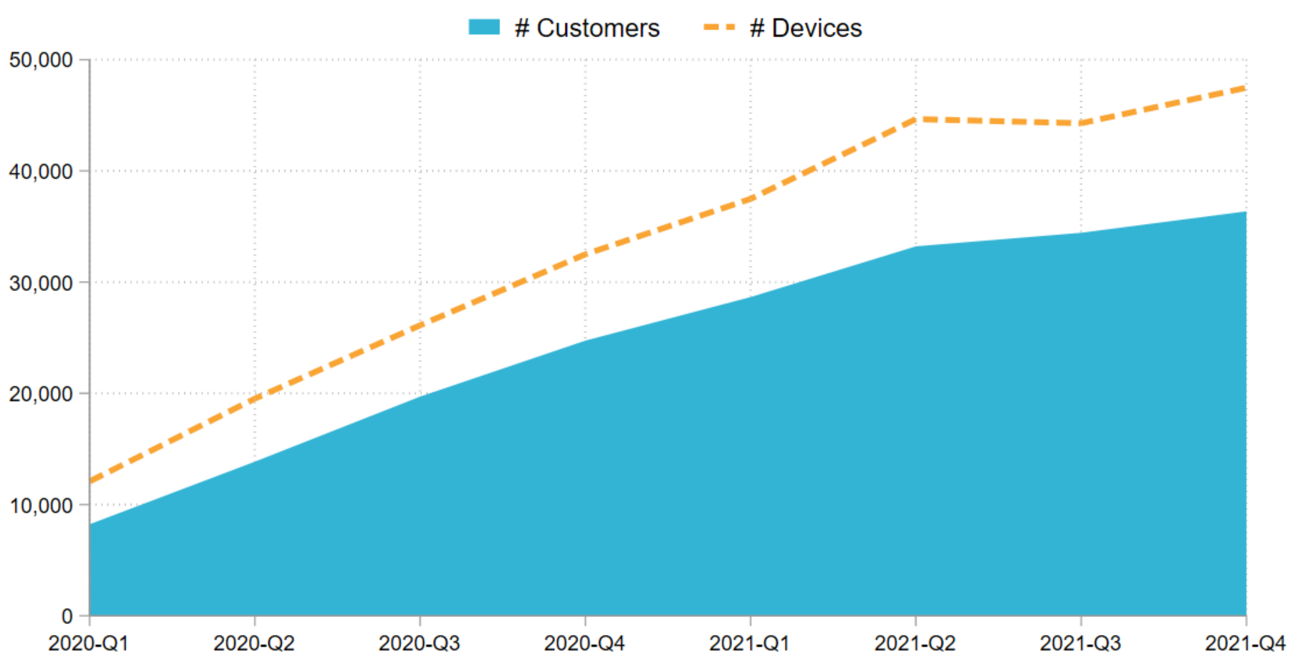


Figure 2-2: BYOT Thermostat Installations (2020-2021)



2.4 Event Characteristics

2.4.1 Direct Load Control Events

Duke Energy dispatched DLC Power Manager events 12 times in 2021. All events occurred between the hours of 3:00 PM and 6:00 PM and were between 30 minutes and 2 hours in duration. Emergency full shed events were dispatched five times, each lasting 28 minutes in duration. Regular shed events made up the remaining 7 dispatches, where 64% cycling was called five times and 50% cycling was called twice. System temperatures observed during events ranged from 86°F to 94°F, with an average event period temperature of 90°F.

The table below summarizes 2021 DLC event conditions.

Table 2-1: Summary of 2021 DLC Events

Date	Start	End	Event Type	Dispatch Group*	Control Group*	System Temperature
6/30/2021	5:30PM	5:58PM	Full shed	GP+A+B	None	86°F
7/16/2021	4:00PM	4:28PM	Full shed	GP+A+B	None	89°F
7/28/2021	3:55PM	5:00PM	64%	GP+A	B	92°F
8/11/2021	4:00PM	4:28PM	Full shed	A	GP	89°F
	4:00PM	4:28PM	64%	B	GP	89°F
8/12/2021	4:00PM	4:28PM	Full shed	B	GP+A	91°F
8/13/2021	3:55PM	5:00PM	64%	A	GP+B	94°F
8/23/2021	4:00PM	4:28PM	Full shed	A	GP+B	91°F
8/27/2021	3:55PM	5:00PM	50%	B	GP+A	90°F
8/30/2021	2:55PM	5:00PM	64%	A	GP	92°F
	3:55PM	6:00PM	64%	B	GP	91°F
9/13/2021	3:55PM	5:00PM	50%	A	GP+B	87°F

* General Population (GP), Group A (A), and Group B (B)

2.4.2 BYOT Events

A total of eight BYOT Power Manager events were called in 2021. Of the eight events called, six were held from 3:55 PM to 5:00 PM. Different combinations of pre-event cooling and event period temperature offsets were applied across events. The least extreme event involved no pre-cooling and a 3°F event offset, whereas the most extreme control involved a 2°F pre-event cooling period for 90 minutes with a 4°F offset during the event. BYOT events occurred during system temperatures ranging from 88°F to 94°F. On four separate dates in 2021, a DLC event overlapped with a BYOT event. This coincidence provides an opportunity to compare program performance between the two separate offerings within the Power Manager program.

The table below summarizes BYOT event conditions in 2021.

Table 2-2: Summary of 2021 BYOT Events

Date	Start	End	Pre Cool	Offset	Dispatch Group*	Control Group*	System Temperature
7/1/2021	3:00PM	5:00PM	60 min 1°F	3°F	GP+A+B	None	88°F
7/30/2021	3:55PM	5:00PM	None	3°F	GP+A+B	None	91°F
8/11/2021	3:55PM	5:00PM	90 min 2°F	4°F	B	GP+A	89°F
8/12/2021	3:55PM	5:00PM	90 min 2°F	4°F	GP+A	B	91°F
8/13/2021	3:55PM	5:00PM	60 min 1°F	3°F	B	GA+A	94°F
8/23/2021	3:55PM	5:00PM	90 min 2°F	4°F	GP+B	A	91°F
8/24/2021	4:55PM	6:00PM	90 min 2°F	4°F	A	GP+B	93°F
8/30/2021	3:55PM	5:00PM	90 min 2°F	3°F	A	GP+B	92°F

* General Population (GP), Group A (A), and Group B (B)

3 Methodology and Data Sources

This section details the study design, data sources, sample sizes, and analysis protocols used for the impact and process evaluations.

In general, analysis methodologies and data sources were consistent for both the DLC and BYOT evaluations. For that reason, information presented in this section does not distinguish between DLC and BYOT. Any meaningful differences in methodologies, data sources, and/or analysis processes between DLC and BYOT evaluations will be noted.

3.1 Data Sources

3.1.1 Impact Evaluation Data Sources

The impact analysis relied on four primary datasets:

- Participant data identifying customer account numbers and group assignments
- Premise-level AMI data in 30-minute intervals for all participants spanning May 2021 through September 2021
- Event tracking data for all DEC Power Manager events called in 2021, including treatment and control group assignments, event scenarios, start/end times for each event
- Hourly weather data for the full event season, used to inform proxy day selection for the within-subjects analysis, as well as to establish relationships between impacts and weather conditions

With the exception of weather data, which was obtained from NOAA, all primary datasets were provided by Duke Energy following the Summer 2021 Power Manager event season. All subsequent datasets used by RI for analysis were compiled from a combination of these primary datasets.

3.1.2 Process Evaluation Data Sources

The process analysis relied on four primary datasets:

- Program tracking and documentation database
- In-depth interviews with key program stakeholders
- Post-event program participant surveys
- Nonevent program participant surveys

3.2 Data Management and Validation

All data sets were thoroughly cleaned and validated to ensure that impacts were estimated using reliable observations from customers who were properly dispatched on event days. The analysis benefitted from a full population-based approach, allowing RI to logically exclude customers who were found to have incomplete or questionable load data, while still maintaining large enough group sizes to produce highly precise estimates.

Recent evaluations of DEC Power Manager found incidence of device failure, signaling deficiency, or other technical dysfunction that prevented a portion of customers from being dispatched as planned for certain events. Most recently, the Summer 2019 evaluation found that, in some cases, large groups of customers did not respond to events as planned. Subsequent investigation and follow-up with Duke Energy suggested that some of the issues discovered were the result of programming error associated with group assignments, and likely not due to paging tower defects or technical flaws with program equipment. With this in mind, RI was deliberate to carefully monitor individual group responses to each event, and to adapt analysis techniques wherever necessary to ensure accurate and authentic results. In 2021, there were no known instances of widespread device failure, signaling deficiency, or other technical problems that jeopardized the reliability of results.

3.3 RCT Analysis Design

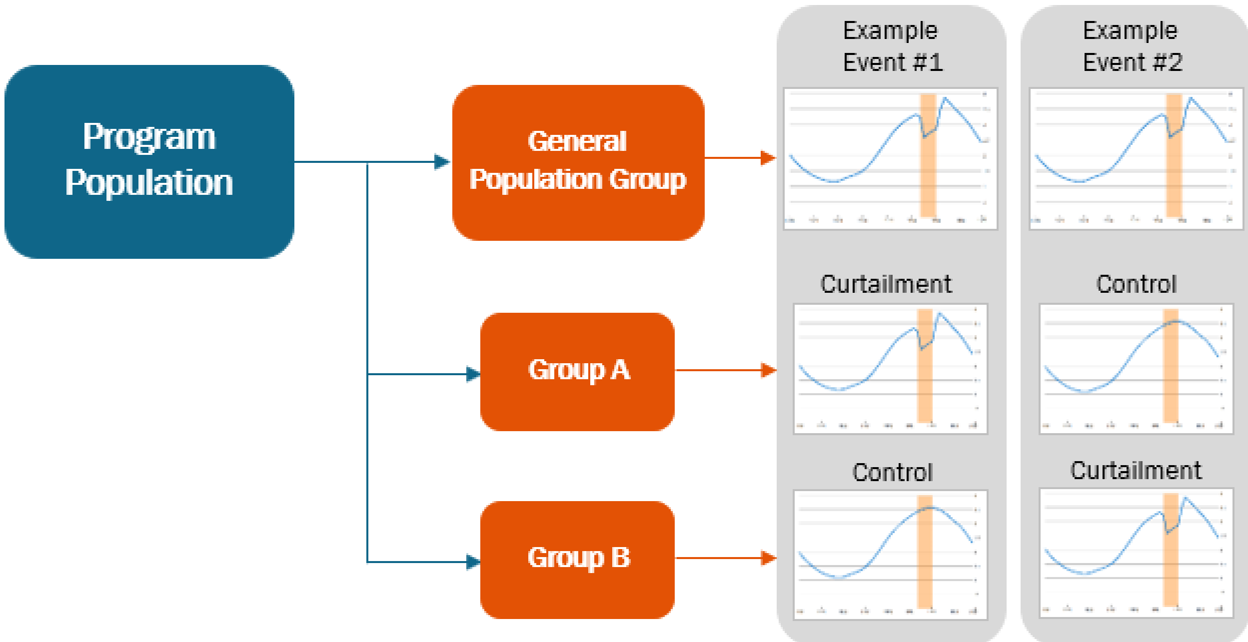
A randomized control trial (RCT) study design is well-recognized as the gold standard for obtaining accurate impact estimates. RCTs have several advantages over other analytical methods, including:

- They require fewer assumptions than engineering-based calculations
- They allow for simpler modeling procedures that are effectively immune to model specification and estimation errors
- They are guaranteed to produce accurate and precise estimates, provided proper randomization and large sample sizes

The RCT design randomly assigns the Power Manager population into three groups – a primary group consisting of a large majority of the population and two research groups, each consisting of smaller, equal shares of the remaining population. For each event, groups are assigned as either treatment or control according to Duke Energy’s operational plan. All devices assigned to the treatment group are controlled during the event window, while devices assigned to the control group are withheld and continue to operate normally. As a result of random group assignment, the only systematic difference between the treatment and control groups is that one set of customers is curtailed while the other group was not.

The figure below shows the conceptual framework of the random group assignment.

Figure 3-1: Randomized Control Trial Design Framework



All customers who were enrolled in the program and had the required equipment installed at their homes by the start of the 2021 summer were randomly assigned into three groups. The table below summarizes the number of households assigned to each group for both the DLC and BYOT options.

Table 3-1: Approximate Group Sizes

Group	Approximate # DLC Households	Approximate # BYOT Households
Group A	5,000	5,000
Group B	5,000	5,000
General Population	230,000	20,000

The purpose of creating three distinctive, randomly assigned groups was twofold. First, it allowed for side-by-side testing of cycling strategies, event start times, or other operational aspects to help optimize the program. Second, it allowed Duke Energy to alternate the group being withheld as control for each event, increasing fairness and helping to avoid exhausting individual customers by dispatching them too often solely for research purposes.

For each event, at least one of the groups was withheld to serve as a control group and establish the electricity load patterns in the absence of curtailment, i.e., the baseline. Within the experimental framework of a RCT, the average usage for control group customers provides an unbiased estimate of what the average usage for treatment customers would have been if an event had not been called. Therefore, estimating event day load impacts requires simply calculating the difference in loads between the treatment and control groups during each interval of the event window, as well as for the hours immediately following the event when snapback can occur. Demand reductions calculated in this way reflect the net impacts and inherently account for offsetting factors, such as device failures, paging network communication issues, and customers' use of fans to compensate for curtailment of air conditioners.

Additional statistical metrics, such as standard error, are calculated to evaluate whether these differences are meaningful, as well as whether different cycling strategies could produce significantly different impacts. The standard error is then used to calculate 90% confidence bands, which are additional measures used to describe the statistical accuracy of the impact estimate.

Equation 3-1: Calculation of Standard Error

$$Std.Error\ of\ Difference\ between\ Means_i = \sqrt{\frac{sd_c^2}{n_c} + \frac{sd_t^2}{n_t}}$$

Where:

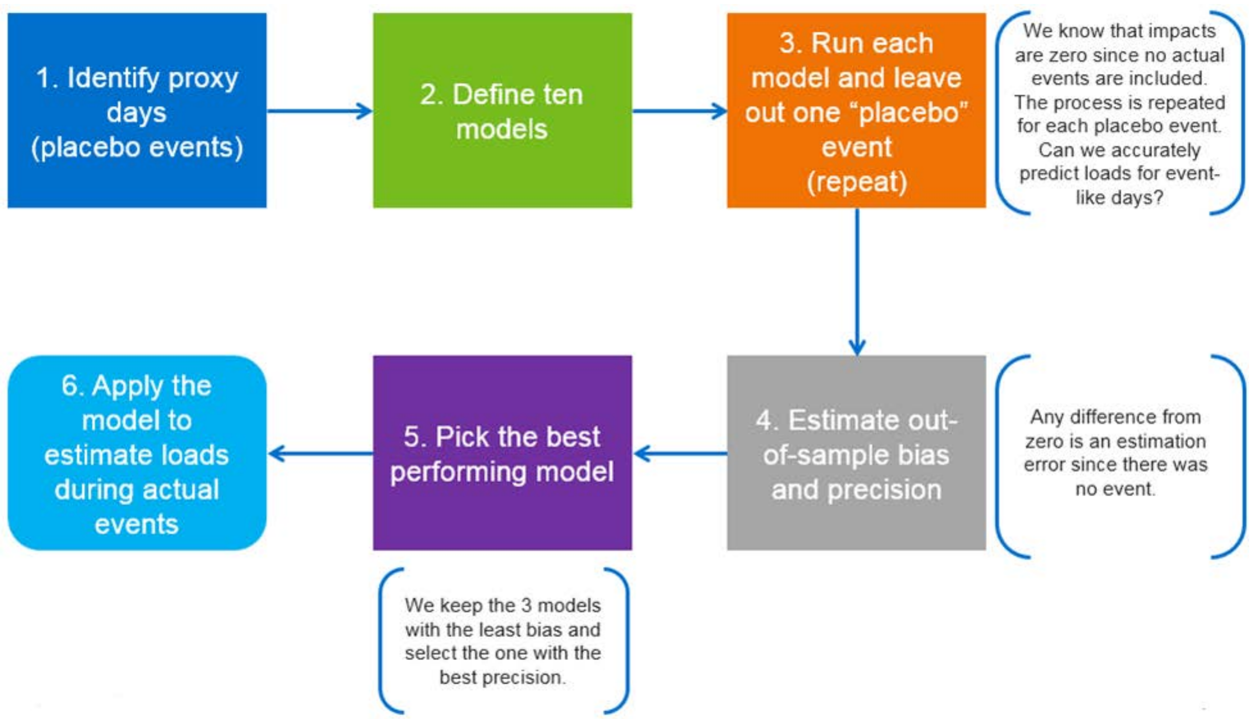
sd = standard deviation
n = sample size
t = indicator for treatment group
c = indicator for control group
i = individual time intervals

3.4 Within-Subjects Analysis Design

Although an RCT approach has many implicit advantages that make it the preferred method for estimating impacts, it is not applicable when no valid control group is available to establish the counterfactual. In these cases, when events were called absent a control group, a within-subjects approach is used, whereby customer loads observed on similar nonevent days are used to establish the counterfactual against which to compare treatment loads. This approach works because the program intervention is introduced on some days and withheld on other days that could otherwise be considered event-worthy, allowing for comparison of load patterns with and without load control.

A key consideration of the within-subjects design is how to select a model that generates the most precise and accurate counterfactual. In many cases, multiple counterfactuals may be plausible, but result in varying estimations of impacts. Using nonevent days with similar temperature conditions, regression modeling was applied to estimate the demand reduction as the difference between the predicted baseline loads and the actual event day loads. To identify the regression model that best predicts the counterfactual, a rigorous model selection process is applied, whereby ten distinct model specifications were tested and ranked using various accuracy and precision metrics. The best performing model was selected and used to estimate the counterfactual for actual event days. The figure below summarizes the regression model selection process.

Figure 3-2: Within-Subjects Regression Model Selection Process



Bias metrics measure the tendency of different approaches to over or under predict and are measured over multiple out-of-sample days. The mean percent error (MPE) describes the relative magnitude and direction of the bias. A negative value indicates a tendency to under predict, and a positive value indicates a tendency to over predict. The precision metrics describe the magnitude of errors for individual event days and are always positive. The closer they are to zero, the more precise the model prediction. The absolute value of the mean percentage error is used to select the three model candidates with the lowest bias. The coefficient of variation of the root mean square error, or CV(RMSE), metric is used to identify the most precise model from the three models with the least bias.

Equation 3-2: Measures of Bias and Precision

Type of Metric	Metric	Description	Mathematical Expression
Bias	Average Error	Absolute error, on average	$AE = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)$
	Mean Percentage Error (MPE)	Indicates the percentage by which the measurement, on average, over or underestimates the true demand reduction	$MPE = \frac{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)}{\bar{y}}$
Precision	Root Mean Squared Error	Measures how close the results are to the actual answer in absolute terms, penalizes large errors more heavily	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}$
	CV(RMSE)	Measures the relative magnitude of errors across event days, regardless of positive or negative direction (typical error)	$CV(RMSE) = \frac{RMSE}{\bar{y}}$

3.5 Process Evaluation Methodology

The following table summarizes the primary data collection tasks and analysis objectives included in the process evaluation.

Table 3-2: Data Collection Techniques and Sample Size by Technology

Data Collection Technique	Description of Analysis Activities Using Collected Data	DLC Sample Size	BYOT Sample Size	Confidence / Precision Level
Document and database review	Review of program documentation, including program manuals, customer communications, as well as the program database. These materials provide evidence of program operations, as well as how these operations are aligned with program savings and other goals.	NA	NA	NA
Interviews of key contacts	Interviews with Duke Energy staff will document program processes, identify strengths/weaknesses and provide a foundation for understanding the customer experience.	3	2	NA
Post-event survey	Phone and web survey of Power Manager customers who experienced an event, to assess event awareness, satisfaction, customer experience and comfort during events, and motivations for participation.	94	106	DLC: 90/8 BYOT: 90/8
Nonevent survey	Phone and web survey of Power Manager customers for whom an event was not called. Nonevent survey data provide a baseline with which to compare post-event responses, to establish levels of event awareness, satisfaction, customer experience and comfort during events, and motivations for participation.	68	82	DLC: 90/10 BYOT: 90/9

3.5.1 Review program documentation and analyze program database

Process evaluation should be guided by a thorough understanding of the primary activities of any program, the marketing messages used to recruit and support participants, and any formal protocols that guide processes. For demand response programs, it is particularly important to understand the event notification procedures, any opt-out processes that exist, and how bill credits or incentives are communicated and applied or delivered. It is also important to understand how the program opportunity is communicated and the types of encouragement provided to participating households. These communications are often the source of program expectations, which can affect participant satisfaction. To support this task, Resource Innovations requested copies of internal program manuals and guidelines as well as copies of marketing materials. The program database analysis consisted of an examination of program tenure, load curtailed per household, and other variables that inform indications of program progress.

3.5.2 In-depth interviews with key program stakeholders

Program stakeholders include program staff and implementation contractors with insight into program plans and operations, emerging issues, and the expected customer experience. The interviews conducted for the Summer 2021 evaluation confirmed the evaluation team's understanding of key program components.

Goals of the interviews include:

- Understand marketing and recruitment efforts, including lessons learned about the key drivers of enrollment
- Identify "typical" Power Manager households, including characteristics of households that successfully participate for multiple years
- Describe event processes
- Understand opt-out procedures
- Confirm enrollment incentive levels and how event incentives are explained to customers
- Understand the customer experience
- Identify any numeric or other program performance goals (kW enrollment, number of households, notification timelines) established for Power Manager
- Describe the working relationship between Duke Energy and the program implementers, including the allocation of program responsibilities
- Understand emergent and future concerns, and plans to address them

3.5.3 Post-event surveys

Guided by information obtained from stakeholder interviews and a review of program guidance documents (including any notification protocols), Resource Innovations developed a survey for participating customers that was deployed immediately following a Power Manager event. The survey was designed to be deployed via phone and email to maximize response rate in the 24 to 48-hour window following an event. DEC DLC post-event surveys were deployed immediately following the event and closed within two days. DEC BYOT post-event surveys were deployed the day following the event and were closed five days after the event. The post-event survey addressed the following topics:

- Awareness of the specific event day and comfort during the event;
- Any actions taken during the event to increase household comfort: Do participants report changing AC settings, using other equipment (including window units, portable units, or ceiling fans) to mitigate heat buildup? Were participants home during the event? Are they usually home during that time period?
- Satisfaction with the Power Manager program, the event bill credits earned, and the number of events typically called;
- Expectations and motivations for enrolling: What did participants expect to gain from enrollment? To what extent are they motivated to earn incentive payments versus altruistic motivations such as helping to address electricity shortfalls during periods of high peak demand and/or reducing the environmental effects of energy production?; and
- Retention and referral: Do participants expect to remain enrolled in the program in future years? Would they recommend the program to others?

To ensure that the survey accurately assessed the experiences of customers during a curtailment event, questions were finalized and fully programmed prior to the event, to enable deployment within 24 hours after an event. Working with Duke Energy and the impact evaluation team, Resource Innovations prepared a random sample of participant households prior to event notification to receive the post-event survey. This sample was linked to the survey software and ready to deploy as soon as the event ended. Any participants for whom email addresses were available received an email invitation with a link to the survey URL. 79% percent of DLC and 71% of BYOT participants were surveyed by phone. Our mixed mode approach ensuring completes by both the telephone and web improves the representativeness of the completed surveys.

