Methodology

Overview of the Evaluation Approach

Participant Surveys
TecMarket Works developed a customer survey for the Power Manager Program participants, which was implemented in October and November of 2014 after participants experienced control events during the summer of 2014.

The complete survey was conducted with a random sample of 80 Power Manager participants in Ohio. The responses from the 80 surveyed participants are included in the analysis for all questions which they were able to complete. These participants were surveyed by TecMarket Works. The survey can be found in *Appendix A: Participant Survey Instrument*.

Event and Non-Event Surveys
TecMarket Works normally conducts surveys throughout the cooling season to measure the effect of Power Manager activation events on program participants. However, during the 2014 cooling season there was a single, one-hour PJM test event in Ohio, and no regular activation events occurred. Therefore the results of Event and Non-Event surveys are not being reported this year, since the only activation event of the season was an atypical test event.

It is not possible to know how many activation events or high temperature non-event days will occur in a given territory until the cooling season has ended, since the conditions which trigger Event and Non-Event surveys are largely determined by the weather, and the weather cannot be accurately predicted more than a few days in advance. Seventy-four Non-Event surveys were conducted in Ohio throughout the summer of 2014, and 41 Event surveys were conducted following the one-hour PJM test event, so the approach and disposition for Event and Non-Event surveys are summarized in this section of the report, although the results of these surveys are not presented in this evaluation.

TecMarket Works conducts after-event phone surveys (Event surveys) to collect participant information for this evaluation. The survey was maintained in a "ready-to-launch" status until notified of a control event affecting switches used by Duke Energy. The surveys were launched as soon as possible following the end of the control event (at 5 p.m. Eastern) and continued over a 27-hour period with all call attempts made during regular surveying hours (10:00 a.m. to 8:00 p.m. Eastern Daylight Time, Monday through Saturday). For example, if a control event occurred on a Monday, calling hours for that particular event were:

- Monday 5 p.m.-8 p.m. Eastern
- Tuesday 10 a.m.-8 p.m. Eastern

Event surveys followed the PJM test event which occurred on August 26, 2014; TecMarket Works surveyed a total of 41 participants in Ohio.

Before we asked the participants about the event, we inquired if they knew that there was a control event within the last two days so that we could understand if they are able to identify when a control event had occurred. The surveyor then notified the customer that they had just had a control event which had begun at <*start hour of control*> and ended at <*end hour of control*>. This allowed the participants to immediately recall the time period of the event and be able to respond to questions regarding the impact of that event on their use of their air conditioner and allow recollection of other actions taken, as well as the impact of the event on their comfort. Once informed of the event that had just occurred, the survey also assessed satisfaction with the program at the point of an event.

TecMarket Works also called Power Manager participants on hot days without control events to conduct the same survey (with slight wording alterations). This survey was conducted on non-event days when the outdoor high temperature was 90°F or more at Cincinnati's major regional airport located in Covington, Kentucky. On and following the high temperature dates of June 17, June 18, July 22, August 27 and September 5, 2014, TecMarket Works surveyed at total of 74 Power Manager participants in Ohio.

The schedule of Power Manager event days and non-event high temperature days used for this survey in Ohio is shown in Table 1, along with the daily high temperatures recorded at the Cincinnati/Covington airport.[2]

Table 1. Schedule of Event and Non-Event High Temperature Days in Ohio

Event ID	State	Type	Event Date	Event Hours	Date of Survey	High temp CVG
OH-nonevent1	OH	Non-Event	17-Jun-14	NA	17-Jun-14	89
OH-nonevent1	OH	Non-Event	17-Jun-14	NA	18-Jun-14	
OH-nonevent2	OH	Non-Event	18-Jun-14	NA	18-Jun-14	89
OH-nonevent2	OH	Non-Event	18-Jun-14	NA	19-Jun-14	
OH-nonevent3	OH	Non-Event	22-Jul-14	NA	22-Jul-14	91
OH-nonevent3	OH	Non-Event	22-Jul-14	NA	23-Jul-14	
OH-event1	OH	PJM Test Event	26-Aug-14	4:00 to 5 p.m.	26-Aug-14	90
OH-event1	OH	PJM Test Event	26-Aug-14	4:00 to 5 p.m.	27-Aug-14	
OH-nonevent4	OH	Non-Event	27-Aug-14	NA	28-Aug-14	92
OH-nonevent5	OH	Non-Event	5-Sep-14	NA	5-Sep-14	89

[2] High temperatures inTable 1 are taken from historical data at wunderground.com.

Data Collection Methods, Sample Sizes, and Sampling Methodology

Participant Surveys

From the list of customers, 578 participants were called between October 24 and November 12, 2014, and a total of 80 usable telephone surveys were completed yielding a response rate of 13.8% (80 out of 578).

Event and Non-Event Surveys

From the list of customers, 1,099 participants were called between June 17 and September 5, 2014, and a total of 115 usable telephone surveys (41 Events and 74 Non-Events) were completed yielding a response rate of 10.5% (115 out of 1,099). [3]

Expected and achieved precision

Participant Surveys

The survey sample methodology for the full participant survey had an expected precision of 90% +/- 9.1% and an achieved precision of 90% +/- 9.1%.

Event and Non-Event Surveys

No results from these surveys are presented in this evaluation, due to a lack of regular activation events in Ohio during 2014. See *Overview of the Evaluation Approach* on page 7.

Number of completes and sample disposition for each data collection effort

Participant Surveys

The participant survey was conducted using a random sample of 4,992 Power Manager participants in Ohio; there were 80 customers willing to participate in the survey.

Event Surveys

The Event surveys were conducted on and following a Power Manager device activation event that occurred on August 26, 2014 (this activation was a PJM test event). TecMarket Works surveyed a total of 41 Power Manager participants.

Non-Event Surveys

The Non-Event surveys were conducted on and following high temperature dates between June 17 and September 5, 2014. TecMarket Works surveyed a total of 74 Power Manager participants.

Threats to validity, sources of bias and how those were addressed

There is a potential for social desirability bias[4] but the customer has no vested interest in their reported program participation, so this bias is expected to be minimal.

[3] Due to the sampling design of this survey, reporting the number of calls and response rate separately for Event and Non-Event groups would not be accurate. Event and Non-Event survey calls are made using the same participant list, and in some cases calls to the same participants may be attempted for both Event and Non-Event surveys. The only difference between Event and Non-Event participants is whether they are surveyed after an activation event or a high-temperature day without an activation event.

Evaluation Dates

Evaluation Component	Dates of Surveys
Participant Surveys	10/24/14 – 11/12/14
Event and Non-Event Surveys	6/17/14 – 9/5/14

[4] Social desirability bias occurs when a respondent gives a false answer due to perceived social pressure to "do the right thing."

Participant Survey Results

TecMarket Works successfully surveyed 80 randomly selected program participants in Ohio. This section presents the results from these surveys. The instrument can be found in *Appendix A: Participant Survey Instrument*.

The results from the completed phone survey are discussed below. Participant demographics and other descriptive information can be found in *Appendix B: Participant Survey Customer Descriptive Data*.

Program Awareness

A large majority (91.3%) of survey participants reported that they were involved with the decision to participate in the Power Manager Program, as shown in Table 2. Only 3.8% of respondents said they were not involved, and the same percentage indicated that the Power Manager device had been installed by a previous occupant prior to the time they moved in.

Table 2. Were You Involved in the Decision to Participate in Duke Energy's Power Manager Program?

Were you involved in the decision to participate in Duke Energy's Power Manager Program?	**Count**	**Percent (N=80)**
Yes	73	91.3%
No	3	3.8%
It was already installed when I moved in.	3	3.8%
Don’t know	1	1.3%

Four-fifths (80.8%) of customers who participated in their household’s decision to sign up for Power Manager were able to recall how they first heard about the program. Two-thirds of these respondents (68.5%) said that they first learned about the program through mail they received from Duke Energy, while telemarketing calls from Duke Energy were the second-most common method of learning about the program (12.3%). The full range of responses is shown in Table 3 below.

Table 3. How Participants First Learned of the Power Manager Program

What are some of the ways you heard about the Power Manager Program?	**Count**	**Percent (N=73)**
Mail from Duke Energy	50	68.5%
Telemarketing call from Duke Energy	9	12.3%
TV, radio, newspaper	2	2.7%
Duke Energy website	1	1.4%
Internet research	1	1.4%
Don't recall	14	19.2%

Note: Multiple responses were allowed per participant.

Program Enrollment

Reasons for Joining the Program

Participants who were involved in the decision to participate in the program were asked to name the reasons they joined the Power Manager program. Respondents were asked to state their "main reason" and also to name any secondary reasons. By far the most popular reason for joining the program was to save money with a combined total of 63.0% of respondents giving this as a primary or secondary reason. Helping to avoid power outages was the second-most frequently mentioned reason (24.7%), while bill credits and helping the environment are tied as the third-most frequent response (17.8%), as shown in Figure 1. These results differ somewhat from the 2013 survey; in last year's survey, saving money (39.1%) and saving energy (34.8%) ranked first and second, while bill credits and helping to avoid outages (26.1%) were tied for the third-most mentioned reasons; the most dramatic change is far more participants mentioning in 2014 that they joined the program to save money (p<.05 using Student's t-test).

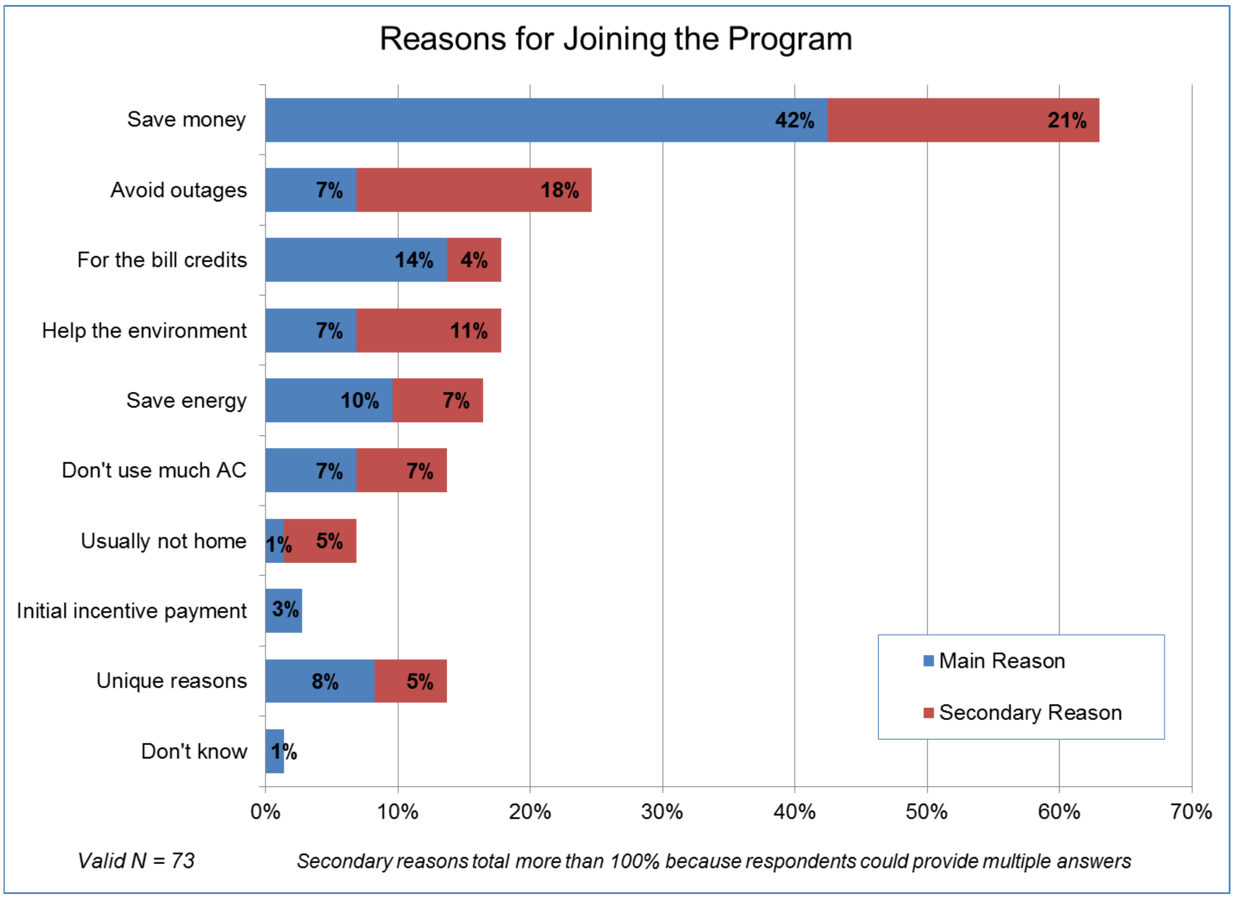

Figure 1. Reasons for Joining the Program

About one participant in six (17.8%) mentioned "helping the environment" as a motive for participating in the program. When asked to explain what they mean by "helping the environment," most of these respondents mentioned conserving energy (six respondents) or reducing emissions (four respondents). Customers who reported unique reasons for participation cited civic responsibility, anticipating little effect on comfort and family testimonials about the program.

Participant Understanding of the Program

During the time of program enrollment Duke Energy provides new program participants with information about how the program works. When asked if they recalled this information, 71.2% of respondents remembered the explanatory information, while 17.8% could not recall it and 11.1% were unsure. Among customers who recalled this information about how the program works, satisfaction with the explanatory information is high with an average rating of 8.80 on a 10-point scale with "1" being not at all satisfied and "10" being very satisfied. A majority (57.7%) of respondents rated their satisfaction a "9" or "10", compared to just 9.6% giving ratings of "7" or lower (Figure 2). When participants who gave ratings of "7" or lower were asked to explain what could be done to improve this situation, three out of four respondents wanted an annual reminder about how the program works and the fourth wanted a phone call from a Duke Energy representative.

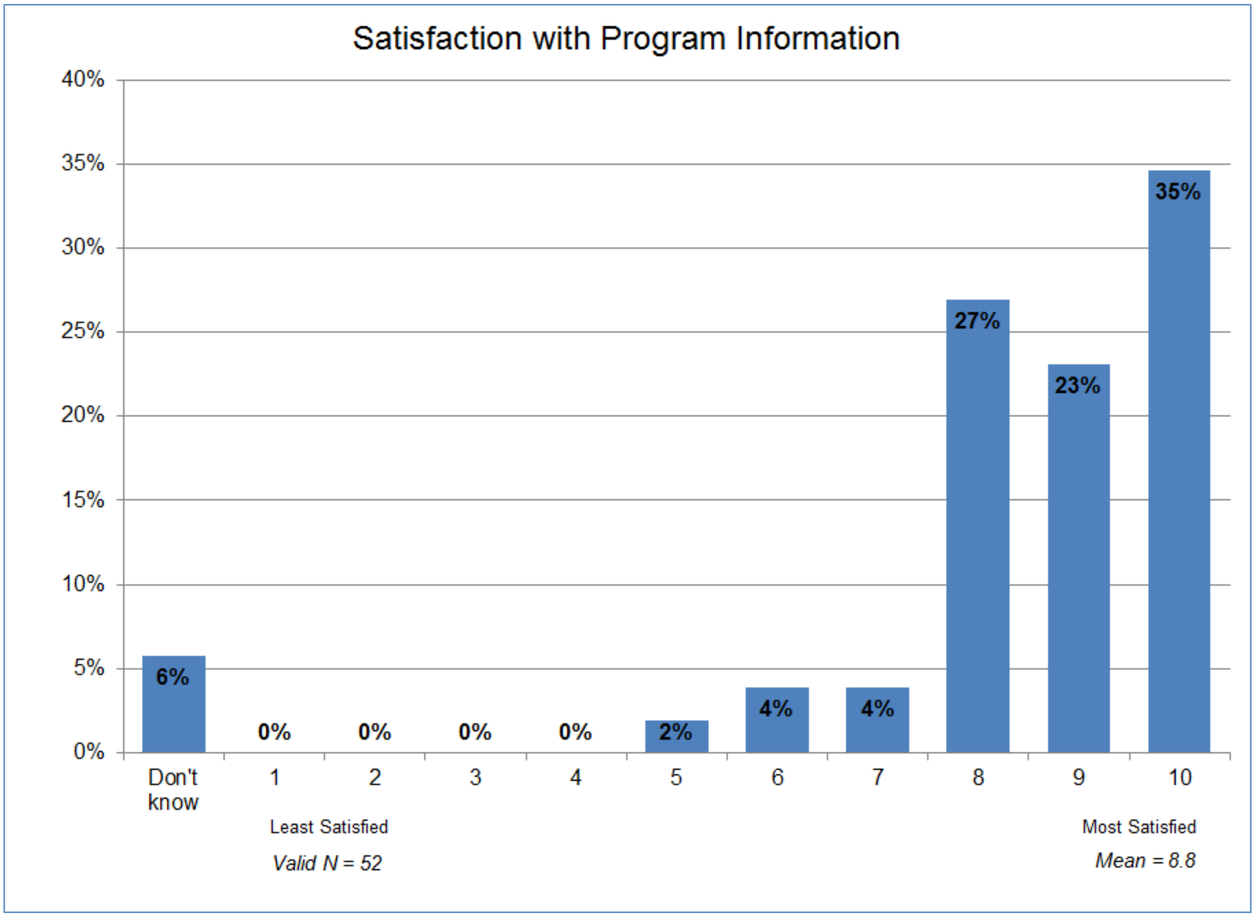

Figure 2. Satisfaction with Program Explanation among Carolina System Customers

Satisfaction with the Enrollment Process

An even higher percentage of Ohio participants indicated that they are satisfied with the program's enrollment process, returning a mean satisfaction rating of 9.43 on the same ten-point scale. In all, 83.6% rated their satisfaction with the enrollment process at “9” or “10”. Only one respondent gave a rating of “7” or lower, explaining: “*I was dissatisfied with the enrollment process because the program was not thoroughly explained. After I enrolled, Duke should have followed up with a phone call to answer questions and quell concerns.*” Figure 3 shows the distribution of satisfaction ratings.

Participants who receive their utility bills from third party companies give the enrollment process a significantly higher mean satisfaction rating (9.58 based on 50 ratings) compared to participants whose utility bills come directly from Duke Energy (9.05 based on 19 ratings; significant at p<.10 using ANOVA).

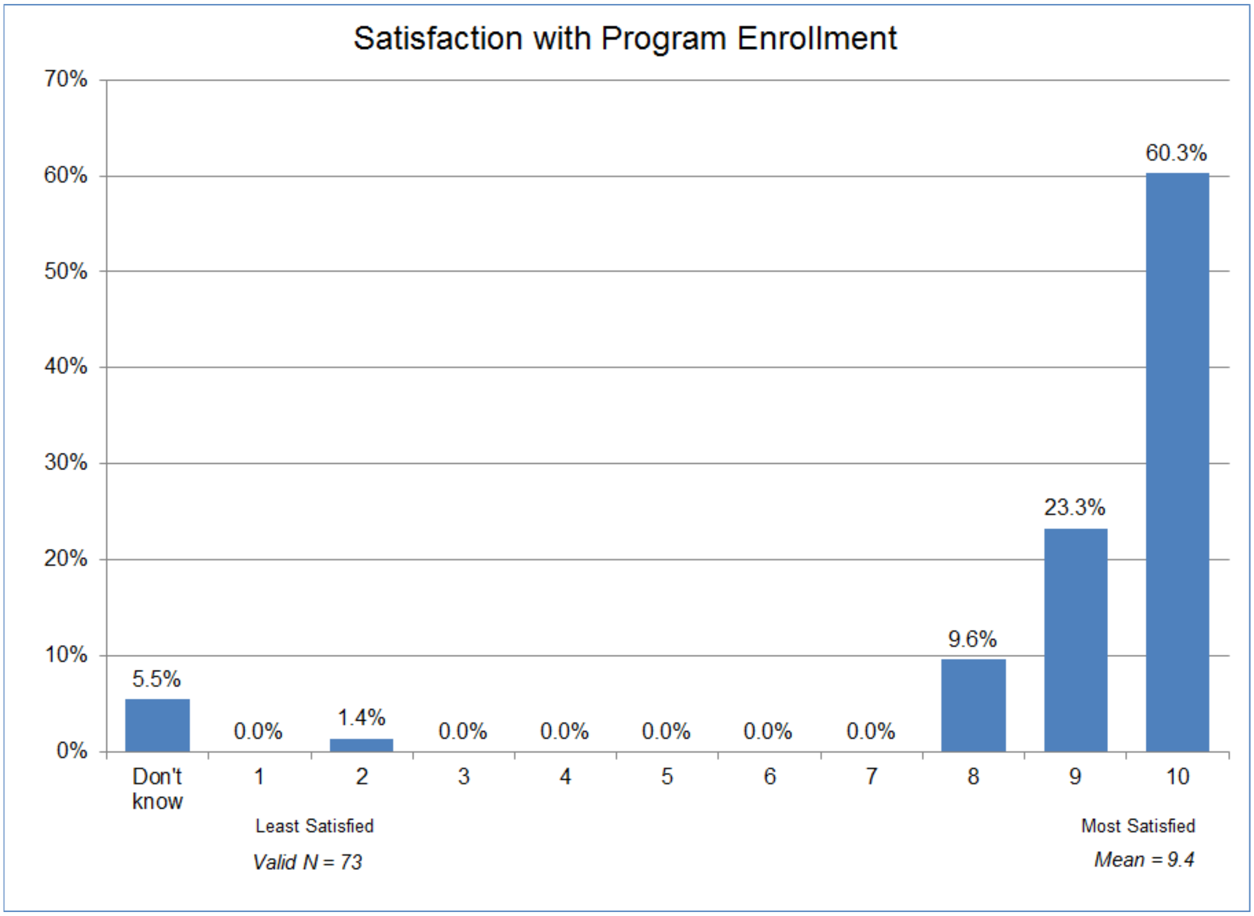

Figure 3. Satisfaction with Program Enrollment

Expectations of Monetary Incentives for Participation

When survey respondents were asked how many dollars they receive in bill credits per year for their participation in the Power Manager program, 67.5% could not provide an estimate, saying they didn’t know. Among the 32.5% who were able to estimate the amount of bill credits they receive, answers varied widely from a low of zero to a high of $1,000. The median estimated annual total for bill credits is $25, the mean is $67 and the mode is $50; the distribution of responses is shown in Table 4. During 2014, there was a single one-hour test event, so participants received the minimum annual bill credits of $5 or $8 depending on their enrollment option.[5]

Table 4. Expected Bill Credits for Participating in Power Manager

What's your best estimate of how many dollars you will receive in yearly bill credits for participating in the program?	**Count**	**Percent (N=80)**
None	2	2.5%
Less than $10	2	2.5%
$10 to $24.99	9	11.3%
$25 to $50	9	11.3%
More than $50	4	5.0%
Don't know	54	67.5%

When participants were asked if they had received any bill credits during 2014 for their participation in the Power Manager program, a significant percentage (48.8%) said that were not sure, and an additional (31.3%) reported that they did not receive any bill credits. In all, only 20.0% of Ohio participants are aware of receiving bill credits during 2014.[6] Customers who receive their utility bills directly from Duke Energy are slightly more likely to confirm that they have received credits in 2014 (28.6%) compared to customers who are billed by third parties (16.9%), though this difference is not statistically significant.

