Power Manager Winter BYOT 2022-2023 Evaluation Report

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1 Executive Summary

This report presents the results and key findings of Resource Innovations' evaluation of the winter 2022-2023 Power Manager Bring Your Own Thermostat (BYOT) program in the Duke Energy Carolinas service territory.

1.1 Background

Power Manager is a voluntary demand response program that offers incentives to residential customers who allow Duke Energy to reduce the home's electric load during days with high energy usage. Through the program, events may be called to help lessen electricity use during times of high demand. Summer demand response events are called by Duke Energy on hot summer days between May and September, and winter events are called during peak hours between December and March. Events are designed to reduce loads during times with the greatest system-wide energy demands. Participating BYOT customers are provided incentives in the form of e-gift cards upon successful enrollment and annually each year they remain on the program.

Power Manager's BYOT option, first made available in late 2019, enables customers to participate in demand response events through their home's qualifying smart thermostat(s). By enrolling their thermostat(s) in the BYOT option, customers agree to let Duke Energy remotely adjust their thermostat during times of peak electric demand. The BYOT option has two further sub-options for participation, "summer only" and "winter-focused". Customers who enrolled in the summer only option (closed to new enrollments) only experience demand response events in the summer. Customer who qualify for and elect the winter-focused option experience both winter and summer demand response events. To qualify for the winter-focused Power Manager BYOT option, customers must have electric-fueled heating controlled by a qualified Wi-Fi connected thermostat, in addition to central air conditioning controlled by the same Wi-Fi enabled thermostat.[1] Upon enrolling, customers receive an initial incentive in the form of a $75 e-gift card, as well as a $25 e-gift card for each additional year of enrollment.[2]

Events called under the BYOT option may vary by duration and setpoint adjustment during the event period, as well as the duration and setpoint adjustment during the pre-heating period. During a pre-heating period, the setpoints of participating thermostats are automatically adjusted upward prior to the start of an event to raise the interior temperature of the home and maintain comfort levels during the event period. At the start of an event, temperature setpoints are then adjusted downward to reduce heating loads during periods of high demand.

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[1] Additionally, Duke Energy's operational plan for the winter-focused option provides for fewer planned summer events relative to the summer only option.

[2] The participation incentive for the winter-focused option was initially a $90 e-gift card for the initial offer period November 2020 through December 2020. The incentive offer for the winter-focused option reverted to the $75 e-gift card in January 2021. At the time of this report, the incentive for winter-focused enrollment has changed to an initial one-time bill credit of $75 and an annual $25 bill credit for each subsequent year the customer remains on the program.

The content of this report relates specifically to customers who participated in the winter-focused BYOT program option during the 2022-2023 winter event season.

1.2 Key Findings

Key findings of the winter 2022-23 BYOT impact analysis are as follows:

- The average load reduction achieved by the winter BYOT events in 2022-2023, reflected in Table 1-1, was 1.74 kW (37%).
- Assuming a total program population of 15,000 homes, the average aggregate load impact for the full program is 26.1 MW.
- The average per household load increase during the 60-minute preheating period was 0.90 kW; the average post-event snapback effect was 0.42 kW per household.
- These events were called on back-to-back days, during a period of extreme cold that occurred over the Christmas holiday (December 24-26); higher temperatures before this 3-day period, as well as changes in usage behaviors during the holiday may have affected per customer impacts.

The expected program capability for a 1-hour event called at 7:00 AM under 12°F conditions, with a 90-minute 3°F pre-heat and a 4°F event offset is 2.33 kW per household. The expected total system-wide load reduction is 35 MW. Table 1-1 shows per household event impacts for each event called in December 2022.

Table 1-1: Summary of 2022 BYOT Event Impacts

Event Date	Start Time (EST)	End Time (EST)	Pre-Heat Duration (Mins.)	Pre-Heat Amount (°F)	Event Offset (°F)	Ref. Load (kW)	Load w/ DR (kW)	Per Home Impact (kW)	Aggregate Impact (MW)	Impact (%)	System Temp. (°F)
12/25/2022	7:00 AM	9:00 AM	60	3	3	4.75	3.30	1.45	21.8	30.47%	19.5
12/26/2022	7:00 AM	8:00 AM	60	3	3	4.62	2.59	2.03	30.5	43.90%	22.0
Average 2022-2023 Winter Event						**4.68**	**2.95**	**1.74**	**26.1**	**37.1%**	**21.0**

1.3 Recommendations

The winter 2022-2023 Power Manager BYOT evaluation provided insights into program performance from a load impact perspective for the winter-focused BYOT program offering. The following recommendations have been developed based on the key findings from the evaluation.

- Continue to promote the winter-focused BYOT Power Manager program to DEC residential customers with Wi-Fi enabled smart thermostats. On average, customers enrolled in BYOT reduce their electric load by 37% during events, providing relief to the grid during periods of high demand.

- Continue to dispatch events under extreme temperature conditions, during times of high system load demand. Opportunities for load reduction are greatest when temperatures are low and heating requirements are greatest.