3.5.4 Nonevent program surveys

In addition to the post-event survey, the evaluation team prepared a survey to be deployed immediately following a hot nonevent day. This nonevent day survey was identical to the post-event survey to facilitate comparison with the results of the event day survey. Like the post-event survey, the nonevent survey was developed, approved, and programmed prior to the demand response season to enable immediate deployment on a sufficiently comparable nonevent day. The nonevent survey sample was developed prior to the demand response season and linked to the programmed survey. Similar to the post-event survey, a survey link was sent via email to participants with email addresses, simultaneous with the phone deployment, improving the representativeness of the data collected.

4 Randomized Control Trial Results

One of the primary goals of the impact evaluation is to understand the load impacts associated with the Power Manager program under a variety of temperature and event conditions. This section presents overall program results for all event days, including general population and emergency shed events. The section also details the results of the research events and investigates weather sensitivity of impacts for 2021 RCT events.

4.1 DLC Program Results

4.1.1 Event Impacts

The load impact estimates resulting from the RCT analysis for the 2021 DLC events are presented in the table below. The load impacts presented for each event are the average per household changes in load during the indicated dispatch windows. The two rows highlighted in yellow indicate program-wide events, which were analyzed via within-subjects approach described in Section 3.4.

Table 4-1: Direct Load Control Event Impacts

Event Date	Start Time	End Time	Event Type	Load w/o DR	Load w/ DR	Impact	% Impact	System Temperature
6/30/2021	5:30 PM	5:58 PM	Full shed	3.28	2.38	0.90	27.5%	86°F
7/16/2021	4:00 PM	4:28 PM	Full shed	3.26	2.19	1.06	32.7%	89°F
7/28/2021	3:55 PM	5:00 PM	64%	3.38	2.68	0.70	20.7%	92°F
8/11/2021	4:00 PM	4:28 PM	Full shed	3.36	2.35	1.01	30.2%	89°F
8/11/2021	4:00 PM	4:28 PM	64%	3.36	2.91	0.45	13.4%	89°F
8/12/2021	4:00 PM	4:28 PM	Full shed	3.42	2.40	1.02	29.8%	91°F
8/13/2021	3:55 PM	5:00 PM	64%	3.57	2.89	0.68	19.0%	94°F
8/23/2021	4:00 PM	4:28 PM	Full shed	3.23	2.27	0.97	29.9%	91°F
8/27/2021	3:55 PM	5:00 PM	50%	3.32	2.74	0.58	17.5%	90°F
8/30/2021	2:55 PM	5:00 PM	64%	3.36	2.68	0.68	20.4%	92°F
8/30/2021	3:55 PM	6:00 PM	64%	3.48	2.81	0.67	19.2%	91°F
9/13/2021	3:55 PM	5:00 PM	50%	2.76	2.37	0.39	14.2%	87°F
Average Full Shed Event				**3.31**	**2.31**	**1.00**	**30.0%**	**89.2°F**
Average 64% Cycling Event				**3.43**	**2.79**	**0.64**	**18.5%**	**91.6°F**
Average 50% Cycling Event				**3.04**	**2.55**	**0.49**	**15.9%**	**88.5°F**
Average Event				**3.31**	**2.56**	**0.76**	**22.8%**	

Overall load impacts for the average customer ranged between 0.39 kW and 0.70 kW during normal operations. The emergency shed events produced higher load impacts compared to normal shed events, with an average per household impact of 1.00 kW.

At least one of the groups was held back as a control group during each event (excluding the two program-wide events) to establish the baseline. While withholding a control group is an essential component of the RCT research design, it adversely affects the aggregate performance of the program since customers being withheld do not contribute load reduction to the total impact. To extrapolate the total load reduction achieved by the entire program during a given event, the average per household impact is multiplied by the total number of enrolled participants.

The RCT results implicitly take into account device inoperability and other offsetting factors. Because randomized group assignment was utilized effectively, each of the individual test groups accurately represents the overall percentage of customers with inoperable devices from among the entire population. As such, the estimated load impacts are appropriately de-rated by the inherent equivalence of non-working devices included in each of the test groups, and do not require any independent adjustment to account for device inoperability.

Event impacts are displayed graphically in a series of figures that follow, with the average customer load profiles shown for the treatment and control groups. The dark blue line represents the average load from control group customers, the orange line reflects average load of the customers participating in the event, and the light blue line shows the average load impact (the difference between the control group and participant customer loads). All of the events show a clear drop in treatment group loads during the event dispatch period, as well as a small snapback in energy usage during the hours immediately following the events. Furthermore, most events show an instantaneous and prominent load drop during the first 30-minute interval of the dispatch period, underpinning the collective response of the load control devices once the event signal is received.

Figure 4-1: Per Household Event Performance, July 28 and August 12

Event Date	7/28/2021
Start Time	3:55 PM
End Time	5:00 PM
Event Strategy	64% cycling
System Temperature	92°F
Event Impact	0.70 kW

Event Date	8/12/2021
Start Time	4:00 PM
End Time	4:28 PM
Event Strategy	Full shed
System Temperature	91°F
Event Impact	1.01 kW

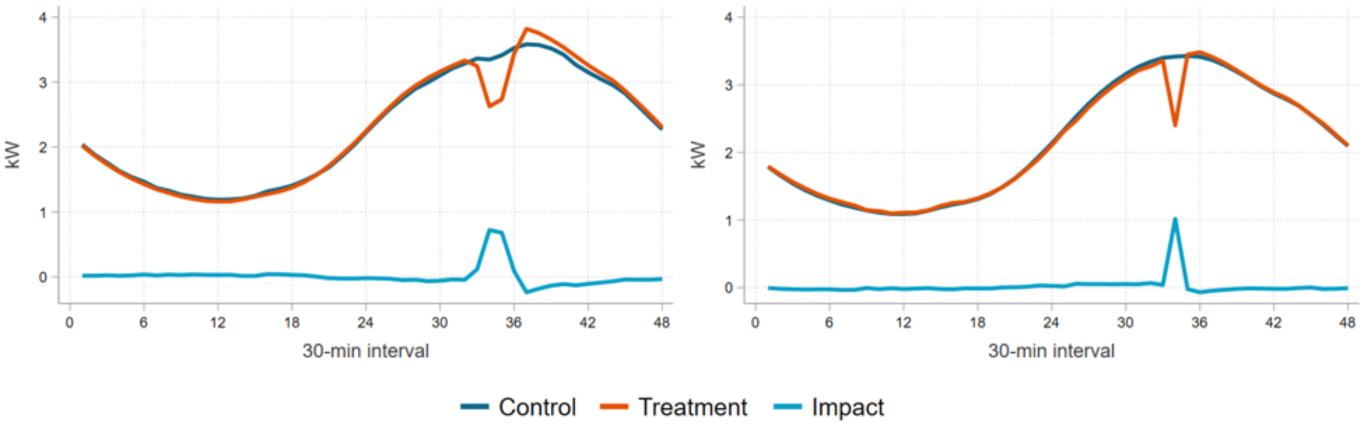


Figure 4-2: Per Household Event Performance, August 13 and August 23

Event Date	8/13/2021
Start Time	3:55 PM
End Time	5:00 PM
Event Strategy	64% cycling
System Temperature	94°F
Event Impact	0.67 kW

Event Date	8/23/2021
Start Time	4:00 PM
End Time	4:28 PM
Event Strategy	Full shed
System Temperature	91°F
Event Impact	0.96 kW

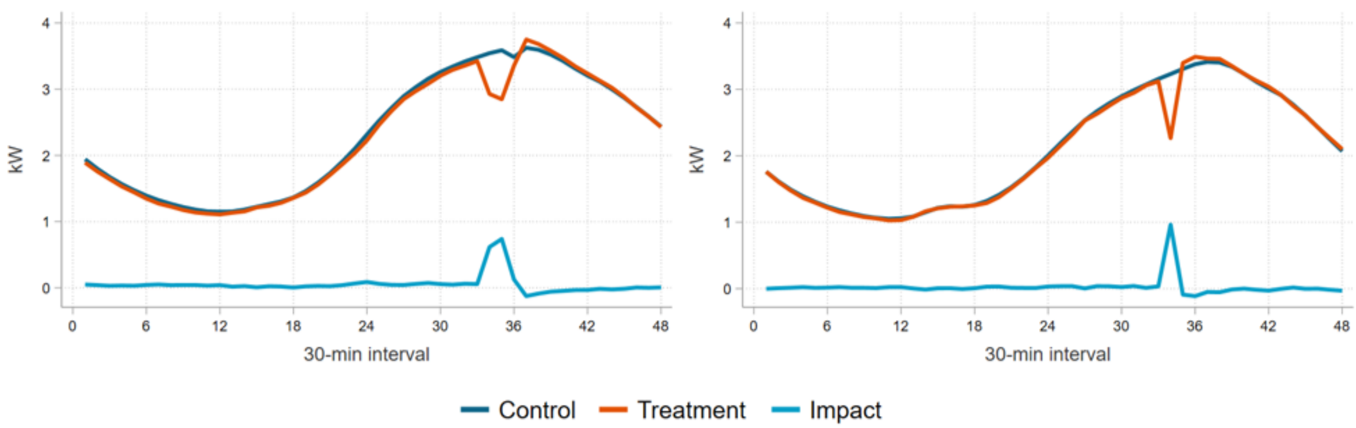
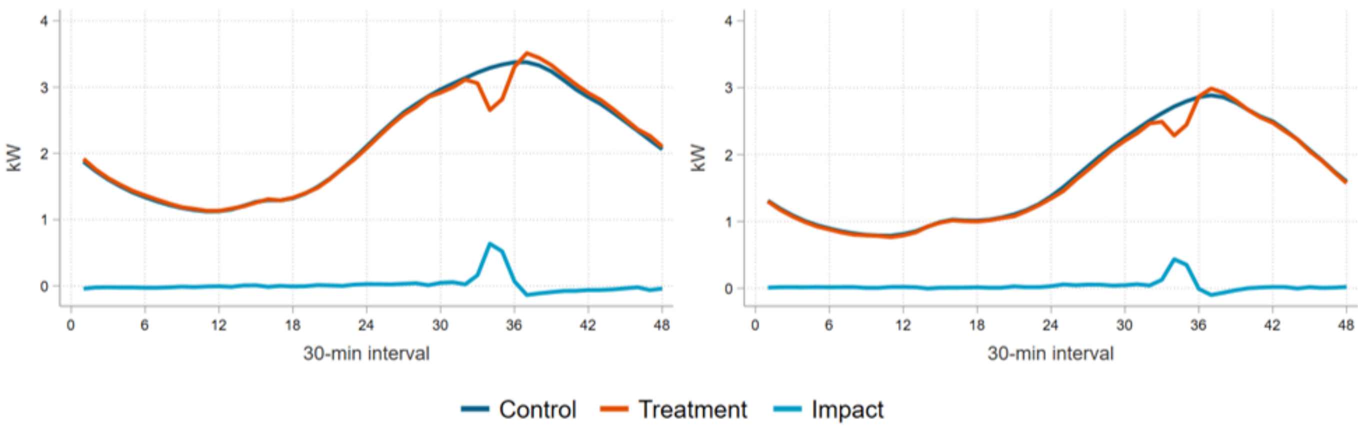


Figure 4-3: Per Household Event Performance, August 27 and September 13

Event Date	8/27/2021
Start Time	3:55 PM
End Time	5:00 PM
Event Strategy	50% cycling
System Temperature	90°F
Event Impact	0.57 kW

Event Date	9/13/2021
Start Time	3:55 PM
End Time	5:00 PM
Event Strategy	50% cycling
System Temperature	87°F
Event Impact	0.39 kW



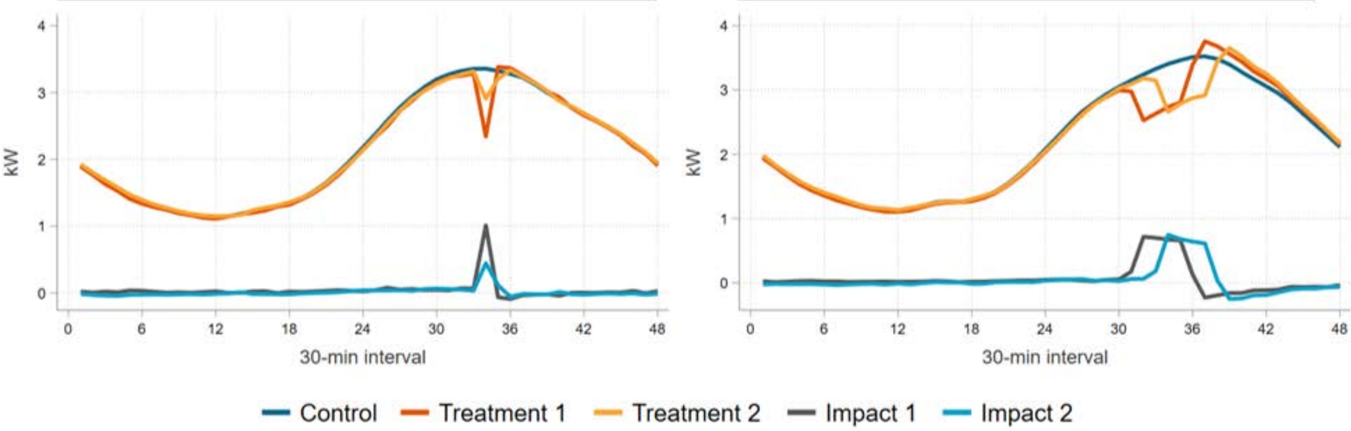
Two events in 2021 involved calling two groups under distinct conditions, i.e., at differing levels of cycling or at different times of day. The design of these events allows for a comparison of achievable impacts under different conditions.

The first such event, called on August 11, involved two groups being called simultaneously, but under different levels of shed. The first group of customers was dispatched at 100% full shed and generated 1.01 kW impact per customer, while a second group was dispatched at 64% cycling and produced smaller impacts of 0.45 kW per household. The other event, called on August 30, involved dispatching two groups under similar cycling, but at different times of day. Groups were dispatched for 125 minutes each, with start times separated by an hour, and produced almost identical per household impacts.

Figure 4-4: Per Household Event Performance, August 11 and August 30

Event Date	8/11/2021	
Start Time	4:00 PM	4:00 PM
End Time	4:28 PM	4:28 PM
Event Strategy	Full shed	64% cycling
System Temperature	89°F	89°F
Event Impact	1.01 kW	0.45 kW

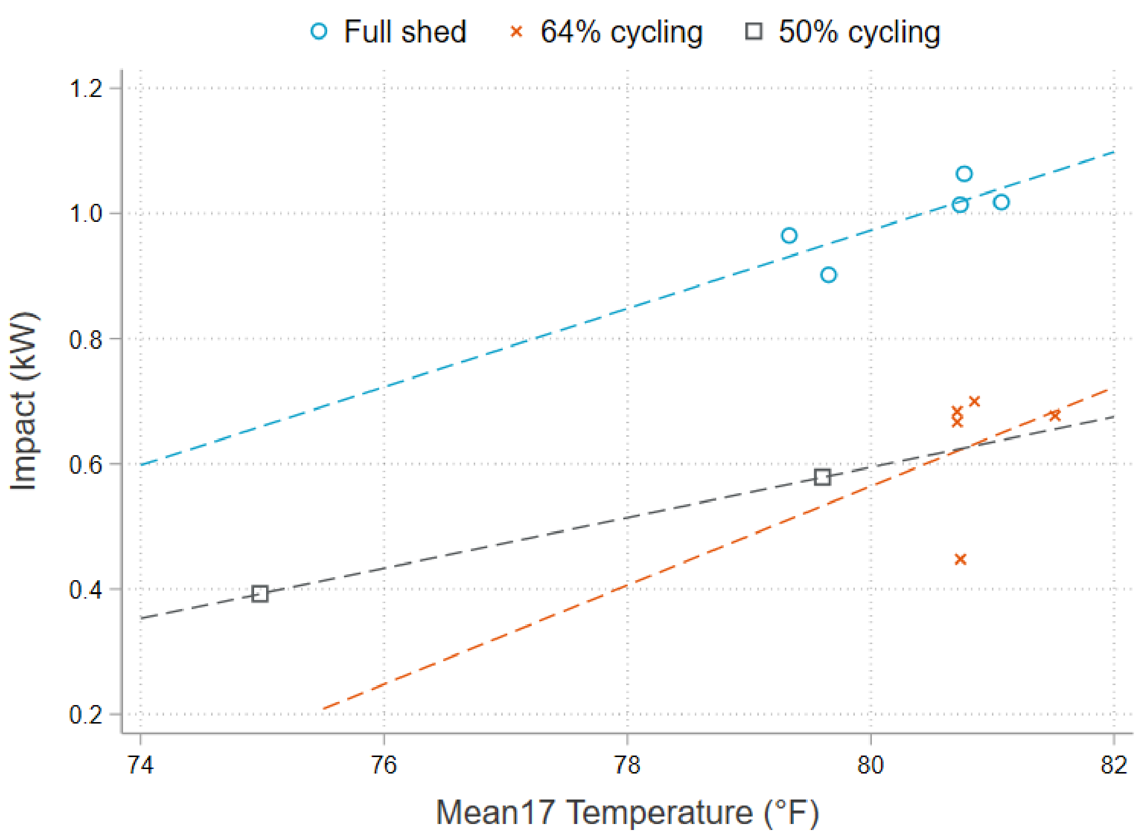
Event Date	8/30/2021	
Start Time	2:55 PM	3:55 PM
End Time	5:00 PM	6:00 PM
Event Strategy	64% cycling	64% cycling
System Temperature	92°F	91°F
Event Impact	0.68 kW	0.67 kW



4.1.2 Weather Sensitivity

The amount of load reduction during events is dependent on weather conditions. The figure below shows estimated per customer impacts for each event as a function of mean17 temperature. Mean17 is defined as the average temperature observed between 12:00 AM midnight and 5:00 PM on a given day (average across hours ending 1 through 17). There is a distinct correlation between higher temperatures and load reduction, with higher impacts on hotter days.

Figure 4-5: Weather Sensitivity of DLC Event Impacts



The key finding is simple: demand reductions grow larger in magnitude when temperatures are hotter, and resources are needed most. Because peak loads are driven by central air conditioner use, the magnitude of air conditioner loads available for curtailment grows in parallel with the need for resources. Not only are air conditioner loads higher, but the program performs at its best when it is hotter.

4.2 BYOT Program Results

4.2.1 Event Impacts

The load impact estimates resulting from the RCT analysis for the 2021 BYOT events are presented in the table below. The load impacts presented for each event are the average per household changes in load during the indicated dispatch windows. As in the DLC option, two events were called program-wide, without a control group, and were analyzed via within-subjects approach described in Section 3.4.

Table 4-2: Bring Your Own Thermostat Event Impacts

Date	Start Time	End Time	Pre-Cool	Offset	Load w/o DR	Load w/ DR	Impact	% Impact	Temperature
7/1/2021	3:00 PM	5:00 PM	60 min 1°F	3°F	2.95	1.78	1.17	39.5%	88°F
7/30/2021	3:55 PM	5:00 PM	None	3°F	3.34	2.04	1.30	38.8%	91°F
8/11/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.29	1.86	1.43	43.6%	89°F
8/12/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.33	1.94	1.39	41.7%	91°F
8/13/2021	3:55 PM	5:00 PM	60 min 1°F	3°F	3.48	2.14	1.34	38.4%	94°F
8/23/2021	3:55 PM	5:00 PM	90 min 2°F	4°F	3.10	1.84	1.25	40.5%	91°F
8/24/2021	4:55 PM	6:00 PM	90 min 2°F	4°F	3.54	2.20	1.35	38.0%	93°F
8/30/2021	3:55 PM	5:00 PM	90 min 2°F	3°F	3.33	2.01	1.32	39.7%	92°F
Average BYOT Event					**3.30**	**1.98**	**1.32**	**40.0%**	**91.1°F**

Overall load impacts for the average BYOT customer ranged between 1.17 kW and 1.43 kW. In general, the four events with a 4°F offset produced larger impacts compared to events with a 3°F offset.

Table 4-3: Summary of BYOT Event Impacts by Type

Pre-Cool Duration	Pre-Cool Offset	Event Offset	# Events	Average Impact	Maximum Impact
None	None	3°F	1	1.30	1.30
60 min	1°F	3°F	2	1.26	1.34
90 min	2°F	3°F	1	1.32	1.32
90 min	2°F	4°F	4	1.36	1.43

Event impacts are displayed graphically in a series of figures that follow, with the average customer load profiles shown for the treatment and control groups. The dark blue line represents the average load from control group customers, the orange line reflects average load of the customers participating in the event, and the light blue line shows the average load impact (the difference between the control group and participant customer loads). All of the events show a clear drop in treatment group loads during the event dispatch period. The figures also clearly depict the increase in load during the pre-cooling phase immediately preceding the event period.

