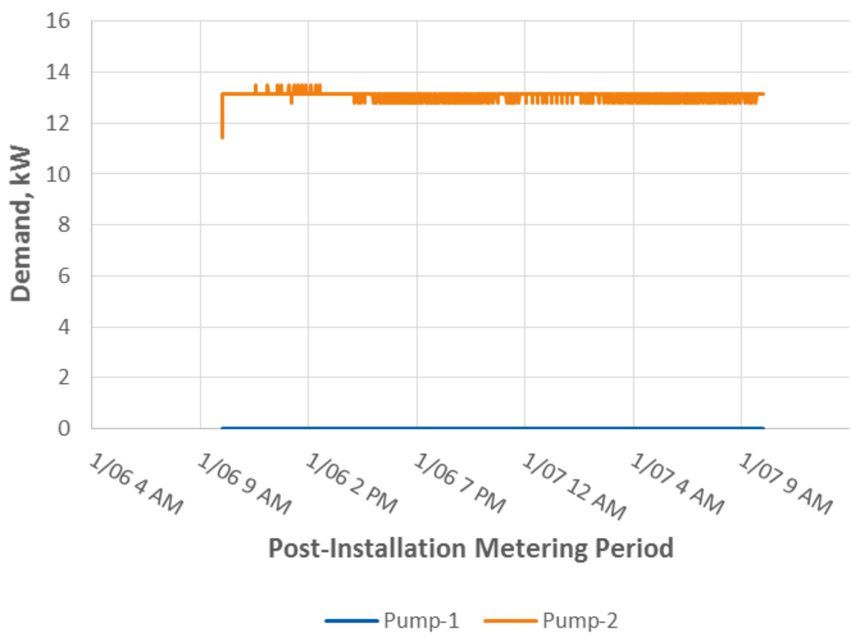
Figure 11. Metered Demand Data for Cooling Tower Pumps



13-1547987

Table 7 summarizes equipment nameplate data collected at the [redacted] location.

Table 7. 13-1547987 Equipment Nameplate Data

Equipment ID	Make	Model Number	Serial Number	hp
VFD Comp	Sullair	V320TS 250AC	201312200008	250
Heat Recovery	N/A	N/A	N/A	N/A

Figure 12 shows the nameplate for the installed 250-hp, VFD air compressor. Figure 13 shows the control screens for the air compressor. During the inspection, the compressor's discharge air pressure was 99 psi and the percent capacity was 62%.

Figure 12. 250-hp VFD Air Compressor Nameplate

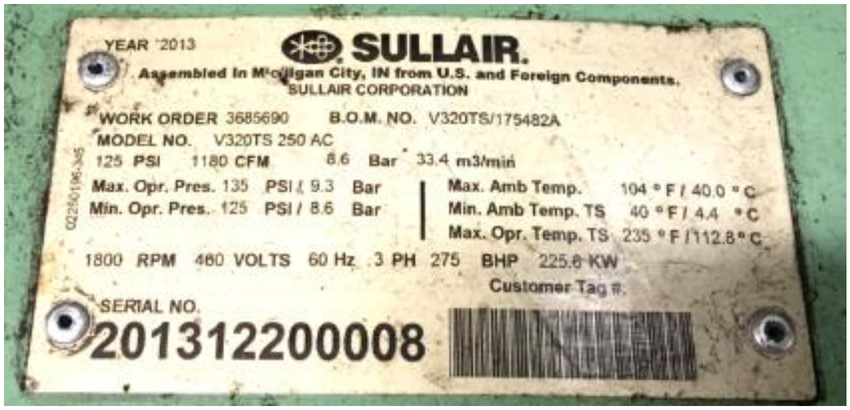


Figure 13. 250-hp VFD Air Compressor Control Screens

Figure 14 shows the compressed air heat recovery system. The image on the right shows the duct removing heat from the compressor; the image on the left shows the mixing room where the heated air is dumped (duct on top) and mixed air is fed into the warehouse through electric duct heaters (bottom).

Figure 14. Compressed Air Heat Recovery System

Cadmus installed two three-phase power meters on the 250-hp, VFD air compressor. One power meter was set up with 100 A CTs and one was set up with 400 A CT to capture compressor demand at high and low VFD speeds. Data were collected for two weeks at one-minute intervals. Table 8 summarizes the installed metering equipment, and Figure 15 shows the meter installation. Figure 16 summarizes the metered demand data for the 250-hp air compressor.

Table 8. 13-1547987 Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
VFD Air Comp	1	1	3 / 400 A
		1	3 / 100 A
Total	**1**	**2**	**6**

Figure 15. 250-hp VFD Air Compressor Meter Equipment Setup

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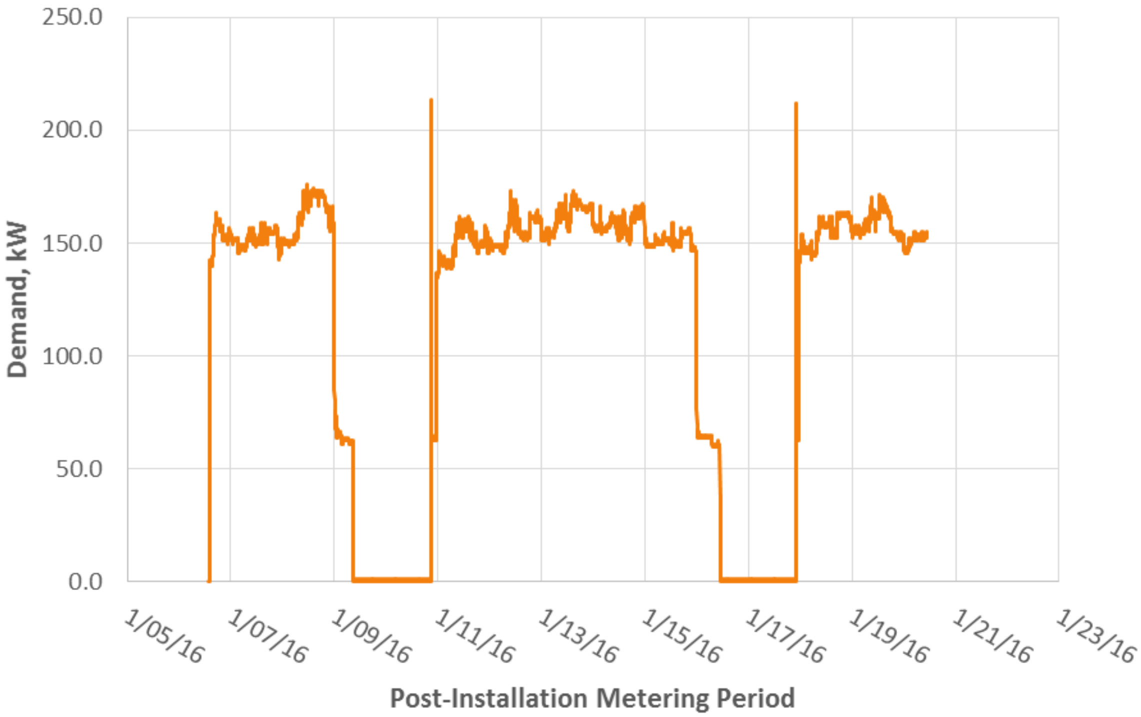
Figure 16. Metered Demand Data for 250-hp VFD Air Compressor



Cadmus used a hand-held anemometer and an IR temperature gun to spot-measure the airflow and to log the temperature of the heated air at various areas of the heat recovery duct. Table 9 provides the temperature readings for the heat recovery duct and the mixing room. Table 10 shows the airflow measurements.

Table 9. Heat Recovery Duct Temperature Spot Measurements

#	Duct Temperature, °F	Mixing Room Temperature, °F
1	86.1	65.0
2	89.2	60.2
3	93.4	67.8
4	92.3	66.8
5	94.6	65.2
6	95.9	62.0
7	97.2	-
Average	**92.7**	**64.5**

Table 10. Heat Recovery Duct Airflow Spot Measurements

#	Airflow, SCFM
1	750
2	605
3	659
4	801
5	731
6	725
7	671
8	843
9	825
10	700
11	538
12	559
Average	**700.6**

Data Accuracy

Table 11. Metering Equipment Accuracy

Measurement	Sensor	Accuracy	Notes
Demand, kW	WattNode Power Meter	±1%	
Current, amps	Magnelab CT	±1%	Recorded load must be < 130% and > 10% of CT rating.

Data Analysis

14-1706227

ECM-1 – Low-Pressure Air Compressor Replacements

Cadmus used the trend data and vendor's performance curves for the installed compressors to verify the installed case equipment demand and operating hours. The two 900-hp air compressors ran constantly during the trend data collection period at an average demand of 1,299.8 kW.

Since the site does not have airflow meters on the installed air compressors, and did not have flow meters on the pre-retrofit air compressors, Cadmus used performance data for the installed air compressors to estimate the compressed air load at the site. The vendor's performance curve (see Figure 17) shows a compressor performance of 5.84 cfm/kW at a design load of 3,833 cfm, assuming a motor efficiency of 96.2%. Cadmus then estimated that the site's total airflow load during the trend data collection was approximately 7,590 cfm based on the equation below.

Airflow, cfm = Trended Demand, kW * Performance, cfm/kW

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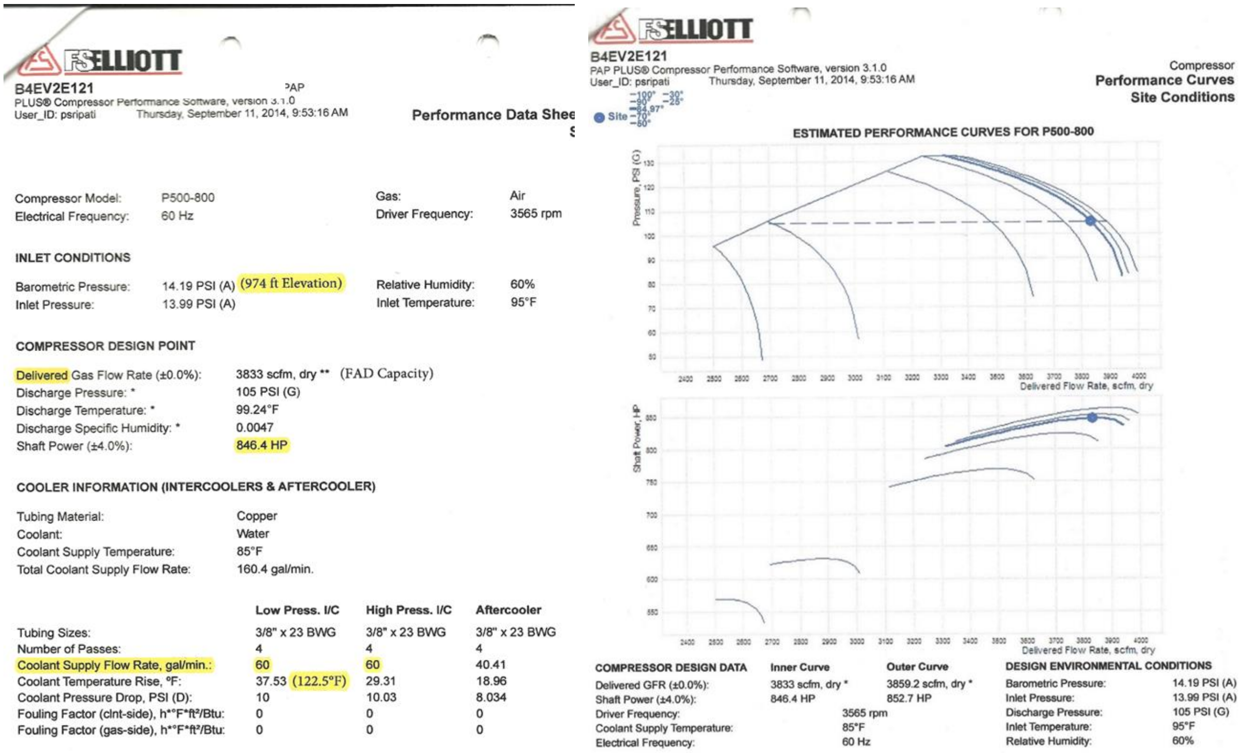
Figure 17. Design Conditions and Performance Curve for Installed Air Compressors



Based on the performance curve above, the maximum airflow for the installed air compressors is 3,940 cfm each, or 7,880 cfm total. Cadmus then estimated the plant's compressed air load during the trend period at 96% (7,590 cfm/7,880 cfm). We then used the performance curves for the installed and pre-retrofit air compressors to calculate the energy required to meet the required load.

Table 12 compares the evaluated installed case overall system performance at various loads. Based on the trended demand data and screenshots of the EMS, which showed both three-stage air compressors operating at comparable power demand, we assumed the installed compressors would share the load equally down to approximately 70% load. Below 70% load, one three-stage air compressor would be able to meet the load. At very low loads, only the existing VFD air compressor would operate.

Table 12. Evaluated Installed Compressed Air System Performance at Various Loads

Percent Load	Compressed Airflow, cfm	Control Description	FS Elliot 3-Stage (2)		VFD (1)		Overall cfm/kW
			Total cfm	cfm/kW	Total cfm	cfm/kW	
100%	7,880	2 3-stage	7,880	6.12	0	0.00	6.12
96%	7,590	2 3-stage	7,590	5.79	0	0.00	5.79
80%	6,304	2 3-stage	6,304	5.00	0	0.00	5.00
60%	4,728	1 3-stage, 1 VFD	3,500	5.35	1,228	5.34	5.35
40%	3,152	1 3-stage	3,152	5.00	0	0.00	5.00
20%	1,576	1 VFD	0	0.00	1,576	5.37	5.37

As shown in Table 12, Cadmus estimated the overall installed case system performance at 96% load to be 5.79 cfm/kW. We assumed the annual operating hours are 8,760 hours based on the trend data and discussions with the facility manager. The evaluated installed case energy use is 11,484,545 kWh and the average and peak demand is 1,311.0 kW.

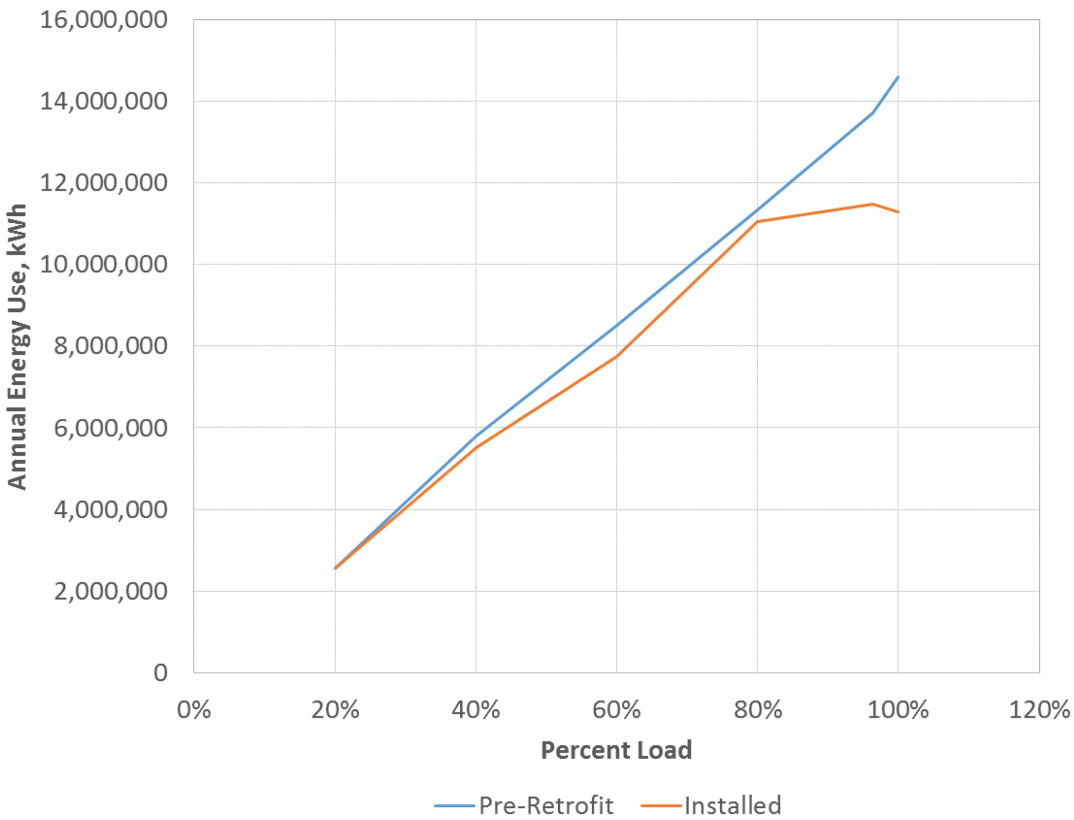
Cadmus collected performance curves for the pre-retrofit air compressors. Table 13 compares the evaluated pre-retrofit overall system performance at various loads. We assumed the load/unload air compressors would be operated up to approximately 80% load before the next load/unload compressor would be turned on and the VFD air compressor would be used for trim. As shown in Table 13, Cadmus estimated the overall pre-retrofit system performance at 96% load to be 4.85 cfm/kW. Pre-retrofit annual operating hours were assumed equal to the installed case. The evaluated pre-retrofit energy use is 13,705,820 kWh and the average and peak demand is 1,564.6 kW.

Table 13. Evaluated Pre-Retrofit Compressed Air System Performance at Various Loads

Percent Load	Compressed Airflow, cfm	Control Description	Load/Unload (8)		VFD (1)		Overall
			Total cfm	cfm/kW	Total cfm	cfm/kW	cfm/kW
100%	7,880	6 load/unload, 1 VFD	7,051	4.71	829	4.93	4.73
96%	7,590	5 load/unload, 1 VFD	5,876	4.71	1,714	5.33	4.85
80%	6,304	4 load/unload, 1 VFD	4,701	4.71	1,603	5.37	4.88
60%	4,728	3 load/unload, 1 VFD	3,526	4.71	1,202	5.34	4.87
40%	3,152	2 load/unload, 1 VFD	2,350	4.71	802	4.90	4.76
20%	1,576	1 VFD	0	0.00	1,576	5.37	5.37

Figure 18 compares the evaluated pre-retrofit and installed case energy use at various compressed air loads. The potential energy savings are highest at high compressed air loads. At very low loads there are no potential savings as only the existing VFD air compressor would operate in both the pre-retrofit and installed cases.

Figure 18. Energy Use Comparison at Various Loads



The evaluated energy savings from this measure are 2,221,275 kWh (16% savings). The annual average (or non-coincident) peak demand reduction is 253.57 kW, and the summer peak coincident demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) is 253.57 kW.

ECM-2 – Low-Pressure Dryer Replacement

Cadmus used the power metered data and trend data for the installed pumps and dryers to verify the installed case equipment demand and operating hours.

The two 1,000-cfm air dryers and one 40-hp cooling tower pump ran constantly during the metering period. Average energy use was calculated by multiplying the average metered demand by total annual operating hours (8,760 hours). The evaluated installed case energy use is 613,648 kWh, with average and peak demands of 70.1 kW.

Pre-retrofit demand for the nine air dryers was based on the original study. The study collected input demand for each dryer. Pre-retrofit annual operating hours were assumed equal to the installed case. The evaluated pre-retrofit energy use is 766,610 kWh. Average and peak demand is 87.5 kW.

The evaluated energy savings from this measure are 152,963 kWh. The annual average peak demand reduction is 17.46 kW, and the summer peak coincident demand reduction is 17.46 kW.

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ECM-3—Compressed Air System Heat Recovery

Cadmus did not meter the four existing 250-hp Atlas Copco air compressors for the high-pressure system but performed a desk review of the calculations submitted in the original application. Since it was unclear how the original study calculated compressor demand in the pre- and post-retrofit cases, Cadmus used manufacturer's data and compressor performance curves to verify the demand.

The evaluated installed case energy use for the high-pressure system is 5,324,692 kWh. The average and peak demands are 607.8 kW.

The evaluated pre-retrofit energy use for the high-pressure system is 6,721,027 kWh. The annual average and peak coincident demands are 767.2 kW.

Evaluated annual energy savings for this measure are 1,396,335 kWh. The average demand reduction and peak coincident demand reduction is 159.4 kW.

The installed air dryer was operating at 4 amps during the site inspection and uses minimal electric energy (~3,400 kWh/year). Since Cadmus did not have access to the pre-retrofit dryer model number, the energy use for the pre- and post-retrofit air dryers was not included in the energy savings calculation.

The evaluated total annual energy savings for this application are 3,770,573 kWh. The average demand reduction is 430.4 kW. The summer peak coincident demand reduction is 430.4 kW.

13-1547987

ECM-1—New VFD Air Compressor

Cadmus used the power metered data to verify installed compressor demand and operating hours. Average weekly operating demand is 125.4 kW, and average percent operating is 82%. Evaluated installed case energy use is 896,280 kWh. Annual average demand is 102.3 kW, and summer peak coincident demand is 155.7 kW.

As Cadmus did not have access to trend data for the [redacted] location, the pre-retrofit compressor average demand of 208.8 kW was based on the original study. Operating hours were assumed equal to the installed case. Evaluated pre-retrofit energy use is 1,492,367 kWh. The average demand is 170.4 kW, and the summer peak coincident demand is 208.8 kW.

Evaluated energy savings for this measure are 596,087 kWh. The annual average demand reduction is 68.0 kW, and the summer peak coincident demand reduction is 53.0 kW.

ECM-2—Compressed Air System Heat Recovery

Cadmus used the spot measurements shown in Table 9 and Table 10 to verify energy savings from the heat recovery duct. The average duct output temperature is 92.7°F, and the average mixing room temperature is 64.5°F. The average airflow provided by the duct is 700.6 cfm.

Assuming the average outside air temperature during the heating months is 30°F, the ratios of the heated air from the compressor and outside air are 55% and 45%, respectively. Total airflow provided to the warehouse was estimated to be the duct airflow divided by 55%, or 1,274 cfm.

According to the site contact, the warehouse is maintained at ~65°F. In the pre-retrofit case, 100% of the air supplied to the space would have been unheated outside air. The average heating demand in the pre-retrofit case was calculated as 48,149 Btu/hr using the following equation:

Pre-Retrofit Heating Demand, Btu/hr =
1.08 * (Space Temp, 65°F – OAT, 30°F) * Total Airflow, 1,274 cfm

The installed case heating demand was calculated at 730 Btu/hr, as follows:

Post-Retrofit Heating Demand, Btu/hr =
1.08 * [Space Temp, 65°F – (Duct Temp, 92.7°F * 55% + OAT, 30°F * 45%)] * Total Airflow, 1,274 cfm

Heating demand savings are 47,419 Btu/hr. As the efficiency of the electric heaters is 100%, electric demand reduction is 13.9 kW. The original study stated that heating was in use for three months of the year, or 2,190 hours. Heating energy savings are 30,436 kWh.

A slight demand penalty arises from the 5-hp heat recovery supply fan. The fan motor efficiency is 87.5%, based on the nameplate, and the load factor is assumed to be 85%; therefore, fan demand is 3.6 kW, and the energy use during the heating months is 7,935 kWh.

Evaluated net energy savings for this measure are 22,501 kWh. Average demand reduction is 10.3 kW. The summer peak coincident demand reduction is 0.0 kW as the heaters would not operate during the summer months.

Evaluated total annual energy savings for this application are 618,587 kWh. Annual average demand reduction is 78.3 kW, and summer peak coincident demand reduction is 53.0 kW.

Conclusion

A summary of the findings and realization rates follow for each application.

14-1706227

Cadmus found most of the equipment installed as expected. The installed cooling tower pumps were 40-hp, compared to the 20-hp expected. The overall annual energy savings realization rate was 53%. The summer coincident peak demand reduction realization rate was 56%. The annual average demand reduction realization rate was 53%. The decrease in energy savings is attributed to the following:

- The installed three-stage air compressors for the low pressure system have a lower performance than expected in the original analysis.

- The original analysis contained minor errors that had a high impact on overall energy savings and demand reduction.

The results of this project emphasize the importance of airflow meters in developing accurate load profiles. Without airflow data, it is difficult to determine whether the compressors are blowing off and what the actual load in the plant is. Cadmus determined the ECM-1 measure savings based on a thorough review of the current compressed air demand and pre-retrofit and installed equipment performance data.

Table 14 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 15 provides the realization rates, compared to energy savings and demand reductions claimed by Duke Energy.

Table 14. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant	Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction
1 & 2	6,085,893	N/A	N/A	N/A	2,374,238	271.0	271.0
3	1,002,105	N/A	N/A	N/A	1,396,335	159.4	159.4
Total	**7,087,999**	**7,087,680**	**775.0**	**809.0**	**3,770,573**	**430.4**	**430.4**

Table 15. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW	Non-Coincident Peak kW
1 & 2	N/A	N/A	N/A
3	N/A	N/A	N/A
Total	**53%**	**56%**	**53%**

13-1547987

Cadmus found the equipment installed as expected. Duke Energy already knew the zero-loss condensate drains had not been installed. Energy savings for the new VFD compressor were higher than expected as average metered demand was ~18% less than expected and operating hours were ~4% higher than expected. Energy savings for the heat recovery system were lower than expected. The original study assumed that, in the pre-retrofit case, the electric heaters would have operated at 100% load during the three-month heating season, which overstated the energy use.

The overall energy savings realization rate was 125%. The summer coincident peak demand reduction realization rate was 95%. The average demand reduction realization rate was 112%.

Table 16 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 17 provides the realization rates, compared to energy savings and demand reductions claimed by Duke Energy.

Table 16. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant	Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction
1	478,767	372,144	55.7	N/A	596,087	53.0	68.0
2	134,572	121,208	0.0	N/A	22,501	0.0	10.3
Total	**613,339**	**494,115**	**55.7**	**69.7**	**618,587**	**53.0**	**78.3**

Table 17. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW	Non-Coincident Peak kW
1	160%	95%	N/A
2	19%	100%	N/A
Total	**125%**	**95%**	**112%**

Application ID 13-1593207
Lighting Retrofit
M&V Report

Prepared for
Duke Energy Carolinas

January 2015, Version 1.0
(Revised August 22, 2016)

Note: This project has been randomly selected from the list of applications for which incentive agreements have been authorized under Duke Energy's Smart $aver® Custom Incentive Program.

The M&V activities described here are undertaken by an independent third-party evaluator of the Smart $aver® Custom Incentive Program.

Findings and conclusions of these activities shall have absolutely no impact on the agreed upon incentive between Duke Energy and [redacted].

Submitted by:

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On August 22, 2016 the Duke Energy projected savings in this report were corrected by Cadmus to correspond to Duke Energy expected savings as found in the Duke Energy program tracking database.

Introduction

This document addresses the M&V activities for the lighting retrofit at [redacted] in [redacted], North Carolina. This lighting retrofit was rebated through Duke Energy's Smart $aver Custom Lighting Incentive program. The following ECMs were implemented as part of this application.

- **ECM-1 –** Retrofitted (1) 85W 4' 1L T12 fixture with 2L 4' F28T8 fixture.
- **ECM-2 –** Retrofitted (30) 125W 8' 1L T12 fixtures with 4' 2L F28T8 fixtures.
- **ECM-3 –** Retrofitted (1) 145W 4' 2L T12 fixture with 4' 2L F28T8 fixture.
- **ECM-4 –** Retrofitted (69) 80W 4' 2LT12 fixtures with 4' 2L F28T8 fixtures.
- **ECM-5 –** Retrofitted (112) 80W 4' 2L T12 fixtures with 4' 2L F17T8 fixtures.
- **ECM-6 –** Retrofitted (3236) 227W 8' 2L T12 fixtures with 4' 2L F28T8 fixtures.
- **ECM-7 –** Retrofitted (144) 160 W 4' 4L T12 fixtures with 4' 2L F28T8 fixtures.
- **ECM-8 –** Retrofitted (2429) 227W 8' 2L T12 fixtures with 4' 4L F28T8 fixtures.
- **ECM-9 –** Removed (266) 455 W Metal Halide fixtures.

Goals and Objectives

A post-retrofit survey of the lighting usage was conducted to determine the power reduction from the lighting upgrade.

The projected savings goals are:

Facility	Application Annual kWh savings	Application kW Savings	Duke Projected Annual kWh savings	Duke Projected kW savings
redacted	6,802,289	793	7,928,096	902
Total	**6,802,289**	**793**	**7,901,837**	**902**

The objective of this M&V project will be to verify the actual:

- Annual gross kWh savings
- Summer peak kW savings
- Coincidence Peak kW savings
- kWh & kW Realization Rates

Project Contacts

Duke Energy M&V Coordinator	Frankie Diersing	p: 513-287-4096
NORESCO Engineer	Katie Gustafson	p: 303-459-7430 kgustafson@noresco.com

Customer Contact	redacted	

Site Locations/ECM's

Address	ECMs Implemented
redacted	1-9

Data Products and Project Output

- Post retrofit survey of lighting fixtures.
- Average post-retrofit lighting fixture load shapes.
- Equivalent Full Load Hours (HOURS) by day type (weekday/weekend).
- Summer peak demand savings.
- Summer utility coincident peak demand savings.
- Annual Energy Savings.

M&V Option

IPMVP Option A

Field Data Points

Post-Installation

Survey data

- Fixture count and wattages.
- Verified that all fixture specifications and quantities were consistent with the application.
- Determined how the lighting is controlled and recorded controller settings.
- Verified that all pre (existing) fixtures were removed.
- Determined what holidays the facility observes through the year.
- Determined if the lighting zones are disabled during the holidays.

Data Accuracy

Measurement	Sensor	Accuracy
Current	CTV-A 20A	±4.5%

Field Data Logging

The following table summarizes the quantities of lighting deployed loggers to monitor the retrofitted fixtures.

ECMs	Hobo (U12)	CTV-A 20A
1-9	14	50
Total	**14**	**50**

Data Analysis

There were three distinct space types monitored in this facility: An industrial production space that is cooled year round by a water-cooled chiller plant, office spaces that are heated and cooled with heat pumps, and office spaces that are heated with electric heat and not cooled. We conducted the following analysis for each of these three space types.

- Used the standard calculation template for estimating pre and post demand and energy consumption that incorporates the methodology described below.
- From survey data calculated the actual pre and post fixture kW.
- Weighted the time-series data according to connected load per control point. Methodology included in analysis worksheet.
- From time-series data determined the actual schedule of post operation.

$$LF(t) = \frac{\sum_{i=1}^{N_{Logged}} \left(Current_{ControlPoint_i} * ScaleFactor_i\right)}{\sum_{i=1}^{N_{Logged}} kWControlPoint_i}$$

$$kW_{Lighting}(t) = LF(t) * \sum_{i=1}^{N_{ControlPoints}} kWControlPoint_i$$

Where

LF(t) = Lighting Load factor at time = t
$kWControlPoint_i$ = connected load of control point i
$CurrentControlPoint_i$ = logged current at control point i from time series data
$ScaleFactor_i$ = Convert logged current to kW
NLogged = population of logged control points
NControlPoints = population of all control points

- Created separate schedules for weekdays and weekends using LF(t).
- Tabulated average operating hours by daytype (e.g. weekday and weekend).
- Extrapolated annual operating hours from the recorded hours of use by daytype.
- Generated the post load shape by plotting surveyed fixture kW against the actual schedule of post operation for each daytype.

- Calculated pre annual operating hours using the post-retrofit schedules by daytype and extrapolated to the full year.
- Calculated energy savings and compared to project application:

$$kWh_{savings} = (N_{Fixtures} * kW_{Fixture} * Hours)_{PRE} - (N_{Fixtures} * kW_{Fixture} * Hours)_{Post}$$

$$NCP\ kW_{savings} = (N_{Fixtures} * kW_{Fixture})_{PRE} - (N_{Fixtures} * kW_{Fixture})_{Post}$$

$$CP\ kW_{savings} = NCP\ kW_{savings}\ x\ CF$$

where:

$N_{Fixtures}$	= number of fixtures installed or replaced
$kW_{Fixture}$	= connected load per fixture
HOURS	= equivalent full load hours per fixture
NCP $kW_{savings}$	= non-coincident peak savings
CP $kW_{savings}$	= coincident peak savings
CF	= coincidence factor

- The savings with HVAC interactions are calculated from:

$$kWh_{savings\ with\ HVAC} = kWh_{savings}\ x\ (1 + WHFe)$$
$$kW_{savings\ with\ HVAC} = kW_{savings}\ x\ (1 + WHFd)$$

where:

WHFe	= waste heat factor for energy
WHFd	= waste heat factor for demand

Verification and Quality Control

1. Visually inspected lighting logger data for consistent operation. Sorted by day type and removed invalid data.
2. Verified the post retrofit lighting fixture specifications and quantities were consistent with the application.
3. Verified that pre-retrofit lighting fixtures were removed from the project. Inspected storeroom for replacement lamps or fixtures.

Recording and Data Exchange Format

1. Hobo logger binary files
2. Excel spreadsheets

Results Summary

The following tables summarize the total estimated savings for the [redacted] lighting retrofit.

Table 1. Energy Savings and Realization Rates.

	Duke Savings	Realized Savings		Realization Rate	
		Lighting Only	Lighting and HVAC	Lighting Only	Lighting and HVAC
Energy (kWh)	7,901,837	6,995,380	7,360,561	89%	93%
Peak Demand (kW)	902	839	960	93%	106%
CP Demand (kW)	902	802	917	89%	102%

The energy and demand savings calculation summary is shown in **Error! Reference source not found.**. Demand savings details are shown in **Error! Reference source not found.**.

Table 2. Summary of Energy and Demand Savings Calculations.

Space Type	Base kW	EE kW	HRS	CF	Lighting Only			With HVAC Interactions			
					kWh savings	NCP kW	CP kW	Interaction Factors	kWh savings	NCP kW	CP kW
Office Heating & Cooling	223.7	68.6	8589	0.98	1,332,214	155.1	152.7	WHFe= 0.103 WHFd= 0.152	2,061,082	250.6	246.8
Office Heating Only	246.5	64.1	8500	0.96	1,550,441	182.4	175.1	WHFe= -0.154 WHFd= 0	1,845,789	256.7	246.4
Warehouse	767.3	265.7	8199	0.95	4,112,724	501.6	474.2	WHFe= 0.113 WHFd=0.194	6,403,149	837.3	791.5
Total	1237.5	398.3	8336	0.96	6,995,380	839.163869	802.0		7,360,561	959.96	917.10

- The office spaces that are heated and cooled are conditioned with heat pumps, the office spaces are that are heated only use electric heat. For both these space types, we used the NORESCO developed HVAC interaction factors for offices.

- The warehouse space of this facility is conditioned with a chiller plant. We used the NORESCO developed HVAC interaction factors for light industrial spaces with DX cooling and economizing.

The following figures show the average daily load shapes for each space type. When extrapolated to the year, the M&V annual operating hours ranged from 8,199 to 8,598, which range from 4.3% less than to 0.2% greater than the hours stated in the application.

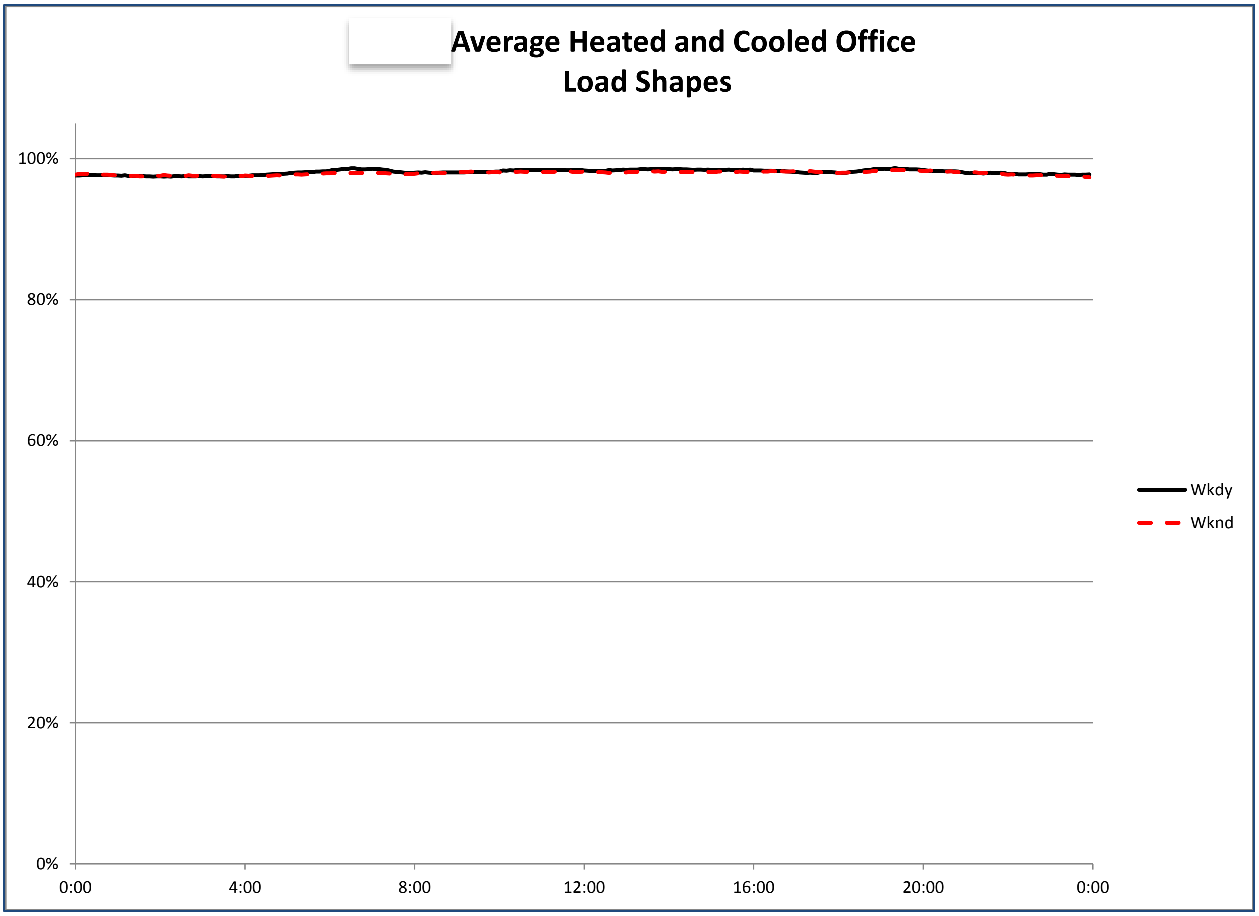

Figure 1: Average heated and cooled office load shapes.

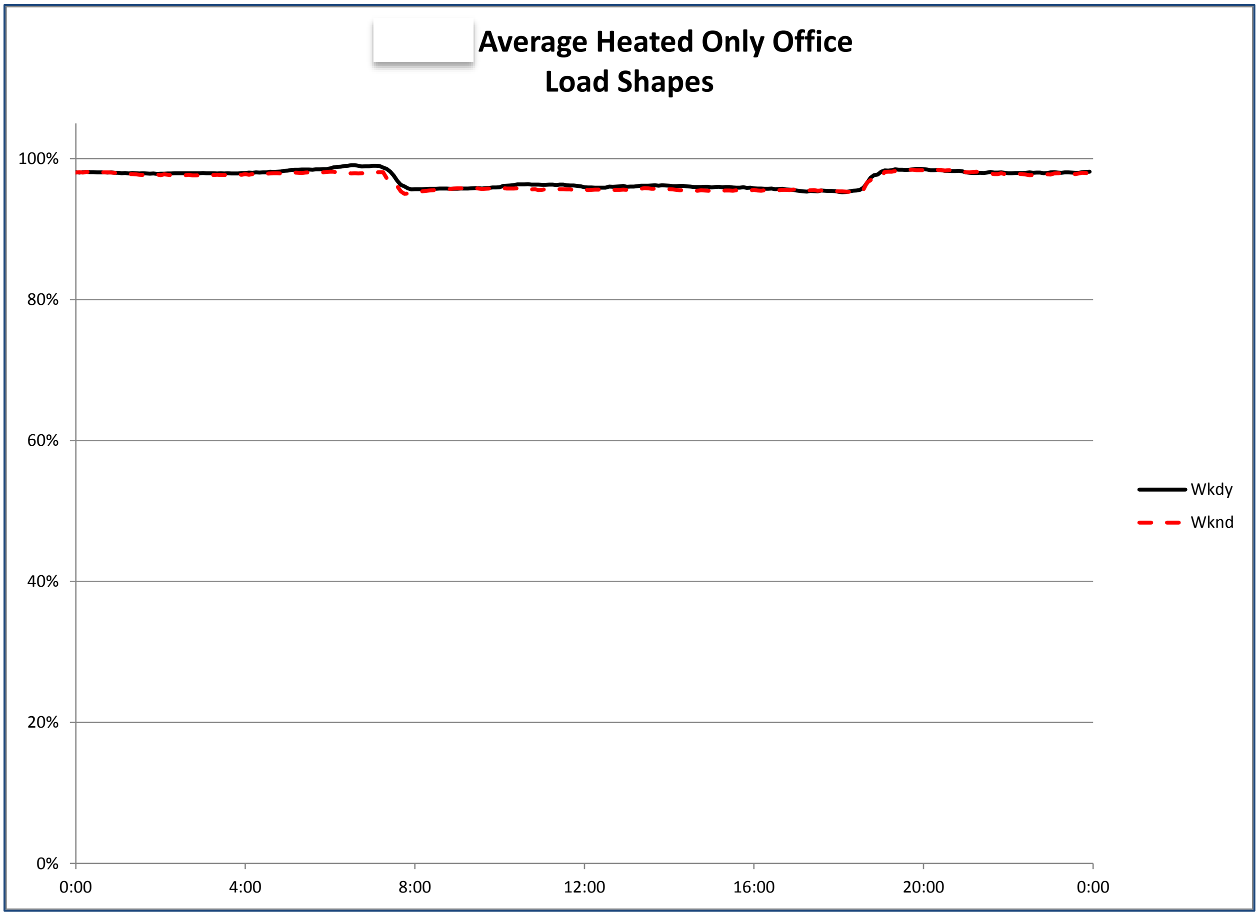

Figure 2: Average heated only office load shapes.

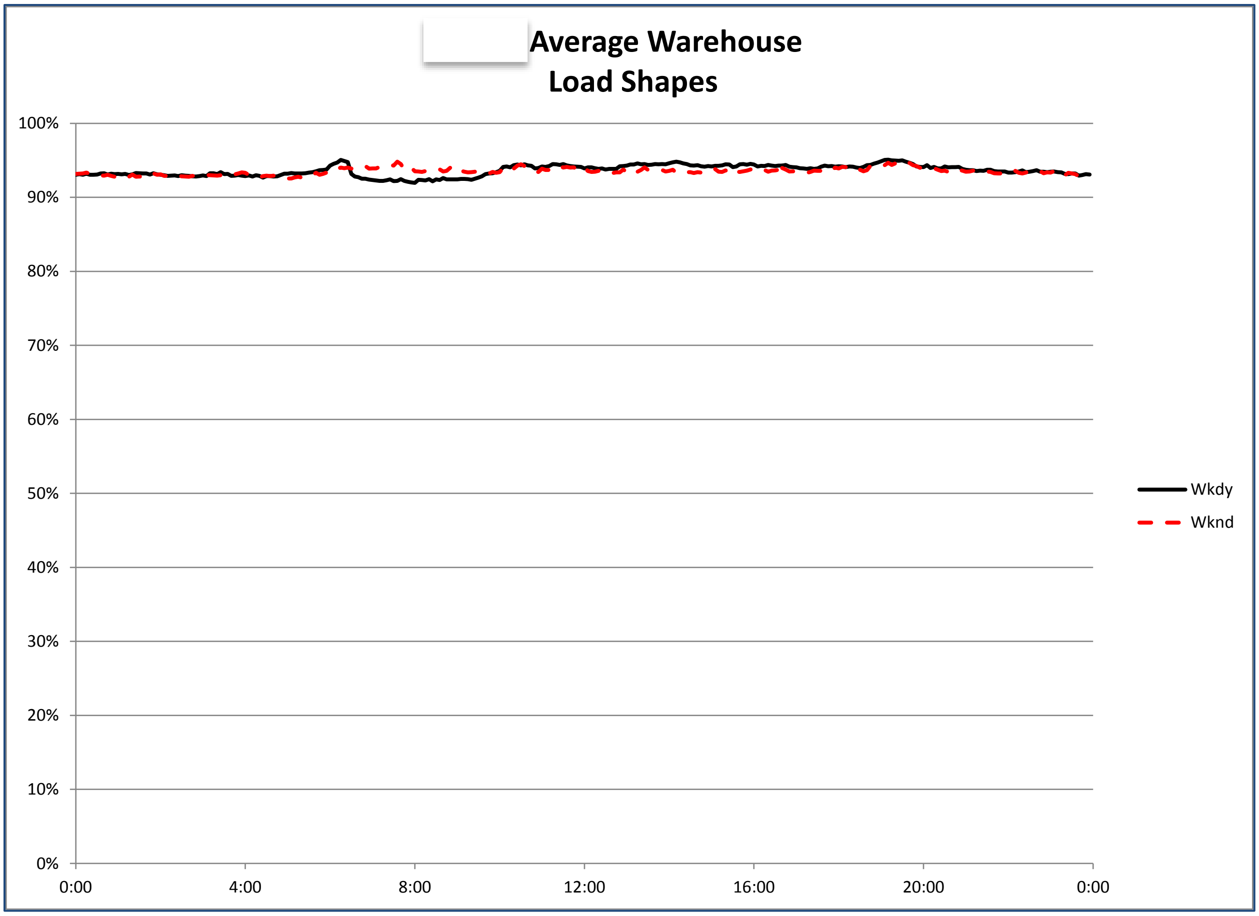

Figure 3: Average warehouse load shapes.

Table 3. Demand Savings Detail.

ECM	EE Technology						Base Technology				
	QTY	EE Fixture Type	W/ Fixture	Source	Cut Sheet W/ Fixture	kW	QTY	Base Fixture Type	W/ Fixture	Source	Connected kW
1	1	RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Nultra	47.7	Spot measured	49	0.05	1	1) F48T12/HO 2) RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Nultra	61.0	Appendix B	0.1
2	30	RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Hultra	47.7	Spot measured	49	1.43	30	1) F96T12/HO/ES Mag STD 2) F96T12/HO/ES Electronic	90.7	Appendix B	2.7
3	1	RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Nultra	47.7	Spot measured	49	0.05	1	1) F48T12/HO 2) RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Nultra	81.0	Appendix B	0.1
4	69	RTR2402T832WNLUS, F28T8/XLSPX41ECO, GE232Max-NUltra	47.7	Spot measured	49	3.29	69	1) F48T12/ES Mag STD 2) F48T12/ES Electronic	67.3	Appendix B	4.6
5	112	RTR2202T817WNLUS, F17T8/SPX41/ECO, GE232Max-NUltra	32.0	Cut Sheet	32	3.58	112	1) F48T12/ES Mag STD 2) F48T12/ES Electronic	67.3	Appendix B	7.5
6	3236	RST1802T832ENCCLSLUT, F28T8/XLSPX41ECO, GE232Max-Nultra	47.7	Spot measured	49	154.34	3236	1) F96T12/HO/ES Mag STD 2) F96T12/HO/ES Electronic	191.0	Appendix B	618.1
7	144	RTR2402T832WNLUS, F28T8/XLSPX41ECO, GE232Max-Nultra	47.7	Spot measured	49	6.87	144	1) F48T12/ES Mag STD 2) F48T12/ES Electronic	134.7	Appendix B	19.4
8	2429	RST1804T832ENCCLSLUT, F28T8/XLSPX41ECO, GE432Max-Nultra	94.2	Spot measured	94	228.71	2429	1) F96T12/HO/ES Mag STD 2) F96T12/HO/ES Electronic	191.0	Appendix B	463.9
9	0	None	0	-	-	0	266	MH	455	Appendix B	121.0

Notes: SPC Apdx B – Appendix B 2013-14 Table of Standard Fixture Wattages. See http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

Because magnetic ballasts are currently being phased out of the market place, we adjusted the base fixture wattage to account for this changing base line. The Duke Energy FES papers assume a 12 year measure life for linear fluorescent fixtures. We assumed that the baseline for the first quarter of the useful life would be a similar T12 fixture with a magnetic ballast. For the last three quarters of the useful life we assumed the baseline would be a similar T12 fixture with an electronic ballast. Table 4 shows the wattages that were used to determine the adjusted baseline. All of these wattages are from Appendix B. Table 5 below details the application annual savings over the measure life. For ECMs 1 and 3 there is not a similar fixture with an electronic ballast. For this reason we assumed that the last three quarters of the useful life baseline would be the fixture that was installed as part of this application. We chose this value because each of these ECMs only have one fixture and this approach offers conservative savings for these measures. The two fixtures used to determine the adjusted baseline are included in the Table 3 above.

Table 4. Adjusted Baseline Wattages.

Adjusted Baseline Calculations			
ECM	Magnetic Ballast W/ Fixture	Electronic Ballast W/ Fixture	Adjusted W/ Fixture
1	85	49	61.0
2	112	80	90.7
3	145	49	81.0
4	82	60	67.3
5	82	60	67.3
6	227	173	191.0
7	164	120	134.7
8	227	173	191.0

Table 5 Measure Life Annual Savings.

Measure Life	Lighting Only			With HVAC Interactions		
	kWh savings	NCP kW	CP kW	kWh savings	NCP kW	CP kW
Year 1	7,731,396	925	886	8,069,986	1,052	1,007
Year 2	7,731,396	925	886	8,069,986	1,052	1,007
Year 3	7,731,396	925	886	8,069,986	1,052	1,007
Year 4	7,731,396	925	886	8,069,986	1,052	1,007
Year 5	6,627,371	796	760	7,005,849	914	872
Year 6	6,627,371	796	760	7,005,849	914	872
Year 7	6,627,371	796	760	7,005,849	914	872
Year 8	6,627,371	796	760	7,005,849	914	872
Year 9	6,627,371	796	760	7,005,849	914	872
Year 10	6,627,371	796	760	7,005,849	914	872
Year 11	6,627,371	796	760	7,005,849	914	872
Year 12	6,627,371	796	760	7,005,849	914	872
Total	83,944,555	10,070	9,624	88,326,736	11,519	11,005

Measure Life Yearly Average	6,995,380	839	802	7,360,561	960	917

Application ID 13-1378419
Performance Contract Renovation
M&V Report

Prepared for
Duke Energy Carolinas

February 2015, Version 1.0
(Revised August 22, 2016)

Note: This project has been randomly selected from the list of applications for which incentive agreements have been authorized under Duke Energy's Smart $aver® Custom Incentive Program.

The M&V activities described here are undertaken by an independent third-party evaluator of the Smart $aver® Custom Incentive Program.

Findings and conclusions of these activities shall have absolutely no impact on the agreed upon incentive between Duke Energy and [redacted]

Submitted by:

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On August 22, 2016 the Duke Energy projected savings in this report were corrected by Cadmus to correspond to Duke Energy expected savings as found in the Duke Energy program tracking database.

Introduction

This report addresses measurement and verification (M&V) activities for the [redacted] custom program application. The application covers various HVAC renovations at 7 different buildings.

[Redacted] Building #1

- Retrofit of the existing pneumatic controls to direct digital controls, and installation of new VFDs on AHUs serving the [redacted] building.
- Existing Equipment includes Central Station AHU with supply and return fans with inlet guide vanes. Existing EMS is a combination of legacy DDC and pneumatic controls.
- New equipment includes the installation of VFDs and new inverter duty motors on supply and return fans. Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS.

[Redacted] Building #2

- Retrofit of the existing pneumatic controls to direct digital controls, AHU VFD, and retrofit of the chiller plant serving the [redacted] building.
- Existing Equipment includes (4) Central Station AHU with supply fans with Inlet guide vanes. Existing EMS is a combination of legacy DDC and pneumatic controls. Secondary CHW pumping is constant volume.
- New equipment includes new AHU's with VFDs. Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS. VFDS are to be installed on secondary CHW pumps.

[Redacted] Building #3

- Retrofit of the existing pneumatic controls to direct digital controls serving the [redacted] building.
- Existing Equipment includes a central Station AHU. Existing EMS is a combination of legacy DDC and pneumatic controls.
- Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS.

[Redacted] Building #4

- Retrofit of the existing pneumatic controls to direct digital control serving the [redacted] building.
- Existing Equipment includes a central Station DD VAV AHU and three RTU's,

- Existing Equipment includes a central Station AHU. Existing EMS is a combination of legacy DDC and pneumatic controls.
- Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS.
- Existing building chilled water system was shut down and chilled water system was tied in to the adjacent [redacted] building chilled water plant.

[Redacted] Building #5

- Retrofit of the existing pneumatic controls to direct digital controls serving the [redacted] building.
- Existing Equipment includes a central Station AHU. Existing EMS is a combination of legacy DDC and pneumatic controls.
- Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS.

[Redacted] Building #6

- Retrofit of the existing pneumatic controls to direct digital controls, AHU VFDs, and retrofit of the chiller plant serving the [redacted] building.
- Existing Equipment includes (7) VAV AHU's with Inlet guide vanes. Existing EMS is a combination of legacy DDC and pneumatic controls. Secondary CHW pumping is constant volume.
- New equipment includes new VFDs on AHU supply fans. Existing pneumatic controls to be replaced and integrated into existing DDC controls to connect to Campus BAS. VFDS are to be installed on secondary CHW pumps.

[Redacted] Plant #7

- Modify chilled water pumping system to be variable and integrate chiller plant optimization program.
- Existing equipment includes (1) 300 ton, (2) 1000 ton and (1) 2000 ton chillers and (2) 300 Bhp hot water boilers.
- Optimize chiller plant with continuous monitoring and adjustment for chiller plant equipment. Provide eight (8) VFDs for the primary chilled water and condenser water pumps.

Goals and Objectives

Pre-and post-retrofit energy models of the building's energy use were created to determine the energy and power reduction achieved by the control system upgrades.

The projected savings goals identified in the application were:

	APPLICATION		DUKE PROJECTIONS		
Facility	**Proposed Annual kWh savings**	**Proposed Summer Peak kW savings**	**Expected Annual kWh savings**	**Expected Summer Coincident peak kW savings**	**Expected Summer Non-coincident peak kW savings**
Building #1	1,212,683	72	1,212,681	67	111
Building #2	535,039	937	535,042	93	95
Building #3	419,256	94	419,254	74	139
Building #4	600,766	61	613,500	61	84
Building #5	294,638	17	294,639	14	31
Building #6	317,167	40	317,164	50	51
Plant #7	1,087,795	79	1,210,414	56	178
Total	**4,467,344**	**1,300**	**4,602,694**	**414**	**689**

The objective of this M&V project was to verify the actual:

- Annual gross electric energy (kWh) savings
- Building peak demand (kW) savings
- Coincident peak demand (kW) savings
- Energy, demand and coincident demand Realization Rates

Project Contacts

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Duke Energy M&V Coordinator	Frankie Diersing	Frankie.diersing@duke-energy.com	o: 513-287-4096 m: 513-673-0573
Customer Contact	Redacted		

Site Locations/ECM's

Address
Redacted

Data Products and Project Output

- Energy consumption pre- and post-retrofit for the entire facility
- Annual energy savings
- Peak demand savings
- Coincident peak demand savings.

M&V Option

IPMVP Option A & D

M&V Implementation

This survey and data collection was for post-retrofit only, and due to the magnitude of the implemented ECMs, was performed on a sample of the buildings listed in the introduction. The buildings that were evaluated are [redacted] Bldg #1, [redacted] Bldg #4, and the [redacted] Plant #7. These are the three largest projects in the original application, and represent about 73% of the total claimed savings. Tasks carried out during the M&V included the following.

- Conducted an interview with the building contact.
- Obtained copies of building floor plans for evaluated buildings.
- For buildings being evaluated, collected billing data (monthly kWh and demand) for January 2011 - present.
- For buildings being evaluated, confirmed trending capability for the points listed in the Field Data Logging section.
- Identified HVAC equipment currently on the new digital control system and collected nameplate data.
- Verified that equipment moved to the new control system is operating properly.
- Obtained pre-retrofit and post-retrofit sequences of operation for all controlled equipment.
- Deployed loggers and established trend logs to monitor operation of supply fans, compressors, economizers, CHW pumps, CO2 levels, and outdoor air temperature and relative humidity.
- Trended EMS data and deployed loggers for three weeks.
- Constructed and calibrated the building energy model.
- Evaluated the energy impacts of the building retrofit in the energy model.

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	Recorded load must be >10% of CT rating
Temperature	Onset Temp/RH	±0.36°F	
True electric power	ElitePro	±1%	
EMS trend points	Various		EMS sensor accuracy not known

Field Data Points

[Redacted] Building #1 (Option A)

One-time measurements for all equipment logged (to check and validate logger/trend data)

- (2) 200 HP AHU supply fan volts, amps, kW, VFD speed and power factor
- (2) 60 HP AHU return fan volts, amps, kW, VFD speed and power factor

[Redacted] Building #4 (Option D)

The following survey data was collected:

- Floor plans, lighting plans, and mechanical showing VAV boxes.
- Utility bills (kWh and kW) from January 2011 to present.
- Nameplate data and quantity for all HVAC equipment.
- Pre-retrofit and post-retrofit sequences of operation for all controlled equipment. Complete the attached HVAC Operating Information tables.
- All other information in the Survey-IT data form. This form includes detailed information about all building systems, including:
    - Building wall, window and floor area
    - Space types and uses
    - HVAC zoning
    - Occupancy schedules and operations (daily, weekly, annually, holidays)
    - Lighting loads and schedules
    - Equipment loads and schedules
    - Temperature setpoints/schedules, Energy Management Systems
    - HVAC system controls
    - Fan and pump operation

  - Shading and blinds
  - Chillers, cooling towers, boilers, central air handlers, and water heating
  - Building envelope, including windows, walls, areas, and construction types

[Redacted] Plant #7 (Option A)

The following survey data was obtained for all equipment logged in the Chiller Plant:

- (2) 2000 ton cooling tower make/model/serial number/VFD Info.
- (1) 300 ton chiller make/model/serial number
- (2) 1000 ton chiller make/model/serial number
- (1) 2000 ton chiller make/model/serial number
- (1) 10 HP Primary CHW pump make/model/serial number
- (2) 40 HP Primary CHW pump make/model/serial number
- (1) 60 HP Primary CHW pump make/model/serial number
- (3) 75 HP Secondary CHW pump make/model/serial number/ VFD Info

The following one-time measurements were taken for all equipment logged (to check and validate logger/trend data)

- (2) 2000 cooling tower volts, amps, kW and power factor, and VFD speed(s). Note number of fans running at the time of the measurements.
- (1) 300 ton chiller volts, amps, kW and power factor
- (2) 1000 ton chiller volts, amps, kW and power factor
- (1) 2000 ton chiller volts, amps, kW and power factor
- (1) 10 HP Primary CHW pump volts, amps, kW, and power factor
- (2) 40 HP Primary CHW pump volts, amps, kW, and power factor
- (1) 60 HP Primary CHW HP pump volts, amps, kW, and power factor
- (3) 75 HP Secondary CHW pump VFD speed, volts, amps, kW, and power factor

Field Data Logging

- Installed data loggers to log the following data points in 5 minute intervals.
- Where BAS was capable of trending the following, trends were set up in place of data loggers. Since kW was not available at the BAS, kW, amperage, and voltage was logged on each type of equipment and trends were set up for VFD speed and static pressure on all equipment. Data was collected for 3 weeks. Unfortunately, some of the trends that were set up by the facility staff were logged at different time periods, which reduced their usefulness during the analysis.

[Redacted] Building #1 (Option A)

1. (2) 200 HP Supply Fan kW and VFD speed(s) and static pressure
    a. Note that the data logger for Supply Fan #1 failed and the data was corrupted, however that fan tracks Supply Fan #2 and so results were not compromised.
2. (2) 60 HP Return Fan kW and VFD speed(s)

[Redacted] Building #4 (Option D)

1. No data logging was performed. Site visit included collecting building information such as nameplate data and building geometry.

[Redacted] Plant #7 (Option A)

1. (2) 2000 ton cooling tower kW and VFD speed(s) (4-25 HP Fans each)
2. (1) 300 ton chiller kW and VFD speed(s)
3. (2) 1000 ton chiller kW and VFD speed(s)
4. (1) 2000 ton chiller kW and VFD speed(s)
5. (1) 10 HP Primary CHW pump kW and GPM
6. (2) 40 HP Primary CHW pump kW and GPM
7. (1) 60 HP Primary CHW pump kW and GPM
8. (3) 75 HP Secondary CHW pump kW, GPM, and VFD speed(s)
9. OA Temperature and RH
10. Chilled Water Supply Temperature (Per chiller and system)
11. Chilled Water Return Temperature (Per chiller and system)
12. Condenser Water Supply Temperature (Per chiller and system)
13. Condenser Water Return Temperature (Per chiller and system)
14. CHW flow rate (Per chiller and system)
15. CW flow rate (Per chiller and system)
16. OA Temperature and RH

Note: Unfortunately, not all points were logged at the same time and interval which created some difficulty with data analysis.

- **Outdoor Air**

1. BAS trends were set up to record OA temperature and RH, Logged for 3 weeks**.**

Logger Table

The following table summarizes all logging equipment that was used to accurately measure the above noted ECM's:

ECM	Elite-Pro	Hobo Energy Logger Pro	Magnelab CT's	24" RoCoil
SF-1 (Building #1)	1		(3) 500 A	
SF-2 (Building #1)	1		(3) 500 A	
RF-1 (Building #1)	1		(3) 100 A	
RF-2 (Building #1)	1		(3) 100 A	
300 ton Chiller (Plant #7)	1		(3) 500 A	
1000 ton Chiller (Plant #7)	1		(3) 1000 A	
2000 ton Chiller (Plant #7)	1			(3) 2100 A
10 HP Primary CHW Pump (Plant #7)		1	(1) 20 A	
(2) 40 HP Primary CHW Pump (Plant #7)		2	(2) 50 A	
60 HP Primary CHW Pump (Plant #7)		1	(1) 100 A	
(3) 75 HP Secondary CHW Pump (Plant #7)	3		(9) 100 A	
Total	**10**	**4**	**31**	**3**

Data Analysis

Each building in this study implemented a different combination of ECMs. In general, there are 3 different ECMs implemented in the various buildings. These ECMs are as follows:

- Installation of new VFDs for supply and return fans on AHUs serving the building. VFDs replaced inlet guide vane flow control.
- Retrofit of the existing pneumatic controls to direct digital controls. Upgraded controls allowed more sophisticated control strategies such as:
    - HVAC operating schedule adjusted from 24/7 operation to off at night.
    - Space temperature setpoints adjusted from constant at all times to adjustable with a night setback.
    - Economizer operation re-established
    - Supply air temperature reset strategy
- [Redacted] Plant #7 modification. Generally this means an old inefficient chiller was removed and the chilled water system was connected to a modern, more efficient chilled water system ([redacted] Building #4).

Due to the magnitude of this M&V study, the savings for every ECM in each building was not calculated. Instead, representative buildings were chosen and the ECM savings were calculated for those buildings only. The ECM realization rate was then applied to each of the other buildings with that ECM. Specifically, the "VFD" ECM was calculated at the [redacted] building #1, and the "controls" and "[redacted] plant #7" ECMs were calculated at the [redacted] building #4. The [redacted] plant #7 is unique and was analyzed separately.

VFD ECM Analysis

Time series kW data was obtained for each VFD installed at the [redacted] building #1. The VFD installed on the AHU fans is used to more efficiently reduce the fan flow rate. Prior to installing the VFD, the fan would run at full speed with variable inlet vane flow control.

To estimate savings, the first step was to develop an approximation of the annual energy use in the post-retrofit case. Because only three weeks of actual data was monitored, that data needed to be extrapolated to a full year. This was accomplished by developing a relationship between fan power and outside air temperature.

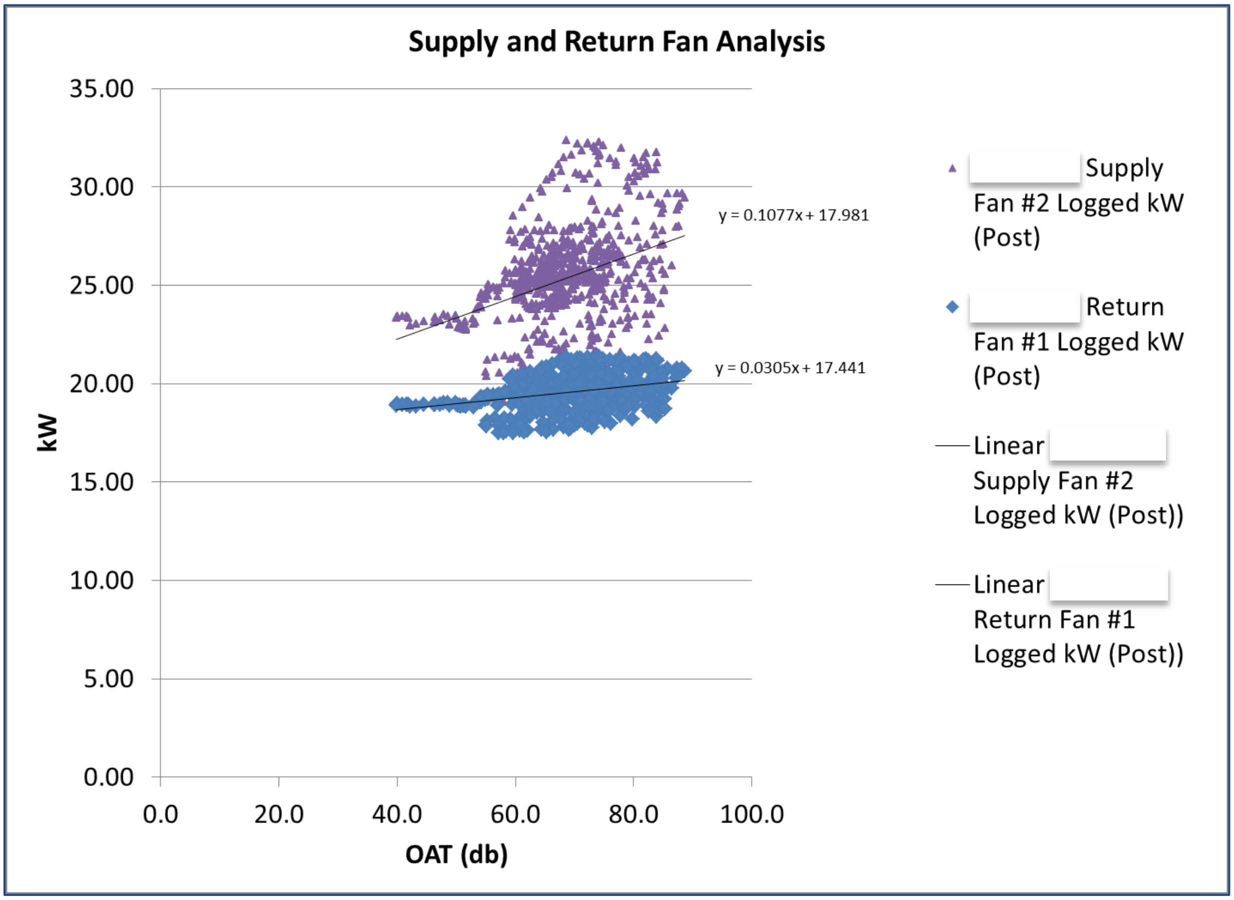

Figure 1. Supply and Return Fan Analysis

Figure 1 above shows the logged supply and return fan power plotted against outside air temperature. The linear equations displayed are an approximation of the relationship between outside air temperature and fan power. Looking at Figure 1, the data appears to be somewhat scattered and the relationship between kW and OAT is not very strong. In an attempt to finder a stronger relationship, the data was sorted, viewed in a few different formats, and filtered. Figure 2 and Figure 3 shown below offer a few different views of the supply fan data.

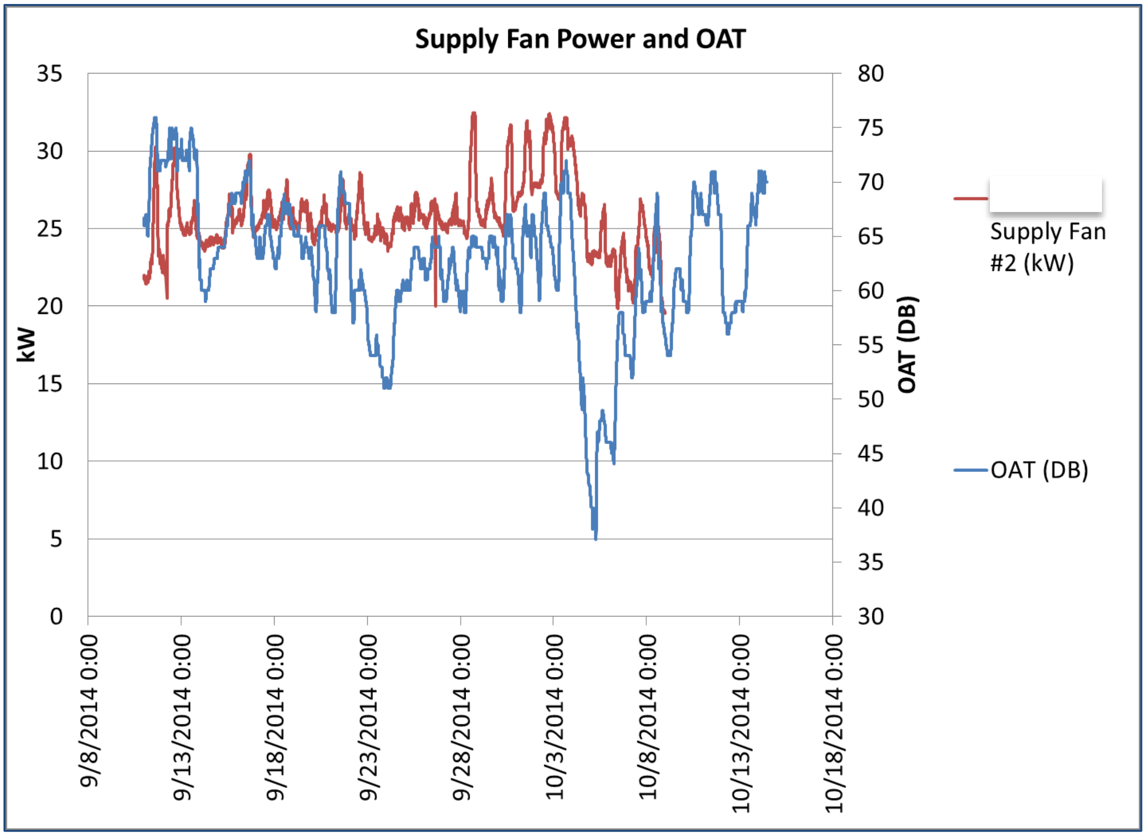

Figure 2. Fan power and OAT

Figure 2 shown above is the supply fan power and outside air temperature (OAT) during the months of September and October 2014. It is evident that there is a relationship between the two; however it is somewhat inconsistent.

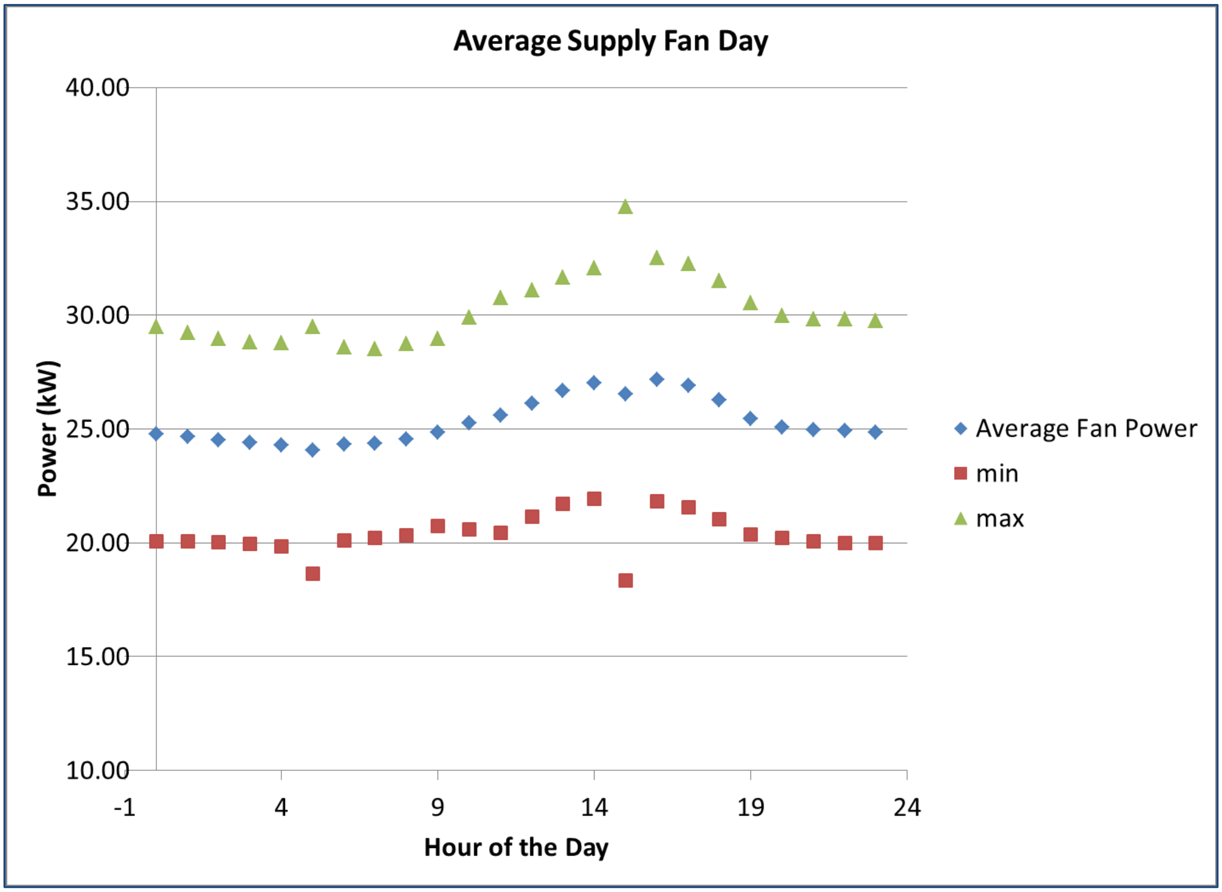

Figure 3. Average Supply Fan Day

Figure 3 shows the average supply fan power during each hour of the day along with the minimum and maximum values during the 6 week monitoring period. It is evident that fan power does follow a pattern during the day peaking around hour 15 (3pm), however the standard deviation is so large as to preclude developing any reasonable relationship. One conclusion to be drawn from Figure 2 and Figure 3 is that there may be a controls issue present in the building which is worth investigating.

Unfortunately, there was simply no way to come up with an improved fan power estimate and so the equations in Figure 1 were used as the best available option. The estimated annual energy use by each of the fans for the post-retrofit case was approximated by applying the linear regression equations in Figure 1 to the hourly average OAT values in a TMY weather file for Charlotte, NC.

Once the post-retrofit fan energy was calculated, the next step was to calculate the pre-retrofit fan energy.

The first step in determining the pre-retrofit fan energy is to determine the power that the fan would draw at full speed. Unfortunately, it was not possible to take a one-time, full-speed power measurement to estimate the full flow power consumption. Instead, kW was logged during the same time period as VFD speed %. By plotting power against speed, a relationship between kW and fan speed was approximated.

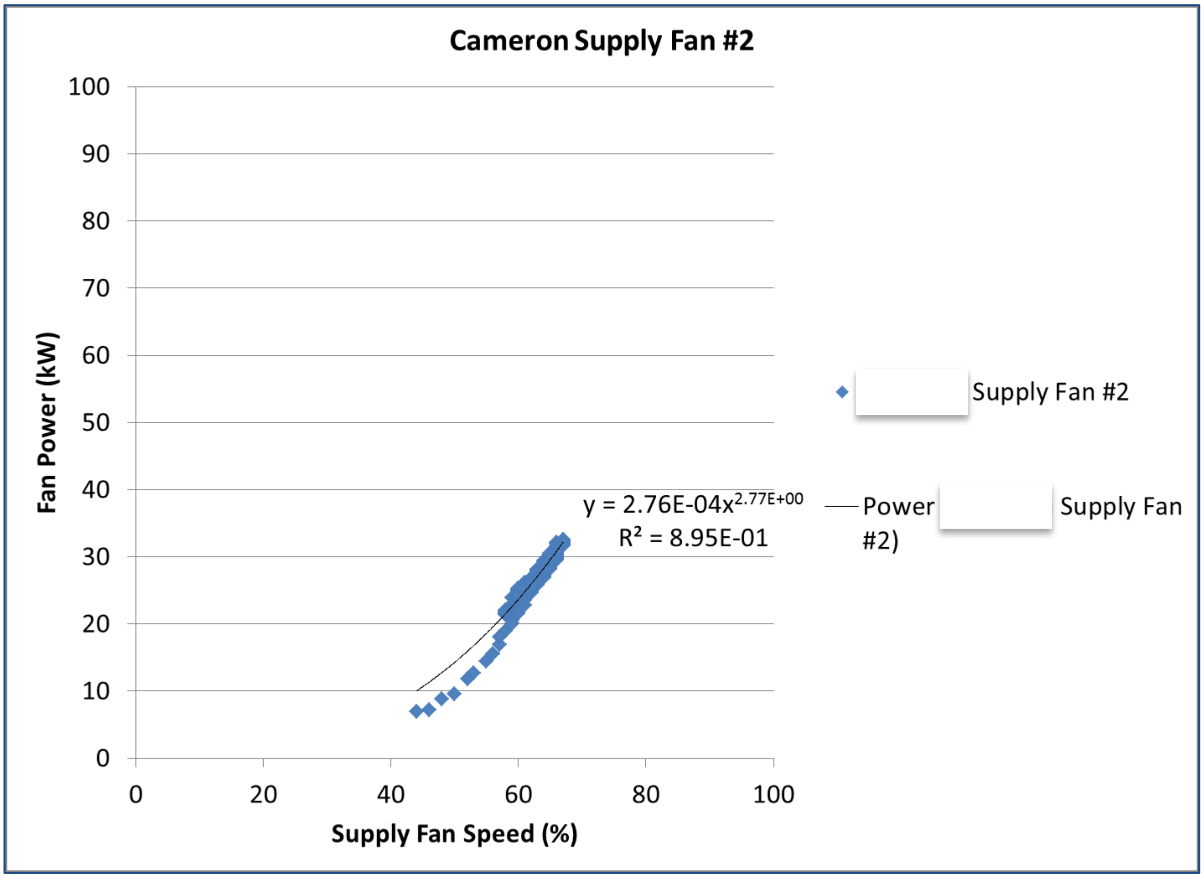

Figure 4. Supply Fan Power vs Speed

Figure 4 above shows the relationship between supply fan power and speed. A curve fit is displayed on the plot which allows extrapolation of the data. Extrapolating the fan speed to 100% provides a reasonable approximation of the maximum fan power which can then be used to calculate the pre-case fan curve with variable inlet vanes.

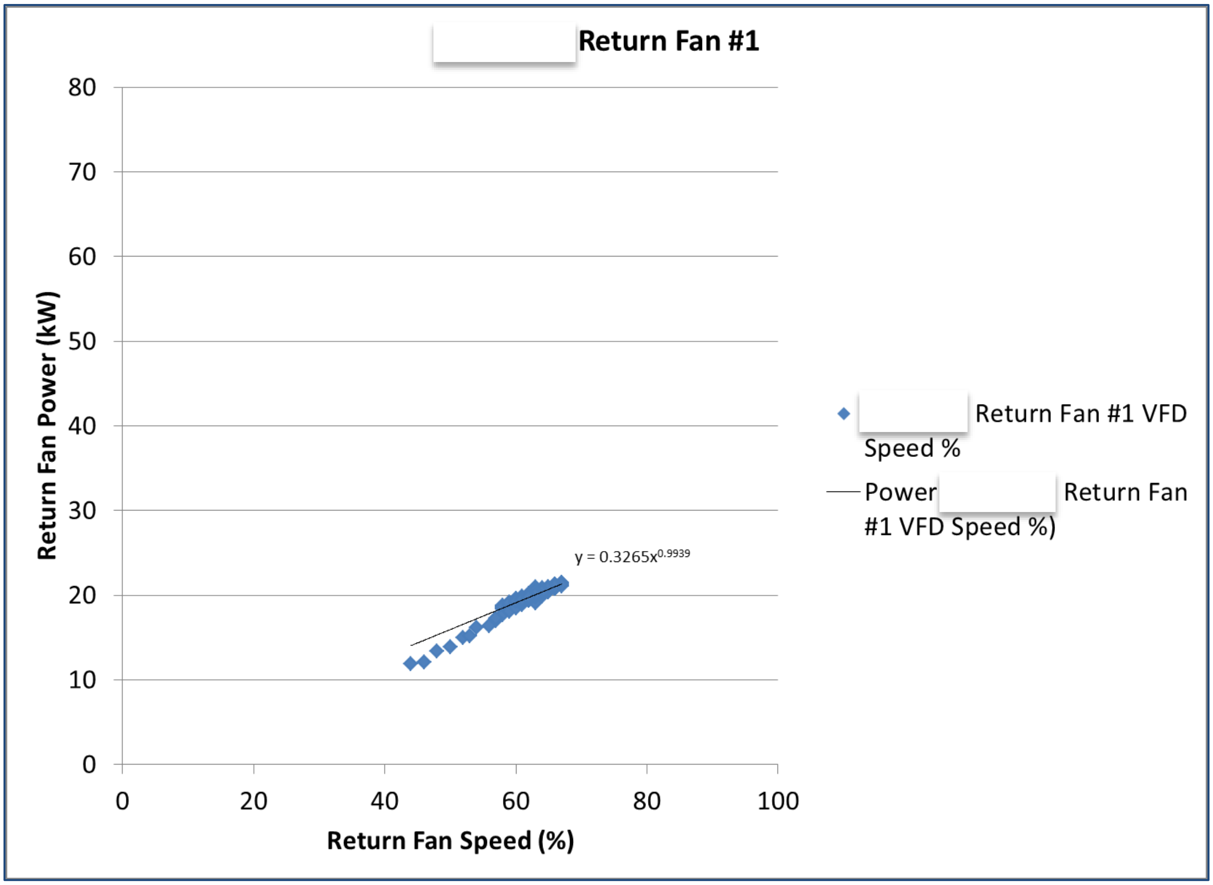

Figure 5. Return Fan Power vs Speed

Figure 5 above shows the same power vs speed relationship as Figure 4 but for the return fan. This relationship was used to estimate maximum return fan power.

The fraction of the maximum kW was calculated at each interval, and the fraction of full flow was calculated assuming the appropriate relationship shown below:

Determine post-retrofit flowrate:

Using the VFD power ratio relationship, estimated the post-retrofit (VFD) flow ratio (*f*) using the following basic equation:

$$H = \frac{a + b * f + d * f^3}{\eta_{drive}}$$

Where:

H = ratio of fan power at flow ratio *f* to the maximum fan power

$$= \frac{kW(f)}{kW_{\max}}$$

$$a = \left(\frac{P_0}{2}\right)^{1.5}$$

$$b = P_0 * (1 - a)$$

$$d = 1 - a - b$$

$$\eta_{drive} = VSD\ efficiency$$

P_0 = pressure offset ratio

f = flow ratio

$$f = \frac{Flow}{Flow_{design}}$$

The pressure offset ratio is defined as the ratio of the static pressure set point to the static pressure rise at the design flow rate. The pressure offset ratio is used to account for the energy required to maintain system static pressure over all flow rate ranges. Typical values range from 0.3 to 0.4.

The above equations were used to develop a relationship for f, the flow ratio, as a function of the power ratio. Once the flow ratio was determined, the pre-retrofit power ratio was calculated using the equation below:

For variable inlet vane control:

$$H = a + \frac{f}{b + c * f^2}$$

Where:

a = 0.354

b $= \frac{2 - p_0}{0.646}$

c $= \frac{p_0 - 1}{0.646}$

The result of this analysis is show in Figure 6 below.