In a follow up question, the 16 participants who recall 2014 bill credits were asked how many times they noticed the bill credits this cooling season: Half (50.0%) reported seeing the credits "once" or "twice," while 37.5% recalled seeing credits at least three times or on "every bill this summer," which could be considered technically correct depending up the timing of their October billing cycle. The full range of times that program participants noticed their bill credits is shown in Table 5.

Table 5. Participant Awareness of Bill Credits Received

How many times have you noticed the Power Manager credits on your bill this summer?	**Count**	**Percent (N=16)**
Once	4	25.0%
Twice	4	25.0%
Three times	2	12.5%
Four or more times	1	6.3%
Every bill this summer	3	18.8%
Other	0	0.0%
Don't know	2	12.5%

[5] Ohio customers who choose the 1.0 kWh option are paid a $25 incentive on sign-up and receive a minimum annual bill credit of $5; customers who choose the 1.5 kWh option are paid $35 on sign-up and receive minimum annual credits of $8.

[6] These credits were reported on October and November billing statements, so some customers would not have seen their bill credits at the time of this survey (interviews concluded on November 12, 2014). Duke Energy confirmed that all surveyed participants have received the appropriate credits on their bills for activation events.

Expectations of Power Manager Events

Surveyed participants were asked how many times Duke Energy said it would activate the Power Manager device on their air conditioners in a summer; only 33.8% said they had specific expectations about the number of activation events to expect per cooling season, while the rest were not sure. Among the 27 participants who were able to answer this question, 85.2% correctly indicated that Power Manager is activated "as needed" based on the demand for electricity (Table 6).

Table 6. Participant Recall of How Often Duke Energy Said It Would Activate the Power Manager Device

How many times per year did Duke Energy tell you it would activate the Power Manager device on your air conditioner?	**Count**	**Percent (N=27)**
Activated as needed / when demand is high	23	85.2%
Once per month	2	7.4%
Once per week to once per month	1	3.7%
Once per day for 15 minutes when at peak load	1	3.7%

Understanding the Program and Getting More Information

When queried about their understanding of the program, a minority of survey respondents report that something about the program was unclear to them: Only 15.0% report having questions about how the program works, compared to 73.8% who feel that they have a good understanding of the program and 11.3% who are not sure.

When asked what it was that they were unclear about, some respondents explained that they had remaining questions about the number and timing of activation events and bill credits, but half of these respondents (50.0%) merely expressed a general lack of clarity about how the program works. Table 7 shows the type and frequency of participant questions about the program, while the list below provides verbatim examples to illustrate each category.

Table 7. Participant Understanding of How the Program Works

Topic or issue requiring clarification	**Count**	**Percent (N=12)**
How the program works overall	6	50.0%
Frequency and timing of activation events	3	25.0%
Bill credits	2	16.7%
Benefits of the program	1	8.3%

Note: Multiple responses were allowed per participant.

Examples of Participants' Questions about the Program

- *I am unaware of the specifics of the program; Duke Energy could provide more information to customers that inherit the device from the previous homeowners.*
- *I am unclear about pretty much everything regarding the program.*
- *I am unclear about the monthly bill credits.*
- *I am unclear about the number of times per year that Duke Energy activates the device and for how long of an interval it typically does so.*

- *I've forgotten a lot about the program, but when we signed up for it I felt like I knew enough about the program to go ahead and sign up.*

A follow-up question asked participants who are unclear about the program if they have contacted Duke Energy for further information. Only one customer said they had done so (8.3% of those with questions about the program), and they rated their satisfaction with the Duke Energy representative they spoke with at “10 out of 10,” the highest possible rating.

Awareness and Response to Activation

A sizeable majority of participants (71.3%) said they are unaware if their Power Manager device has been activated since they joined the program, compared to about a quarter (23.8%) who said they are aware of device activations and 5.0% who indicated they are unsure (Table 8). However there is a large difference between the awareness levels of “Duke Energy customers” (those who receive their bills directly from Duke Energy) and “Non-Duke Energy customers” (those who are billed by other companies): nearly a third of Non-Duke customers (30.5%) claim to be aware of events versus only 4.8% of Duke Energy customers (significantly different at $p<.05$ using Student’s t-test).

Table 8. Awareness of Power Manager Activation since Joining the Program

Are you aware of any times when Duke Energy may have activated your Power Manager device since you joined the program?	**Duke Energy Customers (N=21)**	**Non-Duke Energy Customers (N=59)**	**All Participants Surveyed (N=80)**
Yes	4.8%	30.5%	23.8%
No	90.5%	64.4%	71.3%
Don't Know	4.8%	5.1%	5.0%

When the 19 respondents who were aware that their Power Manager device had been activated were asked how they knew this to be the case, a majority (57.9%) cited rising home temperatures while another 31.6% are aware of activations when they notice that their air conditioner “shuts down” (cycles off), as shown in Figure 4. The participant who gave a unique response stated: “*The AC was making the weirdest fan noise ever; a buzzing mechanical noise*.”

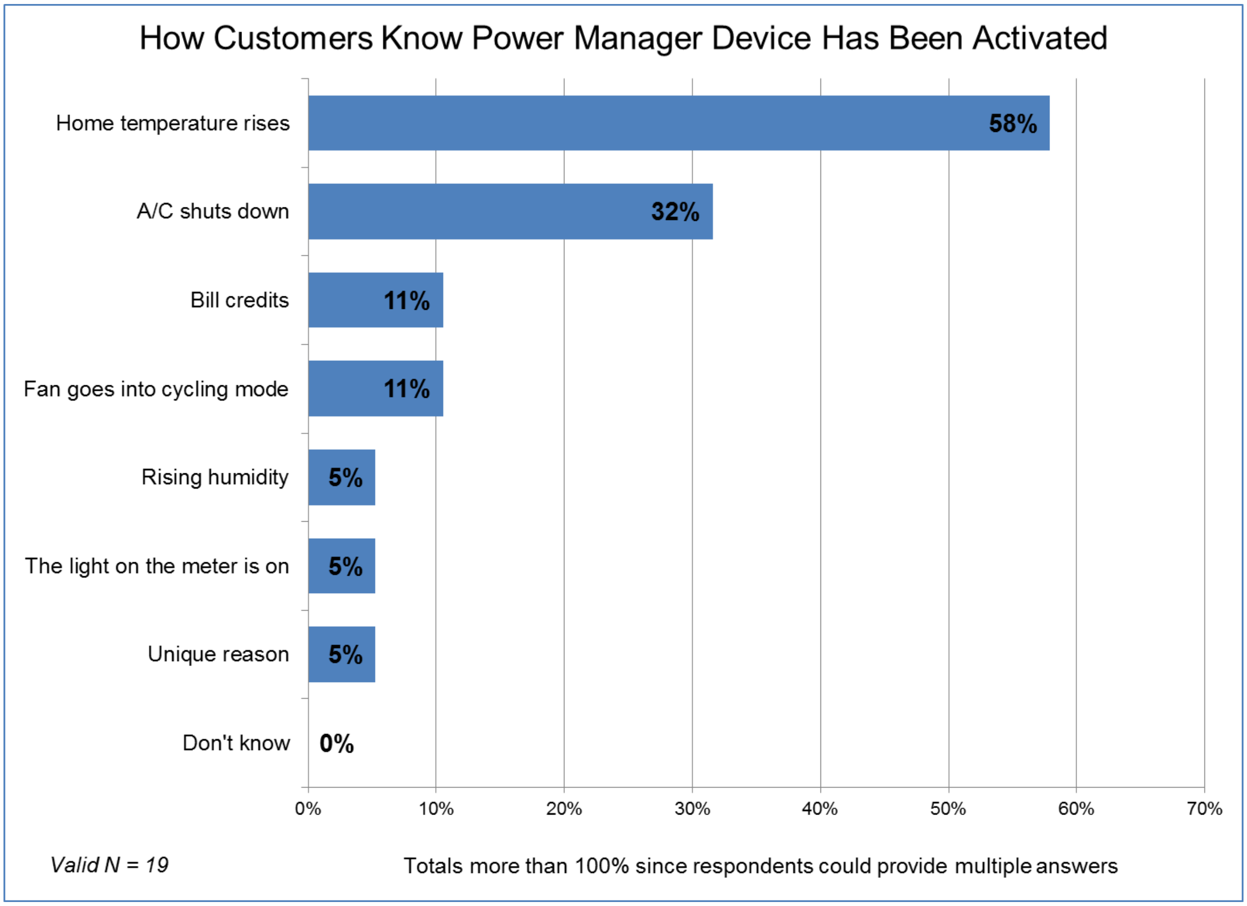

Figure 4. Customer Awareness of Device Activation

Survey participants were asked how many times they believe their Power Manager devices have been activated during 2014; nearly half (47.4%) said that they believe there had been no device activations this year, as shown in Table 9. Another third of participants (36.8%) said that they did not know how many events occurred. Among the three participants who reported a specific number of events for 2014, responses range from “twice” to “four to six times”; among the twelve participants able to estimate the number of events, the mean is less than one activation event and the median is zero events. Overall, these estimates are quite accurate for Ohio participants in 2014, when there was a single one-hour test event during the entire summer (see *Table 1. Schedule of Event and Non-Event High Temperature Days in* Ohio on page 8).

All three of the participants who reported being aware of 2014 activation events are Non-Duke Energy customers (their utility bills are sent by third party companies); the only Duke Energy customer who was aware of their device having been activated since they joined the program said that they “don’t know” if there were any events during 2014.

Table 9. Perceived Number of Power Manager Activations in 2014

During the summer of 2014, about how many times do you believe Duke Energy activated your Power Manager device?	Count	Percent (N=19)
Zero (no activations)	9	47.4%
Twice	2	10.5%
Four to six times	1	5.3%
Don't know	7	36.8%

All three of the participants who believe that there was at least one activation event during the 2014 season reported that they were at home during at least one of these events, and so were asked follow-up questions about their response to the perceived device activation. The sample size of three participants who reported being at home during 2014 activation events is too small to make any generalizations or statistical conclusions about this subgroup; the key finding is that overall only 3.8% of surveyed participants reported that they were home during activation events, while 96.3% either believed there were no events or were not sure if there were any events.

TecMarket Works asked the respondents who reported being at home during control events to think back to the event time and then to rate their comfort before and during the event using a 1-to-10 scale with "1" being very uncomfortable and "10" being very comfortable. Prior to the event, comfort ratings ranged from "5" to "10", with a mean of 7.0. During the event, comfort ratings dropped to a mean of 6.0, with declines ranging from 0 to 2 points on a ten-point scale (Table 10). The difference between "before" and "during" ratings is not statistically significant, in part due to a very small sample size.

Table 10. Comfort Ratings Before and During Control Events (All Respondents At Home During Event)

	Rating before event (N=3)	Rating during event (N=3)	Change
Mean	7.0	6.0	-1.0
Median	6.0	4.0	-2.0

Two out of three participants (66.7%) who recall being at home during a 2014 event reported a decline in comfort during the event, which means that in total only 2.5% of 80 Ohio participants surveyed reported a comfort decline during an event in 2014. When these two participants were asked what they believe caused their decline in comfort, one blamed rising temperatures (50%) and the other blamed Power Manager activation (50%). Thus in total, only 1.3% of 80 Ohio participants surveyed blame Power Manager for a decline in comfort during a 2014 activation event.

The three survey respondents who reported being home during at least one device activation event in 2014 were asked to estimate the number of times that they think Power Manager affected their comfort level. One of these participants reported that Power Manager affected their comfort "zero" times in 2014, while the other participants estimated that their comfort was affected "once" and "four times."

The two participants who reported a decline in comfort during a 2014 event were asked how long it took for their comfort level to return to normal after the activation event: One indicated it took less than one hour, while the other said it took three to four hours for their comfort level to return to normal.

The 19 surveyed participants who are aware that their devices have been activated since they joined the program were asked to estimate how many hours the Power Manager device typically controls their air conditioners; their estimates ranged from five minutes to five hours, with a mean estimate of 2.4 hours and a median estimate of 3.0 hours.[7] The distribution of responses is categorized in Figure 5.

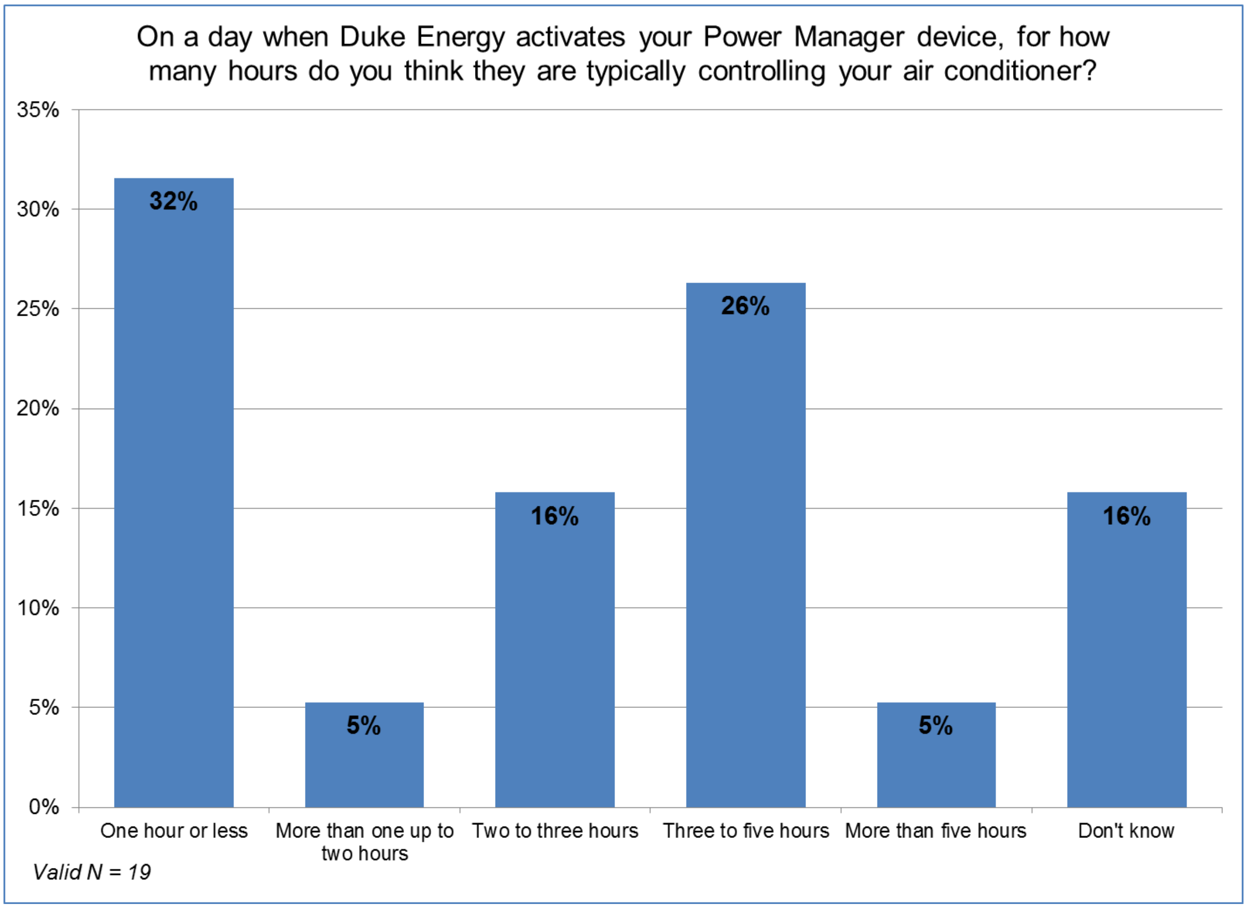

Figure 5. Perception of the Length of Power Manager Activations

The 19 participants who are aware that their devices have been activated since they joined the program were also asked what time of day they think the Power Manager device stops

[7] In Ohio during 2014 there was a single one-hour test event. However estimates in the 2.5 to 3.0 hour range are accurate for event times during summers when there are normal (non-test) activation events.

controlling their air conditioners after a typical activation event. As shown in Figure 6, a majority of program participants (52.6%) gave ending times of either 5:00 p.m. or 6:00 p.m., which aligns with typical event ending times. The range of perceived ending times spans from 4:00 p.m. to 9:00 p.m., and the median response is 6:00 p.m.

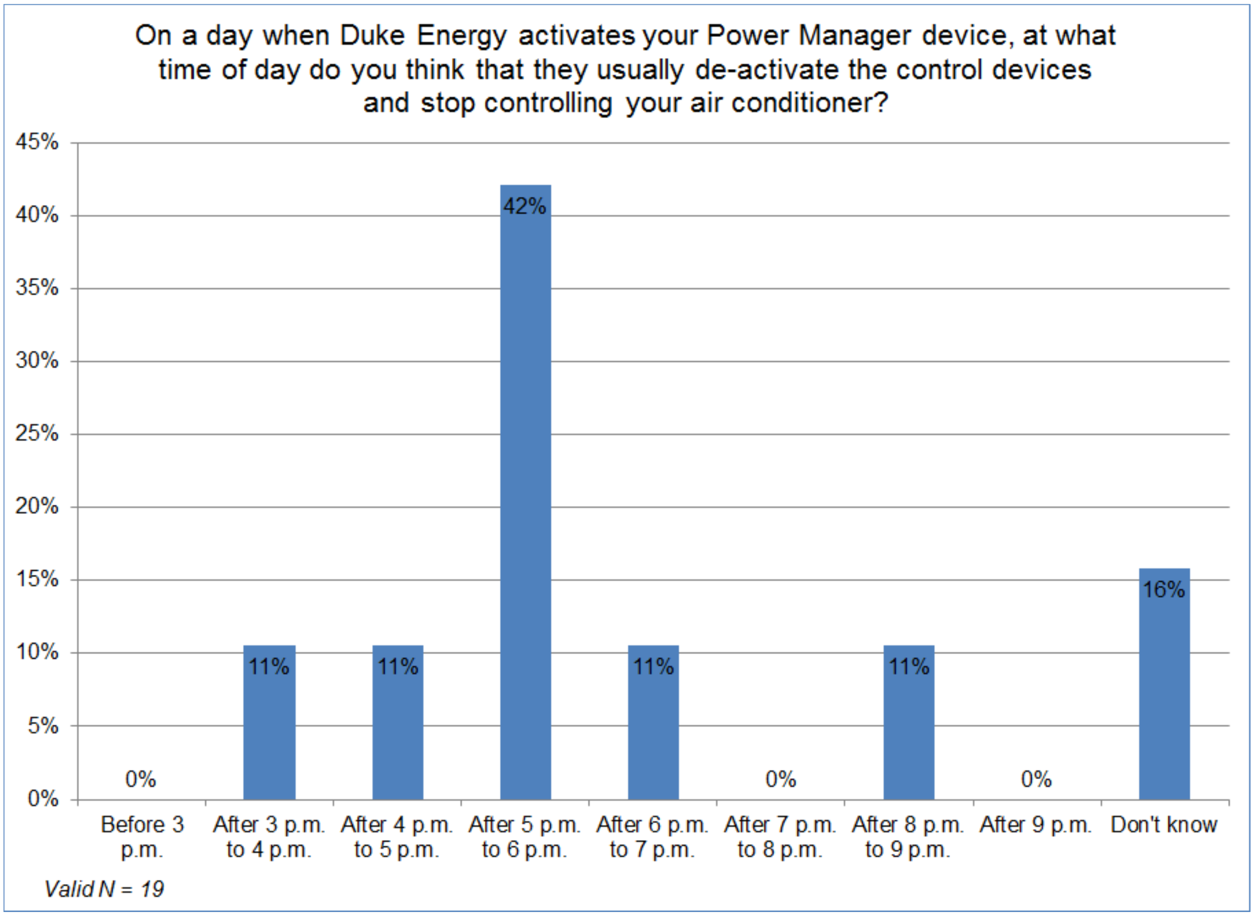

Figure 6. Perception of the Ending Times of Power Manager Activations

Only three surveyed participants reported being at home during a 2014 Power Manager event, so only these three customers were asked what, if any, actions they took in response to the high temperatures that day. One participant who reported a decline in comfort during the event reported that they adjusted their thermostat down from 84 to 79 degrees during the event and then took no further actions. The other participant who reported a decline in comfort turned on fans but did not adjust the thermostat, while the participant who was at home but whose comfort was not affected did not take any action at all (Table 11). Thus overall, only 1.3% of surveyed participants reported setting their thermostat lower during a 2014 activation event.

Table 11. Actions Taken During Power Manager Activation Events in 2014

Participants who were at home during a 2014 event	Count	Percent (N=3)
Adjusted thermostat settings	1	33.3%
Did not adjust thermostat settings	2	66.7%
Turned on fans	1	33.3%
Wore less clothing	0	0.0%
Opened windows	0	0.0%
Closed blinds / shades	0	0.0%
Turned on room / window AC	0	0.0%
Moved to a cooler part of the house	0	0.0%
Nothing else (continued normal activities)	2	66.7%

Note: Multiple responses were allowed per participant.

Air Conditioner Use and Maintenance

The Power Manager program in Ohio is successfully enrolling participants who routinely use their air conditioners throughout the cooling season and are therefore likely to be affected by Power Manager activation events. All participants surveyed use their air conditioning during the summer (0% use it “not at all”) and more than a third (36.3%) of program participants report using their air conditioners on a daily basis during the cooling season. Only 10.0% say that they reserve air conditioning for only the hottest days of the season (Figure 7).