Figure 4-6: Per Household BYOT Event Performance, August 11 and August 12

Event Date	8/11/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	2°F for 90 mins
Offset	4°F
System Temperature	89°F
Event Impact	1.43 kW

Event Date	8/12/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	2°F for 90 mins
Offset	4°F
System Temperature	91°F
Event Impact	1.39 kW

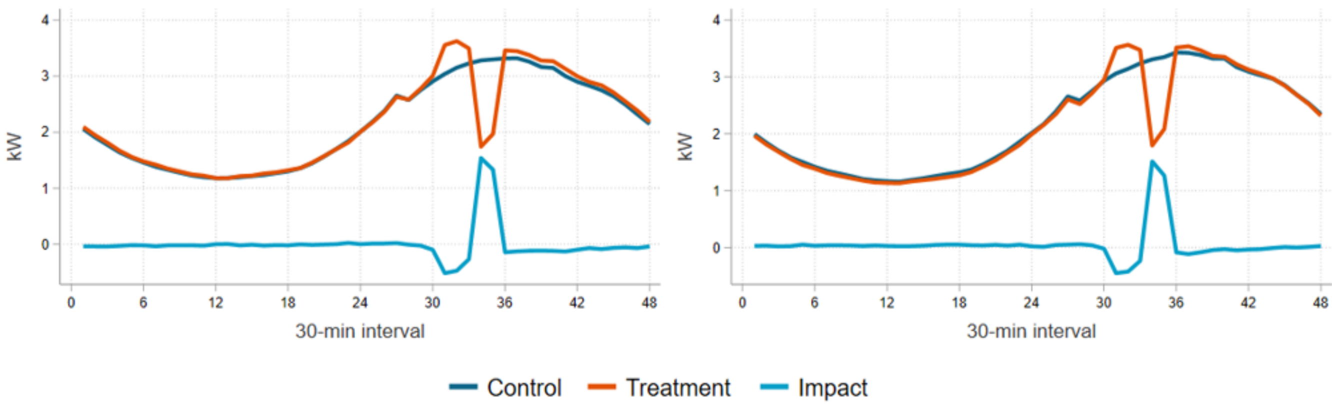


Figure 4-7: Per Household BYOT Event Performance, August 13 and August 23

Event Date	8/13/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	1°F for 60 mins
Offset	3°F
System Temperature	94°F
Event Impact	1.34 kW

Event Date	8/23/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	2°F for 90 mins
Offset	4°F
System Temperature	91°F
Event Impact	1.25 kW

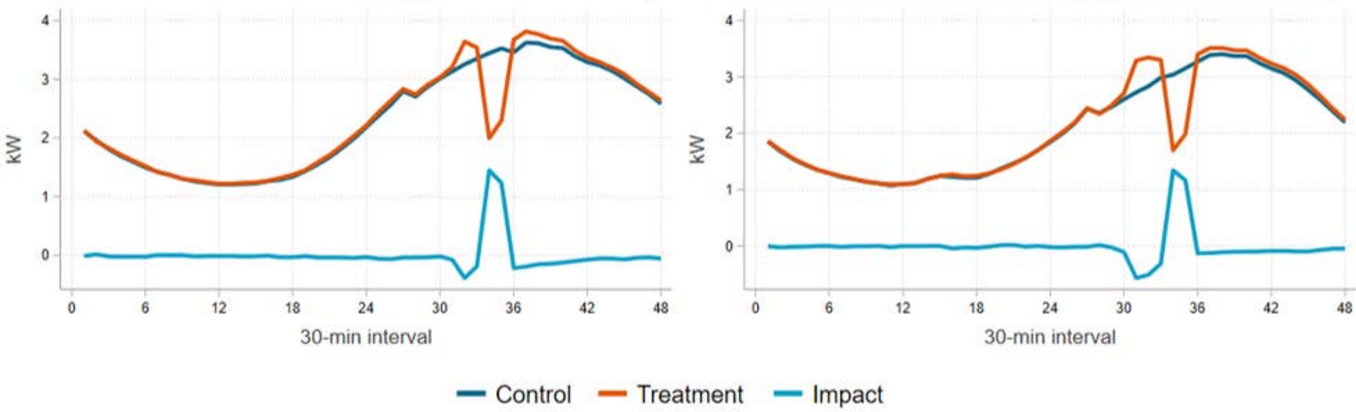
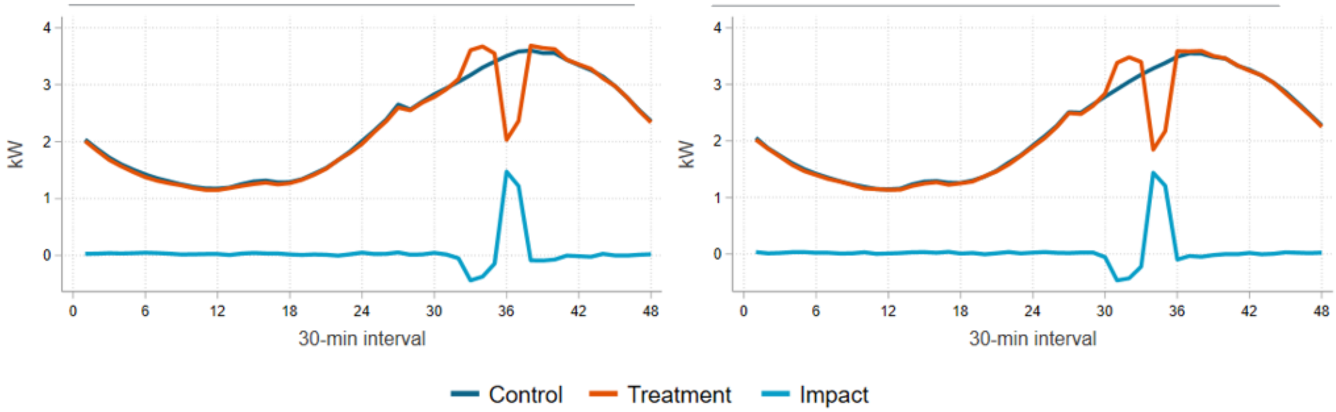


Figure 4-8: Per Household BYOT Event Performance, August 24 and August 30

Event Date	8/24/2021
Start Time	4:55 PM
End Time	6:00 PM
Pre-cool	2°F for 90 mins
Offset	4°F
System Temperature	93°F
Event Impact	1.35 kW

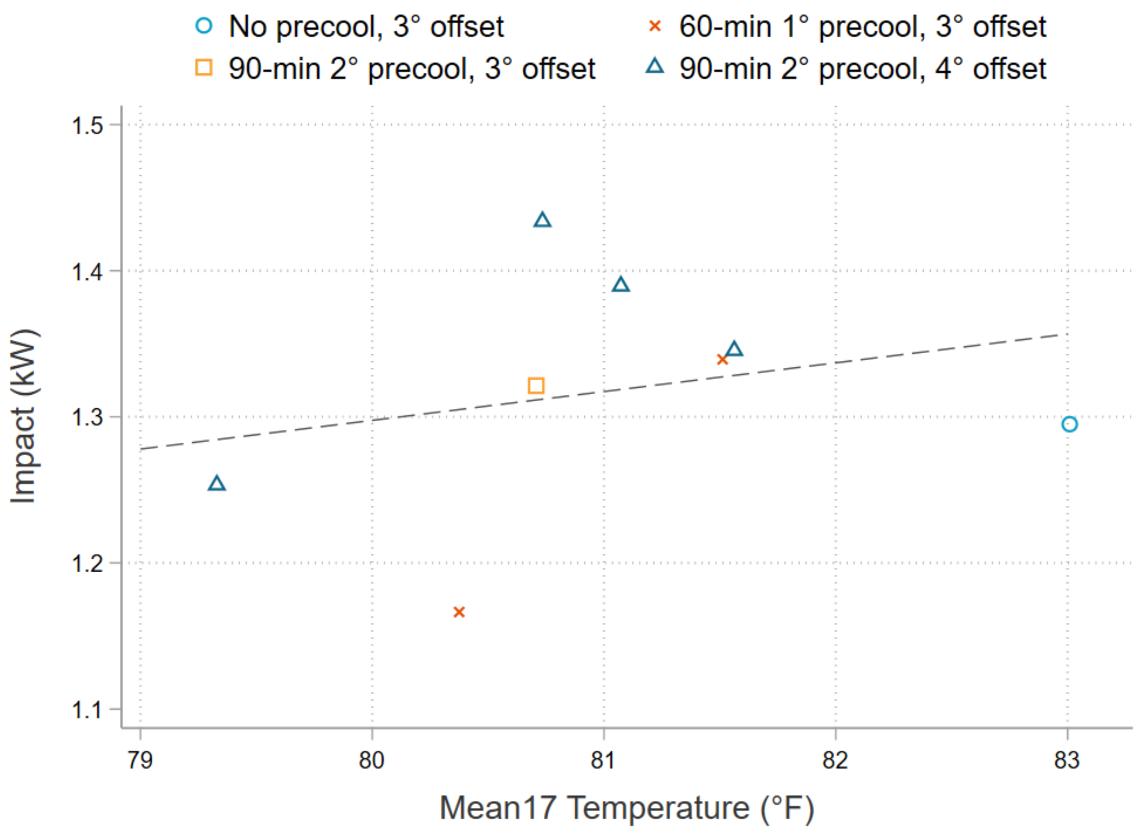
Event Date	8/30/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	2°F for 90 mins
Offset	3°F
System Temperature	92°F
Event Impact	1.32 kW



4.2.2 Weather Sensitivity

As with the DLC events, there is a clear correlation between the magnitude of BYOT event impacts and the mean17 temperature variable. The figure below shows the increasing trend: as the temperature rises, impacts increase.

Figure 4-9: Weather Sensitivity of BYOT Event Impacts



4.3 Key Findings

- DLC impacts ranged between 0.39 and 0.79 kW during normal operations.
- DLC impacts under emergency conditions tended to be larger than those dispatched under normal conditions, averaging 1.0 kW per customer.
- The average BYOT load reduction across all events in was 1.32 kW
- The magnitude of baseline loads and load impacts tend to increase with temperature
- BYOT event impacts tend to grow larger as the magnitude of temperature setpoint offset increases
- There does not appear to be any significant difference in BYOT event performance due to pre-cooling and event period offset condition

5 Within-Subjects Results

In addition to the events described in the previous section, some events were called in Summer 2021 that could not be estimated using RCT approach because they were called for the full program population and did not withhold a control group.

5.1 DLC Within-Subjects Results

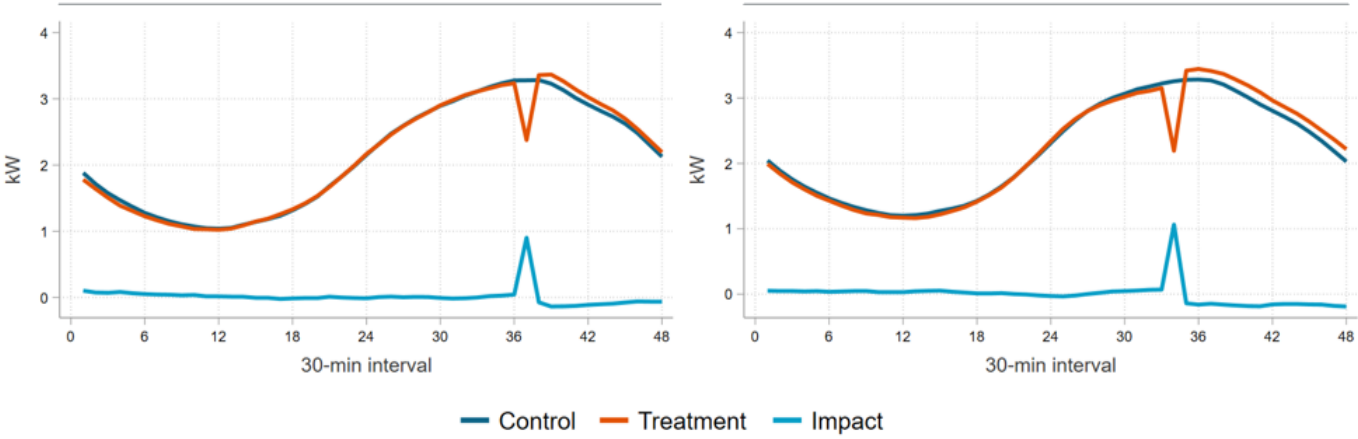
5.1.1 DLC Event Impacts

For each of the two events that were called for the full DLC population, a different set of proxy days was selected and used to generate the baseline loads through the process summarized in Section 3.4. In this way, baselines were found that closely resembled the load patterns of the treatment groups during nonevent hours, and accurately simulate the event period loads absent curtailment, i.e. the counterfactual. Both events called for the entire DLC population in 2021 were full shed events, compared to previous evaluations where at least one full shed and one normal shed event were called per year. Event day loads and impacts for the two within-subjects events are shown in Figure 5-1.

Figure 5-1: Within-Subjects DLC Event Performance, June 30 and July 16

Event Date	6/30/2021
Start Time	5:30 PM
End Time	5:58 PM
Event Strategy	Full shed
System Temperature	86°F
Event Impact	0.90 kW

Event Date	7/16/2021
Start Time	4:00 PM
End Time	4:28 PM
Event Strategy	Full shed
System Temperature	89°F
Event Impact	1.06 kW



5.1.2 Key Findings

- The within-subjects methodology produced accurate reference loads against which to compare treatment loads, leading to highly reliable impact estimates
- Average impacts for within-subjects events in 2021 were similar to analogous RCT events dispatched under emergency conditions (0.98 kW, compared to an RCT average of 1.0 kW).
- The event on July 16 produced per-customer impacts of 1.06 kW, which was the largest single event impacts of the year for the DLC program.

5.2 BYOT Within-Subjects Results

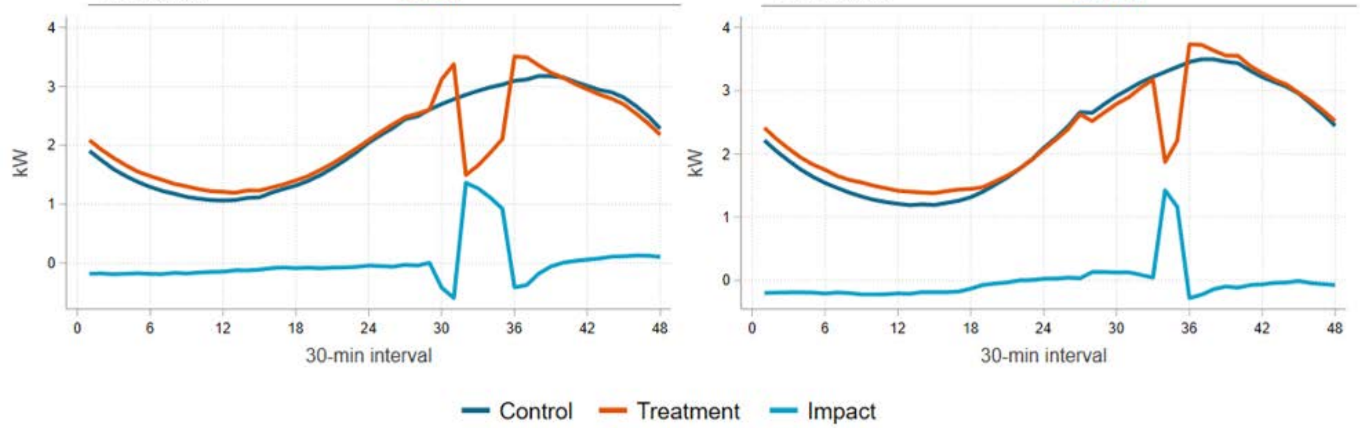
5.2.1 BYOT Event Impacts

Two BYOT events were called population-wide in 2021 and did not involve a control group. For each of these events, a set of non-event proxy days were used to construct a baseline against which to compare event day loads. The first such event was called on July 1 and involved a 3°F offset that lasted for two hours (3:00 PM to 5:00 PM). The event was preceded by a 1°F pre-cool for one hour. The second event, called on July 30, involved a 3°F offset for two hours. There was no pre-cooling for the second event. Event day loads and impacts for the two events are shown in Figure 5-2.

Figure 5-2: Within-Subjects BYOT Event Performance, July 1 and July 30

Event Date	7/1/2021
Start Time	3:00 PM
End Time	5:00 PM
Pre-cool	1°F for 60 mins
Offset	3°F
System Temperature	88°F
Event Impact	1.17 kW

Event Date	7/30/2021
Start Time	3:55 PM
End Time	5:00 PM
Pre-cool	None
Offset	3°F
System Temperature	91°F
Event Impact	1.30 kW



5.2.2 Key Findings

- Per household event impacts for the two population-wide BYOT events called on July 1 and July 30 were 1.17 kW and 1.30 kW, respectively
- The initial (first event interval) load drops were similar for each event
- Pre-cooling on July 1 produced load increases of approximately 0.7 kW during the 60-minute period prior to the event

6 Demand Reduction Capability

A key objective of the Summer 2021 impact evaluation was to quantify the relationship between demand reductions, temperature, and hour of day. This was accomplished by estimating loads under historical weather conditions and applying observed percent load reductions from the 2021 events. The resulting tool, referred to as the time-temperature matrix, allows users to predict the program's load reduction capability under a wide range of temperatures and event conditions.

Similar tools were developed for DLC and BYOT options. However, due to specific contraints in the data, the methodologies used to develop each version of the tool differed. The following sections detail the methodologies, challenges, and results of the Time-Temperature Matrix for both DLC and BYOT events.

6.1 DLC Time-Temperature Matrix

In an ideal program year, a large number of events would be called under a variety of different weather conditions, dispatch windows and cycling strategies so that demand reduction capability could be estimated for a wide range of operating and planning scenarios. In actuality, opportunities for program events can be sporadic, and based on uncertain weather projections, such that they occur infrequently and under fairly similar conditions. In 2021, events were called under a somewhat narrow range of temperature conditions, with system temperatures ranging from 86°F to 94°F. Additionally, no events reached the 100°F target used for estimating program capability. As a result, the ability to predict demand reduction capability across a broader range of conditions – particularly during extremely hot days – was somewhat inhibited.

6.1.1 Methodology

The figure below illustrates weather sensitivity trends of load impacts and peak household demand on hot, nonevent days. The figure, which is based on actual 2021 customer data, shows that Power Manager demand reductions grow on a percent basis as temperatures increase. At the same time, peak household loads available for curtailment also increase with temperatures. The implication is that larger reductions are attainable from larger loads when temperatures are higher.

Figure 6-1: Load Impact Weather Sensitivity

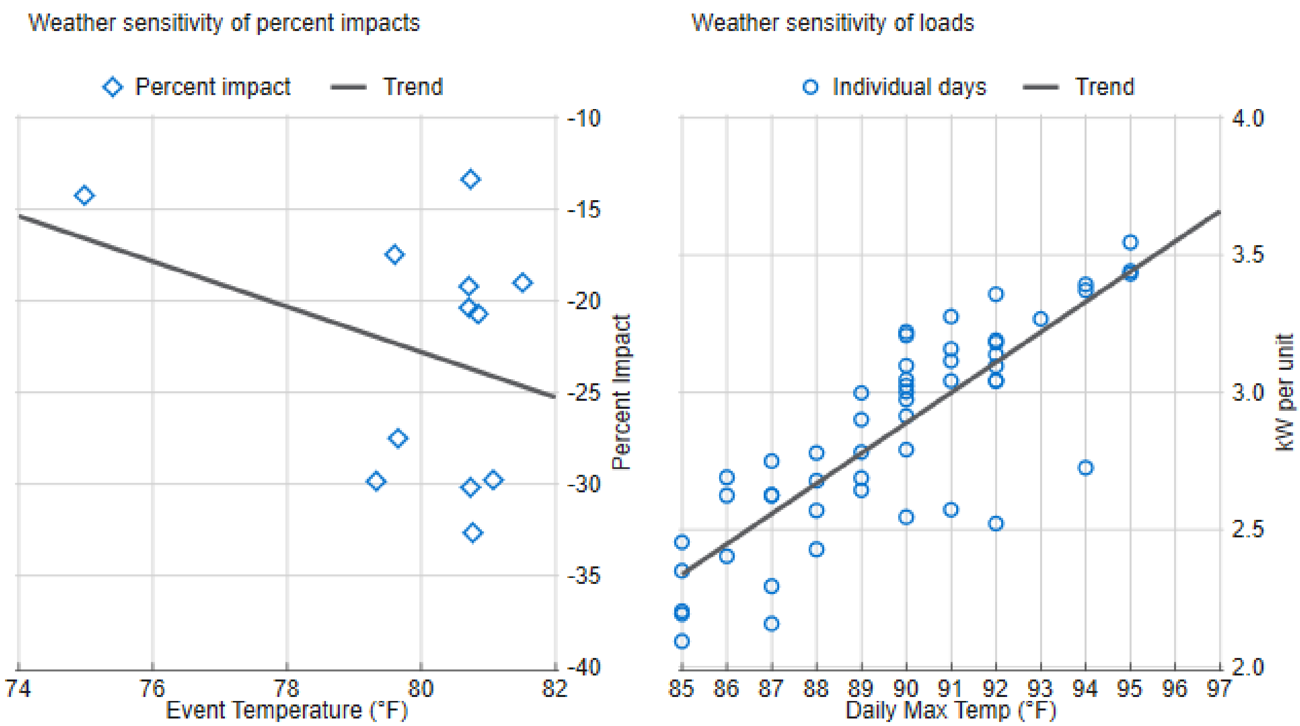
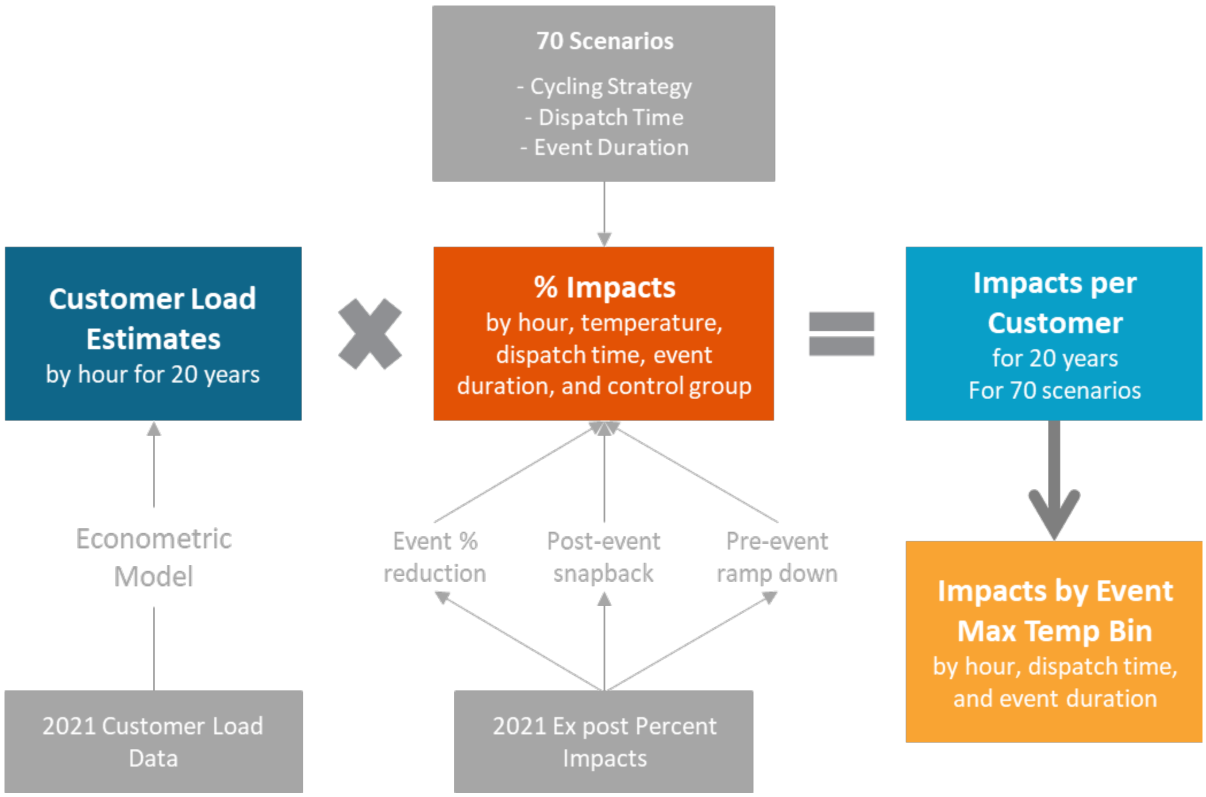


Figure 6-2: Time-Temperature Matrix Development

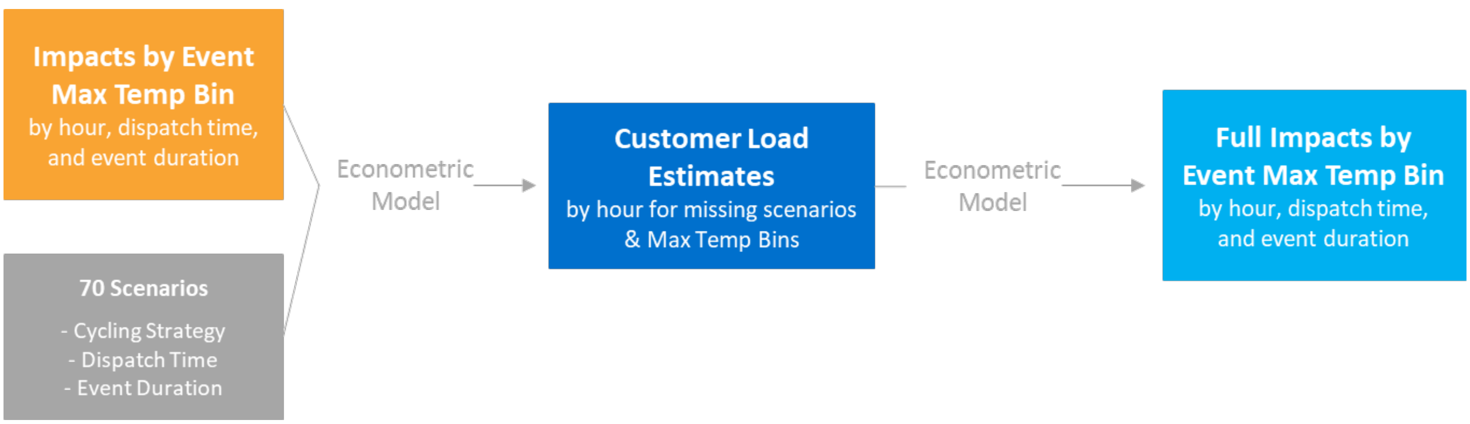


The process shown in the figure above involved the following components:

- Estimates of customer loads were developed by applying 2021 AMI data to the same regression models used to estimate impacts. All weekdays with daily average temperatures above 70˚F were included in the models. The 2021 usage patterns were applied to actual weather patterns experienced over the past ten years rather than hypothetical weather patterns.
- Estimates of the percent reductions were based on three distinct econometric models: load control phase-in, percent reductions during the event, and post-event snapback. The models were based on the percent impacts and temperatures experienced both during the event periods and throughout the event days.
- A total of 70 scenarios were developed to reflect various cycling/control strategies, event dispatch times, and event lengths .
- Estimated impacts per customer were produced by combining the estimated household loads, estimated percent reductions, and dispatch scenarios. The process produced estimated hourly impacts for each hot weekday during 2002-2021 under 70 scenarios.
- In instances where weather data didn't exist to estimate impacts, post-estimation regressions were run in order to properly estimate missing values.
- Multiple days were placed into 2-degree temperature bins and were averaged to produce an expected load reduction profile for each temperature bin.