- Review preheating and post-event snapback load increases and consider requesting vendors develop alternative event related thermostat settings focused on minimizing pre- and post-event load increases.

2 Introduction

This report presents the results of the winter 2022-2023 Power Manager BYOT option impact evaluation 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. The DEC Power Manager program includes two offerings: traditional direct load control (DLC) and a newer option for homes with qualifying smart thermostats. 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 during periods of high system demand. There are two further options for participating BYOT Power Manager: the summer only option whereby participants only experience load control in the summer, and the winter-focused option that additionally provides for load control on cold days between December and March.

2.1 Key Research Questions

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

- What demand reductions were achieved during each event called during the 2022-2023 winter season?
- What is the system load reduction capability of the program under extreme conditions?

2.2 Program Description

All customers participating in the BYOT option must have a qualifying Wi-Fi enabled smart thermostat already installed in their home prior to enrollment in the program. Duke Energy initiates winter BYOT events by remotely adjusting participating thermostats downward, thereby reducing the heating load required. To help maintain comfort levels during the event period, winter BYOT events may also involve a pre-heating period, when thermostats are remotely adjusted upward during the period immediately preceding the event, raising the interior temperature of the home before the event begins.

Winter BYOT events typically occur from December through March. BYOT participants receive financial incentives for their participation in the form of pre-paid gift cards. Upon enrolling, customers receive an initial incentive in the form of a $75 e-gift card, as well as a $25 e-gift card for each additional year of enrollment.[3]

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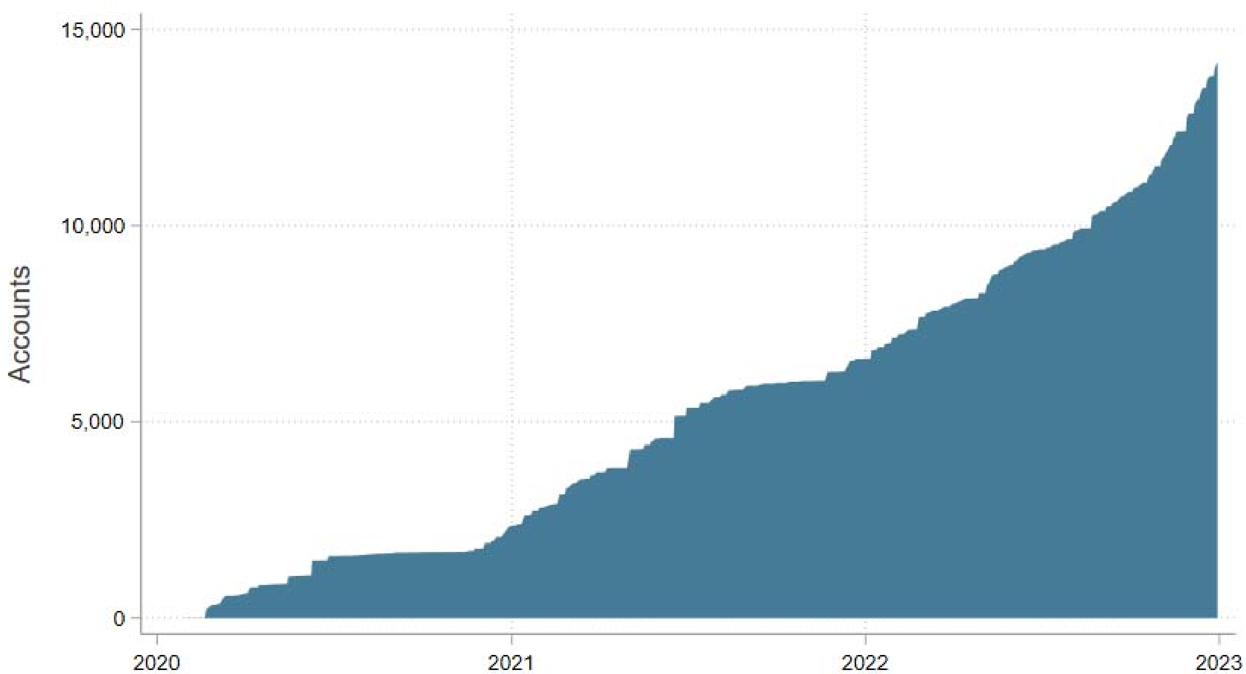
[3] The participation incentive for the winter-focused option was initially a $90 e-gift card for the initial offer period November 2020 through December 2020. The incentive offer for the winter-focused option reverted to the $75 e-gift

During winter BYOT events, Duke Energy remotely adjusts the temperature setpoints of customers' home thermostats downward to reduce heating loads. Setpoint adjustments range from 0°F to 4°F during events, which may last from 1 to 4 hours. Event pre-heating ranges from 0°F to 3°F for up to 2 hours before the start of an event. Duke Energy may apply different combinations of pre-heating and event period offsets that may result in varying changes in load demanded during each phase of the event.