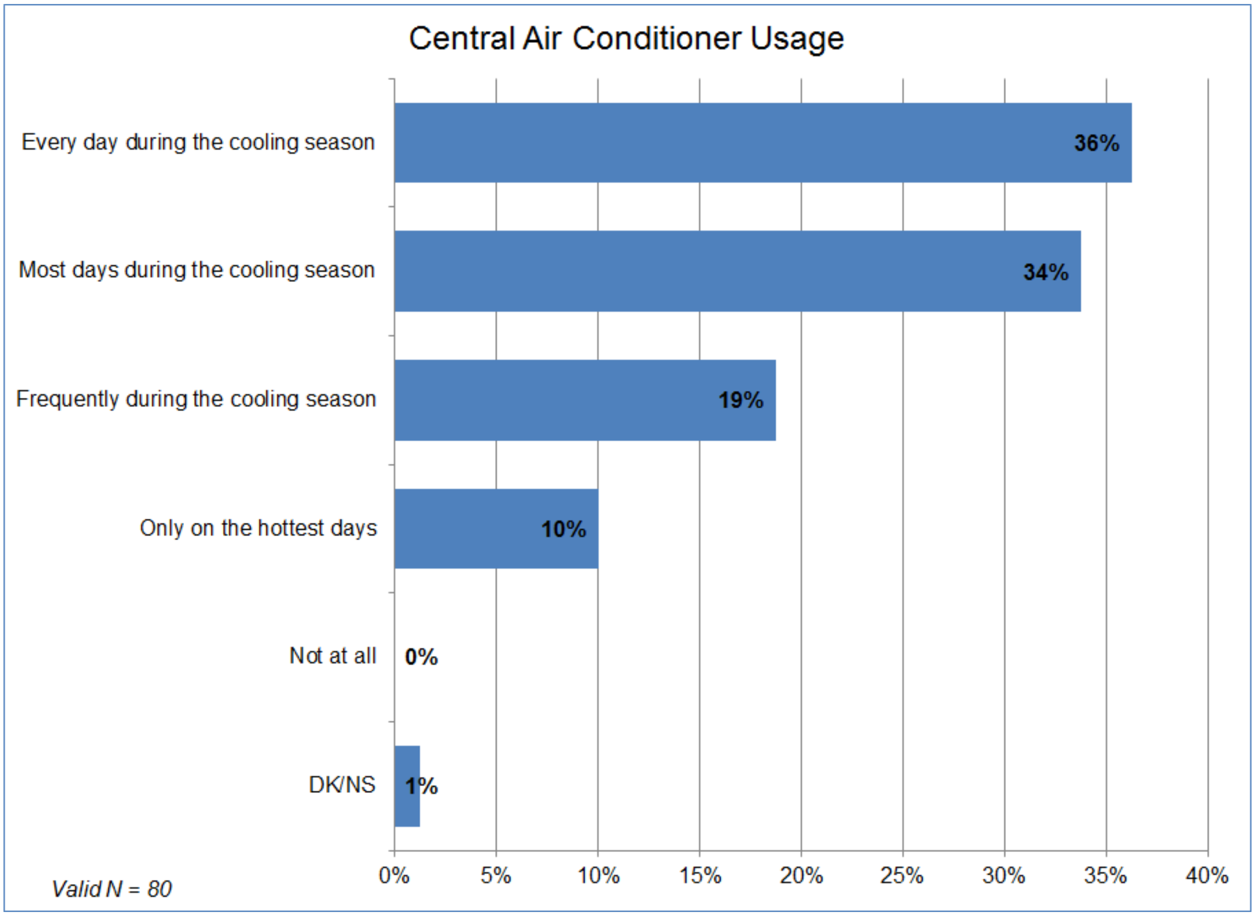

Figure 7. Frequency of Air Conditioner Use

More than two-thirds of participants surveyed (71.3%) report that they use their air conditioners to keep someone comfortable at home during weekday summer afternoons before 6:00 p.m., while virtually all participants (97.5%) use air conditioning to keep someone cool at home after 6:00 p.m.

Table 12. Typical Air Conditioner Usage on Summer Weekdays

Is the air conditioning typically used to keep someone at home comfortable during . . . ?	**Count**	**Percent** (N=80)
Weekday summer afternoons before 6 p.m.	57	71.3%
Summer weekdays after 6 p.m.	78	97.5%

As seen in Table 13, a majority of surveyed participants (70.0%) report having their air conditioners serviced since joining the Power Manager program.

Table 13. Air Conditioner Maintenance

Have you had your air conditioner tuned-up or serviced since you enrolled in the Power Manager program?	**Count**	**Percent** (N=80)
Yes	56	70.0%
No	23	28.8%
Don't know	1	1.3%

Among participants who have had their air conditioners serviced, a majority (51.8%) report that they do not know if their Power Manager device was disconnected during servicing (Table 14), which is not surprising since these services are likely to be performed by a hired professional. Among the minority of customers who know if their device was disconnected or not, more than twice as many respondents report that their device was not disconnected (33.9%) compared to those who report that their device was disconnected (14.3%).

Table 14. Power Manager Device Disconnected During Air Conditioner Maintenance

Was the Power Manager device disconnected while your air conditioner was being serviced?	**Count**	**Percent** (N=56)
Yes	8	14.3%
No	19	33.9%
Don't know	29	51.8%

Among the eight participants who report that their Power Manager devices were disconnected, five (62.5%) are confident that the devices were reconnected, while two customers (25.0%) said their devices were not reconnected, and one (12.5%) was not sure. Overall, this represents at least 3.6% of the participants who had their air conditioners serviced reporting that their devices were not reconnected afterwards (though this rate could be much higher due to half of these participants not knowing whether their devices had been disconnected or not). When the two customers whose devices remained disconnected were asked why their devices had not been reconnected, one participant was unsure while the other said: "*I had my air conditioning unit replaced this summer. The contractor disconnected the Power Manager device and instructed me to call Duke Energy to have the device reconnected. I simply neglected to call Duke to have the device reconnected.*"

Outside Temperatures and Thermostat Settings

Personal comfort levels are necessarily subjective, so Power Manager participants were asked to think of a hot, humid summer day and consider at what outside temperature they begin to feel uncomfortable. Their responses spanned a range from as low as 69° to 72° Fahrenheit up to 91° to 94° Fahrenheit. The median and modal temperature range of discomfort is 85° to 87°. Figure 8 also shows that 15.0% of participants report that they feel uncomfortable when the outdoor temperature is 78° or less, while a mere 3.8% don't begin to feel uncomfortable until the mercury climbs to 91° or higher and all surveyed participants become uncomfortable before the outdoor temperature reaches 95°.

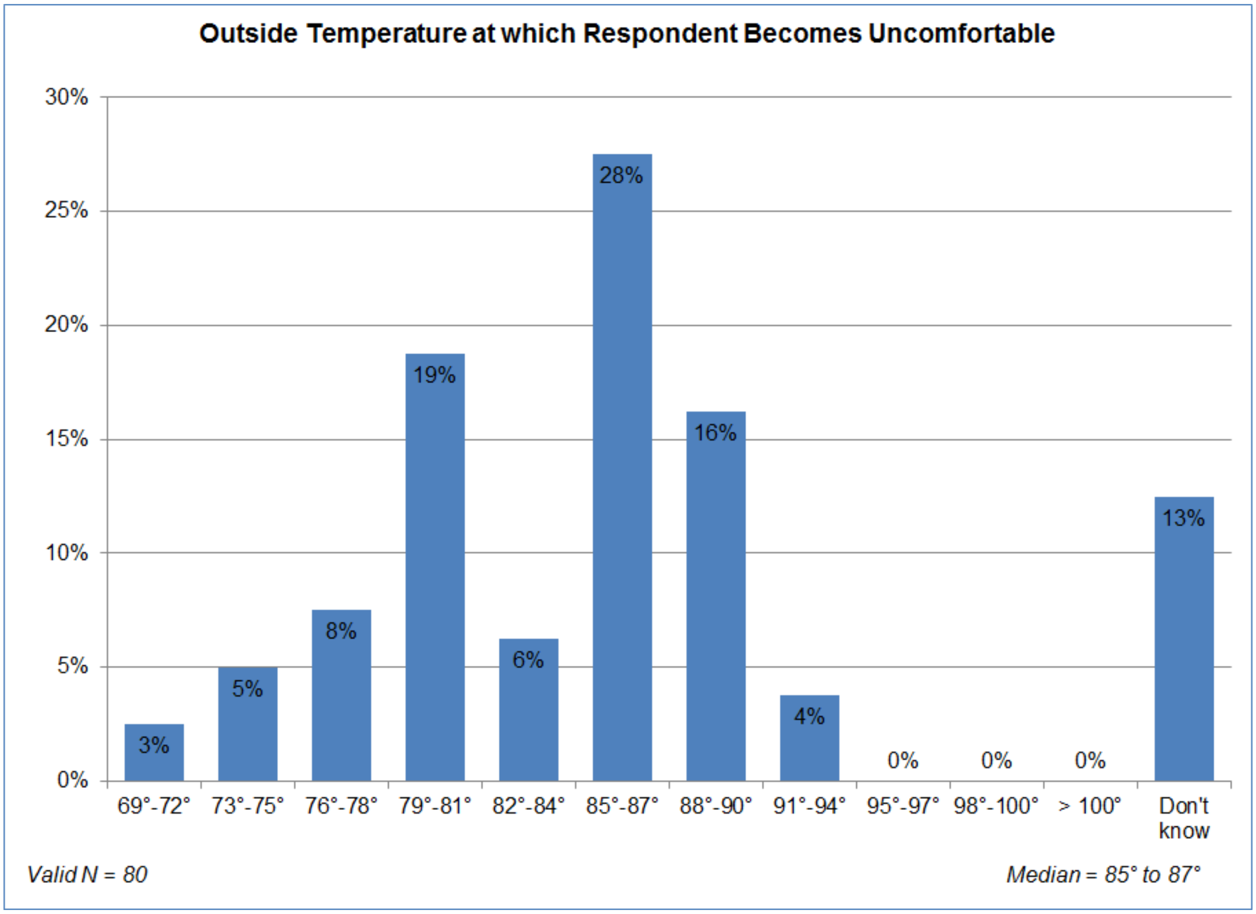

Figure 8. Outside Temperatures at Which Participants Feel Uncomfortably Warm

Participants were also asked for the outside temperature at which they tend to turn on their air conditioners (Figure 9). The median and modal outside temperature range at which air conditioners are turned on is 79° to 81°, which is two categories (about 6°) cooler than the median outdoor temperature at which customers become uncomfortable in their homes.

One participant in eight (12.5%) turn on their AC units when the outdoor temperature is 78° or lower and 17.5% do not turn on cooling until the outdoor temperature rises to 85° or higher. In lieu of giving actual temperatures, another 22.5% of customers said their settings are "programmed into the thermostat." All Ohio participants surveyed who do not program their thermostats turn on their air conditioning before the outdoor temperature reaches 88°.

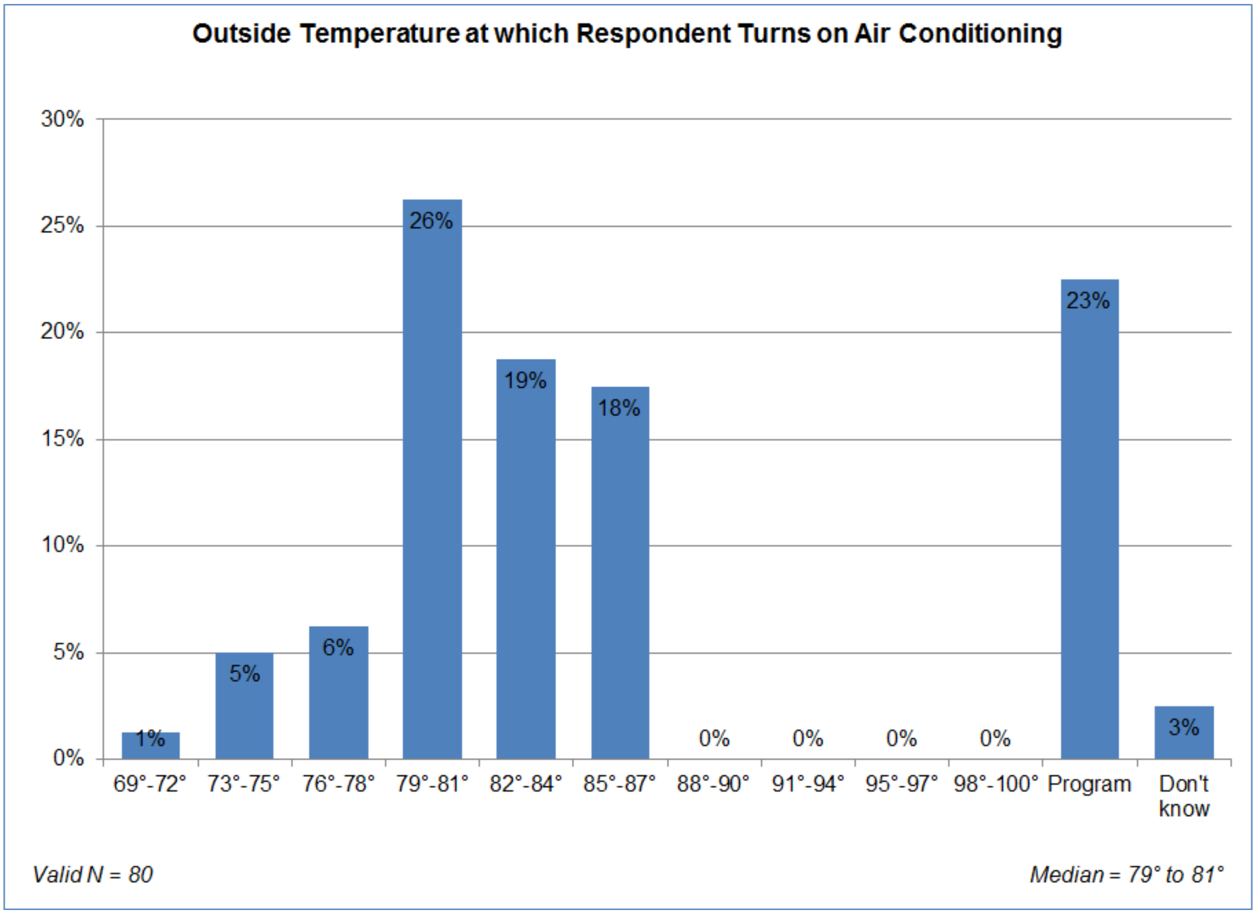

Figure 9. Outside Temperatures at which Participants Turn On Their Air Conditioners

When the temperature points from Figure 8 (discomfort) and Figure 9 (when participants turn on their air conditioners) are compared, it reveals that half (50.0%) of participants turn on their AC units before outdoor temperatures become uncomfortable and 37.9% wait until temperatures have reached the point of discomfort to turn their units on (Figure 10); just 12.1% wait until outside temperatures are higher than the point of discomfort to turn their units on.

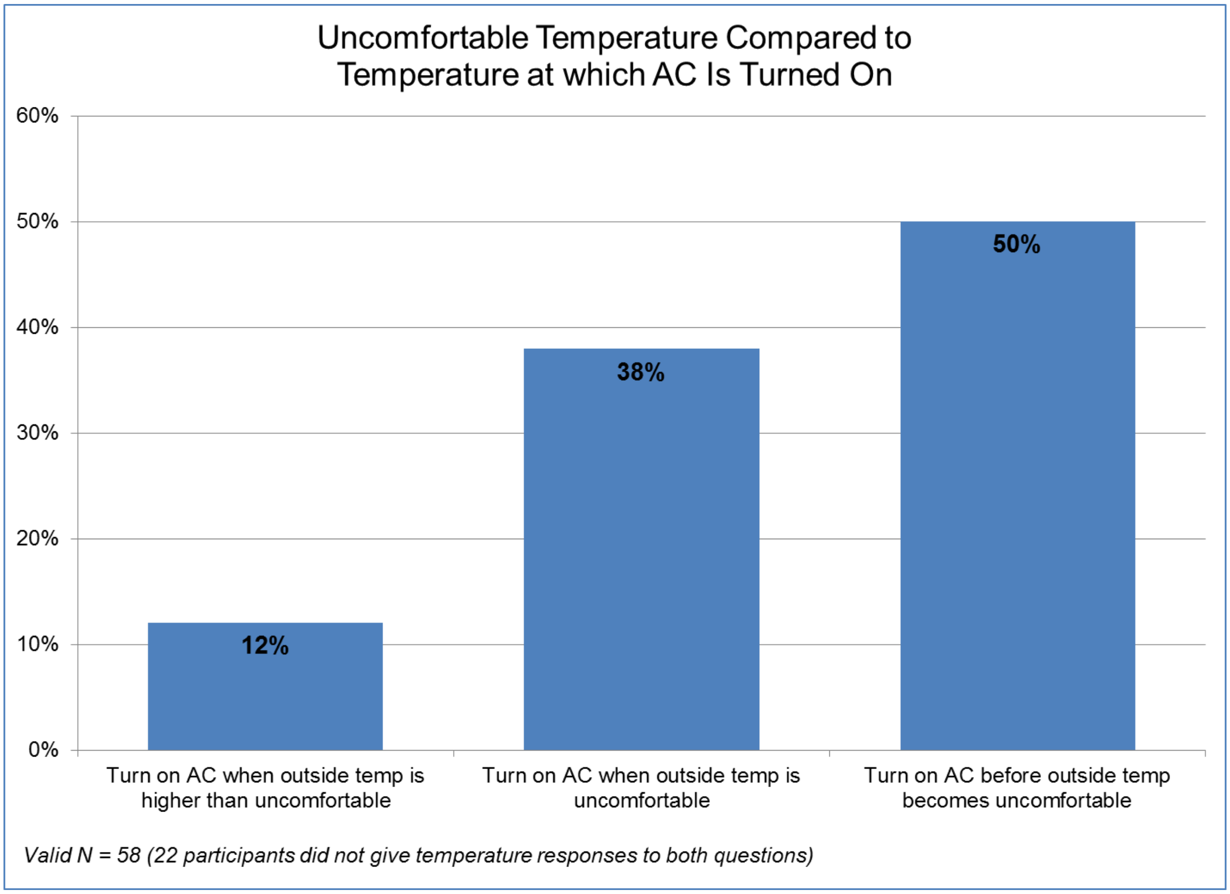

Figure 10. Turning On AC Units When Temperatures Reach an Uncomfortable Level

Eighteen Ohio participants (the 22.5% referenced in Figure 9) did not report a temperature at which they turn on their AC units since the settings are programmed into their thermostats.

These customers were asked a follow-up question regarding when they program their thermostats: Nearly three-quarters (72.2%) indicate that they program their thermostats when the weather gets hot, while 27.8% program their thermostats seasonally (Table 15). This 2014 finding is not significantly different from the 2013 survey, when 58.3% of respondents said they programed their thermostats seasonally.

Table 15. Programmable Thermostats

Do you set your thermostat seasonally or when the weather gets hot?	**Count**	**Percent** (N=18 participants who program thermostats)
I program the thermostat seasonally	5	27.8%
When the weather gets hot	13	72.2%

Thermostat Settings

Figure 11 shows participants' thermostat settings on high temperature weekdays at four time periods throughout the day (6 a.m.-12 p.m., 12 p.m.-6 p.m., 6 p.m.-10 p.m., and 10 p.m.-6 a.m.).

During hot summer weather, temperature settings ranging from 73° to 75° Fahrenheit are favored by 40% of participants throughout the day, while 30% or more set their temperatures to 76° or higher throughout the day. There is not much variation between day parts, although in the evening between 6 p.m. and 10 p.m. participants are less likely set their AC to a temperature of 78° or higher (5.0%) compared to weekday afternoons from noon to 6 p.m. (12.5%; significant at p<.05 using Student's t-test).

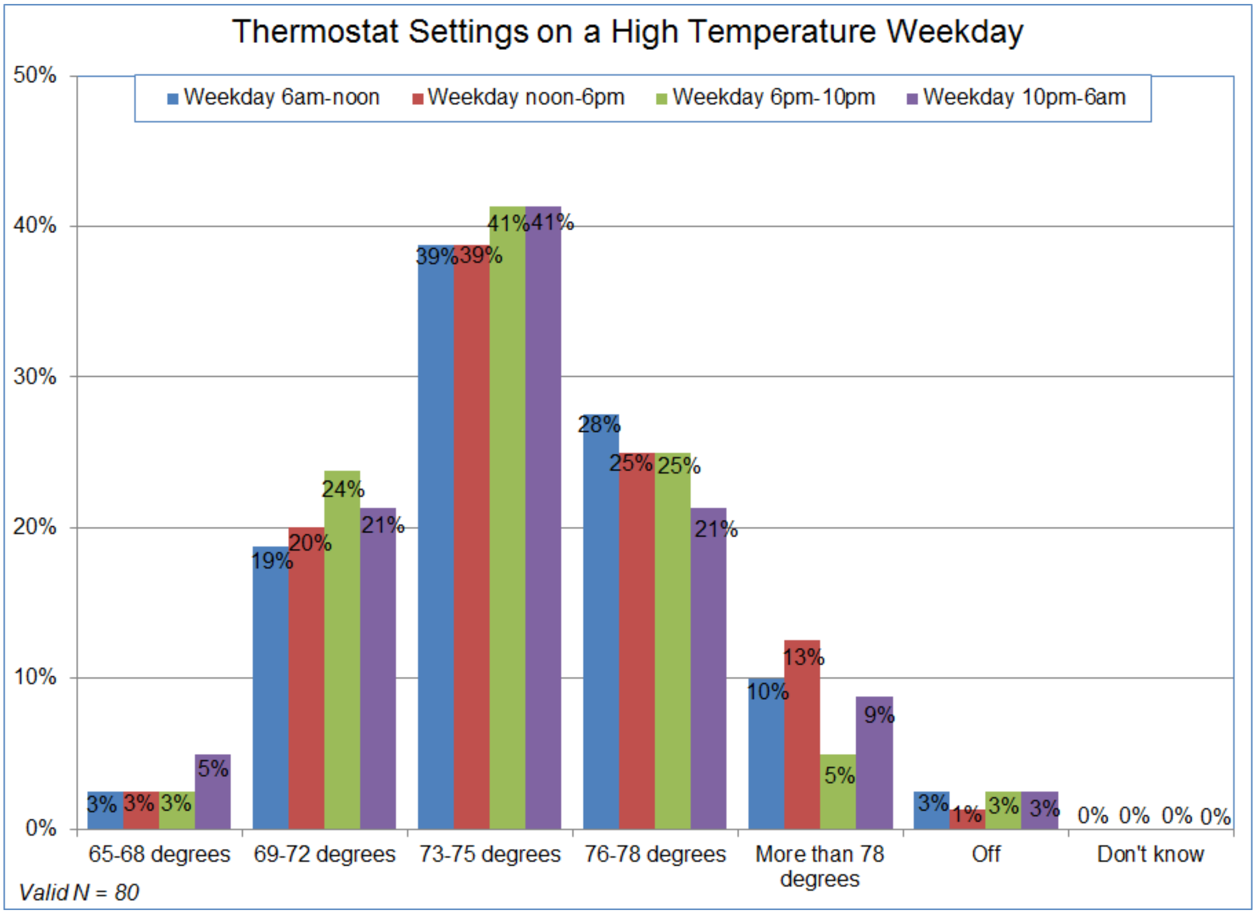

Figure 11. Thermostat Settings on a High Temperature Weekday

As seen in Figure 12, respondents are also asked about their typical temperature settings on a hot weekend day for the same four time periods. On a hot Saturday or Sunday about two-thirds of participants (63.8% or more) use the same temperature settings for each day part that they use during the work week. There are no statistically significant differences in weekend thermostat settings by time of day.