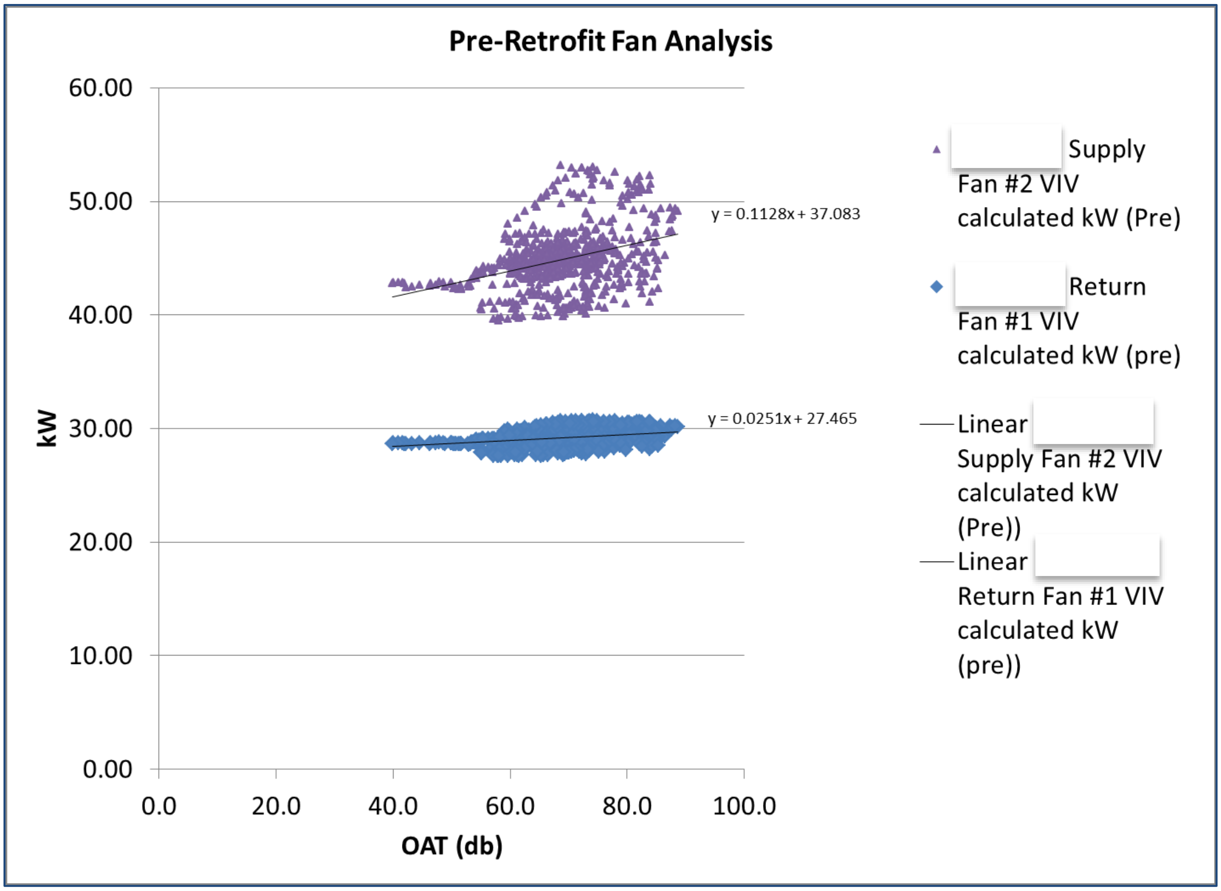

Figure 6. Pre-Retrofit Fan Analysis

From this point, the pre-retrofit fan energy calculation was performed in the same manner as the post-retrofit case. The relationship between fan power and outside air temperature was applied to the outside air temperatures from a TMY weather file to achieve an estimated annual energy use for the supply and return fans.

The last step in estimating the energy savings from this ECM is to simply calculate the difference between the pre-retrofit and post-retrofit annual energy use. The final numbers from this analysis along with realization rates are presented in the results section of this report.

Controls Upgrade Analysis

The [redacted] building #4 was chosen to perform the controls upgrade analysis. NORESCO staff surveyed the [redacted] building #4 and collected all of the information necessary to simulate the building. Once all of the necessary data was collected, an eQUEST model was generated with pre-retrofit operational sequences.

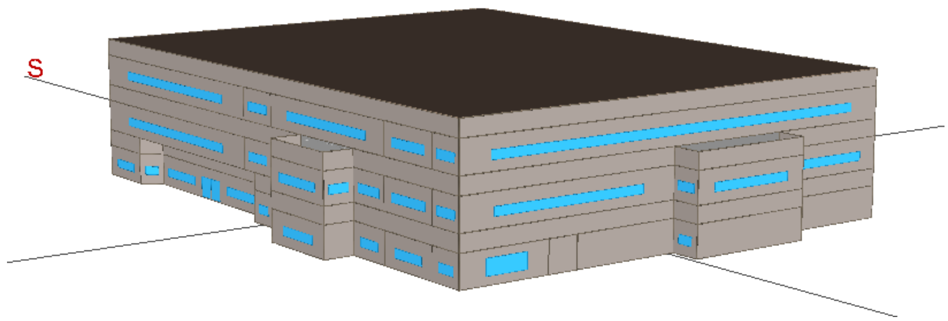

Figure 7. eQuest building representation

The energy model was then calibrated to pre-retrofit utility bills in order to achieve the most accurate pre-retrofit simulation possible. In order to match the energy model results to past utility bills, only those parameters that are not known with a high level of certainty were modified. These parameters included plug loads, certain schedules, and infiltration, among others. Any parameters which were directly affected by the retrofit and have been explicitly monitored during post-retrofit data collection were NOT modified during model calibration.

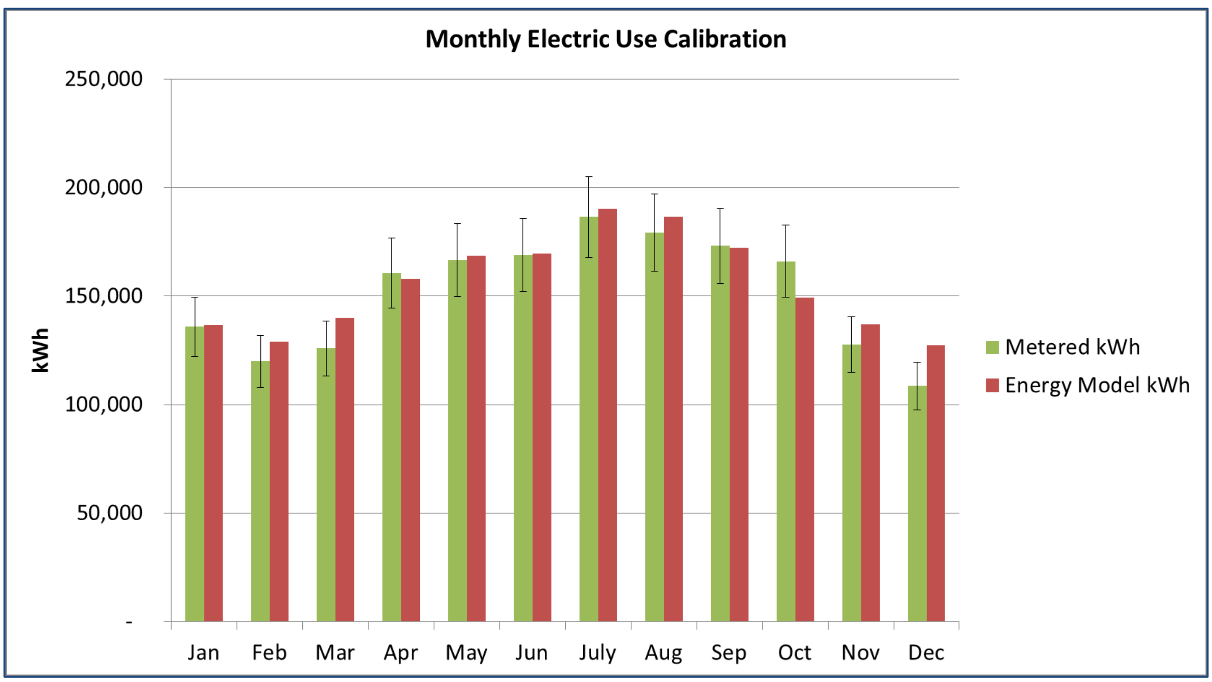

Figure 8. Energy Model Calibration

Figure 8 shown above is a comparison of the actual monthly electric consumption of the building in 2013 to the modeled consumption for each month of that year. 10% error bars are shown on the Metered kWh columns to visually represent the accuracy of the calibration. Generally, the monthly energy model consumption is within the 10% margin with only a couple of months outside that range. The annual energy use predicted by the energy model is within

2.5% of the actual metered energy. This indicates a relatively accurate energy model of the pre-retrofit case.

Once the pre-retrofit model was established, NORESCO revised the model with the post-retrofit changes in sequences of operations. The changes in sequences of operations are listed below:

- HVAC operating schedule adjusted from 24/7 operation to off at night.
- Space temperature set points adjusted from 70.2F at all times to 71 heating, 75 cooling with a night setback.
- Economizer operation re-established
- Supply air temperature reset controls

With these changes made, the model was run again to determine estimated annual post-retrofit energy consumption from the "controls upgrade" ECM. Comparison of the post-retrofit model output with the pre-retrofit output provided an estimate of the annual energy savings.

[Redacted] Plant #7 Modification Analysis
Using the same calibrated energy model for the [redacted] building #4, a third model run was simulated with the following change to model the decommissioning of the chiller in this building:

- Chiller operation changed from constant speed to variable speed and efficiency improved by approximately 25% to match the efficiency of the cooling plant in the adjacent McEniry building.

The results of that simulation were compared with that of the previous "controls upgrade" ECM to determine the savings from the "[redacted] plant #7 modification" ECM.

[Redacted] Plant #7 (Option A analysis)

- **General**

1. Converted time series data on logged equipment into post average load shapes by day-type.
2. Generated pre-retrofit model from performance curves and post retrofit consumption field data.
3. Developed pre/post regression model of total daily kWh as a function of average outdoor drybulb temperature.
4. Extrapolated pre/post total daily kWh to annual kWh using annual weather data (TMY3).
5. Estimated annual energy savings as the difference in the annual totals of pre- and post-kWh.
6. Estimated peak demand savings by subtracting pre/post time series data during peak ambient temperatures.

7. Calculated coincident peak savings by subtracting pre/post peak kW values at July 17, 3-4 pm local time, the coincident peak hour.

- **Pumps**

1. Generated pump kW vs. OAT regression for logged data (post conditions)
2. Generated pump kW vs. OAT regression for the Pre conditions by assuming the pumps will consume a constant amount of power if energized. OAT values remain the same as in the post conditions.
3. Applied equations above to TMY3 data processed into average drybulb temperature for each day of the year.

Time series kW data was obtained for each VFD installed at the [redacted] plant #7. The VFDs installed on the primary chilled water pumps (PCHWP) and condenser water pumps (CWP) are used to reduce the pump flow rate. Prior to installing the VFDs, it was assumed that the pumps would run at full speed with a throttled triple duty valve for flow control.

The primary chilled water pumps and condenser water pumps are dedicated, one set per chiller. During the logging period, only chiller 4 ran. Therefore, logged data was used only for the calculations for PCHWP-4 and CWP- 4. Pump savings for the other pump combinations were based on the results for the Chiller 4 pumps.

Figure 9 and Figure 10 show average hourly logged kW regressed against Outside Air Temperature (OAT) for both the pre and post conditions. For the Pre-condition, it was assumed that the pumps would both run at maximum power when energized. This value was calculated with the following equation:

$$kW_{Pre} = HP_{Pump} \times 0.746 \times 0.9$$

Where: HP_{Pump} = Rated Pump Horsepower
0.746 = Conversion from HP to kW
0.9 = Deration Factor

Both the CWP's and PCHWP's are equipped with triple duty valves. In the "Pre" case, these valves were shut anywhere from 40-60%. Therefore, "Pre" flowrates are assumed to be constant.

The "Post" CW and PCHW flowrates are assumed to be constant. The VFDs were installed to fine tune the flowrate of each pump running. Once the proper flow is achieved (depending on the number of chillers running at the time) the flow can be assumed to be constant. Flow does not appear to vary at any other time except when chillers are energizing/de-energizing.

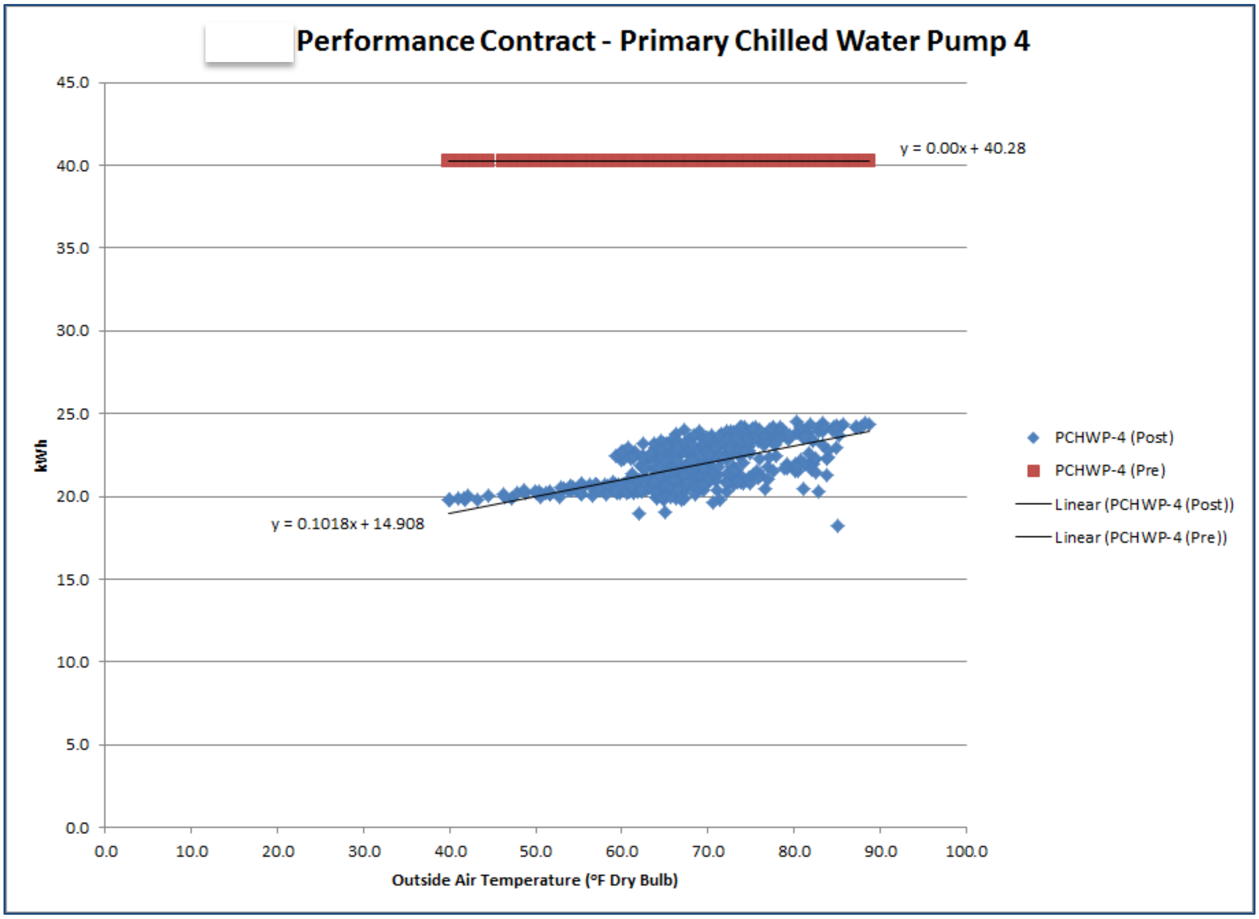

Figure 9. PCHWP-4 OAT Regression

A number of assumptions were made to generate Figure 9 and Figure 10:

- Chilled water and condenser water flows are constant.
- Condenser water pump kW is proportional to chiller plant load
- Chilled water pump flow is proportional to chiller plant load

Condenser water pump data was requested, but not collected. Therefore, condenser water pump kW was assumed to be proportional to chilled water pump kW.

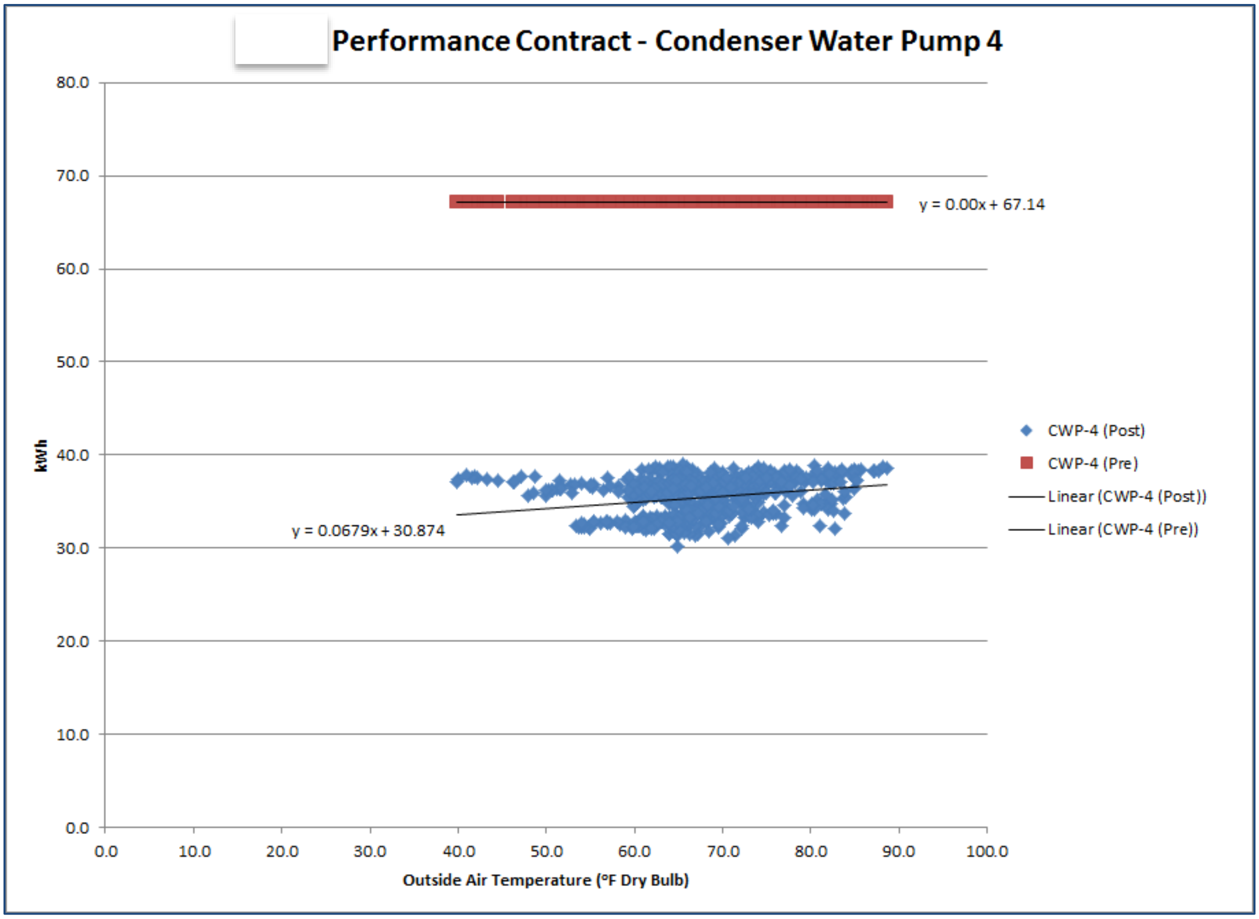

Figure 10. CWP-4 OAT Regression

Figure 11 and Figure 12 were generated by substituting TMY3 data for [redacted], NC into the regression equations found in Figure 9 and Figure 10. Since the chiller staging (and therefore, pump staging) is done automatically by the Tekworkx controller, outdoor air staging temperatures were assumed for each chiller/pump set. Chillers 2 & 3 were assumed to energize in a lead/lag manner over 40°F OAT. Chiller 4 was assumed to run over 40°F OAT and Chiller 1, over 80°F OAT.

Because Chillers 1-3 did not run during the monitoring period, the PCHWP and CWP yearly kWh, coincident peak and non-coincident peak kW values were found by assuming the savings for each of unknown pumps was proportional to the savings for PCHWP-4 and CWP-4. Savings values for PCHWP-2&3 and CWP-2&3 were divided by two to account for the lead/lag operation of these pumps.

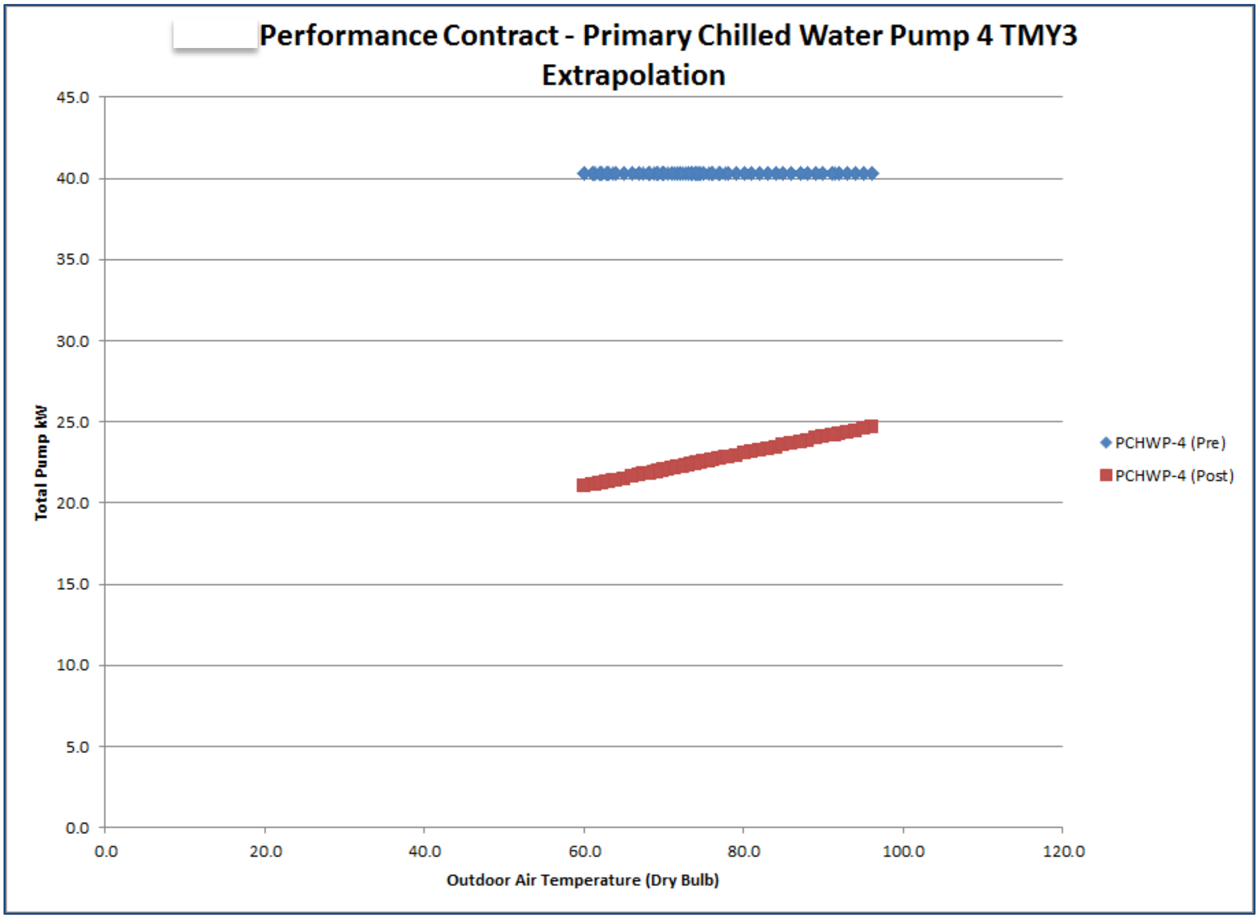

Figure 11. PCHWP-4 TMY3 OAT Annual prediction from regression

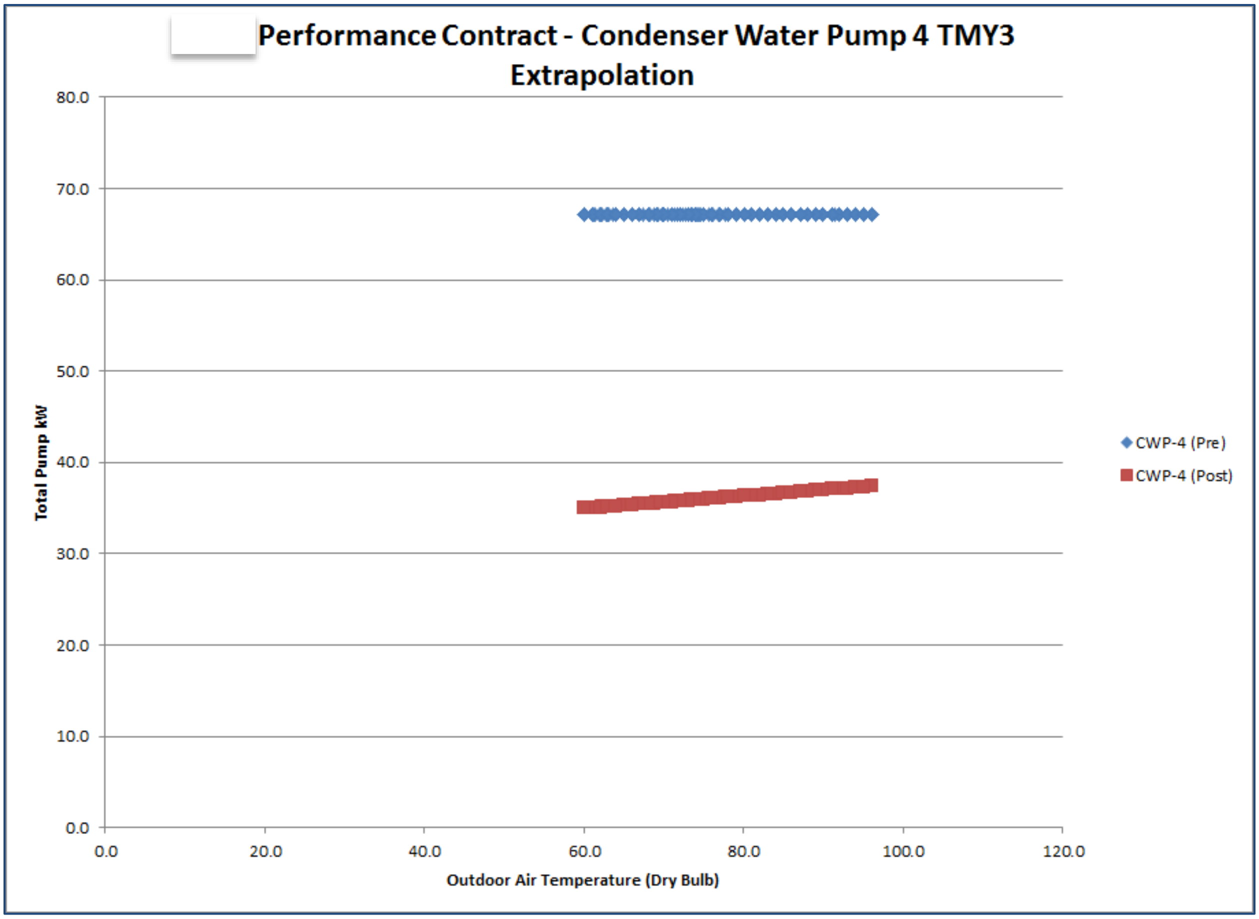

Figure 12. CWP-4 TMY3 OAT Annual prediction from regression

Table 1,

[Redacted] Plant #7 Energy Reduction Results			
ECM	**Actual Savings (kWh)**	**Estimated Savings (kWh)**	**Duke RR (%)**
PCHWP-1	3,417		
PCHWP-2	45,365		
PCHWP-3	45,365		
PCHWP-4	86,865		
CWP-1	7,160		
CWP-2	89,117		
CWP-3	89,117		
CWP-4	151,681		
Total	**518,089**	**1,137,789**	**46%**

Table 2 and Table 3 show the annual savings results for energy, coincident peak and non-coincident peak demand respectively. The monitored data showed that PCHWP-4 had a maximum kW draw of approximately 55% of the nameplate data and that CWP-4 had a maximum draw of approximately 52% of nameplate in the "Post" conditions. The additional VFDs appear to have reduced the overall pump energy consumption.

Table 1. [Redacted] Plant #7 Energy Results

[Redacted] Plant #7 Energy Reduction Results			
ECM	**Actual Savings (kWh)**	**Estimated Savings (kWh)**	**Duke RR (%)**
PCHWP-1	3,417		
PCHWP-2	45,365		
PCHWP-3	45,365		
PCHWP-4	86,865		
CWP-1	7,160		
CWP-2	89,117		
CWP-3	89,117		
CWP-4	151,681		
Total	**518,089**	**1,137,789**	**46%**

Table 2. [Redacted] Plant #7 Coincident Peak Demand Results

[Redacted] Plant #7 Coincident Peak Demand Reduction Results			
ECM	**Actual Savings (kW)**	**Estimated Savings (kW)**	**Duke RR (%)**
PCHWP-1	2.6		
PCHWP-2	5.2		
PCHWP-3	5.2		
PCHWP-4	16.7		
CWP-1	5.9		
CWP-2	11.2		
CWP-3	11.2		
CWP-4	30.5		
Total	**88.5**	**52.6**	**168%**

Table 3. [Redacted] Plant #7 Non-coincident Peak Demand Results

[Redacted] Plant #7 Non-Coincident Peak Demand Reduction Results			
ECM	**Actual Savings (kW)**	**Estimated Savings (kW)**	**Duke RR (%)**
PCHWP-1	2.8		
PCHWP-2	5.6		
PCHWP-3	5.6		
PCHWP-4	15.6		
CWP-1	6.1		
CWP-2	11.4		
CWP-3	11.4		
CWP-4	29.7		

Total	**88.3**	**167.3**	**53%**

Extrapolation to entire project

The results of the sampled buildings and ECMs were scaled to the entire project by applying the individual ECM realization rates to the population. For example, the energy use realization rate for the Variable Frequency Drive ECM at the [redacted] building #1 was 62%. This same realization rate was then applied to all other buildings with that ECM. In this case, both the [redacted] building #6 and the [redacted] building #2 implemented the VFD ECM and so the realization rate *for that ECM* was also assumed to be 62%. Once each ECM realization rate was applied, each building's realization rate was calculated as a weighted average of the individual ECM realization rates.

Results

Once each ECM was calculated and applied to the appropriate buildings, total energy and demand numbers were determined and realization rates were calculated. Final M&V results from the study are shown in Table 4, Table 5, and Table 6.

Table 4. M&V Energy Results

Building	Application Proposed Annual kWh savings	Duke Expected Annual kWh savings	NORESCO M&V kWh savings	kWh Realization Rate of Duke
Building #1	1,212,683	1,212,681	698,671	58%
Building #2	535,039	535,042	284,845	53%
Building #3	419,256	419,254	116,336	28%
Building #4	600,766	613,500	218,100	36%
Building #5	294,638	294,639	81,757	28%
Building #6	317,167	317,164	186,435	59%
Plant #7	1,087,795	1,210,414	518,089	43%
Total	**3,987,344**	**4,602,694**	**2,104,233**	**46%**

The energy use realization rates shown in Table 4 are all less than 100%. This is mostly due to the fact that the "Controls" ECM, which most buildings implemented, does not save as much energy as was assumed in the projections.

Table 5. M&V Coincident Demand Results

Building	Application Proposed Summer Peak kW Savings	Duke Expected Summer Coincident Peak kW Savings	NORESCO M&V Summer Coincident Peak kW Savings	Coincident Peak kW Realization Rate of Duke
Building #1	72	67	196	294%
Building #2	937	93	272	292%
Building #3	94	74	147	200%
Building #4	61	61	53	87%
Building #5	17	14	27	196%
Building #6	40	50	137	274%
Plant #7	79	56	89	159%
Total	**1,300**	**414**	**921**	**222%**

The realization rates for coincident peak demand shown in Table 5 are generally more than 200%. This is mainly due to the fact that the demand reduction from the VFD ECM is much higher than the projections. Typically, a VFD is not expected to reduce peak demand, however in this case the air handling unit supply fans appear to be significantly over-sized. Even during peak cooling conditions, the fans only need to run around 60% of full speed. As a result peak demand savings are considerably more than would normally be expected for the VFD ECM.

Table 6. M&V Non-Coincident Demand Results

Building	Duke Expected Summer Non-coincident Peak kW Savings	NORESCO M&V Summer Non-coincident Peak kW Savings	Non-coincident Peak kW Realization Rate of Duke
Building #1	111	80	72%
Building #2	95	69	73%
Building #3	139	2	1%
Building #4	84	27	32%
Building #5	31	0	0%
Building #6	51	44	86%
Plant #7	178	88	49%
Total	**689**	**309**	**45%**

Application ID 13-1593023
Lighting
M&V Report

August 26, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.

An Employee-Owned Company • www.cadmusgroup.com

CADMUS

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Table of Contents

Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for seven retrofit energy conservation measures (ECMs) included as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing fluorescent and high-pressure sodium (HPS) lighting fixtures with high-performance fluorescent lighting fixtures at one location in [redacted], North Carolina. Energy savings were expected to result from the reduced fixture quantity and wattage and improved efficiency. Descriptions of the measures as submitted in the original application documentation are provided below.

ECMs 1-7: Replace Fluorescent and HPS Fixtures with High-Performance Fluorescent Fixtures

[Redacted] is a textile manufacturing company located in [redacted], North Carolina. The manufacturing facility contains a warehouse, production floor, water treatment system, mechanical spaces, and offices, operating Monday through Saturday, from 4:00 a.m. to 12:00 a.m. The annual electric energy use is approximately 4,932,000 kWh, based on 2012 and 2013 utility data.

As summarized in Table 1, [redacted] chose to retrofit 1,106 fluorescent T12 and T8 fixtures and one HPS fixture throughout the facility with 520 fluorescent T8 fixtures. All installed fluorescent T8 lamp and ballast model numbers were Consortium for Energy Efficiency qualified. All of the lighting fixtures (both manufacturing and office areas) were expected to operate 6,240 hours annually in the original analysis. The seven lighting ECMs are outlined below:

- ECM-1: Replace one-lamp, 8-foot T12 fixtures with four-lamp, 4-foot T8 fixtures
- ECM-2: Replace six-lamp, 4-foot T8 fixtures with four-lamp, 4-foot T8 fixtures
- ECM-3: Replace two-lamp, 5-foot T12 fixtures with two-lamp, 4-foot T8 fixtures
- ECM-4: Replace a 400-watt HPS fixture with a four-lamp, 4-foot T8 fixture
- ECM-5: Replace four-lamp, 4-foot T12 fixtures with two-lamp, 4-foot T8 fixtures
- ECM-6: Replace two-lamp, 5-foot T12 fixtures with two-lamp, 4-foot T8 fixtures (exterior)
- ECM-7: Replace T12 and T8 fixtures with high-performance, two-lamp and four-lamp, 4-foot T8 fixtures

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Table 1. ECM Summary

ECM	Pre-Retrofit		Installed	
	Description	Quantity	Description	Quantity
1	1-lamp, 8-foot T12	815	4-lamp, 4-foot T8	321
2	6-lamp, 4-foot T8	37	4-lamp, 4-foot T8	21
3	2-lamp, 5-foot T12	10	2-lamp, 4-foot T8	10
4	400-watt HPS	1	4-lamp, 4-foot T8	1
5	4-lamp, 4-foot T12	100	2-lamp, 4-foot T8	100
6	2-lamp, 5-foot T12	4	2-lamp, 4-foot T8	4
7	T12 and T8	139	2-lamp and 4-lamp, 4-foot HP T8	63
Total	**-**	**1,106**	**-**	**520**

The project also involved installing 146 occupancy sensors, which were submitted under a separate prescriptive application.

Goals and Objectives

Table 2 shows the projected savings goals identified in the project application.

Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	289,318	N/A	279,146	276,584	44.74	36.59
2	35,256	N/A	33,178	32,874	5.32	5.32
3	2,371	N/A	2,371	2,349	0.38	0.38
4	1,997	N/A	1,997	1,978	0.32	0.32
5	56,160	N/A	56,160	55,645	9.00	9.00
6	3,020	N/A	3,045	3,017	0.49	0.49
7	118,229	N/A	101,144	100,216	16.21	16.21
Total	**506,351**	**N/A**	**477,042**	**472,663**	**76.45**	**68.30**

* Source: DSMore input spreadsheet.

For this M&V project, Cadmus sought to verify actual numbers for the following:

- Facility peak demand reduction (kW)
- Summer utility coincident peak demand reduction (kW)
- Annual energy savings (kWh)
- Annual realization ratios (kW and kWh)

Project Contacts

Table 3 lists the Duke Energy contact who granted approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Monica Redman, Senior DSM & Retail Programs Analyst	monica.redman@duke-energy.com
Cadmus	Christie Amero, Senior Analyst	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECM
redacted	1 through 7

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 22, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information. The facility manufactures a variety of fabric and produces approximately 45,000 yards of fabric per day. The manufacturing area of the facility operates Monday through Saturday, 24 hours per day, year round. The offices are occupied Monday through Friday, from 8:00 a.m. to 5:00 p.m. The offices observe typical federal holidays, but the manufacturing area has scheduled maintenance during holidays and the lighting fixtures do not shut down.

The office area is conditioned by four split-system heat pumps: three 5-ton units and one 7.5-ton unit. According to the facility manager, the offices are maintained at 72°F year round. The manufacturing spaces are cooled by rooftop units with direct expansion cooling coils. Heating for the manufacturing spaces is provided by a gas-fired steam heating system.

The facility manager confirmed that the site had all fluorescent T12 lighting fixtures before the retrofit project, and still use a few fluorescents in the shipping and receiving areas. In addition to the T8 lamps, ceiling-mounted occupancy sensors were installed throughout the manufacturing spaces and offices. The facility manager stated that the staff has noticed an improvement in lighting quality in the manufacturing spaces.

Field Data

ECMs 1-7: Replace Fluorescent and HPS Fixtures with High-Performance Fluorescent Fixtures

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the installed lighting fixture types and to install light loggers. Figure 1 shows one of the two-lamp, 2-foot by 4-foot fluorescent T8 troffers installed in the office areas and Figure 2 shows one of the four-lamp, 4-foot fluorescent T8 strip fixtures installed in the manufacturing spaces.

Figure 1. 2-Lamp, 2-Foot by 4-Foot T8 Troffer in Office

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Figure 2. 4-Lamp, 4-Foot T8 Strip Fixture in Manufacturing Space

Figure 3 shows the make and model numbers of the installed 4-foot, 32-watt T8 lamp (GE F32T8/XL/SPX50HLECO).

Figure 3. Installed T8 Lamp

Cadmus installed seven light loggers throughout the facility to collect fixture operating hours for a three-week period. Table 5 summarizes the locations of installed light loggers and monitored fixture types.

Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Location	Fixture Description	Light Logger Serial Number
1	Main offices/contract room	2-lamp, 2-foot by 4-foot T8 troffer	10171964
2	Break room	2-lamp, 2-foot by 4-foot T8 troffer	10272509
3	Printers	2-lamp, 2-foot by 4-foot T8 troffer	10161965
4	Panel #6 (sampling area)	4-lamp, 4-foot T8 strip	10282642
5	Panel #18	4-lamp, 4-foot T8 strip	10272701
6	Panel #3	4-lamp, 4-foot T8 strip	10187364
7	Panel #8	4-lamp, 4-foot T8 strip	10187375

Data Analysis

ECMs 1-7: Replace Fluorescent and HPS Fixtures with High-Performance Fluorescent Fixtures

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. Table 6 summarizes the light logger data.

Table 6. Summary of Light Logger Data

#	Location	Total Metered Hours	Metered Operating Hours	Percentage Operating	Average Coincidence Factor
1	Main offices	509.9	101.2	20%	50%
2	Break room	509.7	164.2	32%	47%
3	Printers	509.6	105.8	21%	100%
4	Panel #6 (sampling area)	509.3	316.4	62%	100%
5	Panel #18	509.4	392.8	77%	100%
6	Panel #3	508.9	393.6	77%	100%
7	Panel #8	509.0	326.4	64%	100%

The four loggers in the manufacturing and warehouse areas produced a mean projected annual runtime of 6,148 hours and a mean coincidence factor of 100%. The three loggers in office areas produced a mean projected annual runtime of 2,127 hours and a mean coincidence factor of 66%. Cadmus reduced the projected annual operating hours for the four outdoor fluorescent fixtures from 6,240 hours in the original study to 4,380 hours based on anecdotal information from the facility manager. We also reduced the peak coincidence factor for the outdoor fixtures to 0%.

Based on the installed lamp and ballast model numbers collected on site, the total fixture input for the four-lamp, 4-foot T8 strip fixtures is 112 watts, and the total input for the two-lamp, 2-foot by 4-foot T8 troffers is 58 watts. Cadmus adjusted the pre-retrofit T12, T8, and HPS fixture wattages slightly using technical reference manual rated wattages tables. We assumed that the pre-retrofit and installed case fixture quantities were equal to the original application based on sample area counts during the site visit.

The energy savings and peak demand reduction without HVAC interactive effects are 565,042 kWh and 96.09 kW, respectively.

Cadmus also calculated energy savings and demand reductions with HVAC interactive effects, based on the heating and cooling system type collected on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a small office near Charlotte, North Carolina with heat pump cooling and heating and no economizer is 0.047, and the demand factor is 0.152. The energy waste heat factor for light industrial near Charlotte, North Carolina with air conditioned cooling, gas heating, and no economizer is 0.113, and the demand factor is 0.194. The following equation is used to calculate savings with HVAC interactions:

$$kWh_{savings\ with\ HVAC} = kWh_{savings}\ x\ (1 + WHFe)$$

$$kW_{savings\ with\ HVAC} = kW_{savings}\ x\ (1 + WHFd)$$

Where:

WHFe = Waste heat factor for energy

WHFd = Waste heat factor for demand

The total evaluated energy savings for the seven ECMs was 627,232 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 114.45 kW, and the average, or non-coincident, peak demand reduction was 71.60 kW.

Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization rate was 133%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 150%. The average (or non-coincident) peak demand reduction realization rate was 105%.

While the evaluated annual operating hours for all fixture types are lower than that claimed in the original application, the evaluated pre-retrofit fixture wattages were higher and the installed fixture wattages were lower than that claimed in the original application. The original application did not account for HVAC interactive effects, which increased the evaluated energy savings and peak demand reduction by 62,190 kWh and 18.36 kW, respectively.

Table 7 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 8 provides realization rates comparing energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 7. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	289,318	N/A	276,584	44.74	36.59	451,074	78.71	51.49
2	35,256	N/A	32,874	5.32	5.32	36,106	6.67	4.12
3	2,371	N/A	2,349	0.38	0.38	4,448	0.78	0.51
4	1,997	N/A	1,978	0.32	0.32	824	0.27	0.09
5	56,160	N/A	55,645	9.00	9.00	22,713	7.70	2.59
6	3,020	N/A	3,017	0.49	0.49	2,015	0.00	0.23
7	118,229	N/A	100,216	16.21	16.21	110,054	20.32	12.56
Total	**506,351**	**N/A**	**472,663**	**76.45**	**68.30**	**627,232**	**114.45**	**71.60**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	163%	176%	141%
2	110%	126%	78%
3	189%	204%	134%
4	42%	85%	29%
5	41%	86%	29%
6	67%	0%	47%
7	110%	125%	78%
Total	**133%**	**150%**	**105%**

REPORT

My Home Energy Report Program Evaluation

Submitted to Duke Energy Carolinas
February 16, 2017

Principal authors:

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Patrick Burns, Vice President

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Equations

1 Executive Summary

1.1 Program Summary

Duke Energy offers the My Home Energy Report (MyHER) to residential customers who live in single-metered, single family homes with thirteen months of usage history throughout Duke Energy's Carolinas service territory (DEC). MyHER relies on principles of behavioral science to encourage customer engagement with home energy management and energy efficiency. The program accomplishes this primarily by delivering a personalized report comparing each customer's energy use to a peer group of similar homes.[1] MyHER motivates customers to reduce their energy consumption by:

- Comparing their household electricity consumption to that of similar homes
- Suggesting tips for reducing energy use by changing customers' behavior or installing energy efficient equipment
- Educating them about the energy savings benefits of Duke Energy's demand side management (DSM) programs
- Encouraging active management of their home's energy consumption

1.2 Evaluation Objectives and High Level Findings

This report presents the result of Nexant's evaluation activities. Nexant estimated the annual energy impacts associated with MyHER and measured customer satisfaction and engagement for MyHER participants. The MyHER program operates as a randomized, controlled trial: customers are randomly assigned to either "treatment" or "control" for energy savings attribution purposes. Treatment customers are MyHER recipients or participants. The control group is a set of customers from whom the MyHER is intentionally withheld; the control group serves as the baseline against which MyHER impacts are measured. As Duke Energy customers become eligible for the MyHER program, Duke Energy randomly assigns them to one of these two groups.

The energy savings generated by the MyHER program are presented in Table 1-1. The evaluated energy savings for the MyHER program are net of additional energy savings achieved through increased participation by the MyHER treatment group in other Duke Energy programs. Additional information concerning the evaluation period is shown in Table 1-2.

[1] Homes are grouped by characteristics such as location, size, vintage, and heating fuel. Energy use is compared on groups of similar homes.

Table 1-1: Claimed and Evaluated Energy Impacts per Participating Household

	Energy (kWh)	Demand (kW)	Confidence/Precision
Claimed Impacts	183.7	0.0389	N/A
Evaluated Impacts	229.8	0.0581	90/6

*MyHER is an opt-out program. As such, all impacts are considered net impacts; nevertheless, Nexant calculated the impacts of the MyHER program by removing savings achieved by MyHER participants via other Duke Energy Programs.

Table 1-2: Sample Period Start and End Dates

Evaluation Component	Start	End
Impact Evaluation Period*	May 2015	April 2016
Customer Survey Period	June 2016	August 2016

*The MyHER impact analysis provides census estimates for the most recent twelve months prior to the analysis.

1.3 Evaluation Recommendations

The Carolinas MyHER program realized 125% of its claimed impacts during this evaluation period.

Duke Energy undertakes substantial planning and coordination to deliver MyHER to approximately 943,000 DEC customers in North Carolina and 290,000 DEC customers in South Carolina. Duke Energy has developed a production process with the MyHER implementation contractor (Tendril, Inc.) that allows Duke Energy to customize MyHER messages, tips, and promotions on the basis of customer information and exposure to Duke Energy's demand-side management programs. Both Duke Energy and Tendril staff described a rigorous quality control process that has been very successful in preventing lapses in report quality from reaching the customers. Areas for improvement to the program generally circle around opportunities to better support this process and manage risks to it. Appropriate staffing at Tendril to support the technical and data-centered ongoing quality control processes for report mailings is critical to success in this area. Additionally, increased adherence or better development of a data delivery schedule on Tendril's part to initiate the quality control process will improve Duke Energy's ability to conduct their checks in a timely and complete manner. The increased pace of report mailings represents a long chain of quality control tasks for Duke Energy; responsibility for completing these tasks rests with a relatively small staff. Without redundant staffing, Duke Energy should contemplate and manage risks to MyHER program operations presented by turnover or outages in availability of their staff, planned or otherwise.

Nexant recommends additional quality control and monitoring actions for enhancing Duke Energy Carolinas' MyHER program:

- ***Maintain the integrity of the randomized, controlled trial (RCT) design with consistent, simultaneous assignment of newly-eligible customers to the treatment and control groups.*** Nexant recommends that Duke Energy assign customers to either treatment or control when making cohort group assignments. Simultaneous cohort assignment to treatment and control will eliminate any potential sources of bias stemming from time-dependent factors that could lead to observable or unobservable differences between the two groups.

- ***Apply the randomized, controlled trial (RCT) design when considering program enhancements or changes.*** The MyHER program is an excellent tool for customer engagement and communication; Duke Energy may use the MyHER program as a platform for testing different approaches to customer engagement, but Nexant recommends leveraging the reliability and insight provided by RCT approaches when evaluating the results of such test.
- ***Continue to manage MyHER operations with an eye towards change management and prioritization of program changes***. Challenges in quality control have historically followed on the heels of program changes and enhancements. Introduce changes slowly to consistently maintain a product that meets quality control standards and results in report cycles that pass quality assurance checks the first time.
- ***Prioritize appropriate project staffing.*** With MyHER's long, demanding, and ongoing production process, resource availability of appropriate staff can have implications for product quality and timely delivery. Outages and risk of outages of key project resources should be closely managed.
- ***Continue to monitor engagement and evaluate the impacts of the Interactive Portal:*** However, for this evaluation period, the MyHER Interactive Portal savings estimates are too uncertain to determine whether the portal generates incremental savings above and beyond the standard MyHER paper edition. Although impact estimates are very uncertain, it would also be premature to draw the conclusion that MyHER Interactive is not working, and statistical models of monthly impact reflect some directional consistency.

2 Introduction and Program Description

This section presents a brief description of the My Home Energy Report (MyHER) program as it operated in the DEC service territory from May 2015 through April 2016. This description is informed by document review, in-depth interviews with staff, and Nexant's understanding of program nuance developed through regular communication during the evaluation process.

2.1 Program Description

The MyHER program is a Duke Energy Carolinas behavioral product for demand-side management (DSM) of energy consumption and generation capacity requirements. The MyHER presents a comparison of participants' energy use to a peer group of similar homes. It is sent by direct mail eight times a year. The MyHER provides customer-specific information that allows customers to compare their energy use for the month and over the past year to the consumption of similar homes and homes considered energy-efficient. Reports include seasonal and household-appropriate energy savings tips and information on energy efficiency programs offered by DEC. Many tips include low cost suggestions such as behavioral changes. Duke contracts with Tendril Inc. for the management and delivery of its MyHER product.

In March 2015, Duke Energy launched the MyHER Interactive Portal (MyHER Interactive, or Interactive). MyHER Interactive seeks to engage customers in a responsive energy information and education dialogue. When customers enroll in the online portal, they are given the opportunity to update and expand on information about their home and electricity consumption. Customers are also routinely sent energy management tips and conservation challenges via email. The general strategy of the MyHER Interactive Portal is to open communications between customers and the utility, as well as to explore new ways of engaging households in electricity consumption management.

Customers occupying single-family homes with an individual electric meter and at least thirteen months of electricity consumption history are eligible for MyHER. The program is an opt-out program: customers can notify Duke Energy if they no longer wish to receive a MyHER and will be subsequently removed from the program.

Duke Energy placed a portion of eligible customers into a control group to satisfy evaluation, measurement, and verification (EM&V) requirements. These control group customers are not eligible to participate in the MyHER program. Duke Energy reduced the size of the MyHER control group in September and October 2015. This release was done in conjunction with Duke Energy's desire to make the energy savings of MyHER more widely available to its customers and Nexant's observation that the control group size of the DEC MyHER program was much larger than is necessary to reliably estimate the energy savings attributable to Duke Energy's management and deployment of the MyHER program.

Duke Energy has several objectives for the MyHER program, including:

1. Generating cost effective energy savings
2. Increasing customer awareness of household energy use, engagement with Duke Energy, and overall customer satisfaction with services provided by Duke Energy
3. Promoting other energy efficiency program options to residential customers

2.2 Implementation

MyHER is implemented by Tendril Inc., an analytics contractor that prepares and mails the MyHER reports according to a pre-determined annual calendar. Tendril also generates and disseminates the MyHER Interactive Portal reports, emails, energy savings tips, and energy savings challenges. Tendril and Duke Energy coordinate closely on the data transfer and preparation required to successfully manage the MyHER program, and they make adjustments as needed to provide custom tips and messages expected to reflect the characteristics of specific homes. A more detailed discussion of the roles and responsibilities of both organizations appears in Section 4.

Eligibility

MyHER targets residential customers living in single family, single meter, and non-commercial homes with at least thirteen months of electricity consumption history. Approximately 1,100,000 DEC residential customers currently met these requirements as of April 2016. Accounts could still be excluded from the program for reasons such as the following: assignment to the control group, different mailing and service addresses, and enrollment in payment plans based on income (although budget bill customers are eligible). Eligibility criteria for the MyHER program have changed over time, and in some cases, customers were assigned to either treatment or control but later determined to be ineligible for the program. Nexant estimates that approximately 10.3% of assigned customers have been deemed ineligible for the program after having been assigned. Nexant addresses this topic by applying an intention-to-treat analysis (ITT); refer to section 3.1.2.

2.3 Key Research Objectives

The section describes key research objectives and associated evaluation activities.

2.3.1 Impact Evaluation Objectives

The primary objective of the impact evaluation is to describe the impact of the program on energy consumption (kWh). Savings attributable to the program are measured across an average annual and monthly time period. The following research questions guided impact evaluation activities:

1. Is the process used to select customers into treatment and control groups unbiased?
2. Are the sample sizes of control groups used by the various entities optimal and if not,

how should they be modified to be brought into line with reasonable precision targets (e.g., plus or minus 1% precision with 90% confidence).

3. What is the impact of MyHER on the uptake of other Duke Energy programs (downstream and upstream) in the market?
4. What net energy savings are attributable solely to MyHER reports after removing savings already claimed by other DEC energy efficiency programs?
5. What incremental savings are achieved by customers participating in the MyHER Interactive portal?

2.3.2 Process Evaluation Objectives

The program evaluation also seeks to identify improvements to the business processes of program delivery. Process evaluation activities focused on how the program is working and opportunities to make MyHER more effective. The following questions guided process data collection and evaluation activities:

1. Are there opportunities to make the program more efficient, more effective, or to increase participant engagement?
2. What components of the program are most effective and should be replicated or expanded?
3. What additional information, services, tips or other capabilities should MyHER consider?
4. Does MyHER participation increase customer awareness of their energy use and interest in saving energy?
5. To what extent does receiving MyHER increase customer engagement?
6. Do participants hold more favorable opinions of Duke Energy as a result of receiving the reports?
7. Do they express higher levels of stated intentions to save energy?
8. Are they more likely to say they will take advantage of Duke Energy's energy efficiency programs in the future?
9. What prevents households from acting upon information or tips provide by MyHER?
10. How can the program encourage additional action?

2.4 Organization of This Report

The remainder of this report contains the results of the impact analysis (Section 3); the results of the process evaluation activities, including the customer surveys (Section 4); and Nexant's conclusions and recommendations (Section 5).

3 Impact Evaluation

3.1 Methods

The MyHER impact evaluation measures the change in electricity consumption (kWh) resulting from exposure to the normative comparisons and conservation messages presented in Duke Energy's My Home Energy Reports. The approach for estimating MyHER impacts is built into the program delivery strategy. Eligible accounts are randomly assigned to either a treatment (participant) group or a control group. The control group accounts are not exposed to MyHER in order to provide the baseline for estimating savings attributable to the Home Energy Reports. In this randomized controlled trial (RCT) design, the only explanation for the observed differences in energy consumption between the treatment and control group is exposure to MyHER.

The impact estimate is based on monthly billing data and program participation data provided by Duke Energy. The RCT delivery method of the program removes the need for a net-to-gross analysis as the billing analysis directly estimates the net impact of the program. After estimating the total change in energy consumption in treatment group homes, Nexant performed an overlap analysis to quantify the savings associated with increased participation by treatment homes in other DEC energy efficiency offerings. These savings were claimed by other programs; therefore, they are subtracted from the MyHER impact estimates to eliminate double-counting.

3.1.1 Data Sources and Management

The MyHER impact evaluation relied on a large volume of participation and billing data from Duke Energy's data warehouse. Nexant provided a data request for the necessary information in April 2016. Key data elements include the following:

- **Participant List** – a table listing each of the homes assigned to the MyHER program since its inception in 2010. This table also indicated whether the account was in the treatment or control group and the date the home was assigned to either group. Duke Energy also provided a supplemental table of Experian demographic data for program participants.
- **Billing History** – a monthly consumption (kWh) history for each account in the treatment and control group. Records included all months since assignment as well as the pre-assignment usage history required for eligibility. This file also included the meter read date and the number of days in each billing cycle.
- **MyHER Report History** – a record of the approximate 'drop date' of each MyHER report sent to the treatment group accounts, the messaging included, and the recommended actions. This dataset also contained a supplemental table of treatment group accounts omitted from each MyHER mailing in 2015 and 2016, and the associated reason for omission.

- **Participation Tracking Data for Other DEC Energy Efficiency Programs** – a table of the Duke Energy DSM program participation of MyHER control and treatment group accounts. Key fields for analysis include the measure name, quantity, participation date, and net annual kWh and peak demand impacts per unit for each MyHER recipient and control group account participating in other DSM programs offered by Duke Energy.

- **MyHER Interactive Session Data** – a dataset containing information on participants' date of enrollment, the date of each login (e.g. a single MyHER Interactive portal session), and the duration of the session.

In preparation for the impact analysis, Nexant combined and cleaned the participation and billing data provided by the MyHER program staff. The participant list dataset included an average of 1,354,244 distinct accounts (the actual number varies by month); 1,233,115 accounts were assigned to the treatment group and 121,129 accounts assigned to the control group.

Nexant removed the following accounts and data points from the analysis:

- 1,149 records (<0.08%) where the number of days in the billing cycle was equal to zero
- 27 records with a negative value for billed kWh
- 497 records with unrealistically high usage: any month with greater than six times the 99^{th} percentile value for daily kWh usage, or approximately 900 kWh per day
- 62 records having a meter read date more than 100 days before or after the 15^{th} of the bill month to which the usage was assigned

Like most electric utilities, Duke Energy does not bill its customers for usage within a standard calendar month interval. Instead, billing cycles are a function of meter read dates that vary across accounts. Duke Energy "calendarizes" billing records in its data warehouse in a field called "bill month." A record with bill month equal to "201501," for example, corresponds to the year and number of the bill—in this case, the home's first bill for 2015. Typically this will reflect energy captured by a meter read during one of the approximately 20 weekdays in a given month. In this example, the electric usage associated with bill month 201501 would include a mix of December and January days depending on the meter read schedule of the account.

Nexant's analysis of MyHER impacts is based on the meter read date. Nexant estimates MyHER impacts by examining differences in average daily consumption in each month, and by comparing consumption of control group customers to treatment customers. Nexant therefore estimates average daily consumption by calendar month to ensure customers' billed consumption is compared on similar days under similar weather conditions. It is important to remember that monthly impact estimates presented in this report are based on calendar month, not the Duke Energy billing month.

3.1.2 Intention to Treat

Duke Energy maintains a number of eligibility requirements for continued receipt of MyHER. Not all accounts assigned to treatment remained eligible and received MyHER over the study horizon. Several programmatic considerations can prevent a treatment group home from receiving MyHER in a given month. Common reasons for an account not being mailed include the following:

- **Mailing Address Issues** – mailing addresses are subjected to deliverability verification by the printer. If an account fails this check due to an invalid street name, PO Box or other issue, the home will not receive the MyHER mailer.
- **Implausible Bill** – if a home's billed usage for the previous month is less than 150 kWh or greater than 10,000 kWh, Tendril does not mail the MyHER.
- **Insufficient Matching Households** – this filter is referred to as "Small Neighborhood" by Tendril and is a function of the clustering algorithm Tendril uses to produce the usage comparison. If a home can't be clustered with a sufficient number of other homes, it will not receive the MyHER mailer.
- **No Bill Received** – if Tendril does not receive usage data for an account from Duke Energy within the necessary time frame to print and mail, the home will not receive MyHER for the month.

The Nexant data cleaning steps listed in Section 3.1.1 do not impose these filters on the impact evaluation analysis dataset. This is necessary to preserve the RCT design because eligibility filters are not applied to the control group in the same manner as the treatment group. Nexant consequently employed an "intention-to-treat" (ITT) analysis. In the ITT framework, the average energy savings per home *assigned* to the treatment is calculated via billing analysis. This impact estimate is then divided by the proportion of the treatment group homes analyzed that were active MyHER participants. The underlying assumption of this approach is all of the observed energy savings are being generated by the participating accounts.

Nexant relied on Duke Energy's monthly participation counts for the numerator of the proportion treated calculation. MyHER program staff calculate participation monthly according to the business rules and eligibility criteria in place at the time. Access to additional data such as pending disconnects and other operational data prevented Nexant from replicating monthly participation totals identically. The denominator of the proportion treated is the number of treatment group homes with electricity consumption for the month. This calculation is presented by month in Table 3-1 for the study period. The average proportion of assigned accounts that were treated was 89.7%

Table 3-1: Calculation of Treatment Percentage by Bill Month

Bill Month	Number of Treatment Homes Analyzed	DEC Participant Count	Proportion of Homes Treated
201505	1,237,495	1,044,200	84.4%
201506	1,243,446	1,027,432	82.6%
201507	1,245,920	1,057,508	84.9%
201508	1,247,841	1,065,154	85.4%
201509	1,236,403	1,062,208	85.9%
201510	1,224,580	1,062,192	86.7%
201511	1,214,468	1,157,054	95.3%
201512	1,242,769	1,153,632	92.8%
201601	1,238,733	1,172,987	94.7%
201602	1,230,148	1,158,474	94.2%
201603	1,222,422	1,158,535	94.8%
201604	1,213,159	1,150,783	94.9%
Twelve Month Average Proportion			**89.7%**

The monthly participation counts shown in Table 3-1 were also used by Nexant to estimate the aggregate impacts of the MyHER. Per-home kWh savings estimates for each bill month are multiplied by the number of participating homes to arrive at the aggregate MWh impact achieved by the program.

3.1.3 Sampling Plan and Precision of Findings

The MyHER program was implemented as an RCT in which individuals were randomly assigned to a treatment (participant) group and a control group for the purpose of estimating changes in energy use because of the program. Nexant's analysis methodology relies on a census analysis of the homes in both groups so the resulting impact estimates are free of sampling error. However, there is inherent uncertainty associated with the impact estimates because random assignment produces a statistical chance that the control group consumption would not vary in perfect harmony with the treatment group, even in the absence of MyHER exposure. The uncertainty associated with random assignment is a function of the size of the treatment and control groups, as well as the underlying properties of customers' electricity consumption patterns. As group size increases, the uncertainty introduced by randomization decreases, and the precision of the estimates improves.

Nexant's MyHER impact estimates are presented with both an absolute precision and relative precision. Absolute precision estimates are expressed in units of annual energy consumption (kWh) or as a percentage of annual average consumption. The two following statements about the MyHER Carolinas impact analysis reflect absolute precision:

- MyHER saves an average of 229.8 kWh per home, ± 15 kWh.

- Homes in the MyHER treatment group reduced electric consumption by an average of 1.6%, ± 0.05%.

In these examples the uncertainty of the estimate, or margin of error (denoted by "±"), is presented in the same absolute terms as the impact estimate—that is, in terms of annual electricity consumption. Nexant also includes the relative precision of the findings. Relative precision expresses the margin of error as a percentage of the impact estimate itself. Consider the following example:

- The average treatment effect of MyHER is 229.8 kWh with a relative precision of ±6.5%. In this case ± 6.5% is determined by dividing the absolute margin of error by the impact estimate: 15 ÷ 229.8 = 0.065 = 6.5%.

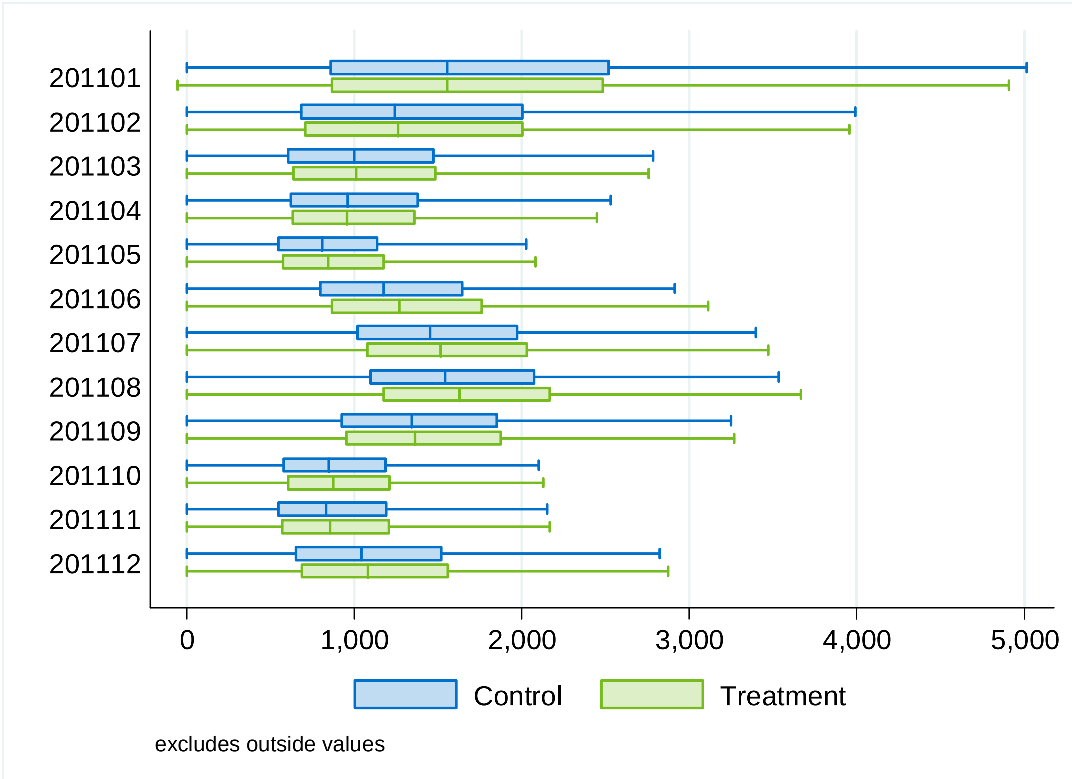
All of the precision estimates in this report are presented at the 90% confidence level and assume a two-tailed distribution.

3.1.4 Equivalence Testing

Straightforward impact estimates are a fundamental property of the RCT design. Random assignment to treatment and control produces a situation in which the treatment and control groups are statistically identical on all dimensions prior to the onset of treatment; the only difference between the treatment and control groups is exposure to MyHER. The impact is therefore simply the difference in average electricity consumption between the two groups. The first step to assessing the impact of an experiment involving a RCT is to determine whether or not the randomization worked as planned.

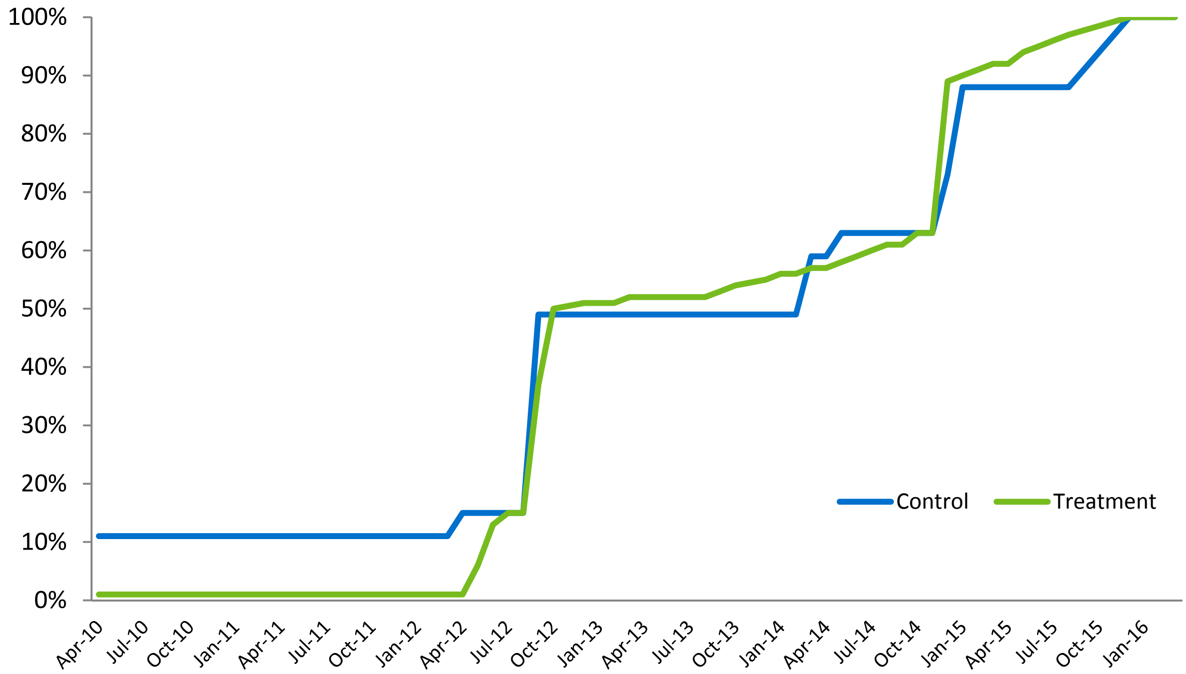
Figure 3-1 is a box-and-whisker plot of the average pre-treatment consumption for the treatment and control groups. The figure depicts the distribution of monthly average consumption in 2011, the time period prior to the full launch of the DEC MyHER program. This figure contains all accounts assigned to treatment and control in 2012 through 2013. While multiple instances of random assignment occurred over this period, Nexant aggregated DEC MyHER customers into annual or biannual cohorts because of the large number of individual assignment occasions. This figure shows some small differences in pre-treatment consumption between the treatment and control group customers. Some of these differences are due to the fact that Figure 3-1 is comprised of multiple instances of customer assignment to treatment or control; nevertheless, Nexant found differences in pre-treatment consumption across many individual occasions of random assignment within this time period. These pre-treatment differences and existence of multiple cohorts led Nexant to select the fixed-effects regression approach, which can appropriately control for such pre-treatment differences in the treatment and control groups.

Figure 3-1: Difference in Average Pre-treatment Billed Consumption for cohorts assigned in 2012 - 2013 (2011 kWh)



The DEC MyHER program consists of several assignment cohorts: the original pilot cohort from 2010, the full program launch in 2012 through 2013 with the selection of Tendril Inc. as the MyHER implementation contractor, and an expansion in 2014 through 2015. Since 2012, the program expanded as newer customers met the program's eligibility criteria. Figure 3-2 shows the timeline of program expansion since 2010 and the assignment history of customers in the treatment and control groups.

Figure 3-2: History of Cohort Assignments for DEC MyHER Program



This figure indicates customers were assigned to treatment and control on an alternating basis after the August 2012 program launch. In 2016, Nexant advised Duke Energy to maintain a simultaneous assignment protocol and to make assignment on an annual or biennial basis. Doing so will minimize any potential sources of bias that could occur due to a lack of simultaneous assignment to treatment and control. While assignments to treatment and control made at any single point in time after 2012 were random, the disproportionate assignment of customers to one group or the other for each instance of assignment resulted in differences in consumption patterns between the treatment and control groups over this time period. Nexant has accounted for these differences in its impact estimation approach.

Nexant estimated MyHER impacts by cohort using a fixed-effects panel regression model. A cohort is a group of accounts that are added to the program at a given time. Nexant mapped the MyHER population into four cohorts that generally follow the major periods when customers were assigned to treatment and control groups. Figure 3-3 indicates the composition of the current program by cohort.

Figure 3-3: Comparison of Treatment and Control Group Composition by Cohort

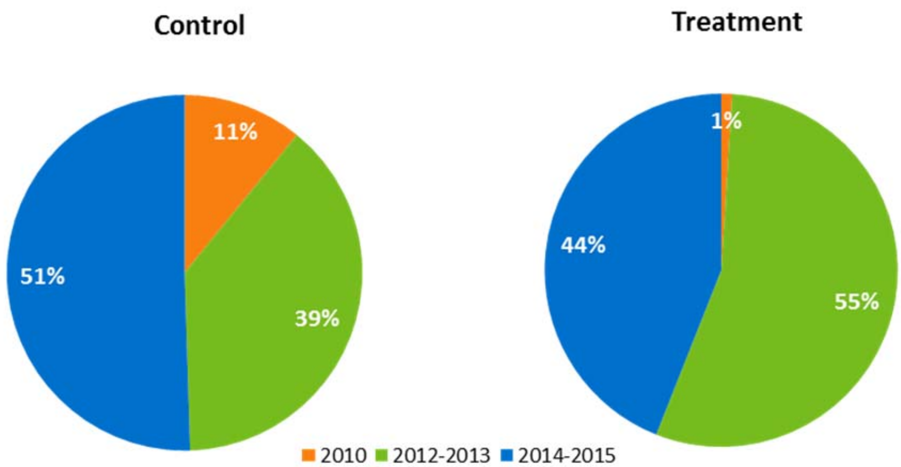


Table 3-2 provides additional summary information for each of the three cohorts. Note that the values presented in Table 3-2 are based on the year prior to each cohort's assignment; the customer counts do not match the current program composition presented in Figure 3-3 because they are measured at different points in time (prior to treatment and in April 2016, respectively. The "number of homes" columns reflect the number of active assigned customers without any filters applied for eligibility. Table 3-2 also compares the average annual kWh usage of each cohort's treatment and control group for the 12 months prior to the beginning of assignment. The pre-assignment usage is relatively balanced between groups for cohorts 1, 2, and 3.

Table 3-2: MyHER Cohort Summary Statistics

Cohort Number	Cohort Description	# Treatment Homes	# Control Homes	Annual kWh Pre-Assignment for Control Group	Annual kWh Pre-Assignment for Treatment Group	Pre-Period
1	2010	6,329	9,908	17,374	17,363	May-09 to Apr-10
2	2012-2013	571,443	33,886	14,521	14,958	Mar-11 to Feb-12
3	2014-2015	342,439	34,806	15,595	14,067	Feb-13 to Jan-14

3.1.5 Regression Analysis

Separating the MyHER population into cohorts accounts for cohort maturation effects and improves statistical precision relative to differences among the cohorts. Nevertheless, there are still some underlying differences between the cohort treatment and control groups that need to be netted out via a difference-in-differences approach. Nexant applied a linear fixed effects regression (LFER) model to each month in the evaluation period to account for these disparities.

The basic form of the LFER model is shown in Equation 3-1; the average treatment effect (ATE) is the sum of the monthly impact estimates from each monthly LFER model. Average daily electricity consumption for treatment and control group customers is modeled using an indicator variable for the billing period of the study, a treatment indicator variable, and a customer-specific intercept term:

Equation 3-1: Fixed Effects Model Specification

$$kWh_{it} = customer_i * \beta_i + I_t * \beta_t + I_t * \tau_t * treatment_{it} + \varepsilon_{it}$$

$$ATE = \sum_{t=1}^{12} \tau_t$$

Table 3-3 provides additional information about the terms and coefficients in Equation 3-1.

Table 3-3: Fixed Effects Regression Model Definition of Terms

Variable	Definition
kWh_{it}	Average daily electricity consumption for customer *i* in billing month *t*.
$customer_i$	An indicator variable that equals one for customer i and zero otherwise. This variable models each customer's average energy use separately.
β_i	The coefficient on the customer indicator variable. Equal to the mean daily energy use for each customer.
I_t	An indicator variable equal to one for each monthly billing period t, and zero otherwise.
β_t	The coefficient on the billing period t, indicator variable. This term measures each billing period's deviation from the customer's average energy use in the same month of previous years.
$treatment_{it}$	The treatment variable. Equal to one when the treatment is in effect for the treatment group. Zero otherwise. Always zero for the control group.
τ_t	The estimated treatment effect in kWh per day per customer in billing month t; the main parameter of interest.
ε_{it}	The error term.

Nexant estimated the LFER model separately for each of the three cohorts and each billing month. Detailed regression output can be found in Appendix E. The model specification includes an interaction term between the treatment indicator variable and the indicator variable for the bill month term. This specification generates a separate estimate of the MyHER daily impact for each bill month. Table 3-4 illustrates the calculation of monthly impact estimates from the regression model coefficients for homes assigned to treatment in the original MyHER pilot. Each month's average treatment effect is multiplied by an assumed number of days in the month equal to 365.25/12 = 30.4375.

Table 3-4: Impact Calculation Example – Cohort 3

Bill Month	Daily Treatment Coefficient (τ)	Monthly Impact (kWh)
201505	-1.00988	-11.9
201506	-0.81431	-9.9
201507	-1.05961	-13.1
201508	-0.93664	-11.8
201509	-1.87292	-23.7
201510	-1.11843	-14.1
201511	-0.90031	-11.3
201512	-0.73122	-9.4
201601	-0.39896	-5.3
201602	-0.43122	-5.7
201603	-0.54891	-7.2
201604	-0.64927	-8.8
12 Month Total Impact		**-132**

Impact estimates from the three cohorts were weighted and combined for each month to calculate a weighted average treatment effect. The weighting factor was the number of homes with billing data that had been assigned to the treatment group during a prior month (e.g. were in the post-treatment period). These estimates of the average MyHER impact per assigned home were then divided by the proportion of customers treated, as shown in Table 3-1, to estimate the average treatment effect per participating home.

3.1.6 Dual Participation Analysis

The regression model outputs and subsequent intention-to-treat adjustments discussed in Section 3.1.5 produce estimates of the total change in electricity consumption in homes exposed to MyHER. Some portion of the savings estimated by the regression is attributable to the propensity of MyHER treatment group homes to participate in other DEC energy efficiency offerings at a greater rate than control group homes. The primary purpose of the dual participation analysis is to quantify annual electricity savings attributable to this incremental DSM participation and subtract it from the MyHER impact estimates. This downward adjustment prevents savings from being double-counted by both the MyHER program and the program where savings were originally claimed.

A secondary objective of the dual participation analysis is to better understand the increased DSM participation, or “uplift” triggered by inclusion of marketing messages within MyHER. The ability to serve as a marketing tool for other DSM initiatives is an important part of what makes MyHER attractive as Duke Energy assumes the role of a trusted energy advisor with its customer base.

Duke Energy EM&V staff provided Nexant with a table of non-MyHER program participation records for the MyHER treatment and control group homes dating back to January 2010. This dataset included nearly 4,330,000 records of efficient measure installations by the MyHER treatment and control group and formed the basis of Nexant's dual participation analysis. Table 3-5 shows the distribution of participation and savings during the MyHER evaluation period across Duke Energy's residential portfolio.

Table 3-5: EE Program Participation by MyHER Customers

Filed Program Name	Number of Records	Net MWh/year	Net kW/year
Smart Saver Residential	342,306	29,023	6,358
Appliance Recycling Program	6,513	3,804	506
Total	**348,819**	**32,827**	**6,864**

The MyHER dual participation analysis included the following steps:

- Match the data to the treatment and control homes by Account ID
- Assign each transaction to a bill month based on the participation date field in the tracking data
- Exclude any installations that occurred prior to the home being assigned to the treatment or control group
- Calculate the daily net energy savings for each efficiency measure
- Sum the daily net energy impact by Account ID for measures installed prior to each bill month
- Calculate the average savings per day for the treatment and control groups by bill month. This calculation is performed separately for each cohort
- Calculate the incremental daily energy saved from energy efficiency (treatment – control) and multiply by the average number of days per bill month (30.4375)
- Take a weighted average across cohorts of the incremental energy savings observed in the treatment group
- Subtract this value from the LFER estimates of treatment effect for each bill month

While the incremental participation rate of the treatment group in other EE programs is modest when considered in total, increased uptake of measures immediately following promotional messaging within MyHER mailers can be much more dramatic. Each MyHER issued has space for one product promotion message that is used to market other Duke Energy programs or initiatives. Duke provided Nexant with records of the exact messages received by each home. Table 3-6 shows the number of homes that received each combination of messages for nine MyHER cycles.

Table 3-6: MyHER Promotional Messaging by Month

Source Month	Message 1	Message 2	Number of Homes
1-Jan-14	Power Manager	Electric Blanket	637,586
1-Jan-14	Videos	Electric Blanket	81,259
1-Mar-14	Low Flow Toilet	811	68
1-Mar-14	Tune Up	811	716,723
1-May-14	Giving Back	Dryer Lint	15,621
1-May-14	HEHC	Dryer Lint	693,313
1-Jun-14	Smart Saver	Grill	679,685
1-Jun-14	Water Heater	Grill	20,245
1-Jul-14	Lighting Store	Wash	719,553
1-Jul-14	SS Ins & Seal	Wash	21,589
1-Aug-14	ARP	Calculator	154
1-Aug-14	SS Ins & Seal	Calculator	723,037
1-Oct-14	Share Warmth	Thank you	728,874
1-Dec-14	HEHC	Doors & Windows	813,415
1-Dec-14	Smart Saver	Doors & Windows	21,340
1-Jan-15	ARP	Water Heater Blanket	921,491
1-Jan-15	SS	Water Heater Blanket	11,306
1-Feb-15	SS HVAC	Replace Windows	206,282
1-Mar-15	Pool Pump	Earth Day	68,634
1-Mar-15	Store	Earth Day	959,454
1-May-15	Interactive	Heart	1,028,106
1-Jun-15	Keep Cool	811	37,210
1-Jun-15	SS	HVAC	998,042
1-Jul-15	SS Ins & Seal	Plant Trees	1,042,112
1-Aug-15	HEHC	Tailgating	219,032
1-Aug-15	School	Tailgating	826,298
1-Oct-15	Green	Interactive	1,134,248
1-Oct-15	PayGo	Interactive	3,040
1-Dec-15	Close Curtains	Share The Warmth	130,714
1-Dec-15	HEHC	Share The Warmth	268,423
1-Dec-15	High Bill Alerts	Share The Warmth	759,262
1-Jan-16	Bulbs Online Store	Water Heater Temp	1,152,678
1-Mar-16	EPP	Crawlspace	321,998
1-Mar-16	PM	Crawlspace	796,598

3.2 Impact Findings

3.2.1 Per-Home kWh and Percent Impacts

Nexant estimates the average participating MyHER home saved 229.8 kWh of electricity from May 2015 to April 2016. This represents a 1.6 percent reduction in total electricity consumption, compared to the control group over the same period. These final estimates reflect an upward adjustment to account for the intention-to-treat methodology and a downward adjustment to prevent double-counting of savings attributable to incremental participation of treatment groups in Duke Energy's energy efficiency programs.

Table 3-7 shows the impact estimates in each bill month for the average home assigned to treatment. The table also shows the subsequent adjustment to account for the fact that only a subset of homes assigned to treatment was actively participating in MyHER during the study period.

Table 3-7: MyHER Impact Estimates with ITT Adjustment

Month	Treatment Homes Analyzed	DEC Participant Count	kWh impact in Assigned Homes	% Treated	kWh Impact in Treated Homes
201505	1,237,495	1,044,200	-11.94	84.4%	-13.80
201506	1,243,446	1,027,432	-15.49	82.6%	-18.18
201507	1,245,920	1,057,508	-24.28	84.9%	-27.96
201508	1,247,841	1,065,154	-24.57	85.4%	-28.17
201509	1,236,403	1,062,208	-33.22	85.9%	-37.89
201510	1,224,580	1,062,192	-17.13	86.7%	-19.40
201511	1,214,468	1,157,054	-19.44	95.3%	-20.36
201512	1,242,769	1,153,632	-9.70	92.8%	-10.40
201601	1,238,733	1,172,987	-7.81	94.7%	-8.22
201602	1,230,148	1,158,474	-13.01	94.2%	-13.77
201603	1,222,422	1,158,535	-13.05	94.8%	-13.73
201604	1,213,159	1,150,783	-20.67	94.9%	-21.74
12-Month Total			**-210**	**89.7%**	**-234**

An adjustment factor of 4.19 annual kWh per home is applied to MyHER impact estimate estimates in Table 3-7 to arrive at the final net verified program impact per home. Section 3.2.6 provides additional detail on the calculation of the 4.19 kWh adjustment for overlapping participation in other Duke EE programs.

Table 3-8: MyHER Impact Estimates with Adjustment for Dual Participation

kWh Savings in Treated Homes	Incremental kWh from EE Programs	Net MyHER Impact Estimate	Control Group Usage (kWh)	Percent Reduction
234	-4.19	229.8	14,287	1.6%

The filed per-home impact for MyHER in DEC is 183.7 kWh per home based on a previous evaluation study. The Nexant evaluation results amounts to a realization rate of 125%.

3.2.2 Aggregate Impacts

The total impact of the MyHER program in the DEC service territory is calculated by multiplying the per-home impacts (adjusted for ITT and incremental EE participation) for each bill month by the number of participating homes. Over the twelve month period examined by Nexant in this evaluation, MyHER participants conserved 251.2 GWh of electricity; or enough energy to power nearly 17,257 homes for an entire year. The aggregate impacts presented in Table 3-9 are at the meter level so they do not reflect line losses which occur during transmission and distribution between the generator and end-use customer.