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. At the time of the 2022-2023 winter season (December 2022-March 2023), approximately 15,000 customers were enrolled in the winter-focused BYOT option. Figure 2-1 presents growth in accounts enrolled in the winter-focused option from the start of the program through the end of 2022.

Figure 2-1: Winter-Focused BYOT Program Account Enrollments



card in January 2021. At the time of this report, the incentive for winter-focused enrollment has changed to an initial one-time bill credit of $75 and an annual $25 bill credit for each subsequent year the customer remains on the program.

2.4 Event Characteristics

Two events were called during the 2022-2023 winter season (Table 2-1), on December 25 and December 26, during an extreme cold spell in the DEC territory. On both days, all enrolled BYOT customers were curtailed beginning at 7:00 AM Eastern Standard Time (EST). Prior to the event, starting at 6:00 AM, program participants experienced a 60-minute preheating period, when thermostat setpoints were adjusted upward by 3°F. During both events, customers' setpoints were adjusted downward by 3°F, relative to their original setpoints prior to the preheating. The December 25 event lasted two hours, from 7:00 AM to 9:00 AM at a temperature of 20°F. The December 26 event lasted one hour at a temperature of 22°F.

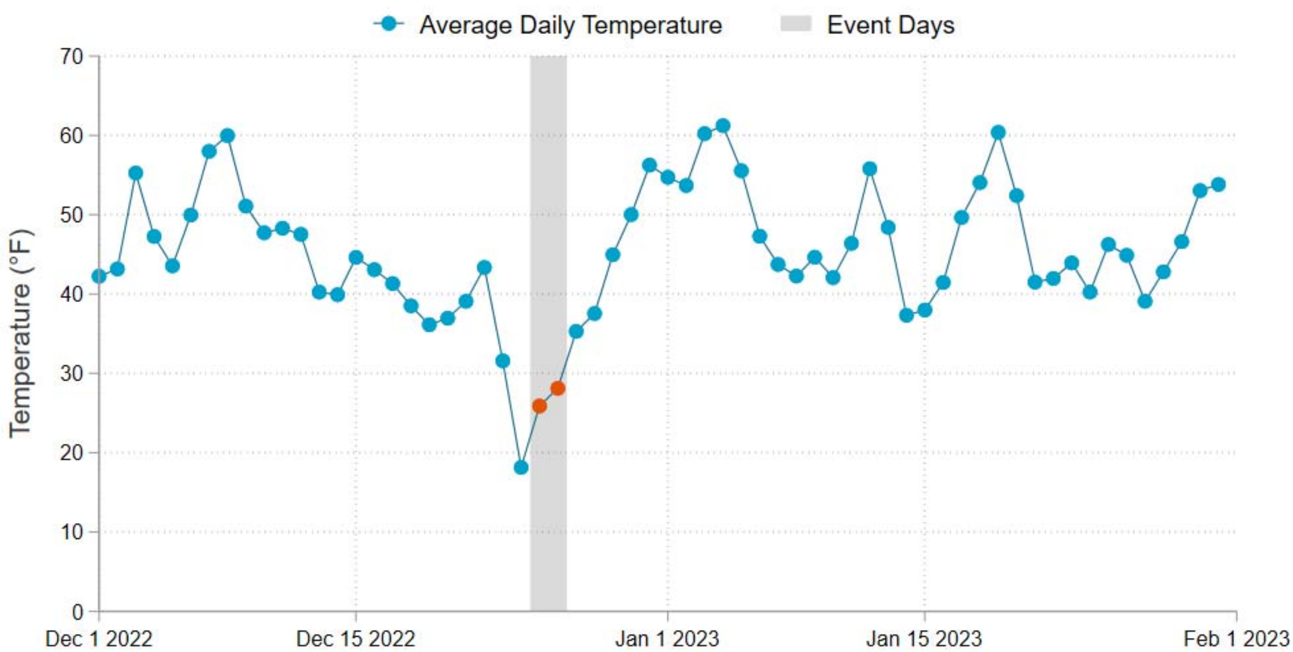
The table below summarizes BYOT event conditions for the winter 2022-2023 season.

Table 2-1: Summary of 2023 BYOT Events

Event Date	Start Time (EST)	End Time (EST)	Pre-Heat Duration (Mins.)	Pre-Heat Offset (°F)	Offset (°F)	System Avg. Temperature (°F)
12/25/2022	7:00 AM	9:00 AM	60	3	3	19.5
12/26/2022	7:00 AM	8:00 AM	60	3	3	22.0

Events occurred during a period of low temperatures in the DEC jurisdiction. Average daily temperatures during the two event days were approximately 19°F lower than non-event days during December and January.

Figure 2-2: Average Daily Temperatures, Dec 2022 - Jan 2023



3 Methodology and Data Sources

This section details the study design, data sources, and analysis protocols used for the impact evaluation.