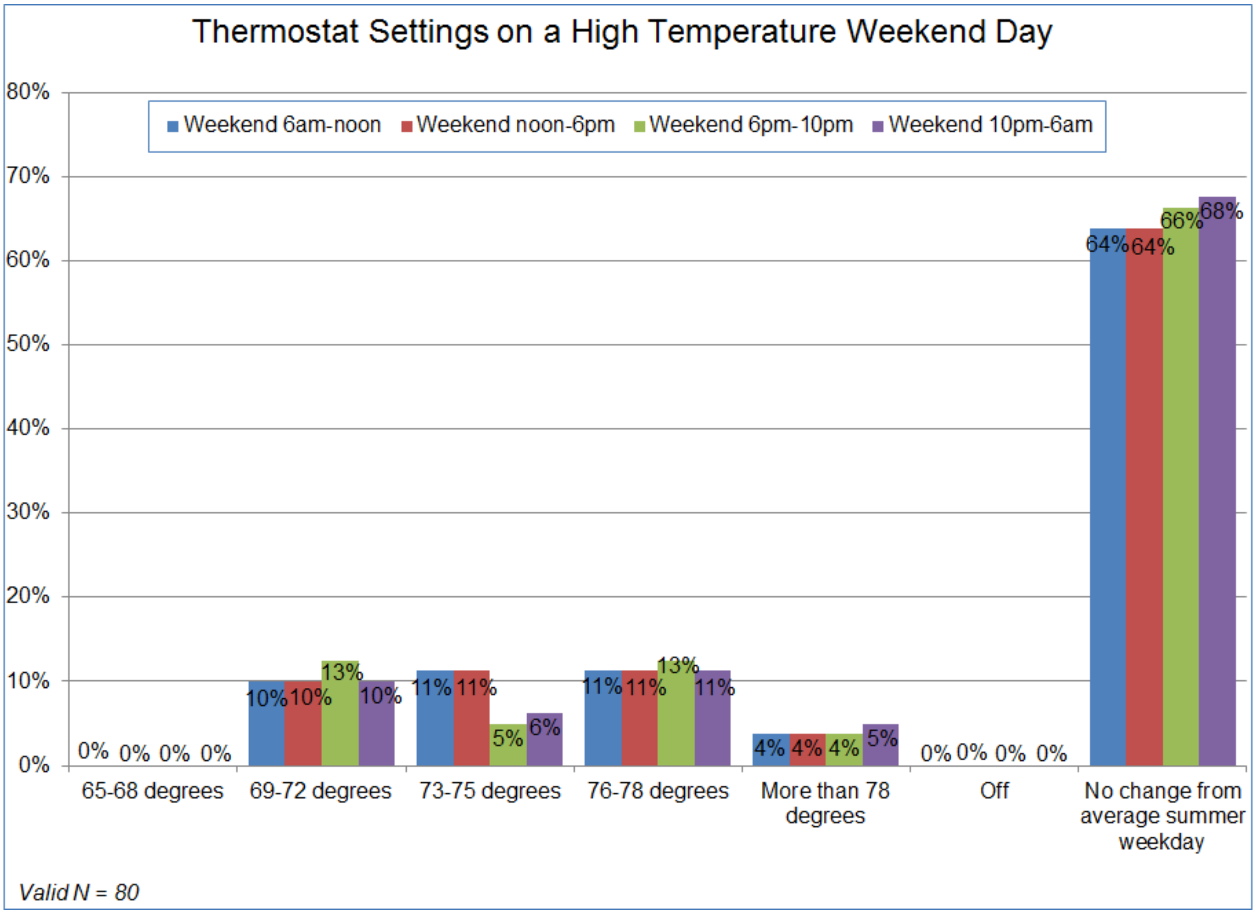

Figure 12. Thermostat Settings on a High Temperature Weekend Day

Nearly all participants surveyed in 2014 keep their thermostat settings the same throughout the entire week[8] (90.0% to 98.7%), as seen in Table 16. Participants are more likely to set their AC to a lower temperature on weekends than weekdays between 6 a.m. and 6 p.m. (7.5% or more compared to 1.3% or less during other times of day; these differences are significant at p<.05 using Student's t-test). None of the surveyed participants set their thermostats higher on weekends than weekdays before 6 p.m., and no more than 2.5% set them higher on weekends than weekdays after 6 p.m.

[8] In addition to the 64% to 68% of participants who responded that they do not set their thermostats differently on weekends (seen in Figure 12), another 26% to 31% of participants reported the same specific temperature ranges for a given time of day throughout the week (for example, customers who set their thermostats to 73° to 75° on a *weekday* from 6 p.m. to 10 p.m. who also set their thermostats to the same temperature range on *weekends* from 6 p.m. to 10 p.m.). This analysis compares weekday and weekend temperature settings during equivalent times of day (weekday evening versus weekend evening), not changes in settings between different times of day (morning versus evening).

Table 16. Changes in Thermostat Settings of Power Manager Participants by Days of Week

Time period	Same on weekdays and weekends	Lower AC temperature on weekends	Higher AC temperature on weekends
6 a.m.-12 p.m.	92.5%	7.5%	0.0%
12 p.m.-6 p.m.	90.0%	10.0%	0.0%
6 p.m.-10 p.m.	96.3%	1.3%	2.5%
10 p.m.-6 a.m.	98.8%	0.0%	1.3%

TecMarket Works divided Power Manager participants into two groups: those that turn their air conditioners on to a set temperature and leave it at that temperature all day, every day ("Non-Adjusters"), and those that change their temperature settings ("Adjusters"). Figure 13 shows that only 23.8% of Power Manager participants surveyed in Ohio are Adjusters; this finding differs from 2013, when 42.0% of participants surveyed gave responses that categorized them as Adjusters ($p<.05$ using Student's t-test).

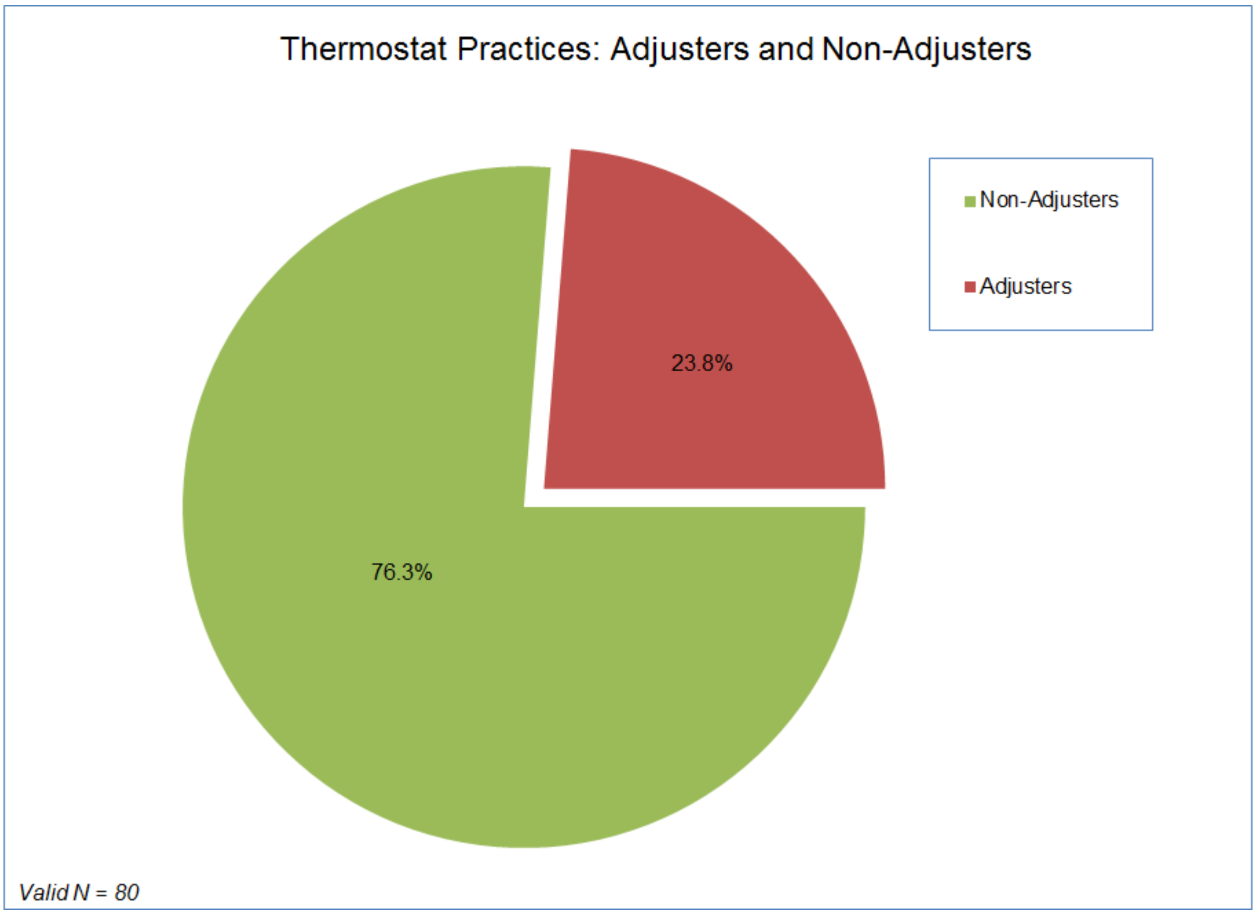

Figure 13. Thermostat Practices of Power Manager Participants

The outside temperatures at which Adjusters and Non-Adjusters become uncomfortable and turn on their air conditioners are shown in Table 17. For both groups, the median range of discomfort is 85° to 87° Fahrenheit. However, Non-Adjusters tend to turn on their cooling units at a lower outdoor temperature: the median temperature range at which Adjusters turn their air conditioning on is 82° to 84°, while for Non-Adjusters the median temperature at which AC units are turned on is 79° to 81°. While Adjusters are by definition making temperature tweaks to their thermostats throughout the week, in aggregate those changes are relatively minor. As a result, both Adjusters and Non-Adjusters maintain similarly consistent median temperature settings of 73° to 75° during evenings after 6 p.m., though for Adjusters the median temperature setting is one category higher at 76° to 78° before 6 p.m.

Table 17. Temperature Points for Non-Adjusters and Adjusters

Median Temperature Settings	Temperature Range in Degrees Fahrenheit	
	Adjusters (N=19)	Non-Adjusters (N=61)
Median temperature of discomfort	85-87°	85-87°
Median temperature to turn AC on	82-84°	79-81°
Median temperature thermostat setting weekdays 6 a.m.-noon	76-78°	73-75°
Median temperature thermostat setting weekdays noon-6 p.m.	76-78°	73-75°
Median temperature thermostat setting weekdays 6 p.m.-10 p.m.	73-75°	73-75°
Median temperature thermostat setting weekdays 10 p.m.-6 a.m.	73-75°	73-75°

As seen in Figure 14, Non-Adjusters have their AC units set at the same temperatures throughout the day (by definition, they do not make temperature adjustments). However Figure 15 shows that from 6 a.m. to 10 p.m., none of the Adjusters have their thermostats set to 68° or lower compared to 10.5% who are setting them that low overnight after 10 p.m. (difference between day parts significant at $p<.10$ using Student's t-test). Similarly, at least 21.1% of Adjusters have their units set at 78° or higher or turned off during every day part except 6 p.m. to 10 p.m. in the evening, when only 5.3% of Adjusters have their units set this high or turned off (also significant at $p<.10$).

By comparison, just 3.3% of Non-Adjusters ever set their thermostats to 68° or lower, and just 8.2% ever set them at 78° or higher. There are no significant differences between times of day for Non-Adjusters (by definition they do not change their temperature settings during the day).

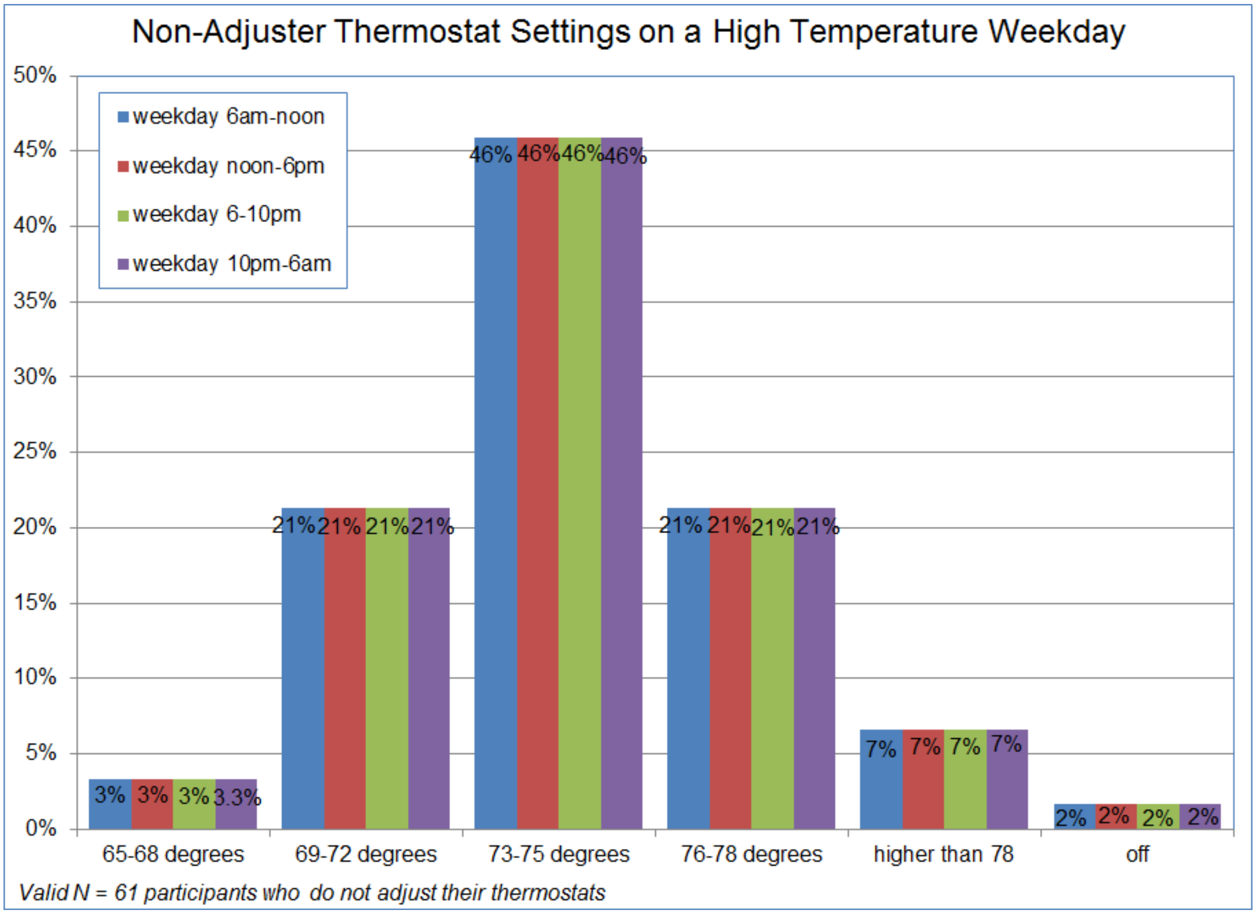

Figure 14. Non-Adjuster Thermostat Settings on High Temperature Weekdays

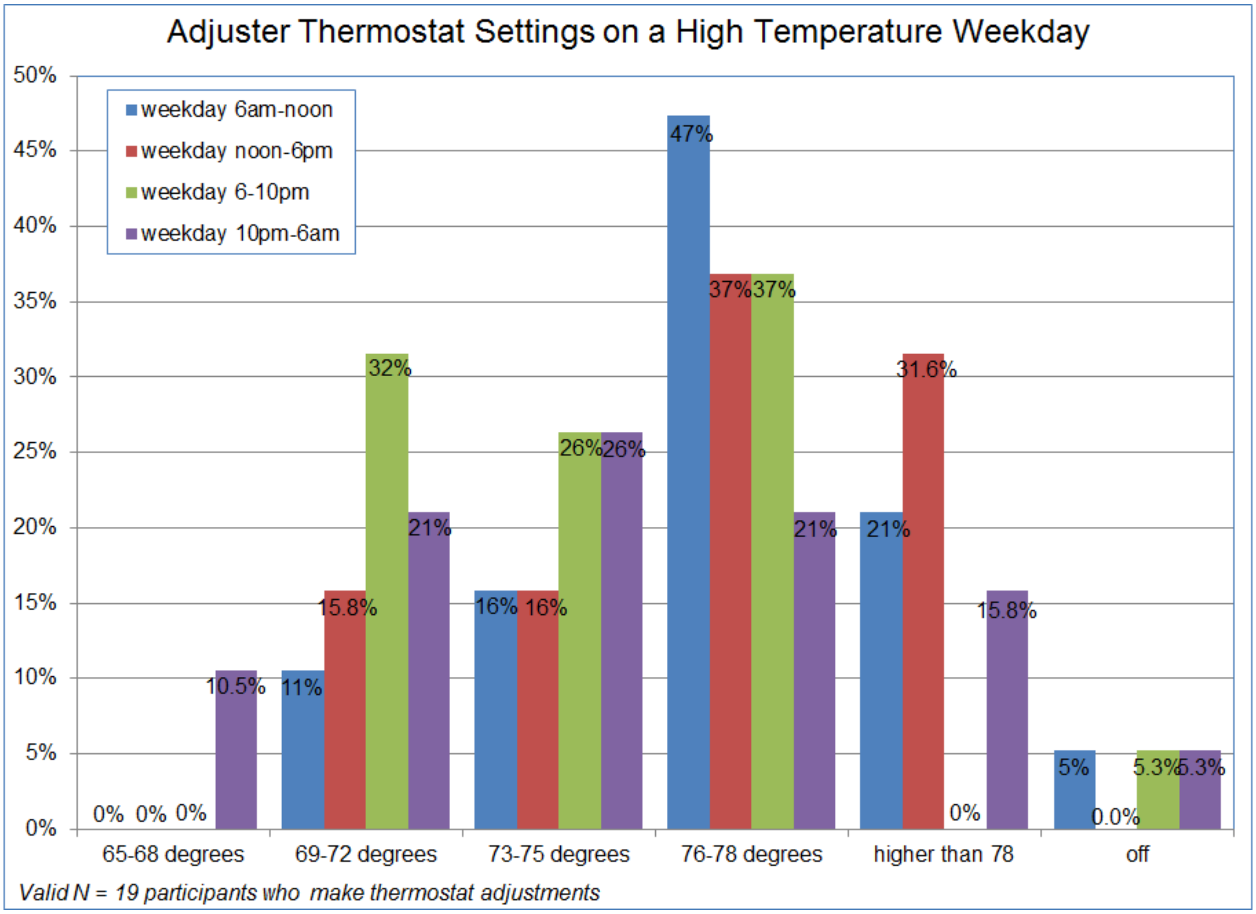

Figure 15. Adjuster Thermostat Settings on High Temperature Weekdays

Table 18 further illustrates that Adjusters are more likely to set their thermostats higher than Non-Adjusters. For most weekday time periods, a higher percentage of Adjusters have set their thermostats to "greater than 78° Fahrenheit" (the highest temperature category) or have their AC units turned off. Roughly a quarter to a third of Adjusters have their thermostats set high or AC units turned off during weekday mornings, afternoons and overnight, though only 5.3% set their temperatures that far back on weekday evenings between 6 p.m. and 10 p.m. By comparison, just 8.2% of Non-Adjusters set their units this high throughout the weekday (differences between groups are significant at p<.10 or better using Student's t-test for every time period except 6 p.m. to 10 p.m.).

Table 18. Incidence of High Weekday Thermostat Settings by Adjusters and Non-Adjusters

Percent of participants who set thermostat to 78+ degrees or turn off AC during time period on a hot summer day	**Adjusters (N=19)**	**Non-Adjusters (N=61)**
Weekday 6 a.m.-12 p.m.	26.3%	8.2%
Weekday 12 p.m.-6 p.m.	31.6%	8.2%
Weekday 6 p.m.-10 p.m.	5.3%	8.2%
Weekday 10 p.m.-6 a.m.	21.1%	8.2%

Table 19 illustrates a major reason why Non-Adjusters use their air conditioners more than Adjusters: While about half of Adjuster households (52.6%) report using AC to keep someone comfortable in the home on weekdays before 6 p.m., more than three-quarters of Non-Adjusters (77.0%) report using the AC to keep comfortable on weekdays before 6 p.m. (this difference is statistically significant at $p<.05$ using Student's t-test). After 6 p.m. on weekdays, virtually all Adjusters (94.7%) and Non-Adjusters (98.4%) use their AC to keep comfortable in the home (this difference is not statistically significant).

Table 19. AC Usage to Keep Someone Comfortable At Home on Weekdays for Adjusters and Non-Adjusters

Is the AC typically used to keep someone at home comfortable during…	**Adjusters (N=19)**	**Non-Adjusters (N=61)**
Weekday summer afternoons before 6 p.m.	52.6%	77.0%
Summer weekdays after 6 p.m.	94.7%	98.4%

These finding are very similar to the 2013 analysis of thermostat Adjusters, when these participants were also found to set their thermostats higher during the day when there is less likely to be someone at home.

Satisfaction with the Program

Overall, Ohio participants are quite satisfied with the Power Manager program. When asked to rate their satisfaction on a ten-point scale where "10" means most satisfied, they gave an average rating of 8.95, with 72.5% of survey respondents rating the program either "9" or "10", and only 11.3% giving the program a rating of "7" or less (Figure 16). There are no significant differences between customers who receive their bills directly from Duke Energy (9.11) and those who are billed by third party companies (8.90).