Table 3-9: MyHER Aggregate Energy Impacts

Month	DEC Participant Count	Per Home kWh Savings	Aggregate GWh
201505	1,044,200	13.64	14.2
201506	1,027,432	18.45	19.0
201507	1,057,508	27.76	29.4
201508	1,065,154	28.16	30.0
201509	1,062,208	37.86	40.2
201510	1,062,192	19.33	20.5
201511	1,157,054	20.28	23.5
201512	1,153,632	9.98	11.5
201601	1,172,987	7.46	8.7
201602	1,158,474	12.98	15.0
201603	1,158,535	12.90	14.9
201604	1,150,783	21.02	24.2
12-Month Total		**229.8**	**251.2**

3.2.3 Precision of Findings

The margin of error of the per-home impact estimate is ± 15 kWh at the 90% confidence interval. Nexant clustered the variation of the LFER model by Account ID to produce a robust estimate of the standard error associated with treatment coefficients. The standard normal z-statistic for the 90% confidence level of 1.645 was then used to estimate the uncertainty associated with each cohort estimate. This uncertainty was then aggregated across cohorts to quantify the precision of the program-level impacts estimates (Table 3-10).

Table 3-10: 90% Confidence Intervals Associated with MyHER Impact Estimates

Parameter	Lower Bound (90%)	Point Estimate	Upper Bound (90%)
Annual Savings per Home	215.0 kWh	229.8 kWh	244.6 kWh
Percent Reduction	1.50%	1.60%	1.70%
Aggregate Impact	235.0 GWh	251.2 GWh	297.4 GWh

The absolute precision of the result is ± 0.05% and the relative precision of ± 6.4% at the 90% confidence level.

3.2.4 Impact Estimates by Cohort

The per-home impact estimates shown in Table 3-7 reflect a weighted average impact across the three cohorts of MyHER customers analyzed. The impact estimates for the individual cohorts varied significantly for the study period. Table 3-11 shows point estimates for each cohort for the period May 2015 to April 2016.

Table 3-11: Annual kWh Impact Estimates by Cohort

Month	Cohort Impacts (kWh)		
	Cohort 1	Cohort 2	Cohort 3
201505	-13	0	-31
201506	-11	-9	-25
201507	-6	-19	-32
201508	-9	-22	-29
201509	-13	-16	-57
201510	-14	-5	-34
201511	-17	-14	-27
201512	-15	0	-22
201601	-22	-4	-12
201602	-13	-13	-13
201603	-14	-10	-17
201604	-6	-22	-20
Total	**-153**	**-135**	**-319**

Cohorts 1 and 3 show the largest average impact during the study period. Table 3-12 shows the margin of error at the 90% confidence level for each cohort's annual impact estimate. The combined margin of error for the entire program is lower than the error for any single cohort because the combined program impact estimate is based on a larger pool of customers. Individual cohort margins of error are high for the small cohorts due to the sizes of these groups relative to the underlying variation in consumption among the treatment and control groups constituting each cohort.

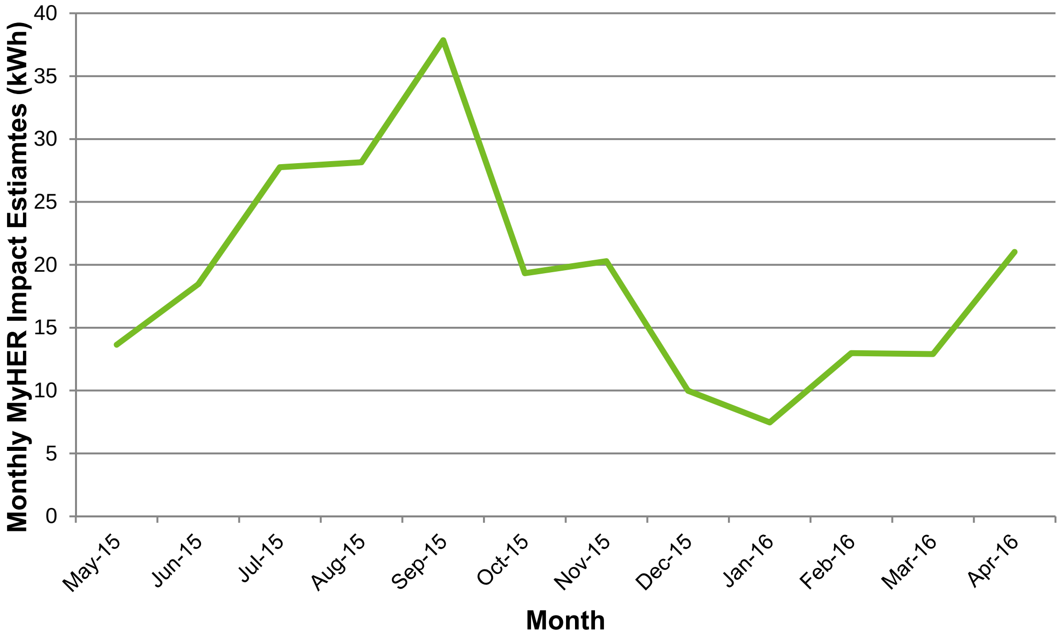
Table 3-12: 90% Confidence Intervals Associated with Cohort Estimates

Cohort Number	Cohort Description	Margin of Error in kWh at 90% Confidence Level
1	2010	± 1
2	2012-2013	± 25
3	2014-2015	± 60

3.2.5 Temporal Patterns

Duke Energy currently mails MyHER to the treatment group eight times per year. These mailers target the summer and winter months and skip the shoulder months. The green series in Figure 3-4 shows the average estimated monthly treatment effect for Cohort 1 (Pilot) in each month from May 2015 to April 2016. There is a definite seasonal pattern to the MyHER savings profile, with the largest impacts occurring during summer months and the smallest impacts occurring during winter months.

Figure 3-4: Average kWh Savings by Month, Pilot Cohort



Based on the observed savings trends, MyHER is actually performing quite well during shoulder months when Tendril does not mail reports. The treatment effect is still relatively strong at approximately 20 kWh per home each month. If Duke Energy wishes to explore the effect of changing the frequency or timing of MyHER delivery, Nexant recommends an experimental design where a portion of the treatment group is randomly selected for an alternative schedule while keep the remaining homes on the current delivery schedule.

Seasonal trends in MyHER average treatment effects likely reflect customers' differing abilities to respond by season. Customers' summer and winter savings may be higher than shoulder, which is due to the fact that there are more opportunities to conserve energy relative to baseline demands for energy in each season. Winter demands can be mitigated by dressing more warmly, using more blankets in the home, or shutting off lights more often (due to fewer daylight hours in the winter). The summer impacts can occur because small changes to thermostat set points can have a greater impact on hot days than on comparatively milder summer days.

3.2.6 Uplift in Other Programs

Section 3.1.6 outlined the methodology Nexant used to calculate the annual kWh savings attributable to increased participation in other DEC programs, a downward adjustment of 4.19 kWh per home, or 5.17 GWh in aggregate, as shown in Table 3-13.

Table 3-13: Monthly Adjustment for Overlapping Participation in Other EE Programs

Bill Month	Incremental kWh from Other EE Programs
201505	0.16
201506	0.13
201507	0.19
201508	0.00
201509	0.03
201510	0.08
201511	0.07
201512	0.42
201601	0.76
201602	0.78
201603	0.84
201604	0.72
Incremental kWh from EE netted out of MyHER	**4.19**

Although these additional savings must be subtracted from the MyHER effect to prevent double-counting, the MyHER promotional messaging clearly played an important role in harvesting these savings.

Table 3-14 shows the average daily energy savings attributable to tracked energy efficiency measures as of April 2016 by cohort and calculates an uplift percentage. In each case the treatment group showed a higher propensity to adopt measures through DEC programs than the control group. Nexant only counted savings for measures installed in the "post" period so the cohorts that have been assigned to MyHER for the longest period of time have accumulated the most savings.

Table 3-14: Uplift Percentage by Cohort

Cohort	Cohort	Daily Net kWh Savings from EE (Treatment Group)	Daily Net kWh Savings from EE (Control Group)	Uplift Percentage
1	2010	26.47	25.88	2.3%
2	2012-2013	6.86	6.75	1.7%
3	2014-2015	2.42	2.27	6.9%

3.2.7 Summer Demand Impacts

Nexant estimated MyHER demand savings using Duke Energy's system load profile data from 2014. This load profile data was provided to Nexant by Duke Energy's load forecasting team for residential customers in North Carolina. Nexant used the 2014 hourly demand estimate to identify the system peak demand hour of July 14, 2014, hour ending 17. Nexant applied the proportion of annual residential load in this hour to our annual MyHER impact savings estimate of 229.8 kWh; the result is an estimated MyHER residential peak demand savings of 0.05837 kW.

Table 3-15: MyHER Demand Impacts

Month	DEC Participant Count	Per Home kWh Savings	Aggregate MW
201507	1,057,508	0.05837	61,727

3.3 MyHER Interactive Portal

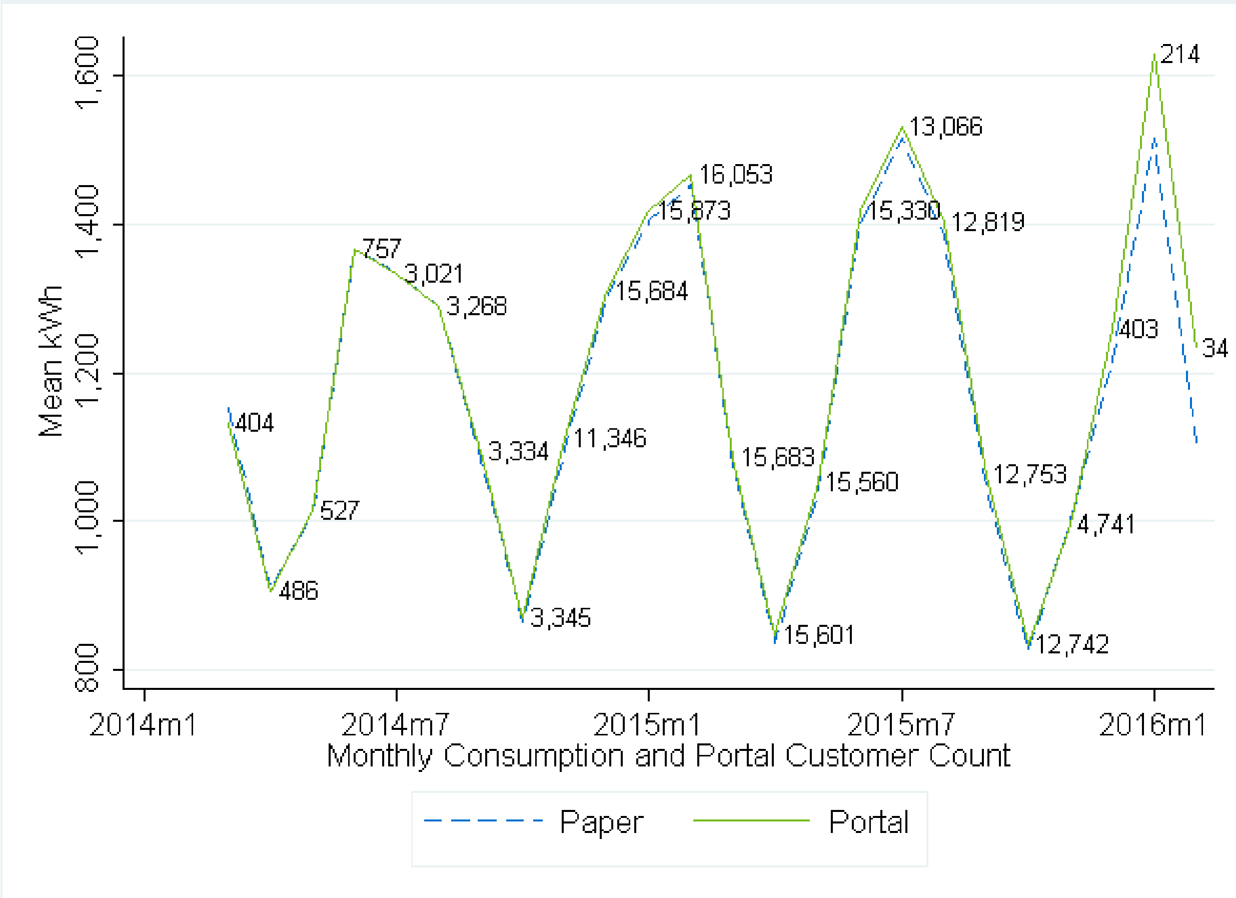
Nexant also evaluated the incremental energy savings generated by Duke Energy's new enhancement to the standard MyHER paper report. Duke Energy launched the MyHER Interactive Portal in March, 2015. The portal offers additional means for customers to customize or update Duke Energy's data on their premises, demographics, and other characteristics that affect consumption and the classification of each customer.

The portal also provides additional custom tips based on updated data provided by the customer. MyHER Interactive also sends email challenges that seek to engage customer in active energy management, additional efficiency upgrades, and conservation behavior. Nexant evaluated the impacts of the MyHER Interactive Portal using a matched comparison group because the MyHER Interactive Portal was not deployed as a randomized, controlled trial (RCT).

3.3.1 Estimation Procedures for MyHER Interactive

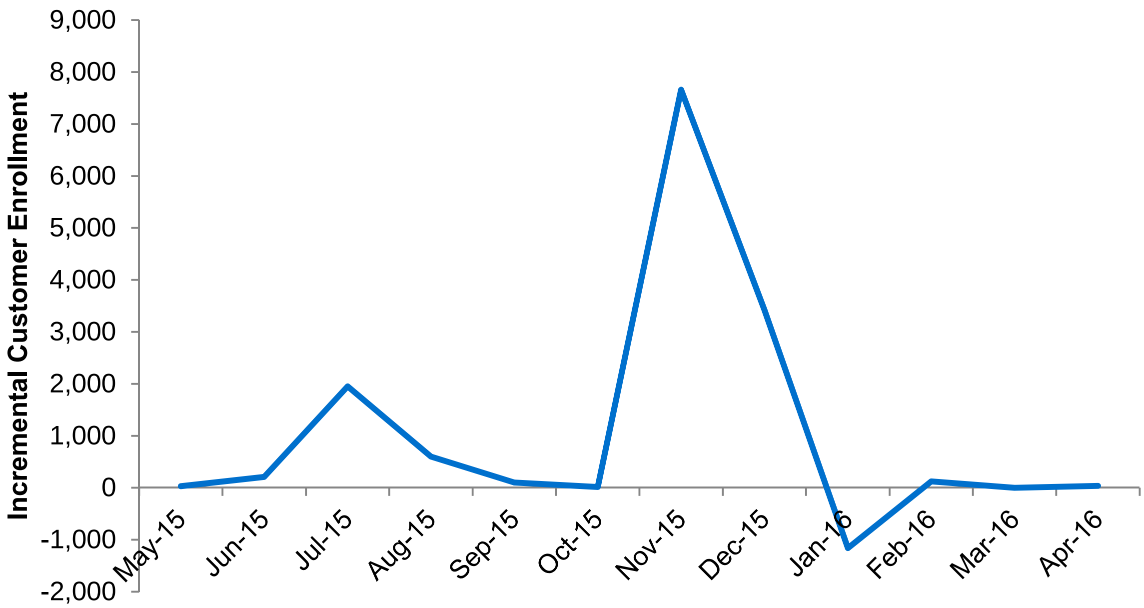
A matched comparison group is a standard approach for establishing a counterfactual baseline when there is no random assignment to treatment and control. The goal of matching estimators is to estimate impacts by matching treatment customers to similar customers that did not participate in the program. The key assumption to matched comparison approaches is that MyHER Interactive participants closely resemble non-participants, except for the fact that one of these two groups participated in the program while the other did not. When a strong comparison group is established, evaluators can reliably conclude that any differences observed after enrollment are due to program's stimulus. After replacing the control group with a matched comparison group, the same statistical modeling approach is used to estimate energy savings impacts. Figure 3-5 presents the pre-treatment consumption for MyHER Interactive customers and a matched comparison group comprised of MyHER customers that receive only paper reports. The matching approach generates two groups with nearly identical consumption patterns over the time period prior to customers' enrollment in MyHER Interactive. Some minor differences remain among the limited numbers of customers that signed up towards the end of this current evaluation period; yet, the fixed effects model specification Nexant applies controls for pre-treatment differences, as discussed earlier in section 3.1.5.

Figure 3-5: MyHER Interactive Portal Customers and Matched Comparison Group



Customers signed up for the MyHER Interactive Portal on a monthly basis, beginning March 2015. Figure 3-5 presents average consumption for such customers in the year prior to enrolling in the MyHER Interactive Portal. The values labeled in Figure 3-5 indicate the number of MyHER Interactive Portal customers that were matched on the basis of pretreatment consumption in each month. The values grow and decline over time in a manner that reflects the signup pattern of MyHER Interactive Customers: the early months show some early adopters while the middle months indicate the pre-treatment period with the greatest share of MyHER participants. This trend is more clearly indicated below in Figure 3-6, which plots the number of customers signing up for MyHER Interactive in each month of the impact evaluation period.

Figure 3-6: Incremental MyHER Interactive Portal Enrollment



3.3.2 Results and Precision

Duke Energy participant counts indicate the total enrollment for the MyHER Interactive portal in April 2016 was 12,987 customers for the DEC territory. This figure represents approximately 1.2% of total MyHER participants. For this evaluation period, the MyHER Interactive Portal savings estimates are too uncertain to determine whether the portal generates incremental savings above and beyond the standard MyHER paper edition. Although impact estimates are very uncertain, it would also be premature to draw the conclusion that MyHER Interactive is not working, and statistical models of monthly impact reflect some directional consistency. Table 3-16 provides impact model results, along with the margin of error for estimated impacts.

Table 3-16: MyHER Interactive Model Results

Bill Month	Impact Estimate (kWh)	Margin of Error (kWh)
201505	7.3	57.1
201506	2.9	66.4
201507	-3.7	64.5
201508	-13.4	35.9
201509	-11	37.9
201510	-2.2	41.1
201511	-9.7	45.2
201512	-9.3	25.9
201601	-5.2	22.9
201602	-15.1	24.4
201603	-11.9	25.3
201604	-8.7	27.8
Annual Totals:	**-80**	**146.6**

Table 3-16 contains point estimates of monthly impacts for the MyHER Interactive component of the program. The point estimate for annual impacts indicates a savings of 80 kWh, but the margins of error around the estimates are larger than the point estimates themselves. Since the resulting error band for these impact estimates includes zero, Nexant cannot conclude that the MyHER Interactive Portal succeeded in generating additional savings during this evaluation period. Nexant also examined tracking data on MyHER Interactive sessions. Duke Energy provided Nexant with a record of approximately 37,837 separate MyHER Interactive sessions from May 2015 to April 2016. Despite the large number of customer login sessions, only 6,786 customers signed into the MyHER Interactive portal more than once, and only 3,428 signed in more than twice. Only 28 customers average longer than one minute per session.

3.4 Impact Conclusions and Recommendations

Nexant's impact evaluation shows that Duke Energy's MyHER program continues to trigger a reduction in electric consumption among homes exposed to the program messaging. MyHER is currently achieving 229.8 kWh annual savings within the time period evaluated. Although MyHER is achieving its primary target of delivering cost-effect savings to the company, and its secondary goal of promoting other DEC initiatives, Nexant provides the following conclusions and recommendations for consideration:

- ***The inconsistent assignment of homes to the MyHER treatment and control group over time has complicated the intended RCT experimental design.*** This issue complicates the impact analysis and increases uncertainty in the impact estimates for cohort 4. In the future, homes should always be assigned to the treatment group with a corresponding assignment of homes to the control group. Assignment of new accounts to the MyHER treatment and control group should be limited to once or twice per year.

- ***Continue to monitor engagement and evaluate the impacts of the Interactive Portal.*** However, for this evaluation period, the MyHER Interactive Portal savings estimates are too uncertain to determine whether the portal generates incremental savings above and beyond the standard MyHER paper edition. Although impact estimates are very uncertain, it would also be premature to draw the conclusion that MyHER Interactive is not working, and statistical models of monthly impact reflect some directional consistency.

4 Process Evaluation

This section presents the results of process evaluation activities including in-depth interviews with Duke Energy and implementation staff and a survey of control and treatment households.

4.1 Methods

Process evaluations support continuous program improvement by identifying opportunities to improve the effectiveness and efficiency of program operations and services. Process evaluations also identify successful program components that should be enhanced or replicated. Process evaluation activities for MyHER sought to document program operational processes and to understand the experience of those receiving MyHER mailings. The customer survey focused on investigating the recall and influence of MyHER messages among recipients, the extent to which MyHER affects customer engagement and satisfaction with Duke Energy, and subsequent actions taken by participants to reduce household energy consumption. A survey of control group households provided a point of comparison for estimating the effect of MyHER on behavior and attitudes of treatment households.

4.1.1 Data Collection and Sampling Plan

The process evaluation included two primary data collection activities: in-depth interviews with program management and implementation staff, and surveys with a sample of households selected to receive MyHER reports as well as a sample of control group households.

Nexant deployed the household surveys using a mixed-mode survey measurement protocol, outlined in Table 4-1. In this protocol customers were contacted by letter on Duke Energy stationery (to assure recipients of the validity of the survey) asking them to go online and complete the survey. The letter contained a two-dollar bill as a cost-effective measure to maximize the survey completion rates. The letter also included a personalized URL for the online survey that points the recipient to a unique location on the internet at which they were able to complete the survey. Customers for whom email addresses were available also received an email inviting them to take the survey online, which also included the same personalized URL that appeared in the letter leading to the survey website at the location where they could complete it. After three weeks, customers who did not respond to the web survey received another letter, this time containing a paper copy of the survey and a return postage-paid envelope asking them to complete the survey by mail. Survey recipients also had the option of calling Nexant at toll-free telephone number to complete the survey by telephone.

Table 4-1: Summary of Process Evaluation Activities

Population	Approach	Population	Sample		Confidence/Precision	
			Expected	Actual	Expected	Actual
Program management and implementation	In-depth interviews	~10	2-5	3	Not applicable	Not applicable
Treatment households	Mixed-mode; mail, web, and phone	~1,200,000	189	233	90/06	90/06
Control group households	Mixed-mode; mail, web, and phone	~120,000	189	213	90/06	90/06

4.1.1.1 Interviews

Nexant conducted interviews with key contacts at Duke Energy and at Tendril. The interviews built upon information obtained during 2015 evaluations of the Duke Energy Ohio and Duke Energy Indiana MyHER programs and allowed the evaluation team to understand any developments or enhancements in program delivery in 2016. A central objective of the interviews was to understand program operations and the main activities required to develop and mail the MyHER to DEC customers approximately eight times a year.

4.1.1.2 Household Surveys

Both treatment and control groups were surveyed. For the treatment households, the survey included questions about the experience of the reports themselves as well as questions to assess engagement and understanding of household energy use; awareness of Duke Energy efficiency program offers; and satisfaction with the services Duke Energy provides to help households manage their energy use. The control group survey excluded questions about the information and utility of the MyHER reports, but included identical questions on the other aspects to facilitate comparison with the treatment group.

Nexant analyzed the survey results to identify differences between treatment and control group households on the following:

- Reported levels of stated intention for future action;
- Levels of awareness of and interest in household energy use;
- The level of behavioral action or equipment-based upgrades;
- Satisfaction with Duke Energy service and efficiency options; and
- Inclination to seek information on managing household energy use from Duke Energy.

This survey approach is consistent with the RCT design basis of the program and supports both the impact and process evaluation activities by providing additional insight into potential program effects.

Survey Dispositions

We mailed 566 letters to randomly selected residential customers in both the treatment and control groups respectively. The survey was completed by 213 treatment households and 233 control households, representing a treatment group response rate of 38% and a control group response rate of 41%. The treatment group had a higher percentage of respondents completing the survey online, as compared to the control group: 58% of the treatment group surveys were completed online while 44% of the control group surveys were completed online. Table 4-2 outlines the treatment and control group survey dispositions.

Table 4-2: Survey Disposition

Mode	Treatment		Control	
	Count	Percent	Count	Percent
Completes by Mode				
Web-based Survey	123	58%	103	44%
Mail/Paper Survey	75	35%	118	51%
Inbound Phone Survey	15	7%	12	5%
Total Completes	**213**	**100%**	**233**	**100%**

4.2 Findings

This section presents the findings from in-depth interviews with staff and implementation contractors and the results of the customer surveys.

4.2.1 Program Processes and Operations

Similar to other Duke Energy jurisdictions, MyHER for DEC is managed primarily through a core team of three Duke Energy staff members: a Behavioral Program Manager with oversight of both residential and nonresidential behavioral programs, a Program Manager in charge of the day-to-day operations of the MyHER program, and a Data Analyst responsible for the substantial data tracking and cleaning tasks that occur at Duke Energy to support the contracted implementation team.

At Tendril, Duke Energy's contracted program implementer, MyHER is supported by a team of people including an Operations Manager, a Home Energy Report Product Manager, and an Account Manager responsible for ensuring that the Duke Energy MyHER products meet expectations for quality, timing, and customer satisfaction. Tendril staff track the number of reports sent, the quality of the reports, the timing of reports, and indications of customer satisfaction.

As MyHER is Duke Energy's flagship behavioral energy efficiency program, its primary goals are to achieve energy savings, increase customer satisfaction, and cross-promote enrollment into Duke Energy energy efficiency and demand response programs. Staff at both organizations described continuous, close coordination to ensure that the data behind the MyHER graphs is accurate, the tips provided to specific households are appropriate, and that MyHERs are delivered within the relatively short timeframe between bills. Program operations are conducted with a customer-focused orientation where the commitment to producing a high-quality product is a demanding process that must be executed consistently throughout the year.

4.2.1.1 MyHER Production

During the period of time under study by this evaluation, MyHERs were mailed out to DEC customers on paper through the U.S. Mail service about eight times a year, where the mailing gaps generally occurred in February, April, September, and November. During the eight treatment months, the reports are generated twice per week, a cadence that is designed to facilitate meeting a key performance indicator: that MyHERs arrive at the customers' homes near the mid-point of their billing cycle so as to make the information presentment as useful and timely as possible.

The production process for any given treatment month begins as soon as meter reads for the first billing cycle are processed by Duke Energy's meter data management system. After processing, billing data is uploaded nightly, five times a week, to Tendril. Once the data has been received, report production proceeds according to the following process: Tendril runs report production and conducts quality control checks. Then a flat file containing all the data from the reports is sent to Duke Energy for an independent quality control check. Upon approval, Tendril produces the PDFs of the reports and promotes them for another Duke Energy quality control check. Upon approval, Tendril then sends the PDFs to the print-house, and the print-house generates a final proof for Duke Energy approval. Finally, after the proof is approved, the print-house prints and mails all the reports, and commences the process of reporting the printing and mailing to Duke Energy.

This long production chain moves quickly: once Tendril generates a batch of reports, the time elapsed until transfer to the print-house is generally 2-3 business days when all processes are completed according to plan. If any quality control problems emerge, that elapsed time can double, which would likely result in the batch's cancellation and merge with the next batch. Considering that the print-house has one week to complete the mailing, and Standard Rate postage can take another week to deliver, making the mid-cycle in-home delivery goal takes dedicated effort to achieve.

This fast-moving process has seen improvements through the implementation of some changes: Firstly, by moving from a once-a-week mailings to twice-a-week. Additionally, Duke Energy has increased the speed with which the data transfer process to Tendril can be completed. These efforts have resulted in improvements in in-home date performance, and has enabled Tendril to realize service-level agreement (SLA) incentives for exceeding in-home delivery date goals.

Embedded in the early days of this production cycle is a quality control process that is undertaken to ensure that the reports contain accurate information and are of high quality production. Duke Energy analyzes a dataset containing all of the information presented in the reports for each production cycle, and this data is checked for essentially anything that could be erroneous, ranging from verifying that all the customers receiving reports are eligible to receive them, that no control customers are getting reports, that the reported electricity usage is correct, that no customers who have opted-out are getting reports, and that no one has gotten more than one report a month. Duke Energy also checks for unexpected cluster assignment changes, presentment of messaging and tips and overall print quality.

These checks have proven to be crucial. In general, problems have not been found to occur every week but some have occurred each quarter, and are subsequently reviewed in Tendril's governance sessions. This visibility typically results in issue resolution on a going-forward basis, however, sometimes the same issues have been reported to pop back up a year or two later. It was recognized by both Duke Energy and Tendril staff that problems, when they occur, occur following changes to the report or cycle processes. The consensus was that when there are no changes implemented, the report generation cycle goes smoothly; all stakeholders agreed that managing changes to program operations is an important part of keeping deliveries running smoothly.

An important component of MyHER program change management and general operations is a shared document repository (Sharepoint) accessible to program staff across both Duke Energy and Tendril. The Sharepoint site contains areas for Duke Energy staff that present program dashboard information summarizing participation, reports of inbound customer calls, emails, and letters pertaining to MyHER. Information on the number of program opt-outs and reasons for opting out. The area shared with Tendril has documentation of approved program changes, contractual requirements, issue resolution logs and information on program processes, including messaging calendars for the free-form text section of the reports. Importantly, the Sharepoint site also documents the QC procedures undertaken internally prior to every report mailing. An original program operations playbook that was created at the inception of the MyHER program is still available and used as a reference document for program eligibility criteria and as a data dictionary.

Opportunities for improving the quality of MyHERs include successful resource planning and turnover management at Tendril, so that enough appropriate resources are consistently directed at the program. Turnover at Tendril was an issue raised in the MyHER evaluation at DEI, and it remained a theme for DEC as well: A key resource at Tendril that worked closely with Duke Energy with the report generation and QC processes left the company, and there was an outage of the appropriate level of support with respect to that resource's data-centric duties.

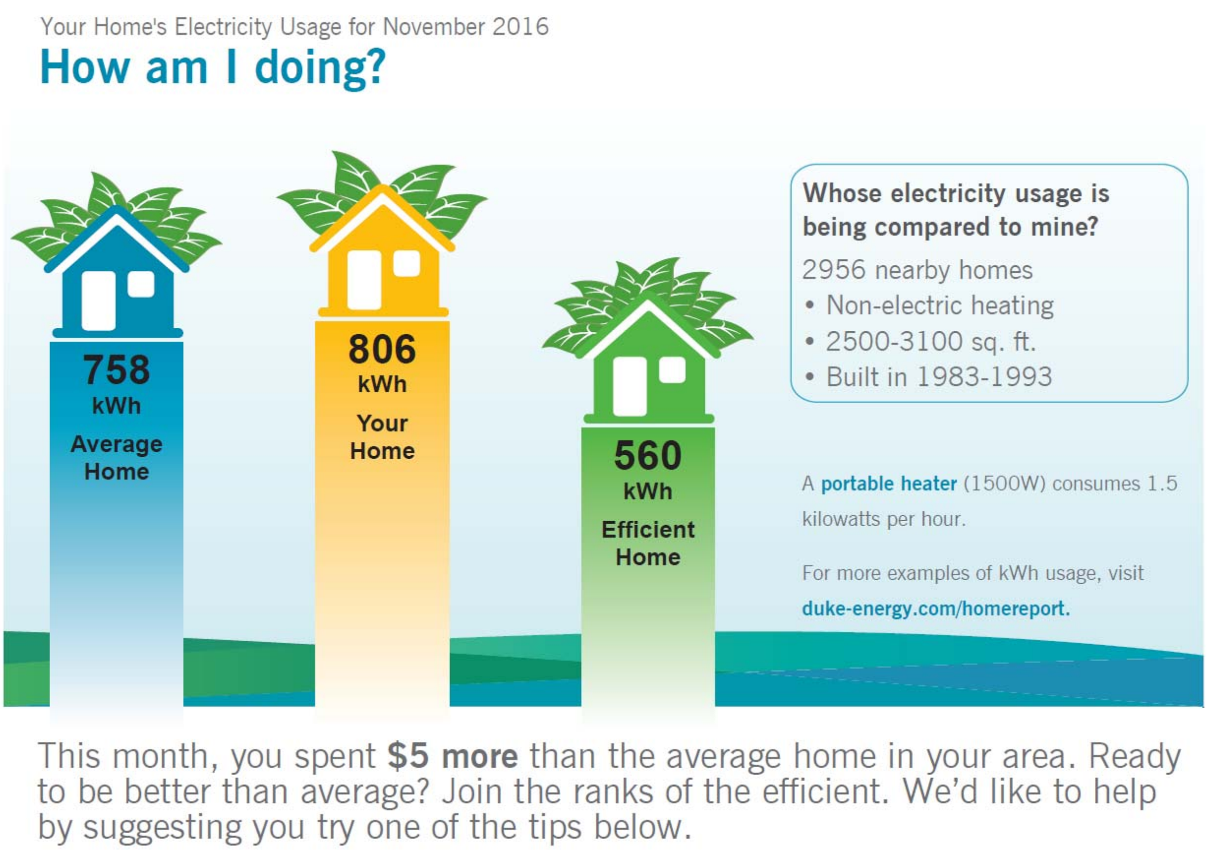
Other opportunities include continuing to maintain documentation in the MyHER Sharepoint filesharing repository that documents internal operations that are most critical to MyHER. Given that a relatively small team manages MyHER, this can help manage risk associated with the potential for turnover internal to Duke Energy. Also, the QC process would run more smoothly if Tendril could consistently deliver flat files on an agreed-upon schedule, or if delays to the schedule were less frequent. Also, stronger attention to upstream and downstream effects of changes could reduce the likelihood of problems with report production, given that they generally occur on the heels of changes.

Duke Energy and Tendril staff all spoke highly of enjoying a relationship with strong and open lines of communications. The ability to prioritize product changes was recognized as an important enabler of successful change rollout.

4.2.1.2 MyHER Components

MyHER reports include several key elements that are customized each month: the bar chart, tips, trend chart, and messages. The front page includes a graph comparing the subject home to the average and most efficient homes for an assigned cluster or "neighborhood." Previously, these graphs were labeled with dollars, but this occasionally caused confusion among recipients if the dollar amount didn't exactly match their recall of a recent bill. In March 2013, Duke Energy shifted to using kWh as the unit of measurement for the bar charts; Duke Energy conducted customer focus groups in an effort to understand the level of confusion this shift might cause and found that customers reported not paying attention to unit of measurement: they were simply absorbing the shape and directionality of the bar charts (Figure 4-1).

Figure 4-1: MyHER Electricity Usage Comparison Bar Chart



A small box next to the graph provides the size of the group of comparison homes, the assumed heating type, the approximate square footage, and the approximate age of similar homes.

According to MyHER staff, a common reason for customer phone calls about MyHER is simply correcting assumed information about a given home. For example, the MyHER could indicate that Duke Energy assumes a home has electric heat when it does not, or have a home in the wrong size category. Any corrections provided in this manner are considered highly reliable and are not changed based on subsequent uploads of third party data.

In addition to the comparison graph, each MyHER includes a set of customized tips under the heading “What can I do to save money and energy?” (Figure 4-2).These tips are designed to provide information relevant to homes with similar characteristics, as presented in the box accompanying the comparison graph.

Figure 4-2: MyHER Tips on Saving Money and Energy

Tips Based on Your Usage and Home Profile

What can I do to save money and energy?

A bright idea for outside!

Use efficient bulbs for your outdoor lighting

Save up to $15 per year.

Consider efficient compact fluorescent (CFL) bulbs for your outdoor lighting needs. CFL bulbs use 75% less energy, and they last 10 times longer than incandescent bulbs. Here's the bonus: CFL bulbs last so long, you won't have to get out your ladder as often to change them.

Reach for that crock pot all year!

Dust off that crock pot

Save up to $12 per year.

Cooking in a crock pot can be much more efficient and convenient than using your oven. A crock pot costs 10 cents to run for 8 hours while an oven costs 32 cents to run for just one hour. Dust off that crock pot and fill it with your favorite meal. You'll savor the flavor and enjoy the savings.

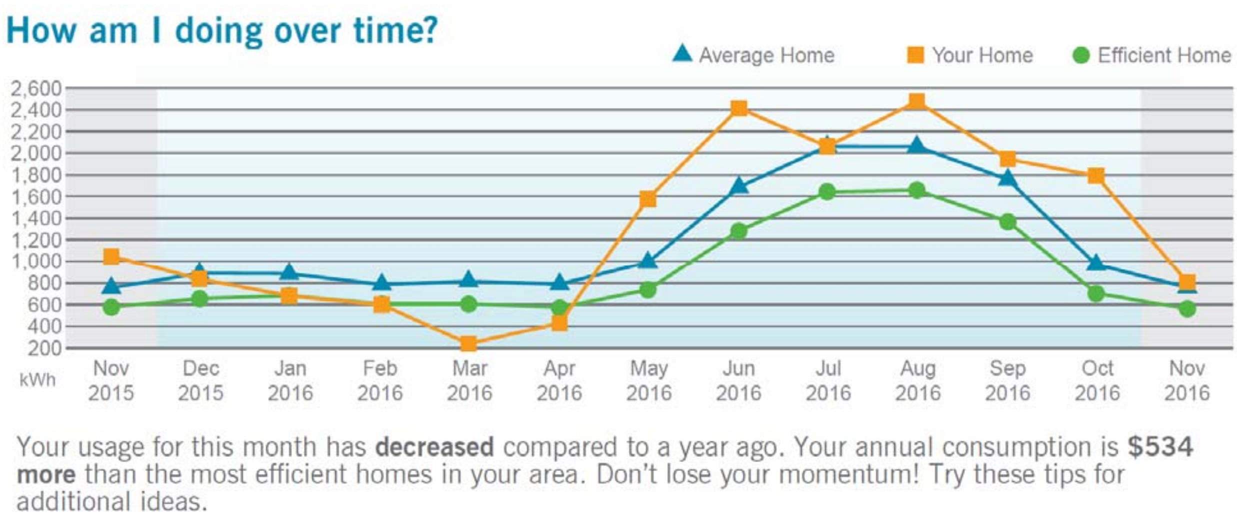
The left margin on the front page of each report contains elements consistent for all recipients: information about what the report does, why Duke Energy is sending them to customers, and email and telephone contact information. Customers occasionally contact Duke Energy with questions or concerns about MyHERs and, rarely, to opt-out. Duke Energy’s efforts to maintain a high-quality MyHER customer experience is reflected by the high value that is placed on program participant satisfaction and as such, it is closely monitored. Only 1% of MyHER customers contact Duke Energy annually and less than 1% of MyHER treatment customers contact Duke Energy to opt-out. Prior studies have found a 70% top-three box[2] satisfaction

[2] Using an 11-point 0 to 10 scale to measure satisfaction levels.

score and the rigorous quality control efforts described earlier have kept most quality-related issues from ever reaching customers.

In addition, each MyHER includes a trend chart that displays how the recipient's home compares to the average and efficient home in energy usage over a year (Figure 4-3). This trend chart can help customers identify certain months where their usage increased relative to the efficient or average home—helping them focus on the equipment and activities most likely to affect their usage. For example, if a home tracks the average home until mid-winter and then spikes well above, that could indicate the heating equipment should be checked.

Figure 4-3: MyHER 12 Month Trend Chart



Finally, MyHERs include space on the back page for Duke Energy to include seasonal and programmatic (free-form) messaging that reflects Duke Energy-specific communication objectives. Ensuring that these messages are relevant and do not conflict with the actions or tips provided on the front page requires on-going coordination and monitoring. Occasionally the action text on the front page will be disabled to accommodate the free form text. These messages are developed annually in cooperation with Duke Energy's marketing and communications group. The schedule is maintained in a campaign calendar, which consists of primary and alternate messages for two content boxes. Duke Energy staff strive to develop messages that are clever, relevant, and upbeat—some recognize events on the calendar (such as Earth Day) while others provide specific program promotional information or promote general home upgrades (even for measures outside of current programs).

Program contacts confirmed that establishing the message calendar early in the program year and stabilizing the messages to avoid late changes continues to be challenging. The message calendar can be difficult to manage because of periodic changes to program promotions and incentive levels. A contact at Tendril confirmed this, noting that while they try to get this text solidified 30 days ahead of the mailing date in the calendar, last minute changes are not uncommon.

In addition to developing the messages included in each MyHER, the program team must also ensure that the messages conform to expectations established to protect the customer experience. Broad targeting efforts taking advantage of seasonal relevance, program eligibility, presence of end use such as pools, are used to cross-promote Duke Energy programs. Customer participation databases are cross checked each month to ensure that customers only receive information about programs they have not already participated in; if a customer is found to have participated in the program being promoted in a given month, that customer will receive an alternate, typically more generic message

Few issues were cited during staff interviews related to the production process specifically related to action tips and messaging. Messaging is part of the QC process and Duke Energy is working with Tendril to develop a tool for reviewing messaging proofs earlier in the production cycle.

Regarding tips, MyHER has a large library of actions tips, between 80 and 90. Half of them were initially developed internally at Duke Energy, and Tendril has continued to add to them. The large library has enabled the program to avoid any repeats to customers for the past three years. Tip freshness is also managed with display rules that ensure that a diversity of tip types (both in the value of the tip and the area of the household they apply to) is shown. There is an opportunity to comprehensively review the tip library to make sure they are still accurate and relevant. Here Duke Energy does check for quality as well: the monetary values estimated by Tendril for each tip action are validated for reasonableness.

4.2.1.3 MyHER Interactive

A MyHER web portal component, called MyHER Interactive, was introduced in March 2015. MyHER Interactive provides an opportunity for customers to log in, set and track goals, and access an “expert” for advice or questions on saving energy. Enrollment and login goals have not yet materialized at DEC as they had been hoped that they would: only 1.5% of Duke Energy’s customers have enrolled, and the initial goal was 5%.

To date, the most successful enrollment generators for MyHER Interactive have been prize sweepstakes and cross-promotion with the High Bill Alerts program. Envelope messaging has been introduced, and email campaigns have been found to be successful. The long-run viability of MyHER Interactive email campaign; however, it is hindered by the fact that Duke Energy has a limited number of emails. Staff interviews revealed that is Duke Energy initiative underway to increase the number of emails available for future email MyHER Interactive enrollment campaigns. The least successful promotion for MyHER Interactive has been promoting it inside the paper MyHERs.

While there is work to be done to enable Duke Energy to reach its MyHER Interactive enrollment goals, an encouraging finding is that there were no issues reported or described concerning Interactive’s production process or with respect to negative customer feedback.

4.2.1.4 MyHER Plans to Further Improve Program Operations

Looking forward, Duke Energy and Tendril have a number of plans underway that are anticipated to further improve program performance and the customer experience with the program:

- Reports will be introduced at the end of 2016 or early 2017 to customers in multi-family dwellings;
- A quality control process enhancement that will allow Duke Energy staff to access PDF proofs prior to promotion into downstream systems will be introduced that will make it easier correct problems if they are identified;
- An initiative will be underway to visually refresh the MyHER product to include more pictures and to update report colors;
- Work to increase enrollment in MyHER Interactive will continue to take place; and
- The viability of producing reports for dual-fuel customers will be studied and considered.

4.2.2 Customer Surveys

The customer surveys included a section of questions focused specifically on the experience of and satisfaction with the information provided in MyHERs—these questions were asked only of households in the treatment group. Both treatment and control households answered the remaining questions, which focused on assessing:

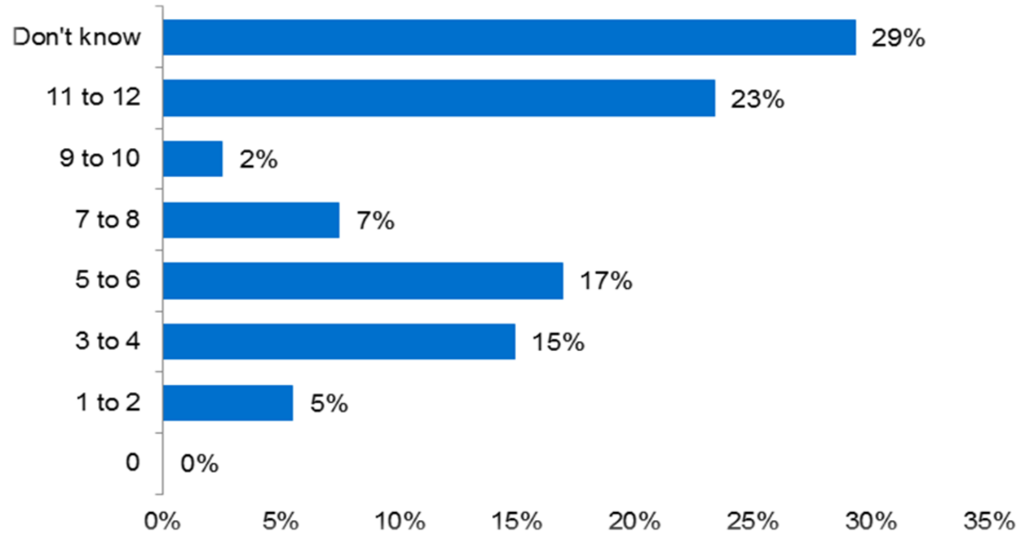
- Awareness of Duke Energy efficiency program offers;
- Satisfaction with the services Duke provides to help households manage their energy use;
- Levels of awareness of and interest in household energy use; motivations and perceived importance; and
- Reported behavioral or equipment-based upgrades.

4.2.2.1 Treatment Households: Experience and Satisfaction with MyHER

Nearly all of the treatment household respondents (94%, or 201 of 213) recalled receiving at least one of the MyHER reports.

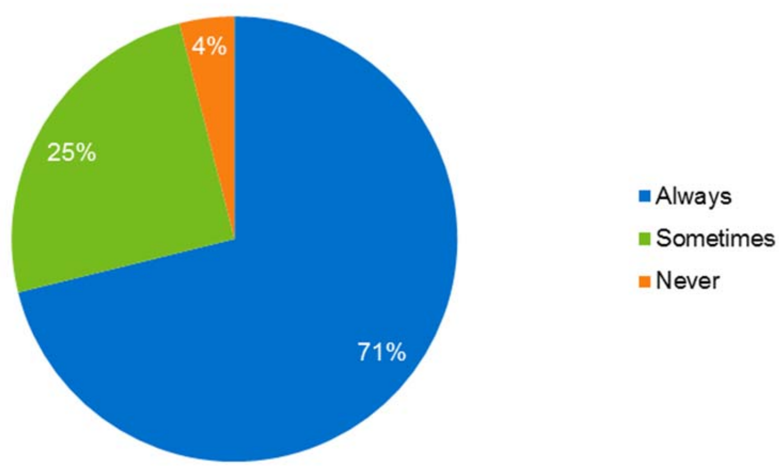
The survey asked those that could recall receiving at least one MyHER if they could recall how many individual reports they had received “in the past 12 months” (Figure 4-4). The survey launched in August 2016, which means that most recipients would have received 5-6 MyHERs. Twenty-nine percent (59 of 201) responded that they could not identify the number of home energy reports were received “in the past 12 months.” The distribution of responses related to recall is consistent with the difficulty of recalling an exact number of reports, however the question is valuable for grounding respondents in the experience of receiving a MyHER before asking them more specific questions about the document.

Figure 4-4: Reported Number of MyHERs Received "In the past 12 months" (n=201)



Survey respondents indicated high interest in the MyHER reports. As shown in Figure 4-5, when asked how often they read the reports, 96% of respondents indicated they "always" or "sometimes" read the reports. Eight respondents (4%) indicated they do not read the reports.

Figure 4-5: How Often Customers Report Reading the MyHER (n=201)



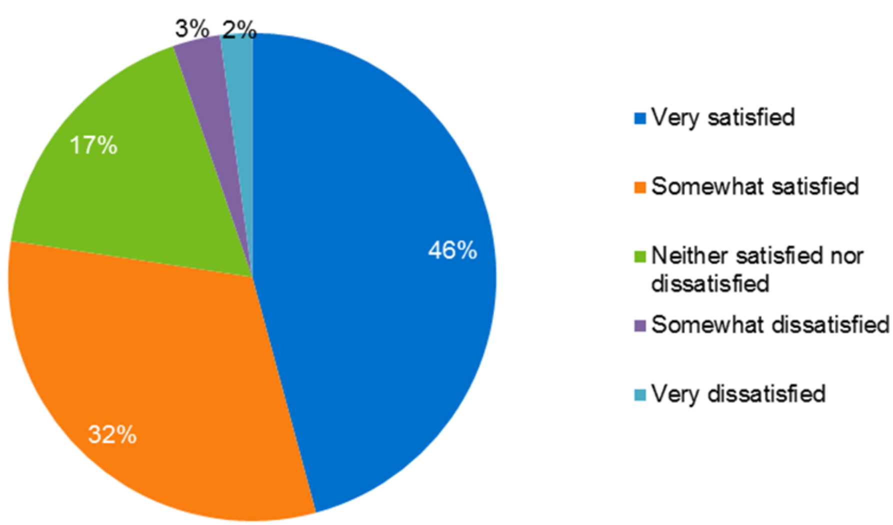
Despite a high "open rate" for MyHER reports, only 39% (76 of 193) of survey respondents recalled specific tips from their reports (Table 4-3). The survey asked these 76 respondents to then provide an open-ended description of the specific tips they could recall. Sixty-eight respondents were able to recall 112 separate MyHER tips. The most commonly reported tips included thermostat setting, switching to energy efficient lighting, and insulation/weatherization recommendations.

Table 4-3: Distribution of Recalled Tips/Information (Multiple Responses Allowed)

Tip or Information	Count	Percent of Respondents Mentioning (n=68)	Percent of Total Mentions (n=112)
Thermostat settings	16	24%	14%
Efficient lighting	30	44%	27%
Weatherization	17	25%	15%
Cold water	5	7%	4%
Upgrade TV/appliance	8	13%	8%
Turn things off/unplug	9	13%	8%
Comparison	6	9%	6%
Hot water	5	7%	4%
Other	11	19%	12%

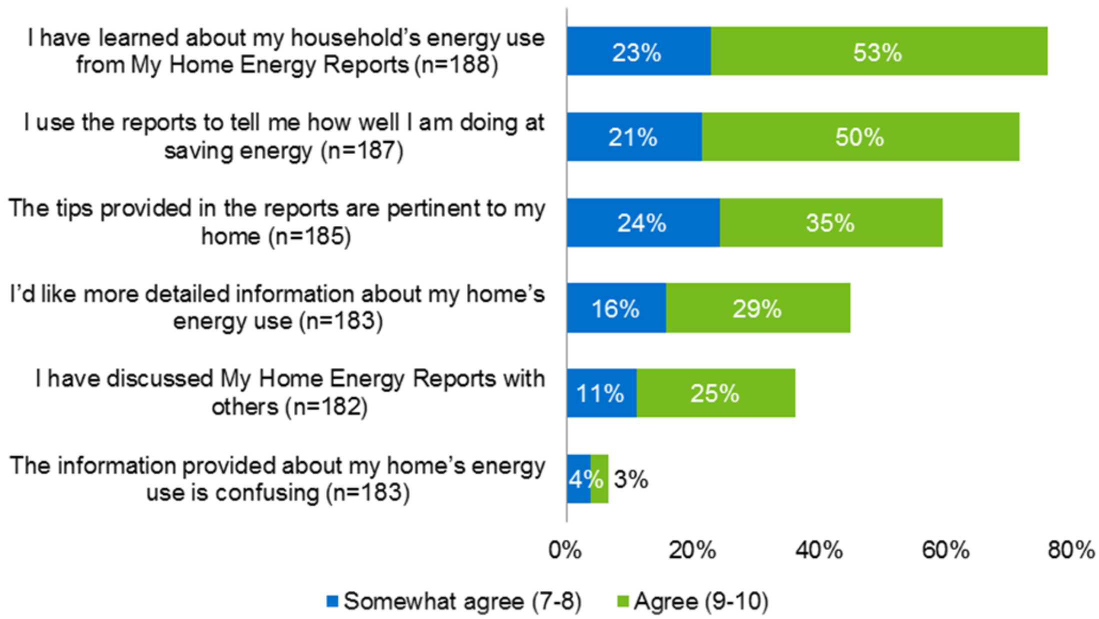
Seventy-seven percent (147 of the 190 respondents that provided a rating) reported being “somewhat” or “very” satisfied with the information contained in the reports (Figure 4-6).

Figure 4-6: Satisfaction with the Information in MyHER Reports (n=190)



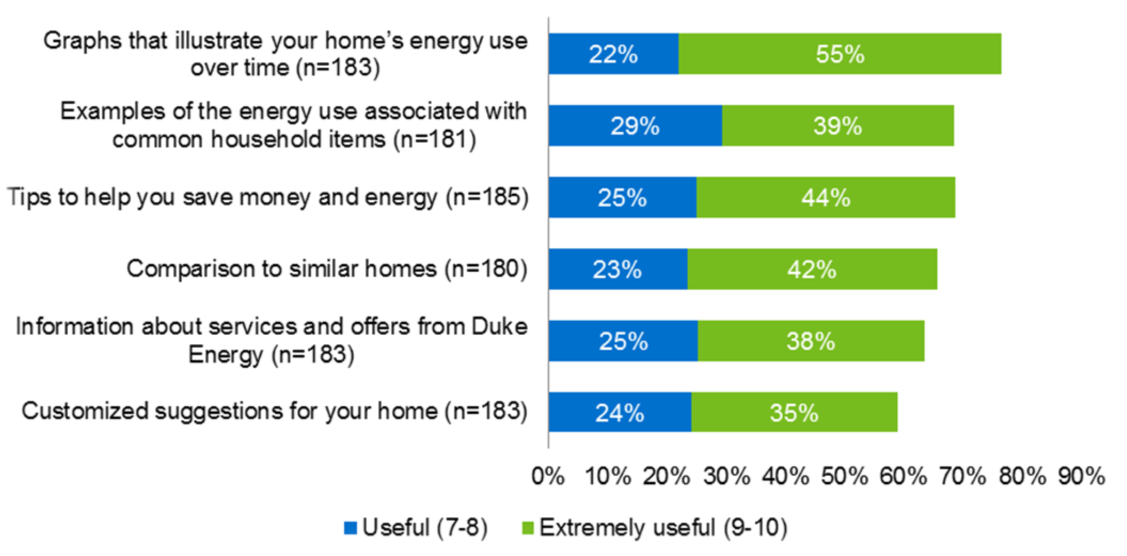
When asked to rate their agreement with a series of statements about MyHERs on a scale of 0 to 10, recipients largely agreed that the reports helped them understand their home’s energy use, with 76% of respondents rating their agreement a seven or higher on a 0-10 point scale, and that they use the report to gauge how successful they are at saving energy (72% rating a seven or higher). Respondents provided weaker agreement to statements about the applicability of the tips provided and desire for more detailed information. Encouragingly, a very small percentage (7%) agreed that the information provided is confusing (Figure 4-7).

Figure 4-7: Level of Agreement with Statements about MyHER (0-10 Scale)



The results shown in Figure 4-8 illustrate that 77% of respondents in treatment group rated the time series graphs of home energy consumption a seven or higher on a 0-10 point scale of usefulness, indicating that treatment households found this feature very useful, followed by a 69% useful rating for both examples of the energy use associated with common household items and tips to help save money and energy. Treatment households rated the time-series graphs more useful than the other MyHER features, as indicated in Figure 4-8.The usefulness of customized suggestions for home was rated the lowest, receiving a seven or higher score of 59%.

Figure 4-8: Rating Usefulness of Key HER Features (0-10 Scale)



The survey provided an open-ended question to elicit suggestions about potential improvements to MyHER among those that had reported reading at least one report. Only 28% (56 of 201) offered suggestions, including sixteen who offered only appreciative comments. Among those offering suggestions for improvement, the most common request, mentioned by 17 of the 56 with suggestions, reflected a desire for more specific information or details about their home and specific actions they should take. Some of these requests reflected interest in understanding at a more granular level how their home uses energy and energy consumption information related to appliances:

- *"I would like to see the actual kWh used under each column (Month/Year). Also, I would like to see 14 months in graph of usage by month."*
- *"Include which days during month are highest in energy consumption and efficiency."*
- *"Indicate in what area energy could be saved."*
- *"When the technology becomes available, more information about what appliances specifically is using the most energy and where improvements can be made."*
- *"A report that specifically tells about how much energy is used for each appliance."*

Other comments centered on unique features or occupancy patterns at respondent homes, disbelief in the relevance of comparison homes, and a few respondents that simply did not see value in the reports. Responses coded as recommending production changes included a variety of different, even conflicting, suggestions, including:

- *"Keep sending the reports and you can send them to an email address to save paper and cost of mailing?"*

- *"More often."*
- *"Send with bill, not separate."*
- *"I think the reports are a waste of money for Duke Energy. I think you could save printing cost, stamp and labor and put toward your grants, or lower customer bills."*

Nexant categorized these suggestions on the basis of their content; the results are presented in Table 4-4. Suggestions categorized as "other" include requests for list of companies in the area that provide energy saving procedures, and reminders to clean or change filters, etc.

Table 4-4: Distribution Suggestions for Improvement (Multiple Responses Allowed)

Suggestion	Count	Percent of Respondents Mentioning (n=56)	Percent of Total Mentions (n=60)
Provide more specific information or details	17	30%	28%
Don't believe comparison/accuracy	9	16%	15%
Appreciate the HER	17	30%	28%
Expressed frustration	2	4%	3%
Other suggestions	5	9%	8%
Don't see value/dislike	6	11%	10%
Address unique home/circumstances	2	4%	3%
Change production (mail, paper, format)	2	4%	3%

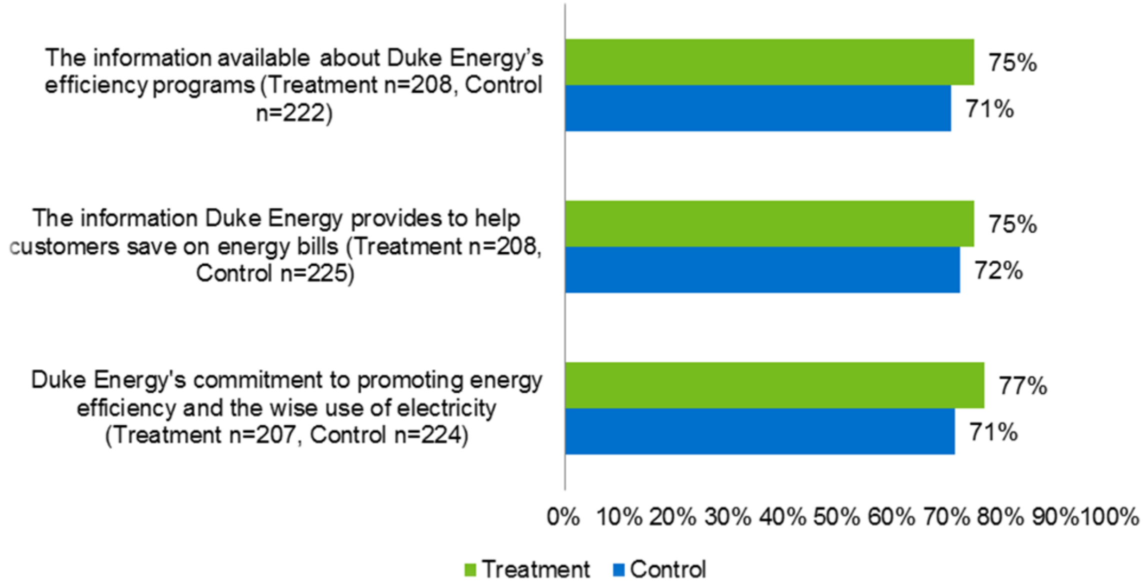
4.3 Comparing Treatment and Control Responses

This section presents the results of survey questions asked of both treatment and control households and compares the response patterns provided. Statistically significant differences between treatment and control households are noted.

4.3.1 Perception of Duke Energy

Both treatment and control groups' overall satisfaction of Duke Energy are high. Seventy-five percent of treatment customers and 67% of control customers are satisfied or very satisfied with Duke Energy as their electric supplier (rated eight or higher on a 0-10 point scale), a statistically significant difference with a 90% level of confidence. Treatment group responses indicate somewhat higher levels of satisfaction with certain aspects of DEC energy efficiency efforts than the control group (Figure 4-9). However, the difference between treatment and control customers with respect to the portion of customers who report being satisfied with these areas of DEC energy efficiency efforts is not statistically significant.

Figure 4-9: Portion Satisfied with Each Communication Element



4.3.2 Engagement with Duke Energy Website

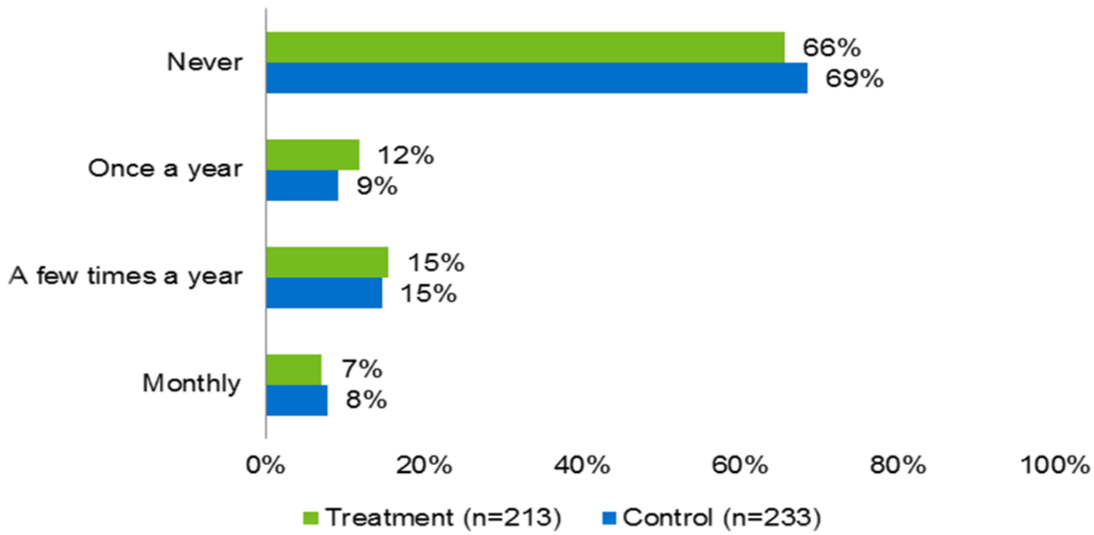
Both groups answered several questions about their use of the Duke Energy website, a proxy for overall engagement with information provided by the utility on energy efficiency and household energy use. Over half of both groups reported they had never logged in to their Duke Energy account. Among those that had logged in, the most commonly reported purpose was to pay their bill. None of the differences in online account usage between treatment and control respondents were statistically significant.

Table 4-5: Use of Duke Energy Online Account

On-line Account Activity	Treatment Group (n=213)	Control Group (n=233)
Never logged in	51%	52%
Pay my bill	31%	33%
Review energy consumption graphs	17%	17%
Look for energy efficiency opportunities or ideas	13%	11%

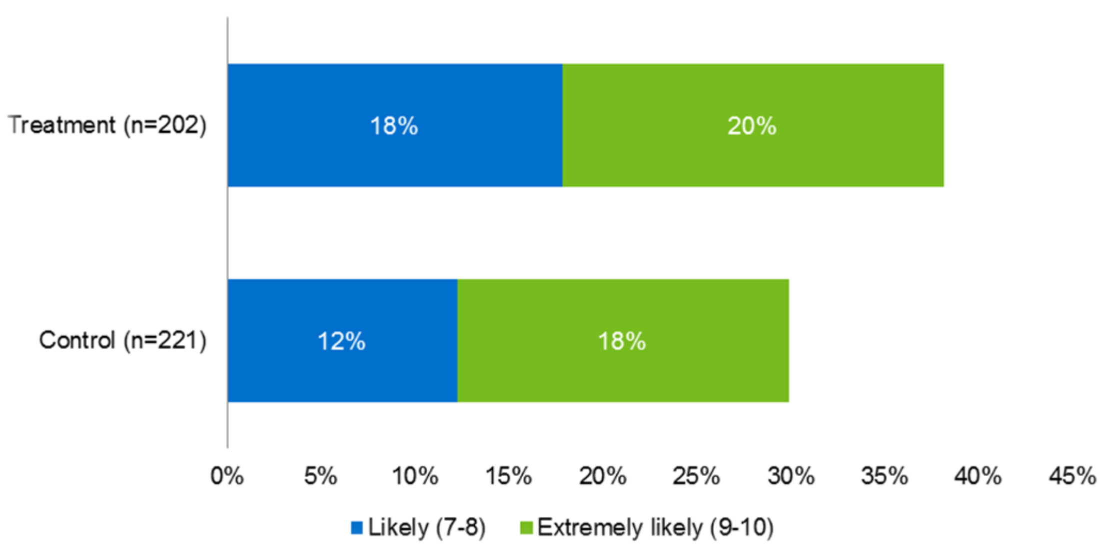
Treatment group households were more likely to report they accessed the Duke Energy website to search for *other* information (for example, information about rebate programs, or how to make their home more energy efficient), but the difference is not statistically significant. Relatively small percentages of both groups report regular usage of the website for purposes other than bill payment.

Figure 4-10: Frequency Accessing the Duke Energy Website to Search for Other Information



About one-third of both groups reported they would be likely to check the DEC website for information before purchasing major household equipment. The portion rating their likelihood a "7" or higher on a 11-point scale is plotted in Figure 4-11.

Figure 4-11: Portion Likely to Check DEC Website prior to Purchasing Major Home Equipment*

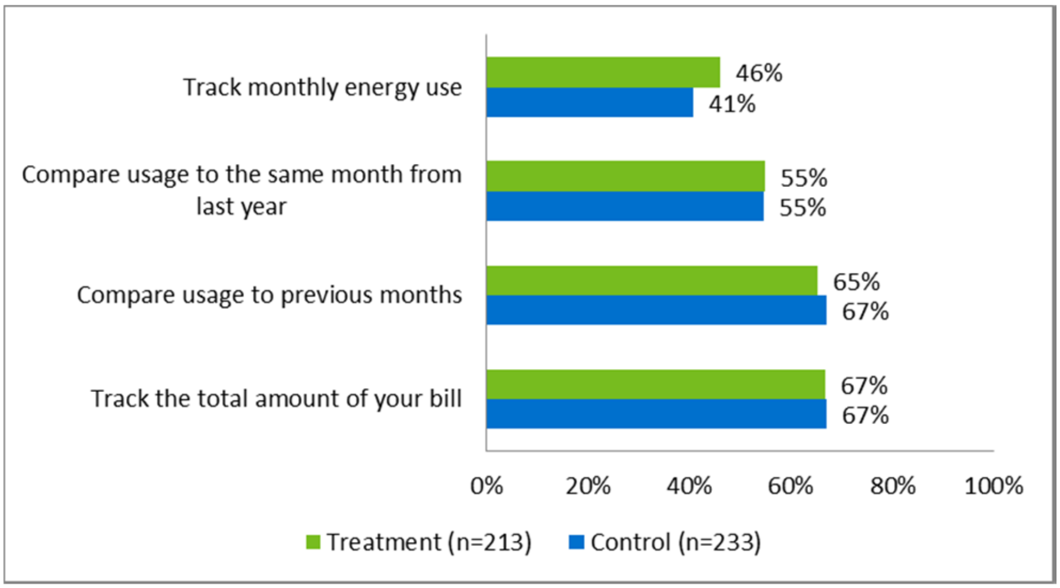


* Statistically significant, p=0.073

4.3.3 Reported Energy Saving Behaviors

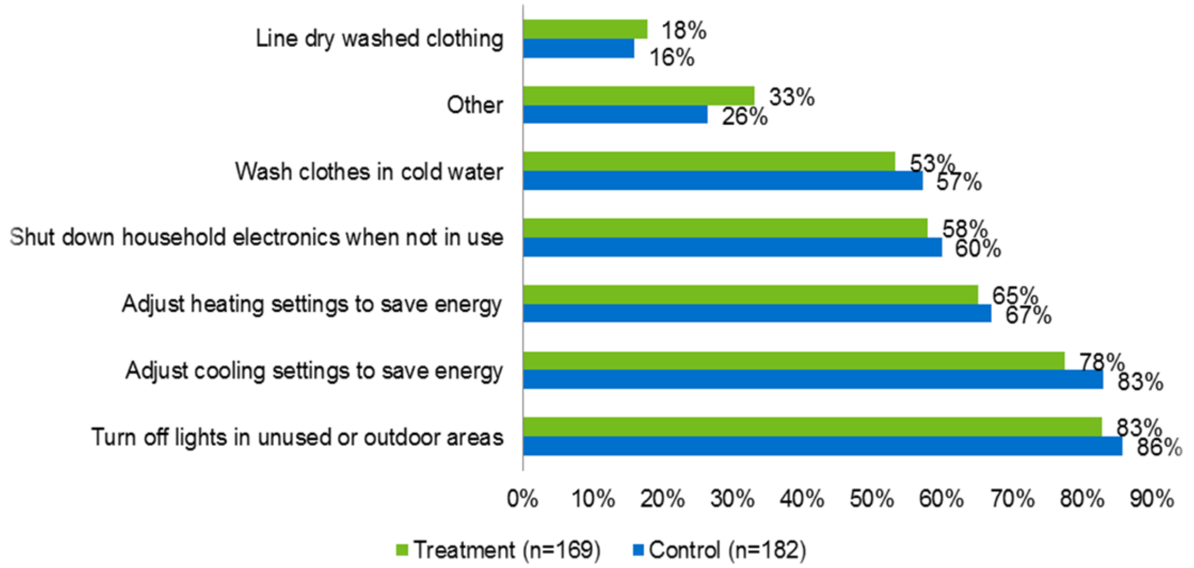
Both groups of respondents report similar strategies for tracking the total amount of the bill and comparing usage to the same month from last year. The treatment group was more likely to track monthly energy use, but the control group was more likely to compare usage to previous months. Figure 4-12 depicts these results.

Figure 4-12: "Which of the Following Do You Do with Regard to Your Household's Energy Use?



Both groups also reported similar levels of energy saving behaviors, as shown in Figure 4-13. The treatment group was slightly more likely to line dry washed clothing. Control customers were slightly more likely to wash clothes in cold water, adjust heating/cooling settings, turn off lights in unused or outdoor areas and shut down household electronics when not in use. None of these differences in reported energy savings behaviors are statistically significant.

Figure 4-13: Reported Energy Saving Behaviors



4.3.4 Equipment Purchases: Past and Future Intention

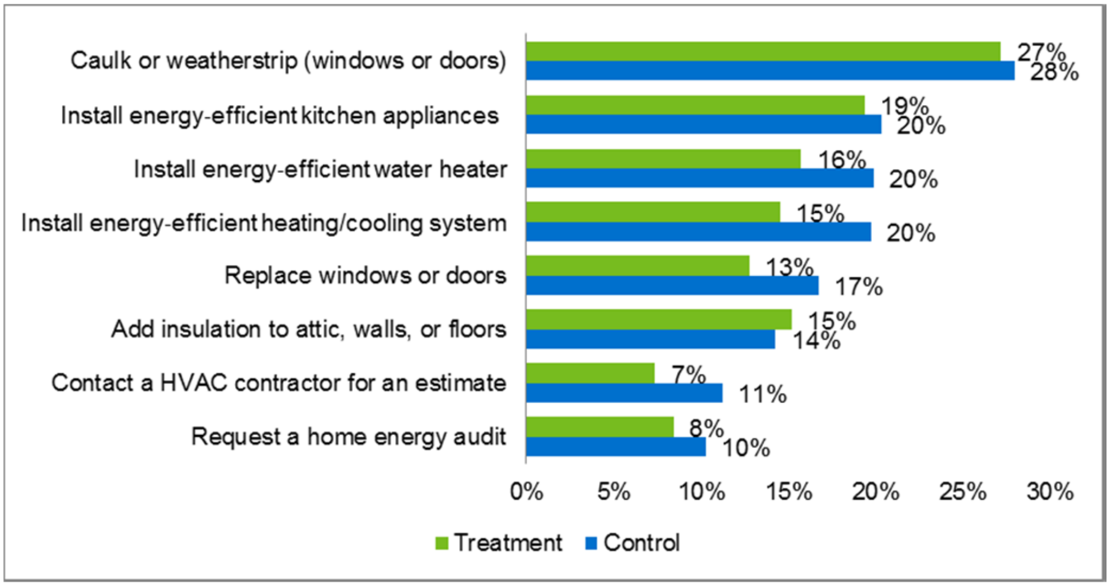
Respondents were provided with a list of potential energy efficiency improvements to their home that customers only rarely implement and asked if they had already done or intended to do each one. Similar portions of each group reported having already completed each upgrade (Table 4-6)..

Table 4-6: Portion Indicating they had "Already Done" Each Upgrade

Upgrade	Control n=233	Treatment n=213
Install energy efficient kitchen appliances	27%	28%
Install energy-efficient heating/cooling system	30%	26%
Install an energy efficient water heater	26%	28%
Replace windows or doors	21%	22%
Caulk or weatherstrip (windows or doors)	24%	23%
Add insulation to attic, walls, or floors	21%	23%
Contact a HVAC contractor for an estimate	6%	9%
Request a home energy audit	4%	6%

Treatment and control group responses were mixed when participants were asked to rate the likelihood of completing the same list of potential energy upgrades in the next 12 months. Perhaps unsurprisingly, the most commonly reported likely upgrade for both groups is the one homeowners can complete without help from a professional; caulking windows and doors In fact, the tips offered emphasize the "do-it-yourself" aspect of caulking and sealing. The control group reported higher likelihood of contacting an HVAC contractor for an estimate, requesting a home energy audit, installing energy efficient kitchen appliances, replacing windows or doors, installing energy-efficient heating/cooling system, and installing energy-efficient water heater. The treatment group was more likely to report planning to add insulation to attic, walls or floors. The portion of each group reporting a "7" or higher on a scale of 0 to10 is presented in Figure 4-14. None of the differences between treatment and control groups are statistically significant.

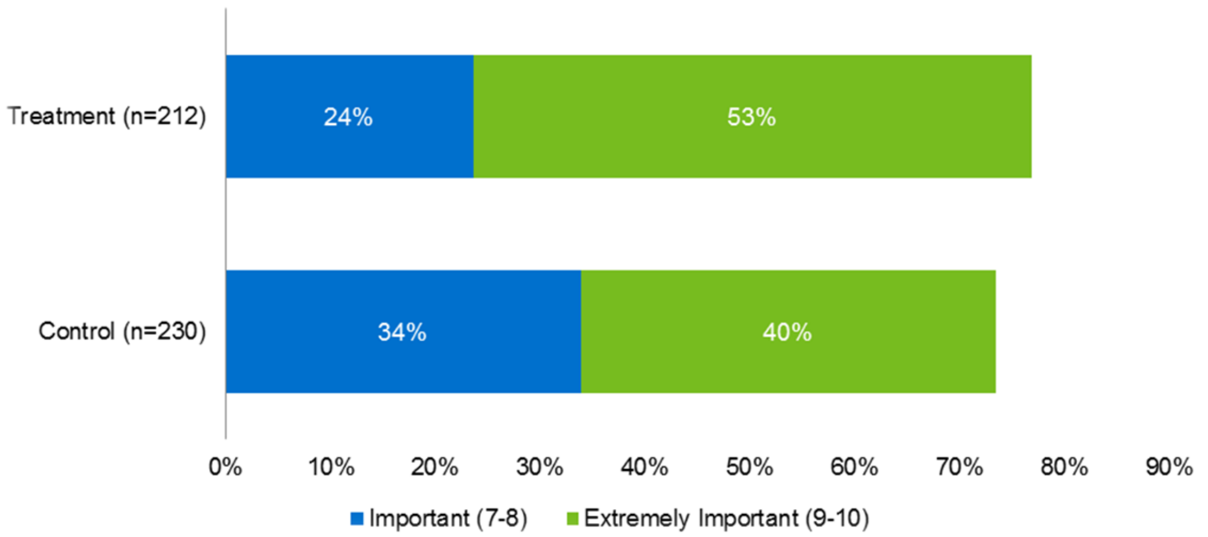
Figure 4-14: Likelihood of Completing Upgrades in the Next 12 Months



4.3.5 Customer Motivation and Awareness

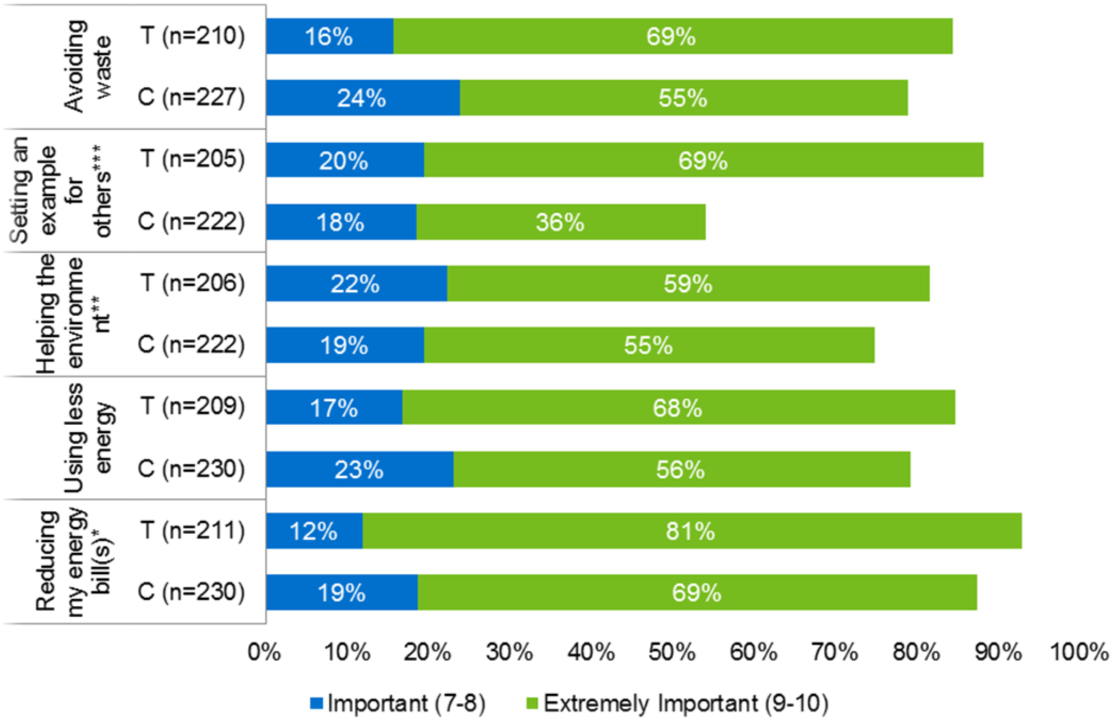
The treatment group is slightly more motivated than the control group to save energy. Seventy-seven percent of treatment customers indicated that knowing they are using energy wisely is important or very important, compared to 74% of control customers. This difference is not statistically significant (Figure 4-15).

Figure 4-15: "How Important Is It for You to Know if Your Household is Using Energy Wisely?"



Customers were asked to rate, on a scale of 0 to 10, the importance of various reasons they might try to reduce their home's energy use. The strongest motivation for both groups is saving money on their energy bills, where 81% of treatment respondents reported that saving money on their energy bills was "very important" compared to 69% of control respondents, a statistically significant difference at the 90% level of confidence. Another significant difference was that 69% of treatment respondents indicated that "setting an example for others" was very important to them, while only 36% of control customers said as much; this difference is also statistically significant at the 95% level of confidence. "Helping the environment" was another statement that was more important to treatment customers than control customers; 59% of treatment customers felt that was very important to them compared to 55% of control customers, a statistically significant difference at the 90% level of confidence. Figure 4-16 contains the frequency of responses to this question, shown as a percentage for both the treatment and control group.

Figure 4-16: "Please Indicate How Important Each Statement Is to You"



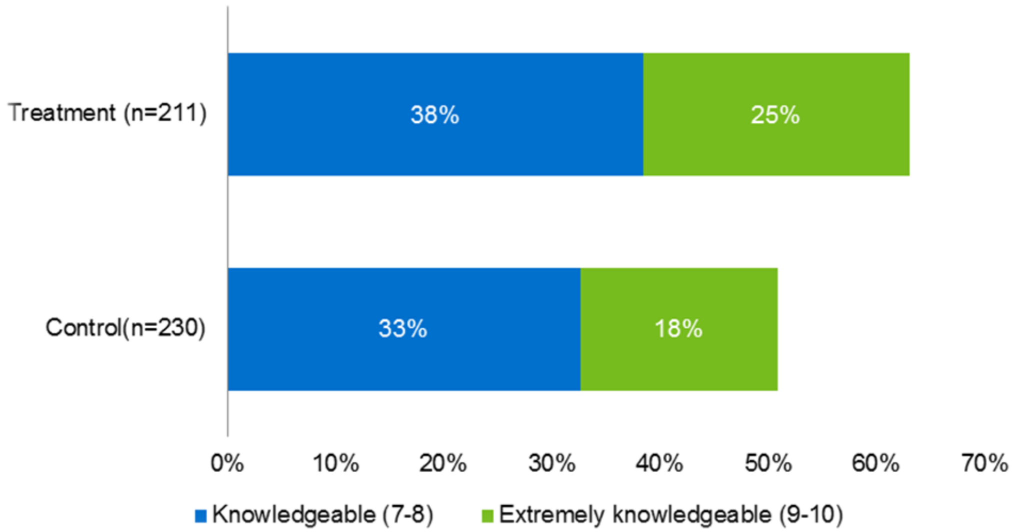
* Statistically significant, p=0.054

** Statistically significant, p=0.091

*** Statistically significant, p=0.039

As indicated by Figure 4-17, the treatment group was also more likely to rate themselves as knowledgeable about saving energy in the home. Within the group of treatment customers, 63% rate themselves above a seven on a 0-10 point scale. Only 51% of control group customers rated themselves this way. The difference is statistically significant at the 90% level of confidence.

Figure 4-17: "How Would You Rate Your Knowledge of the Different Ways You Can Save Energy in Your Home?"*



* Statistically significant, p=0.010

In Section 4.3.1 we presented the portion of treatment households that found each HER feature useful. A similar question was asked of control group respondents, somewhat rephrased to ask them how useful they might expect each feature to be. Table 4-7 presents the portion rating each item a "7" or higher on a 11-point scale. The treatment group rated the usefulness of the time series graph, examples of the energy use associated with common household items and comparisons to similar homes significantly higher than the control group.

Table 4-7: Usefulness, or Hypothetical Usefulness of HER Features, Treatment, and Control

HER Feature	Control Group	Treatment Group
Graphs that illustrate homes energy use over time*	60% (n=217)	77% (n=183)
Tips to help save money and energy	66% (n=224)	69% (n=185)
Examples of the energy use associated with common household items	62% (n=220)	69% (n=181)
Information about services and offers from Duke Energy	58% (n=219)	63% (n=183)
Comparisons to similar homes**	48% (n=219)	66% (n=180)
Customized suggestions for your home	53% (n=216)	59% (n=183)

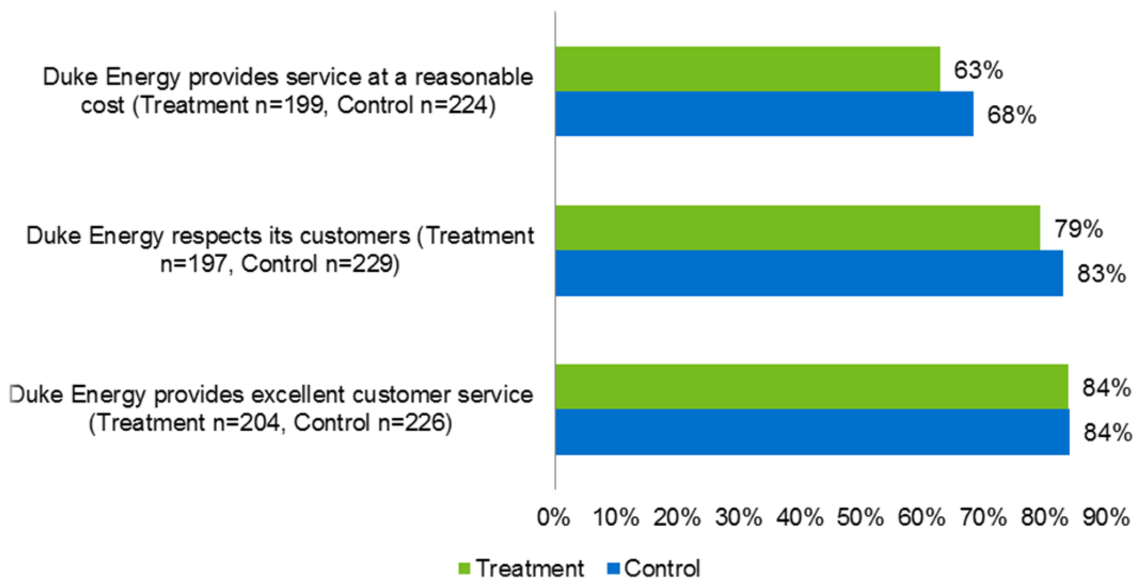
* Statistically significant, p=0.0004

** Statistically significant, p=0.001

4.3.6 Satisfaction with Duke Energy

Control households rated DEC higher on providing service at a reasonable cost and respect, and treatment and control group customers rated DEC the same on customer service (Figure 4-18), with 84% of respondents from both groups strongly agreeing with the statement that "Duke Energy provides excellent customer service".