3.1 Data Sources

The impact analysis relied on four primary datasets:

- Program data identifying participant account numbers and BYOT program enrollment dates.
- Premise-level AMI data in 30-minute intervals for all participants for the month of December 2022.
- Event data for the two DEC BYOT Power Manager events called in December 2022, including details of the event scenarios such as pre-heating offsets and duration, and start and end times for each event.
- Hourly weather data for December 2022, used to inform proxy day selection for a within-subjects analysis for impact estimation, as well as to establish relationships between impacts and temperature.

All data sets were thoroughly cleaned and validated to ensure that impacts were estimated using reliable premise-level observations from program participants who were curtailed on event days.

3.2 Within-Subjects Analysis Design

The two winter 2022-2023 Power Manager BYOT events were called in the absence of a control group. Therefore, a within-subjects approach is used for this impact evaluation, whereby the hourly loads of winter-focused BYOT program participants as observed on similar nonevent days are used to estimate the counterfactual against which to compare their own event-day loads. The critical step of a within-subjects approach is developing unbiased reference loads.

To estimate accurate reference loads for the events, Resource Innovations applied the following process:

1. Examine observed weather and pre-event load data to identify a selection of non-event days that most closely resemble event days in terms of temperature and pre-event hourly loads.
2. Using data from the selected non-event days, apply regression modeling to estimate the relationship between customer loads and outdoor air temperature.
3. Apply the modeled coefficients to the event day temperatures to estimate an hourly load profile for each event day.

4 Within-Subjects Results

Two events were called during the 2022-2023 winter season (Table 2-1) on December 25 and December 26, during an extreme cold spell in the DEC territory. Both events were called for the full BYOT population and did not involve a control group held back from experiencing the event. Absent a control group, Resource Innovations applied a within-subjects impact estimation approach to estimate event period impacts.

This section presents the ex post impacts estimated for each event.

4.1 BYOT Overall Results

The BYOT events called on December 25 and December 26 achieved average per household load impacts of 1.45 kW and 2.03 kW, respectively. The aggregate, program-wide impacts were 21.8 MW and 30.5 MW, respectively.

Table 4-1: BYOT Winter 2022-2023 Event Impacts per Household

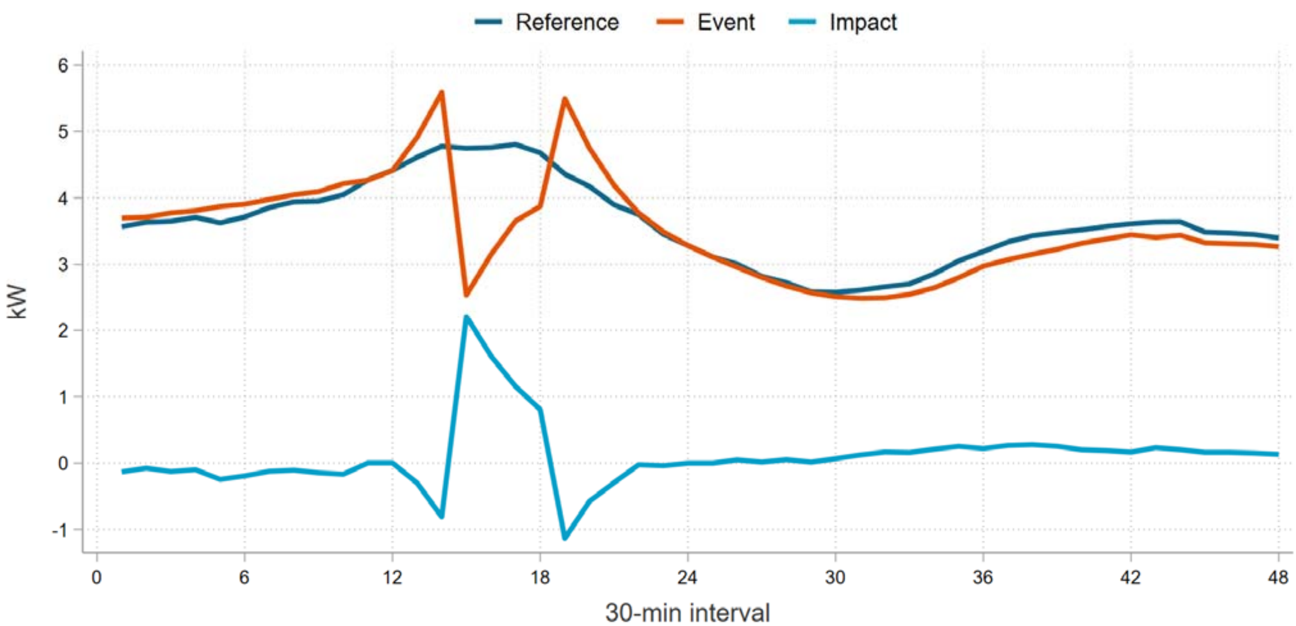
Event Date	Period (EST)	Preheat	Event Offset	Per Household Impact (kW)	Program Impact (MW)	% Impact
12/25/2022	7AM to 9AM	60-min, 3°F	3°F	1.45	21.8	30.1%
12/26/2022	7AM to 8AM	60-min, 3°F	3°F	2.03	30.5	43.9%