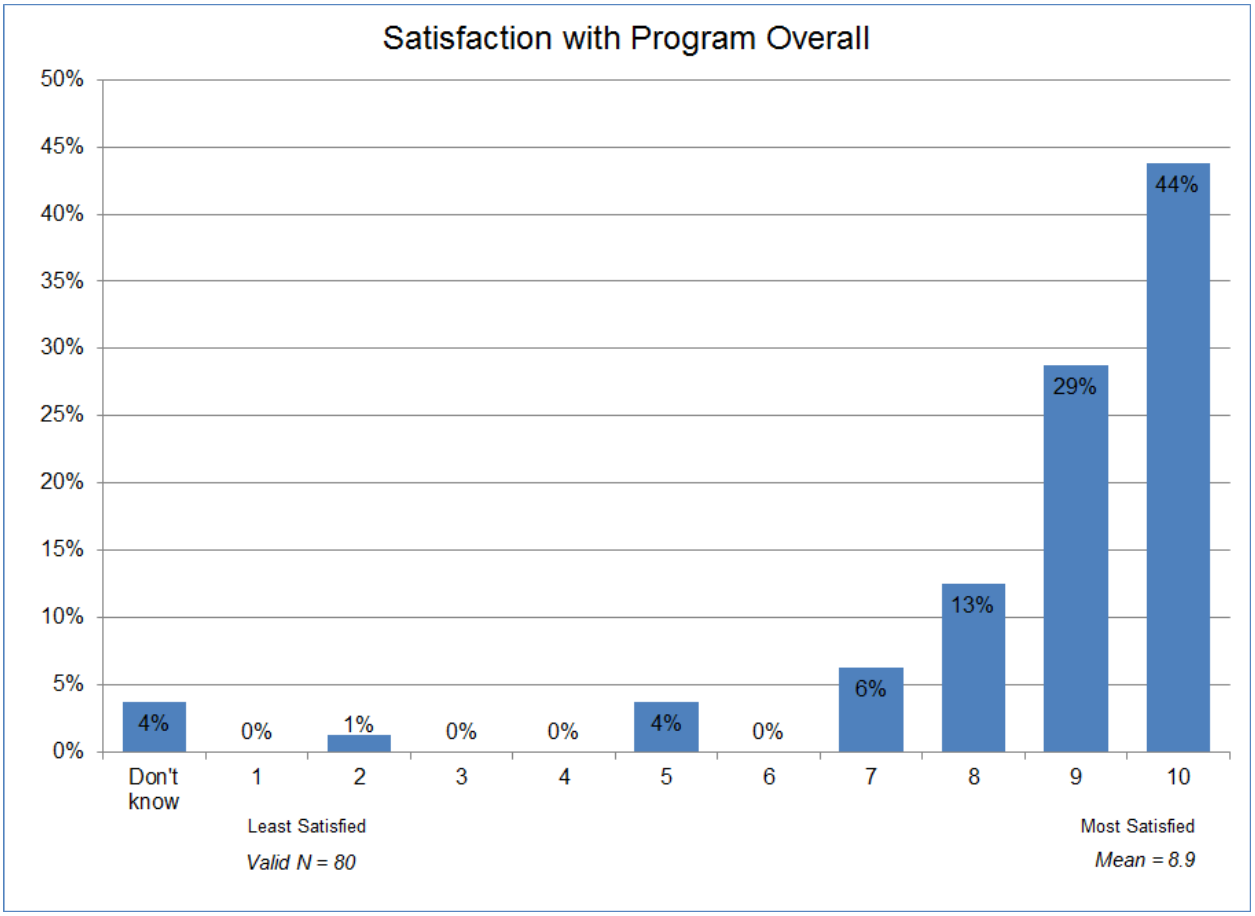

Figure 16. Overall Customer Satisfaction

A follow-up question asked the nine respondents who gave a satisfaction score of “7” or less why they were less than fully satisfied. The most frequently cited reason was that the bill credit amounts were insufficient (n=5), although others mentioned a lack of information about the program (n=2) and frequency of device activation (n=1). One customer gave a unique comment stating “*When I agreed to join the program, I asked to be there when they installed the device and was told that it wouldn't be a problem; then one day when I got home from work the device was already installed.*”

Ohio customers were also asked to rate their satisfaction using a five-point Likert scale, with responses ranging from “very satisfied” to “very dissatisfied”. Overall, 91.3% of program participants indicated that they were either “very” or “somewhat satisfied” with the program (Figure 17). Only 1.3% of customers said they were “somewhat dissatisfied” and none (0%) report being “very dissatisfied” (Figure 16).

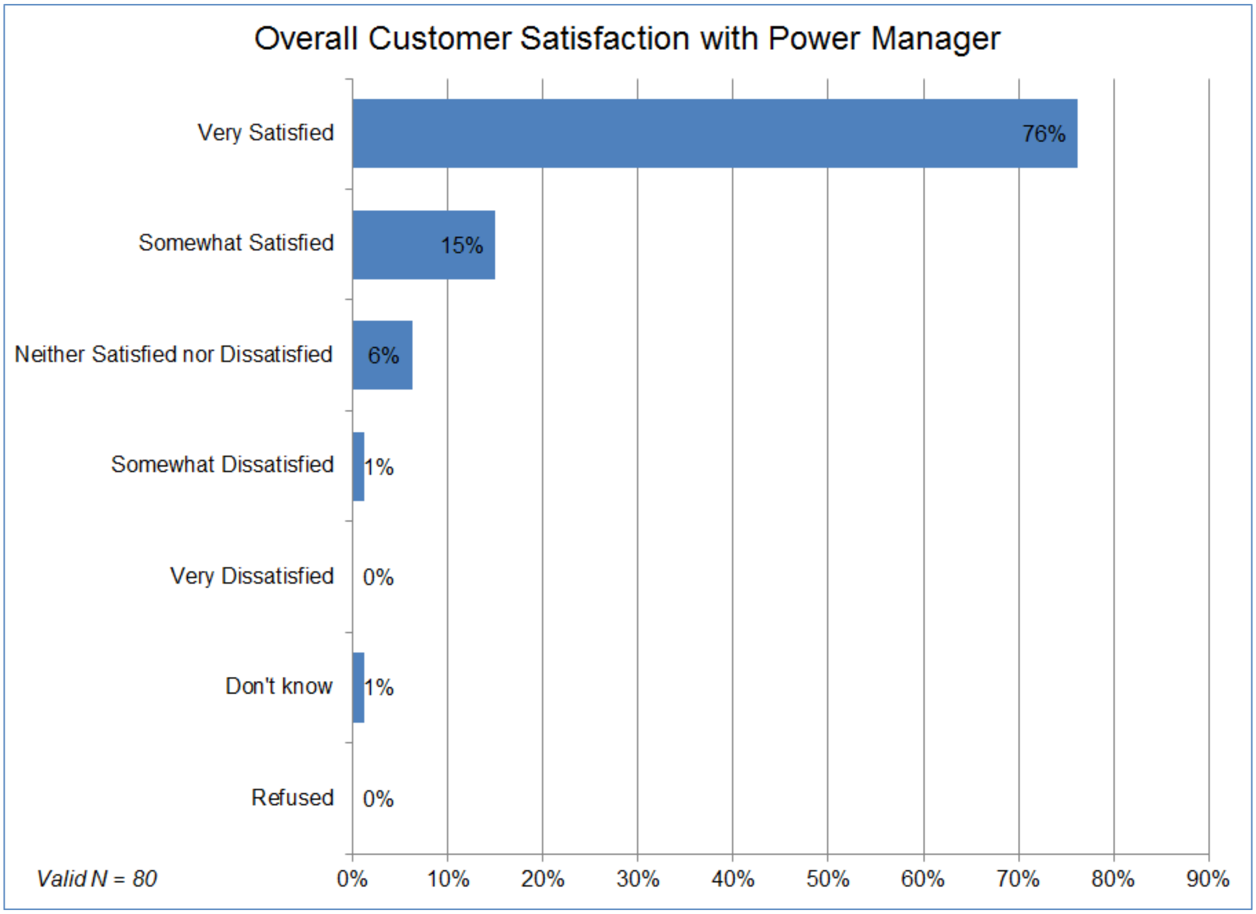

Figure 17. Satisfaction with the Power Manager Program

A follow-up question asked respondents to explain their satisfaction ratings; the responses for participants who were less than "satisfied" are categorized below (some customers mentioned multiple reasons for their lower satisfaction which is why there are more than six responses listed).

Reasons for Lower Satisfaction with Program

- Wanted more information about the program (n=2)
- The program doesn't save customers enough money (n=2),
- Can't tell when the device has been activated (n=2)
- The program helps Duke Energy but not customers
- Unique suggestion: "*The Duke Energy website could provide an educational video about Power Manager.*"[9]

Some customers who are "very" or "somewhat" satisfied with the program cite benefits of the program such as saving money and energy, or helping the environment, but the main driver of satisfaction is its "invisibility" to participants. Typical comments along these lines include "*I am very satisfied because we haven't noticed any discomfort; the program is essentially invisible to*

[9] The Duke Energy website does include a video which explains the Power Manager program.

us,“ and “*I am very satisfied with the Power Manager program because I have never noticed if or when the device has been activated; it has not affected my comfort*.” The complete list of verbatim ratings explanations can be found in *Appendix C: Participant Explanations of Satisfaction Ratings*.

Likelihood of Recommending the Program

Participants were also asked to rate the likelihood that they would recommend Power Manager to others on a ten-point scale where “10” means extremely likely and “1” means extremely unlikely. The average rating from Ohio participants is 8.47, with a majority (52.5%) rating their likelihood of recommending the program at either “9” or “10”. Only 17.5% gave ratings of “7” or lower; this distribution is shown in Figure 18.

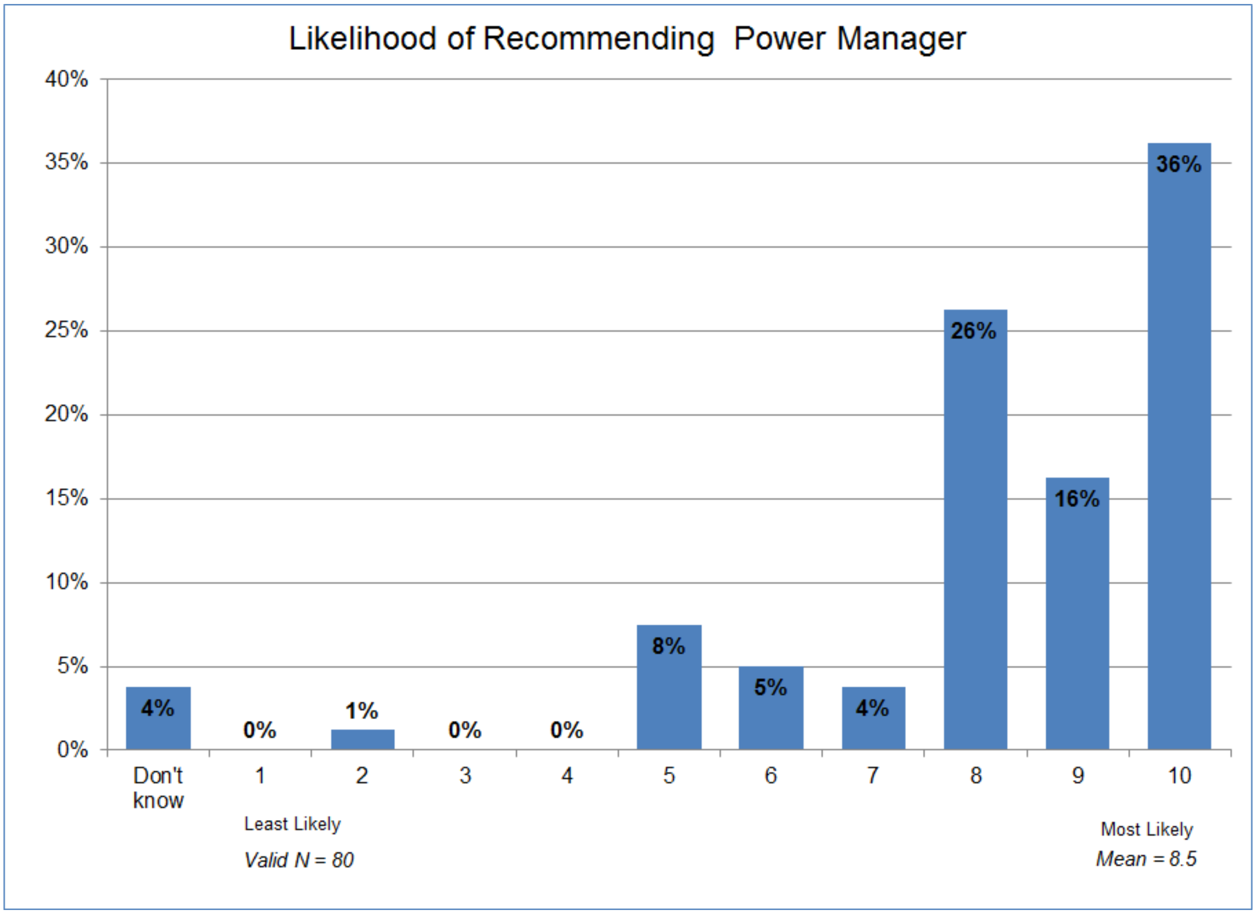

Figure 18. Recommending the Power Manager Program to Others

Participants who gave scores of “7” or lower for recommending the program were asked why they are less likely to recommend the program. Their reasons ranged from neutral remarks, such as not having enough information about the program to recommend it, to personal disinclinations due to a lack of perceived benefit for customers. Their explanations are listed below (some customers mentioned multiple reasons, which have been disaggregated to make categorization clearer).

Reasons for Not Recommending the Program

- Not likely to come up in conversation (n=7)
- Program doesn't seem to benefit customers (n=3)
- Doesn't save much money (n=2)
- I'd need more information first
- I'm ambivalent about the program

Satisfaction with Duke Energy

Overall satisfaction with Duke Energy among Ohio participants is quite strong. Respondents report an average overall satisfaction rating of 8.65 on a ten-point scale where “10” means most satisfied. A majority of respondents (57.5%) rated their satisfaction at a “9” or “10”, while only 10.0% gave scores of “7” or lower. There are no significant differences between customers who receive their bills from Duke Energy directly (8.71) and those who are billed by third party companies (8.62). The full distribution of ratings by participants is presented in Figure 19 below.

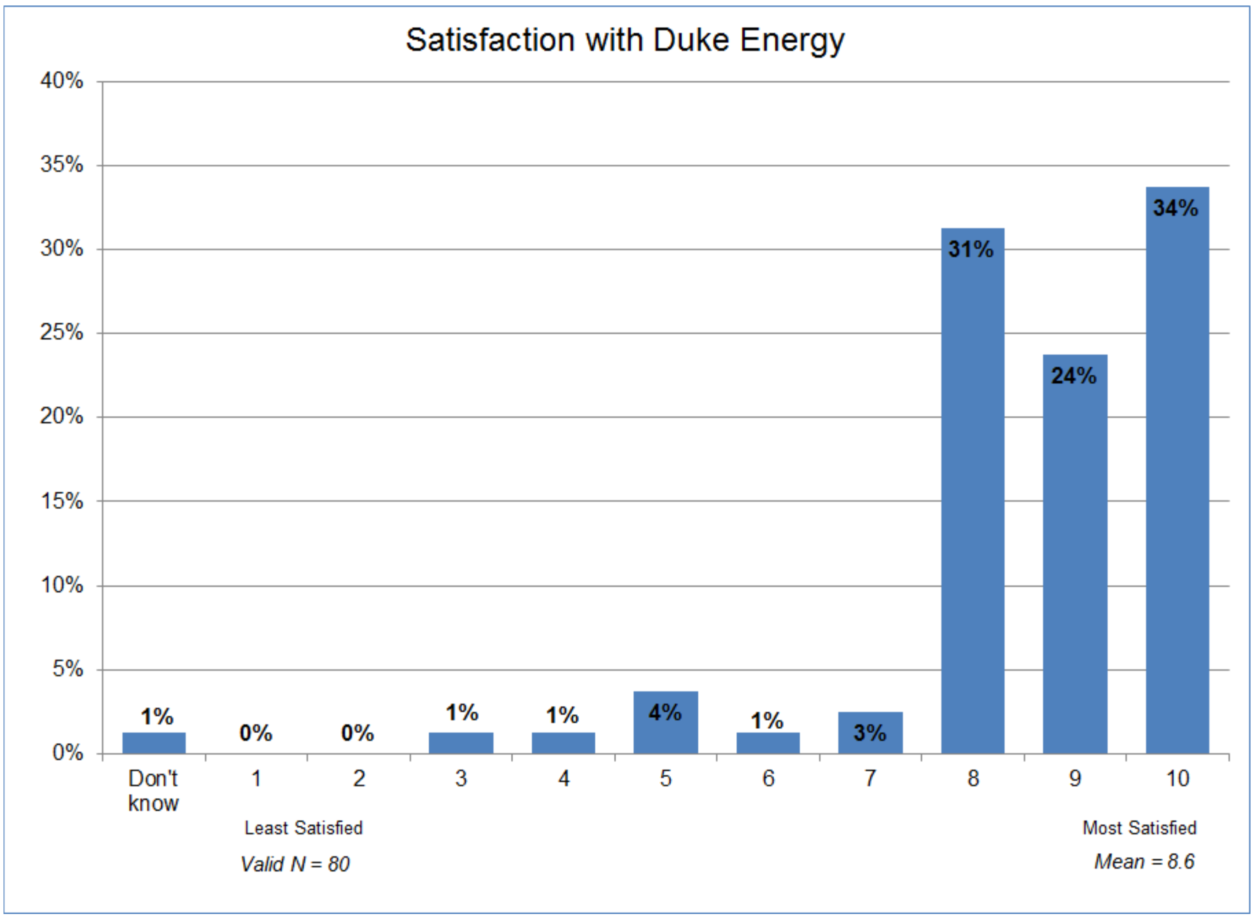

Figure 19. Overall Satisfaction with Duke Energy

Participants who gave a satisfaction score of “7” or lower explained their low ratings with a variety of reasons, including complaints about high bills and energy rates (n=4), followed by mentions of poor customer service (n=2) and power reliability (n=2), and insufficient customer education about the program (n=1).

Ohio participants were also asked to rate their satisfaction with Duke Energy using a five-point Likert scale, ranging from “very satisfied” to “very dissatisfied”. Seventy percent (70.0%) of program participants said they were “very satisfied” with Duke Energy and another 18.8% said they were “somewhat satisfied,” thus in total 88.8% of participants report being satisfied with Duke Energy (Figure 20). In all, just four customers (5.0%) said they were either “somewhat” or “very dissatisfied”. When asked to explain their ratings, these less-than-satisfied customers gave essentially identical reasons to those that were given for low numeric satisfaction ratings (see Figure 19; a complete list of participants’ verbatim explanations for their satisfaction ratings can be found in *Appendix C: Participant Explanations of Satisfaction Ratings)*.

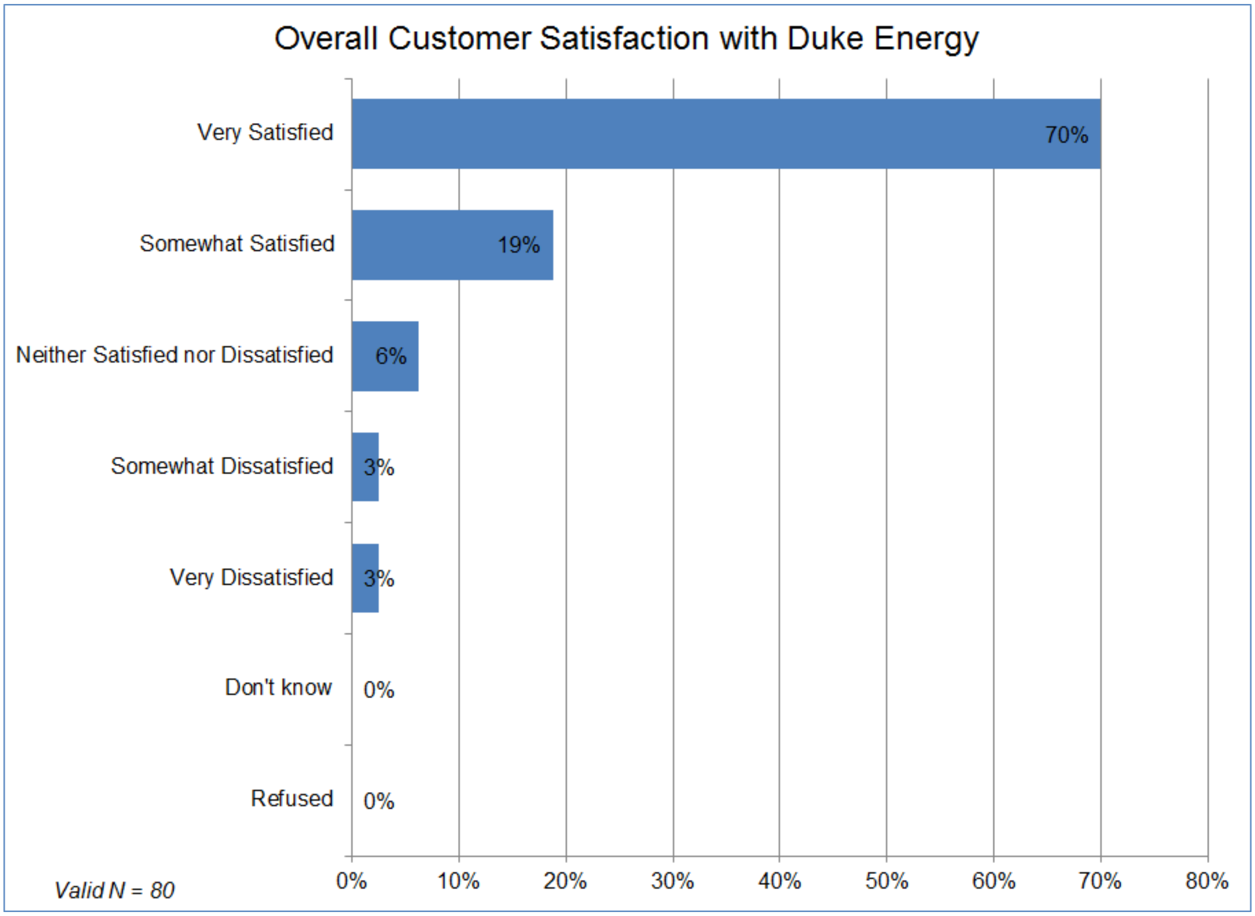

Figure 20. Satisfaction with the Duke Energy

Awareness of Other Duke Energy Programs

TecMarket Works asked participants if they were aware of any other Duke Energy programs besides the Power Manager program. A large majority (80.0%) of participants were able to name at least one other program; the most frequently mentioned programs are free CFLs (70.0%), My Home Energy Report (51.3%), Home Energy House Call (31.3%) and the specialty bulbs

Savings Store (10.0%). Other Duke Energy programs were mentioned by fewer than 10% of participants surveyed, as shown in Table 20.