During the development of the Summer 2021 Time-Temperature Matrix (TTM), it was discovered that the analysis dataset did not contain the data necessary to model impacts for certain scenario and temperature combinations. These combinations typically occur at higher temperatures and when the event starts later in the day. The logic behind this is relatively intuitive; temperatures at the high end of the TTM selection pool are sporadically hit, or not at all. Without historical data to apply usage patterns against, reference loads cannot be modeled nor can impacts be estimated. In order to model impacts as accurately as possible, a secondary modeling cycle was undertaken after initial impacts had been calculated. The second round of models takes the results from existing time-temperature combinations and applies the same regression in order to determine reference loads, temperature profiles and impacts for the missing time-temperature periods. This process is outlined in the figure below.

Figure 6-3: Imputing Missing Time-Temperature Period Values



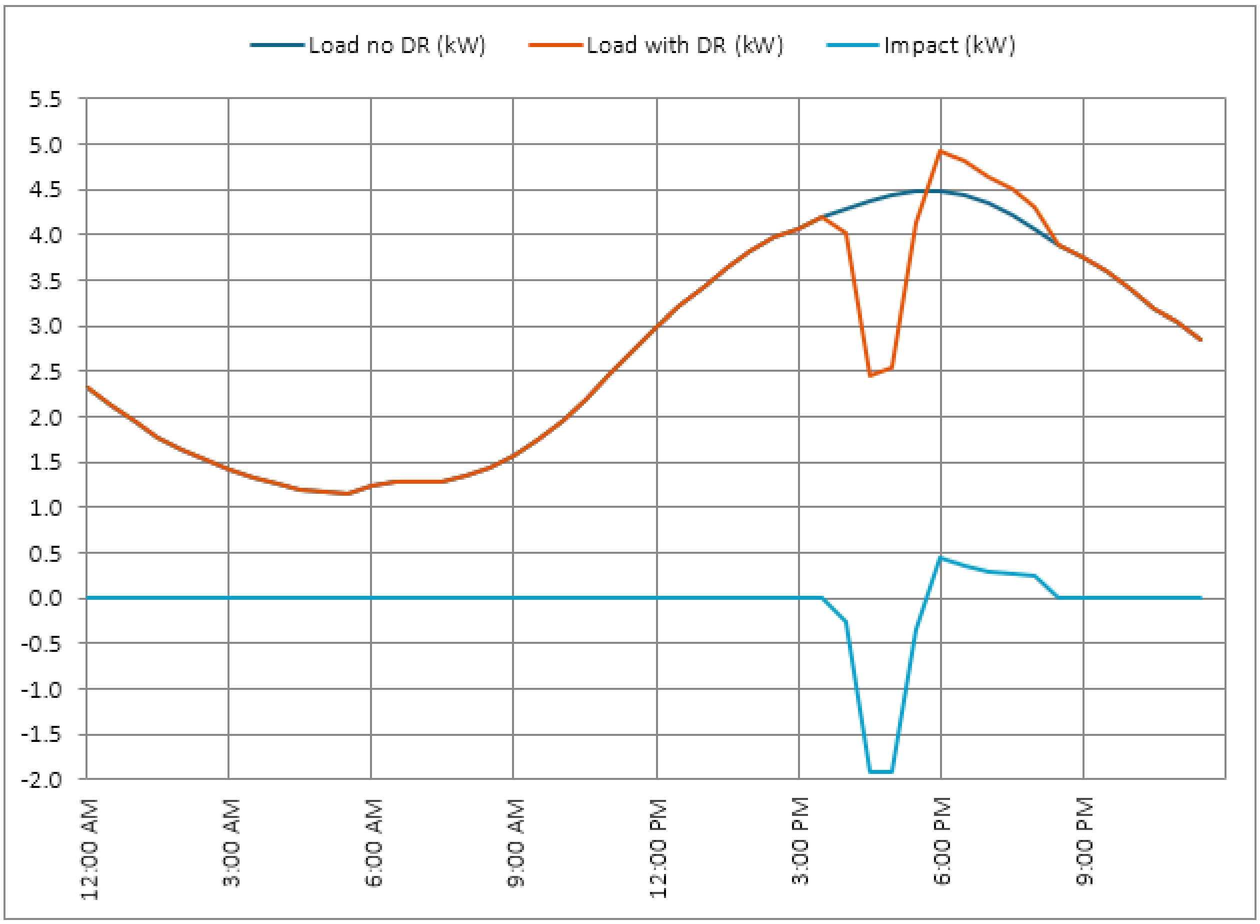
6.1.2 Demand Reduction for Emergency Conditions

While Power Manager is typically dispatched for economic or research reasons, its primary function is to deliver demand relief during extreme conditions, when demand is high and capacity is constrained. Extreme temperature conditions can trigger emergency operations, which are designated to deliver larger demand reductions than normal event cycling. During emergency conditions, all program devices are instructed to instantaneously shed loads. While emergency operations are rare and ideally avoided, they represent the full demand reduction capability of Power Manager. A 1-hour emergency event starting at 4:00 PM and with a maximum temperature of 100°F during the event is provided in the figure shown below. Under these conditions, individual customers are expected to deliver 1.92 kW of demand reduction over a one-hour event window. Because there are approximately 239,700 customers enrolled in Power Manager, the expected aggregate reduction is 459.1 MW.

Figure 6-4: Demand Reduction Capability of DLC Event

Inputs	
Dispatch Type	Emergency Dispatch
Event Start Time	4 PM
Event Duration	1
Event Period Max Temp	100
# Customers	239,700

Event Window Average Impacts		
Load without DR	4.41	kW per customer
Load with DR	2.49	kW per customer
Impact per Customer	-1.92	kW per customer
Program Impact	-459.1	MW
% Impact	-43.4	%



The table below presents estimated load reduction capability under various temperature and time-of-day event conditions, assuming a one-hour event duration.

Table 6-1: Per Customer Impacts (kW) under Emergency Conditons

Daily Max Temperature	Event Start Time 1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
88°F	0.85	0.92	0.99	1.05	1.13
90°F	0.96	1.03	1.10	1.17	1.27
92°F	1.08	1.17	1.24	1.31	1.39
94°F	1.21	1.29	1.36	1.44	1.53
96°F	1.38	1.45	1.52	1.60	1.76
98°F	1.49	1.62	1.79	1.81	1.87
100°F	1.61	1.72	1.79	1.92	1.71

The key takeaway is that impacts grow as temperatures increase and as the event starts later in the day. Impacts increase with later event start times because reference loads are generally increasing from 1:00 PM to 5:00 PM during the summer months. In practice, event day impacts may vary due to unique weather patterns.

6.1.3 Key Findings

Key findings learned from the development of the DLC time-temperature matrix include:

- Impacts generally increase as temperatures increase, and as events are called later in the day.
- The highest predicted impacts occur during 4pm under 100-degree conditions.

Due to constraints with available high temperature weather data in a 10-year period, the time frame of available weather data was expanded to 20 years. The trend in recent years of temperatures rarely exceeding 100 degrees will likely cause 20-year weather data to become the standard to model reference loads.

6.2 BYOT Time-Temperature Matrix

Similar to the DLC event season, relatively few BYOT events were called in Summer 2021. Collectively, they were held under a narrow range of pre-cooling and event conditions, which limited the ability of the Time-Temperature Matrix tool to reliably predict load reductions under the more extreme settings. Of the eight BYOT events called in 2021, four of them were held with the same pre-cooling and event settings. The other four were split between three remaining pre-cooling and event conditions, as shown in Table 4-3.

6.2.1 Methodology

The methodology used to develop the BYOT Time-Temperature Matrix differed somewhat from the one used to produce the DLC Time-Temperature Matrix, primarily because it was difficult to establish a clear correlation between event impacts and certain event settings, such a start time and temperature. This ultimately resulted in modeled impact estimates under extreme conditions that were counterintuitive, unrealistic, or otherwise unbelievable. Rather than submit a tool that is consistent with the standard methodology, but that produced spurious impact predictions, Resource Innovations modified the methodology in a way that resulted in logical estimations that follow known trends in terms of temperature and time-of-day event conditions.

The first step was consistent with the DLC methodology, where reference loads were modeled for a wide range of temperature conditions by applying the observed AMI data from 2021 to 10-year historical weather data. From there, average percent reductions observed for each type of event were applied to the modeled referend loads for each of the various combinations of event start times, maximum temperatures, event durations, and event types.[1] In this way, event impacts, as well as pre- and post-event load increases, are purely a function of the reference loads and are not subject to the modeling error observed in the original approach. Table 6-2 shows the average percent impacts for each period of the four event types.

[1] The term “event type” is used to reflect the four different scenarios, combining pre-cooling duration, pre-cool temperature offset, event period duration, and event period temperature offset, used in 2021.

Table 6-2: Average Percent Impacts by Period and Event Type

Event Type	# Events Called	Period	Average % Impact
No Pre-Cool / 3°F Event Offset	1	Pre-Event	0.0%
		Event	38.8%
		Post-Event	-6.2%
60-minute 1°F Pre-Cool / 3°F Event Offset	2	Pre-Event	-13.6%
		Event	39.3%
		Post-Event	-7.8%
90-minute 2°F Pre-Cool / 3°F Event Offset	1	Pre-Event	-12.4%
		Event	39.7%
		Post-Event	-1.7%
90-minute 2°F Pre-Cool / 4°F Event Offset	4	Pre-Event	-12.8%
		Event	41.0%
		Post-Event	-3.1%

6.2.2 Demand Reduction Capability for BYOT Events

Like DLC events, the primary purpose of BYOT is to relieve (or shift, if pre-cooling) load demand during times of system peak demand. To maintain customers' comfort, the most extreme BYOT events (i.e., those with the largest temperature offsets) are ideally used sparingly and only when needed. Collectively, the 2021 events show that per household load impacts are correlated with the event period temperature offset. Put simply, larger offsets generate greater impacts. Therefore, the most extreme event type is used for estimating the program's load reduction capability.

Figure 6-5: Load Reduction Capability for Extreme BYOT Event

INPUTS	
Event Start Time	4 PM ▼
Event Duration	1 ▼
Event Option	90 min 2 deg precool / 4 deg offset ▼
Event Temperature	100 ▼
# Customers	33,900

OUTPUTS		
Reference Load	4.29	kW
Curtailed Load	2.53	kW
Impact per Customer	-1.76	kW
Program Impact	-59.7	MW
% Impact	-41.0	%

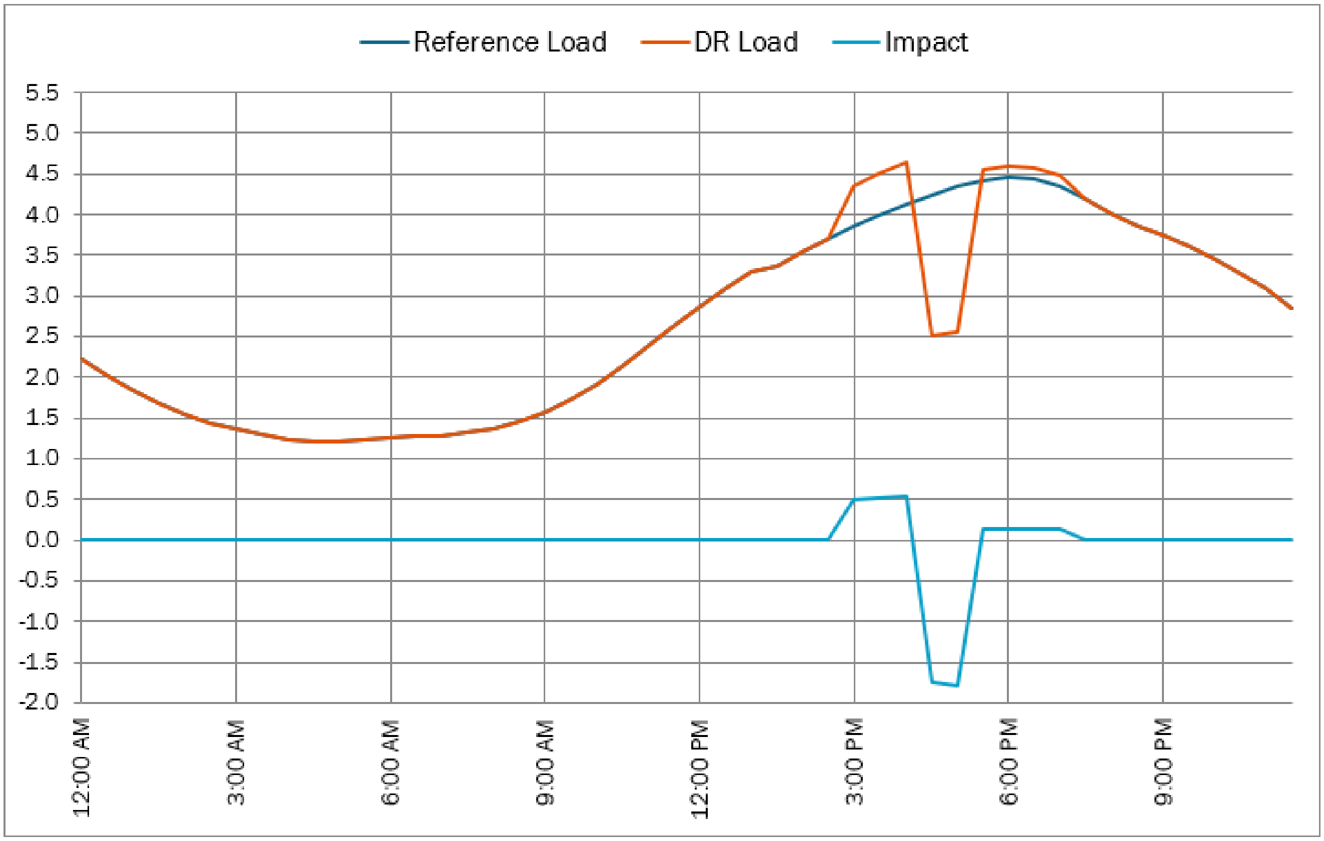


Figure 6-2 shows load impact predictions for an extreme BYOT event. Specifically, a 1-hour BYOT event beginning at 4:00 PM at 100°F that involves a 4°F offset, preceded by a 90-minute 2°F pre-cool, is expected to generate impacts of 1.76 kW per household. Assuming a program population of 33,900 accounts, this translates to approximately 60 MW of system load reduction.

6.2.3 Key Findings

Key takeaways from the BYOT Time-Temperature Matrix include:

- Impacts, which are applied as a percentage of the reference load, are correlated to temperature. As temperatures rise, both reference loads and impacts increase.
- Under the most extreme event settings observed – namely a 4°F offset with a 2°F pre-cool – a 1-hour event beginning at 4:00 PM at 100°F produces a per household impact of 1.76 kW.
- Similar to what was found during the development of the DLC TTM, relatively few events called under a narrow range of event and weather conditions led to significant challenges in modeling impacts for extreme scenarios, ultimately persuading Resource Innovations to modify the methodology used to develop the BYOT TTM.

7 Process Evaluation

Process evaluation, particularly when combined with the insight obtained from impact evaluation, informs efforts to continuously improve programs by identifying program strengths and weaknesses, opportunities to improve program operations, program adjustments likely to increase overall effectiveness, and sources of satisfaction or dissatisfaction among participating customers. The primary objectives for the process evaluation component of the evaluation include:

- Assess the extent to which particpants are aware of events, bill credits, and other key program features
- Understand the participant experience during events, including comfort, occupancy, thermostat adjustments, and strategies employed to mitigate heat
- Identify motivations and potential barriers for participation, including expectations, sources of confusion or concern, intention to stay enrolled, and likelihood of recommending the program to others
- Document the operations, recruitment, enrollment, outreach, notification, and curtailment activities associated with program delivery
- Identify program strengths and potential areas for improvement

Section 7.1 describes the survey disposition, event and nonevent days for both DLC and BYOT surveys. Section 7.2 details the results and findings of the DLC surveys, and Section 7.3 details the results and findings ofr BYOT surveys. Findings from the in-depth interviews are contained in Section 7.4. Section 0 summarizes the key findings from the process evaluation.

7.1 Survey Disposition

To evaluate the effect that Power Manager events have on DLC and BYOT participants, two surveys were sent to random samples of each program's participant population; a post-event survey immediately following a Power Manager event, and a nonevent survey immediately following a hot day where no Power Manager event was called. Table 7-1 presents summary of temperatures during the event and nonevent surveys for both DEC DLC and DEC BYOT customers.

For DLC, the post-event survey was completed by 94 customers following an event day (July 28) and the nonevent survey was completed by 68 customers following a hot nonevent day (July 15). The post-event survey was launched the evening of the event day, and the nonevent survey was launched the evening of the baseline day. For BYOT, the post-survey was completed by 106 customers following an event day (August 11) and the nonevent survey was completed by 82 customers following a hot nonevent day (July 15). The event survey was launched the morning following the event day, and the nonevent survey was launched the afternoon of the baseline day. The nonevent day, July 15, was comparable to the two event days in temperature during the event period.

Table 7-1: Summary of Event and Nonevent Surveys

Jurisdiction & Technology	Date	Event ? (Y/N)	Completes	Survey Start Time	Maximum Daily Temperature (⁰F)	Average Event Temperature (⁰F)	Maximum Daily Heat Index (⁰F)	Average Event Heat Index (⁰F)
DEC DLC	7/28/2021	Y	94	7/28 5:00 PM	91	88.6	97.3	93.6
DEC DLC	7/15/2021	N	68	7/15 4:30 PM	88.7	86.6	93.7	91.9
DEC BYOT	8/11/2021	Y	106	8/12 9:00 AM	90.3	85.2	98.7	91.7
DEC BYOT	7/15/2021	N	82	7/15 4:30 PM	88.7	86.6	93.7	91.9

Table 7-2 presents overall response rates for each program by the method of survey administered (phone/web) for event and nonevent surveys. DLC's overall response rate for the two surveys was 3.7%. Response rates were higher for customers surveyed by phone, with 7.6% of customers on event days and 5.8% of customers on nonevent days responding via phone, compared to 2.8% of customers on event days and 2.5% of customers on treatment days responding via web. The overall response rate for the two BYOT surveys was 4.0%. Response rates were higher for customers surveyed by phone, with 7.0% of customers on event days and 5.4% of customers on nonevent days responding via phone, compared to 2.9% of customers on event days and 2.5% of customers on treatment days responding via web.

Table 7-2: Response Rates by Program and Administration

Overall Response Rates					
Group	Web Treatment	Web Control	Phone Treatment	Phone Control	Total
DEC DLC (n=162)	2.8%	2.5%	7.6%	5.8%	3.7%
DEC BYOT (n=188)	2.9%	2.5%	7.0%	5.4%	4.0%

7.2 DLC Survey Results

7.2.1 Participant Background

Aside from occasional program communications to participants, the primary way that Duke Energy customers experience the Power Manager program is during load control events. A majority of survey respondents, 90.5%, stated that there is normally someone home between the hours of 1:00 pm and 7:00 pm on weekdays. Similarly, large proportions of respondents also reported that they are frequent users of their air conditioning systems. Table 7-3 shows the percentage of respondents that reported they used their air conditioners every day for four different time periods and day type combinations. Generally, between 83.3% and 89.7% of Power Manager survey respondents reported using their air conditioners every day during weekday afternoon and evenings. During the weekend, the rates of customers that use their air conditioners everyday increases; between 85.7% and 95.3% of customers stated that they run their units during weekend afternoons and evenings. Statistically significant differences in response patterns between post-event and nonevent respondents were not observed. The percentage of post and nonevent respondents that use their air conditioner during both weekdays and weekend afternoons and evenings is significantly higher than respondents in 2019, potentially due to an increase in work from home employment.