Impacts shown in Table 4-1 represent the average load reduction observed over all intervals of the event period. The December 25 event produced per household impacts that were 0.58 kW smaller than those produced by the December 26 event, despite being called under idential preheat/offset scenarios and at lower, more extreme temperatures. The primary reason for this is that the December 25 event lasted for two hours, whereas the Decmeber 26 event lasted only one hour. Because impacts typically diminish over the course of the event period as indoor temperatures drop and heating loads kick back in, longer events tend to result in smaller average reductions compared to shorter events. First hour impacts for the Decemer 25 event (1.91 kW) were comparable to the December 26 event impacts (2.03 kW).

Event day loads and impacts for the December 25 event are shown in Figure 4-1.

Figure 4-1: Within-Subjects BYOT Event Performance, December 25, per Household Impacts

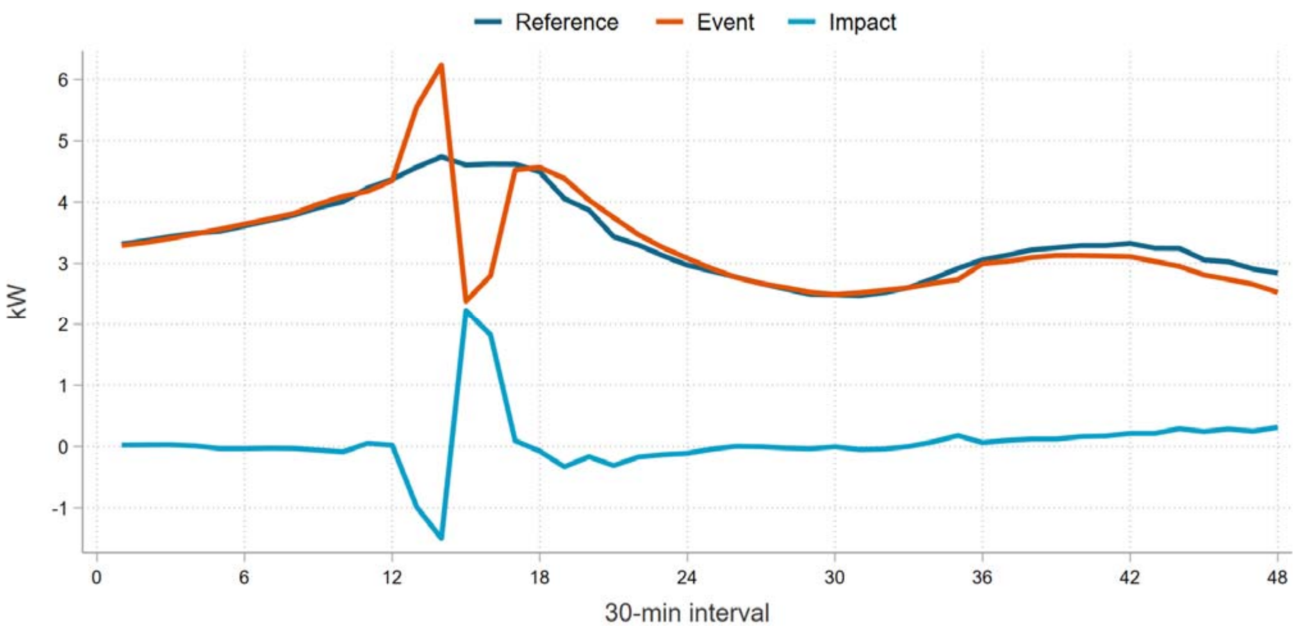
Event Date	12/25/2022
Event Period	7:00 AM to 9:00 AM
Pre-heat	60-minutes, 3°F
Event Offset	3°F
System Temperature	19.5°F
Per Household Impact	1.45 kW
Program Impact	21.8 MW



Event day loads and impacts for the December 26 event are shown in Figure 4-2.

Figure 4-2: Within-Subjects BYOT Event Performance, December 26, per Household Impacts

Event Date	12/26/2022
Event Period	7:00 AM to 8:00 AM
Pre-heat	60-minutes, 3°F
Event Offset	3°F
System Temperature	22°F
Per Household Impact	2.03 kW
Program Impact	30.5 MW



4.2 Preheat and Post-Event Snapback

Winter BYOT Power Manager events are intended to reduce residential electric loads during periods of peak demand by reducing customers' home heating demands at times when it is needed most. Delivering load impacts while maintaining customer comfort often requires preheating the home. For both events called in 2022, the preheat involved adjusting homes' thermostat setpoints upward by 3°F for one hour before the start of the event.

Whereas event periods are defined by load reductions, preheating periods are characterized by load *increases*. Likewise, the period immediately following the event, or the post-event "snapback" period, often experiences increased loads as customers' heating systems return to normal operation. The load increases experienced during the preheat and snapback periods may offset all or a part of the reductions observed during the event.