Table 20. Awareness of Other Duke Energy Programs

What other Duke Energy programs or services have you heard of that help customers save energy?	**Count**	**Percent (N=80)**
Free CFL programs	56	70.0%
My Home Energy Report	41	51.3%
Home Energy House Call	25	31.3%
Savings Store (specialty light bulbs)	8	10.0%
Smart Saver (other than CFL) HVAC or Tune & Seal	3	3.8%
Appliance Recycling	3	3.8%
Personalized Energy Report	2	2.5%
Low Income, Weatherization, or Low Income Weatherization	1	1.3%
K12, NEED, or "Get Energy Smart"	1	1.3%
Other, listed below	4	5.0%
Don't know	16	20.0%

Note: Multiple responses were allowed per participant.

Four participants gave "other" responses to this question, though some do not correspond to Duke Energy program names or offerings. These include: *"People Working Cooperatively," "Retail Fixed Rate Program," "Duke Energy Retail Store," and "the mailer kit."*

Interest in Other Potential Energy Efficiency Programs

TecMarket Works asked participants in the Power Manager program if they would be interested in a similar program for electric water heaters or other devices. As seen in Table 21, a majority of respondents (65.0%) said they would be interested, while 12.5% said they were unsure.

Table 21. Interest in Programs to Cycle Water Heaters or Other Equipment

If Duke Energy were to offer a program that cycles other equipment at your home such as an electric water heater, would you be interested in participating?	**Count**	**Percent (N=80)**
Yes	52	65.0%
No	18	22.5%
Don't know	10	12.5%

Participants who are not interested in a program to cycle water heaters were asked why not. Among the 22.5% who said they would not be interested in such a program, the predominant reason given was that these customers have inappropriate water heaters. Among those who said they were unsure, the most common reason for a tentative reply was that they wanted more information before making a decision. Some examples of these comments are listed below.

<u>No, Not Interested</u>

- *I would not be interested because I have a natural gas-fueled water heater.*
- *I would not be interested because I have a tankless water heater.*

- *All of our appliances are high efficiency.*
- *I do things at different times so I wouldn't want something to be cycling when I needed it.*

Don't Know/Not Sure

- *I might be interested but it would depend on the program specifics such as time of day, credits, etc.*
- *It would depend on what you would want to cycle and how it would affect us.*
- *Our household's demand for hot water fluctuates and I wouldn't want Duke to be controlling the hot water when we need more than usual.*

Customer Ideas for Other Duke Energy Offerings

Participants were also asked if they had suggestions for other programs or services Duke Energy could offer their customers. Only six participants (7.5% of those surveyed) offered suggestions; their unique suggestions are listed below Table 22.

Table 22. Other Programs or Services Duke Energy Should Provide

Are there any programs or services that you think Duke Energy should provide to its residential customers that are currently not provided?	Count	Percent (N=80)
Yes	6	7.5%
No	63	78.8%
Don't know	11	13.8%

Customer Suggestions for Other Duke Energy Offerings

- *Duke Energy could provide programmable thermostats.*
- *Duke Energy should provide a comparison of all the competing energy bidders in the area.*
- *Duke Energy should provide home energy audits and more education regarding the proper disposal of CFLs. I have concerns about mercury.*
- *Duke Energy should provide thermostat control services for customers' homes.*
- *I would like them to offer a solar rebate program and high-efficiency swimming pool heaters. I would also like to pay my utility bill with my credit card to get frequent flier miles.*
- *I'd like to see more solar options. It would be very helpful if Duke sent out more window coverings.*

Appendix A: Participant Survey Instrument

Use four attempts at different times of the day and different days before dropping from contact list. Call times are from 10:00 a.m. to 8:00 p.m. EPT Monday through Saturday. No calls on Sunday.

Note: Only read words in bold type, italics are instructions.

Survey ID ________________

Surveyor Name ________________

Option

( ) 0.5
( ) 1.0
( ) 1.5

For answering machine 1st through penultimate attempts:
Hello, my name is _____ and I am calling with a survey about Duke Energy's Power Manager Program. I am sorry I missed you. I will try again another time.

For answering machine - Final Attempt:
Hello, my name is _____ and I am calling with a survey about Duke Energy's Power Manager Program. This is my last attempt at reaching you, my apologies for any inconvenience.

If person answers:
Hello, my name is _____, and I'm calling on behalf of Duke Energy. According to our information, you presently participate in Duke Energy's Power Manager Program. This program allows Duke Energy to cycle your air conditioner during times of peak energy usage. We are conducting this survey to obtain your opinion about the program. If you qualify, we will send you a check for $20 for completing the survey. This survey will take 25 minutes or less to complete, and the information you provide will be confidential and will help to improve the program.

Do you live at {*address from calling sheet***} ?**

( ) Yes
( ) No
( ) Refuse to answer

If No or Refused, thank them and end the call.

1. **Are you aware of your participation in the Power Manager Program?**

( ) Yes
( ) No
( ) DK/NS

If No or DK/NS,
May I please speak to the person who would be most familiar with your household's participation in the Power Manager Program?
If not available, try to schedule a callback time. If transferred, begin survey from beginning.

We would like to collect some information on why you agreed to participate in the program and how you heard about it.

2. **Were you involved in the decision to participate in Duke Energy's Power Manager Program?**
   ( ) Yes
   ( ) No
   ( ) It was already installed when I moved in.
   ( ) DK/NS

If No, DK/NS or Already Installed, skip to question 8.

3a. **Do you recall how you first heard about the program?**
   ( ) Yes
   ( ) No
   ( ) DK/NS

3b. **What are some of the ways you heard about the Power Manager Program?**
Select all that apply.
   [ ] Something in the mail from Duke Energy
   [ ] Phone call from Duke Energy (telemarketing)
   [ ] Email from Duke Energy
   [ ] Duke Energy website
   [ ] Other website, *specify:* _________________
   [ ] Word-of-mouth (friend/neighbor/landlord)
   [ ] Newspapers
   [ ] Television
   [ ] Radio
   [ ] Social media network, *specify:* _________________
   [ ] Other, *specify:* _________________
   [ ] DK/NS

4. **What was the <u>main</u> reason why you chose to participate in the program?**
   ( ) For the bill credits
   ( ) Helping Duke avoid power shortages/outages
   ( ) Helping Duke avoid building power plants
   ( ) To save energy
   ( ) To save money (through lower utility bills)
   ( ) To help the environment
      Please explain: (to reduce carbon or GHG, etc.) _________________
   ( ) I do not use the air conditioner much

( ) I am usually not home when the events are supposed to occur
( ) Other: ________________
( ) DK/NS

5. **Were there any other reasons why you chose to participate in this program?**
Select all that apply.
[ ] No other reasons
[ ] For the bill credits
[ ] Helping Duke avoid power shortages/outages
[ ] To save energy
[ ] To save money (through lower utility bills)
[ ] To help the environment
Please explain: (to reduce carbon or GHG, etc.) ________________
[ ] I do not use the air conditioner much
[ ] I am usually not home when the events are supposed to occur
[ ] Other, specify: ________________
[ ] DK/NS

6a. **During the time you enrolled, Duke Energy provided you with information that described how the Power Manager program works. Do you recall this information?**
( ) Yes
( ) No
( ) DK/NS

If Yes to q6, ask:
6b. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", how satisfied were you with this information in helping you to understand how the program works?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If 7 or below,
6c. **Why were you less than satisfied with this information?**
____

7a. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", how satisfied were you with the process of enrolling in the program?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If 7 or below,
7b. **Why were you dissatisfied with this enrollment process?**
____

8a. **Do you recall how often Duke Energy said it would activate the Power Manager device on your air conditioner?**
( ) Yes
( ) No

( ) DK/NS

If 'Yes' in q8, ask:
8b. **How many times per year did Duke Energy tell you it would activate the Power Manager device on your air conditioner? ________________**

9. **Is anything unclear to you about how the program works?**
( ) Yes
( ) No
( ) DK/NS

If Yes, ask:
9a. **What is unclear to you? ________________**

10a. **Did you ever contact Duke Energy to find out more about the Power Manager Program?**
( ) Yes
( ) No
( ) DK/NS

If No or DK/NS, skip to q11

10b. **What method did you use to contact Duke Energy?**
Select all that apply.
[ ] Phone
[ ] Email
[ ] In person
[ ] Other: ________________
[ ] DK/NS

10c. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", how satisfied were you with the ease of reaching a Duke Energy representative?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If 7 or below,
10d. **Why were you less than satisfied?**
____

10e. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", how satisfied were you with how the Duke Energy representative responded to your questions?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If 7 or below,
10f. **Why were you less than satisfied with this information?**
Select all that apply.

[ ] Did not respond to my questions/ concerns
[ ] Unable to answer/address my questions/concerns
[ ] Not professional/courteous
[ ] Other: ________________
[ ] DK/NS

11. **Are you aware of any times when Duke Energy may have activated your Power Manager device since you joined the program?**
If they ask what this means, respond with:
"Has your air conditioner been controlled so that it cycles off and on when energy demand is high?"
( ) Yes
( ) No
( ) DK/NS

If No or DK/NS in q11, skip to q23.

12. **How do you know when the device has been activated?**
Select all that apply.
[ ] A/C shuts down
[ ] Home temperature rises
[ ] The light on the meter is on
[ ] Light on AC unit flashes
[ ] Fan goes into cycling mode
[ ] Bill credits
[ ] Lower bill
[ ] Contact or notification from Duke Energy (other than bill)
[ ] Customer called the Power Manager 800 number
[ ] Other: ________________
[ ] DK/NS

13. **During the summer of 2014, about how many times do you believe Duke Energy activated your Power Manager device?**
( ) One or more times *13a. record number of times.* ________________
( ) None (not at all)
( ) DK/NS

14. **Were you or any members of your household home when Duke Energy activated your Power Manager device this past summer?**
( ) Yes
( ) No
( ) DK/NS

If No or DK/NS to q14, skip to question 19a.

15. **Using a scale of 1 to 10 where 1 means very uncomfortable and 10 means very comfortable, how would you describe your level of comfort <u>before</u> your device was activated?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

16. **Using the same scale of 1 to 10 where 1 means very uncomfortable and 10 means very comfortable, how would you describe your level of comfort <u>during</u> the period when the device was activated?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If score from Q16 is lower than score from Q15, ask Q17 and Q18 – otherwise skip ahead to Q19a.

17. **What do you feel caused your decrease in comfort?**
Select all that apply. If customer says "rising temperature" ask whether they are referring to indoor or outdoor temperature, or both.

[ ] Power Manager device activation
[ ] Rising outdoor Temperature
[ ] Rising indoor temperature
[ ] Rising outdoor Humidity
[ ] Rising indoor humidity
[ ] Power Outage
[ ] Other, specify: ________________
[ ] DK/NS

18. **After your comfort level decreased during the Power Manager device activation, how long did it take for the comfort level in your home to return to normal? Would you say…**

( ) **Less than one hour**
( ) **More than 1 but less than 2 hours**
( ) **More than 2 but less than 3 hours**
( ) **More than 3 but less than 4 hours**
( ) **or more than 4 hours**
( ) DK/NS *(do not read)*

19a. **On a day when Duke Energy activates your Power Manager device, for how many hours do you think they are typically controlling your air conditioner?**
Record number of hours ________________

19b. **On a day when Duke Energy activates your Power Manager device, at what time of day do you think that they usually de-activate the control devices and stop controlling your air conditioner?**
Record time of day ________________

20a. **When Duke Energy activated your Power Manager device, did you or any other members of your household adjust the settings on your thermostat?**

( ) Yes

( ) No
( ) DK/NS

If yes, ask:
20b. **At what temperature was it originally set, and what temperature did you set it to during the control event?**
Original temperature setting: degrees F: ________________
Adjusted temperature setting: degrees F: ________________

21. **Did you or other members of your household do anything else to keep cool?**
Select all that apply.
[ ] Continued normal activities/ Did not do anything different
[ ] Turned on room/window air conditioners
[ ] Turned on fan(s)
[ ] Closed blinds/shades
[ ] Moved to a cooler part of the house
[ ] Left the house and went somewhere cool
[ ] Wore less clothing
[ ] Drank more water/cool drinks
[ ] Cooled off with water (shower, bath, sprinkler, hose, pool)
[ ] Opened windows
[ ] Other, specify: ________________
[ ] DK/NS

22. **Thinking about this summer, how many times do you think the activation of the Power Manager program affected your level of comfort?** ________________

23a. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", how satisfied are you with the Power Manager program in general?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If q23 is 7 or below, ask 23b:
23b. **Why were you less than satisfied with Power Manager?**
Select all that apply.
[ ] They activated my Power Manager device more often than I would like
[ ] The bill credits/incentives were not large enough
[ ] I am not using less energy / not saving money on utility bill
[ ] I was uncomfortable when my Power Manager device was activated
[ ] Other *specify*: ________________

24a. **If you were rating your overall satisfaction with the Power Manager Program, would you say you were Very Satisfied, Somewhat Satisfied, Neither Satisfied nor Dissatisfied, Somewhat Dissatisfied, or Very Dissatisfied?**
( ) Very Satisfied
( ) Somewhat Satisfied
( ) Neither Satisfied nor Dissatisfied

( ) Somewhat Dissatisfied
( ) Very Dissatisfied
( ) Refused
( ) DK/NS

24b. **Why do you give it that rating?**

____

25a. **Using a scale of 1 to 10, where 1 means "Extremely Unlikely" and 10 means "Extremely Likely", how likely is it that you would recommend this program to a friend, neighbor, or co-worker?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

For all ratings, ask:
25b. **Why do you give it that rating?**

____

26. **What, if any, Duke Energy programs or services have you heard of that help customers save energy? Any others?**
Select all that apply.
[ ] Smart Saver (other than CFL) – HVAC or Tune & Seal
[ ] Savings Store (specialty light bulbs)
[ ] Water Measures (heat pump water heater, water EE products, pool pumps)
[ ] Personalized Energy Report
[ ] Home Energy House Call
[ ] My Home Energy Report
[ ] CFL Program
[ ] Energy Star Homes
[ ] Low Income, Weatherization, or Low Income Weatherization
[ ] K12, NEED, or "Get Energy Smart"
[ ] Appliance Recycling
[ ] Other, specify: _________________
[ ] DK/NS or None

Now I'm going to ask you some questions about your air conditioning use.

27. **How often do you use your central air conditioner? Would you say you use it ...**
Read answers aloud until they reply.
( ) **Not at all**
( ) **Only on the hottest days**
( ) **Frequently during the cooling season**
( ) **Most days during the cooling season**
( ) **Every day during the cooling season**
( ) DK/NS

28. **Have you had your air conditioner tuned-up or serviced since you enrolled in the Power Manager Program?**

( ) Yes
( ) No
( ) DK/NS
( ) Other: _________________

If Yes to q28, ask:
29a. **Was the Power Manager device disconnected while your air conditioner was being serviced?**

( ) Yes
( ) No
( ) DK/NS

If Yes in Q29a ask:
29b. **Was the Power Manager device re-connected after completing service on the air conditioner?**

( ) Yes
( ) No
( ) DK/NS

If No in Q29b ask:
29c. **Why wasn't the Power Manager device re-connected?**

____

30. **Is the air conditioner typically used to keep someone at home comfortable during weekday summer afternoons before 6 P.M.?**
Note: 'someone' includes pets, if applicable

( ) Yes
( ) No
( ) DK/NS

31. **Is the air conditioner typically used to keep someone at home comfortable during summer weekdays after 6 P.M.?**
Note: 'someone' includes pets, if applicable

( ) Yes
( ) No
( ) DK/NS

32. **When you think of a typical hot and humid summer day, at what outside temperature do you tend to feel uncomfortably warm in your home?**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees

( ) 79-81 degrees
( ) 82-84 degrees
( ) 85-87 degrees
( ) 88-90 degrees
( ) 91-94 degrees
( ) 95-97 degrees
( ) 98-100 degrees
( ) greater than 100 degrees
( ) DK/NS

33a. **At what outside temperature do you tend to turn on the air conditioner?**
( ) It is programmed into the thermostat.
( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) 79-81 degrees
( ) 82-84 degrees
( ) 85-87 degrees
( ) 88-90 degrees
( ) 91-94 degrees
( ) 95-97 degrees
( ) 98-100 degrees
( ) greater than 100 degrees
( ) DK/NS

If "It is programmed into the thermostat", ask:
33b. **Do you set your thermostat seasonally or when the weather gets hot?**
( ) I program the thermostat seasonally
( ) When the weather gets hot
( ) Other: _________________

I am going to read a list of time periods. For each time period, please tell me the temperature that your thermostat is typically set to on a hot summer weekday when you are using the air conditioner, or if it is turned off.

34a. **On a hot weekday morning from 6 am to noon.**
( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) Off
( ) DK/NS

34b. **On a hot weekday afternoon from noon to 6 pm**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) Off
( ) DK/NS

34c. **On a hot weekday evening from 6 pm to 10pm.**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) Off
( ) DK/NS

34d. **During a hot weekday night from 10pm to 6am.**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) Off
( ) DK/NS

I would now like to know the thermostat temperature setting for those same time periods but on a hot summer weekend.

35a. **On a hot weekend morning from 6 am to noon.**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) No change from an average summer week day
( ) Off
( ) DK/NS

35b. **On a hot weekend afternoon from noon to 6 pm**

( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) No change from an average summer week day
( ) Off
( ) DK/NS

35c. **On a hot weekend evening from 6 pm to 10pm.**
( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) No change from an average summer week day
( ) Off
( ) DK/NS

35d. **During a hot weekend night from 10pm to 6am.**
( ) less than 65 degrees
( ) 65-68 degrees
( ) 69-72 degrees
( ) 73-75 degrees
( ) 76-78 degrees
( ) greater than 78 degrees
( ) No change from an average summer week day
( ) Off
( ) DK/NS

36a. **Duke Energy is always looking for other ways to help their customers. If Duke were to offer a program that cycles other equipment at your home such as an electric water heater, would you be interested in participating?**
( ) Yes
( ) No
( ) DK/NS
comments optional: _________________

If No, ask:
36b. **Why not? _________________**

37. **Are there any programs or services that you think Duke Energy should provide to its residential customers that are currently not provided?**
( ) Yes

( ) No
( ) DK/NS

If Yes,
37b. **What services or types of programs? ___________________________________**

38a. **Using a scale of 1 to 10 where 1 indicates "Very Dissatisfied" and 10 indicates "Very Satisfied", What is your overall satisfaction with Duke Energy?**
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) DK/NS

If 7 or below,
38b. **Why are you less than satisfied with Duke Energy? _______________________**

(Ohio only)
39a. **If you were rating your overall satisfaction with Duke Energy, would you say you were Very Satisfied, Somewhat Satisfied, Neither Satisfied nor Dissatisfied, Somewhat Dissatisfied, or Very Dissatisfied?**
( ) Very Satisfied
( ) Somewhat Satisfied
( ) Neither Satisfied nor Dissatisfied
( ) Somewhat Dissatisfied
( ) Very Dissatisfied
( ) Refused
( ) DK/NS

(Ohio only)
39b. **Why do you give it that rating? _____________________________________**

40. **What's your best estimate of how many dollars you will receive in yearly bill credits from Duke Energy for participating in the Power Manager program?**
( ) $: ________________
( ) DK/NS

41a. **Have you received any bill credits this year from Duke Energy for participating in this program?**
( ) Yes
( ) No
( ) DK/NS

If Yes to Q41, ask:
41b. **How many times have you noticed the Power Manager credits on your bill this summer?**
( ) Every bill this summer
( ) Once
( ) Twice
( ) Three

( ) Four or more times
( ) Other, *specify*: ________________
( ) DK/NS

Finally, we have some general demographic questions…

d1. **In what type of building do you live?**
( ) Single-family home, detached construction
( ) Single family home, factory manufactured/modular
( ) Single family, mobile home
( ) Row House
( ) Two or Three family attached residence-traditional structure
( ) Apartment (4 + families)---traditional structure
( ) Condominium---traditional structure
( ) Other: ________________
( ) Refused
( ) DK/NS

d2a. **What year was your residence built?**
( ) 1959 or before
( ) 1960-1979
( ) 1980-1989
( ) 1990-1997
( ) 1998-2000
( ) 2001-2007
( ) 2008-present
( ) DK/NS

d2b. **How long have you been living in your current residence?**
( ) less than 1 year
( ) 1 to 3 years
( ) 3 to 5 years
( ) 5 to 10 years
( ) 10 to 15 years
( ) 15 to 20 years
( ) 20 to 25 years
( ) more than 25 years
( ) DK/NS

d3. **How many rooms are in your home (excluding bathrooms, but including finished basements)?**
( ) 1 to 3
( ) 4
( ) 5
( ) 6

( ) 7
( ) 8
( ) 9
( ) 10 or more
( ) DK/NS

d4. **Which of the following best describes your home's heating system?**
Select all that apply.
[ ] None
[ ] Central forced air furnace
[ ] Electric Baseboard
[ ] Heat Pump
[ ] Geothermal Heat Pump
[ ] Other: _________________
[ ] DK/NS

d5. **How old is your heating system?**
( ) 0-4 years
( ) 5-9 years
( ) 10-14 years
( ) 15-19 years
( ) 19 years or older
( ) DK/NS
( ) Do not have

d6. **What is the primary fuel used in your heating system?**
( ) Electricity
( ) Natural Gas
( ) Oil
( ) Propane
( ) Other: _________________
( ) DK/NS

d7. **What is the secondary fuel used in your primary heating system, if applicable?**
( ) Electricity
( ) Natural Gas
( ) Oil
( ) Propane
( ) Other: _________________
( ) None
( ) DK/NS

d8. **Do you use one or more of the following to cool your home?**
Select all that apply.
[ ] None, do not cool the home
[ ] Heat pump for cooling

[ ] Central air conditioning
[ ] Through the wall or window air conditioning unit
[ ] Geothermal Heat pump
[ ] Other *(please specify?)*: _________________
[ ] DK/NS

d9. **How many window-unit or "through the wall" air conditioner(s) do you use?**
( ) None
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8 or more

d10. **What is the fuel used in your cooling system?**
Select all that apply.
[ ] Electricity
[ ] Natural Gas
[ ] Oil
[ ] Propane
[ ] Other: _________________
[ ] None
[ ] DK/NS

d11. **How old is your cooling system?**
( ) 0-4 years
( ) 5-9 years
( ) 10-14 years
( ) 15-19 years
( ) 19 years or older
( ) DK/NS
( ) Do not have

d12. **What is the fuel used by your water heater?**
Select all that apply.
[ ] Electricity
[ ] Natural Gas
[ ] Oil
[ ] Propane
[ ] Other: _________________
[ ] No water heater
[ ] DK/NS

d13. **How old is your water heater?**

( ) 0-4 years
( ) 5-9 years
( ) 10-14 years
( ) 15-19 years
( ) More than 19 years
( ) DK/NS

d14. **What type of fuel do you use for clothes drying?**
Select all that apply.