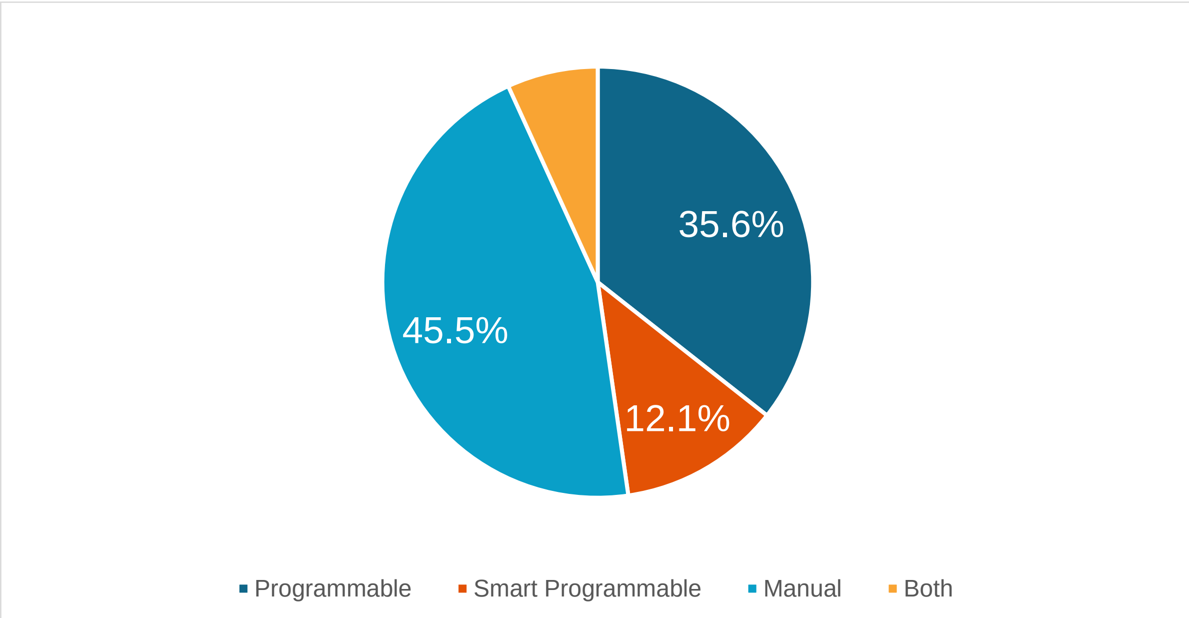
The survey responses indicate that Power Manager participants are largely at home and using their air conditioners during the times that the program is likely to be launched as a resource. As such, monitoring participant comfort levels is confirmed to be an important evaluation activity so that thermal comfort can be maintained at high enough levels to retain customer participation.

Table 7-3: Percent of Respondents that Use their AC Every Day during… – DLC

Day and Time	% of Post-event Respondents (n=94)	% of Nonevent Respondents (n=68)
Weekday Afternoons 1 PM - 7PM	89.7%	88.7%
Weekend Afternoons 1 PM - 7 PM	93.2%	95.3%
Weekday Evenings 7 PM - Midnight	83.3%	84.4%
Weekend Evenings 7 PM - Midnight	85.7%	92.1%

In addition to occupancy patterns and frequency of air conditioning usage, Power Manager participants' experience with the program is affected by how they operate their air conditioning systems. Survey responses show that there is a mix of both manual and programmable thermostats installed in the homes of DLC Power Manager participants. Figure 7-1 summarizes the types of thermostat(s) that survey respondents reported. 35.6% of customers have a programmable thermostat, while 12.1% have a smart programmable thermostat. Another 45.5% of respondents said that they have a manual thermostat installed in their home; 6.8% have both a programmable and manual thermostat in their homes. There was no significant difference in thermostat types between post-event and nonevent survey respondents.

Figure 7-1: “What type of thermostat do you have?” (n=162) – DLC



Respondents were asked which statement best describes how they use their AC system(s) during the summer. Across all respondents, 63.9% stated that they keep their thermostat set at a constant temperature, 17.7% stated that they manually adjust the temperature settings at different times of the day, 11.4% reported using the programmability feature to allow the thermostat to cool to different temperatures at different times, and a further 5.1% state that they manually turn it on and off when it gets too cool or too hot. 1.9% of respondents stated that they never use their air conditioning. There was no significant difference in thermostat use between post-event and nonevent respondents. Table 7-4 shows how DLC respondents use their AC system during the summer.

Table 7-4: “Which of the following best describes how you operate your central AC system(s) during the summer?” – DLC

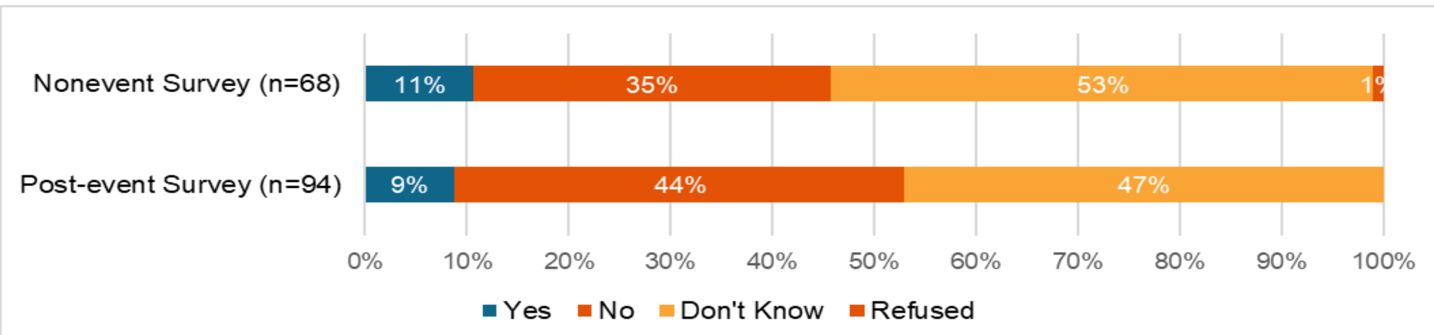
Survey	Keep it set at a constant temperature, so it runs whenever the temperature goes above it	Manually turn the AC on and off when needed	Manually adjust the temperature setting at different times such as when you leave your home or go to bed at night	Allow the program to automatically change the temperature at different times	Never use it	Total
Nonevent Survey (n=94)	62.7%	6.0%	17.9%	10.5%	3.0%	100.0%
Post-event Survey (n=68)	64.8%	4.4%	17.6%	12.1%	1.1%	100.0%
Total	**63.9%**	**5.1%**	**17.7%**	**11.4%**	**1.9%**	**100.0%**

7.2.2 Program and Event Awareness

DLC respondents across both post-event and nonevent surveys were asked if they were aware of the Power Manager program. Of all participants surveyed, 71.6% of DLC participants responded that they are familiar with Power Manager.

Both post-event and nonevent respondents were asked if they believed a Power Manager event occurred in the past few days prior to being surveyed. 10.6% of post-event respondents believed an event had occurred while 8.8% of nonevent respondents believed that an event had occurred. The responses were not significantly different between the post-event and nonevent respondents indicating that DLC participants are generally unaware of when events occur. Note that DLC participants were much less likely to state that an event had occurred in the past few days compared to BYOT participants, regardless of if an event had actually occurred.[2] Figure 7-2 displays the percentage of DLC respondents that believed an event occurred over the past few days.

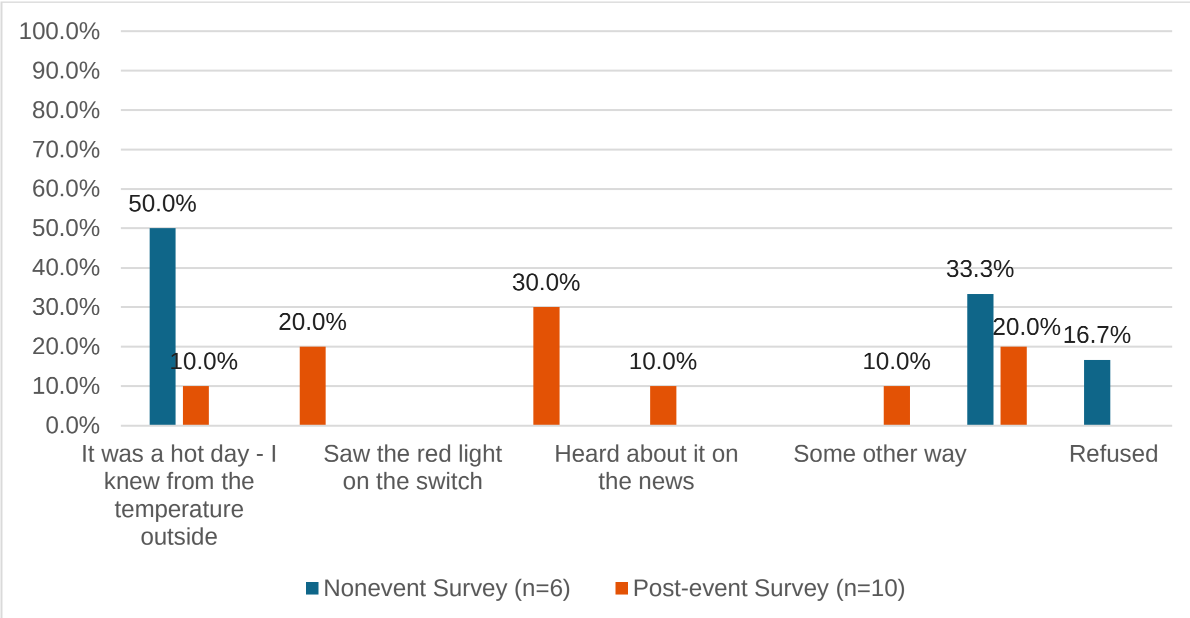
Figure 7-2: "Do you think a Power Manager event occurred in the past few days?" – DLC



Respondents that perceived an event were asked how they determined the event was occurring. Among respondents in the post-event survey, the most common reason given was participants did not hear the air conditioner running as they expected (30.0%). 50.0% of nonevent respondents stated they knew an event occurred because it was hot day outside while the remaining nonevent respondents said, "Don't Know" or "Refused." Figure 7-3 highlights the reasons that participants gave for believing an event occurred.

[2] See Section 7.3.2.

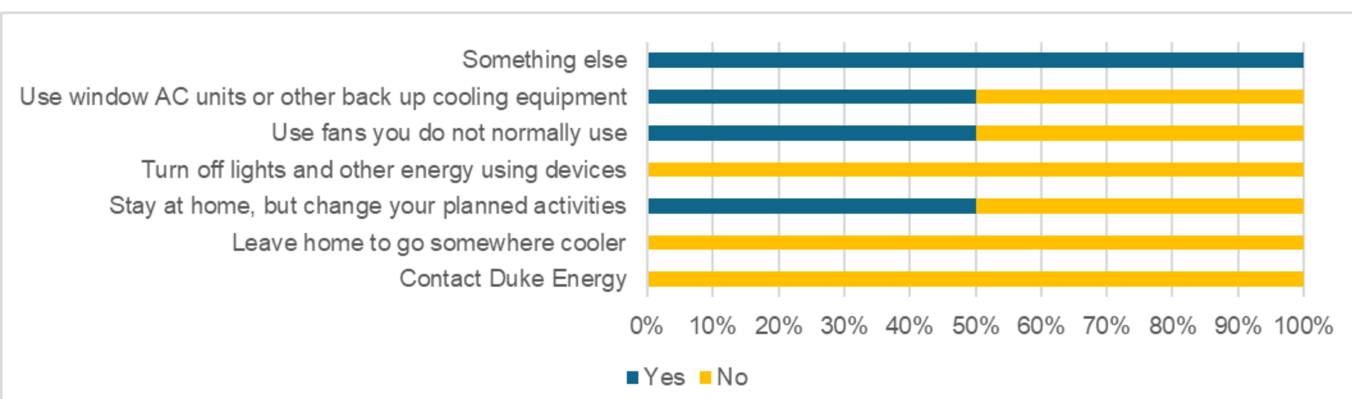
Figure 7-3: "How did you determine an event was occurring?" – DLC



Of those that believed an event had recently occurred, 40% of post-event respondents were able to correctly identify the day the event occurred on. Post-event and nonevent respondents had comparable distributions of when they believed the event occurred.

Respondents that believed an event had occurred and were home during the perceived event were asked whether they took any action in response, regardless of if an event occurred or not. 83.3% of all respondents did not take any action in response to a real or perceived event. Only one post-event and one nonevent respondent described which activities they took in response to the perceived event. DLC participants did not have the option to opt out of the event. Figure 7-4 displays actions taken by both post-event and nonevent respondents in response to a perceived event. "Something else" responses included turning down the AC and getting a cold drink.

Figure 7-4: Actions Taken due to Perceived Event: "Did you…" (n=2) – DLC



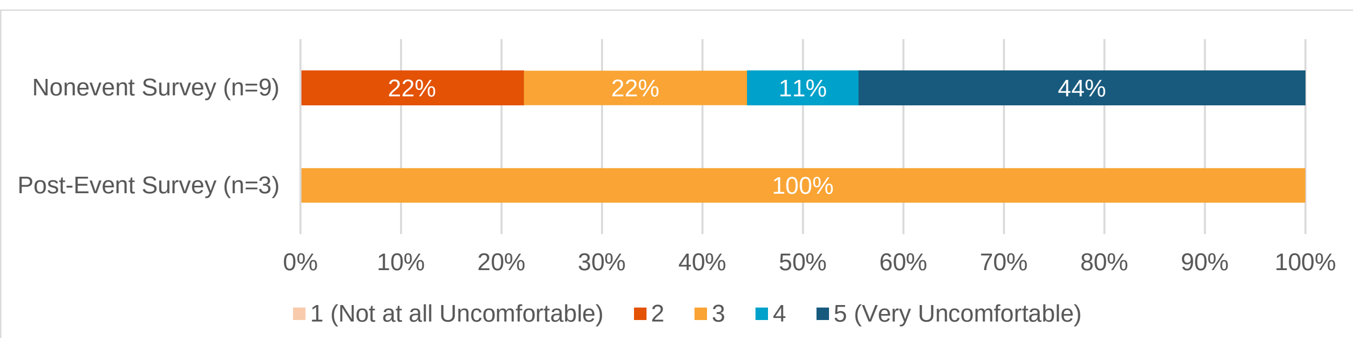
7.2.3 Program Respondent Comfort

To measure if DLC participants experience thermal discomfort during events, post and nonevent survey respondents were asked several questions about their comfort during the event day.[3] First, post-event respondents were asked if they experienced any thermal discomfort during the event day and nonevent respondents were asked if they experienced any thermal discomfort during the baseline day. Overall, 12.9% of all respondents said they were uncomfortable in their homes at any time during the day in question. 9.1% of post-event respondents and 14.7% of nonevent respondents said they were uncomfortable in their home at some point during the day in question. The difference between the percentage of respondents that reported discomfort is not statistically different at the 90% level of confidence. Put differently, the survey data presents no evidence that Power Manager events increase thermal discomfort in the home.

The respondents that reported discomfort on the day in question were asked when their discomfort started and ended. Respondents in the post-event survey did not differ significantly from those in the nonevent survey in the hours during which they reported feeling uncomfortable, indicating that the timing of thermal discomfort was not linked to the Power Manager event.

Customers that responded that they experienced discomfort on the event or non-event day were asked to rate their discomfort on a scale of 1-5. A response of 1 represented not at all uncomfortable while a response of 5 represented very uncomfortable. Figure 7-5 displays the results. No participants stated they were not at all uncomfortable. All post-event respondents that stated they were uncomfortable during the event rated their discomfort at 3. In contrast, nonevent respondents rated their discomfort from 2-5, with 44.4% stating they were very uncomfortable.

Figure 7-5: “Please rate your discomfort on a scale of one-to-five…” – DLC

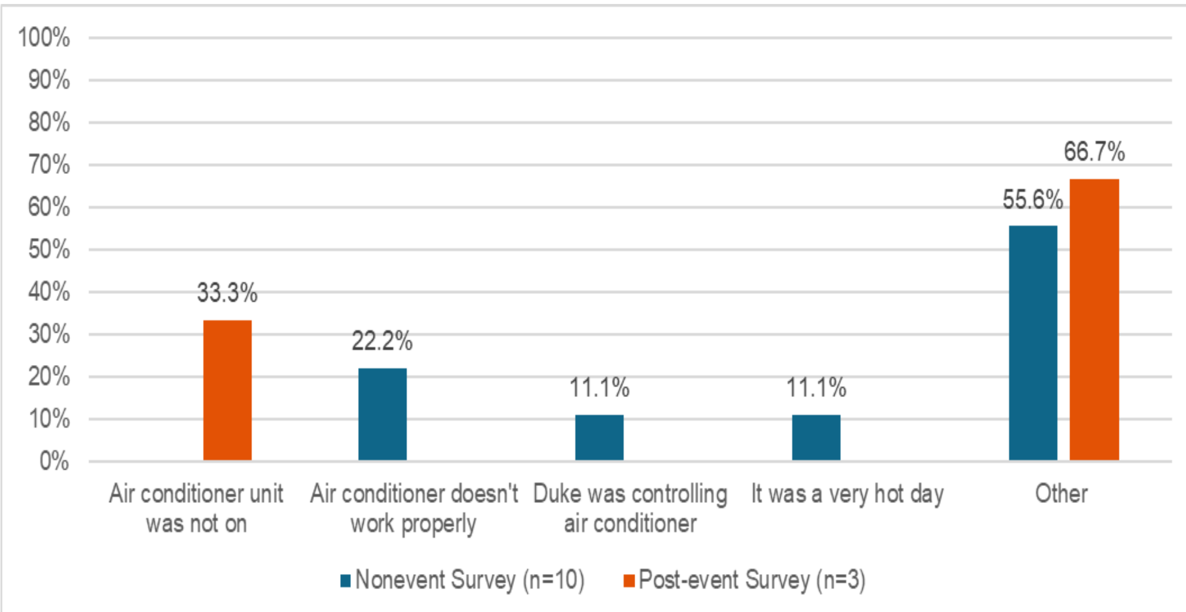


Respondents that stated they were uncomfortable during the event or nonevent day were asked to what they attributed their discomfort. This question was asked before any discussion of Power Manager events, to build an understanding of how customers perceive events. A majority of respondents did not attribute their discomfort to Duke Energy controlling their air conditioner through the Power Manager program, with this response comprising 0% of post-event responses and 11.1%

[3] Due to a survey programming error at the end of the survey deployment period, 57 post-event survey responses were dropped from analysis for the four questions pertaining to thermal discomfort.

of nonevent responses. Figure 7-6 displays respondents' attributions of thermal discomfort. 33.3% of post-event respondents stated that the air conditioner was not on while the remaining 66.7% of post-event respondents stated another reason. Of the "other" responses, most included situational reasons such as the house has poor insulation, or they had the oven on in their home. Nonevent responses were more varied.

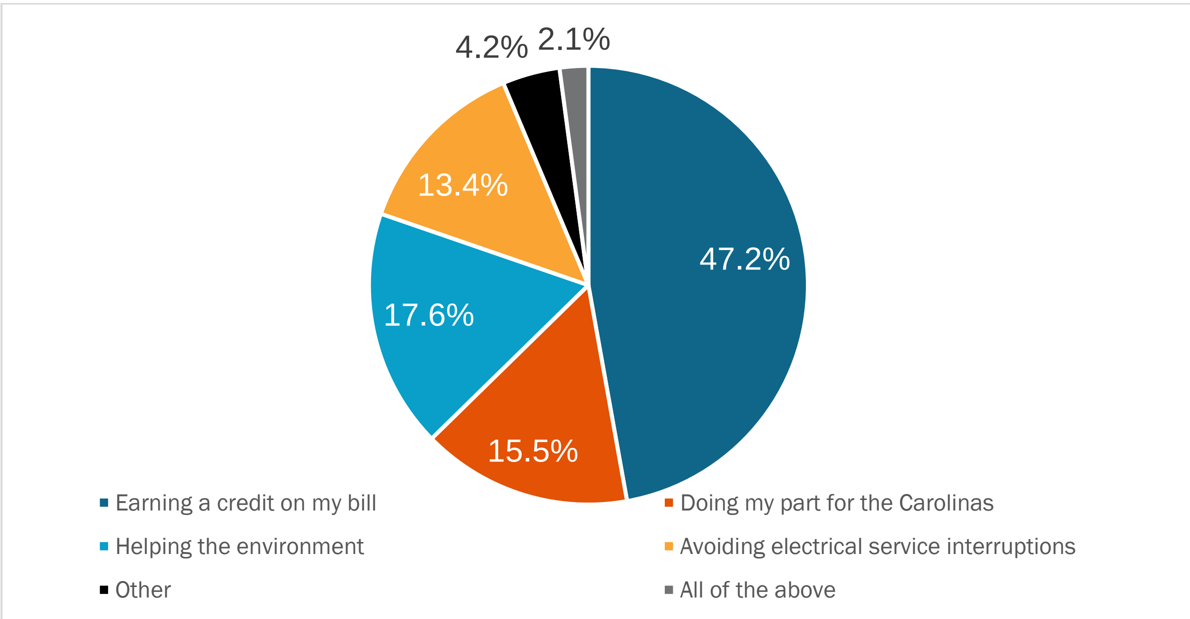
Figure 7-6: "What do you think caused your home to be uncomfortable?" – DLC



7.2.4 Motivation, Satisfaction, and Barriers

Participants in the post-event and nonevent surveys were asked to choose their primary motivation for enrolling in Power Manager from the following list: earning bill credits, helping the environment, doing their part for the Carolinas, avoiding electrical service interruptions, or an open-ended response. The most common reason stated by respondents in both surveys was "earning a bill credit" (47.2%). Other common responses included "helping the environment" (17.6%), and "doing my part for the Carolinas" (15.5%). Respondents that gave an open-ended response often stated "all of the above" which constituted 2.1% of all responses. Figure 7-7 displays the motivations for enrollment chosen by respondents.

Figure 7-7: "Which of the following reasons was most important to you when enrolling in the Power Manager program?" (n= 162) – DLC

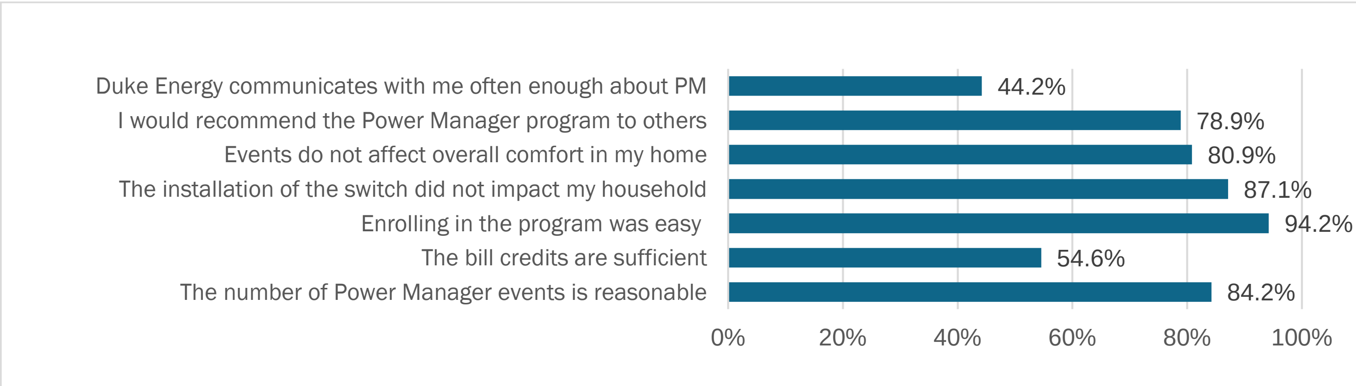


Respondents were asked about how strongly they agreed or disagreed with a series of statements pertaining to satisfaction with Power Manager. Figure 7-8 shows the percentage of respondents that agree or strongly agree with statements about satisfaction with the program.