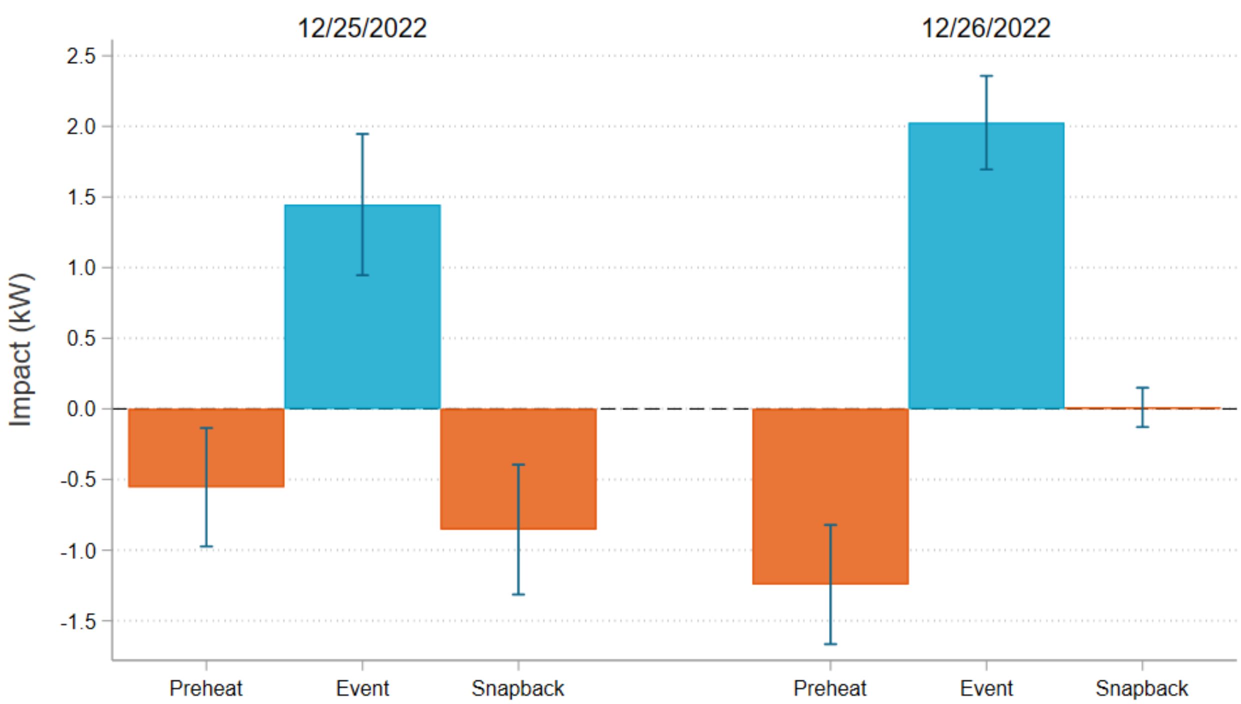
Table 4-2 presents the preheat and post-event snapback impacts estimated for each event.

Table 4-2: Event Preheat and Snapback Impacts

Event Date	Period (EST)	Preheat	Per Household Event Impact (kW)	Per Household Preheat (kW)	Per Household Snapback (kW)	% Preheat	% Snapback
12/25/2022	7AM to 9AM	60-min, 3°F	1.45	-0.55	-0.85	-11.8%	-20.0%
12/26/2022	7AM to 8AM	60-min, 3°F	2.03	-1.24	0.01	-26.7%	0.2%
Average 2022 Winter BYOT Event			1.74	-0.90	-0.42	-19.3%	-9.9%

Both events involved similar preheating periods, where thermostat setpoints were raised by 3°F for one hour prior to the start of the event. However, despite identical preheats, load increases associated with pre-event heating were very different on the two event days. The 12/25 event shows an average load increase of 0.55 kW per household during the preheat, while the 12/26 event was preceded by load increases of 1.24 kW per household. The two events also produced different post-event snapback loads. The 12/25 event produced a 0.85 kW snapback effect, whereas the 12/26 event saw zero snapback.

Figure 4-3: Preheat and Post-Event Snapback Impacts



Differences in preheating and post-event snapback are likely due to two factors:

1. These events occurred over a Christmas holiday weekend, on days when residential usage patterns are already atypical. Household electric loads, and customer responsiveness to BYOT events, are understandably very different on Christmas morning (and the observed holiday on 12/26) than typical event days. Irregular usage patterns and changes in behaviors during the holiday may have affected per customer impacts during the preheat and/or snapback periods.

2. The events had different durations: the 12/25 event lasted two full hours (7AM to 9AM) while the 12/26 event lasted one hour (7AM to 8AM). Post-event snapback impacts, in particular, are affected by the length of the event period. Longer events allow homes to reach colder temperatures. The longer the event, the harder heating systems must work to recover heat lost during the event. The shorter event duration helped to reduce the snapback effect on 12/26.