Figure 4-18: Evidence of Overall Satisfaction with Duke Energy



4.3.7 Evidence of MyHER Effects

As noted above, while formal statistical testing found some differences among treatment and control group households for individual questions, the Nexant team sought to understand if the overall pattern of survey responses differed among treatment and control households. To do this we categorized each survey question by topic area and then counted any survey item in which the treatment households provided a more positive response than the control households.

Nexant's approach consists of the following logical elements:

- Assume the number of positive responses between treatment and control customers will be equal if MyHER lacks influence
- Count the total number of topics and questions asked of both groups
- Note any item for which the treatment group outperformed the control group
- Calculate the probability that the difference in response patterns is due to chance, rather than an underlying difference in populations.

Because this analysis compares the response patterns between the treatment and control groups, if the MyHER program did not influence customers, one would expect the treatment group to "score higher" on roughly half of the questions. In other words, if the MyHER is not influencing treatment group customers, then there is a 50/50 chance that they will "outperform" the control group as many times as not. For a more detailed description of the index framework, see Appendix F.

The pattern of responses displayed in Table 4-8 indicates that the DEC MyHER program did not broadly affect the treatment group's perception of Duke Energy, the group's engagement with the website, or actions for low-cost energy-saving or past and future equipment purchases. However, treatment customers specifically showed favorable comparisons to the control group in the areas of perception of Duke Energy's energy efficiency offerings and position and in motivation, engagement, and awareness of energy efficiency. The number of questions in these categories are too small to subject to a formal statistical test, but the results are indicative of more success in these areas relative to others. In fact, the area of customer motivation, engagement and awareness of energy efficiency is arguably a *raison d'etre* of behavioral programs such as MyHER; the increased engagement in this area among treatment customers should be viewed as a success in MyHER's core mission.

Table 4-8: Survey Response Pattern Index

Question Category	Count of Questions where T>C	Number of Questions in Topic Area	Portion of Questions where T>C
Duke Energy's Public Stance on Energy Efficiency	3	3	100%
Customer Engagement with Duke Energy Website	3	6	50%
Customers' Reported Energy-saving Behaviors	2	7	29%
Customers' Past & Future Equipment Purchases	7	16	44%
Customer Motivation, Engagement & Awareness of Energy Efficiency	8	11	73%
Customer Satisfaction with Duke Energy	1	4	25%
Total	**24**	**47**	**51%**

4.3.8 Respondent Demographics

Nearly all respondents—94% of treatment-group customers and 91% of control-group customers—own their residence. More than half of households surveyed have two or fewer residents, but about 18% of treatment households and 22% control households have four or more residents. There are no apparent, systematic differences in the age of homes assigned to the treatment and control groups (Figure 4-19).

Figure 4-19: "In What Year Was Your Home Built?"

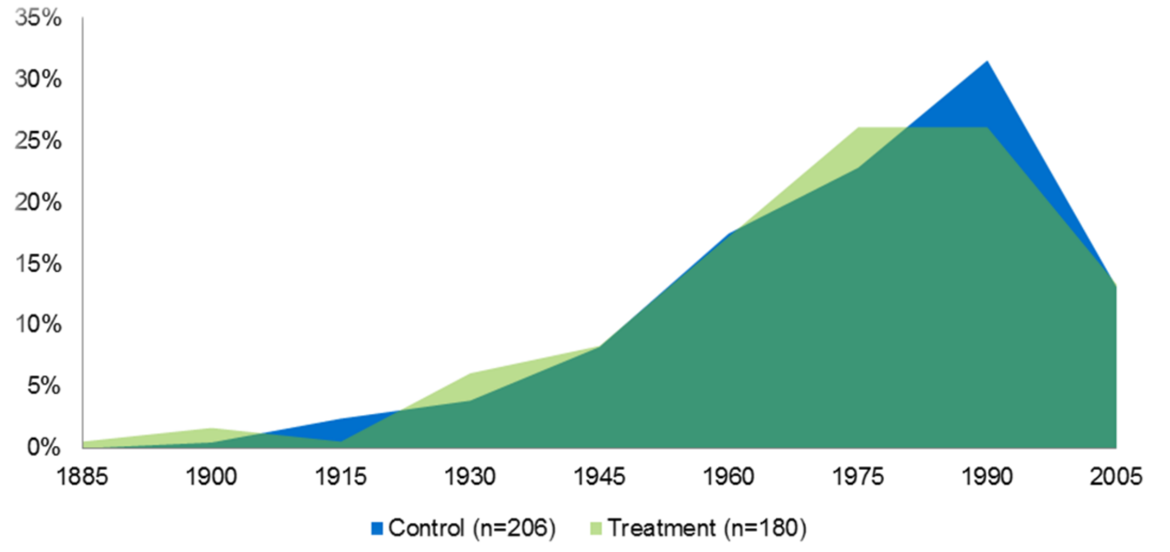
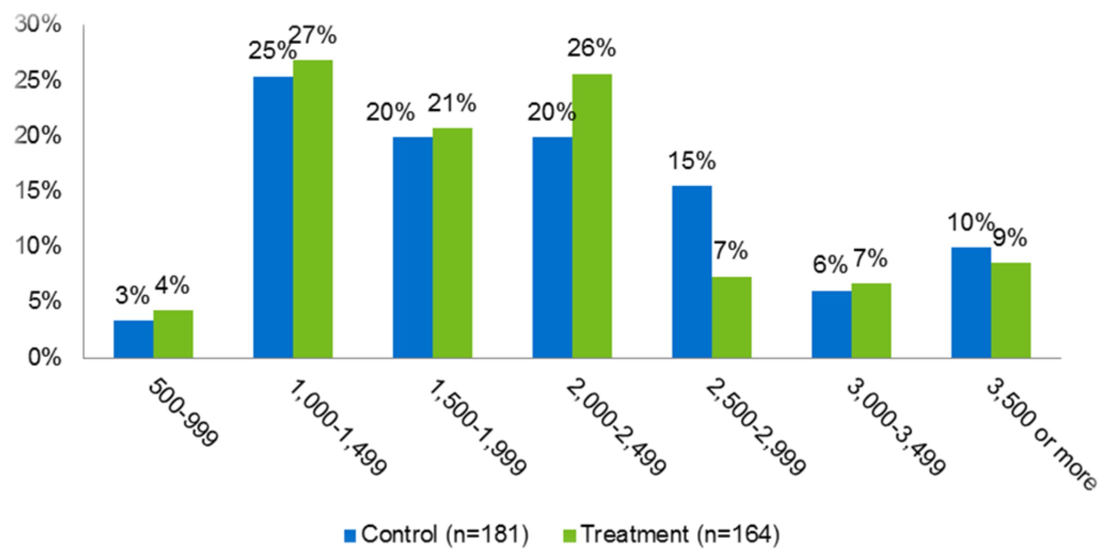


Figure 4-20 shows distribution of home square footage is similar between control and treatment households. The average square footage above ground is 2,260 for control households and 2,110 for treatment households.

Figure 4-20: How many square feet is above-ground living space?



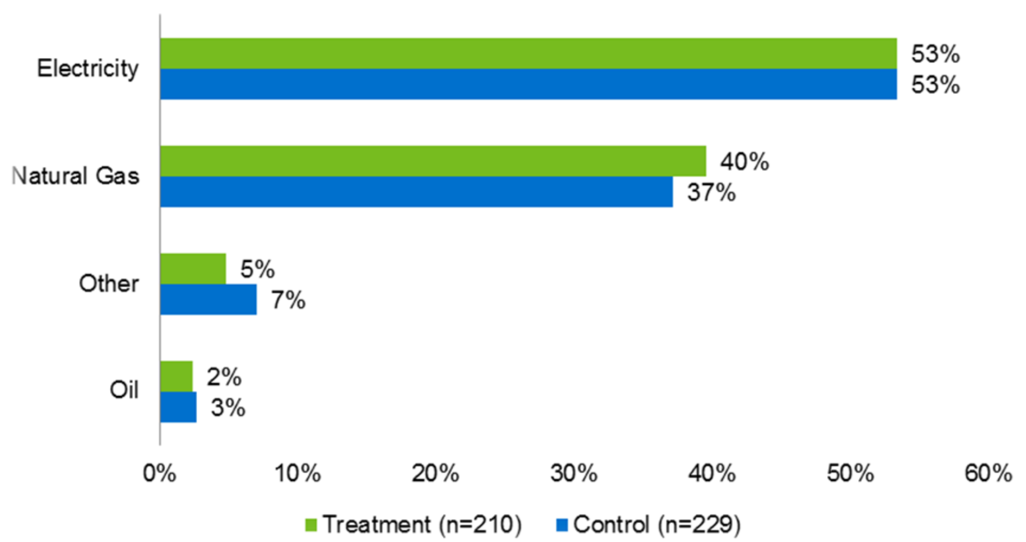
Respondent samples are relatively close to those reported by the U.S. Census for the Carolinas. The lowest age category (25-34) is often underrepresented when sampling based on residence in single family homes, given that many members of that population are in apartments, dormitories, or living with other family members. This common underrepresentation was true in this survey study, as well. The average age of control and treatment group respondents was 58 and 60 respectively (see Table 4-10).

Table 4-9: Respondent Age Relative to Carolinas Census

Age	Treatment Group (n=189)	Control Group (n=210)	Carolinas Census
25-34	3%	8%	13%
35-44	13%	14%	13%
45-54	18%	18%	14%
55-59	17%	12%	7%
60 and over	49%	48%	20%

Figure 4-24 shows the primary heating fuel type used in control and treatment customers' households. The majority of treatment (53%) and control (53%) customers use electricity in their households for heating. Forty percent of treatment customers and 37% of control customers use natural gas for heating.

Figure 4-24 Primary Heating Fuel in Households



4.4 Summary of Process Evaluation Findings

The DEC MyHER program has benefited from a number of process and product management improvements that have enabled meeting and sometimes exceeding in-home date goals. These goals are designed to ensure that reports arrive as close to the mid-point of the customer's billing cycle as possible, maximizing the timeliness and utility of the information presented. These improvements include speeding up the data transfer speed between Duke Energy and Tendril, increasing the frequency of report mailings from once per week to twice per week, and prioritizing major program changes and rollouts. One example of change prioritization was the decision to implement the program roll-out to customers in multi-family dwellings in series, rather than in parallel, with the introduction of Tendril's new clustering algorithm. Both Duke

Energy and Tendril staff noted the importance of careful change management as an enabler of maintaining a production process that consistently meets quality control standards.

The DEC MyHER program is delivered to more than one million residential customers in the Carolinas and is managed with high attention to quality and customer service. Both Duke Energy and Tendril staff described a rigorous quality control process that has been very successful in preventing lapses in report quality from reaching the customers. Areas for improvement to the program generally circle around opportunities to better support this process and manage risks to it. Appropriate staffing at Tendril to support the technical and data-centered ongoing quality control processes for report mailings is critical to success in this area. Additionally, increased adherence or better development of a data delivery schedule on Tendril's part to initiate the quality control process will improve Duke Energy's ability to conduct their checks in a timely and complete manner. The increased pace of report mailings represents a long chain of quality control tasks for Duke Energy; responsibility for completing these tasks rests with a relatively small staff;Duke Energy should contemplate and manage risks to MyHER program operations presented by turnover or outages in availability of their staff, planned or otherwise.

A survey of DEC treatment and control customers shows that, among treatment group households:

- 94% recalled receiving at least one MyHER and 96% of those indicated that they "always" or "sometimes" read the reports.
- 77% reported being "very" or "somewhat" satisfied with information provided by MyHER.
- Around three-quarters of respondents give strong agreement ratings to the statements "I have learned about my household's energy use from My Home Energy Reports" and "I use the reports to tell me how well I am doing at saving energy." Very few (7%) agree strongly with the idea that the energy usage information presented by the reports is confusing.
- The most useful feature of the reports, as rated by treatment customer respondents, are the graphs that illustrate the home's energy usage over time. The least useful-rated feature are customized suggestions for the home.
- Most (72%) had no suggestions to improve the program. Those that did most frequently requested more specific or detailed information in their MyHERs.

In comparing responses of treatment and control group respondents, there were limited areas where treatment customers provided responses that more favorably reflected an increased awareness, engagement, or attitudes towards energy-savings opportunities and actions relative to control customers:

- Treatment group respondents reported slightly higher levels of satisfaction with the information Duke Energy makes available about energy efficiency programs, with information Duke Energy provides to help customers save on energy bills and Duke Energy's commitment to promoting energy efficiency and the wise use of electricity.

- Treatment group respondents reported higher levels overall satisfaction with Duke Energy as their electric service supplier: 75% of treatment customers gave a satisfaction score of 8 or higher (on a scale of 0 to 10), compared to 67% of control customers, a difference that is statistically significant at the 90% level of confidence.
- Treatment and control respondents reported very similar usage of the Duke Energy website to search for *other* information. However, treatment customers more significantly more likely to check website prior to major household purchase, where 38% of treatment customers report that they are likely to do so vs. 30% of control customers.
- Treatment and control customers report using similar strategies for tracking household energy use and report having taken similar energy saving actions.
- Similar portions of treatment and control respondents report having already completed certain energy-savings home upgrades, and similar portions of treatment and control respondents report intending to take those actions in the future.
- The vast majority, 93%, of treatment group customers say that “reducing their energy bills” is important to them, compared to 88% of control customers. Eighty-nine percent of treatment group respondents report that “setting an example for others” is important to them, compared to 54% of control customers. “Helping the environment” is important to 81% of treatment group respondents and is important to 74% of control respondents. All these differences are statistically significant, with at least 90% confidence.
- Treatment customers are more likely to rate themselves as “knowledgeable” about the different ways they can save energy in their home.

An index designed to account for overall survey-wide differences in response patterns between treatment and control customers did not find an overall more positive response pattern in simple frequencies. Across the 47 questions and sub-questions where treatment and control responses pertaining to attitudes, engagement, prior actions taken, intended future actions, and awareness, 24, or 51%, showed more favorable responses by treatment customers. While some areas such as attitudes and engagement showed increases for treatment customers, they were counteracted by no increases in the areas of actions taken and intended future actions.

5 Conclusions and Recommendations

Nexant found that the MyHER program is an effective channel for increasing customer engagement with energy efficiency and demand side management. The RCT program design facilitates reliable estimates of program energy savings. Further, the energy saving generated by the program are corroborated by survey findings of respondent engagement and focus on the importance of saving energy. As a valuable secondary benefit, Nexant found the MyHER is a useful tool for enhancing Duke Energy customer engagement and increases uptake in other Duke Energy efficiency programs. The MyHER program has achieved full deployment among Duke Energy's Carolinas customers and Nexant recommends that Duke Energy continue to focus on program processes and operations to further increase the efficiency of program delivery.

Additionally, Duke Energy launched the MyHER Interactive Portal in March, 2015. The portal offers additional means for customers to customize or update Duke Energy's data on their premises, demographics, and other characteristics that affect consumption and the classification of each customer. The portal also provides additional custom tips based on updated data provided by the customer. MyHER Interactive also sends email challenges that seek to engage customer in active energy management, additional efficiency upgrades, and conservation behavior. Nexant evaluated the impacts of the MyHER Interactive Portal using a matched comparison group because the MyHER Interactive Portal was not deployed as a randomized, controlled trial (RCT).

5.1 Impact Findings

Nexant's impact findings result in an effective realization rate of 125%. This estimate increases the previously filed participant impact from 183.7 kWh to 229.8 kWh annually. Impact estimates account for the fact that MyHER increases uptake of other Duke Energy Carolinas programs. This finding subtracts 4.19 kWh annually from the average household impact of the MyHER program. The impact estimate also employs an "Intention to Treat" approach to account for the fact that program production timelines occasionally result in some homes temporarily not receiving a report. The time period of evaluated impacts is from May 2015 to April 2016. Nexant estimates the MyHER program saved a total of 251.2 GWh during this time period. The confidence and relative precision of this estimate is 90% and 6.5%, respectively.

For this evaluation period, the MyHER Interactive Portal savings estimates are too uncertain to determine whether the portal generates incremental savings above and beyond the standard MyHER paper edition. Although impact estimates are very uncertain, it would also be premature to draw the conclusion that MyHER Interactive is not working, and statistical models of monthly impact reflect some directional consistency.

5.2 Process Findings

The DEC MyHER program is Duke Energy's most mature behavioral program in terms of delivered energy savings. The large volume of data required to generate MyHER and support the program delivery schedule is the primary driver of program activities and focus. Duke Energy and its implementation contractor, Tendril, are successfully managing this process and providing DEC customers valuable information for managing home energy consumption.

The DEC MyHER program has benefited from a number of process and product management improvements that have enabled meeting and sometimes exceeding in-home date goals. These enhancements include speeding up the data transfer speed between Duke Energy and Tendril, increasing the frequency of report mailings from once per week to twice per week, and prioritizing major program changes and rollouts. Careful change management is a key enabler of maintaining a production process that consistently meets MyHER quality control standards.

The DEC MyHER program is delivered to more than one million residential customers in the Carolinas and is managed with high attention to quality and customer service. Appropriate staffing at Tendril to support the ongoing technical and data-centered quality control processes for report mailings is critical to success in this area. To date, the ability to continuously direct enough and appropriate Tendril resources to the project has been challenged at times, but with a small and very dedicated project team at Duke Energy, attention to potential risks to the successful operation of the program due to internal turnover or staffing outages should also be taken and mitigated as well.

MyHER participants have been found in this evaluation's customer surveys to be significantly more satisfied with Duke Energy as their electric service provider, when compared to control customers, which indicates success of a key program goal. However, the surveys also showed mixed findings with respect to whether or not the program broadly enhances customer motivation, awareness, attention, and effort in saving energy. Areas of strength for the program were found in the areas of treatment customers' relatively positive attitudes towards saving energy and engagement with Duke Energy in the area of energy efficiency.

5.3 Program Recommendations

- ***The inconsistent assignment of homes to the MyHER treatment and control group over time has complicated the intended RCT experimental design.*** This issue complicates the impact analysis and increases uncertainty in the impact estimates for cohort 4. In the future, homes should always be assigned to the treatment group with a corresponding assignment of homes to the control group. Assignment of new accounts to the MyHER treatment and control group should be limited to once or twice per year.
- ***Continue to monitor engagement and evaluate the impacts of the Interactive Portal.*** However, for this evaluation period, the MyHER Interactive Portal savings estimates are too uncertain to determine whether the portal generates incremental savings above and beyond the standard MyHER paper edition. Although impact estimates are very uncertain, it would also be premature to draw the conclusion that

MyHER Interactive is not working, and statistical models of monthly impact reflect some directional consistency.

- ***Continue to manage MyHER operations with an eye towards change management and prioritization of program changes***. Challenges in quality control have historically followed on the heels of program changes and enhancements. Introduce changes slowly to consistently maintain a product that meets quality control standards and results in report cycles that pass quality assurance checks the first time.
- ***Prioritize appropriate project staffing.*** With MyHER's long, demanding, and ongoing production process, outages in appropriate staff can have implications for product quality and timely delivery. Outages and risk of outages of key project resources should be closely managed.

Appendix A Summary Form

MyHER Carolinas

Completed EMV Fact Sheet

Description of program

Duke Energy offers the My Home Energy Report (MyHER) to residential customers. MyHER relies on principles of behavioral science to encourage customer engagement with home energy management and energy efficiency. The program accomplishes this primarily by delivering a personalized report comparing each customer's energy use to a peer group of similar homes.

Date	June, 2015 – Dec., 2016
Region(s)	Carolinas
Evaluation Period	March, 2015 – February, 2016
Annual kWh Savings	251.2 GWh
Per Participant kWh Savings	229.8 kWh/home
Coincident kW Impact	0.0581 kW/home
Net-to-Gross Ratio	Not Applicable
Process Evaluation	Yes
Previous Evaluation(s)	2014

Evaluation Methodology

Impact Evaluation Activities

- *Eligible accounts are randomly assigned to either a treatment (participant) group or a control group. The control group accounts are not exposed to MyHER in order to provide the baseline for estimating savings attributable to the Home Energy Reports. In this randomized controlled trial (RCT) design, the only explanation for the observed differences in energy consumption between the treatment and control group is exposure to MyHER*.
- *The impact estimate is based on monthly billing data and program participation data provided by Duke Energy.*
- *The RCT delivery method of the program removes the need for a net-to-gross analysis as the billing analysis directly estimates the net impact of the program.*

Impact Evaluation Findings

- *Realization rate = 125% for energy impacts; 229.8 kWh per home*

Process Evaluation Activities

- *233 web surveys of treatment customers, 213 web surveys for control group customers and staff interviews.*

Process Evaluation Findings

- *Review and finalize any content that can be developed ahead of the monthly production schedule before the data transfers begin.*

Appendix B Measure Impact Results

Table 5-1: DSMore Measure Impact Results

Measure Category	Prod Code	State	Gross Energy Savings (kWh)	Gross Summer Coincident Demand (kW)	Gross Winter Coincident Demand (kW)	Net to Gross Ratio	Net Energy Savings (kWh)	Net Summer Coincident Demand (kW)	Net Winter Coincident Demand (kW)	Measure Life
NC_ My Home Energy Report	HCER	NC/SC	229.8	0.0581	N/A	100%	230	0.0581	N/A	1

Appendix C Survey Instruments

C.1 Treatment Households

Q1. First, we'd like to ask you about your overall opinion of Duke Energy. Please rate how satisfied you are with Duke Energy as your electric supplier.

Not at all Satisfied										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10

Q2. We would also like to know how satisfied you are with several aspects of communication from Duke Energy. Please rate your overall satisfaction with each of the following.

	Very Satisfied	Somewhat Satisfied	Neither	Somewhat Dissatisfied	Very Dissatisfied
The information available about Duke Energy's efficiency programs.	☐	☐	☐	☐	☐
Duke Energy's commitment to promoting energy efficiency and the wise use of electricity.	☐	☐	☐	☐	☐
The information Duke Energy provides to help customers save on energy bills.	☐	☐	☐	☐	☐

Q3. When you log in to your Duke Energy account, which of the following have you done? Check all that apply.

- ☐ I have never logged in
- ☐ Pay my bill
- ☐ Review energy consumption graphs
- ☐ Look for energy efficiency opportunities or ideas
- ☐ None of the above

Q4. How often do you access the Duke Energy website to search for other information (for example: information about rebate programs, or how to make your home more energy efficient)? Select only one.

- ☐ Monthly
- ☐ A few times a year
- ☐ Once a year
- ☐ Never

Q5. If you needed to replace major home equipment or were considering improvements to your home's energy performance today, how likely would you be to check the Duke Energy website for information about energy efficient solutions or incentives?

Not at all Likely										Extremely Likely
0	1	2	3	4	5	6	7	8	9	10

Q6. Over the past 12 months, have you taken any actions to reduce your household energy use?

- ☐ Yes
- ☐ No – **Skip to Q8**

Q7. What actions have you taken? Check all that apply.

- ☐ Adjust heating settings to save energy
- ☐ Adjust cooling settings to save energy
- ☐ Wash clothes in cold water
- ☐ Shut down household electronics when not in use
- ☐ Turn off lights in unused or outdoor areas
- ☐ Line dry washed clothing
- ☐ Other, please specify: ______________________
- ☐ Other, please specify: ______________________

Q8. In the next 12 months, how likely are you to make each of the following energy efficiency improvements? Scale: 0 = Not at all Likely; 10 = Extremely Likely. If you have already made that improvement, check the "Already did it" box.

	Already did it	Not at all Likely										Extremely Likely
Install energy-efficient kitchen appliances	☐	0	1	2	3	4	5	6	7	8	9	10
Install energy-efficient heating/cooling system	☐	0	1	2	3	4	5	6	7	8	9	10
Install energy-efficient water heater	☐	0	1	2	3	4	5	6	7	8	9	10
Replace windows or doors	☐	0	1	2	3	4	5	6	7	8	9	10
Caulk or weatherstrip (windows or doors)	☐	0	1	2	3	4	5	6	7	8	9	10
Add insulation to attic, walls, or floors	☐	0	1	2	3	4	5	6	7	8	9	10
Contact a HVAC contractor for an estimate	☐	0	1	2	3	4	5	6	7	8	9	10
Request a home energy audit	☐	0	1	2	3	4	5	6	7	8	9	10

Q9. How important is it for you to know if your household is using energy wisely?

Not at all Important										Extremely Important
0	1	2	3	4	5	6	7	8	9	10

Q10. Which of the following do you do with regard to your household's energy use? Check all that apply.

- ☐ Track monthly energy use
- ☐ Track the total amount of your bill
- ☐ Compare usage to previous months
- ☐ Compare usage to the same month from last year
- ☐ None of the above

Q11. How would you rate your knowledge of the different ways you can save energy in your home?

Not at all Knowledgeable										Extremely Knowledgeable
0	1	2	3	4	5	6	7	8	9	10

Q12. Duke Energy sends a personalized report called *My Home Energy Report* to a select group of homes. These documents are mailed in a standard envelope every few months and provide customers with information on how their home's electric energy usage compares with similar homes. Have you seen one of these reports?

☐ Yes ☐ No – **Skip to Q21**

Q13. About how many *My Home Energy Reports* have you received in the past 12 months? _______ **If zero, skip to Q21**

Q14. How often do you read the *My Home Energy Reports*?

☐ Always ☐ Sometimes ☐ Never – **Skip to Q21**

Q15. Please indicate how much you agree or disagree with the following statements about *My Home Energy Reports*. Scale: 0 = Strongly Disagree; 10 = Strongly Agree

	Strongly Disagree										Strongly Agree
I have learned about my household's energy use from *My Home Energy Reports*.	0	1	2	3	4	5	6	7	8	9	10
I use the reports to tell me how well I am doing at saving energy.	0	1	2	3	4	5	6	7	8	9	10
The tips provided in the reports are pertinent to my home.	0	1	2	3	4	5	6	7	8	9	10
I'd like more detailed information about my home's energy use.	0	1	2	3	4	5	6	7	8	9	10
I have discussed *My Home Energy Reports* with others.	0	1	2	3	4	5	6	7	8	9	10
The information provided about my home's energy use is confusing.	0	1	2	3	4	5	6	7	8	9	10

Q16. How could Duke Energy make *My Home Energy Reports* more useful for your household? Please provide any suggestions you may have to improve the reports.

____

____

____

Q17. Do you recall any specific tips or information from the *My Home Energy Reports*?

☐ Yes ☐ No – **Skip to Q19**

Q18. What specific tips do you recall?

____

____

Q20. Please rate your satisfaction with the information in the *My Home Energy Reports* you've received.

- ☐ Very Satisfied
- ☐ Somewhat Satisfied
- ☐ Neither Satisfied nor Dissatisfied
- ☐ Somewhat Dissatisfied
- ☐ Very Dissatisfied

Q20a. Why do you say that? ____________________

____

Q21. The statements below provide reasons why households might try to reduce their home's energy use. Please indicate how important each statement is to you. Scale: 0 = Not at all Important; 10 = Extremely Important

	Not at all Important										Extremely Important
Reducing my energy bill(s)	0	1	2	3	4	5	6	7	8	9	10
Using less energy	0	1	2	3	4	5	6	7	8	9	10
Helping the environment	0	1	2	3	4	5	6	7	8	9	10
Setting an example for others	0	1	2	3	4	5	6	7	8	9	10
Avoiding waste	0	1	2	3	4	5	6	7	8	9	10

Q22. Please indicate your level of agreement with each of the following statements:

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Duke Energy provides excellent customer service	☐	☐	☐	☐	☐
Duke Energy respects its customers	☐	☐	☐	☐	☐
Duke Energy provides service at a reasonable cost	☐	☐	☐	☐	☐

We would like to understand the lighting products customers in the Carolinas are using.

Q23a. About how many light bulbs are installed in your home? (Some fixtures contain multiple bulbs.) ________

Q23b. About how many CFLs are installed in your home? Compact fluorescent light bulbs, or CFLs, are small fluorescent bulbs that fit in regular light bulb sockets. They are often made out of thin tubes of twisted glass. ________

Q23c. About how many LED bulbs are installed in your home? LED light bulbs also fit in regular light bulb sockets. They produce light using semiconductor chips and use a lot less energy than incandescent bulbs. ________

Q24. Do you own or rent this residence? ☐ Own ☐ Rent

Q25. Including yourself, how many people live in your home? ________

Q26. In what year was your home built? ________

Q27. How many square feet is the above-ground living space? ________

Q28. What is your primary heating fuel? ☐ Electricity ☐ Natural Gas ☐ Oil ☐ Other

Q29. In what year were you born? ________

C.2 Control Households

Q1. First, we'd like to ask you about your overall opinion of Duke Energy. Please rate how satisfied you are with Duke Energy as your electric supplier.

Not at all Satisfied										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10

Q2. We would also like to know how satisfied you are with several aspects of communication from Duke Energy. Please rate your overall satisfaction with each of the following.

	Very Satisfied	Somewhat Satisfied	Neither	Somewhat Dissatisfied	Very Dissatisfied
The information available about Duke Energy's efficiency programs.	☐	☐	☐	☐	☐
Duke Energy's commitment to promoting energy efficiency and the wise use of electricity.	☐	☐	☐	☐	☐
The information Duke Energy provides to help customers save on energy bills.	☐	☐	☐	☐	☐

Q3. When you log in to your Duke Energy account, which of the following have you done? Check all that apply.

☐ I have never logged in
☐ Pay my bill
☐ Review energy consumption graphs
☐ Look for energy efficiency opportunities or ideas
☐ None of the above

Q4. How often do you access the Duke Energy website to search for other information (for example: information about rebate programs, or how to make your home more energy efficient)? Select only one.

☐ Monthly
☐ A few times a year
☐ Once a year
☐ Never

Q5. If you needed to replace major home equipment or were considering improvements to your home's energy performance today, how likely would you be to check the Duke Energy website for information about energy efficient solutions or incentives?

Not at all Likely										Extremely Likely
0	1	2	3	4	5	6	7	8	9	10

Q6. Over the past 12 months, have you taken any actions to reduce your household energy use?

☐ Yes
☐ No – Skip to Q8

Q7. What actions have you taken? Check all that apply.

- ☐ Adjust heating settings to save energy
- ☐ Adjust cooling settings to save energy
- ☐ Wash clothes in cold water
- ☐ Shut down household electronics when not in use
- ☐ Turn off lights in unused or outdoor areas
- ☐ Line dry washed clothing
- ☐ Other, please specify: ______________________________
- ☐ Other, please specify: ______________________________

Q8. In the next 12 months, how likely are you to make each of the following energy efficiency improvements? Scale: 0 = Not at all Likely; 10 = Extremely Likely. If you have already made that improvement, check the "Already did it" box.

	Already did it	Not at all Likely										Extremely Likely
Install energy-efficient kitchen appliances	☐	0	1	2	3	4	5	6	7	8	9	10
Install energy-efficient heating/cooling system	☐	0	1	2	3	4	5	6	7	8	9	10
Install energy-efficient water heater	☐	0	1	2	3	4	5	6	7	8	9	10
Replace windows or doors	☐	0	1	2	3	4	5	6	7	8	9	10
Caulk or weatherstrip (windows or doors)	☐	0	1	2	3	4	5	6	7	8	9	10
Add insulation to attic, walls, or floors	☐	0	1	2	3	4	5	6	7	8	9	10
Contact a HVAC contractor for an estimate	☐	0	1	2	3	4	5	6	7	8	9	10
Request a home energy audit	☐	0	1	2	3	4	5	6	7	8	9	10

Q9. How important is it for you to know if your household is using energy wisely?

Not at all Important										Extremely Important
0	1	2	3	4	5	6	7	8	9	10

Q10. Which of the following do you do with regard to your household's energy use? Check all that apply.

- ☐ Track monthly energy use
- ☐ Track the total amount of your bill
- ☐ Compare usage to previous months
- ☐ Compare usage to the same month from last year
- ☐ None of the above

Q11. How would you rate your knowledge of the different ways you can save energy in your home?

Not at all Knowledgeable										Extremely Knowledgeable
0	1	2	3	4	5	6	7	8	9	10

Q12. Thinking about the information you have about your home's energy use, please rate how useful each of the following items would be for your household. Scale: 0 = Not at all Useful; 10 = Extremely Useful

	Not at all Useful										Extremely Useful
Your home's energy use compared to that of similar homes	0	1	2	3	4	5	6	7	8	9	10
Tips to help you save money and energy	0	1	2	3	4	5	6	7	8	9	10
Examples of the energy use associated with common household items	0	1	2	3	4	5	6	7	8	9	10
Customized suggestions for your home	0	1	2	3	4	5	6	7	8	9	10
Graphs that illustrate your home's energy use over time	0	1	2	3	4	5	6	7	8	9	10
Information about services and offers from Duke Energy	0	1	2	3	4	5	6	7	8	9	10

Q13. The statements below provide reasons why households might try to reduce their home's energy use. Please indicate how important each statement is to you. Scale: 0 = Not at all Important; 10 = Extremely Important

	Not at all Important										Extremely Important
Reducing my energy bill(s)	0	1	2	3	4	5	6	7	8	9	10
Using less energy	0	1	2	3	4	5	6	7	8	9	10
Helping the environment	0	1	2	3	4	5	6	7	8	9	10
Setting an example for others	0	1	2	3	4	5	6	7	8	9	10
Avoiding waste	0	1	2	3	4	5	6	7	8	9	10

Q14. Please indicate your level of agreement with each of the following statements:

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Duke Energy provides excellent customer service	☐	☐	☐	☐	☐
Duke Energy respects its customers	☐	☐	☐	☐	☐
Duke Energy provides service at a reasonable cost	☐	☐	☐	☐	☐

We would like to understand the lighting products customers in the Carolinas are using.

Q15a. About how many light bulbs are installed in your home? (Some fixtures contain multiple bulbs.) ________

Q15b. About how many CFLs are installed in your home? Compact fluorescent light bulbs, or CFLs, are small fluorescent bulbs that fit in regular light bulb sockets. They are often made out of thin tubes of twisted glass. __________

Q15c. About how many LED bulbs are installed in your home? LED light bulbs also fit in regular light bulb sockets. They produce light using semiconductor chips and use a lot less energy than incandescent bulbs. _________

Q16. Do you own or rent this residence? ☐ Own ☐ Rent

Q17. Including yourself, how many people live in your home? _________

Q18. In what year was your home built? _________

Q19. How many square feet is the above-ground living space? _________

Q20. What is your primary heating fuel? ☐ Electricity ☐ Natural Gas ☐ Oil ☐ Other

Q21. In what year were you born? _________

Thank you! Please return your completed survey using the enclosed envelope.

Appendix D Survey Frequencies: DEC

Q1 First, we'd like to ask you about your overall opinion of Duke Energy. Please rate how satisfied you are with Duke Energy as your electric supplier.

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	1	2	5	0	5	18	11	34	44	35	77	1	233
Percent	**0**	**1**	**2**	**0**	**2**	**8**	**5**	**15**	**19**	**15**	**33**	**0**	**100**
Treatment	1	2	2	2	3	9	11	23	45	50	61	4	213
Percent	**0**	**1**	**1**	**1**	**1**	**4**	**5**	**11**	**21**	**23**	**29**	**2**	**100**
Total	2	4	7	2	8	27	22	57	89	85	138	5	446
Percent	**0**	**1**	**2**	**0**	**2**	**6**	**5**	**13**	**20**	**19**	**31**	**1**	**100**

Q2 We would also like to know how satisfied you are with several aspects of communication from Duke Energy. Please rate your overall satisfaction with each of the following.

Q2_r1 The information available about Duke Energy's efficiency programs

Group	Very Satisfied	Somewhat Satisfied	Neither	Somewhat Dissatisfied	Very Dissatisfied	Don't Know	Total
Control	83	74	32	11	22	11	233
Percent	**36**	**32**	**14**	**5**	**9**	**5**	**100**
Treatment	84	72	30	4	18	5	213
Percent	**39**	**34**	**14**	**2**	**8**	**2**	**100**
Total	167	146	62	15	40	16	446
Percent	**37**	**33**	**14**	**3**	**9**	**4**	**100**

Q2_r2 Duke Energy's commitment to promoting energy efficiency and the wise use of electricity

Group	Very Satisfied	Somewhat Satisfied	Neither	Somewhat Dissatisfied	Very Dissatisfied	Don't Know	Total
Control	90	70	30	14	20	9	233
Percent	**39**	**30**	**13**	**6**	**9**	**4**	**100**
Treatment	84	75	24	6	18	6	213
Percent	**39**	**35**	**11**	**3**	**8**	**3**	**100**
Total	174	145	54	20	38	15	446
Percent	**39**	**33**	**12**	**4**	**9**	**3**	**100**

Q2_r3 The information Duke Energy provides to help customers save on energy bills

Group	Very Satisfied	Somewhat Satisfied	Neither	Somewhat Dissatisfied	Very Dissatisfied	Don't Know	Total
Control	81	82	30	10	22	8	233
Percent	**35**	**35**	**13**	**4**	**9**	**3**	**100**
Treatment	84	72	24	6	22	5	213
Percent	**39**	**34**	**11**	**3**	**10**	**2**	**100**
Total	165	154	54	16	44	13	446
Percent	**37**	**35**	**12**	**4**	**10**	**3**	**100**

Q3 When you log in to your Duke Energy account, which of the following have you done? Check all that apply.

Q3_1 I have never logged in

Group	I Have Never Logged In	I logged In	Total
Control	120	113	233
Percent	**52**	**49**	**100**
Treatment	109	104	213
Percent	**51**	**49**	**100**
Total	229	217	446
Percent	**51**	**49**	**100**

Q3_2 Paid my bill

Group	No	Yes	Total
Control	157	76	233
Percent	**67**	**33**	**100**
Treatment	146	67	213
Percent	**69**	**31**	**100**
Total	303	143	446
Percent	**68**	**32**	**100**

Q3_3 Reviewed energy consumption graphs

Group	No	Yes	Total
Control	193	40	233
Percent	**83**	**17**	**100**
Treatment	177	36	213
Percent	**83**	**17**	**100**
Total	370	76	446
Percent	**83**	**17**	**100**

Q3_4 Looked for energy efficiency opportunities or ideas

Group	No	Yes	Total
Control	208	25	233
Percent	**89**	**11**	**100**
Treatment	185	28	213
Percent	**87**	**13**	**100**
Total	393	53	446
Percent	**88**	**12**	**100**

Q3_5 None of the above

Group	No	Yes	Total
Control	210	23	233
percent	**90**	**10**	**100**
Treatment	193	20	213
Percent	**91**	**9**	**100**
Total	403	43	446
Percent	**90**	**10**	**100**

Q4 How often do you access the Duke Energy website to search for other information (for example: information about rebate programs, or how to make your home more energy efficient)? Select only one.

Group	Monthly	A Few Times a Year	Once a Year	Never	Total
Control	18	34	21	160	233
Percent	**8**	**15**	**9**	**69**	**100**
Treatment	15	33	25	140	213
Percent	**7**	**15**	**12**	**66**	**100**
Total	33	67	46	300	446
Percent	**7**	**15**	**10**	**67**	**100**

Q5 If you needed to replace major home equipment or were considering improvements to your home's energy performance today, how likely would you be to check the Duke Energy website for information about energy efficient solutions or incentives?

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	51	14	11	19	13	27	20	17	10	11	28	12	233
Percent	**22**	**6**	**5**	**8**	**6**	**12**	**9**	**7**	**4**	**5**	**12**	**5**	**100**
Treatment	38	12	13	10	10	23	19	15	21	16	25	11	213
Percent	**18**	**6**	**6**	**5**	**5**	**11**	**9**	**7**	**10**	**8**	**12**	**5**	**100**
Total	89	26	24	29	23	50	39	32	31	27	53	23	446
Percent	**20**	**6**	**5**	**7**	**5**	**11**	**9**	**7**	**7**	**6**	**12**	**5**	**100**

Q6 Over the past 12 months, have you taken any actions to reduce your household energy use?

Group	No	Yes	Total
Control	51	182	233
Percent	**22**	**78**	**100**
Treatment	44	169	213
Percent	**21**	**79**	**100**
Total	95	351	446
Percent	**21**	**79**	**100**

Q7 What actions have you taken? Check all that apply.

Q7_1 Adjusted heating settings to save energy

Group	No	Yes	Missing	Total
Control	60	122	51	233
Percent	**26**	**52**	**22**	**100**
Treatment	59	110	44	213
Percent	**28**	**52**	**21**	**100**
Total	119	232	95	446
Percent	**27**	**52**	**21**	**100**

Q7_2 Adjust cooling settings to save energy

Group	No	Yes	Missing	Total
Control	31	151	51	233
Percent	**13**	**65**	**22**	**100**
Treatment	38	131	44	213
Percent	**18**	**62**	**21**	**100**
Total	69	282	95	446
Percent	**15**	**63**	**21**	**100**

Q7_3 Wash clothes in cold water

Group	No	Yes	Missing	Total
Control	78	104	51	233
Percent	**33**	**45**	**22**	**100**
Treatment	79	90	44	213
Percent	**37**	**42**	**21**	**100**
Total	157	194	95	446
Percent	**35**	**44**	**21**	**100**

Q7_4 Shut down household electronics when not in use

Group	No	Yes	Missing	Total
Control	73	109	51	233
Percent	**31**	**47**	**22**	**100**
Treatment	71	98	44	213
Percent	**33**	**46**	**21**	**100**
Total	144	207	95	446
Percent	**32**	**46**	**21**	**100**

Q7_5 Turn off lights in unused or outdoor areas

Group	No	Yes	Missing	Total
Control	26	156	51	233
Percent	**11**	**67**	**22**	**100**
Treatment	29	140	44	213
Percent	**14**	**66**	**21**	**100**
Total	55	296	95	446
Percent	**12**	**66**	**21**	**100**

Q7_6 Line dry washed clothing

Group	No	Yes	Missing	Total
Control	153	29	51	233
Percent	**66**	**12**	**22**	**100**
Treatment	139	30	44	213
Percent	**65**	**14**	**21**	**100**
Total	292	59	95	446
Percent	**65**	**13**	**21**	**100**

Q7_7 Other

Group	No	Yes	Missing	Total
Control	134	48	51	233
Percent	**58**	**21**	**22**	**100**
Treatment	113	56	44	213
Percent	**53**	**26**	**21**	**100**
Total	247	104	95	446
Percent	**55**	**23**	**21**	**100**

Q7_8 Other

Group	No	Yes	Missing	Total
Control	175	7	51	233
Percent	**75**	**3**	**22**	**100**
Treatment	159	10	44	213
Percent	**75**	**5**	**21**	**100**
Total	334	17	95	446
Percent	**75**	**4**	**21**	**100**

Q8. In the next 12 months, how likely are you to make each of the following energy efficiency improvements? Scale: 0 = Not at all Likely; 10 = Extremely Likely. If you have already made that improvement, check the "Already did it" box.

Q8_r1 Install energy efficient kitchen appliances

Group	Already Did it	Did Not Do it	Total
Control	63	170	233
Percent	**27**	**73**	**100**
Treatment	59	154	213
Percent	**28**	**72**	**100**
Total	122	324	446
Percent	**27**	**73**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	89	16	6	3	2	12	5	11	5	3	15	66	233
Percent	**38**	**7**	**3**	**1**	**1**	**5**	**2**	**5**	**2**	**1**	**6**	**28**	**100**
Treatment	85	14	3	5	2	19	5	7	12	2	11	48	213
Percent	**40**	**7**	**1**	**2**	**1**	**9**	**2**	**3**	**6**	**1**	**5**	**23**	**100**
Total	174	30	9	8	4	31	10	18	17	5	26	114	446
Percent	**39**	**7**	**2**	**2**	**1**	**7**	**2**	**4**	**4**	**1**	**6**	**26**	**100**

Q8_r2 Install energy-efficient heating/cooling system

Group	Already Did It	Did Not Do It	Total
Control	69	164	233
Percent	**30**	**70**	**100**
Treatment	56	157	213
Percent	**26**	**74**	**100**
Total	125	321	446
Percent	**28**	**72**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	92	14	7	3	3	11	4	6	9	3	15	66	233
Percent	**39**	**6**	**3**	**1**	**1**	**5**	**2**	**3**	**4**	**1**	**6**	**28**	**100**
Treatment	94	14	6	7	1	15	4	7	5	1	11	48	213
Percent	**44**	**7**	**3**	**3**	**0**	**7**	**2**	**3**	**2**	**0**	**5**	**23**	**100**
Total	186	28	13	10	4	26	8	13	14	4	26	114	446
Percent	**42**	**6**	**3**	**2**	**1**	**6**	**2**	**3**	**3**	**1**	**6**	**26**	**100**

Q8_r3 Install energy-efficient water heater

Group	Already Did It	Haven't Done It	Total
Control	61	172	233
Percent	**26**	**74**	**100**
Treatment	60	153	213
Percent	**28**	**72**	**100**
Total	121	325	446
Percent	**27**	**73**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	93	18	5	6	5	9	5	2	10	1	22	57	233
Percent	**40**	**8**	**2**	**3**	**2**	**4**	**2**	**1**	**4**	**0**	**9**	**24**	**100**
Treatment	91	17	5	5	0	16	5	8	2	3	13	48	213
Percent	**43**	**8**	**2**	**2**	**0**	**8**	**2**	**4**	**1**	**1**	**6**	**23**	**100**
Total	184	35	10	11	5	25	10	10	12	4	35	105	446
Percent	**41**	**8**	**2**	**2**	**1**	**6**	**2**	**2**	**3**	**1**	**8**	**24**	**100**

Q8_r4 Replace windows or doors

Group	Already Did It	Haven't Done It	Total
Control	48	185	233
Percent	**21**	**79**	**100**
Treatment	47	166	213
Percent	**22**	**78**	**100**
Total	95	351	446
Percent	**21**	**79**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	110	16	8	4	5	7	4	2	8	4	17	48	233
Percent	**47**	**7**	**3**	**2**	**2**	**3**	**2**	**1**	**3**	**2**	**7**	**21**	**100**
Treatment	105	18	7	3	4	10	3	5	5	3	9	41	213
Percent	**49**	**8**	**3**	**1**	**2**	**5**	**1**	**2**	**2**	**1**	**4**	**19**	**100**
Total	215	34	15	7	9	17	7	7	13	7	26	89	446
Percent	**48**	**8**	**3**	**2**	**2**	**4**	**2**	**2**	**3**	**2**	**6**	**20**	**100**

Q8_r5 Caulk or weatherstrip (windows or doors)

Group	Already Did It	Haven't Done It	Total
Control	55	178	233
Percent	**24**	**76**	**100**
Treatment	49	164	213
Percent	**23**	**77**	**100**
Total	104	342	446
Percent	**23**	**77**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	71	14	9	6	6	18	7	10	9	9	23	51	233
Percent	**30**	**6**	**4**	**3**	**3**	**8**	**3**	**4**	**4**	**4**	**10**	**22**	**100**
Treatment	66	15	7	5	4	20	6	8	14	4	20	44	213
Percent	**31**	**7**	**3**	**2**	**2**	**9**	**3**	**4**	**7**	**2**	**9**	**21**	**100**
Total	137	29	16	11	10	38	13	18	23	13	43	95	446
Percent	**31**	**7**	**4**	**2**	**2**	**9**	**3**	**4**	**5**	**3**	**10**	**21**	**100**

Q8_r6 Add insulation to attic, walls, or floors

Group	Already Did It	Haven't Done It	Total
Control	48	185	233
Percent	21	79	100
Treatment	50	163	213
Percent	23	77	100
Total	98	348	446
Percent	22	78	100

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	113	15	6	3	7	8	4	7	6	2	11	51	233
Percent	49	6	3	1	3	3	2	3	3	1	5	22	100
Treatment	96	13	7	4	5	13	7	7	3	5	11	42	213
Percent	45	6	3	2	2	6	3	3	1	2	5	20	100
Total	209	28	13	7	12	21	11	14	9	7	22	93	446
Percent	47	6	3	2	3	5	2	3	2	2	5	21	100

Q8_r7 Contact a HVAC contractor for an estimate

Group	Already Did It	Haven't Done It	Total
Control	15	218	233
Percent	6	94	100
Treatment	19	194	213
Percent	9	91	100
Total	34	412	446
Percent	8	92	100

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	136	14	8	3	5	5	3	6	4	3	9	37	233
Percent	58	6	3	1	2	2	1	3	2	1	4	16	100
Treatment	117	20	4	6	1	12	3	4	1	2	6	37	213
Percent	55	9	2	3	0	6	1	2	0	1	3	17	100
Total	253	34	12	9	6	17	6	10	5	5	15	74	446
Percent	57	8	3	2	1	4	1	2	1	1	3	17	100

Q8_r8 Request a home energy audit

Group	Already Did It	Haven't Done It	Total
Control	9	224	233
Percent	**4**	**96**	**100**
Treatment	13	200	213
Percent	**6**	**94**	**100**
Total	22	424	446
Percent	**5**	**95**	**100**

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	124	21	7	7	4	16	4	2	4	3	12	29	233
Percent	**53**	**9**	**3**	**3**	**2**	**7**	**2**	**1**	**2**	**1**	**5**	**12**	**100**
Treatment	115	17	6	7	0	12	6	4	4	1	6	35	213
Percent	**54**	**8**	**3**	**3**	**0**	**6**	**3**	**2**	**2**	**0**	**3**	**16**	**100**
Total	239	38	13	14	4	28	10	6	8	4	18	64	446
Percent	**54**	**9**	**3**	**3**	**1**	**6**	**2**	**1**	**2**	**1**	**4**	**14**	**100**

Q9 How important is it for you to know if your household is using energy wisely?

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	4	1	5	8	5	19	19	35	43	18	73	3	233
Percent	**2**	**0**	**2**	**3**	**2**	**8**	**8**	**15**	**18**	**8**	**31**	**1**	**100**
Treatment	4	1	1	5	6	18	14	23	27	27	86	1	213
Percent	**2**	**0**	**0**	**2**	**3**	**8**	**7**	**11**	**13**	**13**	**40**	**0**	**100**
Total	8	2	6	13	11	37	33	58	70	45	159	4	446
Percent	**2**	**0**	**1**	**3**	**2**	**8**	**7**	**13**	**16**	**10**	**36**	**1**	**100**

Q10 Which of the following do you do with regard to your household's energy use? Check all that apply.

Q10_1 Track monthly energy use

Group	No	Yes	Total
Control	138	95	233
Percent	59	41	100
Treatment	115	98	213
Percent	54	46	100
Total	253	193	446
Percent	57	43	100

Q10_2 Track the total amount of your bill

Group	No	Yes	Total
Control	77	156	233
Percent	33	67	100
Treatment	71	142	213
Percent	33	67	100
Total	148	298	446
Percent	33	67	100

Q10_3 Compare usage to previous months

Group	No	Yes	Total
Control	77	156	233
Percent	33	67	100
Treatment	74	139	213
Percent	35	65	100
Total	151	295	446
Percent	34	66	100

Q10_4 Compare usage to the same month from last year

Group	No	Yes	Total
Control	106	127	233
Percent	45	55	100
Treatment	96	117	213
Percent	45	55	100
Total	202	244	446
Percent	45	55	100

Q10_5 None of the above

Group	No	Yes	Total
Control	211	22	233
Percent	**91**	**9**	**100**
Treatment	193	20	213
Percent	**91**	**9**	**100**
Total	404	42	446
Percent	**91**	**9**	**100**

Q10_6 Don't know

Group	Know	Don't Know	Total
Control	230	3	233
Percent	**99**	**1**	**100**
Treatment	212	1	213
Percent	**100**	**0**	**100**
Total	442	4	446
Percent	**99**	**1**	**100**

Q11 How would you rate your knowledge of the different ways you can save energy in your home?

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	6	6	9	12	8	43	29	32	43	23	19	3	233
Percent	**3**	**3**	**4**	**5**	**3**	**18**	**12**	**14**	**18**	**10**	**8**	**1**	**100**
Treat	6	2	4	10	5	22	29	38	43	27	25	2	213
Percent	**3**	**1**	**2**	**5**	**2**	**10**	**14**	**18**	**20**	**13**	**12**	**1**	**100**
Total	12	8	13	22	13	65	58	70	86	50	44	5	446
Percent	**3**	**2**	**3**	**5**	**3**	**15**	**13**	**16**	**19**	**11**	**10**	**1**	**100**

Q12 Duke Energy sends a personalized report called My Home Energy Report to a select group of homes. These documents are mailed in a standard envelope every few months and provide customers with information on how their home's electric energy usage compares with similar homes. Have you seen one of these reports? (Only for treatment group)

Group	Yes	No	Total
Treatment	201	12	213
Percent	**94**	**6**	**100**

Q13 About how many My Home Energy Reports have you received in the past 12 months? (Only for treatment group)

Group	1	2	3	4	5	6	7	8	9	10	11	12	Don't Know	Missing	Total
Treatment	1	10	10	20	7	27	3	12	1	4	1	46	59	12	213
Percent	0	5	5	9	3	13	1	6	0	2	0	22	28	6	100

Q14 How often do you read the My Home Energy Reports? (Only for treatment group)

Group	Always	Sometimes	Never	Missing	Total
Treatment	143	50	8	12	213
percent	67	23	4	6	100

Q15 Please indicate how much you agree or disagree with the following statements about My Home Energy Reports. Scale: 0 = Strongly Disagree; 10 = Strongly Agree (Only for treatment group)

Q15_r1 I have learned about my household's energy use from My Home Energy Reports

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	6	4	5	3	2	13	12	21	22	25	75	5	20	213
Percent	3	2	2	1	1	6	6	10	10	12	35	2	9	100

Q15_r2 I use the reports to tell me how well I am doing at saving energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	6	6	7	3	4	13	14	14	26	24	70	6	20	213
Percent	3	3	3	1	2	6	7	7	12	11	33	3	9	100

Q15_r3 The tips provided in the reports are pertinent to my home

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	9	7	6	9	6	23	15	17	28	24	41	8	20	213
Percent	4	3	3	4	3	11	7	8	13	11	19	4	9	100

Q15_r4 I'd like more detailed information about my home's energy use

Group	0	1	2	3	4	5	6	7	8	9	10	Don'tKknow	Missing	Total
Treatment	15	15	14	7	9	24	17	12	17	14	39	10	20	213
Percent	**7**	**7**	**7**	**3**	**4**	**11**	**8**	**6**	**8**	**7**	**18**	**5**	**9**	**100**

Q15_r5 I have discussed My Home Energy Reports with others

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	47	26	13	1	5	17	7	8	12	14	32	11	20	213
Percent	**22**	**12**	**6**	**0**	**2**	**8**	**3**	**4**	**6**	**7**	**15**	**5**	**9**	**100**

Q15_r6 The information provided about my home's energy use is confusing

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	82	28	16	11	6	22	6	3	4	2	3	10	20	213
Percent	**39**	**13**	**8**	**5**	**3**	**10**	**3**	**1**	**2**	**1**	**1**	**5**	**9**	**100**

Q17 Do you recall any specific tips or information from the My Home Energy Reports? (Only for treatment group)

Group	Yes	No	Missing	Total
Treatment	76	117	20	213
Percent	**36**	**55**	**9**	**100**

Q19T Below is a list of My Home Energy Report features. Please rate how useful each feature is to you.
Scale: 0 = Not at all Useful; 10 = Extremely Useful (for treatment group)

Q19T_r1 Comparison to similar homes

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	17	6	6	5	5	19	4	10	32	18	58	13	20	213
Percent	**8**	**3**	**3**	**2**	**2**	**9**	**2**	**5**	**15**	**8**	**27**	**6**	**9**	**100**

Q19T_r2 Tips to help you save money and energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	5	7	4	6	8	16	12	16	30	29	52	8	20	213
Percent	**2**	**3**	**2**	**3**	**4**	**8**	**6**	**8**	**14**	**14**	**24**	**4**	**9**	**100**

Q19T_r3 Examples of the energy use associated with common household items

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	9	5	5	7	7	16	8	15	38	19	52	12	20	213
Percent	**4**	**2**	**2**	**3**	**3**	**8**	**4**	**7**	**18**	**9**	**24**	**6**	**9**	**100**

Q19T_r4 Customized suggestions for your home

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	10	6	11	6	6	23	13	12	32	17	47	10	20	213
Percent	**5**	**3**	**5**	**3**	**3**	**11**	**6**	**6**	**15**	**8**	**22**	**5**	**9**	**100**

Q19T_r5 Graphs that illustrate your home's energy use over time

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Treatment	8	4	5	2	7	12	5	15	25	28	72	10	20	213
Percent	**4**	**2**	**2**	**1**	**3**	**6**	**2**	**7**	**12**	**13**	**34**	**5**	**9**	**100**

Q19T_r6 Information about services and offers from Duke Energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Lnow	Missing	Total
Treatment	11	6	9	3	11	16	11	16	30	20	50	10	20	213
Percent	**5**	**3**	**4**	**1**	**5**	**8**	**5**	**8**	**14**	**9**	**23**	**5**	**9**	**100**

Q19C Thinking about the information you have about your home's energy use, please rate how useful each of the following items would be for your household. Scale: 0 = Not at all Useful; 10 = Extremely (Modified question – asked only of control group, not treatment.)

Q19C_r1 Your home's energy use compared to that of similar homes

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	36	11	10	6	5	27	18	26	29	13	38	14	0	233
Percent	**15**	**5**	**4**	**3**	**2**	**12**	**8**	**11**	**12**	**6**	**16**	**6**	**0**	**100**

Q19C_r2 Tips to help you save money and energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	13	8	5	5	1	25	19	29	37	17	65	9	0	233
Percent	**6**	**3**	**2**	**2**	**0**	**11**	**8**	**12**	**16**	**7**	**28**	**4**	**0**	**100**

Q19C_r3 Examples of the energy use associated with common household items

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	15	5	8	8	5	29	14	28	44	17	47	13	0	233
Percent	6	2	3	3	2	12	6	12	19	7	20	6	0	100

Q19C_r4 Customized suggestions for your home

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	22	13	13	5	6	22	20	14	40	16	45	17	0	233
Percent	9	6	6	2	3	9	9	6	17	7	19	7	0	100

Q19C_r5 Graphs that illustrate your home's energy use over time

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	23	6	5	7	4	25	17	18	38	18	56	16	0	233
Percent	10	3	2	3	2	11	7	8	16	8	24	7	0	100

Q19C_r6 Information about services and offers from Duke Energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Missing	Total
Control	14	11	7	9	6	27	17	23	34	21	50	14	0	233
Percent	6	5	3	4	3	12	7	10	15	9	21	6	0	100

Q20 Please rate your satisfaction with the information in the My Home Energy Reports you've received (Only for treatment group)

Group	Very Satisfied	Somewhat Satisfied	Neither Satisfied nor Dissatisfied	Somewhat Dissatisfied	Very Dissatisfied	Don't Know	Missing	Total
Treatment	87	60	33	6	4	3	20	213
Percent	41	28	15	3	2	1	9	100

Q21 The statements below provide reasons why households might try to reduce their home's energy use. Please indicate how important each statement is to you. Scale: 0 = Not at all Important; 10 = Extremely Important

Q21_r1 Reducing my energy bill(s)

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	5	2	4	3	1	11	3	17	26	28	130	3	233
Percent	**2**	**1**	**2**	**1**	**0**	**5**	**1**	**7**	**11**	**12**	**56**	**1**	**100**
Treatment	1	1	0	1	3	4	5	11	14	34	137	2	213
Percent	**0**	**0**	**0**	**0**	**1**	**2**	**2**	**5**	**7**	**16**	**64**	**1**	**100**
Total	6	3	4	4	4	15	8	28	40	62	267	5	446
Percent	**1**	**1**	**1**	**1**	**1**	**3**	**2**	**6**	**9**	**14**	**60**	**1**	**100**

Q21_r2 Using less energy

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	5	2	6	5	3	17	10	21	32	24	105	3	233
Percent	**2**	**1**	**3**	**2**	**1**	**7**	**4**	**9**	**14**	**10**	**45**	**1**	**100**
Treatment	3	5	1	0	2	14	7	11	24	35	107	4	213
Percent	**1**	**2**	**0**	**0**	**1**	**7**	**3**	**5**	**11**	**16**	**50**	**2**	**100**
Total	8	7	7	5	5	31	17	32	56	59	212	7	446
Percent	**2**	**2**	**2**	**1**	**1**	**7**	**4**	**7**	**13**	**13**	**48**	**2**	**100**

Q21_r3 Helping the environment

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	7	4	8	4	3	20	10	22	21	23	100	11	233
Percent	**3**	**2**	**3**	**2**	**1**	**9**	**4**	**9**	**9**	**10**	**43**	**5**	**100**
Treat	6	3	1	3	2	12	11	19	27	31	91	7	213
Percent	**3**	**1**	**0**	**1**	**1**	**6**	**5**	**9**	**13**	**15**	**43**	**3**	**100**
Total	13	7	9	7	5	32	21	41	48	54	191	18	446
Percent	**3**	**2**	**2**	**2**	**1**	**7**	**5**	**9**	**11**	**12**	**43**	**4**	**100**

Q21_r4 Setting an example for others

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	31	11	5	9	9	29	8	19	22	12	67	11	233
Percent	13	5	2	4	4	12	3	8	9	5	29	5	100
Treat	18	11	8	3	7	20	7	12	28	22	69	8	213
Percent	8	5	4	1	3	9	3	6	13	10	32	4	100
Total	49	22	13	12	16	49	15	31	50	34	136	19	446
Percent	11	5	3	3	4	11	3	7	11	8	30	4	100

Q21_r5 Avoiding waste

Group	0	1	2	3	4	5	6	7	8	9	10	Don't Know	Total
Control	8	5	3	6	2	15	9	15	39	23	102	6	233
Percent	3	2	1	3	1	6	4	6	17	10	44	3	100
Treatment	3	5	1	2	1	13	8	12	21	35	109	3	213
Percent	1	2	0	1	0	6	4	6	10	16	51	1	100
Total	11	10	4	8	3	28	17	27	60	58	211	9	446
Percent	2	2	1	2	1	6	4	6	13	13	47	2	100

Q22 Please indicate your level of agreement with each of the following statements:

Q22_r1 Duke Energy provides excellent customer service

Group	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree	Don't Know	Total
Control	3	9	24	78	112	7	233
Percent	1	4	10	33	48	3	100
Treatment	7	7	19	72	99	9	213
Percent	3	3	9	34	46	4	100
Total	10	16	43	150	211	16	446
Percent	2	4	10	34	47	4	100

Q22_r2 *Duke Energy respects its customers*

Group	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree	Don't Know	Total
Control	7	10	22	80	110	4	233
Percent	**3**	**4**	**9**	**34**	**47**	**2**	**100**
Treatment	9	9	23	61	95	16	213
Percent	**4**	**4**	**11**	**29**	**45**	**8**	**100**
Total	16	19	45	141	205	20	446
Percent	**4**	**4**	**10**	**32**	**46**	**4**	**100**

Q22_r3 *Duke Energy provides service at a reasonable cost*

Group	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree	Don't Know	Total
Control	8	26	37	90	63	9	233
Percent	**3**	**11**	**16**	**39**	**27**	**4**	**100**
Treatment	12	29	33	76	49	14	213
Percent	**6**	**14**	**15**	**36**	**23**	**7**	**100**
Total	20	55	70	166	112	23	446
Percent	**4**	**12**	**16**	**37**	**25**	**5**	**100**

Q24 *Do you own or rent this residence?*

Group	Own	Rent	Prefer Not To Answer	Total
Control	208	21	4	233
Percent	**89**	**9**	**2**	**100**
Treatment	195	12	6	213
Percent	**92**	**6**	**3**	**100**
Total	403	33	10	446
Percent	**90**	**7**	**2**	**100**

Q25 *Including yourself, how many people live in your home?*

Group	1	2	3	4	5	6	7	10	12	Prefer Not To Answer	Total
Control	49	86	40	33	9	2	2	1	1	10	233
Percent	**21**	**37**	**17**	**14**	**4**	**1**	**1**	**0**	**0**	**4**	**100**
Treatment	37	82	41	20	9	5	2	0	0	17	213
Percent	**17**	**39**	**19**	**9**	**4**	**2**	**1**	**0**	**0**	**8**	**100**
Total	86	168	81	53	18	7	4	1	1	27	446
Percent	**19**	**38**	**18**	**12**	**4**	**2**	**1**	**0**	**0**	**6**	**100**

Q28 What is your primary heating fuel?

Group	Electricity	Natural Gas	Oil	Other	Don't Know	Prefer Not To Answer	Total
Control	122	85	6	16	1	3	233
Percent	**52**	**36**	**3**	**7**	**0**	**1**	**100**
Treatment	112	83	5	10	1	2	213
Percent	**53**	**39**	**2**	**5**	**0**	**1**	**100**
Total	234	168	11	26	2	5	446
Percent	**52**	**38**	**2**	**6**	**0**	**1**	**100**

Appendix E Detailed Regression Outputs/Models

Table 5-2: Regression Coefficients for Cohort 1

Linear regression, absorbing indicators	Number of obs	=	111,294
	F(12,16377)	=	1,264
	Prob > F	=	0.000
	R-squared	=	0.8788
	Adj R-squared	=	0.8578
	Root MSE	=	10.7168

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
612	-1.19862	0.1261584	-9.5	0	-1.4459	-0.95133
624	-13.2464	0.1710114	-77.46	0	-13.5816	-12.9112
636	-12.3061	0.1747251	-70.43	0	-12.6485	-11.9636
648	-3.04992	0.1677605	-18.18	0	-3.37875	-2.72109
660	-8.82232	0.1785249	-49.42	0	-9.17225	-8.47239
672	-11.241	0.1923441	-58.44	0	-11.618	-10.864
bill_mo#c.treatment						
600	0	(empty)				
612	-0.35623	0.2038147	-1.75	0.081	-0.75573	0.04327
624	-0.62072	0.2755296	-0.75	0.024	-1.16079	-0.08065
636	-0.66647	0.2805526	0.25	0.018	-1.21639	-0.11656
648	-0.71835	0.272195	1.25	0.008	-1.25188	-0.18482
660	-0.76798	0.2904043	2.25	0.008	-1.3372	-0.19875
672	-0.71759	0.3095764	3.25	0.02	-1.32439	-0.11079
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16378 16378 ***					

Linear regression, absorbing indicators	Number of obs	=	112,704
	F(12,16423)	=	1,264
	Prob > F	=	0.000
	R-squared	=	0.8753
	Adj R-squared	=	0.854
	Root MSE	=	10.2142

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
613	-9.66312	0.1424374	-67.84	0	-9.94231	-9.38392
625	-13.0682	0.1644882	-79.45	0	-13.3906	-12.7458
637	-7.17262	0.1585145	-45.25	0	-7.48332	-6.86191
649	-5.18122	0.1645818	-31.48	0	-5.50381	-4.85862
661	-4.18229	0.1713522	-24.41	0	-4.51815	-3.84642
673	-9.73533	0.1837813	-52.97	0	-10.0956	-9.3751
bill_mo#c.treatment						
601	0	(empty)				
613	-0.09664	0.2252937	-0.43	0.668	-0.53824	0.344965
625	-0.45186	0.2648998	-1.71	0.088	-0.97109	0.067375
637	-0.4374	0.2523944	-1.73	0.083	-0.93212	0.057318
649	-0.47454	0.2662005	-1.78	0.075	-0.99633	0.047238
661	-0.73022	0.2753831	-2.65	0.008	-1.27	-0.19044
673	-0.42009	0.2916443	-1.44	0.15	-0.99175	0.151563
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16424 16424 ***					

Linear regression, absorbing indicators	Number of obs	=	114,361
	F(12,16481)	=	1,061
	Prob > F	=	0.000
	R-squared	=	0.8522
	Adj R-squared	=	0.8273
	Root MSE	=	8.4214

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]

bill_mo						
614	-6.0077	0.1015604	-59.15	0	-6.20677	-5.80863
626	-8.25352	0.1270804	-64.95	0	-8.50261	-8.00443
638	0.789432	0.1232145	6.41	0	0.547918	1.030946
650	-2.24152	0.1246372	-17.98	0	-2.48583	-1.99722
662	-4.11695	0.1298905	-31.7	0	-4.37155	-3.86235
674	-9.35032	0.1428154	-65.47	0	-9.63025	-9.07038
bill_mo#c.treatment						
602	0	(empty)				
614	-0.3753	0.1620422	-2.32	0.021	-0.69292	-0.05768
626	-0.50512	0.2036379	-2.48	0.013	-0.90427	-0.10597
638	-0.57928	0.1945611	-2.98	0.003	-0.96064	-0.19792
650	-0.35184	0.1996665	-1.76	0.078	-0.7432	0.039533
662	-0.5876	0.2082731	-2.82	0.005	-0.99584	-0.17936
674	-0.45678	0.2255886	-2.02	0.043	-0.89895	-0.0146
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16482 16482 ***					

Linear regression, absorbing indicators	Number of obs	=	112,848
	F(13,16486)	=	429
	Prob > F	=	0.000
	R-squared	=	0.859
	Adj R-squared	=	0.8349
	Root MSE	=	6.759

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
615	0.005096	0.0762941	0.0762941	0.947	-0.14445	0.154641
627	-1.30013	0.0871635	0.0871635	0	-1.47098	-1.12928
639	-0.2093	0.1032496	0.1032496	0.043	-0.41168	-0.00692
651	-0.65407	0.1049121	0.1049121	0	-0.85971	-0.44843
663	-3.40513	0.1082168	0.1082168	0	-3.61725	-3.19302
675	-5.24352	0.1225911	0.1225911	0	-5.48381	-5.00323
bill_mo#c.treatment						
603	0.199716	0.1993949	0.1993949	0.317	-0.19112	0.590551

615	-0.12399	0.1561314	0.1561314	0.427	-0.43003	0.182041
627	-0.39102	0.171113	0.171113	0.022	-0.72642	-0.05562
639	-0.29737	0.1918483	0.1918483	0.121	-0.67341	0.078673
651	-0.32395	0.1951201	0.1951201	0.097	-0.7064	0.05851
663	-0.34018	0.2020984	0.2020984	0.092	-0.73631	0.055959
675	-0.19926	0.2175189	0.2175189	0.36	-0.62562	0.227097
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16487 16487 ***					

Linear regression, absorbing indicators	Number of obs	=	115,096
	F(12,16473)	=	817.13
	Prob > F	=	0.000
	R-squared	=	0.8715
	Adj R-squared	=	0.85
	Root MSE	=	7.5136

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
604	3.107172	0.0870828	35.68	0	2.936481	3.277864
616	2.918893	0.1015901	28.73	0	2.719766	3.118021
628	-0.27696	0.1097307	-2.52	0.012	-0.49204	-0.06187
640	-3.99074	0.1157949	-34.46	0	-4.21771	-3.76377
652	-0.95188	0.1250152	-7.61	0	-1.19693	-0.70684
664	-1.22423	0.1329045	-9.21	0	-1.48474	-0.96372
bill_mo#c.treatment						
592	0	(empty)				
604	0.022509	0.136256	0.17	0.869	-0.24457	0.289586
616	-0.40123	0.1607922	-2.5	0.013	-0.7164	-0.08606
628	-0.3617	0.1729559	-2.09	0.037	-0.70072	-0.02269
640	-0.51346	0.1832129	-2.8	0.005	-0.87257	-0.15434
652	-0.41966	0.1987745	-2.11	0.035	-0.80928	-0.03004
664	-0.41526	0.2123746	-1.96	0.051	-0.83153	0.00102
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					

account_id	0 16474 16474 *

Linear regression, absorbing indicators

Number of obs	=	114,041
F(12,16428)	=	1,371.76
Prob > F	=	0.000
R-squared	=	0.8714
Adj R-squared	=	0.8497
Root MSE	=	8.8162

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
605	5.223034	0.0987306	52.9	0	5.029511	5.416556
617	2.626915	0.1176009	22.34	0	2.396404	2.857425
629	-3.34817	0.1289847	-25.96	0	-3.601	-3.09535
641	-6.43527	0.136447	-47.16	0	-6.70272	-6.16782
653	-3.00024	0.14956	-20.06	0	-3.2934	-2.70709
665	-1.77387	0.1588546	-11.17	0	-2.08525	-1.4625
bill_mo#c.treatment						
593	0	(empty)				
605	-0.00489	0.1607789	-0.03	0.976	-0.32004	0.310251
617	-0.22492	0.189107	-1.19	0.234	-0.59559	0.145746
629	-0.41389	0.2047637	-2.02	0.043	-0.81525	-0.01253
641	-0.56686	0.219627	-2.58	0.01	-0.99735	-0.13637
653	-0.56552	0.2404528	-2.35	0.019	-1.03684	-0.09421
665	-0.36427	0.2571127	-1.42	0.157	-0.86824	0.139695
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16429 16429 ***					

Linear regression, absorbing indicators

Number of obs	=	113,193
F(12,16428)	=	2,133.24
Prob > F	=	0.000
R-squared	=	0.8707
Adj R-squared	=	0.8487

Root MSE	=	9.239

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
606	8.425555	0.1068978	78.82	0	8.216024	8.635087
618	5.790821	0.1244045	46.55	0	5.546974	6.034667
630	2.54745	0.1373403	18.55	0	2.278248	2.816652
642	-5.42498	0.1407143	-38.55	0	-5.70079	-5.14916
654	-5.59975	0.1529954	-36.6	0	-5.89964	-5.29987
666	-0.17083	0.1674132	-1.02	0.308	-0.49898	0.157318
bill_mo#c.treatment						
594	0	(empty)				
606	-0.21216	0.1732428	-1.22	0.221	-0.55174	0.127412
618	-0.34662	0.2006946	-1.73	0.084	-0.74001	0.046759
630	-0.17028	0.2181037	-0.78	0.435	-0.59779	0.257223
642	-0.58923	0.2263936	-2.6	0.009	-1.03299	-0.14547
654	-0.48291	0.2450091	-1.97	0.049	-0.96315	-0.00266
666	-0.21137	0.2678416	-0.79	0.43	-0.73637	0.313628
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16393 16393 ***					

Linear regression, absorbing indicators			
	Number of obs	=	113,684
	F(12,16481)	=	1,604.99
	Prob > F	=	0.000
	R-squared	=	0.8733
	Adj R-squared	=	0.852
	Root MSE	=	8.8565

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
607	5.502495	0.1058139	52	0	5.295088	5.709901
619	4.531968	0.1179148	38.43	0	4.300843	4.763094
631	-3.09173	0.1290881	-23.95	0	-3.34475	-2.8387
643	-6.28806	0.1371703	-45.84	0	-6.55693	-6.01919

655	-5.94933	0.1473243	-40.38	0	-6.2381	-5.66056
667	-3.18172	0.1583441	-20.09	0	-3.49209	-2.87135
bill_mo#c.treatment						
595	0	(empty)				
607	-0.07403	0.1711487	-0.43	0.665	-0.4095	0.261438
619	-0.13883	0.1906563	-0.73	0.467	-0.51254	0.234873
631	-0.32045	0.2037984	-1.57	0.116	-0.71991	0.07902
643	-0.61703	0.2183845	-2.83	0.005	-1.04509	-0.18897
655	-0.61007	0.2356834	-2.59	0.01	-1.07203	-0.1481
667	-0.30467	0.2528125	-1.21	0.228	-0.80021	0.190872
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16419 16419 ***					

Linear regression, absorbing indicators	Number of obs	=	114,655
	F(12,16470)	=	952.41
	Prob > F	=	0.000
	R-squared	=	0.8763
	Adj R-squared	=	0.8555
	Root MSE	=	7.5761

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
608	4.762761	0.089821	53.03	0	4.586702	4.93882
620	-0.62552	0.0990191	-6.32	0	-0.81961	-0.43143
632	-2.61214	0.1090833	-23.95	0	-2.82595	-2.39832
644	-1.73559	0.1190815	-14.57	0	-1.96901	-1.50218
656	-1.067	0.1281738	-8.32	0	-1.31824	-0.81577
668	-3.85347	0.1317251	-29.25	0	-4.11167	-3.59528
bill_mo#c.treatment						
596	0	(empty)				
608	-0.16653	0.1438872	-1.16	0.247	-0.44856	0.115506
620	-0.24038	0.155779	-1.54	0.123	-0.54572	0.064968
632	-0.30068	0.173261	-1.74	0.083	-0.64029	0.038934
644	-0.34837	0.1909781	-1.82	0.068	-0.72271	0.02597
656	-0.56721	0.2053654	-2.76	0.006	-0.96975	-0.16467

668	-0.42438	0.2114893	-2.01	0.045	-0.83893	-0.00984
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16471 16471 ***					

Linear regression, absorbing indicators	Number of obs	=	114,847
	F(12,16484)	=	285.82
	Prob > F	=	0.000
	R-squared	=	0.8632
	Adj R-squared	=	0.8402
	Root MSE	=	6.5302

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
609	-0.63106	0.0759421	-8.31	0	-0.77991	-0.4822
621	-1.74888	0.0856466	-20.42	0	-1.91675	-1.581
633	-1.5269	0.0999012	-15.28	0	-1.72272	-1.33108
645	-1.87821	0.0987089	-19.03	0	-2.07169	-1.68473
657	-2.68374	0.1056301	-25.41	0	-2.89079	-2.4767
669	-4.61121	0.1112393	-41.45	0	-4.82925	-4.39317
bill_mo#c.treatment						
597	0	(empty)				
609	-0.23199	0.1215224	-1.91	0.056	-0.47019	0.006206
621	-0.2842	0.1346762	-2.11	0.035	-0.54818	-0.02022
633	-0.4	0.1570315	-2.55	0.011	-0.7078	-0.09221
645	-0.35744	0.1595279	-2.24	0.025	-0.67013	-0.04475
657	-0.39146	0.1687047	-2.32	0.02	-0.72214	-0.06078
669	-0.47577	0.1776962	-2.68	0.007	-0.82408	-0.12747
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16485 16485 ***					

Linear regression, absorbing indicators	Number of obs	=	114,516
	F(12,16477)	=	802.28
	Prob > F	=	0.000
	R-squared	=	0.8555

Adj R-squared	=	0.8312
Root MSE	=	8.4567

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
610	2.559972	0.0928774	27.56	0	2.377923	2.742022
622	-1.27114	0.1006534	-12.63	0	-1.46843	-1.07385
634	1.585976	0.1423356	11.14	0	1.306983	1.864969
646	1.284492	0.1203278	10.67	0	1.048637	1.520348
658	1.379306	0.1316636	10.48	0	1.121231	1.637381
670	-5.28117	0.1288684	-40.98	0	-5.53377	-5.02858
bill_mo#c.treatment						
598	0	(empty)				
610	-0.17511	0.1462514	-1.2	0.231	-0.46178	0.111555
622	-0.29705	0.1596651	-1.86	0.063	-0.61001	0.015912
634	-0.89522	0.2197912	-4.07	0	-1.32604	-0.46441
646	-0.37275	0.1938571	-1.92	0.055	-0.75273	0.007232
658	-0.50036	0.2104477	-2.38	0.017	-0.91286	-0.08786
670	-0.56275	0.2053127	-2.74	0.006	-0.96519	-0.16032
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16478 16478 ***					

Linear regression, absorbing indicators

Number of obs	=	112,762
F(12,16440)	=	1,435.59
Prob > F	=	0.000
R-squared	=	0.8638
Adj R-squared	=	0.8406
Root MSE	=	10.4207

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
611	2.50841	0.1270906	19.74	0	2.259299	2.757521
623	-10.6566	0.1517016	-70.25	0	-10.9539	-10.3592
635	-11.3138	0.162234	-69.74	0	-11.6317	-10.9958

647	-5.43267	0.157612	-34.47	0	-5.7416	-5.12373
659	-8.52598	0.1692622	-50.37	0	-8.85775	-8.19421
671	-16.0944	0.193603	-83.13	0	-16.4739	-15.7149
bill_mo#c.treatment						
599	0	(empty)				
611	-0.11465	0.2038073	-0.56	0.574	-0.51414	0.284832
623	-0.40415	0.2420264	-1.67	0.095	-0.87855	0.07025
635	-0.51947	0.2584384	-2.01	0.044	-1.02604	-0.0129
647	-0.33641	0.2528692	-1.33	0.183	-0.83206	0.159245
659	-0.61806	0.2705374	-2.28	0.022	-1.14834	-0.08778
671	-0.48287	0.3089846	-1.56	0.118	-1.08852	0.122771
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 16441 16441 ***					

* = fixed effect nested within cluster; treated as redundant for DoF computation

Table 5-3: Regression Coefficients for Cohort 2

Linear regression, absorbing indicators			
	Number of obs	=	3,204,135
	F(8,668257)	=	29,219.71
	Prob > F	=	0.000
	R-squared	=	0.8918
	Adj R-squared	=	0.8633
	Root MSE	=	9.7975

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
636	1.106336	0.0416488	26.56	0	1.024706	1.187967
648	8.566422	0.077632	110.35	0	8.414266	8.718578
660	4.187392	0.0771984	54.24	0	4.036085	4.338698
672	2.356293	0.0818163	28.8	0	2.195936	2.516651
bill_mo#c.treatment						
624	0	(empty)				

636	0.434278	0.042595	10.2	0	0.350793	0.517763
648	-0.03733	0.0787153	-0.47	0.635	-0.19161	0.116948
660	-0.00669	0.0783585	-0.09	0.932	-0.16027	0.146886
672	-0.1407	0.0832964	-1.69	0.091	-0.30396	0.022559
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 668258 668258 ***					

Linear regression, absorbing indicators	Number of obs	=	3,220,240
	F(8,669625)	=	31,906.93
	Prob > F	=	0.000
	R-squared	=	0.8864
	Adj R-squared	=	0.8566
	Root MSE	=	9.8561

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
637	5.045016	0.0423091	119.24	0	4.962092	5.12794
649	6.976981	0.0687285	101.52	0	6.842275	7.111686
661	9.403895	0.0854653	110.03	0	9.236386	9.571404
673	3.741878	0.0797557	46.92	0	3.58556	3.898197
bill_mo#c.treatment						
625	0	(empty)				
637	0.419915	0.0430934	9.74	0	0.335454	0.504377
649	-0.0598	0.0694393	-0.86	0.389	-0.1959	0.076299
661	-0.31043	0.08682	-3.58	0	-0.48059	-0.14026
673	-0.42461	0.0811853	-5.23	0	-0.58373	-0.26549
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 669626 669626 ***					

Linear regression, absorbing indicators	Number of obs	=	3,870,424
	F(8,675290)	=	29,132.19
	Prob > F	=	0.000

R-squared	=	0.851
Adj R-squared	=	0.8195
Root MSE	=	8.5564

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
626	-2.91502	0.0122783	-237.41	0	-2.93908	-2.89095
638	5.931207	0.0406641	145.86	0	5.851506	6.010907
650	4.508144	0.0597462	75.45	0	4.391043	4.625245
662	2.374456	0.0607464	39.09	0	2.255396	2.493517
674	-2.87046	0.0587792	-48.83	0	-2.98567	-2.75526
bill_mo#c.treatment						
614	0	(empty)				
626	-0.36301	0.0121177	-29.96	0	-0.38676	-0.33926
638	-0.06013	0.0415849	-1.45	0.148	-0.14163	0.021377
650	-0.27534	0.0603702	-4.56	0	-0.39367	-0.15702
662	-0.33269	0.0614561	-5.41	0	-0.45314	-0.21224
674	-0.33577	0.0596435	-5.63	0	-0.45267	-0.21887
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 675291 675291 ***					

Linear regression, absorbing indicators

Number of obs	=	3,805,067
F(10,675537)	=	13,162.87
Prob > F	=	0.000
R-squared	=	0.8618
Adj R-squared	=	0.832
Root MSE	=	6.5743

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
627	-1.43845	0.01015	-141.72	0	-1.45834	-1.41855
639	0.004987	0.0300843	0.17	0.868	-0.05398	0.063952
651	-0.20772	0.0438757	-4.73	0	-0.29371	-0.12172
663	-2.64688	0.0469542	-56.37	0	-2.73891	-2.55485
675	-2.87264	0.055604	-51.66	0	-2.98163	-2.76366

bill_mo#c.treatment						
615	0	(empty)				
627	2.776811	4.238355	0.66	0.512	-5.53023	11.08385
639	0.246708	0.0301983	8.17	0	0.18752	0.305896
651	-0.26139	0.0441507	-5.92	0	-0.34793	-0.17486
663	-0.15482	0.047459	-3.26	0.001	-0.24783	-0.0618
675	-0.70838	0.0565878	-12.52	0	-0.81929	-0.59747
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 675538 675538 ***					