Overall, Power Manager is very well-received among DEC DLC participants. 80.9% of participants agreed or strongly agreed that events do not affect their comfort in their home and 87.1% said that the installation of the switch did not impact their household. 94.2% agree or strongly agree that enrolling in the program was easy and 84.2% agree that the number of Power Manager events is reasonable. 78.9% of participants agree or strongly agree that they would recommend the program to others.

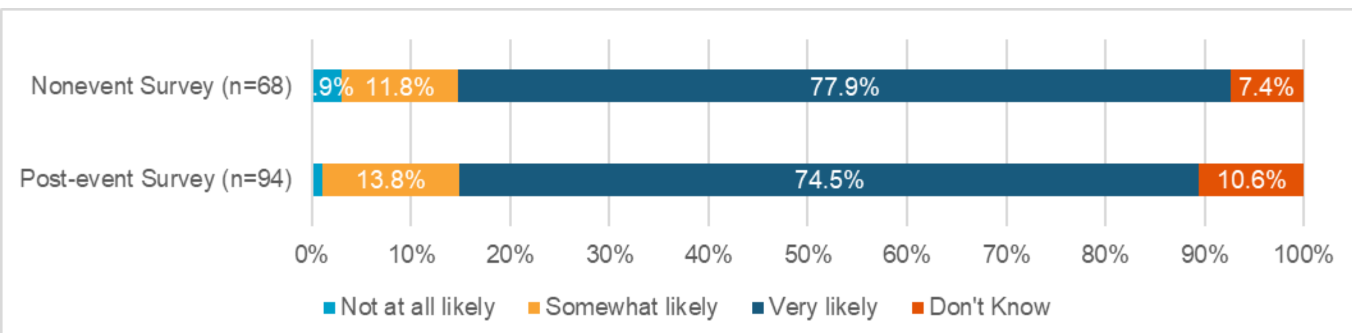
Two areas fall significantly lower in participant satisfaction: communication from Duke Energy and bill credits. 44.2% of participants agree or strongly agree that Duke Energy communicates with them often enough about the program while 34.7% slightly or strongly disagree with this statement. 21.1% of respondents were neutral to the prompt. While 54.6% stated that bill credits are sufficient, 18.2% slightly or strongly disagreed and 27.3% neither agreed nor disagreed.

Figure 7-8: Percentage of Participants that Agree or Strongly Agree with Satisfaction Statements (n=162) – DLC



Participants were asked how likely they were to stay enrolled in Power Manager. A majority (88.9%) of DLC participants were somewhat or very likely to remain enrolled in Power Manager. Of the few participants that stated they were unlikely to stay enrolled, their reasons included: recently installed solar panels, and a reluctance to granting thermostat control to Duke Energy. Figure 7-9 displays DLC survey respondents self-reported likelihood of staying enrolled by survey. Post-event and nonevent responses were very similar, showing that recently experiencing an event does not impact participants' likelihood of remaining enrolled in Power Manager.

Figure 7-9: How likely are you to stay enrolled in Power Manager? – DLC



At the end of the survey, participants were given the option to provide suggestions and feedback in an open-ended format. For DEC DLC, areas receiving the most suggestions were program communication, event notifications, and incentive levels. A significant portion of participants also suggested expansions of the program and increasing program enrollment. Table 7-5 displays the frequency of respondent suggestions. One-quarter of respondents suggested no improvements.

Table 7-5: Open-ended Respondent Suggestions (n=59) – DLC

Response	Frequency
No Suggestion[4]	23.7%
Suggestions on Communication	16.9%
Communicate Bill Credit	5.1%
Event Notifications	15.3%
Increase Bill Credit	20.3%
Increase Services/Program Reach	10.2%
Other	8.5%
Total	**100.0%**

Thirteen DLC participants had suggestions related to program communication. These comments and suggestions were segmented into four areas of feedback: communicate how Power Manager works, communicate about the program more frequently, alleviate customer concerns, and communicate enrollment status. Four participants suggested communication on how Power Manager works:

- "Email me the details of the program"

Two participants suggested more frequent program communications:

- "More frequent communication on this program"

Three respondents made suggestions related to their concerns, often not related to the Power Manager program; four respondents made suggestions about communication of enrollment status:

- "Needs more updates on the program and announcements would help. Email me since that's where I get my bill. Would be a great way to know that I was on the program and just add it to the bill, so I know I'm enrolled in the program"

Some participants also stated in response to a previous question that they would not recommend Power Manager to others because they did not know they were enrolled, also indicating interest in communications on enrollment status.

Nine participants expressed that they would like event notifications, with some detailing how they should be notified:

- "Have an alert sent to the homeowner when instituting such an event."
- "If I could know when an event is triggered, perhaps displayed on thermostat screen or beeping"
- "Alert the customer when an event takes place"

[4] These responses are where the respondent wrote in "I don't have any suggestions".

Eleven participants suggested increases to the incentives and three suggested increased communication around incentives.

- "Make it more of monetary incentive. It is not very much."
- "Bigger payments and publicity."
- "Better communication, if we do get a credit, make it more visible"

Six participants gave suggestions to expand the program and expressed a desire to see greater participation:

- "Increase the incentive to get more people on it to help the climate. That is all."
- "If more people knew about it, they may be more apt to use it. Advertise more often."
- "Make it mandatory instead of voluntary"
- "Provide more ways to save energy"

Overall, Power Manager is a well-received program among DEC DLC participants. While motivations for enrolling in the program vary, the majority enroll to save money on their bill. A majority of DLC participants would recommend the program to others and rate their likelihood of staying enrolled as high. Participants agreed that installation of the switch did not disrupt their home and enrolling in the program was easy. Most participants find the number of Power Manager events reasonable, and do not find their home uncomfortable during events. Survey responses show that DLC respondents were unable to identify when an event had occurred and did not experience thermal discomfort during the event. While around half of respondents were satisfied with bill credits and communications from Duke Energy, these two areas had the lowest levels of participant satisfaction. When given the chance to share feedback and suggestions on bill credits, customer requested higher bill credits – sometimes to increase enrollment – and streamlined communication around bill credits. Participants requested increased communication on how Power Manager works, more frequent communications about the program, and communication of enrollment status most often. Participants of the Power Manager program expressed environmental values. The second most common motivation for enrolling in Power Manager was to help the environment, and some participants suggested increased scope and advertising for the program to support a larger environmental impact.

7.3 BYOT Survey Results

7.3.1 Participant Background

The surveys administered to BYOT participants were very similar to those administered to DLC participants. Some differences in the instrument exist where BYOT customers experience the program differently due to the difference in enabling technology (i.e., a smart thermostat in the home rather than a switch outside on the CAC unit).

BYOT respondents were asked a series of questions regarding their current AC usage habits and behaviors. These questions included whether household members were typically home during weekdays during the summer and how frequently they used AC devices during peak hours. The large majority of respondents (88.0%) reported that a member of their household was home during weekdays, and most respondents stated that they used their air conditioning everyday both in the afternoon and evening, on both weekends and weekdays. Respondents in the post-event survey were more likely to report that they used their air conditioning systems more during weekday evenings, but there were no other statistical differences in frequency of use between the two groups.

Table 7-6 highlights the percentage of respondents that reported that they used their air conditioning system every day on weekdays and weekends during afternoons (1 PM to 7 PM) and evenings (7 PM to midnight).

Table 7-6: Percentage of Respondents that Use AC Every day during… – BYOT

Day and Time	% of Post-event Survey (n=106)	% of Nonevent Survey (n=88)
Weekday Afternoons 1 PM – 7 PM	91.8%	83.3%
Weekend Afternoons 1 PM – 7 PM	87.3%	86.3%
Weekday Evenings 7 PM – Midnight	81.2%	70.5%
Weekend Evenings 7 PM – Midnight	89.1%	77.2%

Participants must have at least one “smart” or internet connected programmable thermostat to be enrolled in the BYOT program. 92 (48.9%) respondents own a single smart thermostat and used no manual thermostats. Of those that had two thermostats, 71 (37.8%) respondents said that both of their thermostats were smart or programmable thermostats, while 12 (6.4%) owned one smart thermostat and one manual thermostat. 11 respondents (5.9%) owned more than two smart thermostats.

Respondents in both surveys were asked which of a series of possible responses describes how they typically use their air conditioning systems. Table 7-7 details how respondents in each survey described their AC use. These responses were not statistically different between the two surveys.

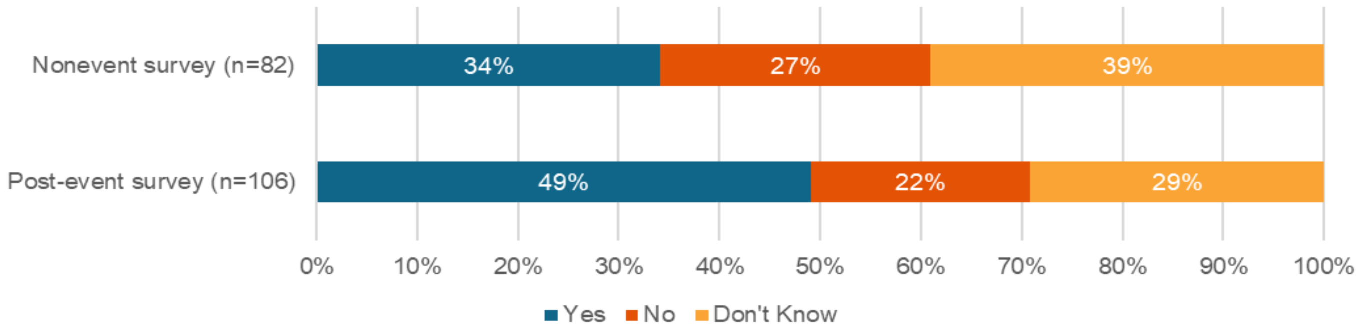
Table 7-7: "Which of the following best describes how you operate your central AC system(s) during the summer?" – BYOT

Survey	Keep it set at a constant temperature, so it runs whenever the temperature goes above it	Manually turn the AC on and off when needed	Manually adjust the temperature setting at different times such as when you leave your home or go to bed at night	Allow the program to automatically change the temperature at different times	Never use it	Total
Nonevent Survey (n=82)	29.3%	7.3%	14.6%	47.6%	0.0%	100.0%
Post-Event Survey (n=106)	26.4%	3.8%	11.3%	58.5%	0.0%	100.0%
Total	**27.7%**	**5.3%**	**12.8%**	**53.7%**	**0.0%**	**100.0%**

7.3.2 Program and Event Awareness

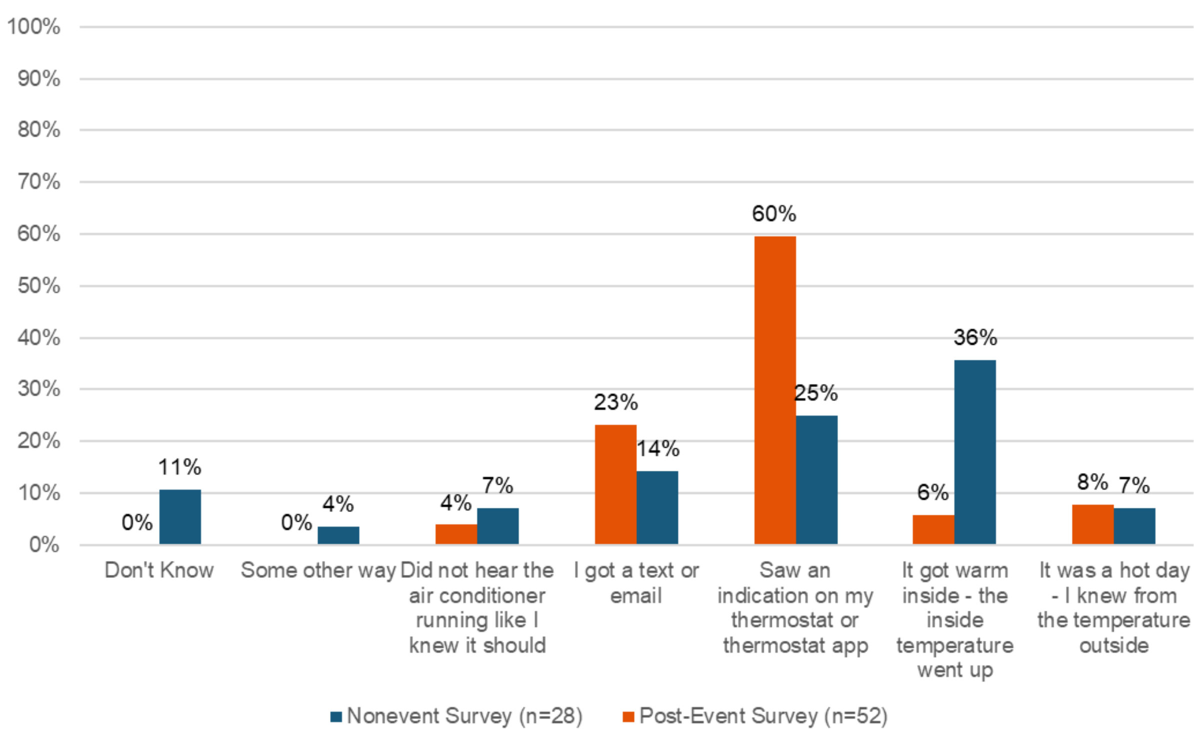
In the BYOT program, all 188 respondents in the post-event and nonevent surveys were asked if they were familiar with Power Manager. 78.2% of all respondents surveyed reported that they were familiar with the program. All respondents in the post-event and nonevent surveys were asked if they thought a Power Manager event occurred in the past few days. Of the 106 respondents in the post-event survey following the actual event on August 11, 49.1% of them correctly indicated that an event had occurred. For comparison, 34.2% of the respondents in the nonevent survey falsely believed that an event had occurred. The proportion of respondents that believed an event occurred following the actual event was not statistically different from the percentage of respondents that believed an event occurred following the nonevent day. Figure 7-10 shows the percentages of respondents that believed that an event occurred in the post-event and nonevent surveys.

Figure 7-10: "Do you think a Power Manager event occurred in the past few days?" – BYOT



Respondents that stated an event happened, whether they were correct or not, were then asked how they determined an event was occurring. Among respondents in the post-event survey, the most common reason given was participants receiving a notification on their thermostat (59.6%). In the nonevent survey, the most common reason participants believed that an event occurred was the temperature increasing in their home (35.7%). Figure 7-11 highlights the reasons that participants said led them to believe that an event occurred.

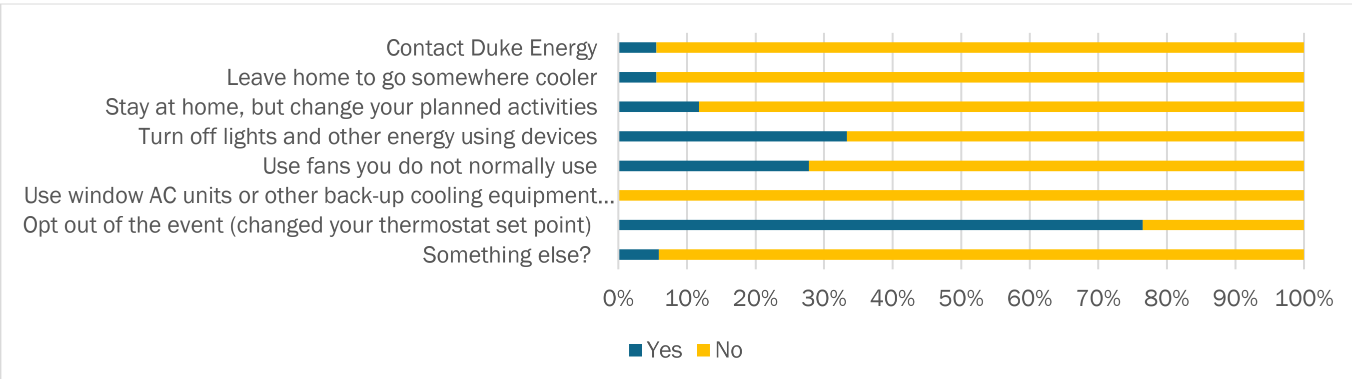
Figure 7-11: "How did you determine an event was occurring?" – BYOT



Those that believed an event occurred were asked which day they believed the event happened on. 60.0% of the respondents in the post-event survey that believed an event occurred recently correctly identified the event day (August 11).

Respondents that believe an event occurred were asked whether they took any action in response, regardless of if an event occurred. The majority of respondents (67.3%) did not take any action in response to a real or perceived event. Figure 7-12 highlights the most common responses. The most common action respondents took was opting out of the event altogether. Other common responses included turning off lights and other devices or using additional fans to keep cool. Very few respondents reported utilizing additional AC units, changing their planned activities, leaving home, or contacting Duke Energy in response to an actual or perceived event.

Figure 7-12: Actions Taken in Response to Real or Perceived BYOT Events: "Did you..." (n=18) – BYOT



Importantly, these responses indicate that participants are in some cases aware of Power Manager events, but do not drastically alter their behavior in response to a real or perceived BYOT event. The most common way that participants became aware of events is via a notification on their thermostat. In some cases, customers on nonevent days misattributed warm temperatures inside their homes to a Power Manager event. While some respondents did choose to opt out of the event, the majority of respondents took no actions when they believed an event occurred.

7.3.3 Program Respondent Comfort

Respondents in both the post-event and nonevent surveys were asked if there was any time during the event day (in the case of the post-event survey) or the nonevent day (in the case of the nonevent survey) that their home was uncomfortable.[5] The majority of respondents in both groups, 69.3%, indicated that they were not uncomfortable. The proportion of respondents that reported experiencing any discomfort was not significantly different between the post-event and nonevent surveys, indicating that the Power Manager event did not cause an increase in participant discomfort.

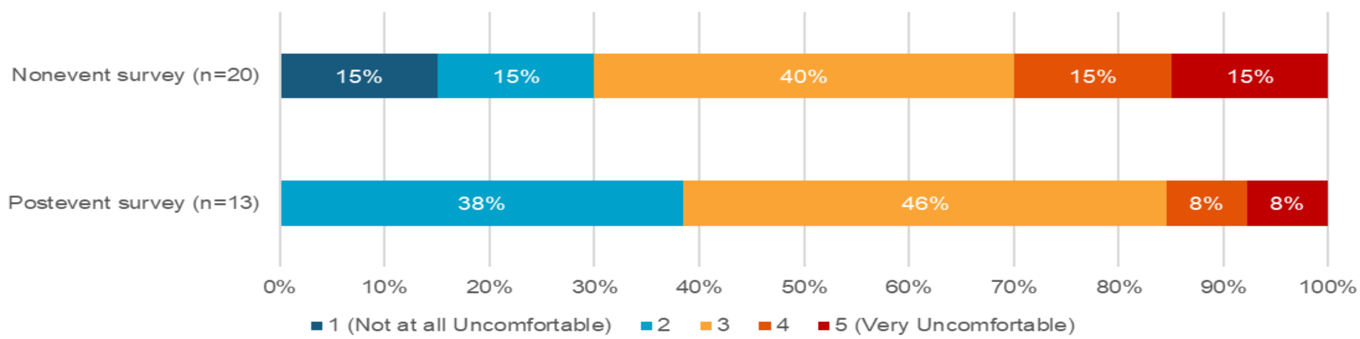
The respondents that reported any discomfort were asked when their discomfort started and ended. Respondents in the post-event survey did not differ significantly from those in the nonevent survey in

[5] Due to a survey programming error at the end of the survey deployment period, 25 post-event survey responses were dropped from analysis for the four questions pertaining to thermal discomfort.

the hours during which they reported feeling uncomfortable, indicating discomfort was not strongly tied to Power Manager event hours.

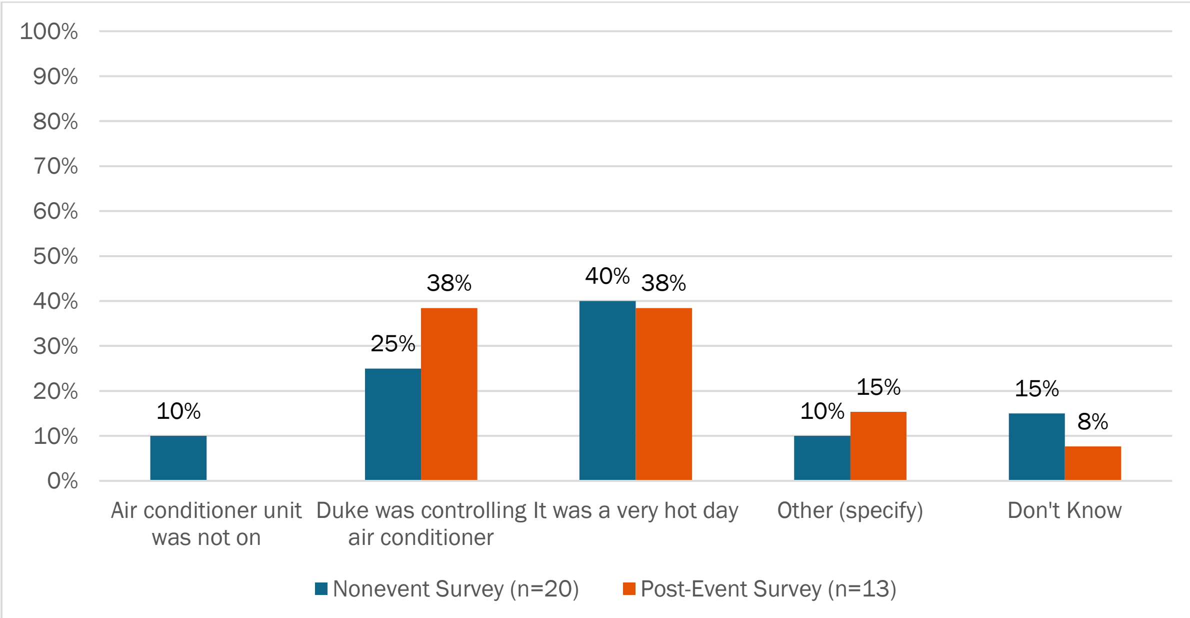
Respondents that indicated they experienced discomfort were asked to rate their discomfort on a scale from 1 (not at all uncomfortable) to 5 (very uncomfortable). The majority of respondents that reported discomfort in both surveys did not describe it as severe, with 75.8% of all respondents in both surveys describing their discomfort as between 1 (not at all uncomfortable) and 3 on the scale. The top-two box score (the percentage of respondents rating their discomfort as a 4 or 5) did not significantly differ between the two surveys, indicating that the severity of reported discomfort among customers during the actual event did not differ from levels of discomfort reported during a similar nonevent day. Figure 7-13 presents respondent ratings of discomfort by group.

Figure 7-13: “Please rate your discomfort on a scale of one-to-five” – BYOT



Lastly, respondents that indicated they felt uncomfortable were also asked what they believed caused the discomfort in their home. 38.5% of the respondents in the post-event survey attributed the discomfort to Duke Energy controlling their air conditioning. For comparison, only 25.0% of the respondents in the nonevent survey attributed their discomfort to Duke Energy controlling their air conditioning unit. These proportions were not statistically different from one another. Figure 7-14 presents reported causes of discomfort for respondents in the post-event and nonevent surveys. It is important to note that this question was asked conditional on respondents reporting discomfort in the first place; the majority of participants in both surveys did not report any discomfort.