4.3 Net Event Impacts

While event period impacts and pre-heat/snapback effects can provide valuable insights on their own, the net performance of an event can be measured by combining all components of the event, from the pre-event heating period through the post-event snapback window. By design, BYOT events are called to reduce loads during times of high system demand, typically the event window. However, net impacts determine the overall changes in energy consumed throughout the period. Do usage increases observed during the preheat and snapback periods offset the reductions achieved during the event window? Table 4-3 provides the net effects of both events called in 2022. The net impact is calculated by combining the event window impacts in Table 4-1 and the pre-heat and post-event snapback impacts in Table 4-2. For both event days, the pre-heat period is defined as the hour before the event, and the post-event snapback is the two hours after the conclusion of the event. Net impacts are expressed in terms of kilowatt-hours (kWh).

Table 4-3: Net Event Impacts

Event Date	Period (EST)	Preheat	Per Household Preheat (kWh)	Per Household Event Impact (kWh)	Per Household Snapback (kWh)	Net Per Household Impact (kWh)
12/25/2022	7AM to 9AM	60-min, 3°F	-0.55	2.89	-1.01	1.33
12/26/2022	7AM to 8AM	60-min, 3°F	-1.24	2.02	-0.23	0.55
Average 2022 Winter BYOT Event			-0.90	2.46	-0.62	0.93

Net impacts varied between the two event days; the 12/25 event resulted in a net decrease of 1.33 kWh, while the event on 12/26 showed a net decrease of 0.55 kWh per household. In both cases, the reduction during the event exceeded the increases during the pre-heat and snapback windows. The 12/25 event exhibited increased load from the pre-heat and snapback periods which offset the event impacts by about 54%. The event on 12/26 had larger load increases in the pre-heat period, which served to offset about 61% of the load reductions observed during the event period; small load increases were observed during the snapback period, which futher offset the load impacts.

5 Demand Reduction Capability

A final objective of the winter 2022-2023 impact evaluation is to estimate the program's load reduction capability under a range of possible temperature and event conditions. This was accomplished by using two years of winter event data (2021-2022 and 2022-2023) to quantify the relationship between demand reductions, temperature, and time-of-day. The resulting tool allows users to forecast the aggregate demand reduction capable under specific scenarios.

The primary purpose of BYOT is to relieve (or shift) load during times of system peak demand, which typically occurs during extreme weather conditions. Winter events called by Duke Energy in the DEC jurisdiction show that per household load impacts are correlated with the event temperature offset: larger offsets deliver greater impacts.

The most extreme event type, as determined by Duke Energy, is used for estimating the program's load reduction capability. Furthermore, to represent value to the system in a high load scenario, Duke Energy Demand Response leadership has developed a standard approach for temperature selections in which ex-ante (projected) capability will be measured. To determine the appropriate extreme winter event temperature, the average of the ten lowest system temperatures was used based on a representative blend of weather stations over the past 20 years.

The forecasting tool developed by Resource Innovations allows users to predict per household and aggregate system-wide load reduction capability under a variety of event scenarios. There are five primary choice inputs in the tool, allowing users to select specific conditions:

- **Event Start Time:** allow users to select the start time of the event. Options range from 6:00 AM to 9:00 AM.
- **Event Duration:** allow users to select the duration of the event, in 30-minute intervals. Options range from 1 interval (30 minutes) to 6 intervals (3 hours).
- **Event Option:** allow users to select the preheat and event offset settings. Six options are provided:
  - No preheat / 3 degree offset
  - 60-minute 2 degree preheat / 2 degree offset
  - 60-minute 3 degree preheat / 3 degree offset
  - 90-minute 3 degree preheat / 3 degree offset
  - 90-minute 3 degree preheat / 4 degree offset
  - 120-minute 3 degree preheat / 3 degree offset
- **Event Temperature:** allow users to select the system temperature at the start of the event. Options range from 12 to 44 degrees Fahrenheit.
- **Number of Customers:** total number of accounts on the program, used to calculate aggregate program impacts for the event.

To estimate program-level demand reduction capability for an extreme scenario, Resource Innovations applied the inputs shown in Table 5-1. The settings were selected with consultation from Duke Energy's Power Manager operations team.