Linear regression, absorbing indicators	Number of obs	=	3,257,352
	F(8,674457)	=	16,757.99
	Prob > F	=	0.000
	R-squared	=	0.8788
	Adj R-squared	=	0.8472
	Root MSE	=	7.1362

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
628	-2.68838	0.0120645	-222.83	0	-2.71202	-2.66473
640	-4.92139	0.0328586	-149.78	0	-4.9858	-4.85699
652	-3.02236	0.0460944	-65.57	0	-3.11271	-2.93202
664	-2.86549	0.0544279	-52.65	0	-2.97216	-2.75881
bill_mo#c.treatment						
616	0	(empty)				
628	0.199248	0.0458611	4.34	0	0.109362	0.289135
640	-0.2318	0.0326855	-7.09	0	-0.29586	-0.16773
652	-0.19431	0.0461531	-4.21	0	-0.28477	-0.10385
664	0.004631	0.0549216	0.08	0.933	-0.10301	0.112275
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					

account_id	0 674458 674458 *

Linear regression, absorbing indicators

Number of obs	=	3,236,291
F(8,671524)	=	36,188.87
Prob > F	=	0.000
R-squared	=	0.8915
Adj R-squared	=	0.8631
Root MSE	=	8.0133

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
629	-4.65996	0.0135649	-343.53	0	-4.68654	-4.63337
641	-7.37438	0.0357229	-206.43	0	-7.44439	-7.30436
653	-4.29665	0.0538897	-79.73	0	-4.40227	-4.19103
665	-1.95642	0.0638041	-30.66	0	-2.08147	-1.83136
bill_mo#c.treatment						
617	0	(empty)				
629	0.49687	0.0311495	15.95	0	0.435818	0.557922
641	0.062878	0.0353753	1.78	0.075	-0.00646	0.132212
653	-0.19421	0.0540644	-3.59	0	-0.30018	-0.08825
665	-0.30523	0.0646136	-4.72	0	-0.43187	-0.17859
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 671525 671525 ***					

Linear regression, absorbing indicators

Number of obs	=	3,217,811
F(8,66958)	=	67,049.05
Prob > F	=	0.000
R-squared	=	0.892
Adj R-squared	=	0.8636
Root MSE	=	8.3993

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
630	-1.62973	0.0146798	-111.02	0	-1.6585	-1.60095
642	-8.28101	0.0379142	-218.41	0	-8.35532	-8.2067
654	-9.51424	0.0576636	-165	0	-9.62725	-9.40122
666	-3.77412	0.0673476	-56.04	0	-3.90612	-3.64212
bill_mo#c.treatment						
618	0	(empty)				
630	-0.67293	0.0257437	-26.14	0	-0.72338	-0.62247
642	-0.40727	0.0375695	-10.84	0	-0.4809	-0.33363
654	-0.28212	0.0578287	-4.88	0	-0.39546	-0.16877
666	-0.62272	0.068193	-9.13	0	-0.75637	-0.48906
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 669583 669583 ***					

Linear regression, absorbing indicators	Number of obs	=	3,239,201
	F(8,671419)	=	4,9451.07
	Prob > F	=	0.000
	R-squared	=	0.8937
	Adj R-squared	=	0.8659
	Root MSE	=	7.9642

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
631	-4.90882	0.0144521	-339.66	0	-4.93714	-4.88049
643	-7.97459	0.0350428	-227.57	0	-8.04327	-7.90591
655	-7.76016	0.0548365	-141.51	0	-7.86763	-7.65268
667	-4.87543	0.0638109	-76.4	0	-5.0005	-4.75036
bill_mo#c.treatment						
619	0	(empty)				
631	-1.42079	0.0238641	-59.54	0	-1.46756	-1.37401
643	-0.82234	0.0345126	-23.83	0	-0.88999	-0.7547
655	-1.08716	0.0549586	-19.78	0	-1.19487	-0.97944

667	-0.72034	0.0645384	-11.16	0	-0.84684	-0.59385
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 671420 671420 ***					

Linear regression, absorbing indicators

Number of obs	=	3,268,187
F(8,674203)	=	5,060.56
Prob > F	=	0.000
R-squared	=	0.8948
Adj R-squared	=	0.8675
Root MSE	=	6.7003

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
632	-1.58006	0.014782	-106.89	0	-1.60904	-1.55109
644	-0.83604	0.0329986	-25.34	0	-0.90072	-0.77137
656	-0.73682	0.0472353	-15.6	0	-0.8294	-0.64424
668	-1.6895	0.0535601	-31.54	0	-1.79447	-1.58452
bill_mo#c.treatment						
620	0	(empty)				
632	0.220677	0.0177559	12.43	0	0.185876	0.255478
644	-0.28234	0.033007	-8.55	0	-0.34703	-0.21765
656	-0.03579	0.0475946	-0.75	0.452	-0.12908	0.057492
668	-0.53646	0.0542967	-9.88	0	-0.64288	-0.43004
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 674204 674204 ***					

Linear regression, absorbing indicators

Number of obs	=	3,282,149
F(8,675407)	=	6,559.55
Prob > F	=	0.000
R-squared	=	0.8807
Adj R-squared	=	0.8498
Root MSE	=	6.023

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
633	-0.14641	0.0152951	-9.57	0	-0.17638	-0.11643
645	-0.43654	0.032699	-13.35	0	-0.50063	-0.37245
657	-1.12804	0.0437282	-25.8	0	-1.21375	-1.04233
669	-2.40365	0.0484878	-49.57	0	-2.49869	-2.30862
bill_mo#c.treatment						
621	0	(empty)				
633	0.099826	0.0172564	5.78	0	0.066004	0.133648
645	-0.06911	0.032864	-2.1	0.035	-0.13352	-0.0047
657	-0.07578	0.044167	-1.72	0.086	-0.16235	0.010784
669	-0.16648	0.0492343	-3.38	0.001	-0.26298	-0.06999
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 675408 675408 ***					

Linear regression, absorbing indicators	Number of obs	=	3,277,779
	F(8,675407)	=	29,988.4
	Prob > F	=	0.000
	R-squared	=	0.8775
	Adj R-squared	=	0.8457
	Root MSE	=	7.9296

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
634	0.809735	0.0343125	23.6	0	0.742484	0.876987
646	2.691673	0.0469082	57.38	0	2.599734	2.783611
658	2.463007	0.059951	41.08	0	2.345505	2.580509
670	-3.44011	0.0622825	-55.23	0	-3.56218	-3.31804
bill_mo#c.treatment						
622	0	(empty)				
634	0.559537	0.0351962	15.9	0	0.490554	0.628521
646	-0.35304	0.0472969	-7.46	0	-0.44574	-0.26034
658	-0.18042	0.0606086	-2.98	0.003	-0.29921	-0.06163

670	-0.45305	0.0633929	-7.15	0	-0.5773	-0.3288
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 674835 674835 ***					

Linear regression, absorbing indicators

Number of obs	=	3,254,277
F(8,675407)	=	38,694.25
Prob > F	=	0.000
R-squared	=	0.8839
Adj R-squared	=	0.8537
Root MSE	=	9.0371

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
635	-0.59765	0.0367039	-16.28	0	-0.66959	-0.52572
647	4.752936	0.0603463	78.76	0	4.634659	4.871213
659	2.177178	0.0696629	31.25	0	2.040641	2.313715
671	-4.75749	0.0717224	-66.33	0	-4.89806	-4.61691
bill_mo#c.treatment						
623	0	(empty)				
635	0.385331	0.0375559	10.26	0	0.311723	0.458939
647	-0.07916	0.0611322	-1.29	0.195	-0.19898	0.040654
659	-0.025	0.0705589	-0.35	0.723	-0.16329	0.113294
671	-0.01412	0.0729895	-0.19	0.847	-0.15718	0.128938
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 672697 672697 ***					

* = fixed effect nested within cluster; treated as redundant for DoF computation

Table 5-4: Regression Coefficients for Cohort 3

Linear regression, absorbing indicators			
	Number of obs	=	1,439,485
	F(5,53112)	=	11,656.12
	Prob > F	=	0.000
	R-squared	=	0.924
	Adj R-squared	=	0.8795
	Root MSE	=	9.4981

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
660	-4.03741	0.0389571	-103.64	0	-4.11376	-3.96106
672	-5.25372	0.0678362	-77.45	0	-5.38668	-5.12076
bill_mo#c.treatment						
648	-0.69739	0.2120417	-3.29	0.001	-1.11299	-0.2818
660	0.461275	0.0389764	11.83	0	0.384882	0.537667
672	-0.39896	0.0677486	-5.89	0	-0.53175	-0.26618
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 531124 531124 ***					

Linear regression, absorbing indicators			
	Number of obs	=	1,774,481
	F(7,534971)	=	13,884.24
	Prob > F	=	0.000
	R-squared	=	0.9089
	Adj R-squared	=	0.8696
	Root MSE	=	9.7682

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
649	1.669091	0.021032	79.36	0	1.627869	1.710313
661	4.830485	0.0426433	113.28	0	4.746906	4.914065
673	-0.45837	0.0672793	-6.81	0	-0.59023	-0.3265
bill_mo#c.treatment						
637	1.701491	3.987865	0.43	0.67	-6.1146	9.51758

649	1.42265	0.1161981	12.24	0	1.194905	1.650395
661	-0.00801	0.0420746	-0.19	0.849	-0.09048	0.074453
673	-0.43122	0.066549	-6.48	0	-0.56165	-0.30078
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 534972 534972 ***					

Linear regression, absorbing indicators

Number of obs	=	1,833,529
F(5,545614)	=	22,103.52
Prob > F	=	0.000
R-squared	=	0.8857
Adj R-squared	=	0.8373
Root MSE	=	8.4536

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
650	-1.31962	0.0185518	-71.13	0	-1.35598	-1.28326
662	-2.78784	0.0349429	-79.78	0	-2.85632	-2.71935
674	-7.36322	0.0611562	-120.4	0	-7.48309	-7.24336
bill_mo#c.treatment						
638	-0.61313	4.152246	-0.15	0.883	-8.7514	7.525141
650	0.653776	0.0848452	7.71	0	0.487482	0.82007
662	-0.08922	0.0325187	-2.74	0.006	-0.15296	-0.02549
674	-0.54891	0.0599729	-9.15	0	-0.66645	-0.43136
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 545615 545615 ***					

Linear regression, absorbing indicators

Number of obs	=	1,800,949
F(7,538452)	=	5,321.92

Prob > F	=	0.000
R-squared	=	0.8875
Adj R-squared	=	0.8395
Root MSE	=	6.2894

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
651	-0.25313	0.013964	-18.13	0	-0.2805	-0.22576
663	-1.76698	0.0267369	-66.09	0	-1.81938	-1.71457
675	-1.84397	0.0466438	-39.53	0	-1.93539	-1.75255
bill_mo#c.treatment						
639	-1.66814	0.9044456	-1.84	0.065	-3.44082	0.104547
651	0.711575	0.0510409	13.94	0	0.611536	0.811613
663	-0.43293	0.0257363	-16.82	0	-0.48337	-0.38249
675	-0.64927	0.046185	-14.06	0	-0.73979	-0.55875
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 538453 538453 ***					

Linear regression, absorbing indicators

Number of obs	=	1,307,974
F(5,478082)	=	4,802.49
Prob > F	=	0.000
R-squared	=	0.9104
Adj R-squared	=	0.8395
Root MSE	=	6.6252

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
652	1.860349	0.015022	123.84	0	1.830906	1.889792
664	3.401588	0.0393103	86.53	0	3.324541	3.478635
bill_mo#c.treatment						
640	-1.76479	1.792113	-0.98	0.325	-5.27728	1.747694

652	0.993712	0.0522762	19.01	0	0.891252	1.096172
664	-1.00988	0.0399177	-25.3	0	-1.08812	-0.93164
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 478083 478083 ***					

Linear regression, absorbing indicators	Number of obs	=	1,329,518
	F(5,478082)	=	20,220.15
	Prob > F	=	0.000
	R-squared	=	0.9195
	Adj R-squared	=	0.873
	Root MSE	=	7.6055

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
653	3.329057	0.0164823	201.98	0	3.296752	3.361362
665	6.864952	0.0470593	145.88	0	6.772717	6.957187
bill_mo#c.treatment						
641	2.138975	0.9856121	2.17	0.03	0.207206	4.070744
653	1.098316	0.0513313	21.4	0	0.997708	1.198924
665	-0.81431	0.0480553	-16.95	0	-0.90849	-0.72012
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 486530 486530 ***					

Linear regression, absorbing indicators	Number of obs	=	1,354,004
	F(5,496811)	=	32,340.93
	Prob > F	=	0.000
	R-squared	=	0.9188

Adj R-squared	=	0.8717
Root MSE	=	7.8862

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
654	-1.1822	0.0165481	-71.44	0	-1.21463	-1.14976
666	6.131956	0.0501981	122.16	0	6.03357	6.230343
bill_mo#c.treatment						
642	5.171823	0.6874035	7.52	0	3.824533	6.519112
654	1.521308	0.0465133	32.71	0	1.430143	1.612472
666	-1.05961	0.0514725	-20.59	0	-1.16049	-0.95872
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 496812 496812 ***					

Linear regression, absorbing indicators

Number of obs	=	1,392,231
F(5,511104)	=	12,107.46
Prob > F	=	0.000
R-squared	=	0.9219
Adj R-squared	=	0.8765
Root MSE	=	7.3802

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
655	0.388286	0.0156132	24.87	0	0.357685	0.418887
667	4.58562	0.0456193	100.52	0	4.496208	4.675033
bill_mo#c.treatment						
643	6.654443	3.518523	1.89	0.059	-0.24175	13.55064
655	0.730407	0.0394433	18.52	0	0.653099	0.807715
667	-0.93664	0.0467282	-20.04	0	-1.02823	-0.84505
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 511105 511105 ***					

Linear regression, absorbing indicators	Number of obs	=	1,422,281
	F(5,522201)	=	1,371.84
	Prob > F	=	0.000
	R-squared	=	0.9189
	Adj R-squared	=	0.8781
	Root MSE	=	6.4189

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
656	0.599252	0.01383	43.33	0	0.572145	0.626358
668	1.70442	0.0401372	42.46	0	1.625752	1.783088
bill_mo#c.treatment						
644	7.184001	4.380494	1.64	0.101	-1.40163	15.76963
656	0.573262	0.0324399	17.67	0	0.509681	0.636843
668	-1.87292	0.0410293	-45.65	0	-1.95334	-1.7925
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 522202 522202 ***					

Linear regression, absorbing indicators	Number of obs	=	1,453,617
	F(5,534416)	=	3,143.37
	Prob > F	=	0.000
	R-squared	=	0.9077
	Adj R-squared	=	0.854
	Root MSE	=	5.7542

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
657	-0.36466	0.0122046	-29.88	0	-0.38858	-0.34074

669	-0.47001	0.0338315	-13.89	0	-0.53631	-0.4037
bill_mo#c.treatment						
645	3.45322	3.44997	1	0.317	-3.30861	10.21505
657	0.343049	0.0283241	12.11	0	0.287534	0.398563
669	-1.11843	0.0346317	-32.29	0	-1.18631	-1.05055
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 534417 534417 ***					

Linear regression, absorbing indicators

Number of obs	=	1,474,444
F(5,543345)	=	28,375.83
Prob > F	=	0.000
R-squared	=	0.9006
Adj R-squared	=	0.8426
Root MSE	=	8.0966

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
658	0.168291	0.016494	10.2	0	0.135963	0.200618
670	-4.78256	0.0444314	-107.64	0	-4.86964	-4.69548
bill_mo#c.treatment						
646	-1.60989	1.272622	-1.27	0.206	-4.10419	0.884409
658	0.314811	0.0382347	8.23	0	0.239872	0.389749
670	-0.90031	0.045925	-19.6	0	-0.99032	-0.8103
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 543346 543346 ***					

Linear regression, absorbing indicators

Number of obs	=	1,467,834

F(5,541061)	=	35,894.03
Prob > F	=	0.000
R-squared	=	0.903
Adj R-squared	=	0.8464
Root MSE	=	9.3949

dailykwh	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
bill_mo						
659	-1.8704	0.021088	-88.69	0	-1.91173	-1.82907
671	-8.01928	0.0541917	-147.98	0	-8.12549	-7.91306
bill_mo#c.treatment						
647	-4.94063	1.18871	-4.16	0	-7.27047	-2.6108
659	-0.02383	0.031911	-0.75	0.455	-0.08638	0.038714
671	-0.73122	0.0554026	-13.2	0	-0.8398	-0.62263
Absorbed degrees of freedom:						
Absorbed FE	**Num. Coefs. = Categoreis - Redundant**					
account_id	**0 541062 541062 ***					

* = fixed effect nested within cluster; treated as redundant for DoF computation

Appendix F Awareness and Engagement Index

The increased engagement and awareness generated by the MyHER program can be difficult to measure. Nexant designed a survey approach that measures different aspects of the MyHER effect, but no one survey question can fully capture the numerous, subtle effects of MyHER that ultimately resulted in the observed energy impacts. Instead, one might expect the overall pattern of survey responses to signal a difference in behavior and attitudes between the MyHER treatment and control group.

Nexant developed a framework for measuring this pattern of MyHER influence by applying straightforward statistical concepts to develop a holistic look at the program's influence on customer behavior. While a single survey question may not result in statistically-significant differences between the treatment and control group, if the treatment group responds more favorably than the control group to a set of survey questions, then we can estimate the probability that the collection of responses fits of a hypothesis of MyHER influence.

Consider a series of coin flips. What is the probability of obtaining 24 heads in 47 coin flips if there is a 50/50 chance of obtaining a heads or tails on any one coin flip? This same principle can be applied to the survey: what is the probability that the treatment group gives a more favorable response to 24 out of 47 survey questions if MyHER has no influence on customer awareness and attitudes about energy efficiency?

Nexant assigned each survey question a category. Table shows the categories, the count of questions in each category for which the treatment group provided a more favorable response than the control group, and the number of questions in each category. A response is considered "favorable" if the treatment group gave a response that is consistent with the program objectives of MyHER.

Table F-1: Classification of Survey Responses and Treatment Group "Success Rate"

Question Category	Count of Questions where T>C	Number of Questions in Topic Area	Portion of Questions where T>C
Duke Energy's Public Stance on Energy Efficiency	3	3	100%
Customer Engagement with Duke Energy Website	3	6	50%
Customers' Reported Energy-saving Behaviors	2	7	29%
Customers' Past & Future Equipment Purchases	7	16	44%
Customer Motivation, Engagement & Awareness of Energy Efficiency	8	11	73%
Customer Satisfaction with Duke Energy	1	4	0%
Total	**24**	**47**	**51%**

If the MyHER program had no effect on participants' awareness, attitudes, and opinions, then we would expect the control group to score better than the treatment group on approximately half of the survey questions. The treatment group provided answers consistent with a MyHER treatment effect in approximately 51% of the survey questions. Using standard statistical techniques (specifically, the non-parametric sign test), Nexant calculated the probability of randomly obtaining this result is 11.5%. The statistical test shows that, overall, we cannot conclude (with a reasonable level of confidence) that the MyHER program has changed the attitudes, awareness, behaviors, and motivations that can lead to saving energy of the customers who receive the reports. However, these survey responses do indicate strengths in the areas of treatment customers' perception of Duke Energy's public stance on energy efficiency as well as their stated levels of motivation, engagement, and awareness of energy efficiency.

Appendix G MyHER Control Group Size Memorandum

September 4, 2015

To: Roshena Ham, Melinda Goins, Rose Stoeckle, Jean Williams; Duke Energy

From: Mike Sullivan, Jesse Smith, Tingting Xue; Nexant

CC: Jim Herndon, Rush Childs, Patrick Burns, Dulane Moran; Nexant

RE: Analysis of Control Group Requirements for DEC MyHER and DEP MyHER Programs

G.1 Introduction

Duke Energy requested that Nexant determine whether it is possible to reduce the control group size of its Duke Energy Carolinas (DEC) MyHER and Duke Energy Progress (DEP) MyHER programs while continuing to meet regulatory EM&V requirements and manage its own risk of under compensation for achieved energy savings. Nexant conducted the analysis of the control group sizes for both DEC and DEP MyHER programs. This memorandum provides detailed information about the analysis, findings, and Nexant's recommendations.

G.2 Background

The DEC and DEP MyHER programs consist of customers from both North Carolina and South Carolina. The programs' backgrounds, key concepts, considerations, and objectives for control group size analysis are the same as those for the DEO MyHER program, which were well-defined in Nexant's DEO MyHER Program Evaluation Report and Memorandum of Control Group Requirements for DEO MyHER.

G.3 Study Approach & Methodology

Nexant's control group analysis for DEP and DEC followed the same study approach used to determine an appropriate control group size for the DEO MyHER program. The simulation was based on DEC and DEP MyHER program tracking records and monthly billing records from Duke's data warehouse. According to Duke Energy's request, there is no need to estimate effects for North Carolina and South Carolina separately. Nevertheless, separate impact estimates for DEC and DEP are desired for the foreseeable future. Nexant also observed a consistent difference in mean energy consumption between the MyHER populations in DEC and DEP (DEP customers use more energy on average). This difference could complicate impact analyses if the two jurisdictions were aggregated. Nexant therefore conducted the analysis of control group size separately for the DEC and DEP MyHER programs. This memorandum describes Nexant's simulation process, its results, and recommendations for how the results may be used by Duke Energy to select its preferred control group size for DEC and DEP MyHER programs.

Because the control group size analysis was conducted in advance of the impact evaluation, there is some uncertainty in what the average savings per home will be for DEP and DEC.

Nexant's approach was to target an absolute margin of error equal to ± 15 kWh per home at the 90% confidence level. Therefore, the relative precision will be a function of the estimated impact size. If the average savings per home turns out to be 150 kWh, the relative precision will be ± 10%. If the average impact is 250 kWh per home, the relative precision will equal ± 6%.

G.4 DEC MyHER Program

Unlike the DEP MyHER program, DEC MyHER had waves of homes assigned through the years of 2010 to 2015. Therefore, the simulations needed to consider the need to analyze these cohorts separately. We defined three distinct cohorts: 2010 customer group, 2012 & 2013 customer group, and 2014 & 2015 customer group, with a separate analysis for each. The overall absolute margin of error for the DEC MyHER was then combined mathematically. The number of active accounts as of June 2015 in the treatment and control groups of DEC MyHER is listed in Table 5-5.

Table 5-5: DEC MyHER Program Control and Treatment Accounts Summary

Duke Energy Carolinas (DEC)		
Year Added	**Treatment Accounts**	**Control Accounts**
2010	6,485	21,195
2012	579,796	126,934
2013	66,867	1,574
2014	381,240	47,440
2015	50,457	29,863
DEC Total	**1,084,845**	**227,006**

G.5 Simulation Process

The simulation process for the DEC MyHER was the same as DEP MyHER, but conducted separately for the three cohorts. For each control group size, the process was repeated 500 times. Since there were no North Carolina customers in the treatment and control groups in the year of 2010, the 2010 cohort only includes customers from South Carolina. The 2012 & 2013 cohort and 2014 & 2015 cohort include both North Carolina and South Carolina customers.

G.6 Results and Recommendations

Table 5-6 presents the simulation results for the DEC MyHER program. Our recommended control group size for each cohort is shown in green: 10,000 for cohort 1; 35,000 for cohort 2; and 35,000 for cohort 3. This will result in a control group size of 80,000 in total for the DEC MyHER program. Each absolute margin of error (kWh) at 90% confidence level that listed in Table 5-6 corresponds to each individual control group size.

Table 5-6: Simulation Results for DEC MyHER "False Experiment"

Cohort Number	Cohort Description	Active Accounts	Control Group Size	Treatment Group Size	Absolute Margin of Error (kWh) at 90% Confidence
1	2010 South Carolina Customers	27,680	**10,000**	17,680	**+/- 46.3**
			15,000	12,680	+/- 45.9
2	2012 & 2013 Carolina Customers	775,171	**35,000**	740,171	**+/- 20.3**
			40,000	735,171	+/- 19.2
			50,000	725,171	+/- 17.7
			75,000	700,171	+/- 15.0
3	2014 & 2015 Carolina Customers	509,000	**35,000**	474,000	**+/- 20.6**
			40,000	469,000	+/- 19.6
			60,000	449,000	+/- 17.2

The combined margin of error across the three DEC cohorts will be narrower than any of the groups individually. The calculation of the combined error bound is shown below.

Step 1: Calculate Error Bound for each cohort based on recommended control group size:

$$Error\ Bound\ of\ Cohort = n * AE$$

Where:

n = Treatment Group Size = Number of Active Accounts – Recommended Control Group Size

AE = Absolute Margin of Error at 90% Confidence Level (kWh) of each cohort

Error Bound of Cohort 1 = 17,680 * 46.3157 = 818,862

Error Bound of Cohort 2 = 740,171 * 20.3272 = 15,045,610

Error Bound of Cohort 3 = 474,000 * 20.5953 = 9,762,171

Step 2: Calculate Combined Error Bound:

$$Combined\ Error\ Bound = \pm \frac{\sqrt{rb1^2 + rb2^2 + rb3^2}}{N1 + N2 + N3}$$

Where:

rb1, rb2, & rb3 = Error Bounds of Cohort 1, 2 & 3, respectively

N1, N2, & N3 = Remaining Treatment Group Size for Cohort 1, 2 & 3, respectively

$$Combined\ Eror\ Bound = \pm \frac{\sqrt{818{,}862^2 + 15{,}045{,}610^2 + 9{,}762{,}171^2}}{17{,}680 + 740{,}171 + 474{,}000}$$

$$\boldsymbol{Combined\ Error\ Bound} = \pm \mathbf{14.6\ kWh}$$

Nexant recommends Duke release approximately 147,000 homes from control to treatment in DEC territory. Table 5-7 shows the number of homes to release from each group.

Table 5-7: Number of homes to release from each cohort for DEC MyHER

Cohort	Cohort Description	Current Control Size	Target Control Size	Number of Accounts to Release
1	2010 South Carolina Customers	21,195	10,000	11,195
2	2012 & 2013 Carolina Customers	128,508	35,000	93,508
3	2014 & 2015 Carolina Customers	77,303	35,000	42,303
DEC Total		**227,006**	**80,000**	**147,006**

G.7 Next Steps

We understand that Duke may wish to move quickly and implement control group release in Ohio and the Carolinas during the October cycle of MyHER. As a result, Nexant has randomly selected control group accounts to release in each jurisdiction should Duke elect to follow the recommendations in this memo and the MyHER Ohio EM&V report. These files were uploaded to the project's secure file transfer protocol (sftp) site in a file named "Control Group Accounts to Release by Jurisdiction – Nexant Recommendations.xlsx". Each group of control group accounts was selected randomly and tested for equivalent usage patterns against the accounts that will remain in the control group. Since the remaining control group accounts will essentially be serving double-duty and providing baseline usage against which to measure impacts of both the original treatment group and this newly released treatment group, Nexant also validated that the pre-assignment usage of the new, smaller control groups show no statistically significant differences with the original treatment group to which they will be added.

Appendix H Review of Ex-ante Savings Estimates Memo

February 10, 2016

To: Benjamin Lowe, Melinda Goins, Rose Stoeckle, Jean Williams; Duke Energy
From: Rush Childs, Mike Sullivan; Nexant
CC: Jim Herndon, Patrick Burns, Dulane Moran; Nexant
RE: Review of Ex-Ante Savings Assumptions – DEC & DEP

H.1 Background

Duke Energy has retained Nexant to perform an impact and process evaluation of its MyHER program in Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) jurisdictions. The evaluation period of performance will be May 2015 through April 2016 for both jurisdictions. This memorandum is pursuant to Milestone D of the Statement of Work for the evaluation – "Review of Ex Ante Estimated/Deemed Savings Assumptions". The MyHER program is an energy awareness and conservation initiative that provides participating homes with reports eight times per year that compare their energy consumption to comparable homes and provide recommendations for saving energy. The review presented in this memo is based on evaluations conducted in other jurisdictions as well as files describing energy consumption for treatment and control groups provided to Nexant by Duke for a 2015 sample size simulation analysis. A brief description of these files is included below.

1) *MyHER deemed savings report DEI DEO DEK DEC 02 01 2015.xlsx.* The savings assumptions shown in Table 5-8 were taken from this spreadsheet.

Table 5-8: DEC and DEP MyHER Ex-Ante Savings Assumptions

State	Measure Name	Annual kWh Gross w/o losses	Saved Summer Coincident kW w/o losses	Annual non-coincident kW w/o losses	Measure Life	Free Rider %
SC	My Home Energy Report (EMV 11.1.13)	183.7	0.0389	0.0572	1	0.00%
NC	My Home Energy Report (EMV 11.1.13)	183.7	0.0389	0.0572	1	0.00%

2) *Program Year 2 (2012-2013) EM&V Report for the Residential Energy Efficiency Benchmarking Program*. This previous evaluation report was submitted in 2014 and examined impacts of an HER offering from a different vendor on approximately 60,000 households.

3) *Process and Impact Evaluation of the My Home Energy Report (MyHER) Program in the Carolina System.* This previous evaluation was submitted in February 2014 and is the basis of the 183.7 kWh per home savings estimate in Table 5-8.

4) *DEC and DEP Sample Composition and Size Analysis - Data Request Response.* On June 5, 2015 Nexant requested a participant list and billing history of each account in the MyHER control and treatment group in the Carolinas. The intent of this data request was to examine the relationship between control group size and the precision of MyHER impact estimates. Ultimately, Nexant recommended a reduction in the control group size for both jurisdictions and Duke implemented the control group release in October 2015. This data set provided useful information about the average electric consumption per home and early indication of the magnitude of savings.

5) *My Home Energy Report Program Evaluation.* This report was submitted in September 2015 and summarized Nexant's evaluation of MyHER in DEO service territory.

H.2 Benchmarking

The 184 kWh/year average impact per treatment customer claimed by Duke in the Carolinas is comparable to other deployments of home energy report programs across the United States. Table 5-9 shows energy savings estimates from 12 other HER deployments, including two in the Duke Energy system. Although this type of summary information can be deceptive because it does not account for differences in the types of homes targeted, duration of exposure, heating fuel saturations, or weather, it indicates that 184 kWh per home annually is a comfortably in the middle of the annual impact estimates observed in other jurisdictions.

Table 5-9: Annual Impact Estimates from HER Deployments

Utility	Implementation Period	# of Treatment Customers	Annual kWh per Treated Home
Pennsylvania Power & Light	June 2012-May 2013	93,924	388
AEP Ohio	2012	197,646	377
Puget Sound Energy	2013	40,000	325
Com-Ed	June 2010-May 2011	45,171	282
Indianapolis Power & Light Company	March 2012-February 2013	25,000	266
Duke Energy Ohio	March 2014-February 2015	299,000	256
Connexus Energy	March 2009-January 2010	40,000	229
Indiana Michigan Power	May 2012-December 2012	47,987	200
FirstEnergy Ohio	2013	73,000	175
Ameren Illinois	August 2010-November 2011	198,494	159
Duke Energy Indiana	August 2014-July 2015	~140,000	~150[3]
Pacific Gas & Electric	2014	1,017,692	104

[3] The DEI MyHER impact estimate is still preliminary at the time this memo was drafted and may change based on the QA\QC process

Because of the differences in pre-treatment electric consumption across jurisdictions and HER deployments it is helpful to also consider impacts on a relative or percent reduction basis. Nexant examined the average billed consumption for members of the DEC and DEP MyHER control groups in 2013 and 2014 and found that DEP homes have higher average consumption than DEC homes. Figure 21 shows the average billed kWh by month for the two jurisdictions as well as the number of control group homes analyzed. The DEP average consumption is higher in all 24 months.

Figure 21: Baseline Consumption Comparison

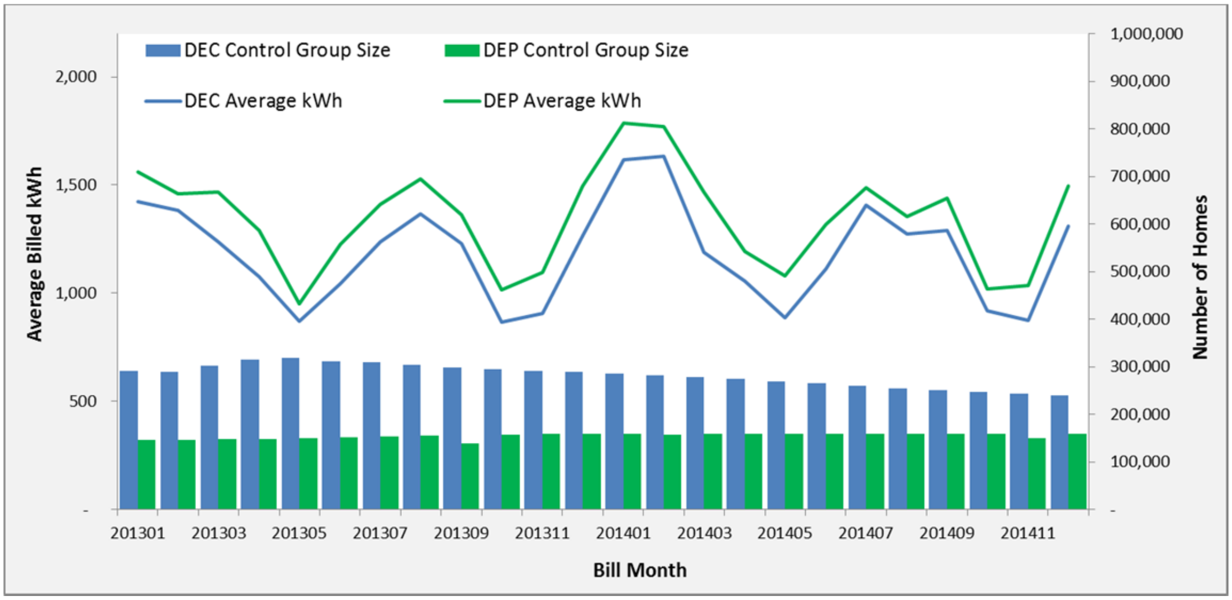


Table 5-10 provides the average annual control group consumption by year for DEC and DEP in addition to a two-year average. The ex-ante savings claim of 183.7 kWh per home represents a 1.29% reduction in consumption for DEC and a 1.14% reduction in consumption for DEP. HER studies generally reveal a percent reduction between 1% and 2%, so the Carolinas ex-ante savings claim appears relatively conservative.

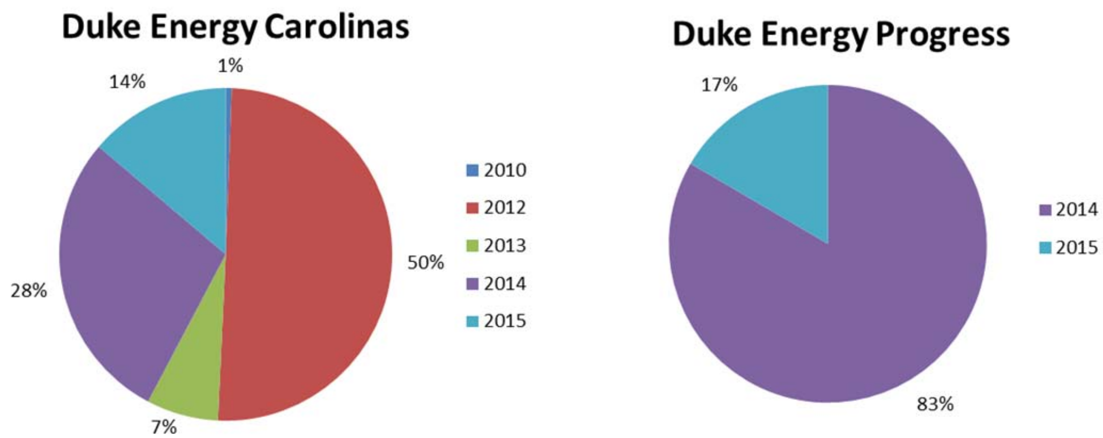
Table 5-10: Average Annual Control Group Consumption by Jurisdiction

Year	DEC	DEP
2013	13,902	15,862
2014	14,569	16,445
Two Year Average	14,235	16,154

H.3 Duration of Exposure

While MyHER participants in DEP service territory have a higher average electric consumption, the MyHER program is more mature in DEC territory. Half of the MyHER treatment group in DEC territory has been receiving MyHER since fall 2012, while MyHER wasn't broadly rolled out in DEP until December 2014. Figure 22 shows the shares of each jurisdiction's treatment group that began receiving MyHER in each year 2010-2015.

Figure 22: Distribution of MyHER Treatment Group by Year of First MyHER Mailer



Nexant's evaluation of MyHER impacts in DEO service territory found a clear upward trend in the magnitude of savings as the duration of exposure increased. This finding is consistent with most other multi-year evaluations of HER impacts across North America. Table 5-11 shows the average kWh impact for homes in the DEO treatment group that received MyHER consistently from beginning of 2012. Each year the kWh savings increase by more than 50 kWh over the previous year.

Table 5-11: Increasing Effect of MyHER over Time (MyHER DEO)

Year	Average Observed kWh Savings per Home	HDD (Base 65 F)	CDD (Base 65 F)
2012	110	4,199	1,439
2013	168	5,029	1,150
2014	220	5,438	1,077

Nexant's analysis to date of MyHER impacts in DEI territory also supports the correlation between duration of exposure and average kWh per home. The homes in DEI who have been receiving MyHER since 2012 produce average annual[4] impacts over 200 kWh per home, while the large group of homes assigned to MyHER in February 2014 averaged less than 150 kWh per home. If the expected relationship between duration of exposure and kWh impacts holds true in the Carolinas, we would expect to see a larger average treatment effect (on a % basis) in DEC territory than DEP.

H.4 Control Group Release

[4] The DEI period of performance analyzed by Nexant is August 2014 through July 2015

The shares presented in Figure 22 were calculated *after* fairly large change in the MyHER group composition that occurred in the middle of the evaluation period of performance. In October 2015 approximately 72,000 homes in DEP and 147,000 homes in DEC were released from the MyHER control group to the treatment group and began receiving MyHER mailers[5]. While this control group release increases the number of homes receiving MyHER, it likely dilutes the average per home impact because the average duration of exposure of homes in the DEC and DEP treatment groups was reduced for November 2015 through April 2016. In both jurisdictions approximately 10% of the treatment group from November 2015 to April 2016 will consist of homes that are new to MyHER and should be expected to have modest savings levels as they will be in the first six months of treatment.

H.5 Previous Evaluation

Nexant also reviewed the previous impact evaluation reports and found no methodological issues that would compromise the findings. However, there are some important programmatic changes that limit the applicability of findings on a forward looking basis.

1) The previous DEP evaluation conducted by Navigant (*Program Year 2 (2012-2013) EM&V Report for the Residential Energy Efficiency Benchmarking Program)* found an average per home annual impact of 260 kWh. During the period analyzed the program was much smaller than its current scope in DEP at approximately 60,000 treatment group homes. The HER vendor for this period was also different with Opower implementing the program rather than Tendril. This evaluation found a difference in savings for the two waves of homes consistent with previous discussions about duration of exposure. The Initial Wave of homes produced average savings of 1.63% (280 kWh) while the Refill Wave that began treatment 18 months later produced average savings of 1.22% (172 kWh).
2) The previous DEC evaluation conducted by TecMarket Works and Integral Analytics (*Process and Impact Evaluation of the My Home Energy Report (MyHER) Program in the Carolina System)* was the basis of the 183.7 kWh per home ex-ante savings. This analysis examined the impacts from June 2012 (SC) and October 2012 (NC) to August 2013 and included approximately 750,000 treatment group homes. The homes analyzed in this previous evaluation represent approximately half of the total DEC treatment group homes Nexant will be analyzing so it is a good indicator of expected impacts. These 750,000 homes will have been exposed to the program for several additional years so their average impacts would be expected to increase. DEC treatment groups that have been added since the previous evaluation will have a shorter duration of exposure and may offset the expected gains from Legacy homes.

Both evaluations utilized a linear fixed effects regression (LFER) model to estimate the treatment effect using billed consumption data provided by Duke. Nexant reviewed the methodology and results presented in the two reports and found no methodological concerns

[5] For the period May to October 2015, the share of homes that began receiving treatment in 2015 would be lower than what is presented in Figure 22

with the approach taken that would cast doubt on the resulting impact estimates. In both the cases, it is important to remember that the current program composition is very different from what was studied previously.

H.6 Randomization

In December 2014 the current DEP MyHER program was launched and the DEC MyHER program was expanded substantially. The kWh savings observed among these waves of homes assigned to MyHER will be critical to the results of the upcoming evaluation as they make up approximately 30% of the current DEC treatment group and over 80% of the current DEP treatment group. Fortunately a large number of homes were randomly assigned to the control group at the same time.

Figure 23 compares the usage of the DEC treatment and control groups added in December 2014 for each month in 2014 (before anyone received a MyHER report). Figure 24 provides a similar comparison for DEP homes assigned to MyHER in December 2014. The dark blue box extends from the 25th percentile to the 75th percentile and the small vertical line is the median. Both plots show that electric consumption patterns of the treatment and control groups are very well aligned. This high quality randomization will minimize the degree to which the regression analysis will need to control for pre-existing differences and produce highly defensible impact estimates.

Figure 23: Comparison of 2014 Usage for December 2014 DEC Assignments

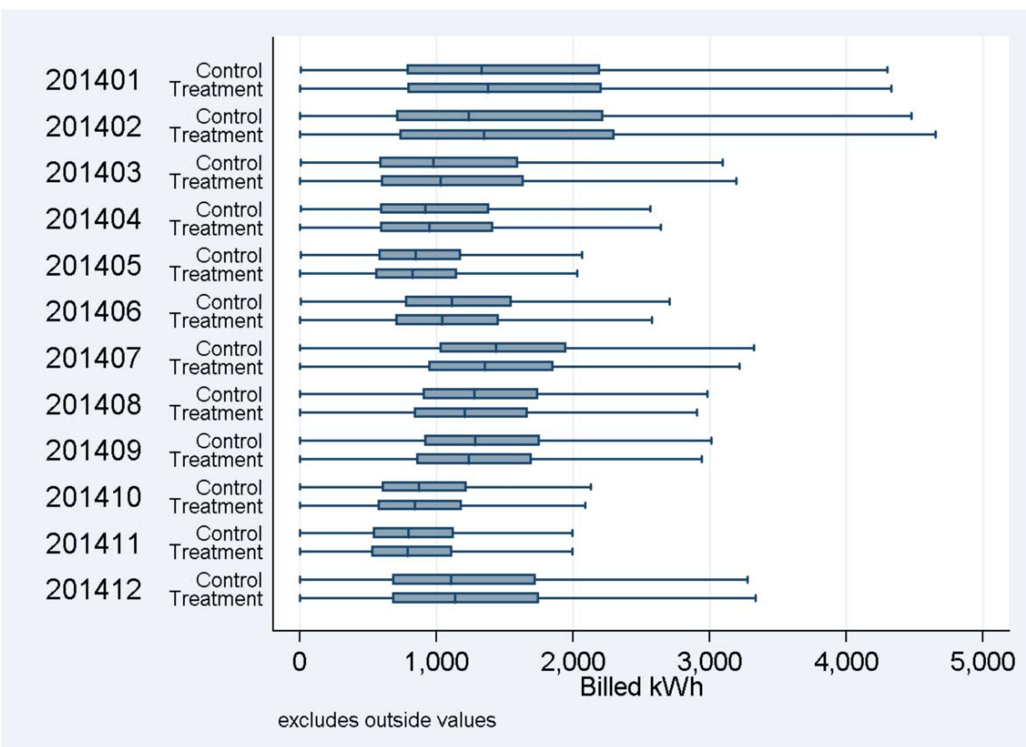
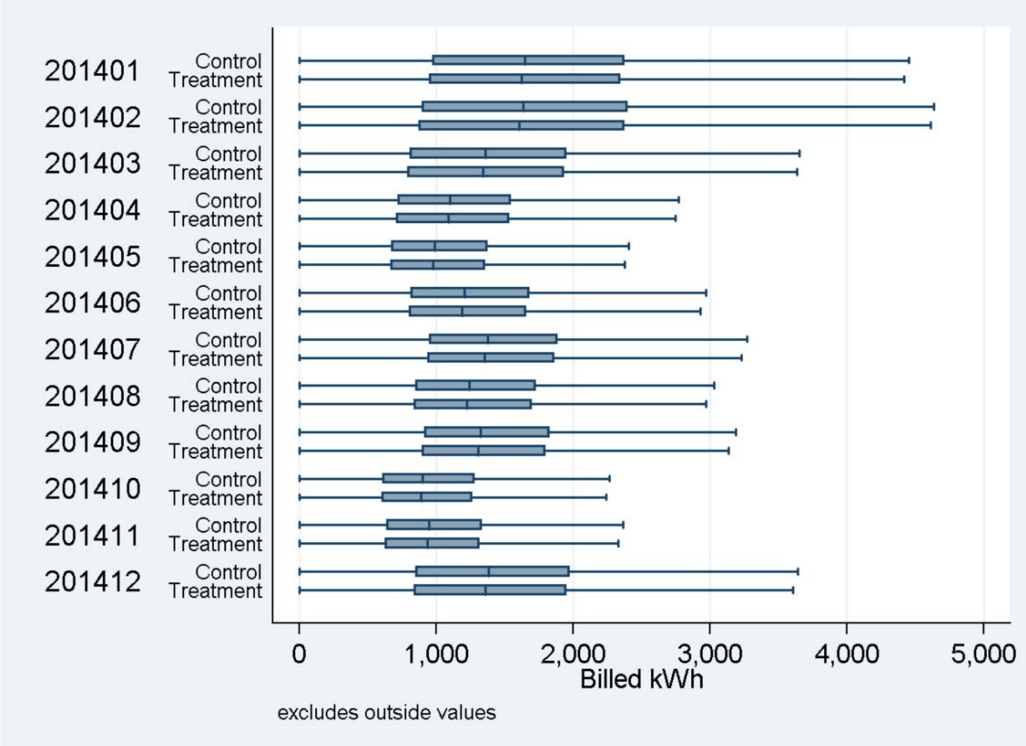


Figure 24: Comparison of 2014 Usage for December 2014 DEP Assignments



REPORT

Reimagine tomorrow.

Duke Carolinas 2016 Power Manager Evaluation

April 11, 2017

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Abstract

This study analyzes the impact of Duke Energy Carolina's Power Manager program on electricity demand for a range of weather conditions, dispatch hours, and load control strategies. Power Manager is a voluntary demand response program that provides incentives to residential customers who allow Duke Energy to reduce the use of their central air conditioner's outdoor compressor and fan on summer days with high energy usage. A key objective of the 2016 evaluation was to quantify the relationship between demand reductions, temperature, hour of day, and cycling strategy—referred to as the time temperature matrix. By design, a large number of events were called under different weather conditions, for different dispatch windows, using various cycling strategies so that demand reduction capability could be estimated for a wide range of operating and planning conditions. Duke Energy Carolinas uses the program's emergency load shed capability for a 102˚F day for planning. While emergency operations are rare and ideally avoided, they represent the full demand reduction capability of Power Manager. If 100% emergency shed becomes necessary on a 102˚F day, Power Manager can deliver 1.87 kW of demand reductions per device or 2.22 kW per household. Because Power Manager currently includes approximately 229,000 devices, the expected aggregate reduction capability is 427.1 MW.[1]

Acknowledgements

The study required careful collaboration with the Duke Energy Carolina's evaluation and operations team, MadDash, Inc., Nexant field engineers, and Nexant's survey data collection lab. In specific, the inputs from Duke Energy's team—Bob Donaldson, Michael Corn, Marjan Salek, Rose Stoeckle, Danielle Maple and Regina Harris—were critical to proper implementation of the study and the analysis. Their comments and edits are reflected throughout the report. Marjan deserves special mention because she took on the critical task of addressing individual devices to the research group and, thus, enabled more extensive testing of operations. Dr. Michael Sullivan and Dr. Jon Cook provided critical input to the design of the study and the sample size simulations. A special thanks to Mad Dash, Inc. whose staff implemented the installation of air conditioner end use data loggers and inspected load control devices. Nexant field engineers were critical in retrieving end use data loggers and downloading the data. The Nexant survey data collection team led the recruitment of the end use sample, coordinated scheduling between field staff and customers, implemented the survey data collection, and coordinated the retrieval of data loggers.

[1] Aggregate impacts are presented throughout the report without rounding error. For example, while 1.87 kW x 229,000 devices equals 428.2 MW, the more granular impacts per device, 1.8652 kW per device were used to estimate aggregate impacts of 427.1 MW (1.8652 kW x 229,000 devices).

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1 Executive Summary

This report presents the results of Nexant's 2016 Power Manager impact and process evaluations for the Duke Energy Carolinas territory. Power Manager is a voluntary demand response program that provides incentives to residential customers who allow Duke Energy to reduce the use of their central air conditioners' outdoor compressors and fans on summer days with high energy usage. Events are typically called on the hottest summer days and are categorized into three groups: 50% cycling; 64% cycling; and 100% shed. During 50% and 64% cycling events, air conditioner control is randomly phased in over the first half hour of the event. At the end of those first 30 minutes, the cycling reduction is sustained through the remainder of the event (typically two or three hours). Over the last 30 minutes of a cycling event, air conditioning control is phased out in the order in which it began. During 100% shed events, which are designed for use during emergency conditions, all devices are instructed to instantaneously shed loads and deliver larger demand reductions than cycling events.

1.1 Impact Evaluation Key Findings

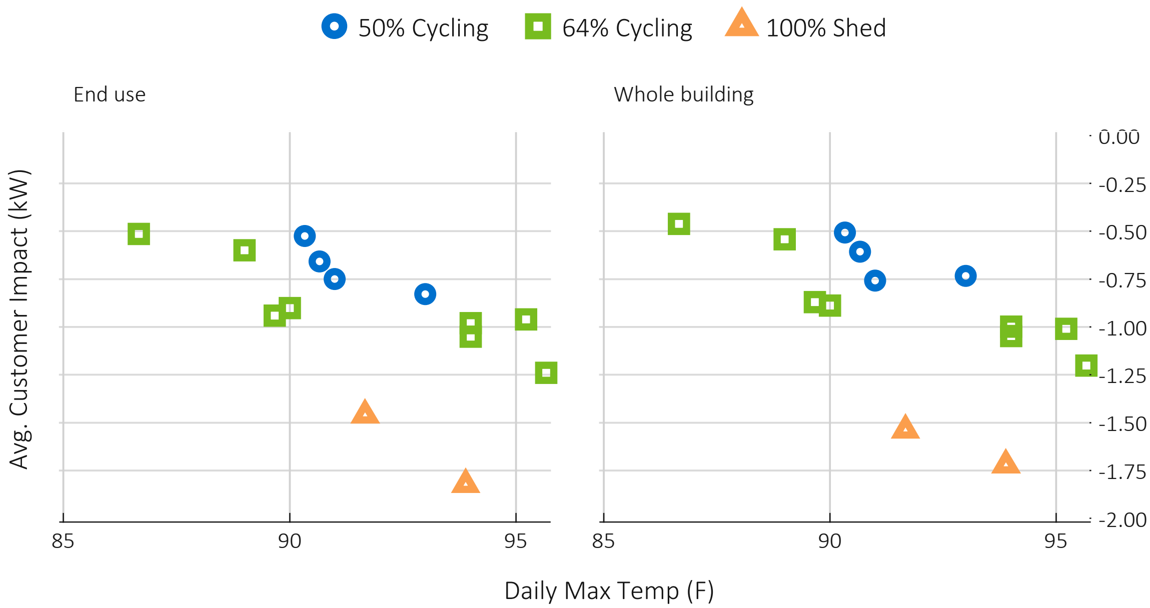
The impact evaluation results are based on customer regressions at the air conditioner (end use) and whole building levels. Nexant collected AC end use data via loggers installed directly on customers' outdoor air conditioner condensing units. Whole building loggers were installed at 122 premises, whereas end use loggers were installed on 144 air conditioners. In the end, 104 whole building loggers and 119 end use loggers were used in the final analysis dataset.[2] In situations where customers had more than one air conditioner, loggers were installed on each. The primary evaluation results are based on the end use data because it produces more precise estimates (due to the larger signal-to-noise ratio). Unless otherwise stated, load impacts are presented on a per customer basis throughout this report.

At the end of summer 2016, approximately 229,000 air conditioner units were actively participating in Power Manager and had load control devices installed. The average household had 1.19 load control devices installed.

Figure 1-1 summarizes the load impacts for all 2016 curtailment events as a function of temperature for whole building and end use logger data. A few notable trends are apparent. Perhaps most important, demand impacts grow in magnitude as temperatures increase—the Power Manager performs best when resources are needed most. Second, as expected, more extensive load control operations (e.g., 64% versus 50% cycling) lead to larger demand reductions. Under hotter conditions in 2016, load reductions exceeded 0.75 kW and 1.0 kW with 50% and 64% load cycling, respectively. Despite being called on cooler days, the 100% shed delivered load reductions of 1.46 kW per household on a 91.7˚F day and 1.82 kW per household on a 93.9˚F day. Third, the temperatures for the 100% shed event fell short of the 102˚F temperature peak expected in extreme years and, as a result, the 2016 shed events do not reflect the load shed capability used for planning.

[2] Some logging devices either did not record data, or returned spurious or unusable data.

Figure 1-1: Load Reduction by Cycling Level as a Function of Temperature



Impacts de-rated for inoperable devices (6.5%)

Table 1-1 summarizes the impacts attained during each event called in 2016 at the whole building and end use levels. By design, events were called under different weather conditions and for different dispatch windows to help define program performance under different operating conditions. At the end use level, average impacts were 0.69 kW, 0.90, and 1.64 kW during the 50%, 64%, and 100% control events, respectively, with larger impacts occurring on event days with higher temperatures. Average demand reductions were 0.65 kW, 0.88 kW, and 1.63 kW during the 50%, 64%, and 100% load shed events, respectively, at the whole house level. The demand impacts were nearly identical regardless of data source analyzed (i.e., whole building vs. end use) and differences are not statistically significant. There is no evidence that customers are compensating for air conditioner load control by increasing other loads.[3]

A key objective of the 2016 evaluation was to quantify the relationship between demand reductions, temperature, hour of day, and cycling strategy—referred to as the time-temperature matrix. In order to develop the time-temperature matrix, the 2016 events were intentionally called for a range of different temperatures, under different cycling strategies and for different dispatch data. The data collected on the weather sensitivity of air conditioner load and the reductions observed for events tested were used to develop estimates of demand reduction for a range of temperatures, including the 102˚F conditions that drive resource planning. The system temperature conditions are calculated by

[3] The comparison of air conditioner end use and whole building loads was implemented not just for Duke Energy Carolinas, but for Duke Energy Ohio, and Duke Energy Indiana. Each analysis produced similar findings. Similar tests have been conducted and PG&E, SDG&E, and IESO and reached similar conclusions.

averaging hourly temperatures of weather stations in Greenville/Spartanburg, South Carolina, Charlotte, North Carolina, and Greensboro, North Carolina. Because dispatch hours vary for individual events, throughout this document, the maximum system temperature for the day is reported for comparison.[4]

Table 1-1: Summary of Event Impacts for Whole Building and End Use

True Cycle	Date	Event Start	Event End	Whole Building			End use (for household)			Daily Max ˚F
				Load without DR	Impact	% Impact	Load without DR	Impact	% Impact	
50%	7/20/2016	3:30 PM	6:00 PM	3.59	-0.76	-21.1%	1.98	-0.75	-38.0%	91.0
	9/6/2016	3:30 PM	6:00 PM	2.68	-0.51	-18.9%	1.47	-0.52	-35.6%	90.3
	9/8/2016	1:30 PM	4:00 PM	3.37	-0.73	-21.8%	1.95	-0.83	-42.5%	93.0
	9/14/2016	3:30 PM	6:00 PM	3.19	-0.61	-19.0%	1.68	-0.66	-39.4%	90.7
	Average	N/A	N/A	**3.21**	**-0.65**	**-20.3%**	**1.77**	**-0.69**	**-39.1%**	**91.3**
64%	6/16/2016	2:30 PM	5:00 PM	3.30	-1.00	-30.3%	1.91	-0.98	-51.4%	94.0
	6/23/2016	2:30 PM	6:00 PM	3.46	-1.05	-30.2%	2.03	-1.05	-51.7%	94.0
	7/8/2016	2:30 PM	6:00 PM	3.94	-1.01	-25.7%	2.28	-0.96	-42.1%	95.2
	7/14/2016	1:30 PM	4:00 PM	3.85	-1.20	-31.2%	2.30	-1.24	-53.9%	95.7
	8/12/2016	3:30 PM	6:00 PM	3.36	-0.87	-25.9%	1.96	-0.94	-48.0%	89.7
	8/31/2016	3:30 PM	6:00 PM	3.39	-0.89	-26.2%	1.90	-0.90	-47.5%	90.0
	9/15/2016	3:30 PM	6:00 PM	2.62	-0.54	-20.7%	1.40	-0.60	-42.9%	89.0
	9/19/2016	1:30 PM	4:00 PM	2.64	-0.46	-17.5%	1.33	-0.51	-38.6%	86.7
	Average	N/A	N/A	**3.32**	**-0.88**	**-26.4%**	**1.89**	**-0.90**	**-47.6%**	**91.8**
100%	8/26/2016	4:00 PM	4:20 PM	3.75	-1.72	-45.9%	2.32	-1.82	-78.7%	93.9
	9/7/2016	5:00 PM	5:20 PM	3.44	-1.54	-44.8%	1.87	-1.46	-78.2%	91.7
	Average	N/A	N/A	**3.59**	**-1.63**	**-45.4%**	**2.09**	**-1.64**	**-78.5%**	**92.8**

* Load impacts reported exclude the first half hour when air conditioner control is randomly phased in.

Because Power Manager delivers larger reductions when temperatures are hotter, the expected load reduction for a 102˚F day are 1.87 kW per device or 2.22 kW per household using 100% shed during the peak hour. At that temperature, expected reductions from non-emergency dispatch – defined as a three

[4] The temperatures during event hours may be lower since electric loads lag temperature peaks due to insulation in homes, coincidence of residential and nonresidential loads and occupancy patterns.

hour 64% cycling event, starting at 3pm – is 1.46 kW per device or 1.74 kW per customer. With 50% cycling, reductions are 0.89 kW per device or 1.05 kW per customer for a three hour event.

Key findings of the impact evaluation include:

- Demand reductions at the end use level were 0.69 kW for the average 50% cycling event, 0.90 for the average 64% cycling event, and 1.64 kW for the average 100% shed event.
- Demand reductions at the whole house level were 0.65 kW per household for the average 50% cycling event, 0.88 kW for the average 64% cycling event, and 1.63 kW for the average 100% shed event.
- Impacts grow larger in magnitude when temperatures are hotter and more AC loads are available for curtailment.
- There is a clear relationship between weather, degree of load cycling control, and the magnitude of impacts.
- Reductions exceeded 1.0 kW per participant multiple times with 64% cycling and 100% shed despite temperatures that fell far short of 102˚F used for system planning.
- Based on the empirical data, Power Manager is expected to deliver 1.87 kW per device or 2.22 kW per household if 100% shed becomes necessary on an extreme weather day, when temperatures are expected to reach 102 ˚F.
- There is no evidence that customers compensate for air conditioner curtailments by increasing other end uses—whole building impacts are indistinguishable from end use impacts.
- Based on field tests for 154 load control devices, 144 (93.5%) of devices were operable, with a 90% confidence interval of ±3.27%.

1.2 Process Evaluation Key Findings

The process evaluation was 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 implemented immediately after an event, and a nonevent day survey implemented on a day with event-like temperatures but without a load control event being called.

Key findings from the process evaluation include:

- 95 Power Manager participants were surveyed within 24 hours of the September 8 event, which had a high temperature of 94°F with a heat index of 95°F.
- 89 Power Manager participants were interviewed during a hot nonevent day, July 13, which had a high of 95°F with a heat index of 95°F. The nonevent day survey was used to establish a baseline for comfort, event awareness, and other key metrics.
- A strong majority of all respondents, 85%, reported that they are familiar with the Power Manager program.

- Only 12% of respondents on the event day reported that their homes were uncomfortable, while all of them experienced a load control event that afternoon. By comparison, 13% of Power Manager customers surveyed on a hot nonevent day reported they felt uncomfortably hot. This small difference is not statistically significant—we cannot conclude that there is a difference in customers' thermal discomfort due to Power Manager events.
- More than 85% of participants would recommend the Power Manager program to others.
- The Power Manager staff and vendors are customer focused and undertake a number of activities both during the load control season and afterward to ensure that participants are satisfied with their Power Manager program experience.

2 Introduction

This report presents the results of the 2016 Power Manager impact and process evaluations for the Duke Energy Carolinas (DEC) territory. Power Manager is a voluntary demand response program that provides 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. The DEC operations team schedules and calls Power Manager events for testing, economic, or system emergency purposes.

2.1 Key Research Questions

The study data collection and analysis activities were designed to investigate impact and process evaluation research questions.

Impact Evaluation Research Questions

- What were the demand reductions achieved during each event called in 2016?
- Did impacts vary for customers in normal and high load control options?
- Were impacts at the whole building level (net) different from AC end use demand reductions (gross)?
- Do impacts vary based on the hours of dispatch and/or weather conditions? If so, how?
- What is the device failure rate?

Process Evaluation Research Questions

- What is the extent to which participants are aware of events, bill credits, and other key program features?
- What is the participant experience during events?
- What are the motivations and potential barriers for participation?
- What are the processes associated with operations and program delivery?
- What are program 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 cycle their central air conditioner's outdoor compressor and fan on summer days with high energy usage. All Power Manager participants have a load cycling switch device installed on all of their outdoor air conditioner units. The device reduces the customer's air conditioner run time when a Power Manager event is called. Duke Energy Carolinas (DEC) initiates events by sending a signal to all participating devices through its own paging network. The signal instructs the switch devices to cycle or fully shed the air conditioning system, reducing AC load during events. The DEC operations team schedules and calls Power Manager events for testing, economic, or system emergency purposes.

The DEC Power Manager event season runs between June and September and participants receive financial incentives for their participation in the form of $8 credits applied to each of their July through October bills. DEC switches use a TrueCycle algorithm, which uses stored historic data, to estimate the run time (or duty cycle) of air conditioners as a function of hour of day and temperature at each specific site, and aims to curtail use by a specified amount—50%, 64%, or 100% (emergency shed).

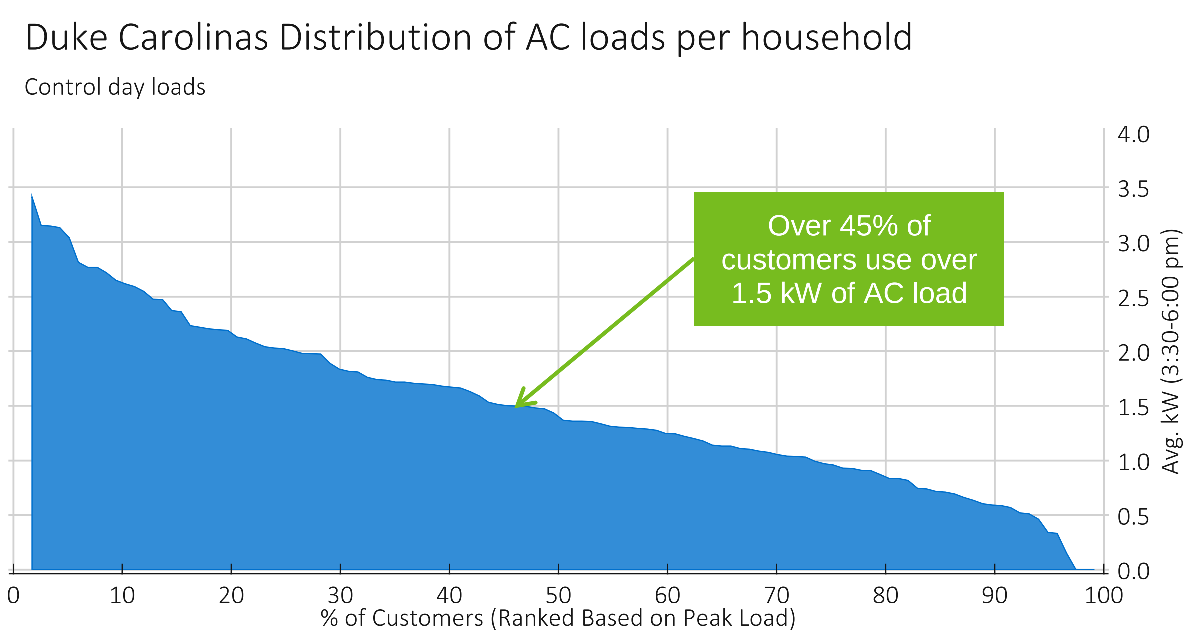
2.3 Participant Characteristics

The Duke Energy Carolinas service territory spans much of the western half of North Carolina and northwestern South Carolina. By the end of September 2016, slightly more than 192,000 customers and 229,000 air conditioners were participating in Power Manager. On average, there are 1.19 air conditioner units per customer. Duke Energy Carolinas serves approximately 2.15 million residential customers, of which roughly 1.27 million are eligible for the Power Manager program. Overall, Duke Energy Carolinas has enrolled 15.1% of eligible customers to date.

A sample of 122 Power Manager participants were selected for inclusion in Nexant's impact evaluation, comprising a total of 144 end use (AC) loggers. Nexant compiled end use data from the 144 loggers and assessed it for quality and completeness. Of the 144 devices installed, 119 loggers returned usable end use data, making up the final impact analysis dataset.

Nexant isolated customers' AC system loads during peak hours (3:30 to 6:00pm) on nonevent days with high average temperatures in order to examine typical AC loads on hot summer days. These are generally analogous to event days and provide a reasonable estimate of what customer AC loads would have been in the absence of a curtailment event. Figure 2-1 shows the distribution of average customer loads (kW) during peak hours on nonevent days. Roughly 45% of sampled customers use more than 1.5 kW of AC load under these typical event conditions.

Figure 2-1: Distribution of Air Conditioner Peak Period Loads

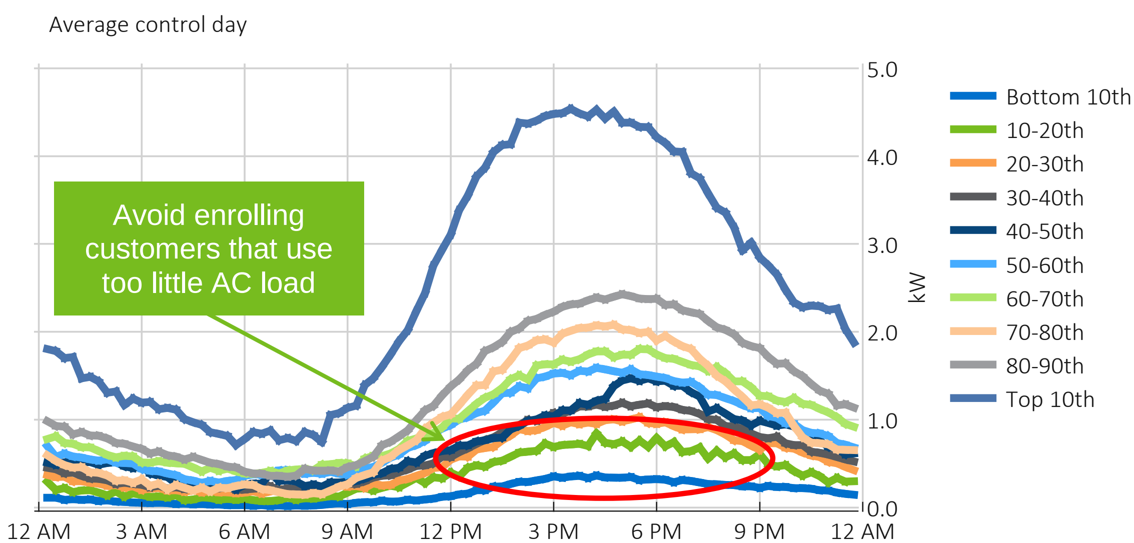


One of the advantages of end use data collection is the ability to assess whether customers use their air conditioners during key hours on hotter days. By design, events were not called on all of the hottest summer days, enabling Nexant to assess typical air conditioner use absent load curtailment events. A total of 47 nonevent days were identified having daily maximum temperatures exceeding 86°F and an average daily maximum temperature of 90°F, compared to an average maximum temperature of 92°F for actual event days.

Figure 2-1 shows the distribution of average air conditioner unit demand during peak hours across sampled customers on nonevent days. Nexant isolated the hours 4 to 6pm to generate the distribution as this period aligns with the timing for most Power Manager events. Power Manager participants' air conditioner use varies substantially, reflecting different occupancy schedules, comfort preferences, and thermostat settings. Roughly 45% of air conditioner loads exceed 1.5 kW during peak hours. As with any program, consumption varies by customer for a variety of reasons. A portion of enrolled customers use little or no air conditioning during late afternoon hours on hotter days. These customers are, in essence, free riders since they receive the participation incentive without providing AC load for curtailment. However, the bulk of the costs for recruitment, equipment, and installation have already been sunk for these customers and, as a result, removing them from the program may not substantially improve cost effectiveness.

Nexant then categorized customers into deciles by average daily loads on nonevent days. This process allows for more targeted consideration of customers that typically use either extremely high or extremely low loads during event-like conditions. Figure 2-2 shows average AC load shapes by decile for sampled participants on nonevent days that are comparable to event days. Despite the general size of AC loads, some customers have small AC loads during peak hours. In general, customers that make up these lower deciles are not ideal candidates for program participation due to relatively low potential for load shed impacts.

Figure 2-2: Air Conditioner End Use Hourly Loads by Size Decile



2.4 2016 Event Characteristics

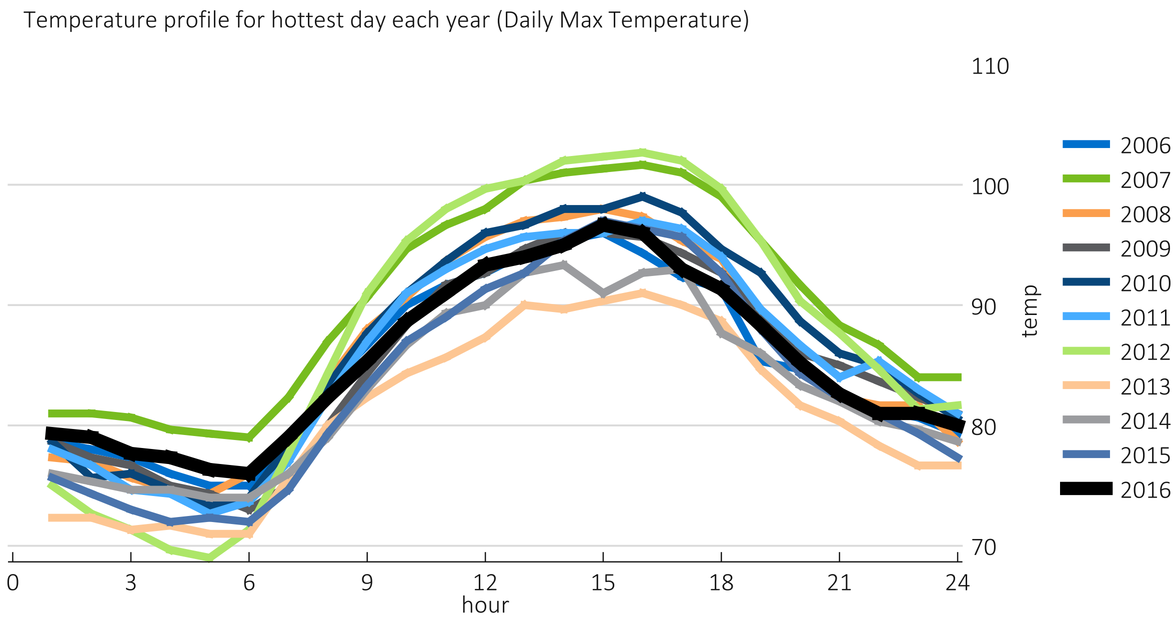
In 2016, Duke Energy Carolinas dispatched Power Manager events 14 times. Some of these events involved dispatching all of the customers enrolled in the program, while other events were only called for customers in the research group in order to provide data for this analysis. By design, events included a wide range of dispatch hours, weather conditions, and control levels. Both test events of the 100% emergency shed lasted 20 minutes; and, all systems were affected simultaneously at the outset of the event window. All of the 50% and 64% cycling events were called at 1:30 pm, 2:30 pm, or 3:30 pm and lasted either 2.5 hours or 3.5 hours. Control of affected air conditioning units was phased in at random over the first 30 minutes of each event. Likewise, the last 30 minutes of these events allowed air conditioning units to resume normal operations in the order they were first controlled. The demand reductions reported in this report for 50% and 64% cycling events exclude the random phase-in and phase-out periods of each event because those periods do not reflect demand reductions when all units are being cycled. Table 2-1 lists the events that were called during the summer of 2016.

Table 2-1: 2016 Event Operations and Characteristics

TrueCycle Level	Event Date	Start Time	End Time	Temperature	# of Customers
50%	7/20/2016	3:30 PM	6:00 PM	91.0	~120
	9/6/2016	1:30 PM	4:00 PM	90.3	~120
	9/8/2016	3:30 PM	6:00 PM	93.0	189,605
	9/14/2016	3:30 PM	6:00 PM	90.7	~120
64%	6/16/2016	1:30 PM	4:00 PM	94.0	~120
	6/23/2016	2:30 PM	5:00 PM	94.0	185,928
	7/8/2016	3:30 PM	6:00 PM	95.2	~120
	7/14/2016	2:30 PM	6:00 PM	95.7	186,744
	8/12/2016	3:30 PM	6:00 PM	89.7	~120
	8/31/2016	3:30 PM	6:00 PM	90.0	~120
	9/15/2016	1:30 PM	4:00 PM	89.0	~120
	9/19/2016	2:30 PM	6:00 PM	86.7	190,564
100%	8/26/2016	4:00 PM	4:20 PM	93.9	~120
	9/7/2016	5:00 PM	5:20 PM	91.7	~120

In comparison to the immediately prior 10 years, 2016 was neither extremely hot nor cool for DEC territory. Figure 2-3 shows how the maximum temperature in 2016 compares to historical hourly temperatures for the weekday with the highest daily maximum temperature. The peak day temperatures, however, fell short of the 102°F used for planning.

Figure 2-3: Comparison of 2016 Maximum Temperature to Historical Years (2006-2016)



3 Methodology and Data Sources

This section details the study design, data sources, sample sizes, and analysis protocols for both the impact and process evaluations. For clarity, details about the methodologies for the impact and process evaluations are presented separately.

3.1 Impact Evaluation Methodology

The 2016 Power Manager impact evaluation included three main activities designed to meet the research objectives. The primary evaluation results are based on a combination of end use (AC) and whole building data. Table 3-1 summarizes the components of the impact evaluation.

Table 3-1: Summary of Impact Evaluation Components

Evaluation Component	Description
Air conditioner end use meter sample (gross)	▪ Data loggers installed on 144 devices, 119 devices used for analysis[5] ▪ Spot measurements of voltage, amps, kW, and connected load conducted at 122 sites ▪ Used to compare end use to whole building demand reductions and assess if customers compensated for air conditioner curtailments ▪ Used nonevent days to infer the baseline ▪ Regression model selected based on out of sample testing of multiple models
Whole building data for customers with end use metered air conditioners (net)	▪ Whole house interval meters installed for same households with air conditioner end use data loggers ▪ Used to compare end use (gross) to whole building demand reductions (net) and assess if customers compensated for air conditioner curtailments ▪ Used nonevent days to infer the baseline ▪ Regression model selected based on out of sample testing of multiple models
Device operability inspections and analysis	▪ Field inspection of 154 devices, of which 10 (6.5%) were inoperable ▪ Event day shape analysis for all customers to identify devices that are and are not curtailing loads during events

3.2 Analysis Protocol for End Use Metered Customers

The DEC study included end use metering for a sample of 144 air conditioner units at 122 households. The main purpose was to assess if whole house demand reductions matched end use demand reductions, or if customers were compensating for air conditioner curtailments by increasing use of fans or other equipment. The field study also provided the opportunity to inspect devices. Nexant was responsible

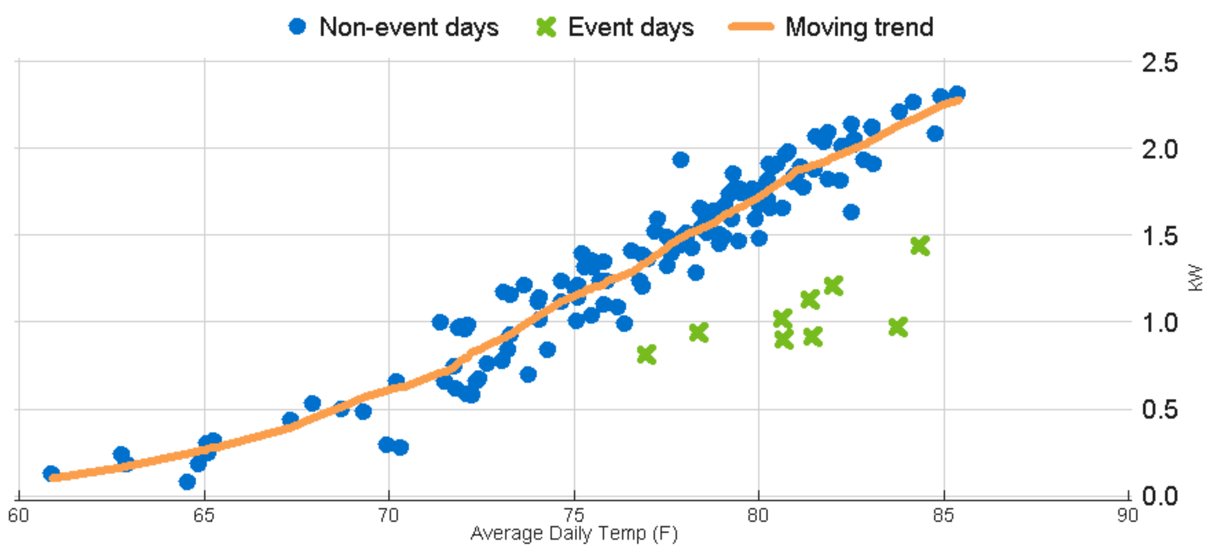
[5] Some device loggers either did not record data for the full summer or did not download data.

for all aspects of the field work, including customer recruitment, scheduling, device inspection, spot measurements, data logger installation, data logger retrieval, data download, and data analysis. For sites with end use metering, demand reductions were calculated using the same method to allow direct comparison between whole building and end use demand reductions.

Nexant modeled the relationship between weather and demand on hot nonevent days to establish what customer energy use patterns would have been absent curtailments, known as the counterfactual. This approach works because the intervention—air conditioner curtailments—is introduced on some days and not on others, making it possible to observe load patterns with and without demand reductions. The repeated ON/OFF pattern enables Nexant to assess whether the outcome—electricity use—rises or falls with the presence or absence of event dispatch instructions. This approach hinges on having comparable nonevent days. When all of the hottest days are event days, the counterfactual is based on extrapolating trends beyond the range of nonevent temperatures, producing less accurate and less unreliable impact estimates for the hottest days. By design, DEC avoided dispatching Power Manager resources on all of the hottest days.

Figure 3-1 illustrates the underlying concept using actual DEC end use load data. The blue circles reflect the individual nonevent weekdays and the orange line shows the trend between peak hour loads and weather. The green X's show the load during event days. The regression modeling calculates the demand reduction as the difference between the estimated loads absent air conditioners and actual loads during event days. Figure 3-1 is simplified for illustration purposes. In practice, regression modeling typically includes explanatory variables other than weather, such as day of week effects and seasonal or monthly effects.

Figure 3-1: Peak Hour Loads (4 to 6pm) as a Function of Temperature



3.3 Data Sources

For the impact evaluation, interval data was collected both at the end use and whole building levels to allow for net impacts vs. gross impacts analysis. End use data was collected using data loggers that were installed on individual AC units. Whole building data was recorded by revenue grade interval meters installed by Duke Energy.

End use and whole building data was used for the same group of customers to eliminate the potential for sampling variability from the net vs. gross analysis. The sample used for the impact evaluation was a simple random sample drawn from the DEC Power Manager program population. Table 3-2 summarizes the whole building and end use data collection activities completed for Nexant's impact analysis.

Table 3-2: Data Collected for Evaluation

Data Collection	Installed or Available	Used for Analysis
Whole building data	122	104
AC end use data	144	119
Spot measurements	139	119
Devices	144	119
Device inspections	154	154

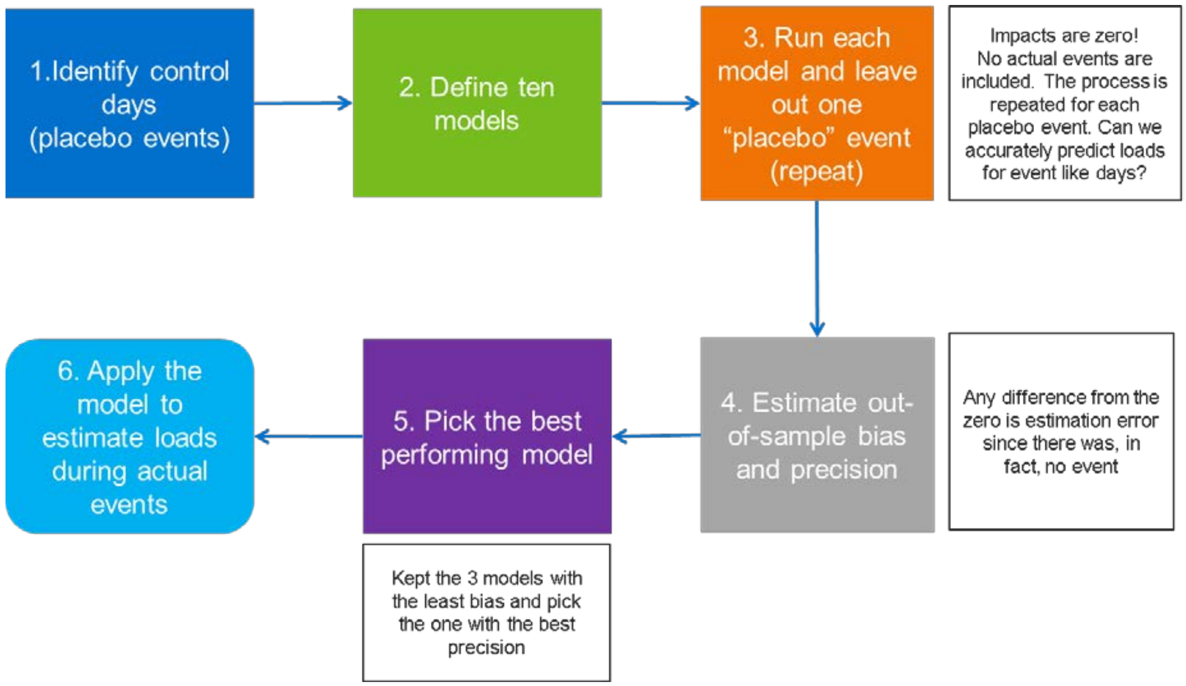
Nexant also requested data related to enrollment, demographics, weather, event details, and past impacts.

3.4 Model Selection Process

A key question every evaluator must address is how to select a model that produces the most accurate and precise counterfactual. In many instances, multiple counterfactuals are plausible but provide different estimated demand reductions. The model selection was based on testing 10 distinct model specifications and employing a systematic approach to identify the most accurate and precise estimation model, described in Figure 3-2.

The process relies on placebo tests. First, the model specifications are defined. Second, hotter, nonevent days are defined as placebo days. Because load control devices were not activated during these days, the impacts are by definition zero and any estimated impact by the models is in fact due to model error. Third, each model is run using nonevent data, leaving out a single placebo day. The regression model is used to predict electricity use on the placebo event day that was withheld, i.e., an out-of-sample prediction. Nexant repeated the process for each placebo day and recorded the actual and predicted loads for each placebo event day. A total of 47 placebo days were employed. Fourth, the out-of-sample predictions for each model are compared to actual electricity usage observed on that day, which are used to calculate metrics for bias and precision. The best model was identified by selecting the model with the highest precision from among the three models with the least bias. This best performing model is used to estimate the counterfactual for actual event days.