Figure 7-14: "What do you think caused your home to be uncomfortable?" – BYOT



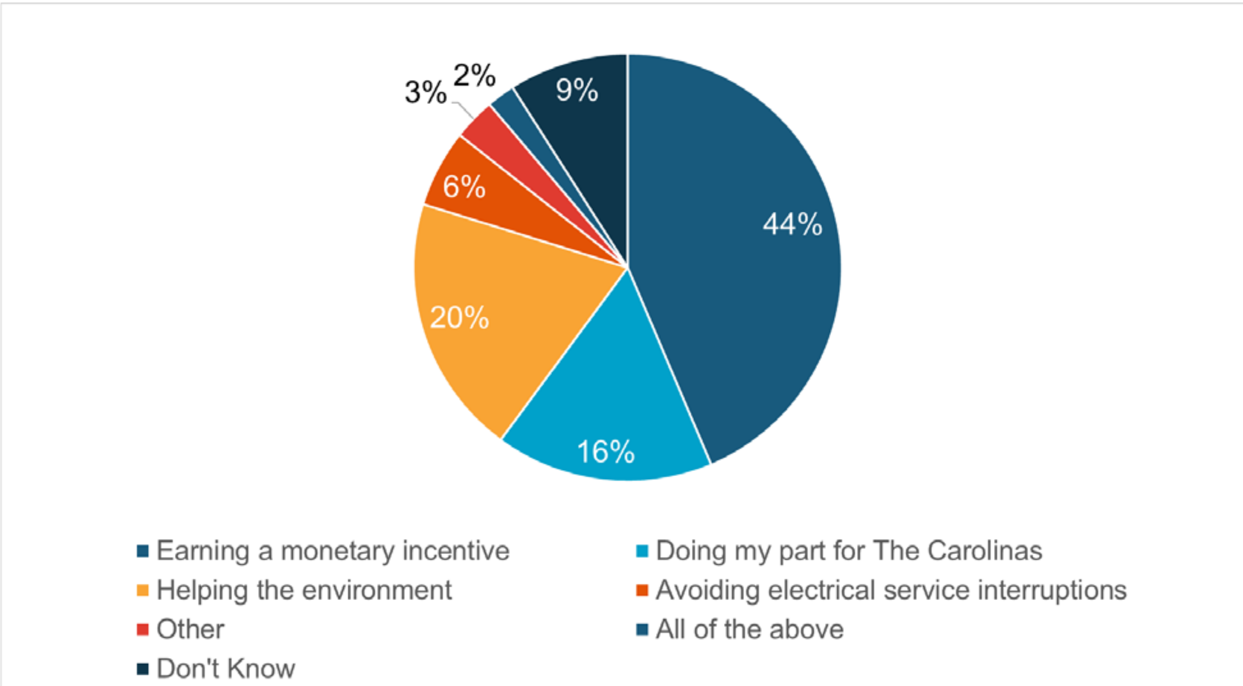
Respondent reports of thermal discomfort from the post-event and nonevent surveys indicate that reported thermal discomfort during BYOT Power Manager events is not significantly more common or more severe than reported discomfort during similar hot summer days. Importantly, this result implies that BYOT Power Manager events do not cause increased discomfort for customers. Respondents that experienced thermal discomfort during the Power Manager event were not significantly more likely to attribute this discomfort to the program than respondents reporting thermal discomfort during the nonevent day.

7.3.4 Motivation, Satisfaction, and Barriers

Participants in the post-event and nonevent surveys were asked what their primary motivation for enrolling in Power Manager was. The most common reason stated by respondents in both surveys was "earning a bill credit"[6] (43.6% of respondents). Other common responses included "helping the environment" (19.7% of respondents), and "doing my part for the Carolinas" (16.5% of respondents). Figure 7-15 showcases the most important motivations for enrollment for respondents in the BYOT program.

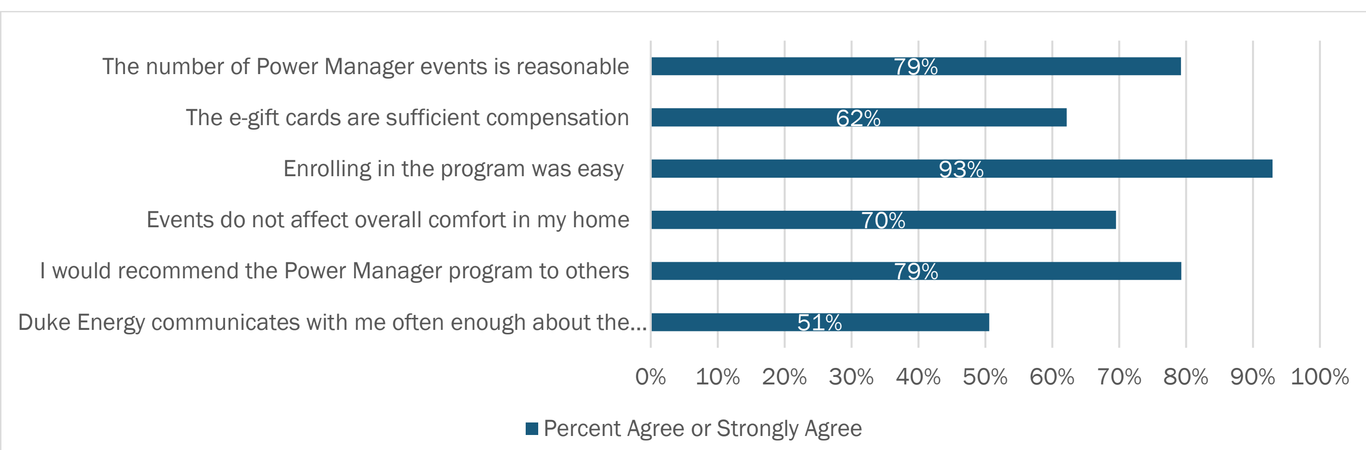
[6] DEC BYOT customers in fact receive electronic gift ("e-gift") cards rather than bill credits as a participation incentive, however BYOT survey respondents saw "earning a bill credit" on their surveys like the DEC DLC customers did, who do receive bill credits as a participation incentive.

Figure 7-15: “Which of the following reasons was most important to you when enrolling in the Power Manager program?” (n=188) - BYOT



BYOT participants were asked how strongly they agreed or disagreed with a series of statements about Power Manager. Respondents were asked to rate their agreement on a scale from 1 (strongly disagree) to 5 (strongly agree). Figure 7-16 showcases the percentage of respondents that “agreed” or “strongly agreed” with these statements.

Figure 7-16: Percentage of Participants that Agree or Strongly Agree with Satisfaction Statements (n=188) – BYOT



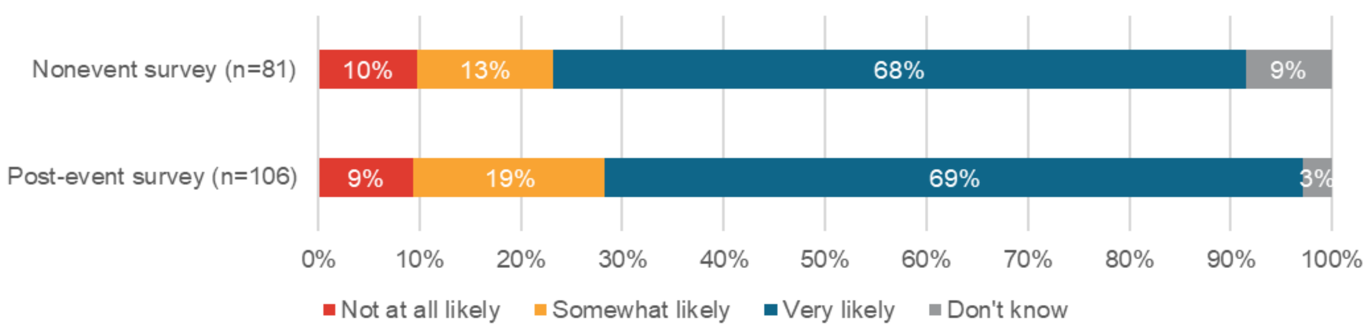
Generally, respondents were positive about Power Manager. 92.9% of respondents agreed or strongly agreed that enrolling in the program was easy. 79.2% of the respondents agreed that the number of events was reasonable. 79.3% of respondents stated that they would recommend Power Manager to others.

Of the statements to which respondents were least likely to say they agreed, 27.3% of respondents disagreed or strongly disagreed that Duke Energy did not communicate with them often enough about the program, and 16.9% of respondents disagreed or strongly disagreed that the e-gift cards were not sufficient compensation.

Both the top-two (percentage that responded “strongly agree” and “agree”) and bottom-two (percentage that responded “strongly disagree” and “disagree”) box scores were compared for respondents in the post-event and nonevent surveys. Compared to respondents in the nonevent survey, participants in the post-event survey were more likely to “disagree” or “strongly disagree” that the e-gift cards were sufficient compensation. However, there were no other statistical differences in the top-2 or bottom-2 box scores for any of the statements between the post-event and nonevent surveys.

Respondents were asked how likely they were to remain enrolled in Power Manager. 68.6% of respondents in both surveys said that they were “very likely” to remain in the program. There was no statistical difference in the likelihood of remaining enrolled between respondents in the post-event survey and the nonevent survey. Figure 7-17 presents the responses to this question by survey.

Figure 7-17: “How likely are you to stay enrolled in Power Manager?” – BYOT



Respondents that stated they were unlikely to recommend Power Manager to others (responded with a score of 1 or 2) or that they were “not at all likely” to remain in the program, were asked why they would not recommend the program. Two respondents stated that were not communicated with enough regarding the program.

> “Should be informed when there is power management. Otherwise at times people may think there is an issue with AC.”

> “Because on summer days it gets pretty hot and it feels like a notification would help more as opposed to it happening automatically and finding out when I'm hot.”

Two respondents who worked from home or had children felt that the program caused too much discomfort for them and their families.

> "It gets too hot in the house. Some people work from home and have to deal with the deadly heat when you change the temperature."
> "Kids that nap in afternoon are bothered by the heat."

Four participants simply stated that they did not enjoy ceding control of their AC systems during events.

> "I don't like the idea of someone else adjusting my thermostat."
> "I would like to be control of my air conditioning"

The survey concluded by allowing respondents to submit suggestions for improving the Power Manager program. 66 respondents offered suggestions for the program. Table 7-8 highlights common responses among participants.

Table 7-8: Open-ended Respondent Suggestions (n=87) – BYOT

Response	Frequency
No Response[7]	18.4%
Suggestions on Communication	21.8%
Communicate Incentive	5.7%
Event Notifications	20.7%
Increase Incentive	10.3%
Change Incentive (bill credit instead of e-gift card)	5.7%
Other	17.2%
Total	**100.0%**

The most common suggestion, offered by 35 respondents, was that Duke Energy communicate more often with participants, either regarding events, incentives, or the program in general.

> "Notify customers if there is a chance it might happen"
> "Increased communication if possible. Events, when, why"
> "Push notifications on cell before they happen"
> "A little more clarification on the rebates available"
> "I would love to know the results of how we are benefiting the environment by enrolling in this program"

Other respondents suggested greater monetary incentives or for the incentive to be offered in the form of a bill credit instead of a e-gift card.

[7] These responses are where the respondent wrote in "I don't have any suggestions".

"Get a credit on my bill instead of a gift card"
"More incentives more gift cards and bill credits"

Overall satisfaction with Power Manager remains high among BYOT participants. The majority of surveyed respondents stated that they were likely to recommend the program to others. Respondents generally agreed that BYOT events did not cause discomfort, and that the number of events was reasonable. The main motivation for enrollment in Power Manager was financial compensation, but environmental reasons also played a role in driving customers to enroll in Power Manager. Customers felt that the weakest aspects of the program were the communication they received from Duke, especially surrounding events, and the incentives offered, with many participants wanting to receive notifications regarding events and wishing to receive a bill credit rather than a gift card.

BYOT participants that stated they were less likely to stay enrolled or recommend the program to others cited lifestyle or family needs as reasons why they would not remain enrolled or recommend. Specifically, participants mentioned working from home or living with small children as motivations for leaving the program. However, it is important to stress that these customers were a minority of participants, and that most BYOT customers intend to remain enrolled.

7.4 Interview Findings

Power Manager is an established Duke Energy demand-side resource that is actively used in the course of operating the Carolinas electric system. The demand savings delivered by Power Manager are made possible through the teamwork of internal and external stakeholders that support two distinct program options, the legacy DLC option and the new BYOT program option. The team manages program budget and goals, communicates with participants, maintains the event dispatch software for the DLC option, coordinates with the BYOT implementer on event option set-up, uses the BYOT implementer software for event dispatch, and generally manages to event dispatch protocols. The Power Manager team also interacts with the customer at every stage of the program lifecycle, from enrollment, device installation, to device removal. Four primary stakeholder groups – the Duke Energy program management team, EnergyHub, Eaton Power Systems, and Franklin Energy – work together to deliver Power Manager to Duke Energy Carolinas customers. Resource Innovations interviewed four individuals from all four organizations. Through our conversations with the Power Manager team, we observe that Power Manager continues to maintain customer-focused and team-oriented program operations.

The remainder of this section will describe the Power Manager customer offering in the Carolinas and what Duke Energy's activities are to bring in new program participants and deliver demand response load impacts to the system. A description of program operations follows immediately below, which is followed in turn by an outline of work that continues after each load control season concludes to ensure Power Manager's continued success. This section concludes with a review of the activities that are planned or currently underway to further improve program operations and participating customer experience.

7.4.1 Program Participation Recruitment and Enrollment

Duke Energy's 2021 enrollment and operational objectives are driven by their integrated resource plan (IRP) and carbon plan. Recruitment of Duke Energy Carolinas customers into Power Manager takes place year-round in order to meet program objectives. As of year-end 2021, Duke Energy had more than 280,000 customers in the Carolinas enrolled in the DLC and BYOT program options. The recruitment approach for the legacy DLC program offer and the BYOT program offer differ – we describe both approaches below.

7.4.1.1 DLC Program Option Recruitment

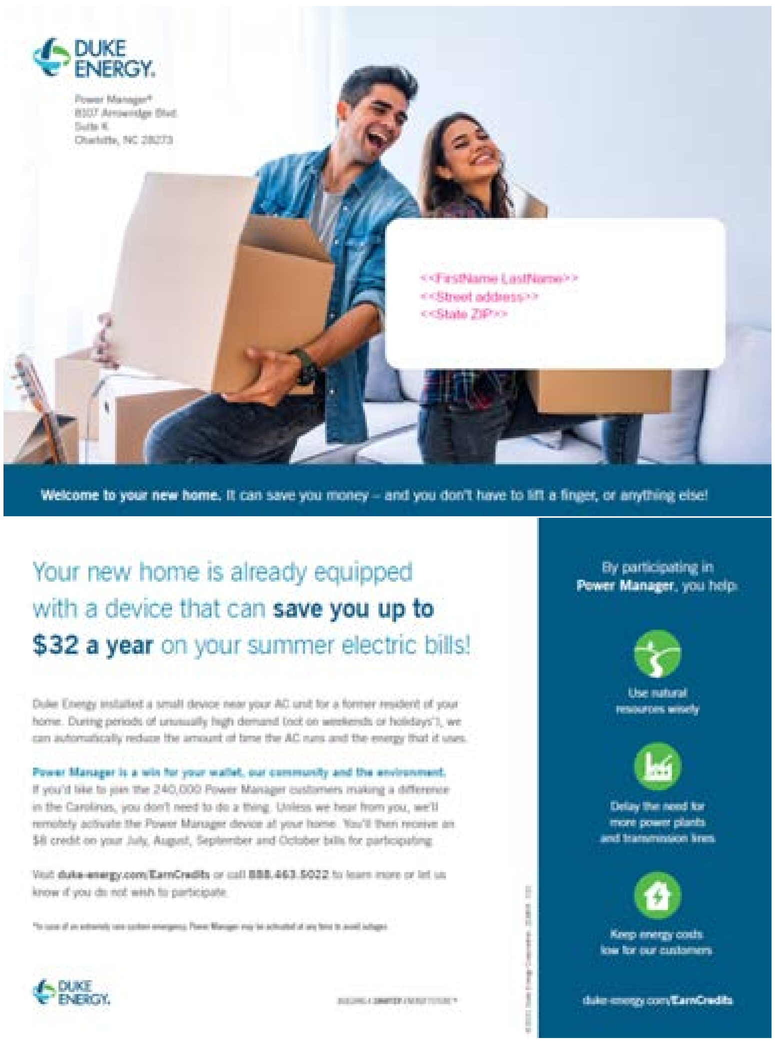
Although customers are sometimes recruited via other channels, outbound calling channel through a third-party call center provider, CustomerLink, is the predominant and most effective recruitment source for the DLC portion of the Power Manager program. The CustomerLink outbound call center is prepared to address common questions or concerns that Duke Energy customers who are not familiar with the program may have, in addition to the primary recruitment need to speak to the basic features and benefits of the program. Outbound callers are ready to explain that Power Manager's program features are friendly to the customer:

- Duke Energy's customer research has shown that the large majority of participants who are home during an event don't notice it.
- There are generally only five to seven events each summer; events typically end by 6 pm, which is when many customers are just coming home from work.
- Excepting rare emergency dispatches, air conditioning units enrolled in the program are cycled rather than completely curtailed.
- Power Manager is not called on weekends or weekday holidays, except for emergency program dispatch.
- The load control devices used by the program—switches that directly control the air conditioner's compressor—are a proven technology that do no harm to the customer's air conditioner or the home's electric distribution system. Because the device is installed on the compressor, which is typically located outside the home, as opposed installations on fans or thermostats, the program design does not require a technician to enter the customer's home—greatly reducing possible problems and subsequent reductions in participant satisfaction.

Additionally, Duke Energy provides CustomerLink with customer participation data in their other residential energy-efficiency programs. Having the ability to refer to this information during recruitment calls helps CustomerLink staff increase the effectiveness of their communications and credibility with potential Power Manager participants. Generally, Duke Energy has found that a person-to-person recruitment conversation is the most effective approach to generating enrollments. This is because most customers have questions as to how the program works and need the assurance of the right information provided in response to the right questions give them the confidence to agree to enroll.

A new enrollment pathway for Power Manager is a move-out-move-in (MOMI) process whereby DLC switches installed at participating households are not automatically removed when customers unenroll from the program. If a customer doesn't request that the DLC device be removed when unenrolling, the device is remotely deactivated. When a new customer moves in, the DLC switch remains deactivated if the former customer requested unenrollment. If the former customer was a program participant at the time of their move-out, the DLC switch is deactivated when the new customer moves in. New customers are mailed a postcard explaining the program and instructing them to call if they do not wish to participate. Figure 7-18 shows an image of the postcard sent for this communication.

Figure 7-18: Postcard for Customers Moving into Home with a Power Manager Device Installed



Power Manager provides $8 in bill credits on participating customers' July through October bills as an incentive to participate. Duke Energy also emphasizes messaging around community and environmental benefits to generate customer interest in and appreciation of the program. Duke

Energy has found that these preferences are correlated with older, higher income, and higher education demographics.

Franklin Energy is another partner, in addition to CustomerLink, that supports Power Manager. Franklin Energy manages Power Manager customer care and handles participants' inquiries about the program and requests for customer service. Franklin Energy is responsible for all Power Manager fieldwork which ranges from scheduling and routing DLC switch installations, managing an inventory of switches and preparing them for installation, training and managing a staff of device installers, responding to any device service calls, and fulfilling customer requests to remove load control devices. Installations for newly enrolled customers takes place within 45 days of the enrollment, but Franklin Energy works to complete those orders faster than that while the enrollment is fresh in the customer's mind. Franklin Energy also manages and staffs all DLC device quality assurance inspections. Duke Energy and Franklin Energy work together to develop targeted recruitment lists used by CustomerLink to allow efficient routing of installations for field technicians.

7.4.1.2 BYOT Program Option Recruitment

Recruitment into the BYOT program option takes a different pathway than the DLC program option. CustomerLink does not conduct outbound recruitment into the BYOT program option. Instead, Duke Energy relies on the smart thermostat manufacturers for most of the BYOT enrollment. Each of the participating thermostat manufacturers communicate with their customers through combinations of email, SMS text, mobile app, website, and via the thermostat itself. As an example of a typical BYOT enrollment scenario, when the customer sets up a new smart thermostat, they are prompted to enter their ZIP code. The ZIP code enables the thermostat provider to recommend enrollment in Power Manager if the ZIP code is a Duke Energy ZIP code. Most enrollments are generated through this pathway. Other enrollments occur after thermostat setup when the thermostat providers periodically email or send in-app messages their customers with invitations to sign up for Power Manager.

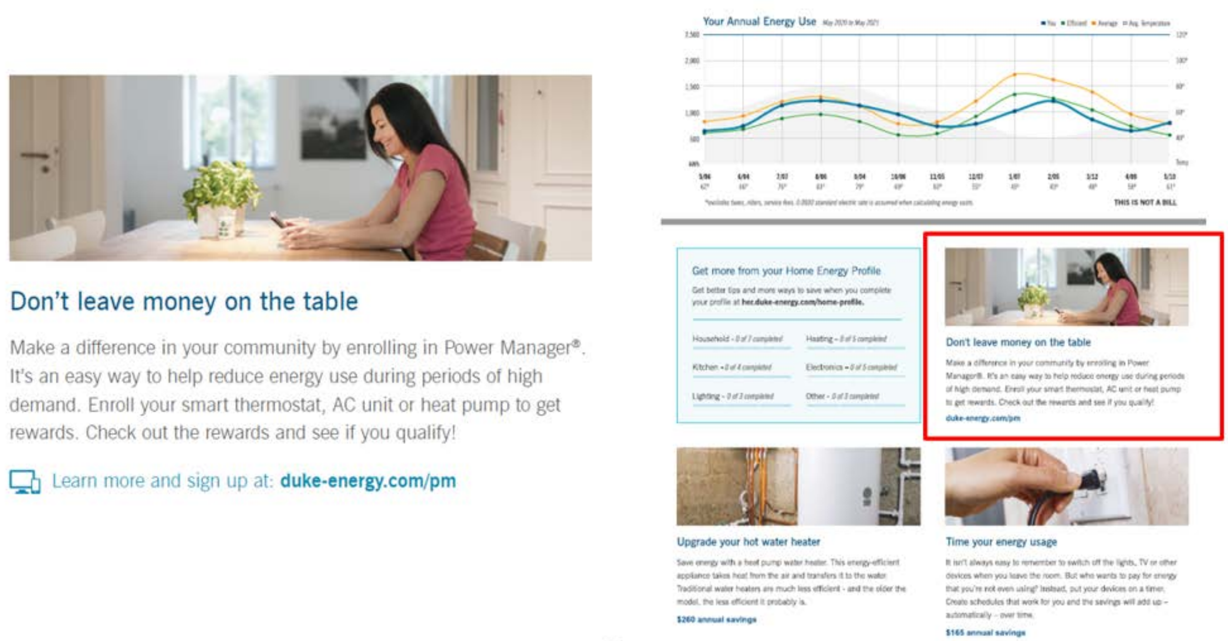
EnergyHub is a service provider engaged by Duke Energy to administer the BYOT program option. They operate a customer service center that is responsible for BYOT program option customer service – which includes providing support to Franklin Energy who serves as the first line of BYOT customer service – answering customer questions and administering program enrollment and unenrollment. EnergyHub is also responsible for aggregating the enrollments from all partner thermostat manufacturers into their program management system. Their system enables visibility into the connectivity (and dispatchability) status of nearly all enrolled thermostats.[8] After verifying connectivity, EnergyHub sends enrollments to Duke Energy for customer identification verification and eligibility verification. Identification verification is necessary because customers are not required to provide their Duke Energy account number for enrollment, which significantly increases program uptake. Duke Energy additionally verifies that the customer is not already enrolled in the DLC program option. EnergyHub is also responsible for distributing enrollment incentives. BYOT program option participants receive a $75 e-gift card upon enrollment as well as $25 annual e-gift cards for each year of enrollment thereafter.