[ ] Electricity
[ ] Natural Gas
[ ] Oil
[ ] Propane
[ ] Other: _________________
[ ] No clothes dryer
[ ] DK/NS

d15. **About how many square feet of living space are in your home?**
(Do not include garages or other unheated areas)
Note: A 10-foot by 12 foot room is 120 square feet

( ) Less than 500
( ) 500 to 999
( ) 1000 to 1499
( ) 1500 to 1999
( ) 2000 to 2499
( ) 2500 to 2999
( ) 3000 to 3499
( ) 3500 to 3999
( ) 4000 or more
( ) DK/NS

d16. **Do you own or rent your home?**

( ) Own
( ) Rent

d17. **How many levels are in your home (not including your basement)?**

( ) One
( ) Two
( ) Three

d18. **Does your home have a heated or unheated basement?**

( ) Heated
( ) Unheated
( ) No basement
( ) DK/NS

d19. **Does your home have an attic?**

( ) Yes
( ) No
( ) DK/NS

d20. **Are your central air/heat ducts located in the attic?**

( ) Yes
( ) No
( ) N/A
( ) DK/NS

d21. **Does your heating system keep your home comfortable in winter?**

( ) Yes
( ) No
( ) DK/NS

d22. **Does your cooling system keep your home comfortable in summer?**

( ) Yes
( ) No
( ) DK/NS

d23a. **Do you have a programmable thermostat?**

( ) Yes
( ) No
( ) DK/NS

d23b. **How many thermostats are there in your home?**

( ) 0
( ) 1
( ) 2
( ) 3
( ) 4 or more
( ) DK/NS

d24. **What temperature is your thermostat set to on a typical summer weekday afternoon?**

( ) Less than 69 degrees
( ) 69-72 degrees
( ) 73-78 degrees
( ) Higher than 78 degrees
( ) Off
( ) DK/NS

d25. **What temperature is your thermostat set to on a typical winter weekday afternoon?**

( ) Less than 67 degrees
( ) 67-70 degrees

( ) 71-73 degrees
( ) 74-77 degrees
( ) 78 degrees or higher
( ) Off
( ) DK/NS

d26. **Would a two-degree increase in the summer afternoon temperature in your home affect your comfort …**
Read all answers until they reply.
( ) **Not at all**
( ) **Slightly**
( ) **Moderately, or**
( ) **Greatly**
( ) DK/NS

d27a. **How many people live in this home?**
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8 or more
( ) Prefer not to answer

d27b. **How many of them are teenagers?**
(age 13-19)
If they ask why: Explain that teenagers are generally associated with higher energy use.
( ) 0
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8 or more
( ) Prefer not to answer

The following questions are for classification purposes only and will not be used for any other purpose than to help Duke Energy continue to improve service.

d28. **What is your age group?**
Read all until they reply.
( ) **18-34**

( ) **35-49**
( ) **50-59**
( ) **60-64**
( ) **65-74**
( ) **Over 74**
( ) Prefer not to answer

d29. **Please indicate your annual household income.**
Read all until they reply.
( ) **Under $15,000**
( ) **$15,000-$29,999**
( ) **$30,000-$49,999**
( ) **$50,000-$74,999**
( ) **$75,000-$100,000**
( ) **Over $100,000**
( ) Prefer Not to Answer
( ) DK/NS

d30. Interviewer: record gender of respondent – do not ask.
( ) Male
( ) Female
( ) DK/NS

We have reached the end of the survey. As I mentioned earlier, we would like to send you $20 for your time and feedback today. Should we send the $20 to *{address on calling sheet}*, **or would a different address be better?**

Confirm Name & complete address from calling sheet. If needed, make any changes to Name or Address on calling sheet, and mark "Changed Info" column.

Shall we use the name and address on the call sheet for their incentive check?
if "No", record any changes on call sheet
( ) Yes
( ) No

You should receive your $20 check in about 4-6 weeks. It will come in an envelope from our company: TecMarket Works.

Thanks again for your time today!
(politely end call)

Appendix B: Participant Survey Customer Descriptive Data

TecMarket Works surveyed 80 participants about their homes and households. Additional descriptive data is provided in this appendix.

In what type of building do you live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Condominium---traditional structure	2	2.5	2.5	2.5
	Single family home, factory manufactured/modular	5	6.3	6.3	8.8
	Single family, mobile home	1	1.3	1.3	10.0
	Single-family home, detached construction	72	90.0	90.0	100.0
	Total	80	100.0	100.0	

What year was your residence built?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1959 and before	35	43.8	43.8	43.8
	1960-1979	18	22.5	22.5	66.3
	1980-1989	7	8.8	8.8	75.0
	1990-1997	11	13.8	13.8	88.8
	1998-2000	3	3.8	3.8	92.5
	2001-2007	5	6.3	6.3	98.8
	2008-present	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

How long have you been living in your current residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 to 3 years	6	7.5	7.5	7.5
	10 to 15 years	13	16.3	16.3	23.8
	15 to 20 years	7	8.8	8.8	32.5
	20 to 25 years	8	10.0	10.0	42.5
	3 to 5 years	5	6.3	6.3	48.8
	5 to 10 years	12	15.0	15.0	63.8
	more than 25 years	29	36.3	36.3	100.0
	Total	80	100.0	100.0	

How many rooms are in your home (excluding bathrooms, but including finished basements)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10 or more	10	12.5	12.5	12.5
	4	5	6.3	6.3	18.8
	5	7	8.8	8.8	27.5
	6	14	17.5	17.5	45.0
	7	19	23.8	23.8	68.8
	8	14	17.5	17.5	86.3
	9	11	13.8	13.8	100.0
	Total	80	100.0	100.0	

Which of the following best describes your home's heating system?	Ohio (N=80)	
	Count	Percent
None	0	0.0%
Central forced air furnace	65	81.3%
Electric Baseboard	0	0.0%
Heat Pump	13	16.3%
Geothermal Heat Pump	0	0.0%
Space heaters	3	3.8%
Wood burning stove or furnace	2	2.5%
Infrared heat / radiant heat	2	2.5%
Don't know	1	1.3%

May total to more than 100% because respondents could give multiple responses.

How old is your heating system?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	15	18.8	18.8	18.8
	10-14 years	18	22.5	22.5	41.3
	15-19 years	10	12.5	12.5	53.8
	19 years or older	12	15.0	15.0	68.8
	5-9 years	21	26.3	26.3	95.0
	DK/NS	4	5.0	5.0	100.0
	Total	80	100.0	100.0	

What is the primary fuel used in your heating system?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	1	1.3	1.3	1.3
	Electricity	15	18.8	18.8	20.0
	Natural Gas	51	63.8	63.8	83.8
	Oil	9	11.3	11.3	95.0
	Propane	4	5.0	5.0	100.0
	Total	80	100.0	100.0	

What is the secondary fuel used in your primary heating system, if applicable?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	2	2.5	2.5	2.5
	Electricity	40	50.0	50.0	52.5
	Natural Gas	1	1.3	1.3	53.8
	None	34	42.5	42.5	96.3
	Oil	1	1.3	1.3	97.5
	Other: "*two ventless gas fireplaces*"	1	1.3	1.3	98.8
	Propane	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

Do you use one or more of the following to cool your home?	Ohio (N=80)	
	Count	Percent
None, do not cool the home	0	0.0%
Heat pump for cooling	14	17.5%
Central air conditioning	65	81.3%
Through the wall or window air conditioning unit	2	2.5%
Geothermal Heat pump	0	0.0%
Other: "*fans*", "*open windows*"	2	2.5%
Don't know	1	1.3%

May total to more than 100% because respondents could give multiple responses.

How many window-unit or "through the wall" air conditioner(s) do you use?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1	1.3	1.3	1.3
	3	1	1.3	1.3	2.5
	None	78	97.5	97.5	100.0
	Total	80	100.0	100.0	

What is the fuel used in your cooling system?	Ohio (N=80)	
	Count	Percent
Electricity	80	100.0%
Natural Gas	1	1.3%
None (no cooling system)	0	0.0%
Don't know	0	0.0%

May total to more than 100% because respondents could give multiple responses.

How old is your cooling system?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	20	25.0	25.0	25.0
	10-14 years	17	21.3	21.3	46.3
	15-19 years	12	15.0	15.0	61.3
	19 years or older	11	13.8	13.8	75.0
	5-9 years	15	18.8	18.8	93.8
	DK/NS	4	5.0	5.0	98.8
	Do not have	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

What is the fuel used by your water heater?	Ohio (N=80)	
	Count	**Percent**
Electricity	34	42.5%
Natural Gas	42	52.5%
Propane	2	2.5%
No water heater	0	0.0%
Don’t know	2	2.5%

May total to more than 100% because respondents could give multiple responses.

How old is your water heater?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	30	37.5	37.5	37.5
	10-14 years	10	12.5	12.5	50.0
	15-19 years	3	3.8	3.8	53.8
	5-9 years	24	30.0	30.0	83.8
	DK/NS	6	7.5	7.5	91.3
	More than 19 years	7	8.8	8.8	100.0
	Total	80	100.0	100.0	

What type of fuel do you use for clothes drying?	**Ohio (N=80)**	
	Count	**Percent**
Electricity	67	83.8%
Natural Gas	14	17.5%
Propane	0	0.0%
No water heater	0	0.0%
Don't know	1	1.3%

May total to more than 100% because respondents could give multiple responses.

About how many square feet of living space are in your home? (Do not include garages or other unheated areas)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1000 to 1499	14	17.5	17.5	17.5
	1500 to 1999	19	23.8	23.8	41.3
	2000 to 2499	21	26.3	26.3	67.5
	2500 to 2999	6	7.5	7.5	75.0
	3000 to 3499	2	2.5	2.5	77.5
	3500 to 3999	1	1.3	1.3	78.8
	500 to 999	5	6.3	6.3	85.0
	DK/NS	12	15.0	15.0	100.0
	Total	80	100.0	100.0	

Do you own or rent your home?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Own	79	98.8	98.8	98.8
	Rent	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

How many levels are in your home (not including your basement)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	One	31	38.8	38.8	38.8
	Two	49	61.3	61.3	100.0
	Total	80	100.0	100.0	

Does your home have a heated or unheated basement?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Heated	59	73.8	73.8	73.8
	No basement	11	13.8	13.8	87.5
	Unheated	10	12.5	12.5	100.0
	Total	80	100.0	100.0	

Does your home have an attic?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	1	1.3	1.3	1.3
	No	14	17.5	17.5	18.8
	Yes	65	81.3	81.3	100.0
	Total	80	100.0	100.0	

Are your central air/heat ducts located in the attic?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	3	3.8	3.8	3.8
	N/A	10	12.5	12.5	16.3
	No	56	70.0	70.0	86.3
	Yes	11	13.8	13.8	100.0
	Total	80	100.0	100.0	

Does your heating system keep your home comfortable in winter?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	3	3.8	3.8	3.8
	Yes	77	96.3	96.3	100.0
	Total	80	100.0	100.0	

Does your cooling system keep your home comfortable in summer?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	1.3	1.3	1.3
	Yes	79	98.8	98.8	100.0
	Total	80	100.0	100.0	

Do you have a programmable thermostat?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	33	41.3	41.3	41.3
	Yes	47	58.8	58.8	100.0
	Total	80	100.0	100.0	

How many thermostats are there in your home?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1	1.3	1.3	1.3
	1	77	96.3	96.3	97.5
	2	1	1.3	1.3	98.8
	3	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

What temperature is your thermostat set to on a typical summer weekday afternoon?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	69-72 degrees	14	17.5	17.5	17.5
	73-78 degrees	53	66.3	66.3	83.8
	Higher than 78 degrees	9	11.3	11.3	95.0
	Less than 69 degrees	2	2.5	2.5	97.5
	Off	2	2.5	2.5	100.0
	Total	80	100.0	100.0	

What temperature is your thermostat set to on a typical winter weekday afternoon?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	67-70 degrees	36	45.0	45.0	45.0
	71-73 degrees	18	22.5	22.5	67.5
	74-77 degrees	5	6.3	6.3	73.8
	78 degrees or higher	2	2.5	2.5	76.3
	Less than 67 degrees	18	22.5	22.5	98.8
	Off	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

Would a two-degree increase in the summer afternoon temperature in your home affect your comfort…

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	1	1.3	1.3	1.3
	Greatly	7	8.8	8.8	10.0
	Moderately	23	28.8	28.8	38.8
	Not at all	23	28.8	28.8	67.5
	Slightly	26	32.5	32.5	100.0
	Total	80	100.0	100.0	

How many people live in this home?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	15	18.8	18.8	18.8
	2	37	46.3	46.3	65.0
	3	12	15.0	15.0	80.0
	4	9	11.3	11.3	91.3
	5	1	1.3	1.3	92.5
	6	3	3.8	3.8	96.3
	7	2	2.5	2.5	98.8
	Prefer not to answer	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

How many of them are teenagers? (age 13-19)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	69	86.3	86.3	86.3
	1	5	6.3	6.3	92.5
	2	4	5.0	5.0	97.5
	3	1	1.3	1.3	98.8
	Prefer not to answer	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

What is your age group?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-34	7	8.8	8.8	8.8
	35-49	14	17.5	17.5	26.3
	50-59	18	22.5	22.5	48.8
	60-64	10	12.5	12.5	61.3
	65-74	12	15.0	15.0	76.3
	Over 74	19	23.8	23.8	100.0
	Total	80	100.0	100.0	

Please indicate your annual household income.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	$15,000-$29,999	4	5.0	5.0	5.0
	$30,000-$49,999	6	7.5	7.5	12.5
	$50,000-$74,999	15	18.8	18.8	31.3
	$75,000-$100,000	7	8.8	8.8	40.0
	DK/NS	4	5.0	5.0	45.0
	Over $100,000	9	11.3	11.3	56.3
	Prefer Not to Answer	34	42.5	42.5	98.8
	Under $15,000	1	1.3	1.3	100.0
	Total	80	100.0	100.0	

Survey respondent gender (recorded by interviewer)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	28	35.0	35.0	35.0
	Male	52	65.0	65.0	100.0
	Total	80	100.0	100.0	

Appendix C: Participant Explanations of Satisfaction Ratings

Surveyed participants were asked to explain their satisfaction ratings for the Power Manager program and for Duke Energy overall; their verbatim comments are categorized and listed below.

<u>"Very satisfied" with Power Manager program (N=61)</u>

- *I've never had any problems with the program.* (n=2)
- *Duke Energy is a very good company and they have good ideas on how to save energy.*
- *I am very satisfied because the device doesn't bother me a lot. I maintain comfort by keeping a fan running and having shades drawn on sunny days.*
- *I am very satisfied because I haven't experienced any problems; the device is working, and does not interfere with our lives.*
- *I am very satisfied because I haven't felt discomfort due to the device. Enrollment and participation are very easy to do.*
- *I am very satisfied because I haven't noticed a difference in comfort, and I appreciate the bill credits.*
- *I am very satisfied because the program did not affect my level of comfort and it helps conserve energy.*
- *I am very satisfied because the program has not been a hindrance. I have no complaints about Power Manager.*
- *I am very satisfied because the program hasn't negatively impacted us and Duke Energy effectively answered all my questions when I first enrolled in the program.*
- *I am very satisfied because the program saves me a little money and it hasn't caused any discernible amount of discomfort.*
- *I am very satisfied because the program was thoroughly explained, I haven't noticed any discomfort, and I consider it my civic duty to help reduce energy consumption.*
- *I am very satisfied because we haven't noticed any discomfort. The program is essentially invisible to us.*
- *I am very satisfied because we haven't noticed any significant difference in our level of comfort.*
- *I am very satisfied with Power Manager because I don't ever notice it.*
- *I am very satisfied with Power Manager because I haven't experienced any problems with it. I had forgotten that I'd even enrolled in the program.*
- *I am very satisfied with Power Manager because I've never noticed it nor had any problems with it.*
- *I am very satisfied with Power Manager because it hasn't affected my comfort. I haven't noticed it. The device works flawlessly.*
- *I am very satisfied with Power Manager because it hasn't negatively impacted my life.*
- *I am very satisfied with Power Manager because it's essentially invisible to me.*

- *I am very satisfied with the Power Manager program because I have never noticed if or when the device has been activated. It has not affected my comfort.*
- *I believe that I am saving money.*
- *I don't even know it's there.*
- *I don't even know what happened. I really don't know anything about the program but I haven't noticed any changes so I'm assuming that everything is working fine.*
- *I don't notice it because I'm not usually home when they are running the device. I did notice that the house was extremely hot once the summer of 2013 but it was an extremely hot day so I wasn't surprised.*
- *I don't pay any attention to it. I haven't noticed anything.*
- *I have been happy with the program because we never notice when it's being activated.*
- *I don't really know when the device is being activated.*
- *I had forgotten that we were even in the program because we've never noticed when the device was being activated.*
- *I haven't been affected by the device except that one time a few years ago when I was actually home during an event.*
- *I haven't been inconvenienced by the program at all.*
- *I haven't had any problems with being in the program.*
- *I haven't had any problems with the program but there's always room for improvement.*
- *I haven't had any problems with the program. It seemed like a good idea at the time because it is supposed to be saving us money.*
- *I haven't noticed any problems with having the device installed. The house stays pretty comfortable all day.*
- *I haven't noticed any problems with our service and any financial savings is welcome.*
- *I haven't noticed anything and it helps with the enormous amount of energy being used every day.*
- *I haven't noticed anything and it saves a little money on our summer bills.*
- *I haven't noticed anything.*
- *I haven't noticed anything. It doesn't seem to affect our level of comfort at all.*
- *I haven't noticed anything. We've had no problems with the program.*
- *I haven't noticed it but I'm not sure how we benefit from being in the program.*
- *I haven't really noticed anything because the house is well insulated.*
- *I like conserving energy and this program makes it easy to do.*
- *I never had any problems with the program*
- *I trust Duke and I know that they won't turn the AC off too long to make me uncomfortable*

- *I was happy to help conserve energy for places like hospitals and places like that really need it on the hot afternoons.*
- *I wish were saving more money but I feel like it's important for everyone to do their part by conserving energy whenever possible.*
- *I'm very satisfied because I haven't had any negatives issues with the program and I appreciate the bill credits.*
- *I've never noticed when the device has been activated and I had actually forgotten that we were signed up for the program.*
- *I've noticed anything so I have no problems with the program.*
- *It does save a bit of money for us every summer and we haven't noticed when the device is being activated. Also, it helps avoid total power loss in our area. That way people who need power consistently throughout the day will be able to have the power that they need at all times.*
- *It doesn't bother us and we get a little credit on our bills in the summer.*
- *It hasn't caused me any problems.*
- *It offers a good and easy way to save money and energy.*
- *It seems to save money on my bill and I've never noticed if the device is running or not.*
- *It's supposed to save me some money on my bills.*
- *Our house really holds the cold well so we don't notice when the device is being activated.*
- *The program is really hassle-free. I get a credit when I signed up and I didn't have to do anything but make a phone to enroll. I've had no problems with the program*
- *We've never had a problem with the program but I don't think that it's really saving us any money.*
- *We've never noticed when the device is activated. We're gone in the afternoons when they are controlling our AC and by the time we get home in the evenings, the house has cooled off enough.*

“Somewhat satisfied” with Power Manager program (N=12)

- *I am somewhat satisfied because I am unaware of the specifics surrounding the program.*
- *I am somewhat satisfied because the program is not a big inconvenience.*
- *I am somewhat satisfied with Power Manager because I'm not fully aware of all the program details.*
- *I don't know how much energy and money we are saving. I suppose the amounts change every year but I'd like to know how much energy we're actually able to conserve by being enrolled in the program.*
- *I haven't noticed any saving on our bill but I also haven't noticed the house getting hot or humid.*

- *I haven't noticed anything and it's supposed to be saving me some money but I haven't noticed that either.*
- *I haven't seen any savings.*
- *It didn't mess with my life. We don't notice when the device is being activated.*
- *It's a good program and I'm happy to help Duke Energy avoid running out of power during peak usage hours. I noticed the device was running a lot in the summer of 2013 but it wasn't an issue the summer of 2014.*
- *That's just how I want to rate them. I don't really have a reason.*
- *They said that they had to install the Power Manager device even though I didn't want it. The guy from Duke Energy came to the house and installed a little device on the AC. He said that everyone had to have it.*
- *We haven't really noticed anything but it really only benefits Duke Energy.*

“Neither satisfied nor dissatisfied” with Power Manager program (N=5)

- *I don't really understand how the program works but it doesn't seem to be saving me any money.*
- *I wish they would run it all the time. It would be a better program for me if it would save more money all the time.*
- *I'm pretty neutral about the program. I don't really think it's doing anything for me and that it's really just helping Duke not run out of power at peak times.*
- *Since we rarely use the AC it's really hard to evaluate the program. We're not home when the device would be running and we usually have the AC off when we're not home.*
- *The difference in the bill is negligible. I can't tell when the device is running, which is good, but I also can't tell when the device has been activated when I see my bill.*

“Somewhat dissatisfied” with Power Manager program (N=1)

- *I am somewhat dissatisfied because I would have preferred more information about the program. The Duke Energy website could provide an educational video about Power Manager.*

“Very dissatisfied” with Power Manager program (N=0)

- No survey participants gave this response.