Figure 3-2: Model Selection



3.5 Bias and Precision Metrics

Table 3-3 summarizes metrics for bias and precision.[6] Bias metrics measure the tendency of different approaches to over or under predict and are measured over multiple 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. This tendency is best measured using multiple days. 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 results. The absolute value of the mean percentage error is used to narrow the models to the three candidates with the least bias. The coefficient of variation of the root mean square error, or CV(RMSE), metric is used to identify the most precise model from among the three candidates with smallest bias.

[6] Bias is also referred to as accuracy. Precision is sometimes called goodness-of-fit.

Table 3-3: 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	$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}$
	CV(RMSE)	Measures the relative magnitude of errors across event days, regardless of positive or negative direction (typical error)	$CV(RMSE) = \frac{RMSE}{\bar{y}}$

Table 3-4: Model Selection

Model	Variables	End-Use				Whole building			
		Bias		Precision		Bias		Precision	
		Avg. Error	Mean Percent Error	Root mean square error	Normalized RMSE	Avg. Error	Mean Percent Error	Root mean square error	Normalized RMSE
1	- Pre-event load (11 am to 1 pm) - Cooling degree hours (Base 70F) - Day of week and month	-0.01	-0.7%	0.11	7.8%	-0.03	-0.9%	0.17	5.9%
2	- Pre-event load (11 am to 1 pm) - Cooling degree days (Base 65F) - Day of week and month	-0.02	-1.2%	0.14	9.6%	-0.03	-1.1%	0.19	6.6%
3	- Pre-event load (11 am to 1 pm) - Maximum temperature for day - Day of week and month	0.00	0.1%	0.16	10.7%	0.00	-0.1%	0.21	7.2%
4	- Pre-event load (11 am to 1 pm) - Avg. temperate in prior 24 hours - Day of week and month	-0.02	-1.5%	0.18	12.1%	-0.04	-1.3%	0.23	8.0%
5	- Pre-event load (11 am to 1 pm) - CDH and CDD - Day of week and month	-0.01	-0.7%	0.11	7.9%	-0.03	-0.9%	0.17	5.9%
6	- Pre-event load (11 am to 1 pm) - Avg. temperate in prior 24 hours and current CDH - Day of week and month	-0.01	-0.7%	0.11	7.9%	-0.03	-0.9%	0.17	6.0%
7	- Pre-event load (11 am to 1 pm) - Average CDH in prior 6 hours and current CDH - Day of week and month	-0.01	-0.4%	0.11	7.3%	-0.01	-0.4%	0.16	5.5%
8	- Pre-event load (11 am to 1 pm) - Average CDH in prior 12 hours and current CDH - Day of week and month	-0.01	-0.4%	0.11	7.6%	-0.02	-0.6%	0.16	5.7%
9	- Pre-event load (11 am to 1 pm) - Average CDH in prior 18 hours and current CDH - Day of week and month	-0.01	-0.7%	0.11	7.8%	-0.02	-0.9%	0.17	5.9%
10	- Pre-event load (11 am to 1 pm) - Average CDH in prior 24 hours and current CDH - Day of week and month	-0.01	-0.7%	0.11	7.9%	-0.03	-0.9%	0.17	6.0%

3.6 Device Operability Testing Protocols

Nexant installed end use data loggers only on air conditioning units having functioning DLC switches at the time of the installation. Switches were inspected to ensure that devices were properly connected and had successfully received a test signal. At the beginning of the site visits for logger installations, field technicians conducted a visual inspection of the installed switch device to determine that it was properly connected and verified that the green light indicating proper connectivity was illuminated. Inspections were conducted in the following areas:

- Load control device
    - Presence
    - Proper installation
    - Physical condition
    - Operability
- Device connection wires
    - Presence
    - Physical condition
    - Secure connection

Systems with switches that failed inspections in any of these areas were abandoned and no loggers were deployed. This data allows for estimates of the number of switch failures that result from several different causes. Switch operability data was used to adjust the per customer impacts generated from the sample consisting of functioning switches when estimating aggregate impacts for the Power Manager population. Results of the switch device inspections are presented in Section 6.1.

3.7 Process Evaluation Methodology

Table 3-5: Summary of Evaluation Activities

Data Collection Technique	Description of Analysis Activities Using Collected Data	Sample Size	Precision / Confidence Level
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.	2-4	NA
Post-event survey	Phone survey of Power Manager customers immediately after an event to assess event awareness, program strengths/weaknesses customer experience during events and motivations for participation.	68	90/10
Nonevent survey	Similar to post-event survey, but conducted after a hot, nonevent day. Comparing nonevent and post-event survey responses will identify customer awareness of events and effects of events on customer comfort.	68	90/10

The process evaluation included four primary data collection tasks in order to achieve the research objectives listed in Table 3-5.

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 are communicated and applied. 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, Nexant requested copies of internal program manuals and guidelines as well as copies of marketing materials. The program database analysis consisted of an examination of the distribution of bill credits and incentive payments, the program tenure, load curtailed per household, and other variables that inform indications of program progress.

In-depth interviews with key program stakeholders—Program stakeholders include program staff, implementation contractors, and staff elsewhere in the utility with insight into program plans and operations, emerging issues, and the expected customer experience. The interviews conducted for the 2016 evaluation informed the customer survey design and confirmed the evaluation team's understanding of key program components. Because Power Manager is implemented consistently across jurisdictions, a common interview structure was feasible.

Goals of the interviews included:

- Understanding marketing and recruitment efforts, including lessons learned about the key drivers of enrollment;
- Identifying "typical" Power Manager households, including characteristics of households that successfully participate for multiple years;
- Describing event processes;
- Understanding opt-out procedures;
- Confirming enrollment incentive levels and how event incentives are explained to customers;
- Understanding any differences in customer experience that might occur depending upon whether or not an event is called for economic or emergency purposes;
- Identifying any numeric or other program performance goals (kW enrollment, number of households, notification timelines) established for Power Manager; and
- Describing the working relationship between Duke Energy and the program implementer including the allocation of program responsibilities.

Post-event surveys—Guided by information obtained from stakeholder interviews and a review of program guidance documents (including any notification protocols), Nexant developed a survey for participating customers that was deployed immediately following a demand response 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. The post-event survey addressed the following topics:

- Awareness of the specific event day;
- Experience of and satisfaction with the event notification process;

- Actions taken in advance of the event to mitigate the effect of AC cycling;
- 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?
- Retention and referral. For how many years have participants been enrolled? Do participants expect to remain enrolled in the program in future years? Would they recommend the program to others? Are there people they would discourage from enrolling? What types of people, and why?

To ensure that the survey accurately assessed the experiences of customers during a curtailment event, questions were finalized and fully programmed by May 1 to enable deployment within 24 hours after an event. Working with Duke Energy and the impact evaluation team, Nexant 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. Up to half of the expected sample (35 households) were surveyed by phone to ensure completes by both modes and improve representativeness.

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 nearly identical to the post-event survey to facilitate comparison with the results of the event day survey, with only references to specific event awareness removed. 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. This improved the speed of data collection and the representativeness of the sample.

4 2016 Event Results

The Power Manager program in the DEC territory was evaluated using within-subjects regression of load data collected from a sample of program participants. The analysis used end use data collected from a random sample of Power Manager customers' outdoor air conditioning units, as well as whole house data from the same group of customers. The same regression model was applied to both sets of data to ensure consistency in the analysis and to allow for valid comparison between results.

One of the primary objectives of the study was to understand the load impacts attributable to Power Manager under a variety of conditions. By design, events were called on days with varying temperature conditions. The analysis of both end use and whole house level data allowed for a comparison of the two in order to determine whether whole house impacts would predict similar impacts to those from end use data. Smaller whole house demand reductions would imply that customers offset air conditioning curtailments through other cooling end uses (e.g., fans). Among its findings, Nexant's impact evaluation determined that there is no evidence that customers compensate for air conditioner curtailments by increasing other end uses—whole building impacts are virtually indistinguishable from end use impacts.

The primary results from the evaluation are based on the end use demand reduction. The estimates for end use data are more precise due to a larger signal-to-noise ratio. The percent reduction is larger and the remaining noise after modeling is smaller.

4.1 End Use Results

The event day load impacts at the end use level are presented in Table 4-1. At the end use level, load reductions are estimated to be 39.1%, 47.6%, and 78.5% of the base load at the 50%, 64%, and 100% control levels, respectively. In absolute terms, kW impacts are estimated to be 0.69 kW, 0.90 kW, and 1.64 kW at 50%, 64%, and 100% control, respectively, for the average event.

The four 50% true cycling events achieved an average load reduction of 0.69 kW, or 39.1% of the 1.77 kW base load. The model found a 90% confidence band ranging from 0.56 kW to 0.82 kW. Among the eight 64% cycling events, the average impact was 0.90 kW, or 47.6% of the 1.89 kW base load. End use impacts approximated or exceeded 1.0 kW during multiple events. The two emergency 100% shed events achieved the largest impacts, despite relatively cool temperatures. The average impact for these events was 1.64 kW, or roughly 78.5% of the 2.09 kW average base load. The average impact for these events had a 90% confidence band ranging from 1.50 kW to 1.78 kW. Impacts shown in Table 4-1 represent the average load reduction during the duration of each event.

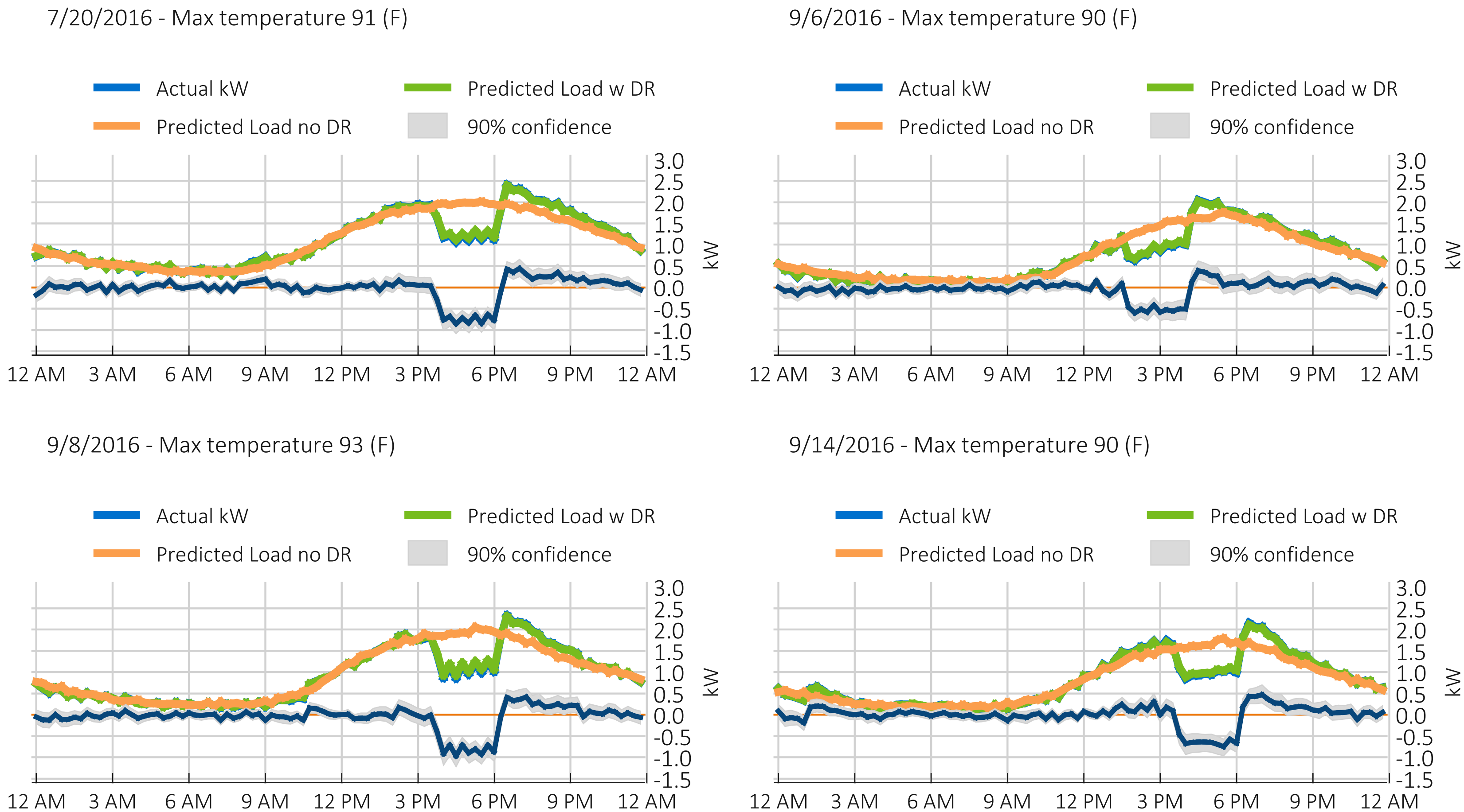
Despite being called on cooler days, the 100% shed delivered load reductions of 1.46 kW per household on a 91.7˚F day and 1.82 kW per household on a 93.9˚F day. Because the temperatures for the 100% shed event fell short of the 102˚F conditions expected in extreme years, the 2016 shed events do not reflect the load shed capability used for planning. The process for estimating the demand reduction capability available for 102˚F conditions are described in Section 6.

Table 4-1: End Use Event Day Load Impacts

True Cycle	Date	Load without DR	Impact	Std. error	90% Confidence Interval		% Impact	90% Confidence interval		Daily Max (F)
					Lower bound	Upper bound		Lower Bound	Upper Bound	
50%	7/20/2016	1.98	-0.75	0.13	-0.54	-0.96	-38.0%	-27.5%	-48.4%	91.0
	9/6/2016	1.47	-0.52	0.13	-0.32	-0.73	-35.6%	-21.5%	-49.7%	90.3
	9/8/2016	1.95	-0.83	0.13	-0.61	-1.05	-42.5%	-31.2%	-53.7%	93.0
	9/14/2016	1.68	-0.66	0.13	-0.44	-0.87	-39.4%	-26.5%	-52.2%	90.7
	Average	**1.77**	**-0.69**	**0.08**	**-0.56**	**-0.82**	**-39.1%**	**-31.7%**	**-46.4%**	**91.3**
64%	6/16/2016	1.91	-0.98	0.12	-0.78	-1.18	-51.4%	-41.0%	-61.8%	94.0
	6/23/2016	2.03	-1.05	0.13	-0.84	-1.27	-51.7%	-41.2%	-62.3%	94.0
	7/8/2016	2.28	-0.96	0.13	-0.75	-1.17	-42.1%	-32.8%	-51.4%	95.2
	7/14/2016	2.30	-1.24	0.13	-1.03	-1.45	-53.9%	-44.8%	-62.9%	95.7
	8/12/2016	1.96	-0.94	0.13	-0.73	-1.15	-48.0%	-37.3%	-58.8%	89.7
	8/31/2016	1.90	-0.90	0.13	-0.70	-1.11	-47.5%	-36.6%	-58.3%	90.0
	9/15/2016	1.40	-0.60	0.12	-0.40	-0.80	-42.9%	-28.5%	-57.3%	89.0
	9/19/2016	1.33	-0.51	0.13	-0.30	-0.73	-38.6%	-22.6%	-54.5%	86.7
	Average	**1.89**	**-0.90**	**0.08**	**-0.77**	**-1.02**	**-47.6%**	**-40.9%**	**-54.2%**	**91.8**
100%	8/26/2016	2.32	-1.82	0.14	-1.60	-2.05	-78.7%	-69.0%	-88.4%	93.9
	9/7/2016	1.87	-1.46	0.14	-1.24	-1.68	-78.2%	-66.3%	-90.2%	91.7
	Average	**2.09**	**-1.64**	**0.08**	**-1.50**	**-1.78**	**-78.5%**	**-71.9%**	**-85.1%**	**92.8**

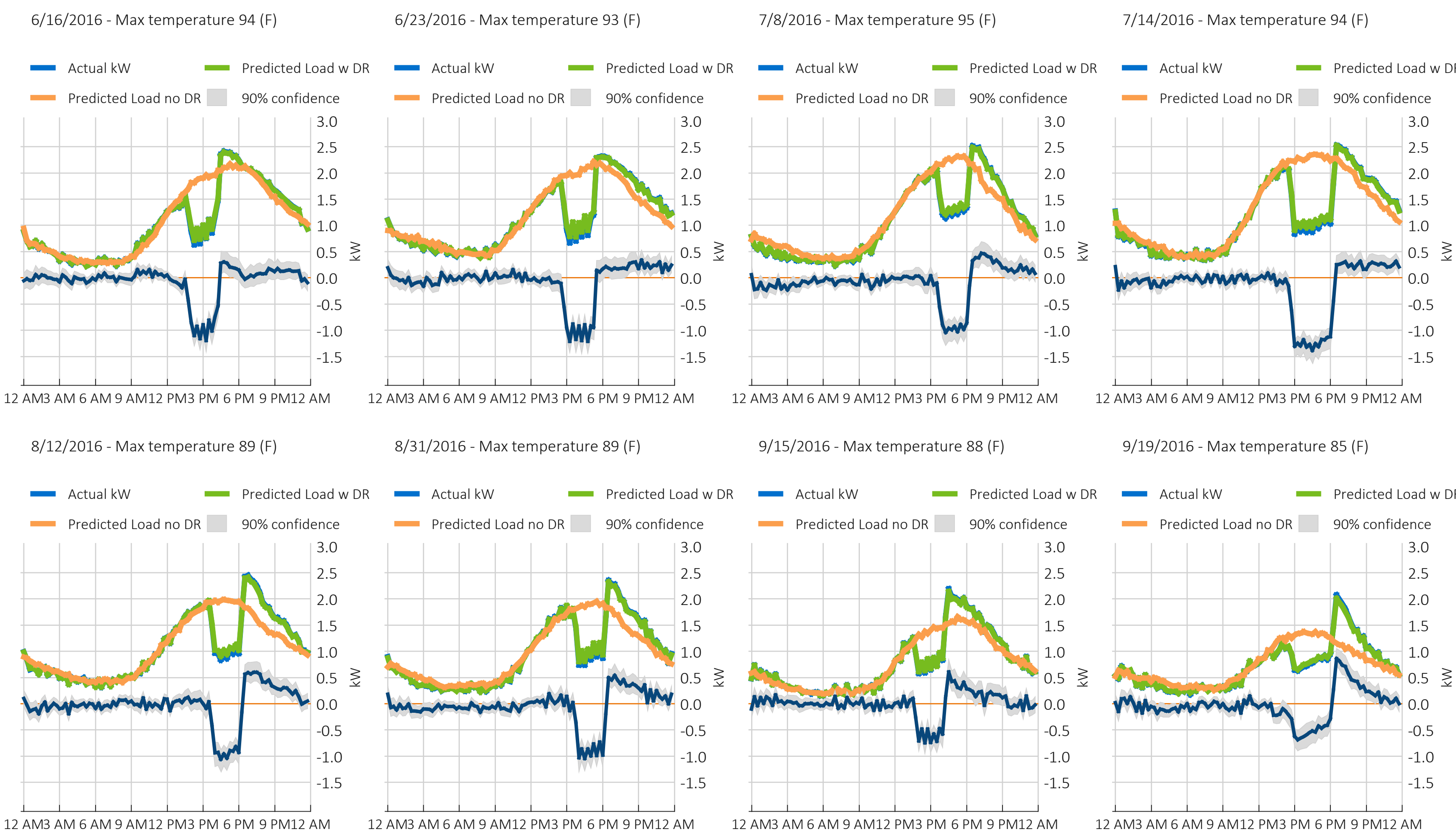
Average customer end use hourly load shapes and corresponding end use hourly impacts are shown for each 50% cycling event day in Figure 4-1. Average load shapes for each 64% cycling event days are shown in Figure 4-2. Average impacts for the 100% shed events are shown in Figure 4-3. The impacts shown in Figures 4-1 through 4-3 have been de-rated by 6.5% to account for the proportion of inoperable switch devices found by Nexant field staff among sampled participants in DEC territory.

Figure 4-1: Average End Use Load Impacts 50% Cycling Events



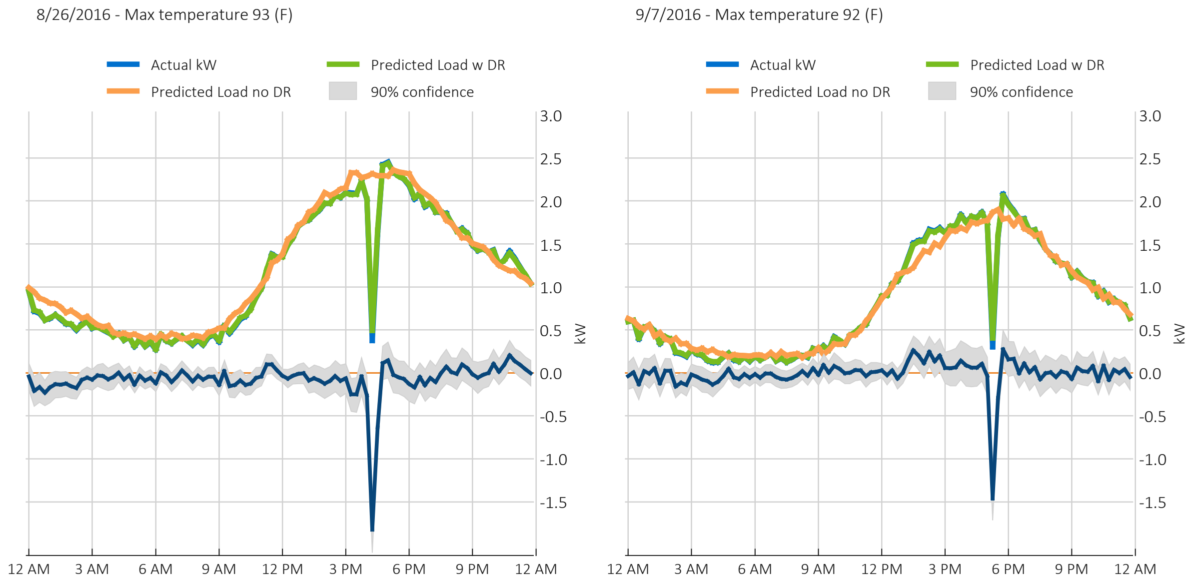
Impacts de-rated for inoperable devices (6.5%)

Figure 4-2: Average End Use Load Impacts 64% Cycling Events



Impacts de-rated for inoperable devices (6.5%)

Figure 4-3: Average End Use Load Impacts 100% Shed Events



Impacts de-rated for inoperable devices (6.5%)

4.2 Whole Building Results

The event day load impacts at the whole building level are presented in Table 4-2. The four 50% cycling events achieved an average load reduction of 0.65 kW, or approximately 20.3% of the 3.21 kW base load. The model found a 90% confidence band ranging from 0.49 kW to 0.81 kW. Among the eight 64% cycling events, the average impact was 0.88 kW, or approximately 26.4% of the 3.32 kW base load. Whole building impacts of 1.0 kW or more were achieved during four of these events. The two emergency 100% shed events achieved the largest impacts. The average impact for these events was 1.63 kW, or roughly 45.4% of the 3.59 average base load. The average impact for these events had a 90% confidence band ranging from 1.47 kW to 1.79 kW. Impacts shown in Table 4-2 represent the average load reduction during the duration of each event.

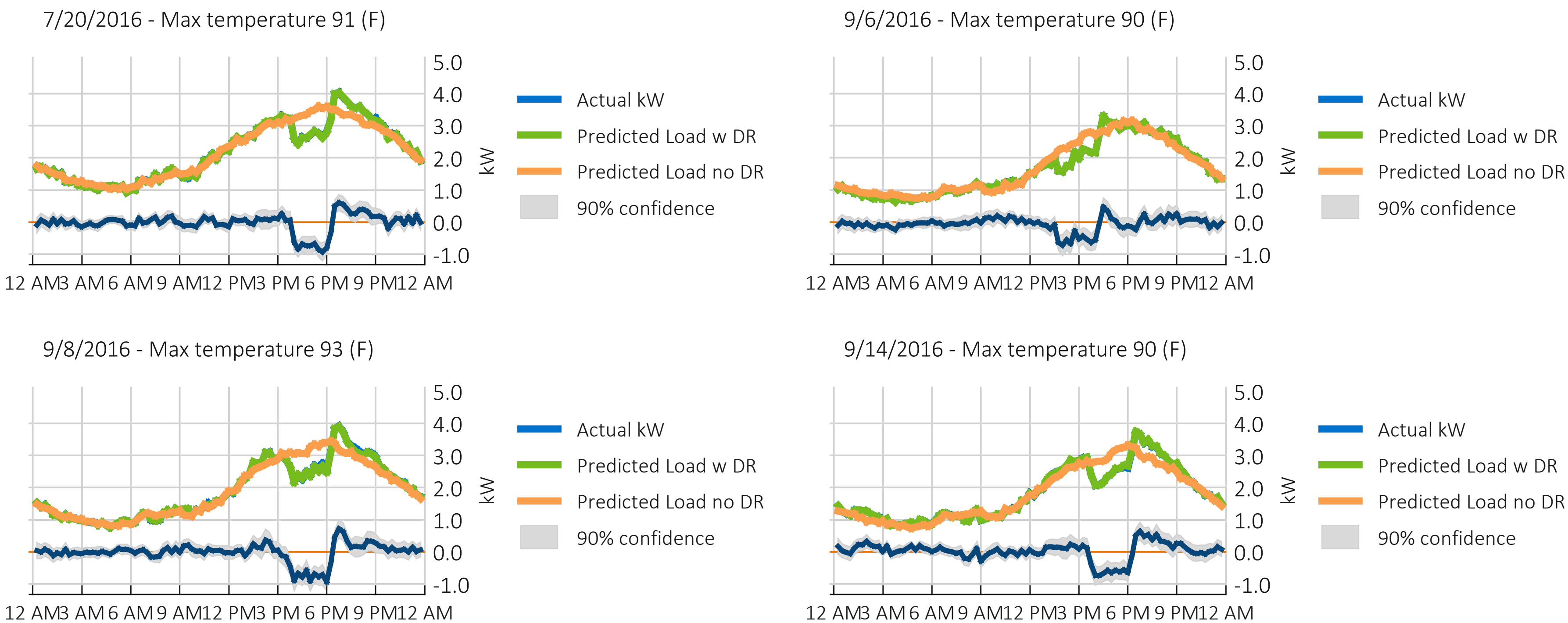
Table 4-2: Whole Building Event Day Load Impacts

True Cycle	Date	Load without DR	Impact	Std. error	90% Confidence Interval		% Impact	90% Confidence interval		Daily Max (F)
					Lower bound	Upper bound		Lower Bound	Upper Bound	
50%	7/20/2016	3.59	-0.76	0.16	-0.50	-1.02	-21.1%	-13.9%	-28.4%	91.0
	9/6/2016	2.68	-0.51	0.18	-0.21	-0.80	-18.9%	-7.8%	-30.0%	90.3
	9/8/2016	3.37	-0.73	0.18	-0.44	-1.03	-21.8%	-13.1%	-30.5%	93.0
	9/14/2016	3.19	-0.61	0.17	-0.33	-0.89	-19.0%	-10.2%	-27.8%	90.7
	Average	**3.21**	**-0.65**	**0.10**	**-0.49**	**-0.81**	**-20.3%**	**-15.4%**	**-25.3%**	**91.3**
64%	6/16/2016	3.30	-1.00	0.17	-0.72	-1.28	-30.3%	-21.8%	-38.8%	94.0
	6/23/2016	3.46	-1.05	0.17	-0.77	-1.32	-30.2%	-22.2%	-38.2%	94.0
	7/8/2016	3.94	-1.01	0.16	-0.74	-1.28	-25.7%	-18.9%	-32.4%	95.2
	7/14/2016	3.85	-1.20	0.16	-0.93	-1.47	-31.2%	-24.3%	-38.1%	95.7
	8/12/2016	3.36	-0.87	0.16	-0.60	-1.14	-25.9%	-18.0%	-33.9%	89.7
	8/31/2016	3.39	-0.89	0.16	-0.63	-1.15	-26.2%	-18.6%	-33.8%	90.0
	9/15/2016	2.62	-0.54	0.18	-0.25	-0.83	-20.7%	-9.6%	-31.8%	89.0
	9/19/2016	2.64	-0.46	0.17	-0.19	-0.74	-17.5%	-7.0%	-27.9%	86.7
	Average	**3.32**	**-0.88**	**0.09**	**-0.72**	**-1.03**	**-26.4%**	**-21.8%**	**-31.1%**	**91.8**
100%	8/26/2016	3.75	-1.72	0.16	-1.46	-1.99	-45.9%	-38.8%	-53.0%	93.9
	9/7/2016	3.44	-1.54	0.16	-1.28	-1.80	-44.8%	-37.2%	-52.3%	91.7
	Average	**3.59**	**-1.63**	**0.10**	**-1.47**	**-1.79**	**-45.4%**	**-40.9%**	**-49.9%**	**92.8**

The four 50% true cycling events were called on days with daily maximum temperatures between 90.3°F and 93°F. Average per household hourly load shapes and corresponding hourly impacts are shown for each 50% cycling event day in Figure 4-4. Average load shapes for each 64% cycling event day are shown in Figure 4-5. Average impacts for the 100% shed events are shown in Figure 4-6. The impacts shown in Figure 4-4, Figure 4-5, and Figure 4-6 have been de-rated by 6.5% to account for the proportion of inoperable switch devices found by Nexant field staff among sampled participants in DEC territory.

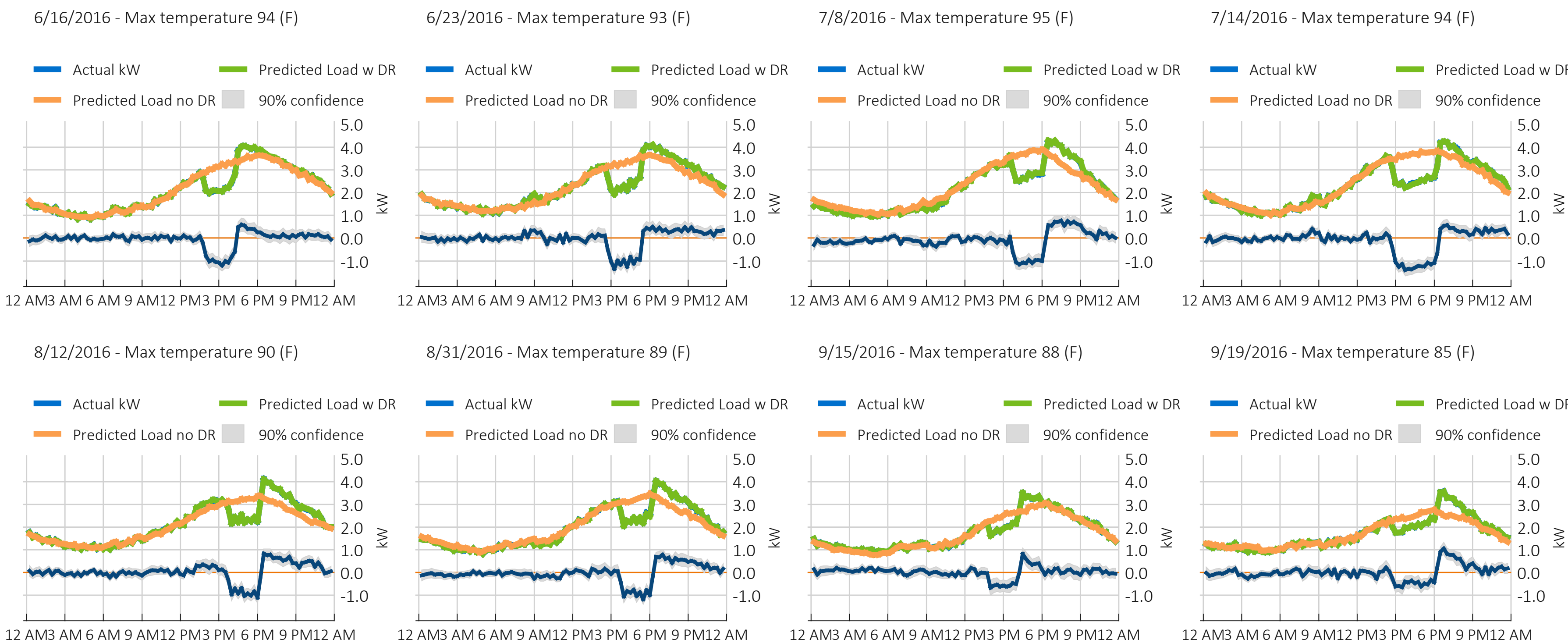
A total of eight 64% cycling events were called with daily maximum temperatures ranging from 86.7°F to 95.7°F. Hotter events occurred during the first half of the 2016 summer (June and July) with milder events being called in later summer months (August and September). Not surprisingly, greater impacts were shown during the earlier, hotter event days.

Figure 4-4: Average Whole Building Load Impacts 50% Cycling Events



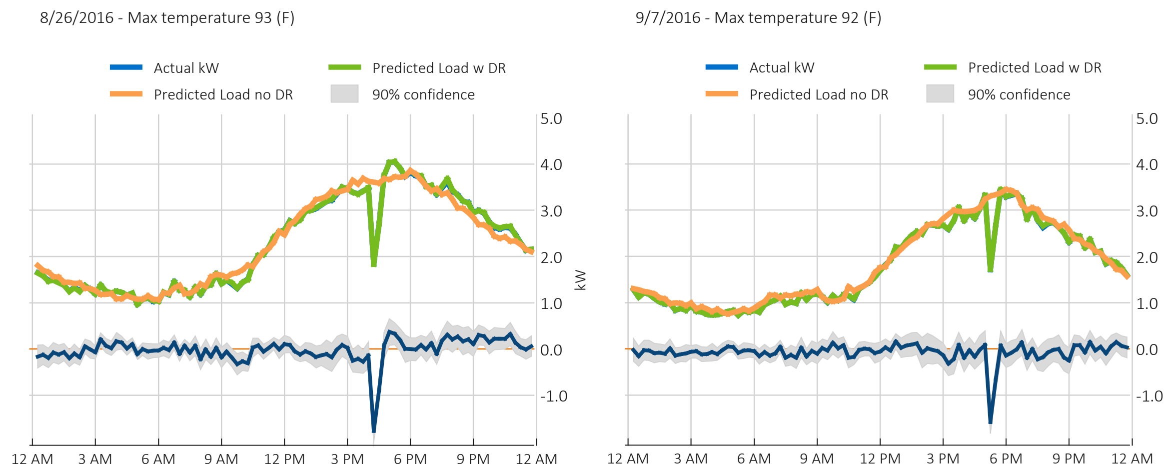
Impacts de-rated for inoperable devices (6.5%)

Figure 4-5: Average Whole Building Load Impacts 64% Cycling Events



Impacts de-rated for inoperable devices (6.5%)

Figure 4-6: Average Whole Building Load Impacts 100% Shed Events



Impacts de-rated for inoperable devices (6.5%)

4.3 Whole Building Versus End Use Impacts

Table 4-3 compares the impacts attained during each event called in 2016 at the whole building and end use levels. Average demand reductions were 0.65 kW, 0.88 kW, and 1.63 kW during the 50%, 64%, and 100% control events, respectively, at the whole house level, with larger impacts occurring on event days with higher temperatures. At the end use level, average impacts were 0.69 kW, 0.90, and 1.64 kW during the 50%, 64%, and 100% control events, respectively.

Table 4-3: Comparison of Whole Building Impacts vs. End Use Impacts

True Cycle	Date	Event Start	Event End	Whole Building			End use (for household)			Daily Max °F
				Load without DR	Impact	% Impact	Load without DR	Impact	% Impact	
50%	7/20/2016	3:30 PM	6:00 PM	3.59	-0.76	-21.1%	1.98	-0.75	-38.0%	91.0
	9/6/2016	3:30 PM	6:00 PM	2.68	-0.51	-18.9%	1.47	-0.52	-35.6%	90.3
	9/8/2016	1:30 PM	4:00 PM	3.37	-0.73	-21.8%	1.95	-0.83	-42.5%	93.0
	9/14/2016	3:30 PM	6:00 PM	3.19	-0.61	-19.0%	1.68	-0.66	-39.4%	90.7
	Average	**N/A**	**N/A**	**3.21**	**-0.65**	**-20.3%**	**1.77**	**-0.69**	**-39.1%**	**91.3**
64%	6/16/2016	2:30 PM	5:00 PM	3.30	-1.00	-30.3%	1.91	-0.98	-51.4%	94.0
	6/23/2016	2:30 PM	6:00 PM	3.46	-1.05	-30.2%	2.03	-1.05	-51.7%	94.0
	7/8/2016	2:30 PM	6:00 PM	3.94	-1.01	-25.7%	2.28	-0.96	-42.1%	95.2
	7/14/2016	1:30 PM	4:00 PM	3.85	-1.20	-31.2%	2.30	-1.24	-53.9%	95.7

True Cycle	Date	Event Start	Event End	Whole Building			End use (for household)			Daily Max °F
				Load without DR	Impact	% Impact	Load without DR	Impact	% Impact	
	8/12/2016	3:30 PM	6:00 PM	3.36	-0.87	-25.9%	1.96	-0.94	-48.0%	89.7
	8/31/2016	3:30 PM	6:00 PM	3.39	-0.89	-26.2%	1.90	-0.90	-47.5%	90.0
	9/15/2016	3:30 PM	6:00 PM	2.62	-0.54	-20.7%	1.40	-0.60	-42.9%	89.0
	9/19/2016	1:30 PM	4:00 PM	2.64	-0.46	-17.5%	1.33	-0.51	-38.6%	86.7
	Average	**N/A**	**N/A**	**3.32**	**-0.88**	**-26.4%**	**1.89**	**-0.90**	**-47.6%**	**91.8**
100%	8/26/2016	4:00 PM	4:20 PM	3.75	-1.72	-45.9%	2.32	-1.82	-78.7%	93.9
	9/7/2016	5:00 PM	5:20 PM	3.44	-1.54	-44.8%	1.87	-1.46	-78.2%	91.7
	Average	**N/A**	**N/A**	**3.59**	**-1.63**	**-45.4%**	**2.09**	**-1.64**	**-78.5%**	**92.8**

* Load impacts reported exclude the first half hour when air conditioner control is randomly phased in.

The following set of graphics provides visual comparisons of the average hourly impacts derived from the regression analysis for each DEC Power Manager event. The key takeaway from Table 4-3, Figure 4-7, and Figure 4-8 is that, while slight deviations occur, the magnitude of the impacts shown by the whole building analysis vs. end use analysis are within the margin of estimation error. As discussed previously, this indicates that customers do not compensate for Power Manager's air conditioner curtailments through other end uses.

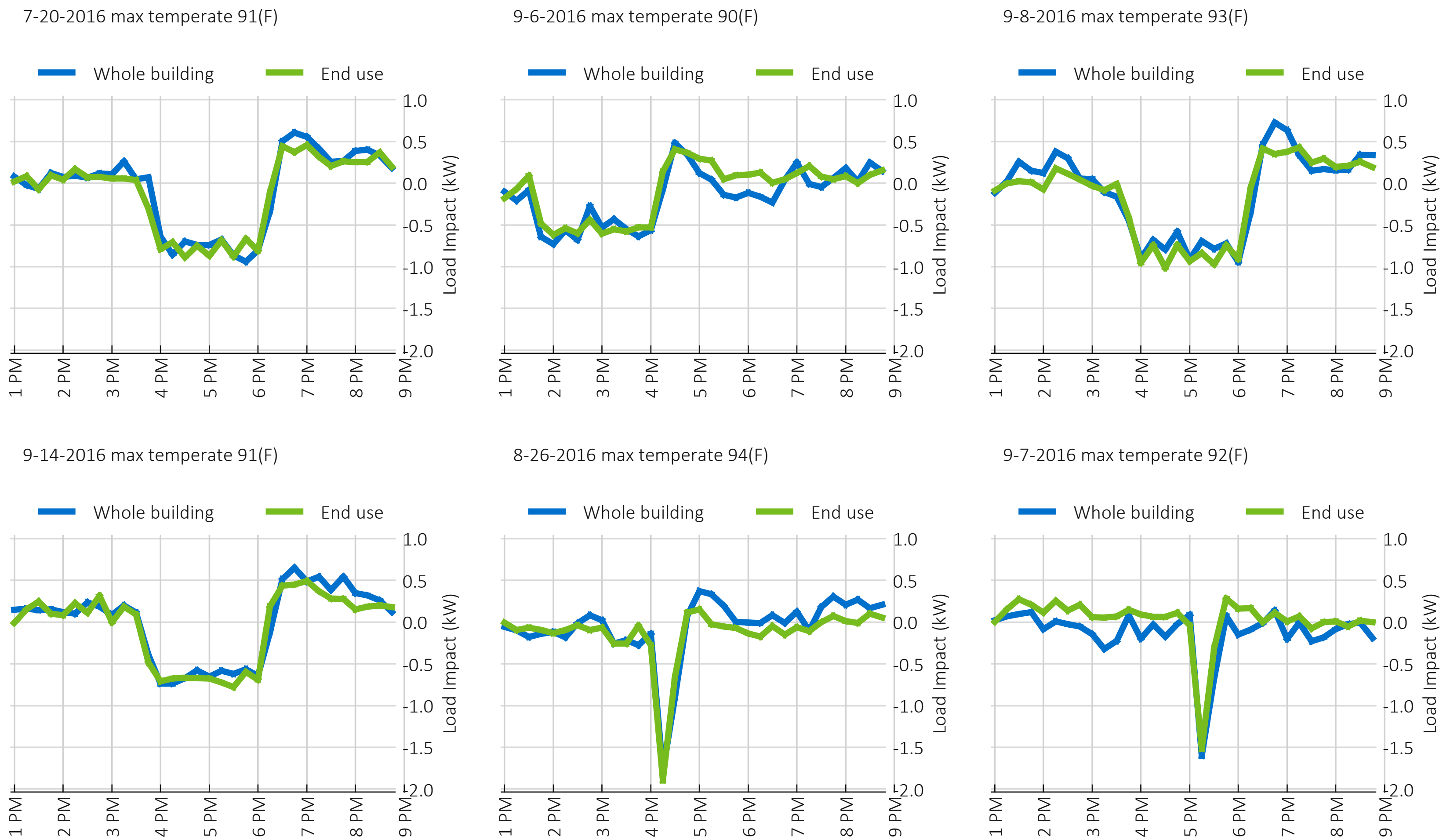
Figure 4-7 compares load impacts derived from whole building data vs. those derived from end use data for each of the eight 64% cycling events. In general, events called under hotter temperatures achieve greater load reductions. Results show that per household impacts of 1.0 kW or greater are achievable under hotter temperature conditions.

Figure 4-8 compares load impacts derived from whole building data vs. those derived from end use data for each of the four 50% cycling events (7/20/2016, 9/6/2016, 9/8/2016, and 9/14/2016) as well as for the two 100% shed events (8/26/2016 and 9/7/2016).

Figure 4-7: Comparison of Whole Building vs. End Use Impacts for 64% Load Cycling Events

Whole building and end use regression impacts de-rated for inoperable devices (6.5%)

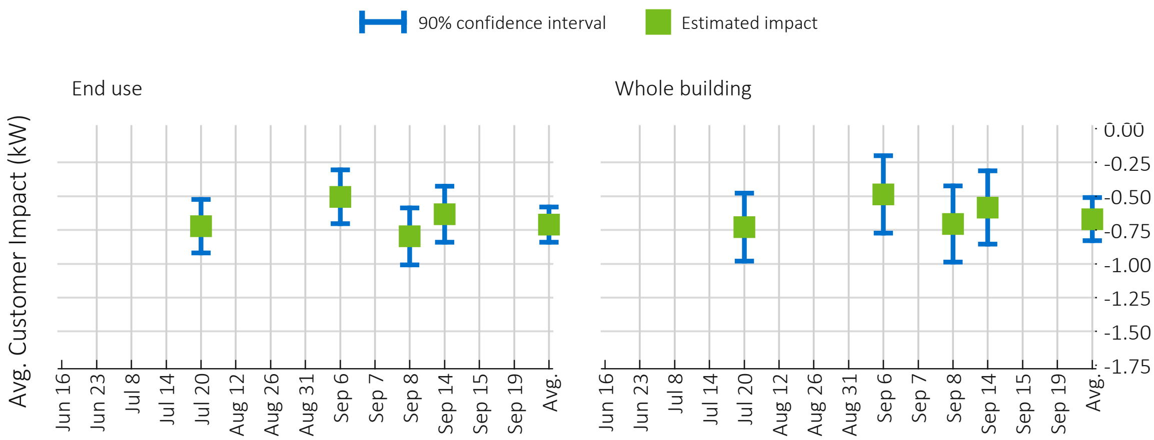
Figure 4-8: Comparison of Whole Building vs. End Use Impacts for 50% and 100% Control Events



Whole building and end use regression impacts de-rated for inoperable devices (6.5%)

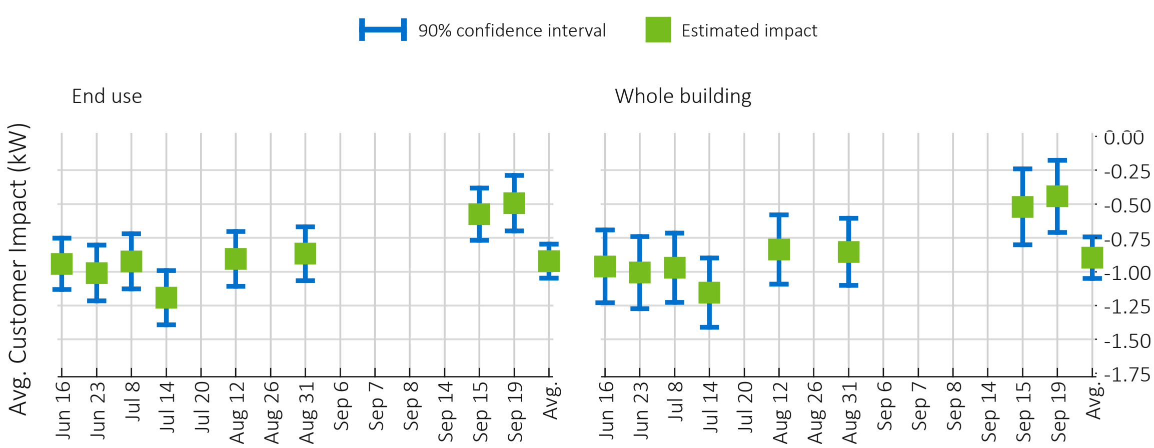
Figure 4-9, Figure 4-10, and Figure 4-11 show comparisons of end use vs. whole building load impacts for each event under 50% cycling, 64% cycling, and 100% shed, respectively. These plots show the point estimates for load reduction on each event day, along with the 90% confidence intervals. As a rule of thumb, the whole building impacts have slightly wider confidence intervals than the end use impacts due to additional noise in the whole building data stemming from other end uses that are captured by the whole building measurements. The figures show that differences between the whole building and end use load impact estimates for each event day fall within the range of estimation uncertainty, and are thus statistically similar to one another.

Figure 4-9: Comparison of Whole Building and End Use Impacts 50% Cycling Events



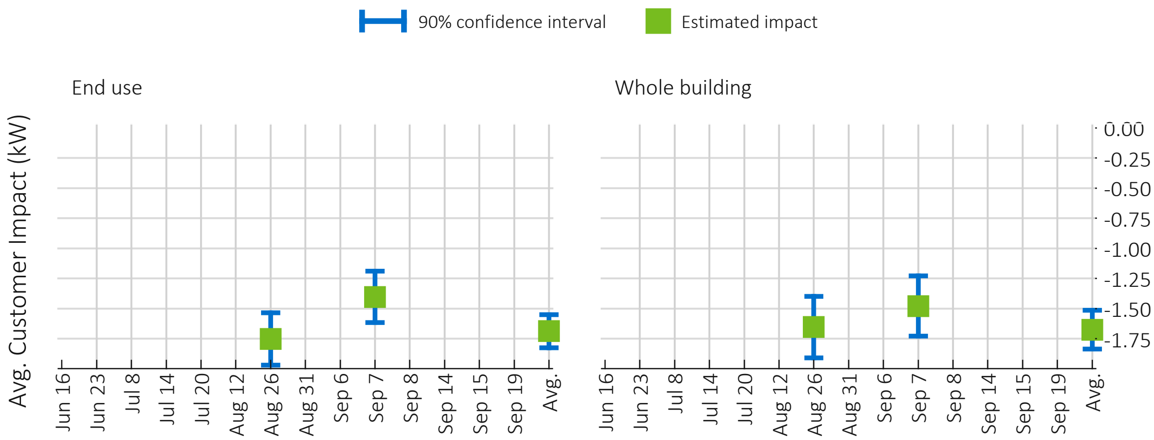
Impacts de-rated for inoperable devices (6.5%)

Figure 4-10: Comparison of Whole Building and End Use Impacts 64% Cycling Events



Impacts de-rated for inoperable devices (6.5%)

Figure 4-11: Comparison of Whole Building and End Use Impacts 100% Shed Events



Impacts de-rated for inoperable devices (6.5%)

4.4 Weather Sensitivity

Power Manager load reductions grow with hotter weather and with deeper cycling. The program delivers larger demand reductions precisely when resources are needed most. Average load impacts during each event are shown in Figure 4-12 as a function of daily maximum temperature. Impacts are broken down by cycling option and are shown at the end use and whole building level. Again, these results show that the sensitivity to temperature change is very similar between whole building and end use impacts. On hotter days (above 93°F), impacts exceeded 1.0 kW for 64% and 100% control. Furthermore, while the trend or larger reductions with hotter weather is clear for 100% shed events and 64% cycling impacts, the trend is less clear for 50% cycling due to having only four events under a limited range of temperatures.

The larger demand reductions with hotter weather are both due to larger air conditioning demand and due to larger percent reductions. This can be seen in Figure 4-13. The panel on the left shows the 2016 end use air conditioner percent demand reductions, while the panel on the right shows 2016 air conditioner demand per unit for the 4 to 6pm period of nonevent days. While 2016 did not experience 102˚F conditions, the data relationship between percent reductions and weather and air conditioner loads and weather can be used to produce an estimate of demand reduction capability for planning purposes.

Figure 4-12: 2016 Load Reductions by Cycling Level as a Function of Temperature and Control Strategy

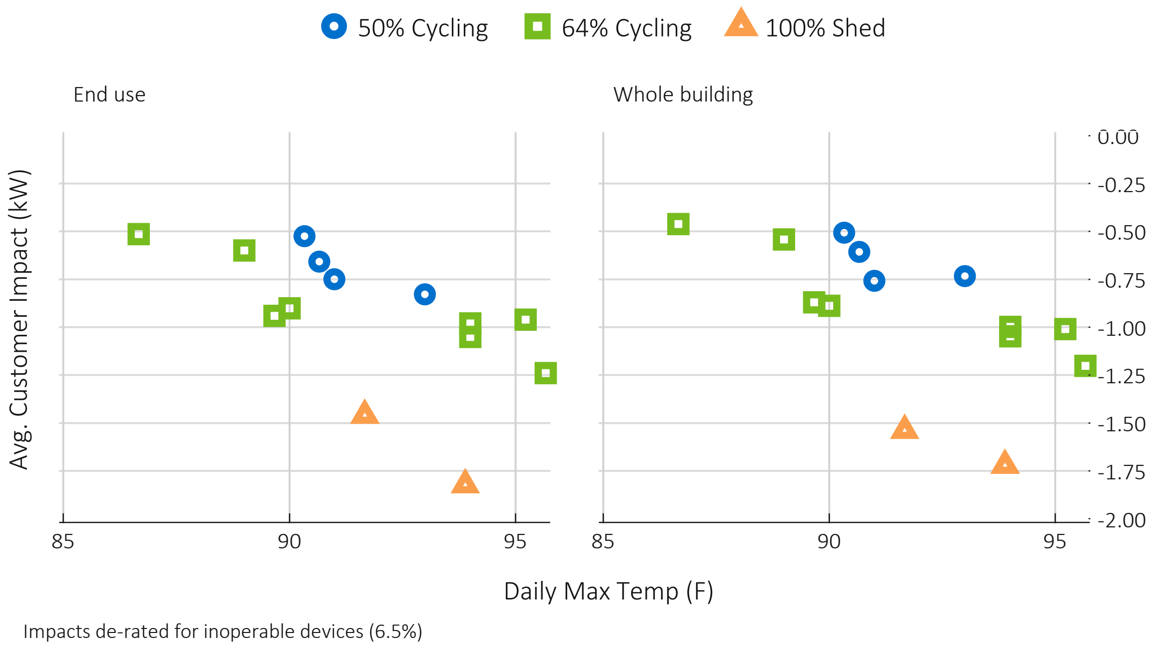
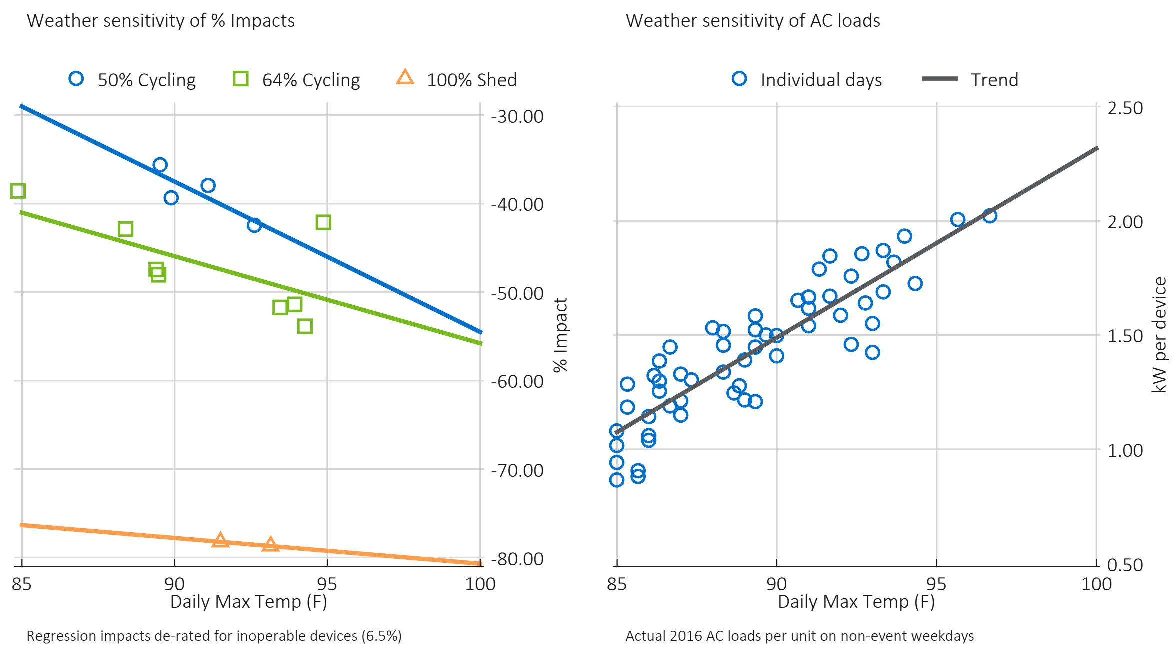


Figure 4-13: Both Air Conditioning Loads and Percent Demand Reductions are Weather Sensitive



4.5 Key Findings

A few key findings are worth highlighting:

- Demand reductions at the end use level were 0.69 kW for the average 50% cycling event, 0.90 for the average 64% cycling event, and 1.64 kW for the average 100% shed event.
- Demand reductions at the whole house level were 0.65 kW per household for the average 50% cycling event, 0.88 kW for the 64% cycling event, and 1.63 kW for the 100% shed event.
- Impacts grow larger in magnitude when temperatures are hotter and more AC loads are available for curtailment.
- There is a clear relationship between weather, degree of load cycling control, and the magnitude of impacts.
- During hotter conditions, reductions exceeding 1.0 kW per participant are attainable with 64% and 100% control.
- There is no evidence that customers compensate for air conditioner curtailments by increasing other end uses—whole building impacts are indistinguishable from end use impacts.

5 Demand Reduction Capability—Time-Temperature Matrix

A key objective of the 2016 evaluation was to quantify the relationship between demand reductions, temperature, hour of day, and cycling strategy—referred to as the time-temperature matrix. By design, a large number of events were called under different weather conditions, for different dispatch windows, using various cycling strategies so that demand reduction capability could be estimated for a wide range of operating and planning conditions.

Weather conditions vary substantially from year to year as shown earlier in Figure 2-3. Because 2016 conditions did not approach the 102˚F conditions Duke Carolinas has previously experienced multiple times, the reductions capability had to be estimated based on the data available.

5.1 Methodology

Figure 5-1 was introduced earlier, but is worth revisiting because it illustrates the essential trends and challenges. Not only do Power Manager demand reductions grow on a percentage basis with hotter weather and with deeper cycling, but so do the air conditioner loads available for curtailment. The implication is that larger percent reductions are attainable from larger loads when temperatures are hotter. However, producing estimates of the reduction capability for 102˚F, unavoidably requires extrapolation of patterns observed in 2016 to conditions that were hotter than those experienced in 2016.

Figure 5-1: Both Air Conditioning Loads and Percent Demand Reductions are Weather Sensitive

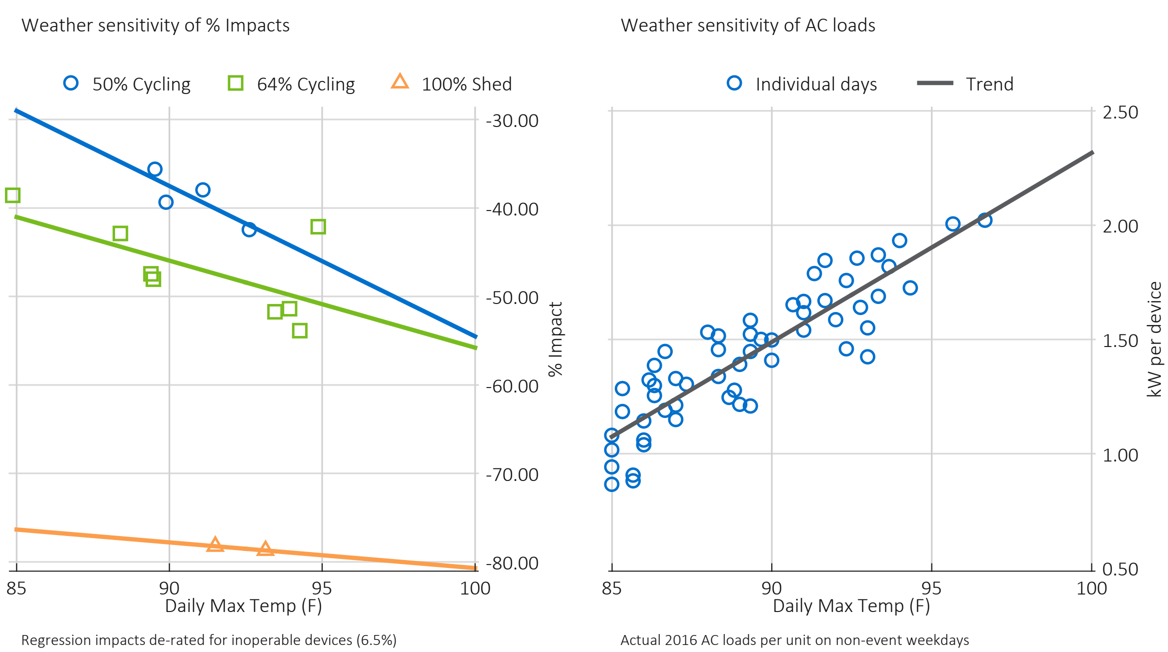


Figure 5-2: Time Temperature Matrix Development Process

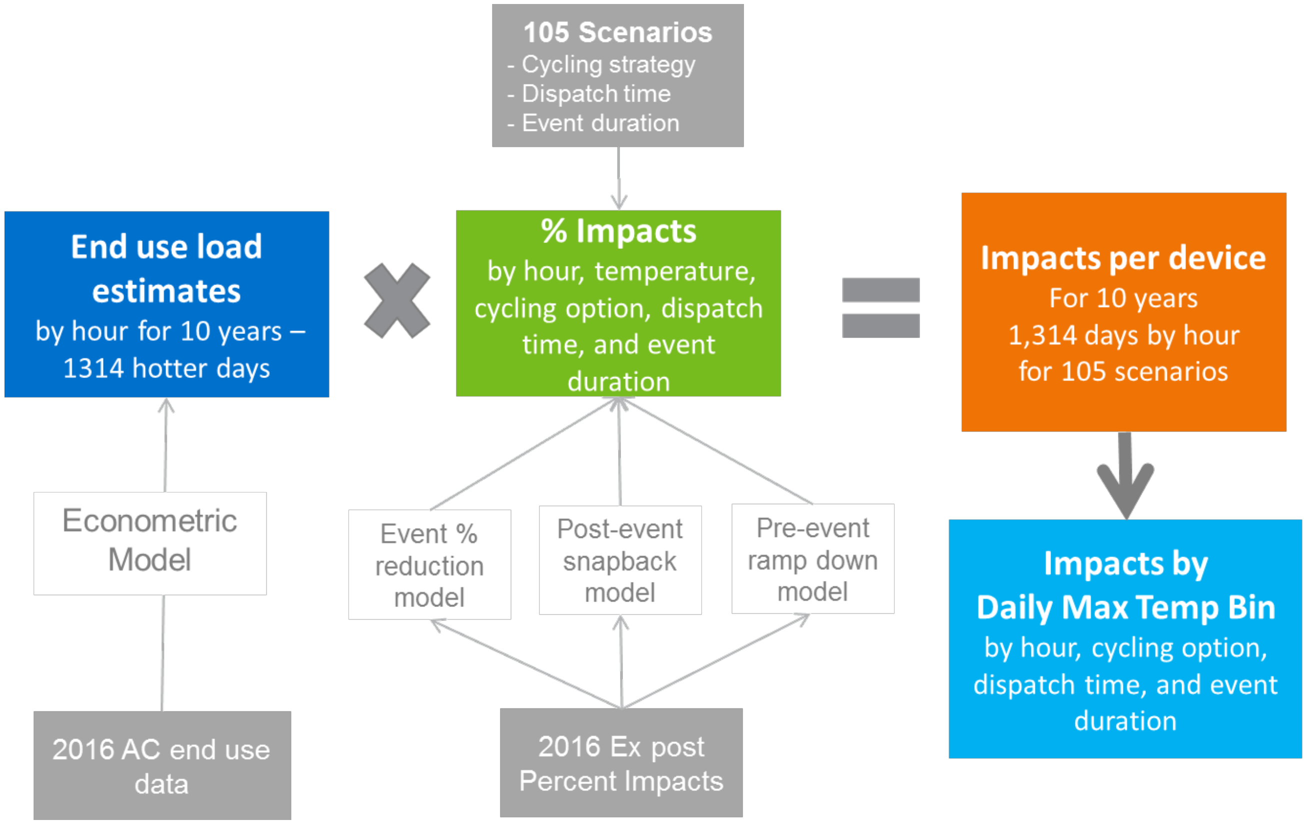


Figure 5-2 illustrates the process used to estimate the demand reduction capability under various conditions:

- Estimates of air conditioner loads were developed using the 2016 air conditioner end use data and using the same regression models used to estimate impacts. All weekdays with daily maximum temperatures above 75˚F were included in the models. The models were used to estimate air conditioner load patterns for 1,314 days in 10 years. Because the models were based on 2016 data, they reflect current usage patterns and levels of efficiency. The 2016 air conditioner patterns were applied to actual weather patterns experienced in past 10 years and not hypothetical weather patterns.
- Estimates of the percent reductions were based on three distinct econometric models of load control phase in, percent reductions during the event, and post-event snapback. The models were based on the percent impacts and temperatures experienced during 2016 events.
- A total of 105 scenarios were develop to reflect various cycling/control strategies, event dispatch times, and event lengths.
- Estimated impacts per device were produced. This was done by combining the estimated air conditioner loads, estimated percent reductions, and dispatch scenarios. The process produced estimated hourly impacts for each of 1,314 hotter weekdays in 2006-2016 under 105 scenarios each.

- Multiple days in narrow temperature bins were averaged to produce an expected reduction profile. Days with the similar daily maximum temperature can have distinct temperature profiles and the heat buildup influenced the amount of air conditioner load.

5.2 Demand Reduction Capability for 102˚F Conditions

While Power Manager is typically dispatched for economic reasons or research, its primary purpose is to deliver demand relief during extreme conditions when demand is high and capacity is constrained. Since 2006, Duke Energy Carolinas has experienced 5 weekdays and 2 weekend days when system temperatures reached 100˚F or more. Several of these days occurred in 2007, when on the hottest weekday system temperatures reached 103˚F. Extreme temperature conditions can trigger Power Manager emergency operations where all devices are instructed to instantaneously shed loads and deliver larger demand reductions than normal cycling events (100% emergency shed). While emergency operations are rare and ideally avoided, they represent the full demand reduction capability of Power Manager.

Figure 5-3: Demand Reduction Capability on a 102˚F with 100% Emergency Shed

INPUTS	
True Cycle	100
Event start (excludes phase in)	4 PM
Event duration	1
Daily Max Temp (F)	102
Devices	229,000

Event Window Avg. Impacts		
Load without DR	2.35	kW per device
Load with DR	0.49	kW per device
Impact per device	-1.8652	kW per device
Impact (MW)	-427.1	MW
% Impact	-79.3%	%

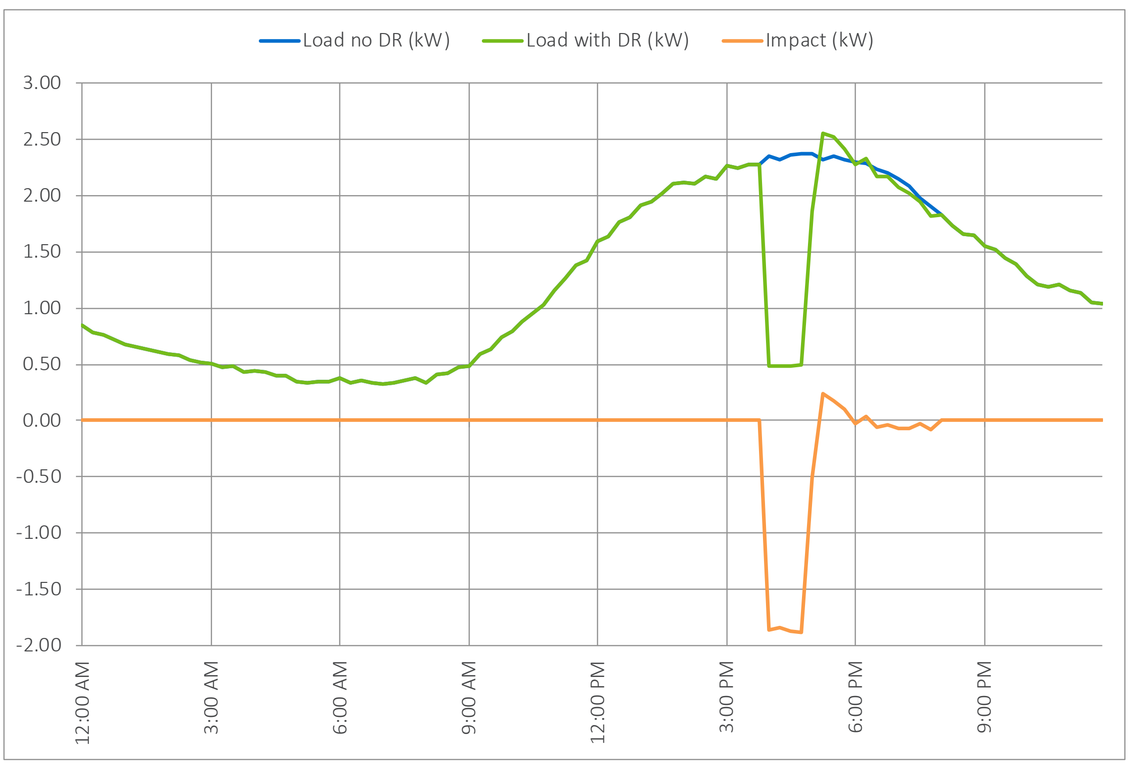


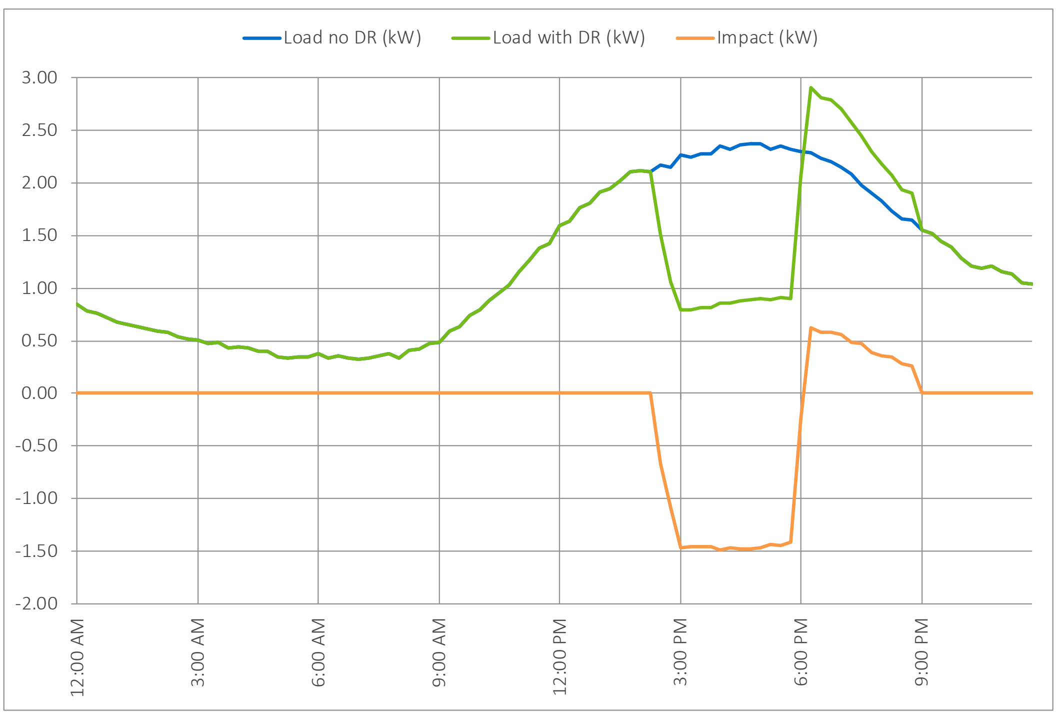
Figure 5-3 shows the demand reduction capability of the program if 100% shed becomes necessary on a 102˚F day for a single hour. Individual air conditioner units are expected to deliver 1.87 kW of demand reduction or 2.22 kW per household (on average Power Manager participants have 1.19 units). Because there are approximately 229,000 devices, the expected aggregate reductions total is 427.1 MW.[7]

Power Manager can deliver substantial demand reductions under 102˚F conditions, even if emergency shed operations are not employed and non-emergency dispatch is employed. With a three hour 64% cycling event, demand reductions average 334.2 MW across the dispatch hours, as shown in Figure 5-4. With longer events, reductions vary slightly across fifteen minute intervals but are generally larger when air conditioner use is highest. The reduction capability is lowest, averaging 202.9 MW across three dispatch hours, when less extensive load control strategies, such as 50% cycling, are employed, as show in Figure 5-5

Figure 5-4: Demand Reduction Capability on a 102˚F with 64% Cycling

INPUTS	
True Cycle	64
Event start (excludes phase in)	3 PM
Event duration	3
Daily Max Temp (F)	102
Devices	229,000

Event Window Avg. Impacts		
Load without DR	2.32	kW per device
Load with DR	0.86	kW per device
Impact per device	-1.4596	kW per device
Impact (MW)	-334.2	MW
% Impact	-62.9%	%

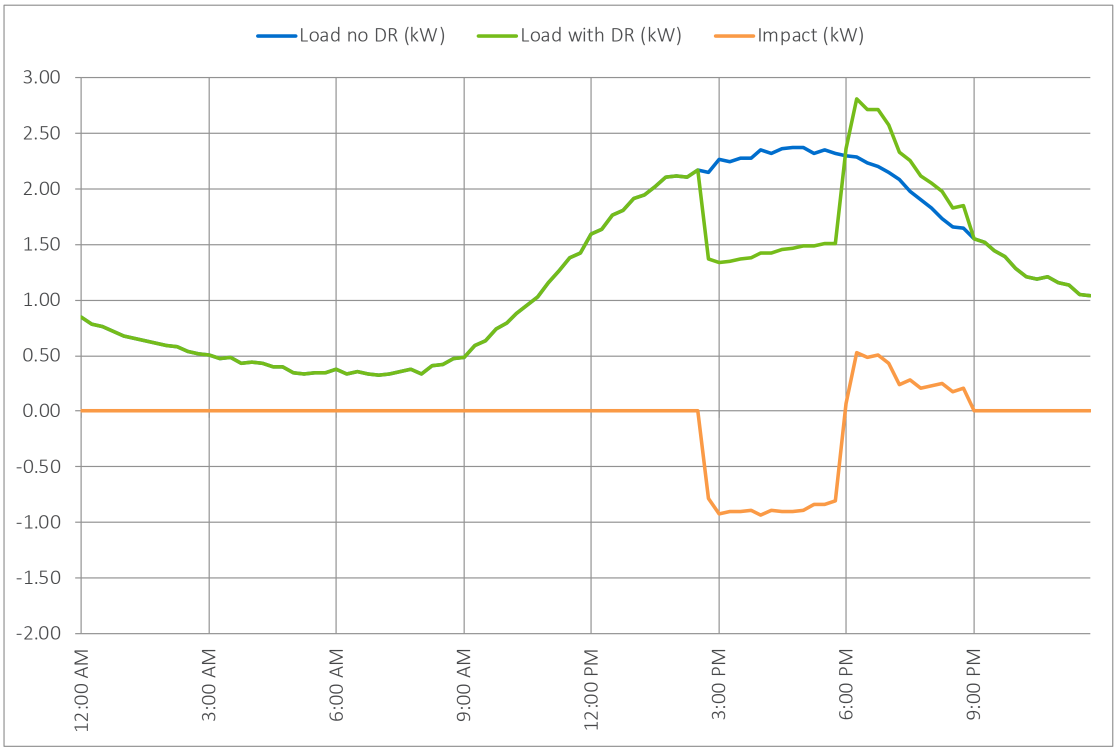


7 Aggregate impacts are presented throughout the report without rounding error. For example, while 1.87 kW x 229,000 devices equals 428.2 MW, the more granular impacts per device, 1.8652 kW per device were used to estimate aggregate impacts of 427.1 MW (1.8652 kW x 229,000 devices).

Figure 5-5: Demand Reduction Capability on a 102˚F using 50% Cycling

INPUTS	
True Cycle	50
Event start (excludes phase in)	3 PM
Event duration	3
Daily Max Temp (F)	102
Devices	229,000

Event Window Avg. Impacts		
Load without DR	2.32	kW per device
Load with DR	1.43	kW per device
Impact per device	-0.8859	kW per device
Impact (MW)	-202.9	MW
% Impact	-38.2%	%



5.3 Demand Reduction Capability by Temperature, Cycling Strategy, and Event Start Time

Table 5-1 summarizes the estimated demand reduction for 100% emergency shed by event start time, and daily maximum system temperature, assuming a one hour event. Table 5-2 summarizes similar information for non-emergency dispatch operations assuming a three hour event. Most non-emergency operations start at 3pm or 4 pm. All estimated impacts exclude the 30 minute periods when the 64% and 50% cycling are randomly phased in and phased out. In practice, event day impacts may vary due to unique weather patterns or day characteristics.

Table 5-1: Emergency Shed Per Device Demand Impacts by Temperature and Event Start

True Cycle	Daily Max (F)	Start Time (1 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
100	74	-0.16	-0.20	-0.25	-0.26	-0.28	-0.30	-0.28
	76	-0.21	-0.27	-0.34	-0.37	-0.40	-0.41	-0.38
	78	-0.22	-0.28	-0.37	-0.41	-0.44	-0.46	-0.42
	80	-0.28	-0.37	-0.47	-0.52	-0.55	-0.56	-0.53
	82	-0.34	-0.45	-0.57	-0.63	-0.68	-0.69	-0.65
	84	-0.45	-0.58	-0.69	-0.75	-0.80	-0.80	-0.74
	86	-0.56	-0.71	-0.82	-0.89	-0.93	-0.93	-0.87
	88	-0.69	-0.84	-0.96	-1.02	-1.06	-1.05	-0.99
	90	-0.77	-0.94	-1.06	-1.13	-1.17	-1.15	-1.08
	92	-0.91	-1.09	-1.21	-1.27	-1.29	-1.26	-1.18
	94	-1.01	-1.19	-1.31	-1.37	-1.40	-1.38	-1.31
	96	-1.14	-1.33	-1.45	-1.51	-1.54	-1.53	-1.45
	98	-1.19	-1.41	-1.53	-1.60	-1.64	-1.62	-1.53
	100	-1.34	-1.57	-1.70	-1.79	-1.83	-1.81	-1.70
	102	-1.35	-1.59	-1.69	-1.80	-1.87	-1.86	-1.79

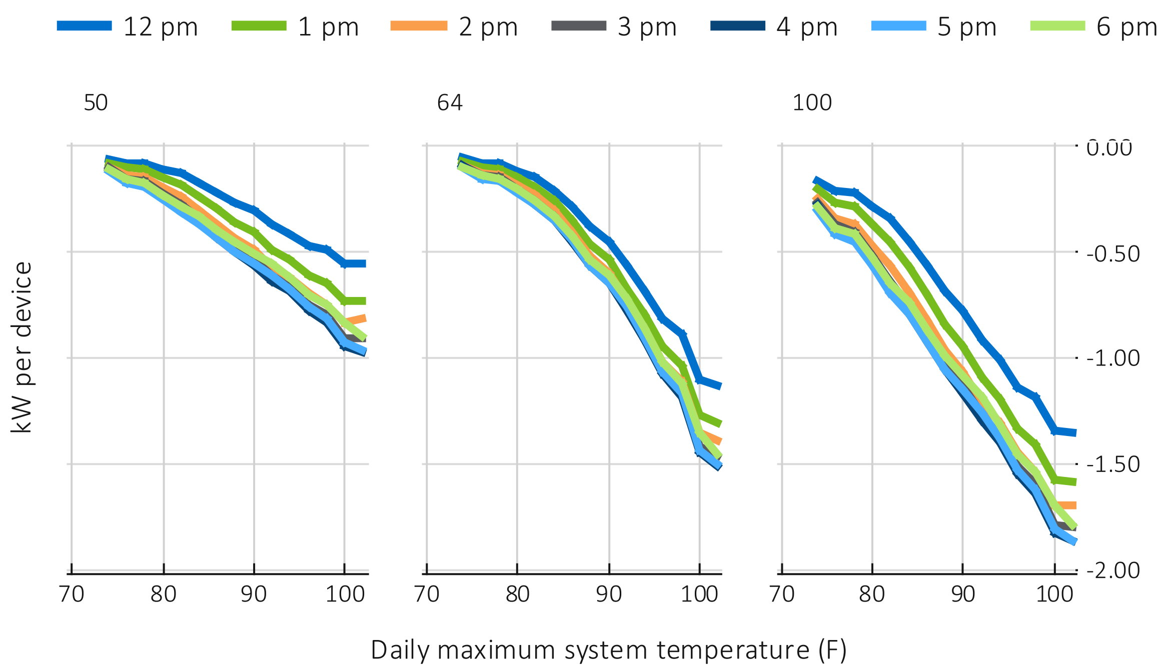
Table 5-2: Non-Emergency Dispatch Per Device Demand Impacts by Temperature and Event Start

True Cycle	Daily Max (F)	Start Time (3 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
50	74	-0.07	-0.08	-0.09	-0.10	-0.10	-0.10	-0.10
	76	-0.09	-0.12	-0.14	-0.15	-0.15	-0.14	-0.13
	78	-0.10	-0.13	-0.15	-0.17	-0.17	-0.16	-0.14
	80	-0.13	-0.17	-0.20	-0.22	-0.22	-0.20	-0.18
	82	-0.17	-0.21	-0.25	-0.28	-0.28	-0.26	-0.23
	84	-0.21	-0.27	-0.31	-0.33	-0.33	-0.30	-0.26
	86	-0.27	-0.33	-0.37	-0.39	-0.39	-0.36	-0.31
	88	-0.32	-0.39	-0.43	-0.46	-0.45	-0.41	-0.35
	90	-0.37	-0.44	-0.49	-0.51	-0.50	-0.46	-0.39
	92	-0.44	-0.52	-0.56	-0.58	-0.56	-0.51	-0.43
	94	-0.48	-0.56	-0.61	-0.63	-0.62	-0.57	-0.48
	96	-0.55	-0.64	-0.69	-0.71	-0.70	-0.64	-0.54
	98	-0.58	-0.68	-0.74	-0.76	-0.75	-0.69	-0.58
	100	-0.65	-0.77	-0.84	-0.87	-0.85	-0.76	-0.64
	102	-0.65	-0.76	-0.84	-0.89	-0.88	-0.82	-0.69
64	74	-0.07	-0.08	-0.08	-0.09	-0.09	-0.09	-0.09
	76	-0.10	-0.11	-0.13	-0.14	-0.14	-0.13	-0.12
	78	-0.10	-0.12	-0.14	-0.15	-0.15	-0.14	-0.13
	80	-0.14	-0.17	-0.19	-0.20	-0.20	-0.19	-0.18
	82	-0.18	-0.22	-0.24	-0.26	-0.26	-0.25	-0.22
	84	-0.25	-0.29	-0.32	-0.33	-0.33	-0.31	-0.28
	86	-0.33	-0.38	-0.41	-0.43	-0.42	-0.40	-0.36
	88	-0.44	-0.49	-0.52	-0.54	-0.53	-0.51	-0.46
	90	-0.51	-0.57	-0.61	-0.62	-0.62	-0.59	-0.53
	92	-0.64	-0.70	-0.74	-0.75	-0.73	-0.69	-0.63
	94	-0.76	-0.83	-0.87	-0.88	-0.87	-0.83	-0.76
	96	-0.90	-0.98	-1.02	-1.04	-1.03	-0.98	-0.90
	98	-0.99	-1.07	-1.12	-1.14	-1.13	-1.08	-0.98
	100	-1.21	-1.32	-1.38	-1.40	-1.38	-1.31	-1.19
	102	-1.25	-1.36	-1.42	-1.46	-1.46	-1.40	-1.28

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

Figure 5-6 provides a visual summary of the reduction capability for a one hour event by cycling strategy and start time. As expected, reductions are larger with hotter temperatures and more aggressive load control operations. The start time also influences the magnitude of reductions which, generally, are larger during hours when air conditioner loads are highest. Appendix B includes the demand reduction capability for a range of event durations.

Figure 5-6: Per Device Demand Impacts by Cycling Strategy, Temperature Conditions, and Event Start



1 hour events, excluding 30 minute phase in period

5.4 Key Findings

Key findings from the development of the time temperature matrix include:

- While emergency operations are rare and ideally avoided, they represent the full demand reduction capability of Power Manager;
- Not only do Power Manager demand reductions grow on a percentage basis with hotter weather and with deeper cycling, but so do the air conditioner loads available for curtailment;
- If 100% emergency shed becomes necessary on a 102˚F day, Power Manager can deliver 1.87 kW of demand reductions per device or 2.22 kW per household;
- Because there are approximately 229,000 devices, the expected aggregate reductions total 427.1 MW;
- Reductions are larger with hotter temperatures and more aggressive load control operations; and
- The event start time also influences the magnitude of reductions which, generally, are larger during hours when air conditioner loads are highest.

6 Device Operability and Site Level Performance

A significant problem in load control programs is nonperforming devices or sites. This can be due to broken or disconnected control devices, or devices failing to receive control event paging signals. It also can occur because of broken air conditioner units or because some customers do not use their air conditioners during event hours. Due to the significant cost of direct verification of device operation, utilities often assume a customer remains a part of the program without any ongoing verification. It is not financially feasible to blindly send service technicians to every property to check device operation. Until recently, with no way to identify broken devices, it has been easier and more cost effective to recruit new customers. If DEC is able to remotely identify sites that underperform because of broken or missing devices or because of paging network communication failures, it could increase the aggregate impacts of the program without as much cost as new customer acquisition.