[8] Nest thermostat connectivity status was not visible to EnergyHub in 2021 but will be in 2022.

EnergyHub observes that multiple marketing touches through different channels increase program uptake. For example, if a customer sees a Power Manager promotion from Duke Energy, followed by another promotion from Nest, they are more likely to sign up using the second prompt that appeared in the different communication channel. EnergyHub also observes that BYOT program option participants tend to be in higher income brackets. They recommend reaching customers with lower levels of income via utility-operated online stores where the thermostat is sold at a discounted price.

Duke Energy also directly promotes Power Manager (both the DLC and BYOT options) through direct mail, email, and in MyHER reports. Figure 7-19 shows the presentment of Power Manager promotions in MyHER.

Figure 7-19:: MyHER Power Manager Promotional Message



7.4.2 Power Manager Program Operations

Most Power Manager events are scheduled by the Power Manager DLC option and BYOT option program manager, mainly considering local system and weather conditions as well as EM&V testing needs. Duke Energy's Energy Control Center (ECC) also has access to dispatch Power Manager's DLC option. The ECC has the responsibility of balancing the supply and demand of electricity on the grid for Duke Energy Carolinas. Power Manager is rarely used in an emergency full-shed capacity, but the ECC uses the cycling option on occasion. Because Power Manager provides a low-cost, reliable, and quickly dispatchable asset, it is designated as a "virtual power plant" resource and contributes to the system's operating reserve margins.

Under normal operations, the Power Manager program manager includes staff from ECC and Fuel and Systems Optimization in event decision making, including discussions in anticipation of days where events are possible. Advance event discussion and preparation makes the day-of event calling process operate smoothly. The Power Manager program manager maintains control of the decision to call nonemergency events. Power Manager is viewed as an important resource for the Duke Energy Carolinas system that depends on the participating customers' willingness to remain enrolled. Therefore, all events are called with the program manager's view towards whether or not it will be a detriment to the experience of the participants and their continued participation. Considerations taken in this area are the number of events that have already been called during the current summer, during that week, at what hours events are taking place, and the depth of the load shed under consideration (i.e., thermostat setbacks, cycling level).

Apart from determining whether a given day will be a Power Manager event day, Power Manager program operations for the DLC and BYOT options are different, largely because Duke Energy manages the operations of the DLC option and outsources the operations of the BYOT option to EnergyHub.

7.4.2.1 DLC Program Option Operations

Preparations for the cooling season begin in the spring each year. Three primary activities occur in the spring to prepare the DLC option program participants and the operational team for the summer. Participants receive a reminder/thank you postcard before the summer load control season begins. Duke Energy sends these communications annually to remind and thank customers for their participation in the program, provide tips for having a comfortable experience during events, and to recognize the benefits of the program in terms of reducing system load and providing environmental benefits. The 2021 reminder postcard, with removable magnet featuring program information, is shown in Figure 7-20.

Figure 7-20: Reminder and Thank You Postcard

Beyond the monthly credits that are present on customer's bills during load control season, these cards are usually the only communication customers are provided from the program each year.

Another important springtime activity for the DLC program option is programming or addressing active DLC devices for the upcoming season. This activity is primarily undertaken to support the Resource Innovations impact evaluation, which relies on randomized control trials (RCTs) to facilitate impact estimation. A number of different randomly assigned groups of DLC devices are defined each spring so that whenever an event is launched, at least one group of devices does not experience load control and can serve as a control group in the RCT. DLC devices are programmed by Duke Energy using the Eaton Power Systems Yukon software. Duke Energy staff are responsible for device programming each year using Yukon. Consultants from Eaton Power Systems also play a role as the provider of the DLC devices and Yukon software. They serve as a resource to assist Duke Energy in maintaining the Yukon software system, managing occasional device firmware issues, addressing the DLC devices, and training Franklin Energy's device installers.

An annual all-hands Spring Training event hosted by Duke Energy brings together Eaton Power Systems, Franklin Energy, and Duke Energy to discuss the upcoming load control season. The Spring Training is cited by all stakeholders that Resource Innovations interviewed as a crucial aspect of program operations. Not only do these meetings allow for in-depth coverage of emerging issues, but they are also critical in maintaining the overall collegiality and professionalism that facilitates effective communication amongst the stakeholders, enabling quick resolution problems when they arise. Spring Training keeps stakeholders are aware of each other's responsibilities, knowledge base, and workload, and are thus able to efficiently troubleshoot and find the appropriate staff for solving problems. Weekly meetings are held between Duke Energy and Franklin Energy, with Eaton Power Systems joining once a month.

When a non-emergency DLC event is launched, the DLCs use the Eaton Power Systems TrueCycle algorithm, which uses participants' actual AC usage patterns to determine the cycling pattern needed that will yield a 64% or 50% reduction of each AC unit's expected runtime during a cycling event. During emergency full-shed events, AC units experience 100% full shed.

Duke Energy has also worked with Eaton Power Systems to implement the "Assets" dispatch feature of Yukon software. Yukon Assets ties Franklin Energy's program participation data to Duke Energy's customer information and program dispatch capabilities to provide greater flexibility in managing Power Manager events. With help of this upgrade, Duke Energy has the ability to dispatch Power Manager based on the geographic location of active DLC devices.

Duke Energy does not notify DLC option participants either in advance or during event dispatches. However, Duke Energy maintains a toll-free hotline that program participants may call to get updates on the status of whether or not the program is planning to dispatch an event or whether an event is in progress. Franklin Energy notes that the highest volume of calls come in the summertime. Their phone center operations include placing an "ambush message" at the beginning of their telephone interactive voice response (IVR) menu so as to notify callers that Power Manager has called an event. DLC option participants may opt of an event prior to or during an event via telephone call to Franklin Energy. Duke Energy also notes the pattern of most customer inquiries occurring in the early summer when customers turn on their air conditioning for the first time. If there are issues with the functionality of a customer's air conditioning unit, those issues can be conflated potential issues with the DLC device. Franklin Energy's staff helps distinguish between air conditioner issues versus DLC device issues and, if necessary, send a technician to investigate.

7.4.2.2 BYOT Program Option Operations

Duke Energy organizes and participates in fewer planning and organizational activities around preparing the BYOT program option for the cooling season. This is a result of the value that EnergyHub brings to the program as the implementer. At the outset of each cooling season, EnergyHub communicates with Duke Energy to understand their goals for enrollment and per household load impact for the year, and to affirm commitments to platform availability uptime, and the timing of delivering preliminary estimates of load impacts from the thermostat manufacturers. EnergyHub additionally advises Duke Energy on dispatch strategy (i.e., number of degrees setback, pre-cooling) that will help ensure Duke Energy meets their operational goals. The EnergyHub and Duke Energy teams meet weekly to coordinate.

As soon as Duke Energy verifies an enrolled customer's eligibility for the program, their thermostat is immediately available for dispatch by EnergyHub. Like the DLC option, however, experimental groups are set up in the spring to support RCTs that the Resource Innovations impact evaluation depends on. In this case, Resource Innovations provides the RCT group assignments to Duke Energy, and Duke Energy simply provides it to EnergyHub for implementation – Duke Energy staff are not involved in addressing thermostats enrolled in the program. The group assignments ensure that there is always a group of customers held back from each event to serve as a control group for the impact evaluation. EnergyHub reports that their system is flexible enough to accommodate programming many experimental groups. Their system can launch any of those groups with any combination of dispatch strategies. They report that programming the 2021 experimental groups was a straightforward task to carry out.

EnergyHub, per scheduling and set-up of the event by the Duke Energy program manager, dispatches BYOT events using their headend system that communicates with all enrolled thermostats via API calls to the thermostat manufacturers which in turn communicate with the thermostats. EnergyHub has the ability to dispatch events with at least 15 minutes' notice.

The BYOT program option offers the capability of pre-cooling participants' homes prior to events (so long as EnergyHub receives enough advance notice to leave time for pre-cooling). DLC devices do not offer this capability. Pre-cooling enables deeper thermostat setbacks during event hours with less impact on thermal comfort in the home. Unlike the DLC program option, BYOT option participants are informed prior to and during events through their thermostat provider's mobile apps or websites and on the thermostat itself.

BYOT program participants can opt-out of events by adjusting their thermostat setpoints. They also have an opportunity to opt-out in advance of the event if they receive or see the notification. EnergyHub reports that very few customers opt-out in advance (3%); they report that overall, opt-out rates typically range between 20-30%. EnergyHub works to minimize opt-outs through advising utilities like Duke Energy to avoid overburdening program participants with very deep setbacks or very long events, or overcommunicating with too many pre-event notifications.

7.4.3 Program Monitoring and Postseason Maintenance

7.4.3.1 DLC Program Option Monitoring and Maintenance

Franklin Energy, as the third-party contractor that manages DLC option customer service, has service level agreements in place with Duke Energy that outline service benchmarks, with both penalties for nonperformance and opportunities for incentives when benchmarks are exceeded. There are specific benchmarks in place to ensure that, during event days in particular, customer calls coming into Franklin Energy are handled quickly, efficiently, and that accurate information is provided to the customers calling in. The Duke Energy program manager monitors the number of calls coming in to the toll-free notification line. The program manager also monitors number of calls coming into the Franklin Energy call center to detect any emerging issues associated with the program experience. Device removal requests are also tracked for this purpose.

During and after the cooling season, Duke Energy and Franklin Energy work together to carry out quality assurance (QA) inspections of a number of DLC devices each year. In the past, Duke Energy would provide Franklin Energy with a random sample of DLC option participating homes. Franklin Energy would then visit each home to inspect the DLC device for connectivity and operability. In recent years, Duke Energy has moved to an AMI data-driven targeting for the homes to visit for QA. AMI data is used to identify DLC option participants that likely have non-functioning DLC devices. With this new targeted QA approach, QA visits have been reduced by about 60%, while tripling the proportion of devices reconnected and doubling the proportion of devices re-installed and also increasing the number of devices replaced. 2021 was an exception year with respect to the QA process. Duke Energy implemented a new customer information system in 2021. The DLC option QA process changed focus for the year to validate alignment between Duke Energy's customer information system, Franklin Energy's enrollment records, and Duke Energy's billing system. QA visits performed in 2021 were conducted in connection with the database alignment project.

7.4.3.2 BYOT Program Option Monitoring and Maintenance

EnergyHub performs an annual connectivity optimization activity whereby customers are removed from the program if their thermostats remain disconnected for more than 60 days. The $25 annual participation incentive helps when EnergyHub communicates with these customers prior to removal from the program – the reminder that the annual $25 incentive will be lost motivates customers to reconnect their thermostats. EnergyHub also engages with Duke Energy on strategies that have the potential to increase the load shed. EnergyHub's dispatch team often runs API test calls to make sure the platform is meeting uptime requirements with all thermostat manufacturers during the event season.

7.4.4 Upcoming Program Changes and Initiatives

Duke Energy and their partners are implementing a number of program enhancements that leverage a prior investment that maintain Power Manager as a cost-effective system resource for the Carolinas. Duke Energy's partners also offer a number of recommendations to contribute to continuous program improvement.

Eaton Power System will continue to work with Duke Energy in 2022 to complete the implementation of the Yukon module, Assets. Assets currently facilitates the mapping of all DLC devices to a location geocode in the Yukon system, through a connection to the Duke Energy customer information system. With the final implementation of Assets, Duke Energy will be able to dispatch Power Manager events to target a particular state, or part of a state aligned with Duke Energy's transmission regions.

Since annual DLC device programming is undertaken each year to support load impact evaluations, which is an effort staffed by Duke Energy, Eaton Power Systems recommends that Duke Energy and Resource Innovations work to make EM&V programming as similar as possible to the prior year. With fewer parameters to change, the programming process will have less risk of error and will require less effort to undertake.

Duke Energy will also expand the lineup of channels for sharing event-related information with DLC option participants. Starting in 2022, Duke Energy's website will include a banner that indicates a

Power Manager event is underway on event days. Also starting in 2022, Duke Energy sent the annual season reminder to slightly over half of its Power Manager DLC participants via email, in lieu of the postcard sent to the remaining participants. The email was sent to customers who had given permission for Duke Energy to send them emails.

On the BYOT side of the program, EnergyHub recommends enhancing the annual goalsetting process to include an EnergyHub-hosted survey to get feedback on the customer segments that the program option is succeeding with, and which segments could stand increased focus to increase uptake.

In the near-to medium term, Duke Energy has been working with Eaton Power Systems to include the capability to control strip heating for wintertime load control. This is because DEC has become a winter-peaking service territory. With that in mind, Eaton Power Systems, Franklin Energy, and Duke Energy have been working together in preparation for the expected Commission approval of the heat strip option. Duke Energy intends to begin enrolling strip heating load control participants in the fourth quarter of 2022. The BYOT program option has already begun winter heating load control through EnergyHub in the winter of 2021/2022.

7.5 Key Findings

7.5.1 DLC Key Findings

Key findings from the 2021 process evaluation for DEC DLC participants include:

- 162 DLC Power Manager participants were surveyed in July, on one event and one nonevent day. The event day had a maximum daily temperature of 91°F and a maximum daily heat index of 97.3°F while the nonevent day had a maximum daily temperature of 88.7°F and maximum daily heat index of 93.7°F.
- Of the 162 participants that completed the survey, 68 customers were surveyed following an event and 94 were surveyed following a similar nonevent day. The nonevent survey was used to establish a baseline for comfort, event awareness, and other key metrics.
- A majority of all DLC respondents, 71.6%, reported that they are familiar with the Power Manager program.
- About 12.9% of both sets of survey respondents—those that had and those that had not experienced an event—reported that their homes were uncomfortable during the event or nonevent day. There is no increase in customers' thermal discomfort due to Power Manager events.
- 47.2% of respondents reported that "Earning a credit on my bill" is the primary reason they are participating in Power Manager. The second-most common motivation was "helping the environment."
- Overall, 88.9% of survey respondents state that they are "very" or "somewhat" likely to remain in the program.
- 78.9% of respondents "strongly" or "somewhat" agreed that they would recommend the Power Manager program to others.

- Overall, respondents most often made suggestions around program communication and incentive levels.
- In-depth interviews reveal that Duke Energy leads and manages three partner vendors to operate and maintain the DLC option of Power Manager as a reliable resource for the Carolinas electric system. The operations team is building on the long-term success of the program by expanding it to make residential strip heating loads available for program dispatch starting in the winter of 2022/2023.
- In-depth interviews reveal two areas of process improvement for the DLC option. First, that EM&V programming each year should be kept as simple as possible and should reflect as few changes as possible from the prior year to mitigate risks of making programming errors. Second, Duke Energy should resume normal QA inspections of devices after a hiatus to support inspections related to enrollment database reconciliation.

7.5.2 BYOT Key Findings

- 188 BYOT Power Manager participants were surveyed in July and August, on a hot nonevent day and on an event day, respectively. The event day had a maximum daily temperature of 90.3°F and a maximum daily heat index of 98.7°F while the nonevent day had a maximum daily temperature of 88.7°F and maximum daily heat index of 93.7°F.
- Of the 188 participants that completed the survey, 106 customers were surveyed following an event and 82 were surveyed following a similar nonevent day. The nonevent survey was used to establish a baseline for comfort, event awareness, and other key metrics.
- A majority of respondents, 78.2%, reported that they are familiar with the Power Manager program.
- About 20.3% of both sets of survey respondents—those that had and those that had not experienced an event—reported that their homes were uncomfortable. There is no increase in customers' thermal discomfort due to Power Manager events.
- 41.5% of respondents reported that "Earning a credit on my bill" is the primary reason they are participating in Power Manager. The second-most common motivation was "helping the environment."
- Overall, 85.1% of survey respondents state that they are "very" or "somewhat" likely to remain in the program.
- 79.3% of respondents "strongly" or "somewhat" agreed that they would recommend the Power Manager program to others.
- Overall, the most common respondent suggestions for Duke were to communicate more frequently prior to and during Power Manager events and to replace the gift card incentive with a bill credit.
- In-depth interviews with BYOT option stakeholders show that Duke Energy's implementer EnergyHub delivers value by managing the BYOT implementation, which relieves Duke Energy program staff of much of the effort that is expended in managing the DLC option.
- The typical BYOT option participant is in a higher than average income bracket. EnergyHub recommends utility-run online stores as an effective way to get smart thermostats into lower income households and enrolled in Power Manager through discounts and promotional messaging.

8 Conclusions and Recommendations

8.1 Impact Evaluation Conclusions and Recommendations

8.1.1 DLC Impact Evaluation

Conclusion: Overall, the Power Manager DLC program produces significant results in reducing peak load demand for Duke Energy's residential customers. On average, Summer 2021 events achieved 30% load reduction per household for emergency dispatch events.

> **Recommendation:** Continue to promote the Power Manager program to DEC residential customers who exhibit high peak load consumption. Customers with higher-than-average peak loads remain the best candidates for program participation and have the greatest potential to contribute to demand savings.

Conclusion: The time-temperature matrix predicts demand reductions of 1.92 kW per household for a 1-hour event beginning at 4:00PM with an event period temperature of 100°F. However, the time-temperature matrix is limited by a narrow range of empirical data.

> **Recommendation:** Revisit the time-temperature matrix requirements and consider developing a model of program capabilities across a relatively modest band of temperatures, reflecting the current dispatch strategy. For example, reporting estimated impacts under a range of temperatures regularly observed during most event seasons for a 1-hour event starting at 4:00PM.

8.1.2 BYOT Impact Evaluation

Conclusion: The Power Manager BYOT program produces significant results in reducing peak load demand for Duke Energy's residential customers. On average, Summer 2021 events achieved 1.32 kW (40%) load reduction per household.

> **Recommendation:** Continue to promote the Power Manager program to DEC residential customers who exhibit high peak load consumption. Customers with higher-than-average peak loads remain the best candidates for program participation and have the greatest potential to contribute to demand savings.

Conclusion: BYOT impacts tend to increase as the event period offset and pre-cooling conditions become more intense. Event period offsets of 4°F produced greater impacts compared to events with 3°F offsets.

> **Recommendation:** For planning purposes, apply more extreme event offsets in order to generate greater load impacts during events.

Conclusion: The time-temperature matrix predicts demand reductions of 1.76 kW per household for a 1-hour event beginning at 4:00PM with 90-minute 2 degree precool with a 4 degree event offset. However, the time-temperature matrix is limited by a narrow range of empirical data.

> **Recommendation:** Revisit the time-temperature matrix requirements and consider developing a model of program capabilities across a relatively modest band of temperatures, reflecting the current dispatch strategy. For example, reporting estimated impacts under a range of temperatures regularly observed during most event seasons for a 1-hour event starting at 4:00PM.

8.2 Process Evaluation Conclusions and Recommendations

Conclusion: There were no differences in levels of agreement between event and nonevent participants with statements about whether an event had occurred recently, about thermal discomfort, or about perceptions of the cause of any discomfort for DLC and BYOT. In short, customers are not able to reliably perceive Power Manager curtailment events. However, BYOT post-event respondents were sometimes able to identify which day an event had occurred, due to the notification on their thermostat.

> **Recommendation:** Continue to prioritize participant comfort and satisfaction during curtailment events.

Conclusion: 78.9% of DLC and 79.3% of BYOT Power Manager customers are likely to recommend the program to others. 88.9% of DLC and 85.1% of BYOT Power manager customers are likely to remain enrolled. There were no differences between event and nonevent respondents for either question, nor for any other satisfaction questions. Therefore, Power Manager events do not affect customer satisfaction in either direction.

> **Recommendation:** Continue to prioritize practices that are focused on maximizing customer satisfaction in the design and implementation of the Power Manager program.

Conclusion: 71.6% of DLC participants are familiar with the Power Manager program, representing no change from the previous evaluation in PY 2019. 78.2% of BYOT participants are familiar with the Power Management program. The majority of suggestions for both DLC and BYOT for improvement from customers spoke to perceived communication gaps from Duke Energy. 22.8% of suggestions from DLC participants related to increasing communication from Duke Energy, while 5.3% specifically suggested increased communications about bill credits and 15.8% specifically suggestion increased communications around events (event notifications). 21.8% of BYOT respondents provided suggestions on communications, 5.7% suggested for increased communications around e-gift cards and 20.7% specifically suggested increased notification of events.

> **Recommendation:** Evaluate each jurisdiction's communication strategy: before, during, and after load control seasons, and consider changes. Improved communication can improve

customer satisfaction and increase positive word-of-mouth awareness. One possibility is to provide monthly summary emails to participants, highlighting bill credits or e-gift cards earned, and allowing customers a repeated opportunity to learn more about the program.

Recommendation: Prioritize making Power Manager event notifications available on the program website and via email.

Conclusion: "Targeted" QA protocols, using AMI data to identify switches that may be malfunctioning or missing, have yielded strong results in the past. QA inspections at sites identified through AMI data analysis were suspended in 2021 to accommodate QA site inspections in support of an initiative to align program enrollment and customer information databases at Duke Energy and Franklin Energy.

Recommendation: Return to AMI data analysis-based QA inspections as soon as possible, and consider increasing the number of inspections scheduled given the 2021 hiatus.

Conclusion: The current approach to communications amongst DLC option stakeholders has been effective in building professional teamwork and helps to make the program run smoothly, even when problems arise.

Recommendation: Continue to prioritize inter-organizational communications with Spring Trainings, weekly and monthly calls, and other existing approaches.

Conclusion: Duke Energy Carolinas has transitioned to winter-peaking operational conditions, and the Power Manager program will have to adapt to maintain viability as a resource to manage peak loads. The BYOT option already offers winter load reduction capability.

Recommendation: Prioritize launching the winter capability for the DLC option. Eaton Power Systems, Franklin Energy, and Duke Energy are working together in preparation for a winter-focused strip heating program option.

Conclusion: The new Assets module of the Yukon dispatch system offers opportunities to dispatch the DLC option locationally. As customer saturation becomes an increasingly pertinent issue, "Assets" may offer a way to address it.

Recommendation: Test locational dispatch capabilities in 2022 or 2023 once the final upgrades to the Assets module are complete.

Conclusion: BYOT option participants currently tend to have higher levels of income than average.

Recommendation: Drive enrollment of households from income brackets lower than that of the current typical BYOT customer by continuing to offer discounted BYOT-eligible thermostats on Duke Energy's-sponsored online storefront.