Table 5-1: Extreme Event Forecasting Tool Inputs

Input	Setting
Event Start Time	7:00 AM
Event Duration	2 intervals (1 hour)
Event Option	90-minute 3 degree preheat / 4 degree offset
Event Temperature	12°F
# Customers	15,000

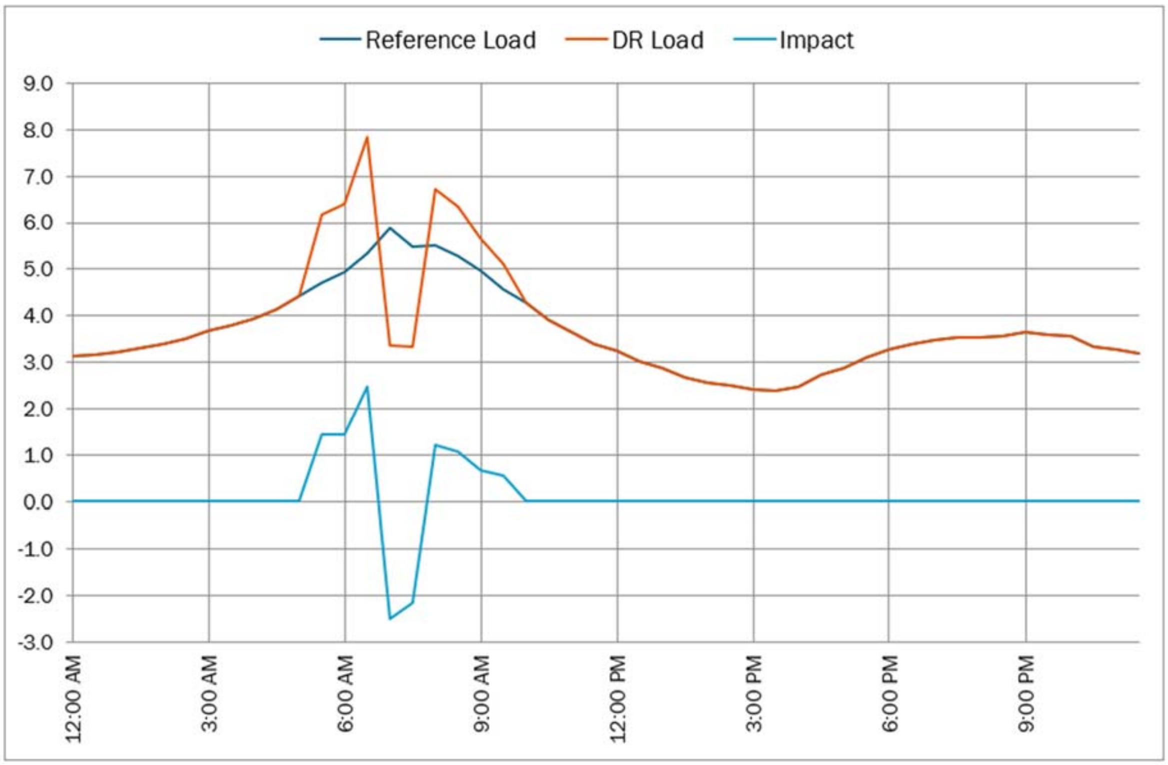
Figure 5-1 shows expected impacts for a 1-hour event called at 7:00am under 12°F conditions, with a 90-minute 3°F pre-heat and a 4°F event offset. The tool predicts an average impact of -2.33 kW per household.[4] The total system-wide load reduction is 35 MW.

[4] Load reductions are presented as negative values for Duke Energy's ex ante reporting purposes; in all other sections of this report, positive values are used to represent load reductions.

Figure 5-1: Load Reduction Capability for Extreme Winter-Focused BYOT Event

INPUTS	
Event Start Time	7:00 AM ▼
Event Duration	2 ▼
Event Option	90 min 3 deg preheat / 4 deg offset ▼
Event Temperature	12 ▼
# Customers	15,000

OUTPUTS		
Reference Load	5.69	kW
Curtailed Load	3.35	kW
Impact per Customer	-2.33	kW
Program Impact	-35.0	MW
% Impact	-41.1	%



6 Conclusions and Recommendations

Conclusion: The Power Manager BYOT program produces significant results in reducing peak load demand for Duke Energy's residential customers. The two winter 2022-2023 events achieved 1.45 kW and 2.03 kW load reduction per household, respectively. Aggregate, program-wide impacts were 21.8 MW and 30.5 MW, respectively.

> **Recommendation:** Continue to promote the winter-focused BYOT Power Manager program to DEC residential customers with Wi-Fi enabled smart thermostats. On average, customers enrolled in BYOT reduce their electric load by 37% during events, providing relief to the grid during period of high demand.

Conclusion: Winter Power Manager BYOT event impacts are largest during extreme temperature scenarios, when household heating needs are greatest.

> **Recommendation:** Continue to dispatch events under extreme temperature conditions, during times of high system load demand. Opportunities for load reduction are greatest when temperatures are low and heating requirements are greatest.

Conclusion: BYOT events result in net reductions in household energy usage, where load reductions observed during the event exceed the counteractive load increases during the preheat and snapback periods. Still, preheating prior to the event and post-event snapback resulted in considerable load increases prior to and following the event period. Net impacts were determined to be 1.33 kWh per household during the 12/25 event and 0.55 kWh per household during the 12/26 event.

> **Recommendation:** Review preheating and post-event snapback load increases and consider requesting vendors develop alternative event related thermostat settings focused on minimizing pre and post event load increases.