Using 15 minute interval data from DEC's air conditioning cycling load control program, Nexant undertook the task of creating methods to identify probable inoperable or missing devices. Our effort involved two main steps:

- A field study designed to physically test whether load control devices were functional. The main purpose of this study component was to quantify the share of inoperable devices. This estimate, however, does not factor in paging network communication failures or sites that do not have their air conditioner on during event hours. As described later in this report, the incidence rate is one of the critical components affecting the precision of efforts to identify broken or missing devices.
- Use of data analytics to develop methods that identify sites that underperform or that do not deliver demand reductions. A device that is not functional does not reduce air conditioner demand over multiple events.

The field study was implemented in tandem with the installation of air conditioner data loggers and served to quantify the device failure base rate. While data analytics was used to identify underperforming sites, a separate verification test to determine the precision of the diagnosis has not yet been implemented. Nexant's expectation is that using whole building smart meter data to identify nonperforming or missing devices will lead to substantial improvements over blindly sending technicians to assess device performance. These efforts, however, are most precise if they are restricted to households that clearly use air conditioners during hotter weather conditions. These customers also offer greater impact potential since they use air conditioners during peak conditions. Diagnosis of nonperforming devices is less accurate when it is applied to sites with low or no air conditioner use during peak hours of hotter days.

6.1 Device Operability Field Test

As part of the study, Nexant was responsible for all field work related to customer recruitment for end-use data collection as well as installation and collection of data loggers. Customers were recruited from a random sample of the Power Manager participant population. Prior to installing data loggers on air conditioners, Nexant tested whether load control devices were functional. The inspection consisted of:

- Onsite spot measurements of the kW, voltage, amperage, and power factor;

- Information about the AC unit;
- Inspection of the load control device for presence, proper installation, physical condition, and operability; and
- Inspection of the load control device connection wires, including presence, physical condition, and whether the connection was secure.

Because data quality is essential for accurate program evaluation, Nexant ensured that all site visits related to logger installations/retrievals were carefully planned and executed by trained technicians having appropriate experience. Nexant field engineers installed loggers only on systems having operable switches. The rigor taken to assess device operability prior to logger installation is described in Section 3.6 of this report. Results of onsite device operability checks are based on inspections during logger installations in March 2016 and are summarized in Table 6-1.

Based on field tests, 144 out of the 154 devices tested, 93.5%, of devices are operable, with a 90% confidence interval of ±3.27%. This does not account for devices that do not perform due to paging network issues or because the air conditioner is not in use during afternoon peak hours of hotter days.

Table 6-1: End Use Logger Device Operability

Metric	Value
Devices inspected	154
Inoperable devices	10
Operable devices (i.e., loggers installed)	144
Device failure rate	6.5%

6.2 Results

Figure 6-1 illustrates the six prototypical load shapes produced by the cluster analysis. The shapes for customers in groups 2, 3, and 5 suggest a distinct load drop. Customers in group 6 have a smaller but still distinct load drop. The shapes for groups 1 and 4 suggest no load reduction took place for these customers during events despite the automation. This could be due to missing or failing devices, paging network gaps, or lack of air conditioner loads.

Figure 6-1: Prototypical Event Load Shapes

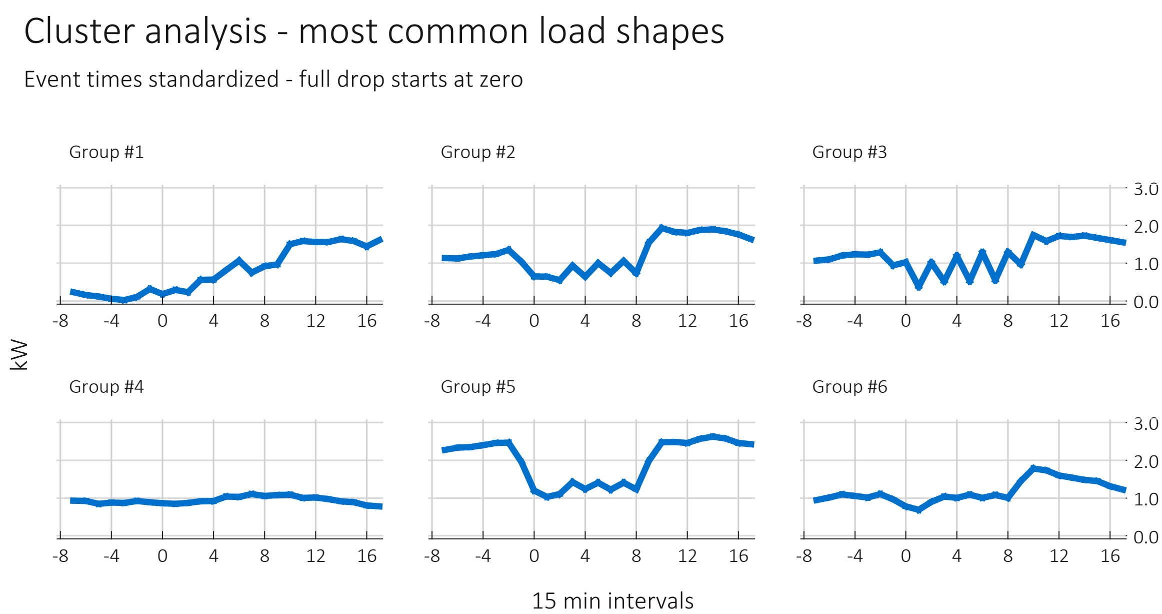
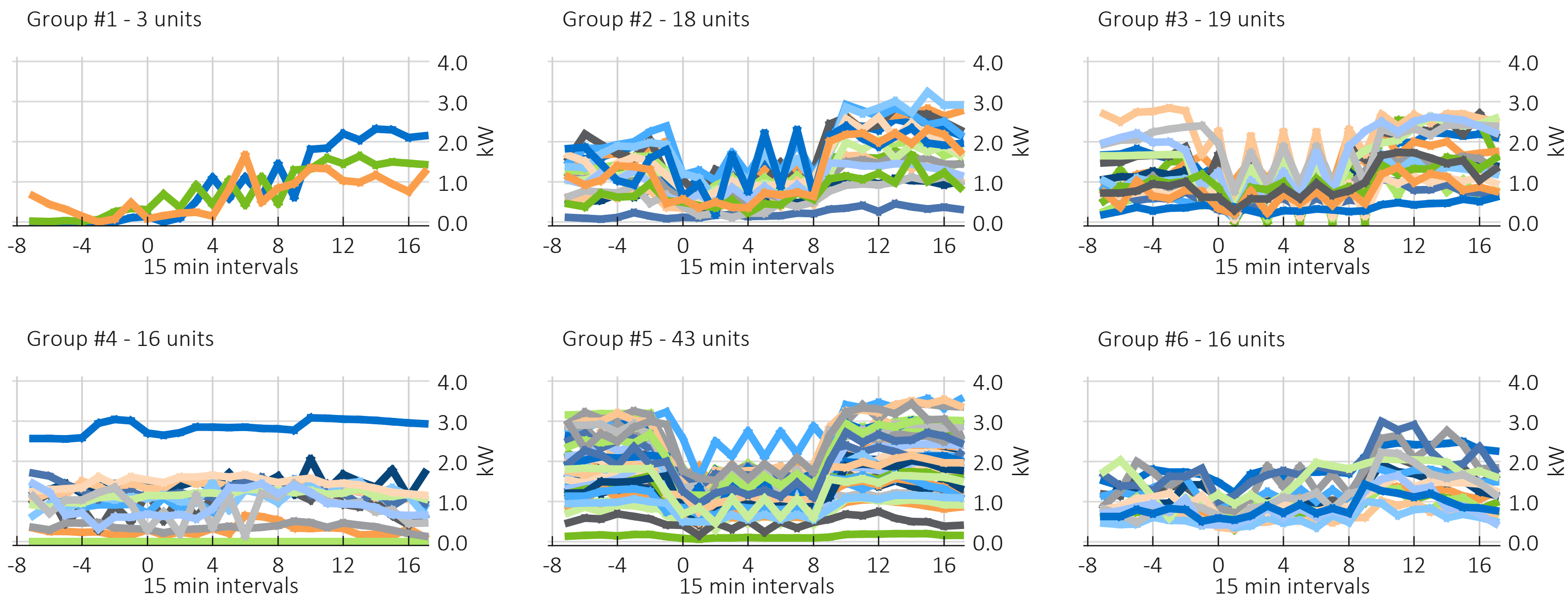


Figure 6-2 visualizes the categorization for individual units. The customers in each group follow the prototypical shapes but sometimes differ in size due to the fact that the algorithm isolated shapes. In total, 19 of 115 units analyzed (16.5%) did not exhibit a demand reduction pattern and another 13.9% were assigned to group 6, which delivered smaller percent load reductions. It is important to separate performance from weather sensitivity and customer size. Smaller customers may be underperformers due to the lack of air conditioners, and are less cost effective, even with a functional device. Thus, we recommend focusing direct verification efforts on larger customers.

Figure 6-2: Event Day Load Shape Clusters

Carolinas cluster analysis - most common event day load shapes

Event times standardized - full drop starts at zero



Each line is a AC unit during the average event day
Based on end-use load data

6.3 Key Findings

Key findings from the investigation into device operability include:

- End use data loggers were only installed on air conditioner units with functional load control devices;
- Based on field tests, 144 out of the 154 (93.5%) devices tested are operable, with a 90% confidence interval of ±3.27%, excluding devices that do not perform due to paging network issues or because the air conditioner is not in use during afternoon peak hours of hotter days;
- Most sites with inoperable devices have multiple failures;
- The event day load profiles suggest that 19 of 115 units analyzed (16.5%) did not exhibit a demand reduction pattern. This could be due to failing or missing devices, paging network issues, or lack of air conditioner loads; and
- Efforts to inspect paging network strength and verify that devices are present and operable should focus on larger customers. They are less prone to misdiagnosis and more cost effective.

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:

- Assessing the extent to which participants are aware of events, bill credits, and other key program features;
- Understanding the participant experience during events: comfort, occupancy, thermostat adjustments, and strategies employed to mitigate heat;
- Identifying 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;
- Documenting the operations, recruitment, enrollment, outreach, notification, and curtailment activities associated with program delivery; and
- Identifying program strengths and potential areas for improvement.

7.1 Survey Disposition

Nexant developed a survey for customers participating in the Power Manager program that was deployed immediately following a Power Manager event. The survey was administered via phone and email to maximize response rates during the 24 hour window directly following a Power Manager event. The post-event survey addressed the following topics:

- Awareness of the specific event day.
- Any actions that increased household comfort during a Power Manager event. 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 and bill credits earned.
- 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?
- Do participants expect to remain enrolled in the program in future years?

In addition to the post-event survey, a nonevent survey was also deployed immediately following a hot, nonevent day. This nonevent day survey was identical to the post-event survey to establish a baseline and facilitate comparison with the results of the event day survey. Both the event and nonevent surveys were administered to Power Manager participants. Since event awareness and thermal comfort are primary areas of inquiry for the survey, the nonevent baseline data (from the nonevent surveys) provides the opportunity to net out any propensity for thermal discomfort or belief that a Power Manager event is occurring that would naturally happen on any hot day of the summer. In this way, it is possible to evaluate whether statistically significant differences in event awareness and reports of thermal discomfort exist between customers who actually experience a Power Manager event and customers who do not.

The survey was completed by 95 customers on an event day (the *event* group) and 89 customers on a hot nonevent day (the *baseline* group). The overall response rate was 9%. All surveys were conducted on the day of the event or the nonevent. The plan was to survey about 50% of respondents by phone and 50% by email, but on the event day more people were reached by telephone than expected. The distribution of phone calls and emails, with response rates, is shown in Table 7-1 . All responses in this section summarizing survey results have been weighted to reflect the survey design for 50% of completions by phone and email each.

The temperature on the event day was a high of 94°F with a heat index of 95°F, which was nearly the same as the temperature on the nonevent day, which was a high of 95°F with a heat index of 95°F. Table 7-1 outlines the event and nonevent baseline group survey dispositions.

Table 7-1: Survey Disposition

Total Responses	Group Size	Date	Temperature	Phone/ Email Distribution	Response Rate
184 Responses	95 Event Day	Thursday, September 8	high 94° F (heat index 95° F)	56% Phone	13%
				44% Email	6%
	89 Nonevent day (Baseline)	Wednesday, July 13	high 95° F (heat index 95° F)	58% Phone	16%
				42% Email	6%

Most households surveyed have two or fewer residents, and only 8% of event and 17% of nonevent baseline households have four or more residents. There was no apparent systematic difference in the age of respondents between the event and nonevent baseline groups. The mean age of respondents is 65 years and the most commonly reported level of education was a bachelor's degree: 29% of respondents said that they graduated from college. Nearly as many (26%) have some college or an associate's degree and 22% have a graduate or professional degree.

7.2 Program and Event Awareness

The customer surveys were designed with the key objective of evaluating participants' awareness of Power Manager events, but a few questions were also included to gauge participants' general awareness of the program and its key features. Every respondent who was contacted to complete the survey was a Power Manager participant at the time of the survey, and a strong majority of the respondents, 85%, reported that they are in fact familiar with the Power Manager program. Respondents also reported on whether or not they had seen Power Manager event credits on their bill. Less than a majority of respondents affirmed that they have seen credits on their bill: 32% of respondents reported that they have seen a credit, while 35% reported that they had not, and the balance of respondents, 33%, reported that they did not know. It is possible that due to the timing of the nonevent survey, which was midseason, these customers had not yet seen credits in 2016. With many customers receiving paperless bills, it is possible that some customers rarely look at the line item details on their monthly statement. Duke Energy screened the list of customers who said they did not receive bill credits to make sure errors were not made; all in fact received a bill credit when they should have.

Both of these questions were asked of both the event group and the nonevent baseline group. That is, the questions were asked of a group of customers that had experienced a Power Manager event that day and a group of customers who had not. It would not be expected that there would be significant differences in these questions addressing program awareness between these groups. Indeed, the responses to these two questions do not significantly differ across event and nonevent baseline groups.

The bill credits are designed to be a program feature that enhances customer satisfaction with the program; with less than half of respondents recalling receiving a bill credit, an opportunity exists to improve participants' awareness of this customer-friendly program feature.

Every Power Manager participant who was randomly selected to receive the post-event survey, i.e., the event group, experienced an actual Power Manager event that day, Thursday, September 8. A total of 95 customers completed the post-event survey. Only 12% of the event group respondents reported that their homes were uncomfortable that day, while all of them experienced a load control event that afternoon. As a program with no pre-event notification, a decrease in thermal comfort in the home is the key factor for assessing event awareness. In the Carolinas, with only 12% of respondents stating that they were uncomfortable the day of the event, event awareness by that measure is quite low. However, it could also be that a number of those respondents would say that their home was uncomfortably hot at times on any hot day of the year, regardless of whether or not the Power Manager program had a load control event. To control for this possibility, another randomly selected group of Power Manager participants were also surveyed on a hot day when a Power Manager event did not occur, Wednesday, July 13. A total of 13% of respondents reported that their home was uncomfortable on this nonevent day. The small difference in the portion of respondents in the post-event survey and the nonevent survey that stated that their homes were uncomfortable that day (12% and 13%, respectively), is not statistically significant, therefore, the increase in reported thermal discomfort cannot be ascribed to the Power Manager event. The response frequencies are tabulated in Table 7-2.

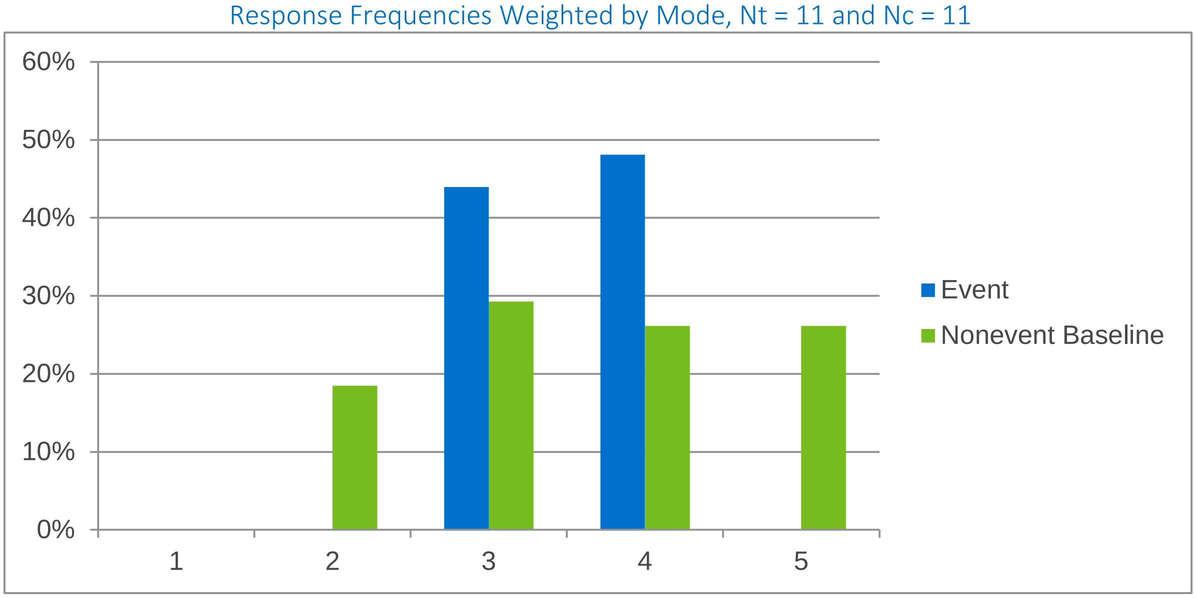
Table 7-2: Was there any time today when the temperature in your home was uncomfortable?
Response Frequencies Weighted by Mode, Nt = 95 and Nc = 89

Response	Event	Nonevent Baseline
Yes	12%	13%
No	78%	78%
Don't know	9%	9%
Refused	1%	0%

Of those relatively few customers (11 post-event and 11 nonevent survey respondents) who reported that they were uncomfortable at some time during the day of the survey, the majority (12 people) reported becoming uncomfortable between 2 and 3pm. The rest were distributed throughout the day, from 4am to 6pm. Asked when the period of thermal discomfort in their home ended, there was a shift in responses towards later in the day, with 16 respondents reporting that their homes stopped feeling uncomfortable between 4 and 7pm. Three respondents listed times earlier than 4pm, and one respondent listed 10pm.

These customers who reported thermal discomfort were also asked to rate their discomfort using a five-point scale, where 1 represents "not at all uncomfortable" and 5 represents "very uncomfortable." Frequencies of the responses are summarized in Figure 7-1, for which the chi-squared statistical test shows no discernable difference in the distributions of post-event and nonevent survey responses (at the 90% level of confidence). In sum, there appears to be no difference in thermal discomfort between the event group and the nonevent baseline group. The survey does not present evidence that Power Manager events led to more customers reporting discomfort in their homes, or to higher degrees of discomfort.

Figure 7-1: Please rate your discomfort using a scale of one to five, where one means "not at all uncomfortable" and five means "very uncomfortable."
Response Frequencies Weighted by Mode, Nt = 11 and Nc = 11



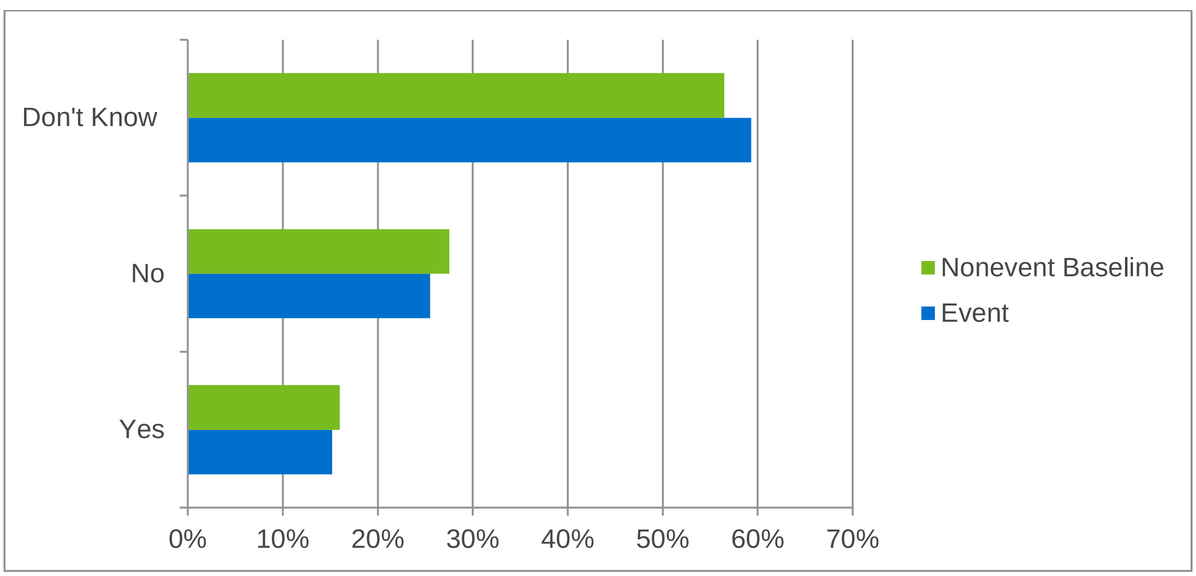
Those respondents who reported that their homes had been uncomfortably hot that day were asked to state in their own words what they think caused the discomfort. The most commonly reported rationale is that the discomfort in their home was due to the weather being hot; 54% of 11 event respondents and 26% of 11 nonevent respondents gave that reason. The second most common reason was that the air conditioner was not on: 30% of event and 15% of nonevent respondents said this. Only 16% of event respondents and 11% of nonevent respondents ascribed their thermal discomfort to Duke controlling their air conditioners (not a statistically significant difference). Table 6-3 summarizes the responses given to this survey question, across event and nonevent baseline customers and altogether. The totals may not add up to 100% because respondents could cite more than one reason. The difference in distribution of answers between the two groups is not statistically significant; this is not unexpected given the small number of customers who answered this question.

Table 7-3: What do you think caused the temperature to be uncomfortable?
Response Frequencies Weighted by Mode, N_t = 11 and N_c = 11

Reason	Event	Nonevent Baseline	All
Air conditioner unit was not on	30%	15%	23%
Air conditioner doesn't work properly	0%	22%	11%
Duke Energy was controlling air conditioner	16%	11%	13%
It was a very hot day	54%	26%	40%
Other	0%	26%	13%

All survey respondents were also asked directly whether or not they thought a Power Manager event had been called in the past few days. The most common response was "don't know," where 59% of event customers and 56% of nonevent customers stated that they didn't know if there was a Power Manager event in the past few days. The prevalence of "don't know" responses here is not surprising in light of the fact that Duke Energy does not actively notify participants of load control events. Figure 7-2 presents response frequencies for event and nonevent respondents; the differences between event and nonevent responses to this question were not statistically significant. Across all respondents together, 58% did not know if there was a Power Manager event recently, 16% thought that there was an event recently, and 26% did not think that there was an event recently.

Figure 7-2: Do you think a Power Manager event occurred in the past few days?
Response Frequencies Weighted by Mode, N_t = 95 and N_c = 89



The relatively few respondents (14 event and 13 nonevent) who thought there was a Power Manager event recently were asked a few questions about the event(s) that they perceived to have happened. First, when asked on what day they thought the event occurred, 36% of the event customers correctly stated that there was an event that day; for comparison, 6% of nonevent customers said there was an event day that day. Directionally, these survey responses indicate that among customers who thought a Power Manager event recently occurred, customers who actually experienced an event that day are more likely to correctly identify that event day than customers who did not actually experience an event that day. But with only a single nonevent baseline customer and five event customers to compare in this response category, it is not possible to rule out that this difference is due to chance alone.

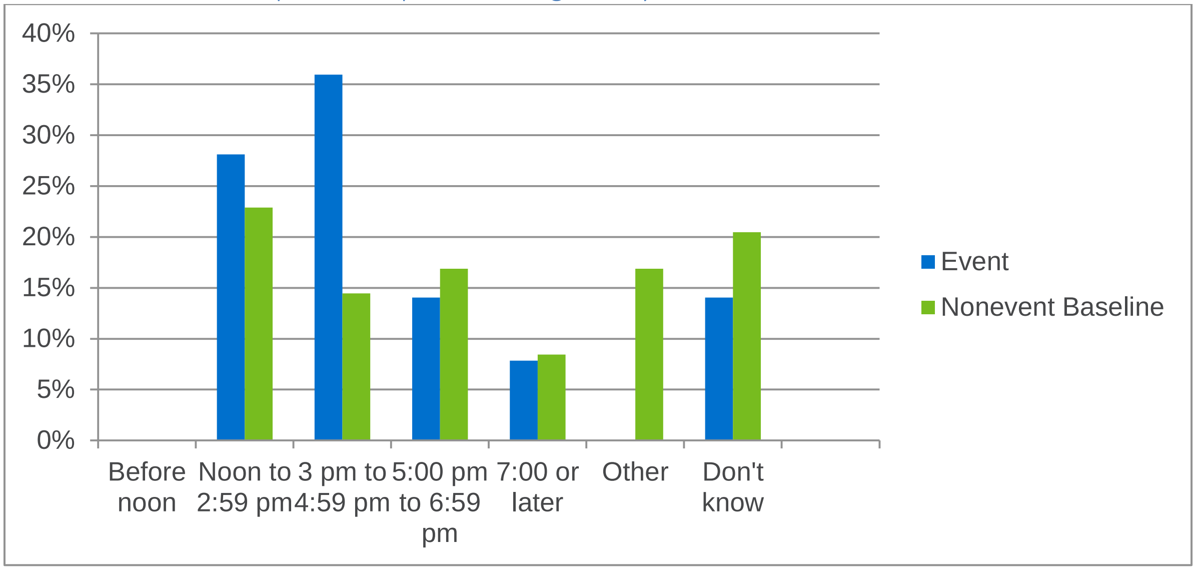
These customers were also asked to describe how they determined that a Power Manager event was occurring, and the responses are summarized in Table 7-4. The most common response, given by 57% of respondents, is that they concluded an event was occurring because the temperature inside their home went up. The next most commonly reported rationale was because they did not hear the air conditioning running the way they normally do, with 14% of respondents giving this reason. There were no statistically significant differences between the response patterns of event customers and nonevent customers for this question.

Table 7-4: How did you determine that an event was occurring?
Response Frequencies Weighted by Mode, N_t = 14 and N_c = 13

Reason	Event	Nonevent Baseline	All
It got warmer inside - the inside temperature went up	58%	53%	57%
Did not hear the air conditioner running like I knew it should	14%	14%	14%
Some other way	8%	8%	8%
It was a hot day outside - I knew from the temperature outside	6%	0%	3%
Don't know	8%	22%	15%

These respondents who thought there was a Power Manager event recently were also asked what time they thought the event occurred and whether or not they were home at that time. All respondents said that they first noticed the event during the period of noon to 7pm, except for two who noticed it during the night and several who said they were not sure. However, the event customers tended to respond that they thought the event started earlier in the day, while the nonevent customers' responses resembles a uniform distribution across time of day. The chi-squared test for differences in these distributions is statistically significant at the 95% level of confidence (p-value = 0.028), suggesting that the event customers who noticed an event tended to notice it closer to the time it actually started and that nonevent customers were not any more likely to think that a perceived event began at any particular time of day, consistent with the fact that they did not actually experience an event.

Figure 7-3: About what time did you first notice this event?
Response Frequencies Weighted by Mode, N_t = 14 and N_c = 13



7.3 Program Experience

Aside from occasional program communications to program participants, the primary way that Duke Energy customers experience the Power Manager program is during load control events. A large majority of survey respondents, 83%, stated that there is normally someone home between the hours of noon to 6pm on weekdays. Similarly, large proportions of respondents also reported that they are frequent users of their air conditioning systems. Table 7-5 shows the percentage of respondents who reported that they used their air conditioners every day for four different time periods and day type combinations. Generally, between 85% and 94% of Power Manager survey respondents reported using their air conditioners every day, considering both weekdays and weekends, during both the afternoon and the evening. Statistically significant differences in response patterns were not observed here.

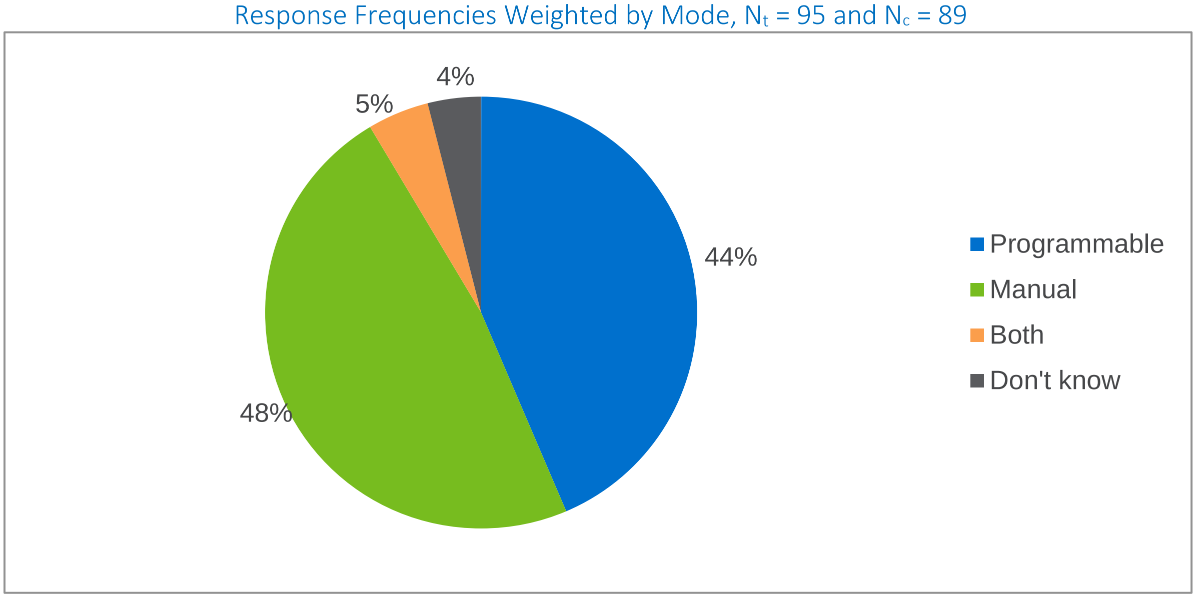
These survey responses confirm that Power Manager participants are in fact largely at home and using their air conditioners during the times that the program is likely to be launched when the need arises to use the program resource. As such, monitoring participant comfort levels is confirmed to be an important evaluation activity so that thermal comfort can be maintained at high enough levels to retain customer participation.

Table 7-5: How frequently do you or someone else in your household use your air conditioning system? Response Frequencies Weighted by Mode, N_t = 95 and N_c = 89

Day and Time	% of Event Respondents Responding "every day"	% of Nonevent Respondents Responding "every day"
...weekday afternoons (12-6 PM)	85%	94%
...weekend afternoons (12-6 PM)	90%	94%
...weekday evenings (6 PM-12 AM)	87%	89%
...weekend evenings (6 PM-12 AM)	90%	94%

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. Beginning with the type of thermostat(s) installed in the home, survey responses show that there is a mix of both manual and programmable thermostats installed in the homes of Power Manager participants. Figure 6-4 summarizes the types of thermostat(s) that survey respondents reported. About half, 48%, have a manual thermostat, while 44% of respondents say that they have a programmable thermostat.

Figure 7-4: What type of thermostat(s) do you have?
Response Frequencies Weighted by Mode, N_t = 95 and N_c = 89



Among the customers who have programmable thermostats, 32% reported using the programmability feature to allow the thermostat to cool to different temperatures at different times, and a further 58% of customers set their thermostat at a constant temperature, representing 90% of respondents. Among customers without programmable thermostats, 60% say that they keep their thermostat set at a constant temperature. This relatively high incidence of using a thermostat setpoint should encourage thermal comfort associated with events. If during the course of an event, the home's internal temperature rises by one or two degrees, when the event is over, the thermostat will reliably detect the higher temperature and automatically cool the home to the desired temperature, without relying on the customer to feel uncomfortable first and manually turn the air conditioning on themselves. These reported air conditioning usage behaviors are supportive of the earlier finding that, on the whole, Power Manager participants are not aware of events when they occur.

In a similar vein, we asked customers who reported that they thought there was a Power Manager event recently whether or not they took any actions as a result of the perceived event. Only 5 customers (of 27 who said that they thought there was a Power Manager event) said they did something different because of the event. They all reported using fans they do not normally use, but none of them used any extra air conditioning units. None of them left home to go somewhere cooler, and only one customer reported changing their planned activities. Responses to these questions also provide more evidence that Power Manager events are not disruptive to participants. Participants who used other appliances for cooling chose fans, a low-energy usage cooling appliance.

7.4 Motivation and Potential Barriers for Program Participation

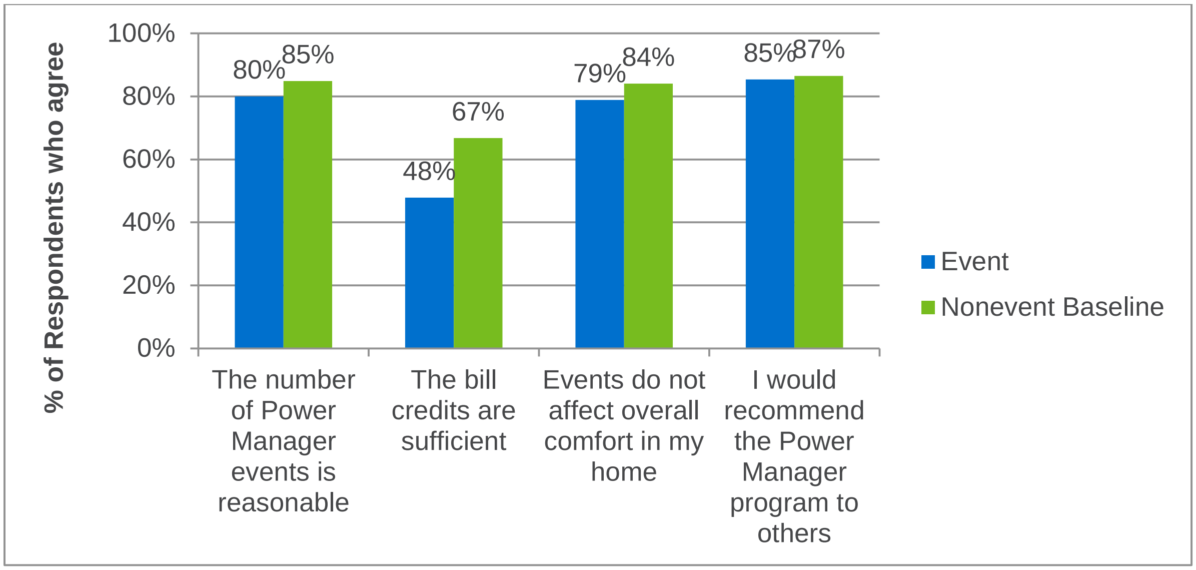
Respondents were provided with a list of possible reasons for enrolling and asked which reason was most important to them, and the survey responses reveal that Power Manager participants are motivated to be a part of the program by a diverse set of interests. The most frequently reported motivation is the bill credits, with 49% of respondents citing this as their most important motivator. The second-highest motivator is helping the environment; 17% of respondents said helping the environment was the most important reason for enrolling. The remaining 34% of respondents were mostly split between “doing my part for DEC” and “avoiding electrical service interruptions.” Only 8% answered “don’t know.” Table 7-6 summarizes the survey responses. Differences in response patterns between event and nonevent baseline groups are not statistically significant.

Table 7-6: Which of the following reasons was most important to you when enrolling?
Response Frequencies Weighted by Mode, $N_t = 95$ and $N_c = 89$

Reason	Event	Nonevent Baseline	All
Earning a credit on my bill	53%	44%	49%
Helping the environment	13%	20%	17%
Doing my part for DEC	12%	16%	14%
Avoiding electrical service interruptions	8%	16%	12%
Don't know	13%	4%	8%

Customers were asked to rate, on a scale of 1 to 5, their agreement with various positive statements about Power Manager. Customers widely agreed that they would recommend the Power Manager program to others; that Power Manager events do not affect the overall comfort in their home; and that the number of Power Manager events is reasonable. Over 75% of both event and nonevent baseline customers agreed with those statements. But only 67% of event customers and 48% of nonevent baseline customers agree that the bill credits are sufficient. The distribution of responses for those who answered each question is shown in Figure 7-5.

Figure 7-5: How would you rate the following statements about Power Manager? Response Frequencies Weighted by Mode, N_t = 95 and N_c = 89



The survey concluded with an opportunity for customers to provide free form suggestions on how they think the Power Manager program might be improved. Only 34% of respondents (62 of 184) offered suggestions. Among those offering suggestions for improvement, there were four common requests. The first, mentioned by 20 of 62 people, reflected a desire for more bill credits. The second, mentioned by 13 people, expressed a desire for notification before or during an event:

- "Maybe develop a better way to advise customers when the system is being activated, as well as the reasons for activation."
- "It would be nice if Duke would call and let me know when they're going to turn it off."
- "Since you have my email, we could be notified when you activate the program."
- "Provide a text message advising it is/will happen."

The third most common comment, reported by 10 people, was that Power Manager is a good program. Several commented that the program is imperceptible to them, and some commented that the program is flawless except for the small bill credits:

- "I don't ever notice it, so it works fine for me."
- "It's invisible."
- "They got a good thing going."
- "If they could lower our bills. Otherwise, I give them a good rating."
- "It's a good program…I do think that possibly the program could be adjusted $$-wise."

Five people complained about the load control and suggested that Duke change the cycling pattern. Many of these comments are based on flawed understanding of the program. Six people mentioned that they would like to have feedback after an event to inform them about their participation and the credits they earned; sometimes they don't read their bill closely and they want a more prominent notification. Some of the comments in these areas include:

- "After an event when the power comes back on it needs to stay on for at least 20 minutes or so. In the past it came on then went right back off in 5 minutes then went off for the normal off time then came back on and went off in 5 minutes."
- "My bill comes directly to online banking, so I don't actually look at a statement anymore. I'm on EPP, so I don't see the credits. Could you send an email when you issue a credit, so I know I'm getting the benefit?"

Table 7-7 summarizes categorizations of the freeform responses. Many respondents gave more than one comment, and often they gave one comment that fit into a specific category and one that fell into "other." Since the answers often fit into multiple categories, the percentages add up to more than 100%.

Table 7-7: What suggestions do you have to make the Power Manager program work better for you? Response Frequencies Weighted by Mode, N_t = 34 and N_c = 28

Statement	Event	Nonevent Baseline	All
I want more credits	30%	35%	32%
Other	31%	16%	24%
I want more notification	30%	12%	21%
It's a good program	15%	18%	16%
I want more feedback	9%	12%	10%
Change the cycling strategy	11%	4%	8%

Responses were positive when participants were asked to rate the likelihood of staying enrolled in Power Manager, with the large majority of respondents saying that they intend to stay in the program. Overall, 78% of respondents said they would "very likely" remain enrolled. Responses are tabulated in Table 7-8. The four customers who said they were not at all likely to stay enrolled gave disparate explanations. Their explanations are shown in Table 7-9.

Table 7-8: How likely is it that you will stay enrolled in Power Manager? Would you say…? Response Frequencies Weighted by Mode, N_t = 95 and N_c = 89

Response	Event	Nonevent Baseline	All
Not at all likely	4%	0%	2%
Somewhat likely	11%	14%	12%
Very likely	79%	77%	78%
Don't know	5%	8%	7%

Table 7-9: Why are you not at all likely to stay enrolled in Power Manager?
N_t = 4 and N_c = 0

Response	Group
I am now home all the time due to a disability.	Event
I do not want this program. I am not supposed to be in this program.	Event
It is very uncomfortable.	Event
They have not been truthful about the program; they don't save me money.	Event

7.5 Interview Findings

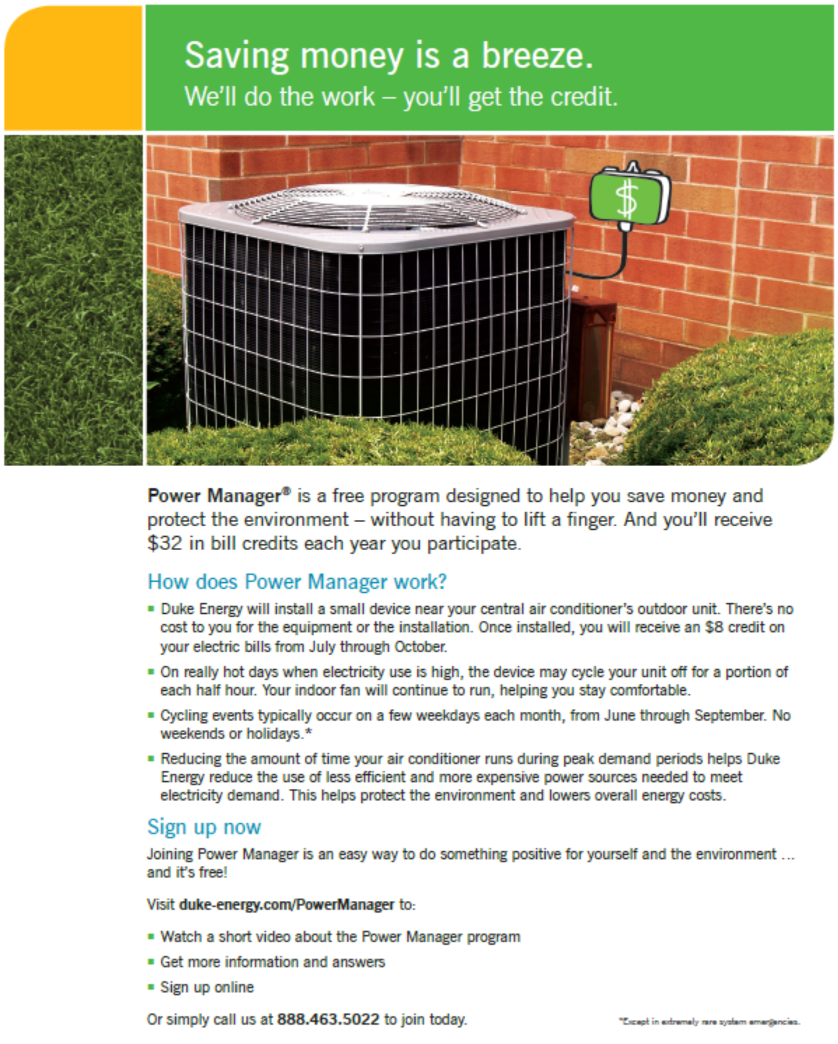
Power Manager is a mature demand-side resource that is actively used in the course of operating Duke Energy Carolinas' electric system. The demand savings delivered by Power Manager are made possible through the teamwork of internal and external stakeholders that manage the program's budget and goals, communicate with participants, maintain the Yukon event dispatch software, and interact with the customer at every stage of the program lifecycle, from enrollment, to device installation, to device removal. Three primary stakeholder groups, the Duke Energy program management team, Eaton Power Systems, and GoodCents, worked together to deliver Power Manager to customers. Nexant interviewed seven individuals from these organizations. Overall, through the course of our conversations, we observe that Power Manager maintains a customer focused orientation and is currently engaged in a number of initiatives to improve program operations and customer service. The remainder of this section will describe the Power Manager offering at DEC and what Duke Energy's activities are to bring in new program participants and support annual enrollment goals. A description of Duke Energy's activities to maintain Power Manager as a reliable system resource follows, 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.

7.5.1 Program Offer and Enrollment Goals

Work to recruit new Duke Energy Carolinas participants into Power Manager takes place year-round. DEC's enrollment goal for 2016 was 19,750 devices. This relatively high annual enrollment target requires a year-round recruitment effort, rather than a shorter campaign limited to the spring season. The majority of recruitment into Power Manager takes place through outbound calling, fulfilled by the third party call center provider, CustomerLink. In some years, there are also direct mail and email recruitment campaigns initiated and managed by Duke Energy.

As an outbound call center, CustomerLink is prepared to address common questions or concerns that DEC customers who are not familiar with the program may have, in addition to describing the basic features of the program, many of which are friendly to the program participants. Outbound callers are ready to speak to the fact that Duke Energy's customer research has shown that 85% of customers who are home during an event don't notice it, that there are generally only five to seven events each summer, and that events typically end by 6pm, which is when many customers are just coming home from work. Another participant friendly aspect of the program is that air conditioning units enrolled in the program are cycled rather than completely curtailed.[8] Power Manager is also not called on weekends or weekday holidays. The load control devices used by the program—switches that directly control the air conditioner's compressor—are a proven technology that does no harm to the customer's air conditioner or the home's electric distribution system. Figure 6-6 provides an example of recent Power Manager marketing collateral used in the DEC jurisdiction.

Figure 7-6: Excerpt from Power Manager Direct Mail Marketing Collateral



The Duke Energy Carolinas program offer provides monthly bill credits in the amount of $8 to incentivize participation, where the bill credits apply from July to October. With only a modest financial incentive

[8] Unless a load control event is called as a result of a system emergency. In that case air conditioning units could experience full load shed. Emergency Power Manager events are extremely rare.

for participation, Duke Energy emphasizes messaging around community and environmental benefits to generate customer interest in the program. The program offer, which centers on the use of the outdoor switch, rather than an indoor programmable communicating thermostat, is found generally to be most successful with customer segments that are attracted to "set-it-and-forget-it" arrangements and those customers who would prefer not to have a service provider enter the home. Duke Energy has found that these preferences are correlated with older, higher income, and higher education demographics.

GoodCents is a third party provider that manages Power Manager customer care and handles participants' inquiries about the programs and requests for customer service, in addition to all fieldwork. Power Manager fieldwork ranges from scheduling and routing load control device installations, training and managing a staff of device installers, responding to any device service calls, and fulfilling customer requests to remove load control devices. GoodCents reports that most new device installations are handled within 30 days of the customer's enrollment, and that most customers don't request installation appointments to work around pets or access issues. As a result, most installation appointments can be fulfilled using cost-effective routing and scheduling. GoodCents also manages and staffs all quality assurance inspections and fieldwork.

7.5.2 Power Manager Program Operation and Maintenance

In terms of maintaining Power Manager as a reliable system resource for the Duke Energy Carolinas system operators, Eaton Power System plays an important role as the provider of the switches and as a resource to assist Duke Energy program staff in maintaining the Yukon software system, managing firmware issues that can arise from time to time, addressing the switches for normal service and evaluation, measurement and verification (EM&V) activities and training GoodCents' switch installers. An annual all-hands Spring Training event hosted by Duke Energy brings all the Power Manager program stakeholders together to discuss the upcoming load control season's work. Also particular to 2016, a large scale quality assurance audit effort of load control switches was undertaken and staffed by GoodCents.

When it's time to start calling events during the summer load control season, there is no proactive customer notification for each event. However, customers may call a toll-free number to get updates on the status of whether or not Duke Energy plans to call or has called a Power Manager event. At Duke Energy Carolinas, program managers decide when load control events will be called on a day-of basis, mainly considering local system and weather conditions. The DEC System Operations Center (SOC) also has access to dispatch Power Manager on an emergency basis; however, Power Manager has very rarely been used in this emergency capacity. Under normal operations, the event calling team involves staff in SOC and Fuel and Systems Optimization in addition to demand response operations. However, overall demand response operations staff maintain 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 a view towards whether or not it will be a detriment to the experience of the participants. Considerations taken in this area are the number of events that have already been called during the current summer, or, during heat spells, during that week. Demand response operations staff also consider other finer points that lie outside of the program rules that can influence customers' willingness to continue to participate in the program; for example, whether or not Power Manager event hours have frequently gone into the late afternoon/early evening.

7.5.3 Program Monitoring and Postseason Program Maintenance

Duke Energy undertakes a number of activities both during the load control season and afterward to ensure that participants are satisfied with their Power Manager program experience and that the program is on track to provide an excellent customer experience going forward.

GoodCents, as the third party contractor that manages Power Manager customer contacts, 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 GoodCents are handled quickly, efficiently, and that accurate information is provided to the customers calling in. Additionally, Duke Energy program managers monitor the number of calls coming in to the toll-free notification line, in addition to the number of calls coming into the GoodCents call center to detect any emerging issues associated with the program experience. Device removal requests are also tracked for this purpose.

Duke Energy uses seasonal reminder/thank you cards that are sent near the start of the load control season to: remind and thank customers for their participation in the program, provide tips for having a comfortable experience with the program, and recognize the program's contributions to reducing system load.

7.5.4 Upcoming Program Changes and Initiatives

Duke Energy is also engaged in initiatives to change the program offering to make it more attractive to customers and to improve program performance. Duke Energy Carolinas will be assessing using its website as an additional source of event notification, making it easier for customers to access information about Power Manager events. Finally, Duke Energy is also engaged in replacing certain models of older switches.

7.6 Key Findings

Key findings from the process evaluation include:

- 95 Power Manager participants were surveyed within 24 hours of the September 9 event, which had a high temperature of 94°F with a heat index of 95°F.
- 89 Power Manager participants were interviewed during a hot nonevent day, July 13, which had a high of 95°F with a heat index of 95°F. The nonevent day survey was used to establish a baseline for comfort, event awareness, and other key metrics.
- A strong majority of all respondents, 85%, reported that they are familiar with the Power Manager program.
- Only 12% of respondents on the event day reported that their homes were uncomfortable, while all of them experienced a load control event that afternoon. By comparison, 13% of Power Manager customers surveyed on a hot nonevent day reported they felt uncomfortably hot. This

small difference is not statistically significant—we cannot conclude that there is a difference in customers' thermal discomfort due to Power Manager events.

- More than 85% of participants would recommend the Power Manager program to others.
- The Power Manager staff and vendors are customer focused and undertake a number of activities both during the load control season and afterward to ensure that participants are satisfied with their Power Manager program experience.

Appendix A Regression Models Tested

All regression models were performed and the average customer loads throughout the summer using 15 minute interval data. The same sample of customers was analyzed using whole house interval and air conditioner end use data. The analysis only included days when maximum temperature exceeded 75˚F.

For the individual event day impacts (ex post), the regression equation took the general form of Equation 1, which will be estimated using a dataset made up of hourly observations of the average load in the M&V sample. Equation 2 describes the model used to estimate average event impacts for the general population events. The average event impacts were estimated separately to account for the effect of repeated events on confidence intervals.

Equation 1 and Equation 2 represent a within-subjects approach in which the observations on nonevent days are used to predict the counterfactual load for Power Manager customers on event days. A few points are noteworthy. The models were run separately for each 15 minute interval (equivalent to a fully interacted model) to account for occupancy patterns and produce different weather coefficients and constants. The only component that varied across the 10 models tested was how the weather variables were specified. Table A-1 shows the weather variables and explains the underlying concept for each model tested. To improve precision, same-day loads for the pre-event hours of 11am to 1pm were included to capture any differences between event and nonevent days that are not reflected in the model. The pre-event same day load variable functions as a same-day adjustment and is included because customers are not notified of the event in advance.

Equation 1: Ex Post Regression Model Individual Events

$$kW_{t,i} = a_i + \sum_{j=1}^{J} b_{i,j}\mathrm{event}_{t,j} + c \cdot preeventkW_t + d_i \cdot weather_{i,t} + \sum_{k=1}^{7} e_{i,k}\mathrm{dayofweek}_{i,k} + \sum_{l=5}^{10} f_{i,l}\, month_t + \varepsilon_{i,t}$$

Equation 2: Ex Post Regression Model Average Event (General Population Events)

$$kW_{t,i} = a_i + b_i\mathrm{avgevent}_t + c \cdot preeventkW_t + d_i \cdot weather_{i,t} + \sum_{k=1}^{7} b_{i,k}\mathrm{dayofweek}_{i,k} + \sum_{l=5}^{10} f_{i,l}\, month_t + \varepsilon_{i,t}$$

Where:

a	Is the constant or intercept
$b_{i,j}$	Represents the event effect of Power Manager during each interval, i, and each event day, j
c-f	Are other model coefficients
i, k, l	i, k *and* l are indicators that represent individual 15 minute intervals (96 in a day), days of the week, and months of the year
t	Represents each date in the analysis dataset
event	Is a binary variable indicating whether Power Manager was dispatched on that day
preeventKW	Represents the same-day loads for the pre-event hours of 11am to 1pm. The variable functions as a same-day adjustment and is included because customers are not notified of the event in advance
weather	10 different ways to specify if weather was tested. Those are detailed in Table A-1
dayofweek	Are a set of mutually exclusive binary variables to capture day of week effects
month	Are a set of mutually exclusive binary variables to capture monthly or seasonal effects
ε	Represents the error term

Table A-1: Weather Variables by Model Tested

Model	Weather variables	Concept
1	Cooling Degree Hour Base 70˚F (CDH)	The same hour temperature drives electricity use but air conditioner loads are only linear when temperatures are above 70˚F
2	Cooling Degree Day Base 65˚F (CDD)	The overall daily average temperature drives electricity use but air conditioner loads are only linear when average daily temperatures exceed 65˚F
3	Daily Maximum Temperature	The daily maximum temperature drives air conditioner electricity use
4	Average temperature over the 24 hours immediately prior	Heat buildup over the 24 hours immediately prior to time period drives electricity use
5	CDH and CDD	Both the daily average temperatures and same hour temperatures drive air conditioner electricity use
6	Same hour CDH and average temperature over the 24 hours immediately prior	Air conditioner use if influenced both by the temperature during that hour and by average temperature over the 24 hours immediately prior
7	Same hour CDH and average CDH over the 6 hours immediately prior	Air conditioner use if influenced both by the temperature during that hour and by heat buildup, as measured by CDH, over the 6 hours immediately prior
8	Same hour CDH and average CDH over the 12 hours immediately prior	Air conditioner use if influenced both by the temperature during that hour and by heat buildup, as measured by CDH, over the 12 hours immediately prior
9	Same hour CDH and average CDH over the 18 hours immediately prior	Air conditioner use if influenced both by the temperature during that hour and by heat buildup, as measured by CDH, over the 18 hours immediately prior
10	Same hour CDH and average CDH over the 24 hours immediately prior	Air conditioner use if influenced both by the temperature during that hour and by heat buildup, as measured by CDH, over the 24 hours immediately prior

Appendix B Per Device Demand Reduction Tables

Table B-1: One Hour Event Per Device Demand Impacts by Cycling Strategy, Temperature, and Event Start

True Cycle	Daily Max (F)	Start Time (1 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
50	74	-0.06	-0.08	-0.10	-0.10	-0.11	-0.12	-0.11
	76	-0.08	-0.10	-0.14	-0.15	-0.17	-0.17	-0.15
	78	-0.08	-0.11	-0.15	-0.17	-0.18	-0.19	-0.17
	80	-0.10	-0.15	-0.19	-0.22	-0.24	-0.24	-0.22
	82	-0.13	-0.18	-0.24	-0.28	-0.31	-0.31	-0.29
	84	-0.17	-0.23	-0.30	-0.34	-0.36	-0.36	-0.33
	86	-0.22	-0.29	-0.36	-0.41	-0.43	-0.43	-0.39
	88	-0.27	-0.36	-0.43	-0.47	-0.50	-0.49	-0.46
	90	-0.31	-0.41	-0.49	-0.53	-0.56	-0.55	-0.50
	92	-0.37	-0.49	-0.57	-0.61	-0.63	-0.61	-0.55
	94	-0.41	-0.53	-0.62	-0.66	-0.69	-0.67	-0.62
	96	-0.47	-0.61	-0.69	-0.75	-0.77	-0.76	-0.70
	98	-0.49	-0.65	-0.75	-0.80	-0.83	-0.82	-0.75
	100	-0.56	-0.73	-0.83	-0.91	-0.94	-0.93	-0.83
	102	-0.55	-0.73	-0.82	-0.91	-0.97	-0.96	-0.90
64	74	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.10
	76	-0.08	-0.10	-0.13	-0.14	-0.15	-0.15	-0.14
	78	-0.08	-0.10	-0.13	-0.15	-0.16	-0.16	-0.15
	80	-0.12	-0.15	-0.18	-0.20	-0.21	-0.22	-0.20
	82	-0.15	-0.19	-0.23	-0.26	-0.27	-0.28	-0.26
	84	-0.21	-0.26	-0.31	-0.33	-0.35	-0.35	-0.33
	86	-0.28	-0.35	-0.40	-0.43	-0.45	-0.45	-0.42
	88	-0.38	-0.46	-0.51	-0.54	-0.56	-0.56	-0.53
	90	-0.45	-0.54	-0.60	-0.63	-0.65	-0.64	-0.61
	92	-0.57	-0.67	-0.73	-0.76	-0.78	-0.76	-0.72
	94	-0.68	-0.79	-0.86	-0.90	-0.91	-0.90	-0.86
	96	-0.82	-0.94	-1.02	-1.06	-1.08	-1.07	-1.02
	98	-0.89	-1.03	-1.11	-1.16	-1.18	-1.17	-1.12
	100	-1.10	-1.27	-1.36	-1.42	-1.45	-1.43	-1.36
	102	-1.13	-1.31	-1.39	-1.46	-1.51	-1.50	-1.45
100	74	-0.16	-0.20	-0.25	-0.26	-0.28	-0.30	-0.28
	76	-0.21	-0.27	-0.34	-0.37	-0.40	-0.41	-0.38
	78	-0.22	-0.28	-0.37	-0.41	-0.44	-0.46	-0.42
	80	-0.28	-0.37	-0.47	-0.52	-0.55	-0.56	-0.53
	82	-0.34	-0.45	-0.57	-0.63	-0.68	-0.69	-0.65
	84	-0.45	-0.58	-0.69	-0.75	-0.80	-0.80	-0.74
	86	-0.56	-0.71	-0.82	-0.89	-0.93	-0.93	-0.87
	88	-0.69	-0.84	-0.96	-1.02	-1.06	-1.05	-0.99
	90	-0.77	-0.94	-1.06	-1.13	-1.17	-1.15	-1.08
	92	-0.91	-1.09	-1.21	-1.27	-1.29	-1.26	-1.18
	94	-1.01	-1.19	-1.31	-1.37	-1.40	-1.38	-1.31
	96	-1.14	-1.33	-1.45	-1.51	-1.54	-1.53	-1.45
	98	-1.19	-1.41	-1.53	-1.60	-1.64	-1.62	-1.53
	100	-1.34	-1.57	-1.70	-1.79	-1.83	-1.81	-1.70
	102	-1.35	-1.59	-1.69	-1.80	-1.87	-1.86	-1.79

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

Table B-2: 2 Hour Event Per Device Demand Impacts by Cycling Strategy, Temperature, and Event Start

True Cycle	Daily Max (F)	Start Time (2 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
50	74	-0.06	-0.08	-0.10	-0.10	-0.11	-0.11	-0.10
	76	-0.09	-0.11	-0.14	-0.15	-0.16	-0.16	-0.14
	78	-0.09	-0.12	-0.15	-0.17	-0.18	-0.18	-0.16
	80	-0.12	-0.16	-0.20	-0.22	-0.23	-0.23	-0.20
	82	-0.15	-0.20	-0.25	-0.28	-0.30	-0.29	-0.25
	84	-0.19	-0.26	-0.31	-0.34	-0.35	-0.34	-0.29
	86	-0.24	-0.32	-0.37	-0.40	-0.42	-0.40	-0.35
	88	-0.30	-0.38	-0.44	-0.47	-0.48	-0.46	-0.40
	90	-0.34	-0.43	-0.49	-0.53	-0.54	-0.51	-0.45
	92	-0.41	-0.51	-0.57	-0.60	-0.60	-0.56	-0.49
	94	-0.45	-0.55	-0.62	-0.65	-0.66	-0.62	-0.55
	96	-0.52	-0.63	-0.70	-0.74	-0.74	-0.71	-0.62
	98	-0.55	-0.67	-0.75	-0.79	-0.80	-0.76	-0.67
	100	-0.62	-0.75	-0.84	-0.90	-0.91	-0.85	-0.74
	102	-0.62	-0.75	-0.83	-0.91	-0.93	-0.90	-0.80
64	74	-0.06	-0.08	-0.08	-0.09	-0.10	-0.10	-0.09
	76	-0.09	-0.11	-0.13	-0.14	-0.15	-0.14	-0.13
	78	-0.09	-0.12	-0.14	-0.15	-0.16	-0.15	-0.14
	80	-0.13	-0.16	-0.19	-0.20	-0.21	-0.21	-0.19
	82	-0.16	-0.21	-0.24	-0.26	-0.27	-0.26	-0.24
	84	-0.23	-0.28	-0.31	-0.33	-0.34	-0.33	-0.30
	86	-0.31	-0.37	-0.41	-0.43	-0.44	-0.43	-0.39
	88	-0.41	-0.48	-0.52	-0.54	-0.55	-0.54	-0.50
	90	-0.49	-0.56	-0.61	-0.63	-0.64	-0.62	-0.57
	92	-0.61	-0.69	-0.74	-0.76	-0.76	-0.73	-0.67
	94	-0.73	-0.82	-0.87	-0.89	-0.90	-0.87	-0.82
	96	-0.87	-0.97	-1.02	-1.05	-1.06	-1.03	-0.96
	98	-0.95	-1.06	-1.12	-1.15	-1.16	-1.13	-1.06
	100	-1.17	-1.30	-1.37	-1.42	-1.42	-1.38	-1.28
	102	-1.21	-1.33	-1.41	-1.47	-1.49	-1.46	-1.38
100	74	-0.18	-0.23	-0.25	-0.27	-0.29	-0.29	-0.27
	76	-0.24	-0.30	-0.36	-0.39	-0.41	-0.40	-0.36
	78	-0.25	-0.32	-0.39	-0.43	-0.45	-0.44	-0.40
	80	-0.33	-0.42	-0.49	-0.54	-0.56	-0.55	-0.50
	82	-0.40	-0.51	-0.60	-0.66	-0.69	-0.67	-0.61
	84	-0.51	-0.63	-0.72	-0.77	-0.80	-0.77	-0.70
	86	-0.63	-0.76	-0.86	-0.91	-0.93	-0.90	-0.82
	88	-0.77	-0.90	-0.99	-1.04	-1.05	-1.02	-0.94
	90	-0.86	-1.00	-1.10	-1.15	-1.16	-1.12	-1.02
	92	-1.00	-1.15	-1.24	-1.28	-1.28	-1.22	-1.12
	94	-1.10	-1.25	-1.34	-1.39	-1.39	-1.35	-1.25
	96	-1.23	-1.39	-1.48	-1.53	-1.54	-1.49	-1.38
	98	-1.30	-1.47	-1.57	-1.62	-1.63	-1.58	-1.46
	100	-1.46	-1.63	-1.74	-1.81	-1.82	-1.75	-1.61
	102	-1.47	-1.64	-1.75	-1.83	-1.86	-1.82	-1.70

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

Table B-3: Three Hour Event Per Device Demand Impacts by Cycling Strategy, Temperature, and Event Start

True Cycle	Daily Max (F)	Start Time (3 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
	74	-0.07	-0.08	-0.09	-0.10	-0.10	-0.10	-0.10
	76	-0.09	-0.12	-0.14	-0.15	-0.15	-0.14	-0.13
	78	-0.10	-0.13	-0.15	-0.17	-0.17	-0.16	-0.14
	80	-0.13	-0.17	-0.20	-0.22	-0.22	-0.20	-0.18
	82	-0.17	-0.21	-0.25	-0.28	-0.28	-0.26	-0.23
	84	-0.21	-0.27	-0.31	-0.33	-0.33	-0.30	-0.26
	86	-0.27	-0.33	-0.37	-0.39	-0.39	-0.36	-0.31
50	88	-0.32	-0.39	-0.43	-0.46	-0.45	-0.41	-0.35
	90	-0.37	-0.44	-0.49	-0.51	-0.50	-0.46	-0.39
	92	-0.44	-0.52	-0.56	-0.58	-0.56	-0.51	-0.43
	94	-0.48	-0.56	-0.61	-0.63	-0.62	-0.57	-0.48
	96	-0.55	-0.64	-0.69	-0.71	-0.70	-0.64	-0.54
	98	-0.58	-0.68	-0.74	-0.76	-0.75	-0.69	-0.58
	100	-0.65	-0.77	-0.84	-0.87	-0.85	-0.76	-0.64
	102	-0.65	-0.76	-0.84	-0.89	-0.88	-0.82	-0.69
	74	-0.07	-0.08	-0.08	-0.09	-0.09	-0.09	-0.09
	76	-0.10	-0.11	-0.13	-0.14	-0.14	-0.13	-0.12
	78	-0.10	-0.12	-0.14	-0.15	-0.15	-0.14	-0.13
	80	-0.14	-0.17	-0.19	-0.20	-0.20	-0.19	-0.18
	82	-0.18	-0.22	-0.24	-0.26	-0.26	-0.25	-0.22
	84	-0.25	-0.29	-0.32	-0.33	-0.33	-0.31	-0.28
	86	-0.33	-0.38	-0.41	-0.43	-0.42	-0.40	-0.36
64	88	-0.44	-0.49	-0.52	-0.54	-0.53	-0.51	-0.46
	90	-0.51	-0.57	-0.61	-0.62	-0.62	-0.59	-0.53
	92	-0.64	-0.70	-0.74	-0.75	-0.73	-0.69	-0.63
	94	-0.76	-0.83	-0.87	-0.88	-0.87	-0.83	-0.76
	96	-0.90	-0.98	-1.02	-1.04	-1.03	-0.98	-0.90
	98	-0.99	-1.07	-1.12	-1.14	-1.13	-1.08	-0.98
	100	-1.21	-1.32	-1.38	-1.40	-1.38	-1.31	-1.19
	102	-1.25	-1.36	-1.42	-1.46	-1.46	-1.40	-1.28
	74	-0.20	-0.24	-0.26	-0.28	-0.29	-0.28	-0.27
	76	-0.27	-0.33	-0.37	-0.40	-0.40	-0.38	-0.35
	78	-0.29	-0.35	-0.41	-0.44	-0.44	-0.42	-0.38
	80	-0.37	-0.45	-0.51	-0.55	-0.55	-0.52	-0.47
	82	-0.45	-0.55	-0.63	-0.67	-0.67	-0.64	-0.57
	84	-0.57	-0.67	-0.75	-0.78	-0.78	-0.73	-0.65
	86	-0.70	-0.81	-0.88	-0.91	-0.91	-0.85	-0.76
100	88	-0.83	-0.94	-1.01	-1.04	-1.03	-0.98	-0.87
	90	-0.93	-1.05	-1.12	-1.15	-1.13	-1.07	-0.96
	92	-1.07	-1.19	-1.26	-1.27	-1.25	-1.16	-1.04
	94	-1.17	-1.29	-1.36	-1.38	-1.37	-1.29	-1.17
	96	-1.30	-1.43	-1.50	-1.53	-1.51	-1.43	-1.29
	98	-1.38	-1.51	-1.59	-1.62	-1.60	-1.51	-1.36
	100	-1.54	-1.69	-1.77	-1.81	-1.78	-1.67	-1.50
	102	-1.54	-1.69	-1.79	-1.84	-1.84	-1.75	-1.59

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

Table B-4: Four Hour Event Per Device Demand Impacts by Cycling Strategy, Temperature, and Event Start

True Cycle	Daily Max (F)	Start Time (4 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
50	74	-0.07	-0.08	-0.09	-0.10	-0.10	-0.10	-0.09
	76	-0.10	-0.12	-0.14	-0.14	-0.14	-0.13	-0.12
	78	-0.11	-0.13	-0.15	-0.16	-0.16	-0.15	-0.13
	80	-0.14	-0.17	-0.20	-0.21	-0.20	-0.18	-0.16
	82	-0.18	-0.22	-0.25	-0.26	-0.26	-0.23	-0.20
	84	-0.23	-0.27	-0.30	-0.31	-0.30	-0.27	-0.23
	86	-0.28	-0.33	-0.36	-0.37	-0.36	-0.32	-0.27
	88	-0.34	-0.39	-0.42	-0.43	-0.41	-0.37	-0.31
	90	-0.38	-0.44	-0.48	-0.48	-0.46	-0.41	-0.35
	92	-0.45	-0.52	-0.55	-0.54	-0.51	-0.45	-0.38
	94	-0.49	-0.56	-0.59	-0.60	-0.57	-0.50	-0.42
	96	-0.56	-0.63	-0.67	-0.67	-0.64	-0.57	-0.47
	98	-0.60	-0.68	-0.72	-0.72	-0.69	-0.61	-0.51
	100	-0.68	-0.77	-0.82	-0.82	-0.77	-0.67	-0.55
	102	-0.67	-0.77	-0.83	-0.85	-0.81	-0.72	-0.60
64	74	-0.07	-0.08	-0.08	-0.09	-0.09	-0.09	-0.08
	76	-0.10	-0.12	-0.13	-0.13	-0.13	-0.13	-0.12
	78	-0.11	-0.13	-0.14	-0.14	-0.14	-0.14	-0.12
	80	-0.15	-0.17	-0.19	-0.19	-0.19	-0.18	-0.16
	82	-0.19	-0.22	-0.24	-0.25	-0.25	-0.23	-0.21
	84	-0.26	-0.29	-0.31	-0.32	-0.31	-0.29	-0.26
	86	-0.35	-0.38	-0.41	-0.41	-0.40	-0.37	-0.34
	88	-0.45	-0.49	-0.52	-0.52	-0.51	-0.47	-0.43
	90	-0.53	-0.58	-0.60	-0.61	-0.59	-0.55	-0.50
	92	-0.65	-0.70	-0.73	-0.72	-0.70	-0.65	-0.58
	94	-0.78	-0.83	-0.86	-0.86	-0.84	-0.78	-0.71
	96	-0.92	-0.98	-1.02	-1.02	-0.99	-0.92	-0.84
	98	-1.01	-1.08	-1.12	-1.12	-1.09	-1.01	-0.92
	100	-1.24	-1.33	-1.37	-1.37	-1.33	-1.24	-1.11
	102	-1.28	-1.37	-1.42	-1.44	-1.41	-1.32	-1.20
100	74	-0.22	-0.25	-0.27	-0.28	-0.28	-0.27	-0.26
	76	-0.30	-0.35	-0.38	-0.39	-0.39	-0.37	-0.34
	78	-0.32	-0.37	-0.42	-0.43	-0.42	-0.40	-0.36
	80	-0.41	-0.48	-0.53	-0.54	-0.53	-0.49	-0.44
	82	-0.50	-0.58	-0.64	-0.66	-0.65	-0.60	-0.53
	84	-0.62	-0.70	-0.76	-0.77	-0.75	-0.69	-0.60
	86	-0.74	-0.84	-0.89	-0.90	-0.87	-0.80	-0.71
	88	-0.88	-0.97	-1.02	-1.03	-1.00	-0.92	-0.82
	90	-0.98	-1.08	-1.13	-1.13	-1.09	-1.01	-0.90
	92	-1.12	-1.22	-1.26	-1.25	-1.20	-1.10	-0.98
	94	-1.22	-1.32	-1.37	-1.37	-1.32	-1.22	-1.09
	96	-1.36	-1.46	-1.51	-1.51	-1.46	-1.35	-1.20
	98	-1.43	-1.54	-1.60	-1.60	-1.54	-1.43	-1.27
	100	-1.60	-1.72	-1.78	-1.78	-1.71	-1.58	-1.40
	102	-1.61	-1.74	-1.80	-1.83	-1.78	-1.65	-1.48

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

Table B-5: Five Hour Event Per Device Demand Impacts by Cycling Strategy, Temperature, and Event Start

True Cycle	Daily Max (F)	Start Time (5 Hour Event)*						
		12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
50	74	-0.07	-0.08	-0.09	-0.09	-0.09	-0.09	-0.09
	76	-0.10	-0.12	-0.13	-0.13	-0.13	-0.12	-0.11
	78	-0.11	-0.13	-0.14	-0.15	-0.14	-0.13	-0.12
	80	-0.15	-0.17	-0.19	-0.19	-0.18	-0.17	-0.14
	82	-0.19	-0.22	-0.24	-0.24	-0.23	-0.21	-0.18
	84	-0.23	-0.27	-0.29	-0.29	-0.27	-0.24	-0.20
	86	-0.29	-0.33	-0.35	-0.34	-0.32	-0.28	-0.24
	88	-0.34	-0.39	-0.41	-0.40	-0.37	-0.33	-0.28
	90	-0.39	-0.44	-0.46	-0.45	-0.41	-0.36	-0.31
	92	-0.46	-0.50	-0.52	-0.50	-0.46	-0.40	-0.33
	94	-0.50	-0.55	-0.57	-0.55	-0.51	-0.45	-0.37
	96	-0.56	-0.62	-0.64	-0.62	-0.57	-0.50	-0.41
	98	-0.60	-0.67	-0.69	-0.67	-0.62	-0.54	-0.44
	100	-0.68	-0.76	-0.78	-0.76	-0.69	-0.59	-0.48
	102	-0.68	-0.76	-0.80	-0.79	-0.73	-0.63	-0.52
64	74	-0.07	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
	76	-0.11	-0.12	-0.13	-0.13	-0.13	-0.12	-0.11
	78	-0.11	-0.13	-0.14	-0.14	-0.13	-0.13	-0.12
	80	-0.16	-0.17	-0.19	-0.19	-0.18	-0.17	-0.15
	82	-0.20	-0.22	-0.24	-0.24	-0.23	-0.21	-0.19
	84	-0.27	-0.29	-0.31	-0.31	-0.29	-0.27	-0.24
	86	-0.35	-0.38	-0.40	-0.40	-0.38	-0.35	-0.31
	88	-0.46	-0.49	-0.51	-0.50	-0.48	-0.44	-0.40
	90	-0.54	-0.58	-0.59	-0.58	-0.56	-0.51	-0.46
	92	-0.66	-0.70	-0.71	-0.70	-0.66	-0.61	-0.54
	94	-0.79	-0.83	-0.84	-0.83	-0.79	-0.73	-0.66
	96	-0.93	-0.98	-1.00	-0.98	-0.94	-0.87	-0.78
	98	-1.02	-1.08	-1.10	-1.08	-1.03	-0.95	-0.86
	100	-1.26	-1.33	-1.34	-1.32	-1.26	-1.16	-1.04
	102	-1.30	-1.37	-1.40	-1.39	-1.33	-1.24	-1.11
100	74	-0.23	-0.26	-0.27	-0.28	-0.27	-0.27	-0.26
	76	-0.32	-0.36	-0.38	-0.38	-0.38	-0.36	-0.33
	78	-0.34	-0.39	-0.42	-0.42	-0.41	-0.38	-0.34
	80	-0.44	-0.50	-0.53	-0.53	-0.50	-0.47	-0.41
	82	-0.54	-0.61	-0.64	-0.64	-0.61	-0.56	-0.49
	84	-0.65	-0.72	-0.76	-0.75	-0.71	-0.64	-0.56
	86	-0.78	-0.85	-0.89	-0.88	-0.83	-0.75	-0.66
	88	-0.91	-0.99	-1.02	-1.00	-0.95	-0.87	-0.77
	90	-1.02	-1.09	-1.12	-1.10	-1.04	-0.95	-0.84
	92	-1.16	-1.23	-1.24	-1.21	-1.14	-1.03	-0.91
	94	-1.26	-1.33	-1.36	-1.33	-1.26	-1.15	-1.02
	96	-1.39	-1.47	-1.50	-1.47	-1.39	-1.27	-1.13
	98	-1.47	-1.56	-1.58	-1.55	-1.47	-1.34	-1.20
	100	-1.64	-1.74	-1.76	-1.73	-1.63	-1.48	-1.32
	102	-1.66	-1.76	-1.80	-1.78	-1.70	-1.56	-1.38

*Estimates exclude 30 minute phase in period and reflect the average reduction expected for the event

NAVIGANT

EM&V Report for the Small Business Energy Saver Program

Duke Energy Progress and Duke Energy Carolinas

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September 27, 2016
Revised June 6, 2017

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1. EVALUATION SUMMARY

1.1 Program Summary

The Small Business Energy Saver (SBES) Program is part of a portfolio of energy efficiency programs operated by Duke Energy. Duke Energy selected Lime Energy to implement the SBES program again in the Duke Energy Progress (DEP) jurisdiction, as well as the Duke Energy Carolinas (DEC) jurisdiction for this evaluation cycle. The program caters specifically to small business customers and offers a performance-based incentive up to 80 percent of the total project cost, inclusive of both materials and installation, on high-efficiency lighting and refrigeration equipment.

The SBES Program generates energy savings and peak demand reductions by offering eligible customers a streamlined service including marketing outreach, technical expertise, and performance incentives to reduce equipment and installation costs from market rates on high-efficiency lighting, refrigeration, and HVAC equipment. The SBES Program seeks to bundle all eligible measures together and sell them as a single project in order to maximize the total achievable energy and demand savings, while working with customers to advise equipment selection to meet their unique needs.

1.2 Evaluation Objectives and High Level Findings

Evaluation, Measurement, and Verification (EM&V) involves the use of a variety of analytic approaches, including on-site verification of installed measures and application of engineering models. EM&V also encompasses an evaluation of program processes and customer feedback, typically conducted through participant surveys and program staff interviews. This report details the EM&V activities that Navigant Consulting, Inc. (Navigant) performed on behalf of Duke Energy for the SBES Program.

This report covers EM&V activities performed for projects covering the following periods, referenced simply as PY2015 for the remainder of this report:

- January 1, 2015 through February 29, 2016 (DEP)
- August 1, 2014 (program start) through February 29, 2016 (DEC)

The primary purpose of the evaluation assessment is to estimate net annual energy and peak demand impacts associated with SBES activity. Net savings are calculated as the reported "gross" savings from Duke Energy, verified and adjusted through EM&V, and netted for free ridership (i.e., savings that would have occurred even in the absence of the program) and spillover (i.e., additional savings attributable to the program but not captured in program records).

The EM&V assessment of the SBES program included impact and process evaluations.

- The impact evaluation consisted of engineering analysis and on-site field verification and metering to validate energy and demand impacts of reported measure categories, as well as a customer survey to assess net impacts.
- The process evaluation used customer surveys with 151 participants and interviews with program staff and the implementation contractor to characterize the program delivery and identify opportunities to improve the program design and processes. The customer survey data also formed the basis of the evaluation team's estimation of free ridership and spillover, used to calculate an NTG ratio.

The evaluation team verified gross energy savings at 111 percent of deemed reported energy savings for DEP and 112 percent for DEC, and gross peak demand reductions at 96 percent for DEP and DEC. A net-to-gross (NTG) ratio was estimated at 1.03, yielding total verified net energy savings of 55,947 megawatt-hours (MWh) for DEP and 89,506 MWh for DEC, and net peak demand reductions of 11.5 megawatts (MW) for DEP and 20.4MW for DEC (Table 1-1 through Table 1-4).

Table 1-1. Program Claimed and Evaluated Gross Energy Impacts

	Jurisdiction	Claimed	Evaluated	Realization Rate
Gross Energy Impacts (MWh)	DEP	48,772	54,318	1.11
Gross Energy Impacts (MWh)	DEC	77,269	86,899	1.12

Source: Navigant analysis and Duke Energy tracking data.

Table 1-2. Program Claimed and Evaluated Gross Peak Demand Impacts

	Jurisdiction	Claimed	Evaluated	Realization Rate
Gross Summer Peak Demand Impacts (MW)	DEP	11.7	11.2	0.96
Gross Winter Peak Demand Impacts (MW)	DEP	11.7	6.2	0.53
Gross Summer Peak Demand Impacts (MW)	DEC	20.5	19.8	0.96
Gross Winter Peak Demand Impacts (MW)	DEC	20.5	10.9	0.53

Source: Navigant analysis and Duke Energy tracking data.

Table 1-3. Program Net Energy Impacts

	Jurisdiction	MWh
Net Energy Impacts (MWh)	DEP	55,947
Net Energy Impacts (MWh)	DEC	89,506

Source: Navigant analysis.

Table 1-4. Program Net Peak Demand Impacts

	Jurisdiction	MW
Net Summer Peak Demand Impacts (MW)	DEP	11.5
Net Winter Peak Demand Impacts (MW)	DEP	6.4
Net Summer Peak Demand Impacts (MW)	DEC	20.4
Net Winter Peak Demand Impacts (MW)	DEC	11.2

Source: Navigant analysis.

1.3 Evaluation Parameters and Sample Period

To accomplish the evaluation objectives, Navigant performed a variety of primary and secondary research activities including:

- Engineering review of measure savings algorithms
- Field verification and metering to assess installed quantities and characteristics
- Participant surveys with customers to assess satisfaction and decision-making processes.

Table 1-5 summarizes the evaluated parameters. The targeted sampling confidence and precision for both DEP and DEC was 90 percent ± 10 percent, and the achieved was 90 percent ± 7.0 percent for energy savings, 8.5 percent for summer and 12.4 percent for winter peak demand reductions.[1]

Table 1-5. Evaluated Parameters

Evaluated Parameter	Description	Details
Efficiency Characteristics	Inputs and assumptions used to estimate energy and demand savings	1. Lighting wattage 2. Operating hours 3. Coincidence factors 4. HVAC interactive effects 5. Baseline characteristics
In-Service Rates	The percentage of program measures in use as compared to reported	1. Measure quantities found onsite
Satisfaction	Customer satisfaction with various stages of their project	1. Overall satisfaction with program 2. Satisfaction with implementation and installation contractors 3. Satisfaction with program equipment
Free Ridership	Fraction of reported savings that would have occurred in the absence of the program	
Spillover	Additional, non-reported savings that occurred as a result of participation in the program	

Source: Navigant analysis

[1] Navigant designed the impact sample to achieve 90/10 confidence and precision using the industry-standard coefficient of variation of 0.5 and results from previous (PY2013 and PY2014) SBES program evaluations in the DEP jurisdiction. The sample quotas were met as planned, and the final precision was different due to natural variation in individual site level characteristics.

This evaluation covers program participation from August 2014 through February 2016. Table 1-6 shows the start and end dates of Navigant's sample period for evaluation activities.

Table 1-6. Sample Period Start and End Dates

Activity	Start Date	End Date
Field Verification and metering	March 15, 2016	April 22, 2016
Participant Phone Surveys	May 3, 2016	May 5, 2016

Source: Navigant analysis

1.4 Recommendations

The evaluation team recommends five discrete actions for improving the SBES Program, based on insights gained through the comprehensive evaluation effort. These recommendations provide Duke Energy with a roadmap to fine-tune the SBES Program for continued success and include the following broad objectives. Table 1-7 summarizes these program recommendations.

Table 1-7. Summary of PY2015 SBES Recommendations

Increasing Program Participation
1. **Continue to emphasize non-energy benefits** of program participation, such as increased lighting quality, comfort for both business employees and customers, environmental benefits, and reduced maintenance. Now that the program has transitioned primarily to LED measures, increased education on the benefits that LED measures offer should enhance participation.
Increasing Customer Satisfaction
2. **Continue to prioritize customer satisfaction through installation contractor training and customer follow-up services**. The IC has improved in this area from PY2014, but a minority of customers are still reporting issues with installation and communication. Additionally, some customers are not perceiving savings on their electric bill, so managing this expectation would enhance customer satisfaction.
3. **Phase out fluorescent T8 lighting systems**. Linear LED lighting offers substantial savings above high-performance/reduced wattage T8 lamps and ballasts, which may be perceived as outdated.
Improving Accuracy of Reported Savings
4. **Add HVAC interactive effects and update coincidence factors for lighting measures**. This is the key impact finding to improve the accuracy of savings estimates. The IC should apply relevant HVAC interactive effects and coincidence factors to lighting measures as is appropriate, and ensure that outdoor lighting measures on daylight sensors do not accrue peak demand reductions during summer daylight hours.
5. **Ensure that efficient lighting power ratings for linear LED systems are accurate**. Navigant did not perform live measurements of connected linear LED systems to determine power draw, and upon review of manufacturer specifications for lighting power there are different wattages that the system may draw depending on the specific configuration. As the share of savings attributed to linear LED systems grow, this should be quantified to reduce EM&V risk in future years.

Source: Navigant analysis

2. PROGRAM DESCRIPTION

The Small Business Energy Saver (SBES) Program is part of a portfolio of energy efficiency programs operated by Duke Energy. The program began as a pilot in early 2013 in South Carolina before expanding into the remainder of the Duke Energy Progress (DEP) jurisdiction. The program further expanded into the Duke Energy Carolina (DEC) jurisdiction in August 2014. In 2015, the program showed continued growth compared to 2014 measured by both participant count and claimed energy savings and peak demand reductions.

2.1 Program Design

The SBES Program is available to qualifying commercial customers with less than 100 kilowatts (kW) demand service. The SBES Program recognizes that customers with lower savings potential may benefit from a streamlined, one-stop, turnkey delivery model and relatively high incentives to invest in energy efficiency. Additionally, small businesses may lack internal staffing dedicated to energy management and can benefit from energy audits and installations performed by an outside vendor.

The program offers incentives in the form of a discount for the installation of measures, including high-efficiency lighting and refrigeration equipment. These incentives increase adoption of efficient technologies beyond what would occur naturally in the market. In PY2015, the SBES Program (IC) achieved the majority of program savings from lighting measures, which tend to be the most cost-effective and easiest to market to potential participants. The IC also achieved program savings from refrigeration measures at a similar level to PY2014.

The program offers a performance-based incentive up to 80 percent of the total project cost, inclusive of both materials and installation. Multiple factors drive the total project cost, including selection of equipment and unique installation requirements.

2.2 Reported Program Participation and Savings

Duke Energy maintains a tracking database that identifies key characteristics of each project, including participant data, installed measures, and estimated energy and peak demand reductions based on assumed ("deemed") savings values. In addition, the IC maintains a tracking database that contains additional measure level details that are useful for EM&V activities. For PY2015 Navigant only reviewed the IC database. Duke Energy ensured that the IC database savings accurately represent all claimed program savings.

Table 2-1 provides a summary of the gross reported energy and demand savings and participation for PY2013 through PY2015. Note the significant year over year growth for PY2015, along with an increase in average measures installed per project and average savings per project.

Table 2-1. Reported Participation and Gross Savings Summary

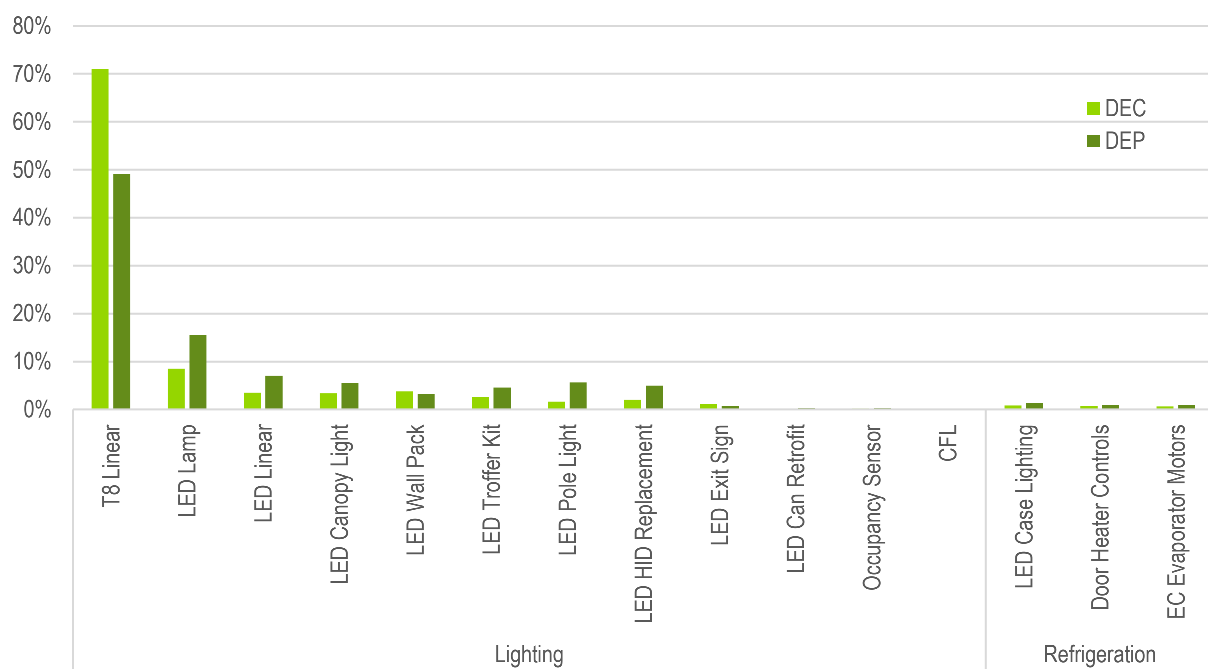
Reported Metrics	PY2013 (DEP)	PY2014 (DEP)	PY2015 (DEP)	PY2015 (DEC)
Participants	675	1,759	1,790	3,080
Measures Installed	42,537	108,816	132,977	234,788
Gross Annual Energy Savings (MWh)	14,242	38,665	48,772	77,269
Average Quantity of Measures per Project	63	62	74	76
Average Gross Savings Per Project (MWh)	21.1	22.0	27.2	25.1

Source: SBES Tracking Database

2.2.1 Program Summary by Measure

Efficient T8 lighting retrofits were the highest contributor to program energy savings in PY2015 across both jurisdictions, followed by a variety of LED lighting measures. In addition, refrigeration measures, compact fluorescent lamps (CFLs), and occupancy sensors also contributed to savings. Navigant found a higher share of savings from T8 fluorescent retrofits in the DEC jurisdiction, likely due to the fall and winter 2014 projects that were part of this evaluation cycle. The SBES program has rapidly adopted LED lighting products in PY2015. Figure 2-1 shows the reported gross savings by measure category as reported by Duke Energy.

Figure 2-1. Reported Gross Energy Savings by Measure Category and Jurisdiction

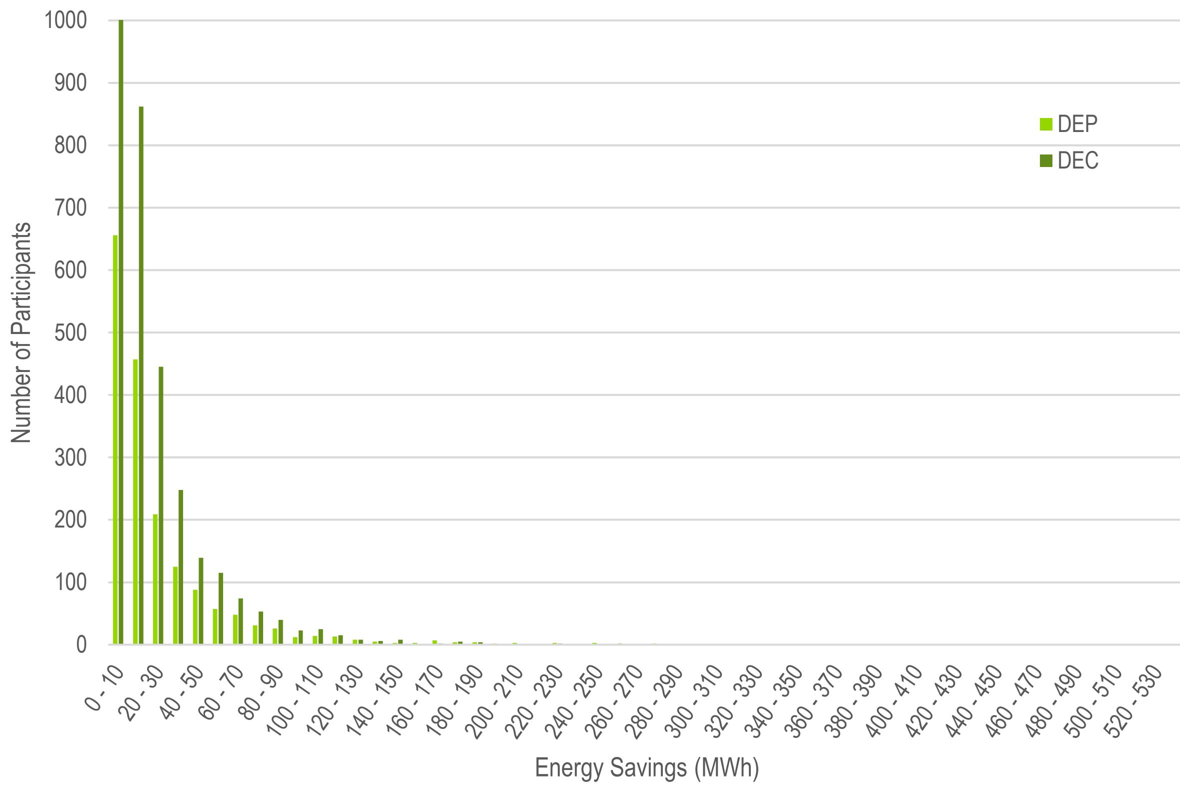


Source: SBES Tracking Database

2.2.2 Savings by Project

Because the SBES program is limited to small business customers only, the variations in project energy and peak demand savings and the quantity of measures installed exhibit less spread than typical large business program offerings. Nevertheless, there is still a mix of various project sizes, as shown in Figure 2-2, with very few project sites reporting savings over 200 MWh per year. The largest site reported savings of over 500 MWh per year.

Figure 2-2. Histogram of Reported Energy Savings per Project



Source: SBES Tracking Database

The evaluation team reviewed the business type data in the tracking database as well, but found that there was not a facility type field that could be easily mapped to deemed savings values for HVAC interactive effects and coincidence factors, which will be explored further in this report.

3. KEY RESEARCH OBJECTIVES

As outlined in the Statement of Work (SOW), the primary purpose of the EM&V activities is to estimate verified net annual energy and peak demand impacts associated with program activity for PY2015. Additional research objectives include the following:

3.1 Impact Evaluation

The impact evaluation focuses on quantifying the magnitude of verified energy savings and peak demand reductions. Objectives include:

- Verify deemed savings estimates through review of measure assumptions and calculations.
- Perform on-site verification of measure installations, and collect data for use in an engineering analysis.
- Estimate the amount of observed energy and peak demand savings (both summer and winter) by measure via engineering analysis.

3.2 Net-to-Gross Analysis

The net-to-gross analysis focuses on estimating the share of energy savings and peak demand reductions that can be directly attributed to the SBES program itself. Objectives include:

- Assess the Net-to-Gross ratio by addressing spillover and free-ridership in customer surveys.

3.3 Process Evaluation

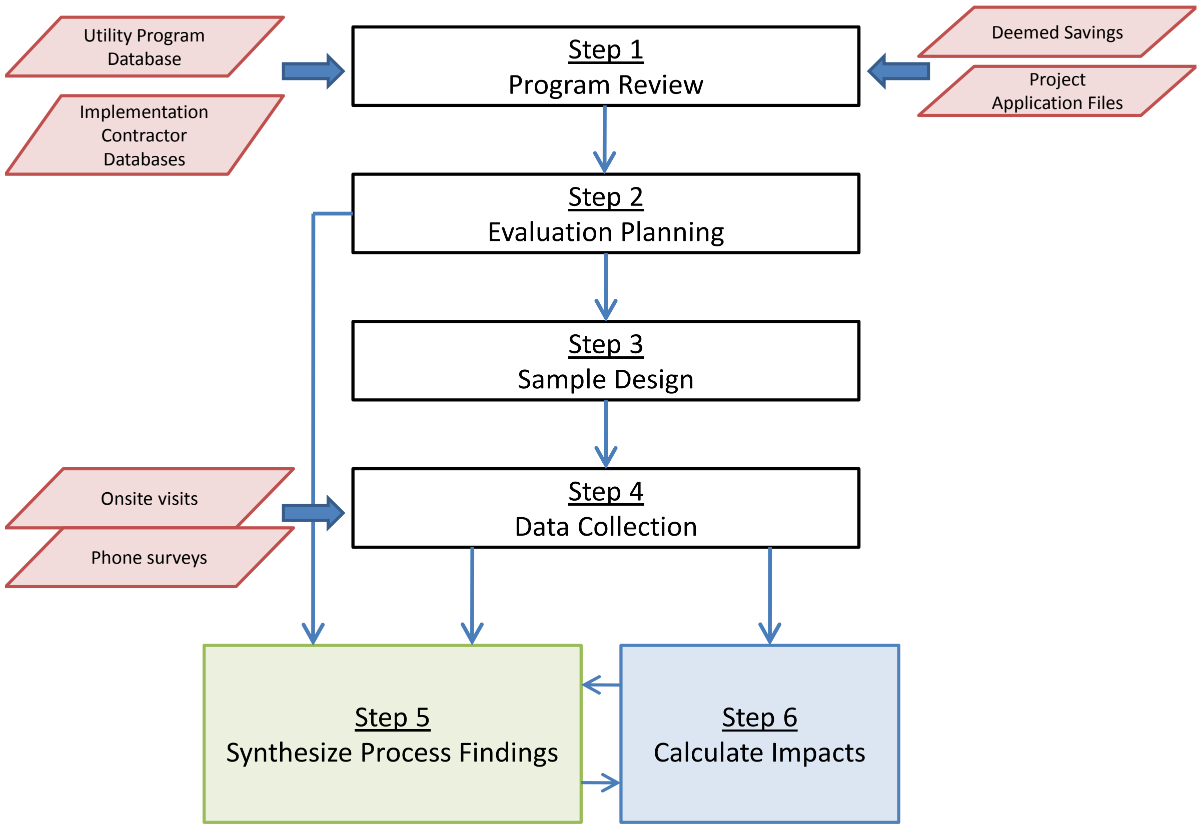
The process evaluation focuses on the program implementation and the customer experience. Objectives include:

- Perform interviews with program management and Implementation Contractor.
- Perform participant surveys with customers.
- Identify barriers to participation in the program, and how the program can address these barriers.
- Identify program strengths and the potential for introducing additional measures.

3.4 Evaluation Overview

Figure 3-1 outlines the high-level approach used for evaluating the SBES Program, which is designed to address the research objectives outlined above. The impact, net-to-gross, and process sections provide further detail for each of the individual EM&V activities.

Figure 3-1. Evaluation Process Flow Diagram



Source: Navigant

4. IMPACT EVALUATION

The purpose of this impact evaluation is to quantify the verified energy and demand savings estimates for the SBES Program in both the DEP and DEC jurisdictions. Table 4-1 and Table 4-2 show high-level program results of Navigant's impact analysis. Ultimately, Duke Energy can use these results as an input to system planning.

Table 4-1. PY2015 SBES Summary of Program Impacts for DEP

DEP	Energy Savings (MWh)	Summer Peak Demand Reductions (MW)	Winter Peak Demand Reductions (MW)
Reported Gross Savings	48,772	11.7	11.7
Realization Rate	1.11	0.96	0.53
Verified Gross Savings	54,318	11.2	6.2
NTGR	1.03	1.03	1.03
Verified Net Savings	55,947	11.5	6.4

Source: Navigant analysis

Table 4-2. PY2015 SBES Summary of Program Impacts for DEC

DEC	Annual Energy Savings (MWh)	Summer Peak Demand Reductions (kW)	Winter Peak Demand Reductions (kW)
Reported Gross Savings	77,269	20.5	20.5
Realization Rate	1.12	0.96	0.53
Verified Gross Savings	86,899	19.8	10.9
NTGR	1.03	1.03	1.03
Verified Net Savings	89,506	20.4	11.2

Source: Navigant analysis

4.1 Impact Methodology

The methodology for assessing the gross energy savings and peak demand reductions follows IPMVP Option A (Retrofit Isolation: Key Parameter Measurement). This involves an engineering-based approach for estimating savings, supplemented by key parameter measurements. This included using time-of-use lighting loggers to directly measure operating hours and coincidence factors for program- incented lighting measures. Note that for the limited set of refrigeration measures, verification activities were performed on-site to assess installation and operation.

The evaluation team employed the following steps to conduct the impact analysis:

1. **Review Field Data and Design Sample** – First, the team analyzed the tracking data to determine the most appropriate sampling methodology. The team created four strata (small, medium, and large lighting, and refrigeration) to ensure that a variety of different businesses and

measures were captured in the site visits. A subset of each strata was selected for more detailed logging (19 of 57 total sites visits were logged).

2. **Pull Sample** – Next, the team pulled a sample from the four strata and scheduled site visits, including several backup sites in the event that a visitation could not be arranged.
3. **Perform Participant Site Visits** – The evaluation team used an electronic data collection system in the field to ensure consistency and decrease data processing time. For all site visits, Navigant field technicians uploaded all collected site data to the online system as soon as they were completed. Navigant performed quality control verifications for all field data collection forms and online data entry. This included a thorough inspection of each site's building characteristic inputs, operating schedules, measure-level in-service rates, and descriptions. The following steps were taken at each participant site:
   a. At each customer site, the team first determined the in-service rate (ISR) of the equipment for each measure found. The field technicians accomplished this by visually verifying and counting all equipment included in the project documentation at each site.
   b. The team then calculated the difference in watts between the base-case fixtures and the energy-efficient fixtures for each fixture type installed on-site. The team verified efficient fixture wattage through visual inspection, while deriving base-case fixture wattage from customer-provided data found in the documentation review, if available, or from information found by field technicians during the site visits. There is typically little to no information about the specifications of base-case equipment that has been removed from a site. If both customer data and field data were insufficient, the team utilized the IC tracking data and assessed the reasonableness of their assumptions.
   c. Operating hours were determined from a detailed customer interview for each unique lighting schedule in the building, and adjusted for holiday building closures. For the subset of sites that received logging, the EM&V team left time-of-use loggers in place for roughly three weeks and then returned to retrieve the logging equipment.
   d. Coincidence factors were taken from prior EEB program findings[2] and previous SBES reports[3] for similar building types for the verification only sites. For logged sites, the team calculated both summer and winter coincidence factors from the logger data.
4. **Calculate Site-Level Savings** – The team calculated site-level energy and demand savings for each site in the sample based on operational characteristics found on site and engineering-based parameter estimates.
5. **Calculate Program-Level Savings** – The team calculated verification rates for all sites and applied a ratio, representing the adjustment based on the logger data, resulting in final verified savings for each sampled site. Lastly, the team calculated stratum-level realizations rates, applied those realization rates to the projects that fell into their respective strata, and arrived at final program-level realization rates. Navigant utilized the stratified ratio estimation method to determine program-level verified gross savings for each jurisdiction by applying strata-level realization rates to the projects within each jurisdiction.

[2] PY2013 DEP EEB EM&V Report

[3] PY2013 and PY2014 DEP SBES EM&V Report

4.2 Sample Design

After reviewing the Duke Energy and IC tracking data, the evaluation team opted to split up the population of projects into four strata based on the projects' estimated energy savings to ensure that the sample represented both small, medium and large customers, and that field verification assessed a large percentage of program savings. The strata were designed according to the following guidelines:

1. First, all projects with refrigeration measures were assigned to a single stratum.
2. The remaining projects were sorted from highest claimed savings to lowest claimed savings.
3. The team then examined the reported savings and selected criteria that would result in three strata, each containing an approximately equal share of total claimed savings:
    - Lighting Large – greater than 65,000 kWh reported savings;
    - Lighting Medium – between 25,000 kWh and 65,000 kWh reported savings;
    - Lighting Small – less than 25,000 kWh savings;
    - Refrigeration – all projects with refrigeration savings.

Note that the stratum cutoff points for PY2015 are higher than in PY2014 due to the larger average per-project savings in this evaluation. The limits in PY2014 were 20,000 kWh and 40,000 kWh.

In order to achieve a 10 percent relative precision at a 90 percent confidence interval, the evaluation team targeted 57 total sites, which were spread roughly equally among the three lighting strata and a smaller refrigeration stratum.

The evaluation team conducted on-site verification at 57 sites during the summer of 2016. While on-site, the team conducted customer interviews and visual verification to collect data on building operation, HVAC system details, and seasonal and holiday schedules. Key evaluation parameters came primarily from on-site data; however, where this data was lacking or was deemed unusable, customer application data was used in its place. As there are many parameter inputs to the savings calculation for each site, this approach ensures that the best available data are used for each site's savings estimation. Table 4-3 below details the final site visit disposition.

Table 4-3. Onsite Sample Summary

Strata	Population Size	Onsite Verification Sample Size	Onsite Metering Sample Size (Subset of Verification Sample)
Lighting Large	328	16	6
Lighting Medium	1025	18	7
Lighting Small	3,327	17	6
Refrigeration	195	6	0
Total	**4,875**	**57**	**19**

Source: Navigant analysis

4.3 Algorithms and Parameters

Navigant used data collected from the field and the engineering review to calculate site-level energy and demand savings, using the following algorithms. Table 4-4 shows the algorithms that the evaluation team used to calculate verified savings for lighting measures. The impact evaluation effort focused on verifying the inputs for these algorithms.

Table 4-4. Verified Savings Algorithms for Lighting Measures

Measure	Energy Savings Algorithm	Coincident Peak Demand Savings Algorithm
Lighting Measures	kWh_Verified = Qty_Verified x HOU x Verified_Watts_Reduced x IF_Energy	kW_Verified = Verified x CF x Verified_Watts_Reduced x IF_Demand
Refrigeration	kWh_Verified = Unit_Savings x Qty_Verified	kW_Verified = Unit_Savings x Qty_Verified

ISR = in-service rate (not in calculation, calculated to provide context)
Fixture_Quantity_Verified = quantity of equipment verified on-site
HOU = verified operating hours
CF = coincidence factor
IF_Energy = heating, ventilating, and air conditioning (HVAC) interaction factor for energy savings calculations
IF_Demand = interaction factor for demand savings calculations
Verified Watts Reduced = watts of baseline equipment - watts of energy-efficient equipment.
Unit_Savings = deemed per unit savings appropriate for measure.

Source: Navigant analysis

The detailed description of each parameter and any related assumption are as follows:

4.3.1 Fixture Quantity Verified and In-Service Rate (ISR)

The Navigant evaluation team visually counted fixtures on-site to quantify the quantity and type of lighting equipment installed. The team calculated the ISR as the ratio between the findings from the on-site verification compared to the quantity reported in the program-tracking databases. On-site verifications determined the total number of installed measure-level equipment.

4.3.2 Verified Watts

The team calculated base and efficient watts at the measure level. Efficient nameplate wattages were determined using manufacturer specifications based on fixture-level data collected on-site. The project documentation contained in the IC tracking database determined base wattages. In the cases where efficient fixture data were unavailable, due to inaccessible fixtures, the wattages found in the IC database values were applied.

4.3.3 HVAC Interactive Effects

Reductions in lighting energy generally increase a building's heating requirements (load) and decrease cooling requirements. The HVAC interactive effects accounts for these secondary effects on the HVAC system energy use and acts as a multiplier in the energy savings algorithms. The team applied the HVAC interactive effects used in prior EEB and SBES program evaluations (both 2013 and 2014) for consistency, which were sourced from a 2011 Navigant study (including over 120 buildings) in Maryland that used building energy models of field-verified building characteristics (i.e., HVAC, lighting, and envelope) and actual billing data to assess the interactive effects of lighting energy reductions on HVAC system energy use. The resulting interaction factors are specific to both building type (e.g., office, warehouse) and heating/cooling systems.

4.3.4 Annual Operating Hours

Measure-level annual operating hours were determined from a detailed interview with the SBES customer. Hours used per day or week were rolled up to annual hours of use and corrected for holidays, seasonal variations in use, and any other change in operating characteristics. For logged sites, the team extrapolated the time of use logger data to develop annual hours of operation.

4.3.5 Coincidence Factor (CF)

Coincidence factors represent the portion of installed lighting that is operational during the utility peak performance hours. These were determined similarly to HVAC interactive effects by using deemed values by building type in addition to data collected on-site. For example, light-emitting diode (LED) exit signs that are on all day receive a CF on 1.0, while exterior lights on daylight sensors receive a CF of 0.0. For logged sites, the team extrapolated the time of use logger data to develop coincidence factors.

4.3.6 Unit Savings

For refrigeration measures, the engineering analysis follows a deemed savings methodology based on the NY Technical Reference Manual (TRM) unit savings. The assumptions and parameters used to estimate reported energy savings and peak demand reductions were deemed appropriate by the evaluation team. The team verified that the measures were installed and operational during on-site visits to projects that installed efficient refrigeration equipment.

4.4 Key Impact Findings

The energy realization rates by strata are shown in Table 4-5. This shows the verification realization rate, the metering realization rate, and the final realization rate by strata. Note that strata-level realization rates are derived from both DEP and DEC projects, and are applied to each jurisdiction separately to calculate program level verified energy savings and peak demand reductions.

Table 4-5. Energy Impacts by Strata

Strata	Verification Realization Rate (kWh)	Metering Realization Rate Adjustment (kWh)	Total Realization Rate (kWh)
Lighting Large	0.94	1.12	1.06
Lighting Medium	1.09	1.03	1.12
Lighting Small	1.20	1.00	1.20
Refrigeration	1.05	n/a	1.05
Total	**1.08**	**1.04**	**1.12**

Source: Navigant analysis

The summer and winter peak demand reductions are shown in Table 4-6 and Table 4-7. Contrary to the energy adjustments based on metering, there is a more substantial reduction in the realization due to application of measure-specific coincidence factors based on logger data for both the summer and winter periods. A winter coincidence factor was calculated based on the logged data, with the summer coincidence factors used as the basis for statistical comparison given the lack of more appropriate parameters.

Table 4-6. Summer Peak Demand Impacts by Strata

Strata	Verification Realization Rate (kW)	Metering Realization Rate Adjustment (kW)	Total Realization Rate (kW)
Lighting Large	1.09	1.01	1.11
Lighting Medium	1.04	0.93	0.96
Lighting Small	1.27	0.72	0.91
Refrigeration	0.58	n/a	0.58
Total	**1.10**	**0.87**	**0.96**

Source: Navigant analysis

Table 4-7. Winter Peak Demand Impacts by Strata

Strata	Verification Realization Rate (Winter kW)	Metering Realization Rate Adjustment (Winter kW)	Total Realization Rate (Winter kW)
Lighting Large	0.83	0.70	0.58
Lighting Medium	0.77	0.72	0.56
Lighting Small	0.94	0.50	0.47
Refrigeration	0.47	n/a	0.47
Total	**0.82**	**0.64**	**0.53**

Source: Navigant analysis

Overall, the verification realization rates are slightly above 1.0 for energy savings and summer peak demand reduction. This indicates that the program is accurately reporting impacts at the aggregate program level, despite varying realization rates for each individual stratum. The winter peak demand reductions were not characterized specifically by Duke Energy, so in turn Navigant compared verified winter savings with deemed reported summer savings.

4.5 Detailed Impact Findings

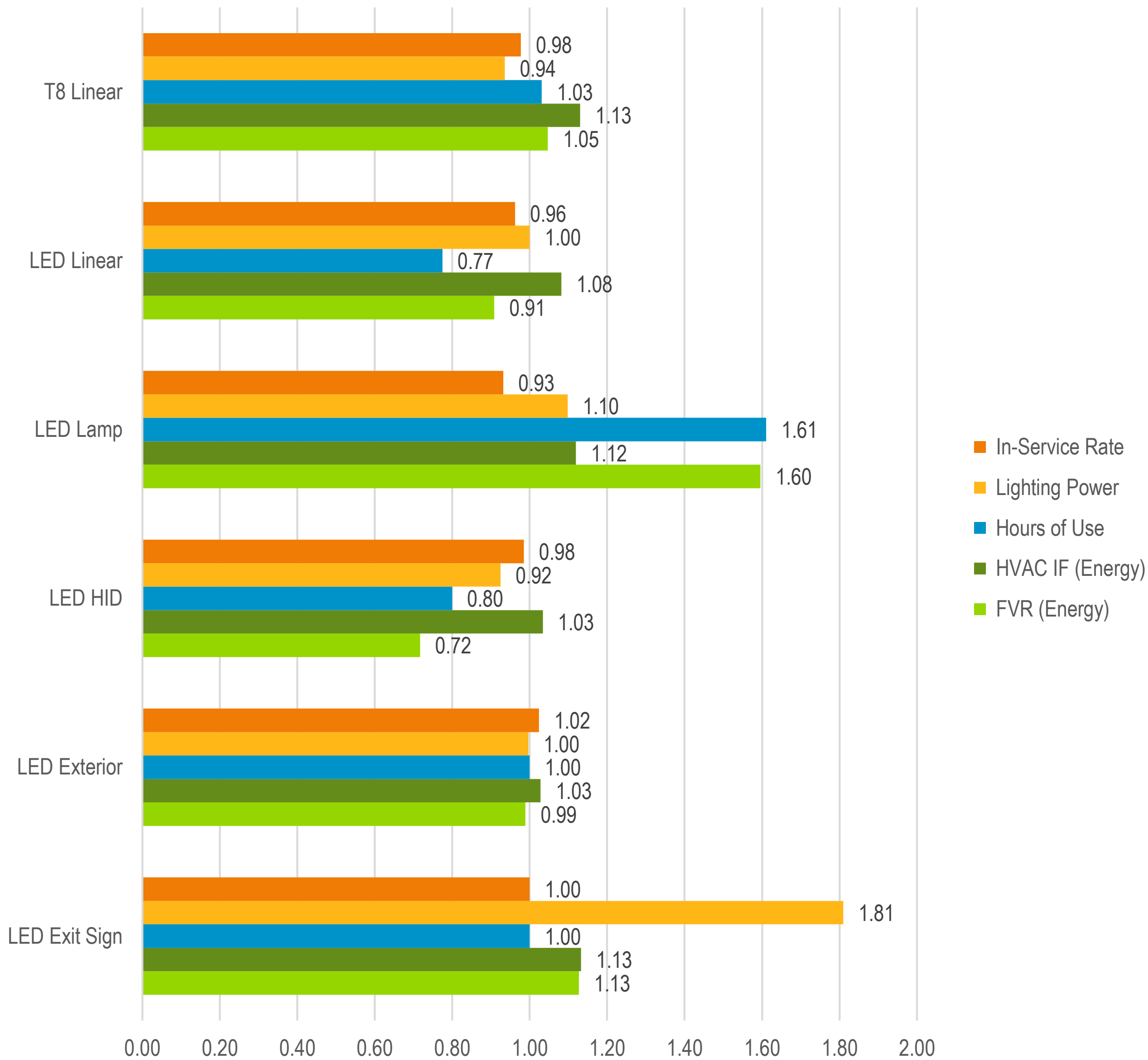
This section examines findings from the evaluation of lighting measures in order to identify the main drivers of the verified savings values. The evaluation team uses the Field Verification Rate (FVR) to describe the overall verified savings relative to the reported savings for each measure. FVRs reflect differences between the quantity of equipment installed on-site and the quantity reported in the tracking database, as well as differences between operating characteristics verified in the field and assumed operating characteristics in the program deemed savings estimates. The team calculates the field verification rate as the verified savings divided by the reported savings by measure, which is driven by a combination of the in-service rate, the hours of use adjustment rate, the lighting power adjustment rate, the HVAC interactive effect adjustment rate, and the coincidence factor, described as follows:

1. **In-Service Rate**[4] **(ISR)** is the ratio of the verified (i.e., installed) quantity to the reported quantity.
2. **Hours of Use (HOU) Adjustment Rate** reflects discrepancies between reported and verified operating hours.
3. **Lighting Power Adjustment Rate** is a ratio of the verified wattage difference between the efficient and baseline equipment to the reported wattage difference between the efficient and baseline equipment.
4. **HVAC Interactive Effect (IE) Adjustment Rate** is a multiplier that reflects HVAC interactive effects due to space heating and cooling loads due to a reduction in heat output from efficient lighting. Note that the IC did not deem HVAC IE for any measures so this adjustment is equal to the average HVAC IE itself. There are separate adjustments for energy savings and peak demand reduction.
5. **Coincidence Factor** represents the portion of installed lighting that is on during the peak utility hours. This affects only summer and winter peak demand reductions, not energy savings.

Figure 4-1 below shows the relative effect of each of the aforementioned adjustment rates on the measure-level FVR for energy savings, which the following subsections describe in further detail. Note that FVR cannot be used to derive program level realization rates. This is because the contributions of each parameter update are described relative to their reported value, while the program analysis was structured to stratify savings by participant energy savings per site rather than by individual measures.

[4] In-Service Rate is an industry-standard term that describes verified quantities of installed equipment relative to reported quantities.

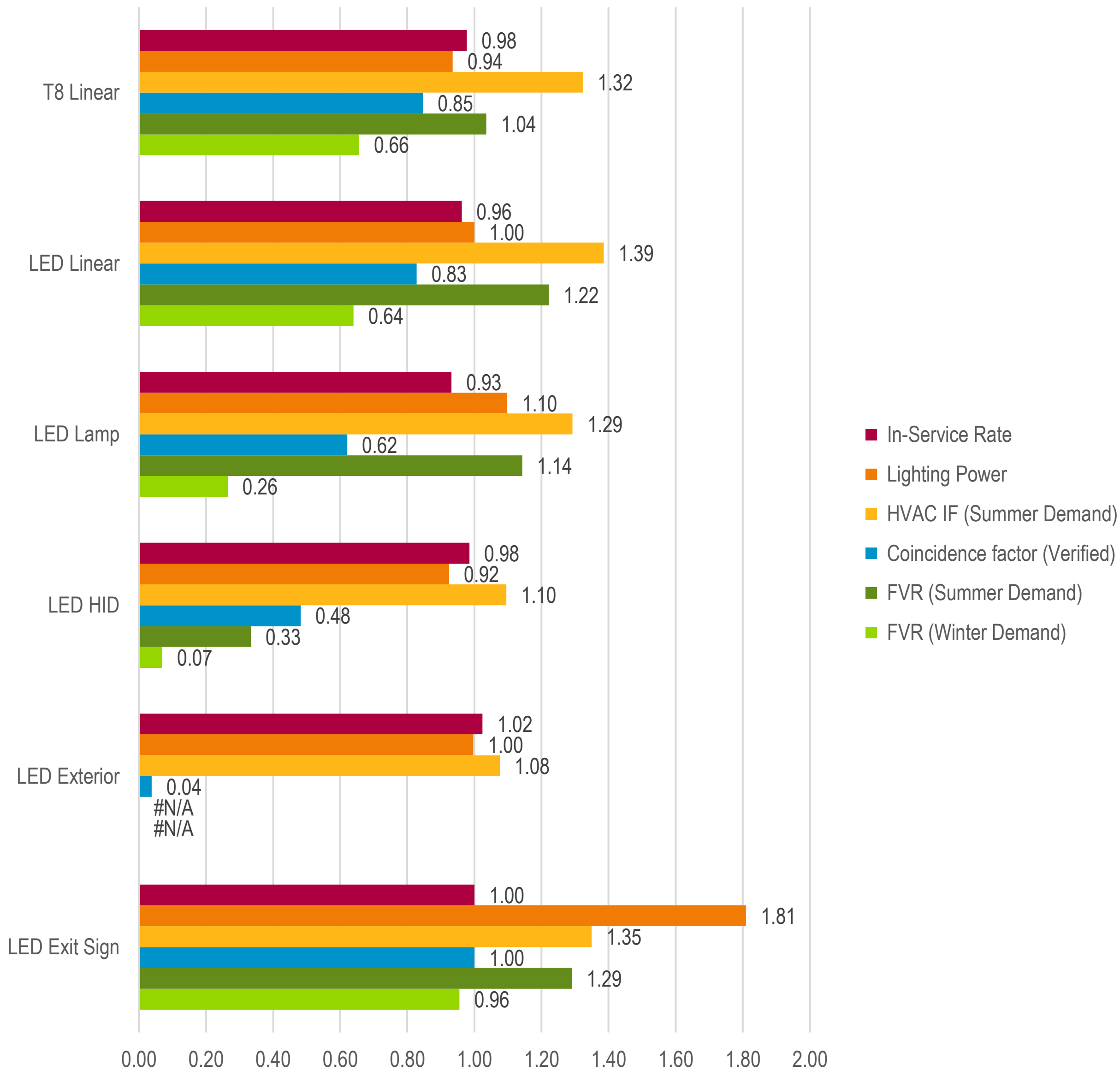
Figure 4-1. Gross Energy Savings Field Verification Rates



Source: Navigant analysis

Figure 4-2 below shows the relative effect of each of the aforementioned adjustment rates on the measure-level FVR for summer peak demand reductions, which the following subsections describe in further detail.

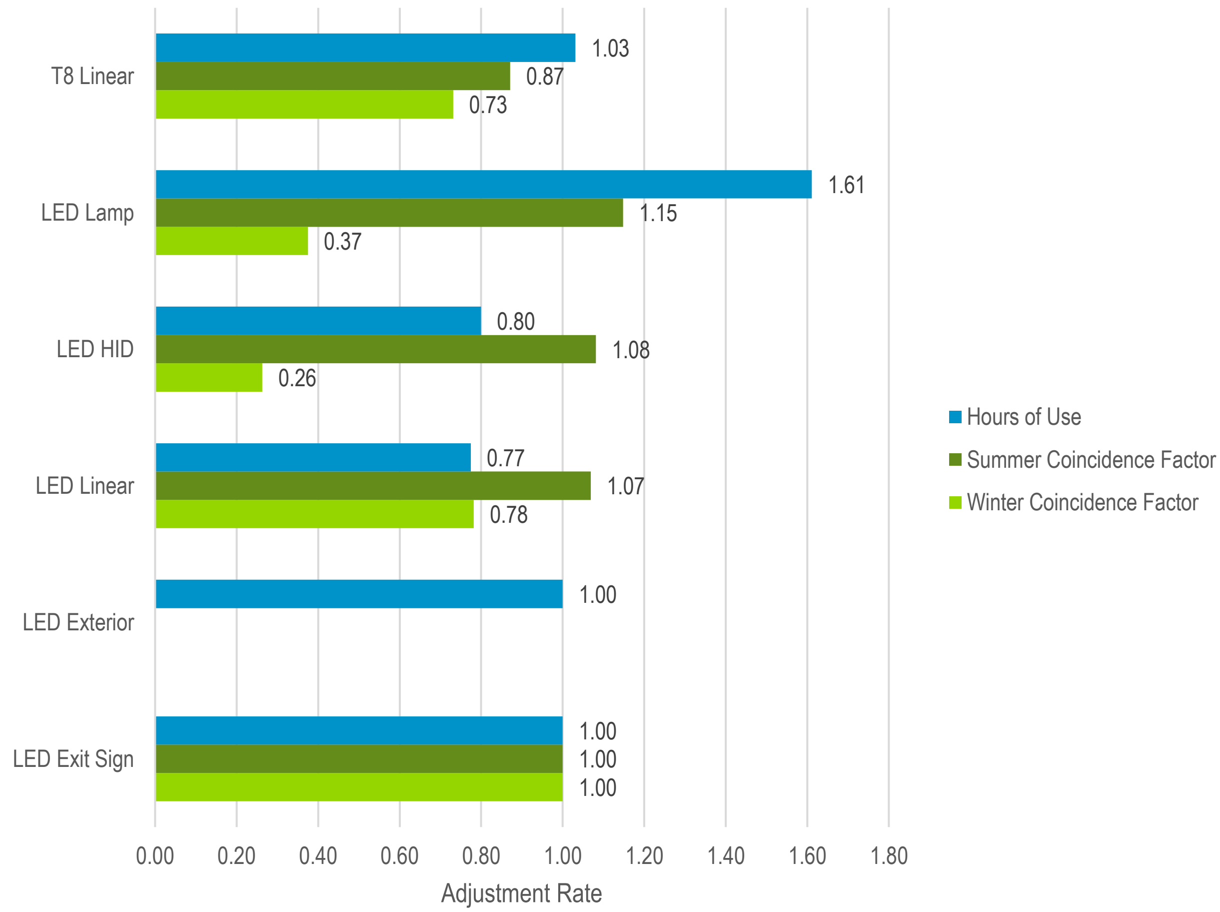
Figure 4-2. Gross Peak Demand Reductions Field Verification Rates



Source: Navigant analysis

The final adjustment to develop site-specific verified gross savings is the ratio of metered HOU and CF compared to estimated (or deemed) HOU and CF used for verification. The results of these adjustments, analogous to FVR, are shown in Figure 4-3 below. The metered data results in a downward adjustment for both HOU and CF, but this effect is more pronounced for CF due to the high rigor of the HOU estimates compared to the CF estimates in the tracking data.

Figure 4-3. HOU and CF Adjustments from Metered Data



Source: Navigant analysis

The remainder of this section discusses in more detail the parameters that are part of the energy and peak demand savings algorithms: ISR, HOU, lighting power, HVAC interactive effects and coincidence factors.

4.5.1 In-Service Rates

One of the primary functions of evaluation, particularly for lighting measures, is to verify the quantity of the installed equipment relative to the reported quantity. The resulting ratio is the ISR. As shown in Figure 4-1 above, the ISR for each measure varies from 0.93 for LED screw-in lamps and 1.02 for LED exterior fixtures.

4.5.2 Hours-of-Use Adjustments

HOU is another key parameter for estimating lighting energy savings. The evaluation team estimated this parameter through customer interviews for each unique lighting schedule, similar to the approach taken by the IC. During the on-site customer interviews, the team found that the hours of use that site technicians reported was very close to the HOU reported in the tracking database. The team notes that overall the IC is accurately characterizing hours of use based on both customer interviews and, the metered data.

4.5.3 Lighting Power

The evaluation team based the lighting power parameter on the actual power draw of the baseline and efficient equipment. The baseline equipment is assumed to be as-found lighting installed and in use at the time of the audit; however, because the baseline equipment was no longer present at the participant sites, the team could not verify the baseline power draw and defaulted to the IC-provided value.

The evaluation team verified the efficient equipment wattage from manufacturer specification sheets to provide a more accurate lighting power figure than the deemed values that the IC used. Overall lighting power level differences were minor across the measure categories, between 0.92 for LED HID replacements and 1.81 for LED Exit Signs. This is an improvement from PY2014 and contributes to a higher realization rate for PY2015. The high wattage adjustment resulted overall in a small increase in savings due to the relative contributions of this measure.

The evaluation team would like to note that newer linear LED systems can be configured in a variety of ways, including with or without an electronic ballast. The manufacturer specifications for these systems typically do not account for every installation scenario with different ballast brands, models, and configurations possible. The team did not perform power measurements as part of this evaluation, but encourages the IC team to ensure that the power consumption of these systems is accurately characterized as their contribution to total program savings grows.

4.5.4 HVAC Interactive Effects

The evaluation team applied HVAC interactive effects for both energy, summer and winter peak demand. The deemed values are based on the building type and the heating and cooling system types as verified in the field for the sample sites. However, the IC did not apply HVAC IE for any of the lighting measures claimed in PY2015, as in previous evaluations. This adjustment is between 1.03 and 1.13 for energy and 1.08 and 1.39 for summer peak demand. Deemed values are described in Section 9 below for energy and summer peak demand; winter peak demand interactive effects were assumed to be 1.0 for all measures.

4.5.5 Coincidence Factors

Similar to the HVAC interactive effects, the team applied coincidence factors consistent with the deemed values used in the EEB Program. This factor takes into account that not all lights are on for the duration of the peak demand period. Coincidence factors range from 0.42 to 0.99, based on building type. The IC applied a coincidence factor of 1.0 for all lighting measures with the exception of occupancy sensors. Deemed values are shown in Section 8 below. The metered data further validates the deemed coincidence factors, but a sufficient sample size was not developed to determine new deemed coincidence factors at this time.

5. NET-TO-GROSS ANALYSIS

The impact analysis described in the preceding sections addresses *gross program savings*, based on program records, modified by an engineering review, field verification, and metering of measure installations. *Net savings* incorporate the influence of free ridership (savings that would have occurred even in the absence of the program) and spillover (additional savings influenced by the program but not captured in program records) and are commonly expressed as a NTG ratio applied to the verified gross savings values.

Table 5-1 shows the results of Navigant's NTG analysis. Navigant anticipated low free ridership and spillover based on previous findings from the PY2013 and PY2014 SBES evaluations. The estimated free-ridership and spillover shown for PY2015 are slightly higher than thefindings from the previous evaluations

Table 5-1. Net-to-Gross Results

	PY2013 (DEP)	PY2014 (DEP)	PY2015 (DEP & DEC)
Estimated Free Ridership	0.04	0.04	0.06
Estimated Spillover	0.02	0.07	0.09
Estimated NTG	0.98	1.03	1.03

Source: Navigant analysis

The results are consistent with the program theory and delivery model, whereby the Implementation Contractor (IC) actively recruits participants and presents a suite of energy efficiency measures to potential customers. Customers are not eligible to retroactively claim incentives under this program, which reduces the potential for free ridership significantly.

This report provides definitions, methods, and further detail on the analysis and findings of the net savings assessment. The discussion is divided into the following three sections:

- Defining free ridership, spillover, and net-to-gross (NTG) ratio
- Methods for estimating free ridership and spillover
- Results for free ridership, spillover, and NTG ratio

5.1 Defining Free Ridership, Spillover, and Net-to-Gross Ratio

The methodology for assessing the energy savings attributable to a program is based on a NTG ratio. The NTG ratio has two main components: free ridership and spillover.

Free ridership is the share of the gross savings that is due to actions participants would have taken even in the absence of the program (i.e., actions that the program did not induce). This is meant to account for naturally occurring adoption of energy efficient technology. The SBES Program covers a range of energy efficient lighting and refrigeration measures and is designed to move the overall market for energy efficiency forward. However, it is likely that some participants would have wanted to install, for various reasons, some high efficiency equipment (possibly a subset of those installed under the SBES Program), even if they had not participated in the program or been influenced by the program in any way.

Spillover captures program savings that go beyond the measures installed through the program. Also called "market effects," the term "spillover" is often used because it reflects savings that extend beyond the bounds of the program records. Spillover adds to a program's measured savings by incorporating indirect (i.e., non-incentivized) savings and effects that the program has had on the market above and beyond the directly incentivized or directly induced program measures.

Total spillover is a combination of non-reported actions to be taken at the project site itself (*within-facility spillover*) and at other sites (*outside-facility spillover*). Each type of spillover is meant to capture a different aspect of the energy savings caused by the program, but not included in program records.

The **overall NTG ratio** accounts for both the net savings at participating projects and spillover savings that result from the program but are not included in the program's accounting of energy savings. When the NTG ratio is multiplied by the estimated gross program savings, the result is an estimate of energy savings that are attributable to the program (i.e., savings that would not have occurred without the program).

The basic equation is shown in Equation 1.

Equation 1. Net-to-Gross Ratio

$$NTG = 1 - \text{Free Ridership} + \text{Spillover}$$

The underlying concept inherent in the application of the NTG formula is that *only* savings caused by the program should be included in the final net program savings estimate but that this estimate should include *all* savings caused by the program.

5.2 Methods for Estimating Free Ridership and Spillover

5.2.1 Estimating Free Ridership

Data to assess free ridership were gathered through the self-report method—a series of survey questions asked of SBES participants. Free ridership was asked in both direct questions, which aimed at obtaining respondent estimates of the appropriate free ridership rate that should be applied to them, and in supporting or influencing questions, which could be used to verify whether the direct responses are consistent with participants' views of the program's influence.

Respondents were asked three categories of program-influence questions:

- **Likelihood:** to estimate the likelihood that they would have incorporated lighting measures "of the same high level of efficiency," if not for the assistance of the SBES Program. In cases where respondents indicated that they might have incorporated some, but not all, of the measures, they were asked to estimate the share of measures that would have been incorporated anyway at high efficiency. This flexibility in how respondents could conceptualize and convey their views on free ridership allowed respondents to give their most informed response, thus improving the accuracy of the free-ridership estimates.
- **Prior planning:** to further estimate the probability that a participant would have implemented the measures without the program. Participants were asked the extent to which they had considered installing the same level of energy-efficient lighting prior to participating in the program. The general approach holds that if customers were not definitively planning to install all of the

efficiency lighting prior to participation, then the program can reasonably be credited with at least a portion of the energy savings resulting from the high-efficiency lighting. Strong free ridership is reflected by those participants who indicated they had already allocated funds for the purchase and selected the lighting and an installer.

- **Program importance:** to clarify the role that program components (e.g., information, incentives) played in decision-making, and to provide supporting information on free ridership. Responses to these questions were analyzed for each respondent, not just in aggregate, and were used to identify whether the direct responses on free ridership were consistent with how each respondent rated the "influence" of the program.

Free-ridership scores were calculated for each of these categories[5] and then averaged and divided by 100 to convert the scores into a free-ridership percentage. Next, a timing multiplier was applied to the average of the three scores to reflect the fact that respondents indicating that their energy efficiency actions would not have occurred until far into the future may be overestimating their level of free ridership. Participants were asked, without the program, when they would have installed the equipment. Respondents who indicated that they would not have installed the lighting for at least two years were not considered free riders and had a timing multiplier of 0. If they would have installed at the same time as they did, they had a timing multiplier of 1; within one year, 0.67; and between one and two years, 0.33. Participants were also asked when they learned about the financial incentive; if they learned about it after the equipment was installed, then they had a free ridership ratio of 1.

5.2.2 Estimating Spillover

The basic method for assessing participant spillover (both within-facility and outside-facility) was an approach that asked a set of questions to determine the following:

- **Whether spillover exists at all.** These were yes/no questions that asked, for example, whether the respondent incorporated energy efficiency measures or designs that were not recorded in program records. Questions related to extra measures installed at the project site (within-facility spillover) and to measures installed in non-program projects (outside-facility spillover) within the service territory.
- **The share of those savings that could be attributed to the influence of the program.** Participants were asked if they could estimate the energy savings from these additional extra

[5] Scores were calculated by the following formulas:

» Likelihood: The likelihood score is 0 for those that "definitely would NOT have installed the same energy efficient measure" and 1 for those that "definitely WOULD have installed the same energy efficient measure." For those that "MAY HAVE installed the same energy efficient measure," the likelihood score is their answer to the following question: "On a scale of 0 to 10 where 0 is DEFINITELY WOULD NOT have installed and 10 is DEFINITELY WOULD have installed the same energy efficient measure, can you tell me the likelihood that you would have installed the same energy efficient measure?" If more than one measure was installed in the project, then this score was also multiplied by the respondent's answer to what share they would have done.

» Prior planning: If participants stated they had considered installing the measure prior to program participation, then the prior planning score is the average of their answers to the following two questions: "On a scale of 0 to 10, where 0 means you 'Had not yet planned for equipment and installation' and 10 means you 'Had identified and selected specific equipment and the contractor to install it', please tell me how far along your plans were" and "On a scale of 0 to 10, where 0 means 'Had not yet budgeted or considered payment' and 10 means 'Already had sufficient funds budgeted and approved for purchase', please tell me how far along your budget had been planned and approved."

» Program importance: This score was calculated by taking the maximum importance on a 0 to 10 scale of the four program importance questions and subtracting from 10 (i.e., the higher the program importance, the lower the influence on free ridership).

measures to be less than, similar to, or more than the energy savings from the SBES program equipment.

- **Program importance.** Estimates were derived from a question asking the program importance, on a 0 to 10 scale. Participants were also asked how the program influenced their decisions to incorporate additional energy efficiency measures.

If respondents said no, they did not install additional measures; they had a zero score for spillover. If they said yes, then the individual's spillover was estimated as the self-reported savings as a share of project savings, multiplied by the program-influence score. Then, a 50 percent discount was applied to reflect uncertainty in the self-reported savings and divided by 10 to convert the score to a spillover percentage.

5.2.3 Combining Results across Respondents

The evaluation team determined free ridership and spillover estimates for each of the following:

- Individual respondents, by evaluating the responses to the relevant questions and applying the rules-based approach discussed above
- Measure categories:
  - For free ridership: by taking the average of each respondent's score within each category
  - For spillover: by taking the sum of the individual spillover results for each measure category and weighting each category by the population
- The program as a whole, by combining measure-level results
  - For free ridership: measure category results were subsequently weighted by each category's share of total savings
  - For spillover: measure category results were summed and then weighted by the sum of the reported savings for the sample (which were also weighted by the population)

5.3 Results for Free Ridership, Spillover, and Net-to-Gross

This section presents the results of the attribution analysis for the SBES Program. Specifically, results are presented for free ridership and spillover (within-facility and outside-facility), which are used collectively to calculate an NTG ratio.

5.3.1 Review of Data Collection Efforts for Attribution Analysis

The EM&V team conducted 151 surveys with SBES participants to estimate free ridership, spillover, and NTG ratios. Table 5-2 shows the number of completions, by measure group.

Table 5-2. Attribution Survey Completes by Project Type

Measure Category	DEP Surverys	DEC Surveys	Total Surveys
Lighting	45	91	136
Refrigeration	7	8	15
Total	**52**	**99**	**151**

Source: Navigant analysis

5.3.2 Free-Ridership Results

The evaluation team asked participants a series of questions regarding the likelihood, scope, and timing of the investments in energy-efficient lighting if the respondent had not participated in the program. The purpose of the surveys was to elicit explicit estimates of free ridership and perspectives on the influence of the program. The evaluation team estimates free-ridership for the SBES Program at 6 percent of program-reported savings.

5.3.3 Spillover Results

The SBES Program influenced approximately 15 percent of participants to install additional energy efficiency measures on-site (up from 9 percent in PY2014) and influenced 12 percent of participants (up from 6 percent in PY2014) to install additional measures at other locations. Based on the survey findings, the evaluation team estimates the overall program spillover to be 9 percent of program-reported savings. Participants reported a variety of spillover measures installed, including AC units, additional lighting, and appliances.

5.3.4 Net-to-Gross Ratio

As stated above, the NTG ratio is defined as follows in Equation 2 below.

Equation 2. Net-to-Gross Ratio

NTG = 1 – free ridership + spillover

Using the overall free ridership value of 6 percent and the overall spillover value of 9 percent, the NTG ratio is 1 – 0.06 + 0.09 = 1.03. The estimated NTG ratio of 1.03 implies that for every 100 megawatt-hours (MWh) of realized savings recorded in SBES records, 103 MWh is attributable to the program.

Table 5-3. SBES Free Ridership, Spillover, and NTG Ratio

	Free Ridership	Spillover	NTG Ratio
SBES Program Total	0.06	0.09	1.03

Source: Navigant analysis

6. SUMMARY FORM

Program Name

Completed EMV Fact Sheet

Description of program

Duke Energy's Small Business Energy Saver Program provides energy efficient equipment to eligible small business customer at up to an 80 percent discount. The program is delivered through an implementation contractor that coordinates all aspects of the program, from the initial audit, ordering equipment, coordinating installation, and invoicing.

The program consists of lighting and refrigeration measures.

- **Lighting measures:** LED lamps and fixtures, T8 fluorescent fixtures, occupancy sensors.
- **Refrigeration measures:** LED case lighting, EC motor upgrades, compressor and fan motor controls.

Date	July 15, 2016
Region(s)	Duke Energy Progress; Duke Energy Carolinas
Evaluation Period	DEP 1/1/15 – 2/29/16 DEC 8/1/14 – 2/29/16
Annual kWh Savings	DEP 55,947,456 kWh DEC 89,505,687 kWh
Per Participant kWh Savings	DEP 27,247 DEC 25,087
Coincident kW Impact	DEP 11,650 DEC 20,603
Net-to-Gross Ratio	1.03
Process Evaluation	Annual
Previous Evaluation(s)	2013 and 2014 (DEP)

Evaluation Methodology

The evaluation team used engineering analysis, onsite field inspections, and time-of-use metering as the primary basis for estimating program impacts. Additionally, telephone surveys were conducted with participants to assess customer satisfaction and determine a net-to-gross ratio. Interviews were conducted with program and implementation team staff to understand program operational changes and enhancements.

Impact Evaluation Details

- **Onsite visits were conducted at 57 participant sites, while 19 of those sites were logged.** The evaluation team inspected program equipment to assess measure quantities and characteristics to compare with the program tracking database, and installed lighting loggers to verify hours of use and coincidence factors.
- **In-Service rates (ISRs) varied by equipment type.** The evaluation team found ISRs ranging from 0.93 for LED screw-in lamps to 1.02 for exterior LED fixtures.
- **Participants achieved an average of 27,247 kWh of energy savings per year in DEP, and 25,087 kWh in DEC.** The program is accurately characterizing energy and demand impacts.

7. PROCESS EVALUATION

The purpose of the process evaluation is to understand, document and provide feedback on the program implementation components and customer experience for the Small Business Energy Saver (SBES) Program in the DEP and DEC jurisdictions.

The feedback received indicates that **the SBES Program is a successful, mature program for PY2015, but could benefit from continuous improvements** as in previous years. Customer satisfaction with the implementer and contractor are very high, but there are instances where the installation contractor was responsible for a negative customer experience.

7.1 Process Methodology

The evaluation team conducted in-depth interviews with SBES Program staff, IC staff, and customer participant surveys, as noted previously. In addition, the team gathered information from interactions with participants during the site verification visits. The interviews with program and IC staff focused on program changes for PY2015 and included a review of program processes to provide the evaluation team with an understanding of the program's operations, nuances and qualitative and quantitative questions on customer satisfaction, participation, marketing, and outreach.

The process findings summarized in this document are based on the results of:

- Participant surveys with 151 program participants;
- Onsite visits at 57 program participant sites;
- Interviews with the Duke Energy Program Manager and the Implementation Contractor (IC) staff; and
- A review of the program documentation.

7.2 Sampling Plan and Achievements

The participant survey targeted a random sample of all PY2015 program participants broken out by measure family. The two measure families are lighting and refrigeration. Navigant weighed customer responses by their stratum savings for net-to-gross findings as described in the preceding section.

The survey effort targeted 150 participants and successfully completed surveys with 151 customers, of which 136 were participants that only installed lighting measures and 15 were participants that installed some refrigeration measures. The survey targets were loosely designed to achieve 90/10 confidence and precision, with significant oversampling due to the relatively inexpensive per-survey cost.

7.3 Program Review

The evaluation team designed the program review task to understand changes and updates to the program design, implementation and energy and demand savings assumptions. The key program characteristics include the following:

- **Program Design** – The SBES program is designed to offer high incentives (up to 80 percent of the total cost of the project) on efficient equipment to reduce energy use and peak demand. It specifically targets small business customers that are difficult to reach and often do not pursue energy efficiency on their own. In PY2015 the program rolled out new marketing materials centered around case studies for various types of small business customers.

- **Program Implementation** – A third-party contractor administers the SBES program on Duke Energy's behalf. The IC handles all aspects of the program, including customer recruitment, facility assessments, equipment installation (through independent installers contracted by the IC), and payment and incentive processing. The IC reports energy and peak demand reduction estimates to Duke Energy. The IC has continued to refine their processes to ensure that savings estimates are reasonable, customer complaints are handled in a timely manner.
- **Incentive Model** – The IC offers potential participants a recommended package of energy efficiency measures along with equipment pricing and installation costs. The incentive is proportional to estimated energy savings and can be as high as 80 percent of the total cost of the project.
- **Savings Estimates** – Energy and peak demand savings are estimated on a per-fixture basis, taking into account existing equipment, proposed equipment, and operational characteristics unique to each customer.

7.4 Key Process Findings

The following sections detail the process findings from all relevant sources of program information, including interviews with Duke Energy and IC staff, interactions with customers during verification site visits, and the results of the customer surveys, organized by topic. This discussion addresses 1) marketing and outreach; 2) customer experience; 3) implementation contractor; 4) installation contractor; 5) program incentives; 6) lighting equipment; and 7) participant suggested improvements.

The feedback received indicates that the SBES Program continues to be a successful program in PY2015, has expanded into the DEC jurisdiction effectively, and is a mature program in Duke Energy portfolio. The Duke Energy program management team and the IC staff and management have made several improvements to the program in PY2015, especially concerning installation contractor training, automated checks in the auditing tool, marketing, and new LED measures. Key findings are as follows:

- The primary channel through which customers hear about the program is Duke Energy (38 percent), followed by the implementation contractor (28 percent).
- Participants listed energy savings, reduced energy bills, and better quality equipment as the primary reasons for participating in the SBES Program.
- A majority of SBES participants were satisfied with the program. On a scale of 0 to 10, where 0 indicates "not satisfied at all" and 10 indicates "extremely satisfied":
    - 87 percent of participants indicated 8-10 for satisfaction with overall program experience.
    - 87 percent of participants indicated 8-10 for satisfaction with the contractor's quality of work.
    - 91 percent of participants indicated 8-10 for satisfaction with their new equipment.
- Eighty-nine percent of participants stated that equipment offered through the program allowed them to upgrade all of the equipment they wanted at the time.
- Eighty-seven percent of participants said they plan to participate in other Duke Energy programs in the future.

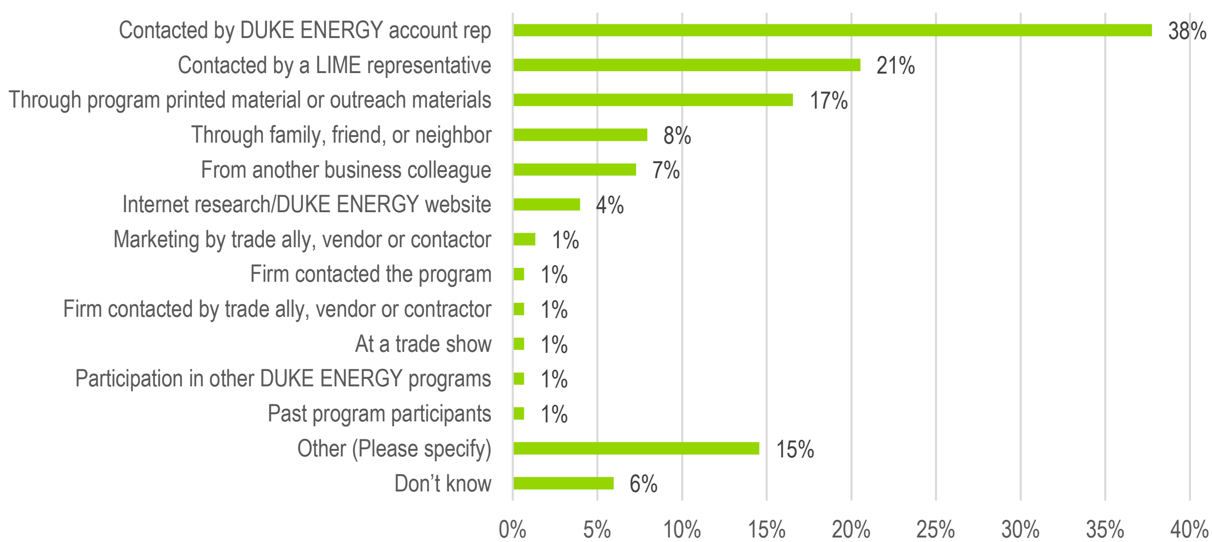
The following sections detail the process findings and addresses the following topics:

1. Marketing and outreach;
2. Customer experience;
3. Implementation contractor;
4. Installation contractor;
5. Measure incentives;
6. Upgraded equipment; and
7. Suggested improvements.

7.4.1 Marketing and Outreach

Duke Energy markets the program to eligible customers primarily through direct contact that Duke Energy and the IC initiate. Participants were asked to indicate all the sources through which they learned about the program. Over half of the participants indicated that they learned about the program directly from the IC staff (either through direct contact or outreach materials), and an additional quarter indicated they had learned about the program through Duke Energy themselves. Figure 7-1 shows the range of ways in which customers found out about the program. Significantly more customers reported that they learned about the program through Duke Energy directly (38 percent in PY2015 compared to 26 percent in PY2014)

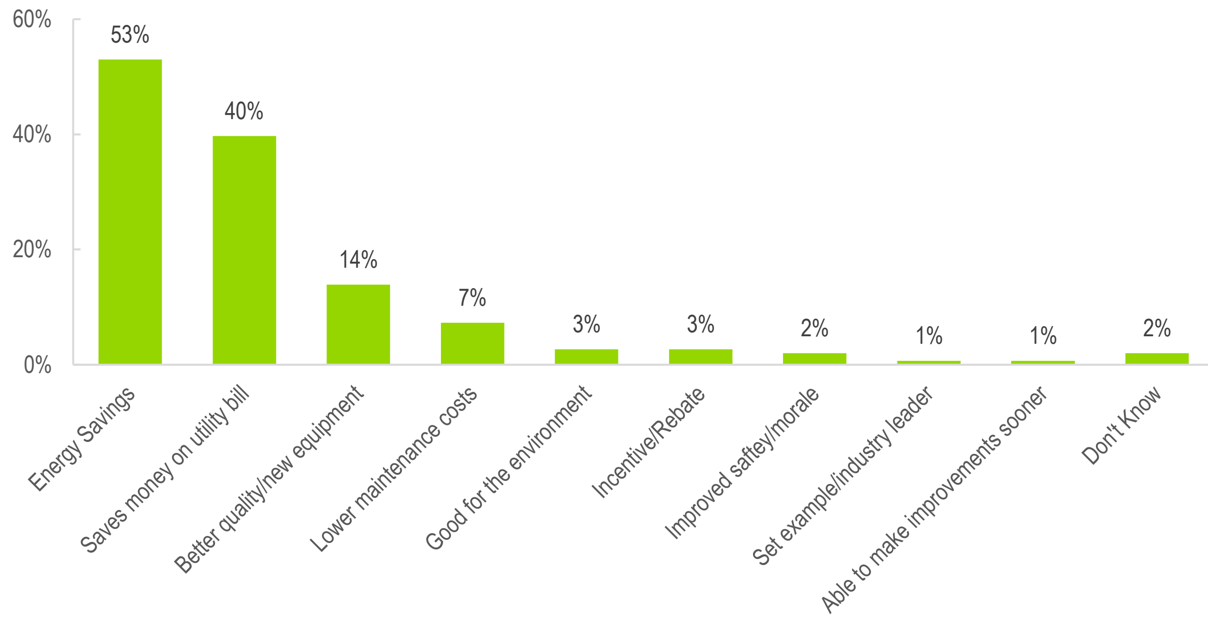
Figure 7-1. How Program Participants First Learned About the SBES Program (n = 151)



Source: Navigant analysis

When asked about the main benefits of participating in the program, over 50 percent of survey respondents cited energy savings as a reason they decided to participate in the program (see Figure 7-2 below). Beyond energy savings and, in turn, utility bill savings, participants cited higher-quality equipment, and the lower maintenance costs associated with new equipment as reasons to participate in the program. Coordinated efforts to market all of the benefits of program participation are key to enhancing participation across the variety of small business customer that Duke Energy serves.

Figure 7-2. Primary Reasons for Deciding to Participate in the Program[6] (n = 151)



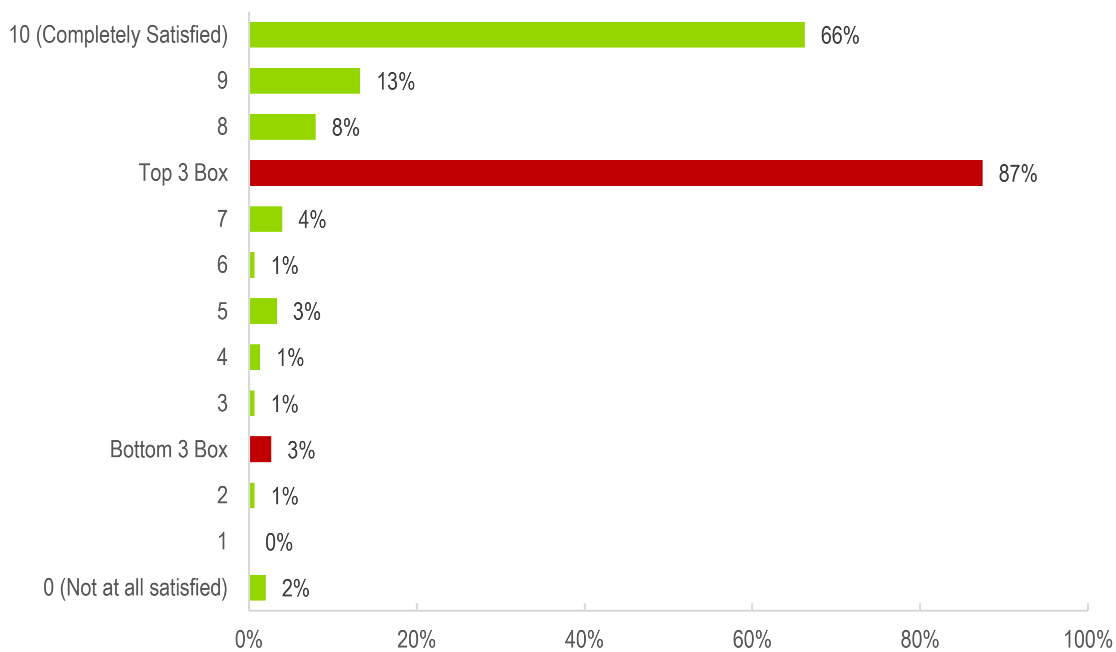
Source: Navigant analysis

[6]Totals exceed 100% because respondents could offer more than one answer.

7.4.2 Customer Experience

Customers reported very high satisfaction with their overall program experience in PY2015 through both the participant survey and informal polling conducted on-site during verification visits. On a scale of 0 to 10, where 0 is "not satisfied at all" and 10 is "extremely satisfied", 87 percent of participants scored their overall experience with the program as an 8, 9, or 10, with 66 percent responding that their experience was a 10 (see Figure 7-3). Participants who assigned low scores to their overall experience did so because typically they did not perceive monetary savings on their bill. One customer reported that they thought their new lights were already outdated, and another was not happy with the installation. Overall satisfaction remains similar to PY2014 levels.

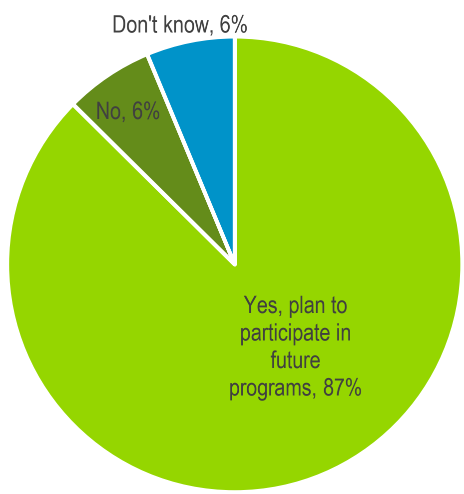
Figure 7-3: Customer Satisfaction with Overall Program (n=151)



Source: Navigant analysis

Eighty-seven percent of participants said they plan to participate in other Duke Energy programs in the future (see Figure 7-4), compared to 83 percent in PY2014. This indicates increased satisfaction as well, and a continued opportunity to market the program to previous participants as a wider range of measures become available and cost-effective.

Figure 7-4. Participants Who Plan to Participate in Other Duke Energy Programs in the Future (n = 151)



Source: Navigant analysis

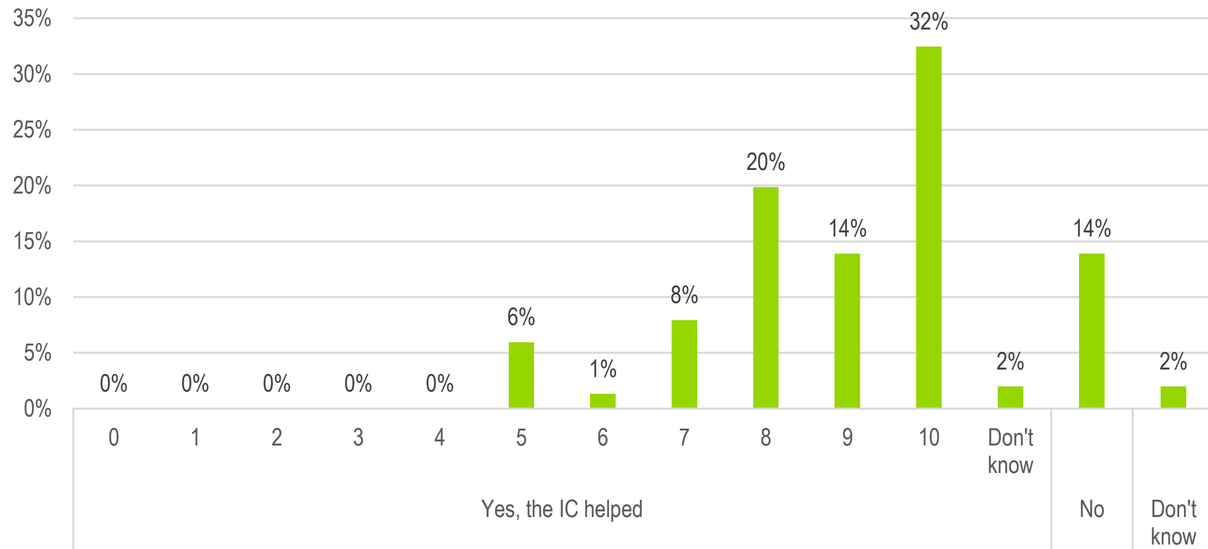
7.4.3 Implementation Contractor

Customer survey results indicate that the IC plays a critical role in all program processes in line with the program design, including program marketing, outreach, recruiting, auditing, billing and customer service, and providing detailed tracking data to Duke Energy.

Navigant found that the measure installation tracking data is thorough, accurate, and detailed. This enabled the field verification team to locate specific measure installations quickly. The IC conducted consistent and thorough audits for most completed projects and generally covered all of the lighting fixtures in a facility that were not already energy efficient. The auditor’s intentions were clear in the tracking data and demonstrated an understanding of the lighting that would best serve the customer’s needs while providing substantial energy savings. Navigant found some discrepancies between the final work as recorded by the implementation contractor in the database and what was found onsite (such as some fixtures that were not retrofitted), but overall the accuracy was found to be very high.

The IC helped 81 percent of SBES Program participants with their choice of lighting, and 66 percent stated that a recommendation from the IC was important (score of 8-10) in their decision to install the energy-efficient equipment (see Figure 7-5). Results are similar to PY2014.

Figure 7-5. Participants Whom the IC Helped in Their Equipment Decision (n = 151)

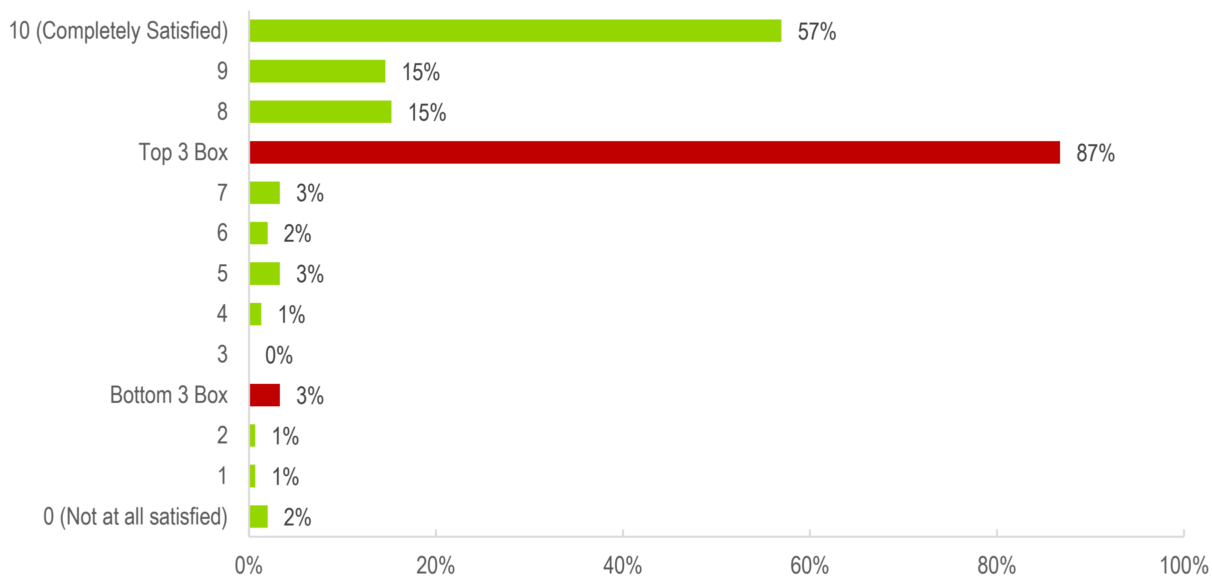


Source: Navigant analysis

7.4.4 Installation Contractors

Customer satisfaction with contractor quality of work is high, and has improved slightly from PY2014 as well. Figure 7-6 shows that 87 percent of survey respondents ranked their satisfaction with contractor work as an 8, 9, or 10, compared to 84 percent in PY2014.

Figure 7-6: Customer Satisfaction with Contractor Quality of Work (n=151)



Source: Navigant analysis

A few customers indicated that they experienced installation issues that required follow-up visits, or that work took longer than expected. Other participants were impressed by the speed the installation contractors were able to get the work done. This indicates that the customer experience varies between installation contractors, but overwhelmingly participants are satisfied with this portion of the program.

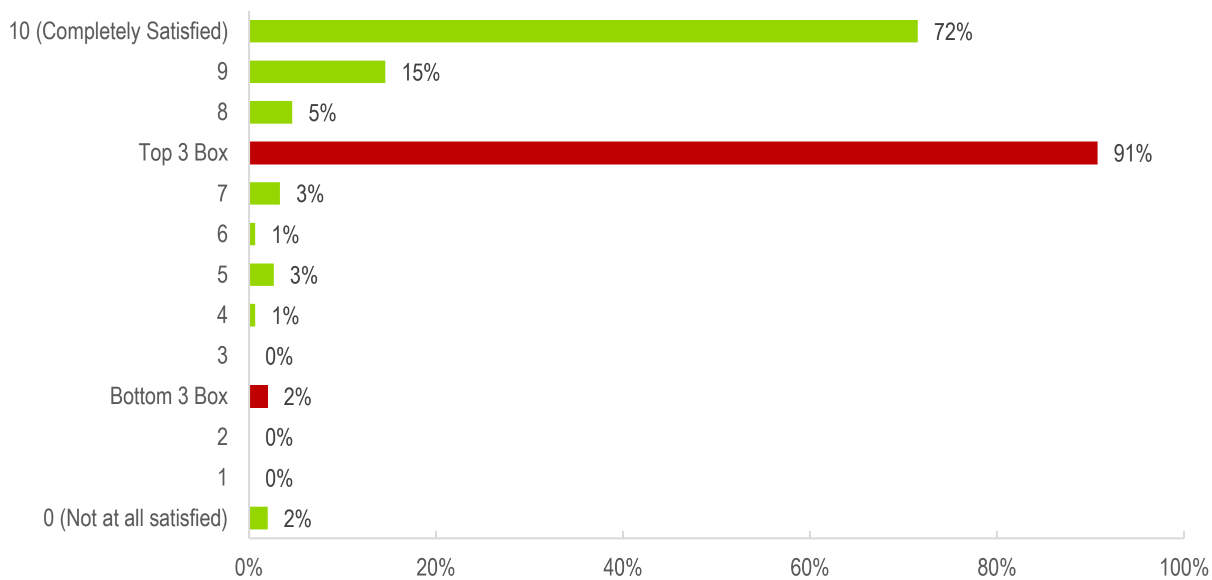
7.4.5 Measure Incentives

The incentives offered through the SBES program appear to sufficiently motivate customers to upgrade to energy-efficient lighting and refrigeration. From discussions with decision makers on site, the incentive levels were appropriate. Several customers also expressed interest in efficient HVAC equipment, but this was not available to them at the time.

7.4.6 Upgraded Equipment

The majority of customers agreed that the new lighting measures were a significant improvement in light quality, and that the auditors were willing to work with customers to make sure that the new lighting fit their needs. Almost all participants (91 percent) indicated they were satisfied with their new equipment (see Figure 7-7), similar to previous findings. A higher percentage of customer reported a top satisfaction score of 10 in PY2015 at 72 percent, compared to 67 percent in PY2014.

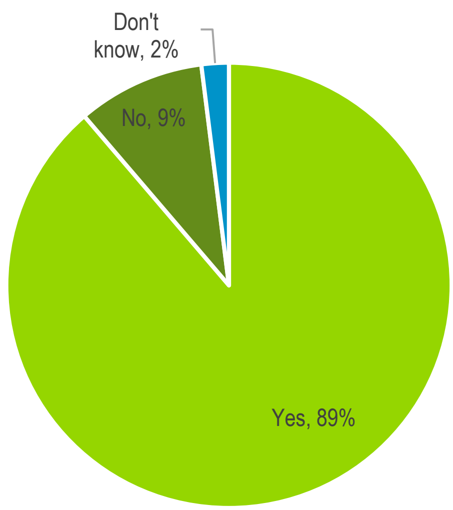
Figure 7-7: Participant Satisfaction with New Equipment (n=151)



Source: Navigant analysis

Another important survey finding was that 89 percent of participants stated that equipment offered through the program allowed them to upgrade all of the lighting equipment they wanted at the time of the project, rather than piecing together the upgrades in multiple phases (see Figure 7-8). This is an increase from 82 percent in PY2014, which indicates that auditors are getting better at capturing all possible measures at a site, or also that as LED prices have come down and savings have increased more lighting measures have become cost-effective.

Figure 7-8. Participants Who Stated that Equipment Offered Through the Program Allowed Them to Upgrade All of the Equipment They Wanted at the Time (n = 151)



Source: Navigant analysis

7.4.7 Suggested Improvements

Some customers reported difficulties they faced and provided suggested improvements in the survey's open-ended questions. The list below summarizes a few key points; responses that are more detailed will appear in the final SBES evaluation report.

Summary of Improvements Mentioned by Customers

- Higher incentives on eligible equipment;
- More equipment offerings, such as AC and motors;
- Greater publicity for the program and other Duke Energy offerings;
- More up-to-date equipment;
- Opportunity for savings for new construction

8. CONCLUSIONS AND RECOMMENDATIONS

The evaluation team performed extensive on-site work, telephone surveys, and analysis to determine gross and net verified savings. Overall conclusions and recommendations appear in the following sections.

8.1 Conclusions

Overall, the SBES Program is a well performing, mature program in the DEP jurisdiction that has successfully expanded into the DEC jurisdiction. The key to continued success is working through quality and training issues as they arise.

- **Participants continue to be overwhelmingly satisfied with the SBES Program and Duke Energy**, including overall service, pricing, installation, and efficient equipment quality.
- **Duke Energy has successfully expanded into the DEC jurisdiction** in PY2015. The program had no apparent issues scaling up operations in the DEC service territory, and there are no meaningful differences in the EM&V team's findings between the two jurisdictions.
- **The program has increased average project savings substantially** compared to PY2014. This is driven by new LED measures that have higher per-unit savings, and targeting of larger customers that are able to generate more savings per site.
- The Duke Energy program management team and the IC have **demonstrated a commitment to quality** by quickly implementing program changes based on evaluation feedback provided in the PY2014 evaluation. Additionally, the IC team has created new branded marketing materials with case studies for a variety of small business facilities.
- The **installation of high–efficiency equipment continues to be the key selling point**. The SBES Program successfully added linear LED retrofit measures to the suite of program offerings for PY2015, replacing T8 fluorescent fixtures. LED measures have grown considerably as a share of total program savings, while refrigeration has remained stable from PY2014 at under 10 percent.
- The **energy savings realization rate is 1.11 for DEP and 1.12 for DEC,** and is driven by several EM&V adjustments that roughly balanced out. The key adjustments the EM&V team made were the in-service rates and HVAC interactive effects. The **peak demand realization rate is lower at 0.96 for DEP and DEC** and is driven by HVAC interactive effects and coincidence factors.
- The evaluation effort estimated **free ridership for the SBES Program at 6 percent and spillover at 9 percent**, which drives an **NTG ratio of 1.03**. This indicates that the SBES Program is successfully reaching customers that would have not completed energy efficiency upgrades in the absence of the program. Spillover has increased from PY2014 and indicates that the program is showcasing the benefits of energy efficiency.

8.2 Recommendations

The evaluation team recommends five actions for improving the SBES Program, based on insights gained through the comprehensive evaluation effort for PY2015. These recommendations provide Duke

Energy with a roadmap to fine-tune the SBES Program for continued success and include the following broad objectives:

Increasing Program Participation

1. **Continue to emphasize non-energy benefits** of program participation, such as increased lighting quality, comfort for both business employees and customers, environmental benefits, and reduced maintenance. Now that the program has transitioned primarily to LED measures, increased education on the benefits that LED measures offer should enhance participation.

Increasing Customer Satisfaction

2. **Continue to prioritize customer satisfaction through installation contractor training and customer follow-up services.** The IC has improved in this area from PY2014, but a minority of customers are still reporting issues with installation and communication. Additionally, some customers are not perceiving savings on their electric bill, so managing this expectation would enhance customer satisfaction.
3. **Phase out fluorescent T8 lighting systems.** Linear LED lighting offers substantial savings above high-performance/reduced wattage T8 lamps and ballasts, which may be perceived as outdated.

Improving Accuracy of Reported Savings

4. **Add HVAC interactive effects and update coincidence factors for lighting measures**. This is the key impact finding to improve the accuracy of savings estimates. The IC should apply relevant HVAC interactive effects and coincidence factors to lighting measures as is appropriate, and ensure that outdoor lighting measures on daylight sensors do not accrue peak demand reductions during summer daylight hours.
5. **Ensure that efficient lighting power ratings for linear LED systems are accurate.** Navigant did not perform live metering of connected linear LED systems, but upon review of manufacturer specifications for lighting power there are different wattages that the system may draw depending on the specific configuration. As the share of savings attributed to linear LED systems grow, this should be quantified to reduce EM&V risk in future years.