“Don’t know” satisfaction with Power Manager program (N=1)

- *I don't feel sufficiently informed about the program to give it an accurate satisfaction rating.*

<u>"Very satisfied" with Duke Energy overall (N=56)</u>

- *I've never had any problems with Duke Energy.* (n=7)
- *Anytime we've had a problem with service Duke Energy comes out and fixes it right away. I've never had any problems with them and they have good customer service.*
- *I've always been very satisfied with Duke. I've never had a problem with them and through work I've participated in the Smart $aver [non-residential] program which I liked. We replaced a lot of old inefficient lighting.*
- *Every time I've needed to call they're very responsive.*
- *I am very satisfied because Duke Energy does a good job fixing power outages quickly. A minor gripe would be that they tore up part of my driveway without prior notice this past summer.*
- *I am very satisfied because Duke Energy does their job well. They're a good company. I appreciate the incentive programs.*
- *I am very satisfied because Duke Energy is forgiving when I'm occasionally late paying my bill. I appreciate the free CFLs and Duke's various energy efficiency programs. It's hard to compare energy providers because of the limited information that's available.*
- *I am very satisfied because of Duke Energy's reliability and accurate billing.*
- *I am very satisfied Duke Energy because their service is reliable and they offer fairly good rates.*
- *I am very satisfied with Duke Energy because I haven't experienced any problems with them. They're reliable.*
- *I am very satisfied with Duke Energy because I haven't had any problems with them. On the rare occasions when I've experienced service outages they've made repairs quickly.*
- *I am very satisfied with Duke Energy because I never have any problems with them.*
- *I am very satisfied with Duke Energy because I think they have done a good job. I was initially leery when Duke took over for Cincinnati Gas & Electric but my fears have been quelled.*
- *I am very satisfied with Duke Energy because I've never had any problems with them.*
- *I am very satisfied with Duke Energy because of their seamless service reliability.*
- *I am very satisfied with Duke Energy because their service is diligent.*
- *I am very satisfied with Duke Energy because they demonstrated a willingness to work with me on some billing issues.*
- *I am very satisfied with Duke Energy because they have greatly reduced the number of power outages. I used to need a battery-powered clock because I couldn't trust Duke's electrical service reliability.*
- *I am very satisfied with Duke Energy because they offer comparatively better service than other energy providers.*
- *I am very satisfied with Duke Energy because they restore power quickly during outages and provide responsive customer service.*

- *I am very satisfied with Duke Energy because they've provided prompt service whenever I've had issues.*
- *I am very satisfied with Energy but would have preferred more information about the Power Manager program when I first moved in.*
- *I had one little time I smelled gas and they came right away. They gave me comfort and safety without alarming me. They serviced me just fine.*
- *I haven't had any problems with Duke and my cousin used to work for them.*
- *I haven't had any problems with Duke and we don't have frequent power outages*
- *I haven't had any problems with Duke but they call me at least three times every day and they try to get me to switch companies. They say that they're going to save me money and that they are with Duke Energy but I don't want to switch my power company. They should call so much.*
- *I haven't had any problems with Duke Energy ever and I've been a customer since they took over CG & E.*
- *I haven't had any problems with Duke Energy. I had switched to Jess Electric but they couldn't explain my bill to me so I went back to Duke Energy.*
- *I haven't had any problems with Duke. One time a squirrel chewed through the wire that comes into the house and we had a big issue with that. It electrocuted the Time Warner guy and all my appliances fried but the insurance company paid for most of that. It's not really any fault on Duke's part. It was the squirrel that caused the problem but that's the closest to a problem with Duke we've ever had.*
- *I like Duke because I've never had any problems with them and they always fix stuff quickly when something goes wrong.*
- *I never had any conflict with them.*
- *I'm very happy with them.*
- *I've always been satisfied but very satisfied seems a bit more satisfied than I am but I'm more satisfied than somewhat. We've never had any problems.*
- *I've always used Duke Energy since we came to the United States. They are good at keeping the power running and when there is an outage they are good at getting the power back on quickly.*
- *I've never had any problems with Duke and I trust them.*
- *I've never had any problems with Duke and they have reasonable rates.*
- *I've never had any problems with Duke and we don't lose power much.*
- *I've never had any problems with Duke Energy but the rates keep going up and I'm on a fixed income which is making it hard to keep up with the rising rates.*
- *I've never had any problems with Duke Energy so I'll rate them well.*
- *I've had no problems with Duke but there's always room for improvement.*
- *It's easy to deal with Duke.*
- *The customer service representatives gave me the run around when I needed to change the billing name to mine after my mother's death. I went Cincinnati call center and spoke with a manager there to get the situation taken care of.*

- *The service is consistent and I trust them. Other companies might not be as consistent with the service so I wouldn't want to switch. It's better to stay with a provider that you know is going to be able to provide consistent power instead of going with a provider that you don't know as well even if they promise to save you a few cents here and there.*
- *They are easy to communicate with every time I have problems.*
- *They are pretty good.*
- *They do a good job.*
- *They do a pretty good job. They get the power back on quickly when it goes out.*
- *They give me what I want and don't bother me with anything.*
- *We haven't had any problems with Duke Energy ever and we've been in the same house for 42 years.*

“Somewhat satisfied” with Duke Energy overall (N=15)

- *I am only somewhat satisfied because of Duke Energy's frustrating customer service and line repair policies. I experienced a week-long power outage which resulted in losing all of our refrigerated food. I was disappointed in Duke's slow response to the service outage.*
- *I am somewhat satisfied because Duke Energy provides good customer service and makes repairs quickly. No big complaints, though I wish the rates were cheaper.*
- *I am somewhat satisfied because I think Duke Energy is fair but they tend to increase their rates too often.*
- *I am somewhat satisfied with Duke because the energy-related stuff in my life is confusing. I can't decide what to do when my Duke Energy contract is up and how to deal with all these other energy providers competing for my business.*
- *I don't really have any problems with Duke but I would prefer if they were a bit more environmentally inclined.*
- *I haven't really had any problems with Duke but our house is connected to an older transformer so our house and the neighbor's house lose power quite often. It would be better if that didn't happen.*
- *I still prefer CG & E over Duke Energy because CG & E was more efficient at getting things fixed quickly and addressing my concerns. Duke's customer service just isn't as good. Also the Duke bills are more confusing than CG & E’s were.*
- *I've never had any problems with service. I received a letter from Duke about the Duke Energy Retail Fixed Rate Program where I could keep the same rate until 2017 but when I called to sign up I was on hold for hours each time and never got through.*
- *We have a lot of power outage issues.*
- *The rates are too high and they keep going up.*
- *The service is very reliable but it's not like we have a choice. I just wish rates were more stable.*

- *Nothing is bad but it's kind of hard to rate a power company higher than average. It's not like they can "wow" you with more than just reliable power.*
- *They're a pretty good company but I still wish that they were Cincinnati Gas and Electric.*
- *We haven't had any problems with Duke.*
- *I have no idea. That's just how I rate them.*

"Neither satisfied nor dissatisfied" with Duke Energy overall (N=5)

- *I am neither satisfied nor dissatisfied with Duke Energy because of their high energy rates and lack of consumer education.*
- *I am neither satisfied nor dissatisfied with Duke Energy because they're somewhat expensive.*
- *I haven't had any problems but I don't care really. I'm ambivalent about them.*
- *I've never had any problems with Duke Energy but the rates are high and they keep raising the rates.*
- *The rates are very high. We have a very efficient household but our even payment is still $250 per month.*

"Somewhat dissatisfied" with Duke Energy overall (N=2)

- *The rates are high and I don't understand what all those little charges are for. It's really hard to get to someone on the phone to help explain what they are. The power goes on and off for a few seconds almost every day and all the electronics in the house need to reset.*
- *They seem like a pretty heartless corporation because they are so quick to shut off the power to people's homes when they miss a bill. It's happened to me a few times because I travel for work and sometimes I'm not home in time to get the bill paid in time. They even shut it off once right before Thanksgiving.*

"Very dissatisfied" with Duke Energy overall (N=2)

- *Duke Energy has terrible customer relations. When I call I can't ever get someone on the phone and when I do get someone on the phone they usually can't answer my questions. Lately I've been getting letters from Duke about being able to lock down a given rate for 12 months from another supplier. I don't understand how these other suppliers can be giving out lower rates than Duke but still be Duke at the same time. I don't know what they're promising and if I can even believe them. When I call Duke Energy with questions about this, I'm told that they can't help me and that I need to talk with Duke Energy Retail. I don't understand what the difference is. Duke Energy does a horrible job of informing the customer.*
- *My bill is about $300 every month but our usage is less than $30. For some reason there are multiple high-priced riders on our bill that we have to pay every month. I'm a veteran on disability and after I pay my bills every month I'm left with $50 for food*

and other luxuries. I don't understand what these riders are about and no one I call can explain to me why I'm paying them.

Impact Evaluation and Review of the 2014 Power Manager Program® Ohio

August 27, 2015

Duke Energy
139 East 4th Street
Cincinnati, Ohio 45202

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CADMUS

Prepared by:

Duke Energy Ohio and
Cadmus

Contact: Danielle Maple, Analyst
Duke Energy
Demand Response Analytics

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Executive Summary

Power Manager is a voluntary residential load control program available to Duke Energy Ohio homeowners with qualified central air conditioning. Each year, program customers receive a monthly bill credit for participating during the summer months of May through September that we have an event. Participants agree to allow Duke Energy Ohio to cycle their air conditioning units during peak periods of energy demand, when energy costs are high, or for emergency purposes when program-induced load reductions would aid in the reliability of delivering energy to the region. Customers may choose to “opt” out of oneevent each month by contacting the Customer Service center and requesting that they not participate if an event were to occur on a particular date.

Duke Energy Ohio conducted the Program Year 2014 (PY2014) impact evaluation using a variety of commonly accepted, utility industry statistical practices and applications to measure and report results of the program. These included sample selection and validation, air conditioner duty cycle modeling, model simulations, switch device operability analysis, weather normalization, and monthly capability weighting of expected capacity. Due to a lack of events in PY2014, Duke Energy Ohio used impact evaluation models created in 2013. The approaches employed by Duke Energy Ohio were then reviewed by an independent, third-party evaluator (Cadmus) commensurate with standard evaluation, measurement, and verification (EM&V) industry practice. Based on research conducted by Cadmus in other jurisdictions, as well as a critical review of the processes used for Power Manager, the findings for PY2014 are comprehensive and credible.

Program Year 2014 Highlights

- There were 47,960 active switches installed at the end of September 2014.
- For PY2014, the operability study conducted in Ohio revealed that Power Manager switch devices were operational at a 85.4% rate (see Table 1).
- For PY2014, the total summer Ohio Power Manager Program capacity—adjusted for peak normal weather and de-rated for operability and calculated at the point of generation—was 47.8 MW.
- During PY2014, there was one (1) Power Manager event in Ohio. This event was part of the required PJM annual test for demand response capacity resources.
- Duke Energy Ohio was faced with operational and market challenges due to a lack of significant hot weather and low energy prices. The program team decided not to call events for days when the program impact would have been marginal and of little economic impact.

Table 1. PY2014 Program Summary

Program Year	Active Switches	Summer Capacity	Operability Rate	Average Realization Rate (1.0 kW)	Average Realization Rate (1.5 kW)
PY2014	47,960	47.8 MW	85.4%	105.0%	98.7%

Introduction

Power Manager is a voluntary residential load control program available to Duke Energy Ohio homeowners with qualified central air conditioning. Each year, program customers receive a monthly bill credit for participating during the summer months of May through September that we have an event. Participants agree to allow Duke Energy Ohio to cycle their air conditioning units during peak periods of demand, when energy costs are high, or for emergency purposes when program-induced load reductions would aid in the reliability of delivering energy to the region. Customers may choose to "opt" out of oneevent each month by contacting the Customer Service center and requesting that they not participate if an event were to occur on a particular date.

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Program Participation

When a customer enrolls in the Power Manager Program, Duke Energy Ohio professionally installs a switch device at the customer premise that allows the air conditioning unit to be cycled for a temporary basis. Participating customers receive a one-time sign-up incentive that is based ontheir preference of level of load shed time they prefer (1.0 kW or 1.5 kW). For PY2014, the initial signup incentive was $25 for 1.0 kW or $35 for 1.5 kW load shed option. Participants are also eligible to receive a per-event energy credit on their electric bill during event months (May-September).

The switch devices are installed outside the residence in close proximity to the air conditioning unit and they cycle the air conditioner unit in response to event signals sent over an internal paging network. Customers with multiple air conditioning units can receive multiple credits.

Duke Energy Ohio may call Power Manager cycling events on non-holiday weekdays during the summer months of May through September. There were 47,960 active switches enrolled at the end of September 2014 (see Table 2).

Table 2. Power Manager Program Participation Summary (as of end of September)[1]

Program Year	Active Switches	Annual Change	Summer Capacity (MW)
PY2014	47,960	3.52%	47.8
PY2013	46,329	8.76%	46.1
PY2012	42,597	N/A	44.9

[1] Capacity reported at the point of generation.

Analytical Methodology

Duke Energy Ohio conducted the impact evaluation of the Power Manager Program in a three step approach:

1. Tested the operability of the active switch devices installed at the customer premises
2. Calculated the impact or demand reduction per switch during events as determined by a duty cycle analysis
3. Provided documentation to Cadmus for review and approval as the independent EM&V contractor

Operability Study

For PY2014, Duke Energy Ohio determined the operability of the active switch devices installed at the customer premises using a representative sample group of customers. There are two components of device operability: the setup factor and the shed factor.

- ***Setup Factor*** - Quantifies the proper installation and configuration of switch devices in the sample group (including the physical installation, wiring, and programming)
- ***Shed Factor*** - Quantifies performance during actual load control events for switches with the correct setup, and measures the switch effectiveness at achieving the programmed load shed

Combined, the setup and shed factors provide an overall operability rate, which is used to de-rate the program impacts and capacity.

Setup Factor

The setup factor used in this evaluation was established in the 2013 Operability Study, which occurs every four years. In March 2013, Duke Energy Ohio selected a random sample of 150 households with 158 switch devices[2] from the population of Power Manager participants in Ohio and Kentucky.[3] The sample size was designed to target ±5% precision at the 90% confidence level. The combination of households selected from Ohio and Kentucky met the ±5% precision at the 90% confidence level.

[2] Multiple switch devices may be installed at a single household with more than one air conditioning unit enrolled in the program.

[3] Due to timing and sample selection, future Operability Studies (i.e. PY2016 and beyond) will only include participant data from Ohio customers.

In July 2013, Duke Energy Ohio collected switch data from the sample group, downloading it directly from the switch devices. A total of 5 households were dropped from the operability study (reflecting 5 participating switches) due to the following reasons:

- 3 households due to access problems (gates on households, large dogs)
- 2 households with no data due to the switches not being on

Table 3. PY2013 Operability Group Removals

	Households	Switches
Beginning Sample Group	150	158
Removals from Sample Group	(5)	(5)
Final Sample Group	145	153

The final operability sample group size was 145 households with 153 load control devices. Table 4 summarizes the Operability group observations pertaining to the setup factor.

Table 4. Operability Group Observations of Setup Factor

Reason for Removal from Operability Study	Switch Device Count	Qualifying Multiplier	Weighted Factor
Switch disconnected from air conditioner	14	0.00	0
No switch present at customer premise	3	0.00	0
1.5 kW switch configured as 1.0 kW switch	6	0.67 (2/3)	4
Switch set up correctly	130	1.00	130
Total	**153**		**134**
Set-Up Factor	**0.876**		

Duke Energy Ohio calculated the setup factor to be 87.6%.

Setup Factor = Total Weighted Factor / Total Switch Device Count

Shed Factor

As defined in Appendix A, Duke Energy Ohio used the 97.5% shed factor from the last operability study findings in the PY2013 report.

Shed Factor = Total Weighted Factor / Total Switch Device Count

Operability Study Findings

The operability study performerd in 2013 revealed that Power Manager switch devices were operational at a 85.4% rate. Duke Energy Ohio applied this de-rate factor to all program switch devices to more accurately represent the available program capacity and kW reduction during events.

The following calculation determined switch operability:

*87.6% [2013 sample group setup factor] * 97.5% [2013 sample group shed factor] = 85.4%*

The historical operability study results are shown in Table 5.

Table 5. Historical Operability Study Performance

Program Year	Setup Factor	Shed Factor	De-Rating Factor
PY2013	87.6%	97.5%	85.4%
PY2010	N/A	N/A	93.1%[4]

Impact Study

The program event Impact results were calculated using a duty cycle analysis model. An hourly historical duty cycle, or percentage of runtime, is recorded and later collected in the field for the customers selected to be in the EM&V group. The historical profile is created by instructing the switch devices to record key run time data on specified days. The dates saved are non-event program days with high temperatures, typically above 90°. Each "saved day" goes into the switch device historical profile as a weighted proportion. This process creates a unique historical air conditioning usage profile which serves as a representative sample for the larger general population of switch devices in the program. The historical profile is compared to the actual air conditioning run time during an event day. Event impacts are calculated on an hourly basis. During PY2014, there was a 1-hr required PJM test event. Due to a lack of events, Duke Energy Ohio used impact evaluation models (potential impact kW) from the PY2013 impact report to estimate MW impacts shown in Table 6.[5]

Table 6. Impact Results on 8/26/2014

Date	Hour (EDT)	De-Rated Impact (MW)	Switch Count (1.5 kW)	Switch Count (1.0 kW)	Temperature (°F)
8/26/2014	17	48.38	6,865	41,232	88°

Impact Per Switch Realization Rate

Table 7 details the realization rate between the actual impact per switch and expected impact per switch on an event day. These numbers are not de-rated or accounted for line losses. The actual impact per switch is based on the average impact for each cycling strategy: Target Cycle and True Cycle. Those averages are then weighted according to the switch percentages in the population. The actual impact per switch will vary during each event day based off temperatures and programming in the switch. The calculation for the realization rate is:

Realization Rate (%) = Actual Impact / Expected Impact

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[3] De-Rating factors prior to 2010 were not split out between Setup and Shed Factors.

[4] The PY2013 load impact methodology is provided in Appendix B.

Table 7. Impact Realization Rate

Date	Hour (EDT)	Expected Impact/Switch	Actual Impact/Switch	Realization Rate
8/26/2014	17	1.5 kW	1.48 kW	98.7%
		1.0 kW	1.05 kW	105.0%

PY2013 Load Impact Results

Table 8 details the calculated demand reduction per switch device under peak normal weather and using the de-rated impact from the operability study.

Table 8. Demand Reduction per Switch Device

Switch Type	Control Strategy	Potential Impact (kW)	De-rating Factor	De-rated Impact (kW)
Cannon	Target Cycle 1.5	1.53	0.854	1.31
	Target Cycle 1.0	1.02	0.854	0.87

PY2014 Program Capacity

Table 9 details the PY2014 Ohio Power Manager Program capacity, adjusted for peak normal weather, de-rated, and calculated at the point of generation. The loss factor used for Ohio in PY2014 was 6.3%.

Table 9. PY2014 Program Capacity, Ohio (MWs)

State	Control Strategy	May	June	July	August	September	Average Summer Capability
Ohio	Cycling	47.88	47.91	47.84	47.72	47.52	47.77

Independent Third-Party Review of Impacts

Duke Energy Ohio conducted the impact analysis of the Power Manager Program. Cadmus reviewed the results presented in this report to ensure proper methodology. With limited events called during PY2014, Duke Energy Ohio’s approach of using historical data was both cost-effective and justified.

Cadmus reviewed the current operability rate for PY2014 of 85.4% and determined Duke Energy Ohio is in reasonable standing.

Cadmus determined that Duke Energy Ohio’s impact evaluation provides an accurate estimate of PY2014 program impacts.

Appendix A

The following data is from the PY2013 Power Manager EM&V Report

2013 Operability Study for Ohio Cannon Load Control Devices

Cannon devices were instructed to execute a Target Cycle. With Target Cycle, each device calculates a unique shed time for each hour of load control based on the Amps parameter for the attached AC unit (entered into the device at installation) and the expected hourly run-time of the attached AC unit stored in the historical profile registers. Expected run-time is accumulated in the historical profile by saving run-time of the attached AC unit on days with weather conditions similar to load control days.

Table 10 shows the list of events occurred during the summer of 2013 for Cannon switches. The data collection included both device scan data and device data logs. Device data logs contain hourly shed minutes and hourly run-time for the attached AC unit. We obtained shed minutes during each hour of load control from device data logs and this information was used to assess shed performance of devices.

Table 10. OH PM events for Cannon devices

Event Date	Event Duration (EDT)
7/15/2013	2:30 – 5:00 pm
7/16/2013	2:30 – 6:00 pm
7/17/2013	2:30 – 5:00 pm
7/18/2013	2:30 – 5:00 pm

The shed factor measures correct response by properly configured devices to paging signals sent immediately prior to and during a load control event. In the PY2013 study, 136 devices were properly configured to shed. The shed factor was calculated by dividing the total non-zero shed event hours by total event hours for each device. Table 11summarizes the results pertaining to the shed factor. From this data, the shed factor estimate is 97.5%.

Table 11. Shed Factor

Factor	Count	Weighted Factor
0	1	0
0.17	1	0.17
0.26	1	0.26
0.63	1	0.63
0.83	1	0.83
0.9	2	1.8
0.93	1	0.93
1	128	128
Sum	**136**	**132.62**
Shed Factor	**0.975**	

Shed Factor = Sum of Weighted Factor / Total count

Appendix B

The following data is from the PY2013 Power Manager EM&V Report

Load Impact Results – 2013 Impact Report

Load impacts described in this section are computed with population estimates of load reduction per switch, rather than load reduction per household. Simulation results are converted to load reduction per switch using the factor of 1.048 switches per household. Population estimates of load reduction per household are divided by this factor to get corresponding population estimates of load reduction per switch. The estimate of switches per household is determined from the M&V sample.

Table 12 shows de-rating factors used for the 2013 impact evaluation. Cannon factors in Ohio were determined by operability studies conducted in 2013.

Table 12. De-Rating Factors for Impact Evaluation

Switch Type	Ohio
Cannon	0.854

PM load control was activated in Ohio on 7 days during the summer of 2013. Table 13 gives hourly impact results adjusted with line losses for each control day.

Table 13. 2013 PM Impact Results

Event Date	Hour	PM Impact (MW)
7/15/2013	16	47.9
	17	48.8
7/16/2013	16	47.0
	17	48.4
	18	47.9
7/17/2013	16	56.3
	17	56.2
7/18/2013	16	49.1
	17	50.4
8/28/2013	16	56.6
9/10/2013	16	47.2
	17	47.0
9/11/2013	15	37.0
	16	38.3
	17	42.0

Table 14 gives estimated load reduction per switch not adjusted for line losses under peak normal weather conditions for different PM program options and load control technologies. Table 15 shows the summer monthly load reduction adjusted for line losses under peak normal weather conditions. Table 16 shows the peak normal weather conditions used to calculate the results. The system peak is assumed

to occur in the hour 4:00-5:00 pm EDT in Ohio (impacts for hour 18 reported due to requirement by PJM).

Table 14. Shed kW/switch with Peak Normal Weather

Switch Type	Control Strategy	Potential Impact	De-rated Impact
Cannon	TC 1.5	1.53	1.31
	TC 1.0	1.02	0.87

Table 15. Monthly Peak Normal Weather Load Reduction De-rated Impacts, Adjusted for Line Losses for Cycling

State	Control Strategy	May	June	July	August	September	Summer Capability
Ohio	Cycling	45.6	45.7	46.1	46.1	46.1	46.1

Table 16. Peak Normal Weather

Hour	Ohio	
	Temp	Dewpt
11	85.3	71.8
12	87.6	71.9
13	89.9	71.9
14	92.0	71.5
15	93.1	70.7
16	93.9	70.5
17	92.5	70.0
18	92.4	69.5

The last column of Table 15 shows the weighted average capability of the Power Manager program across the summer months in 2013. This weighted average value is calculated using the summer monthly values and weighting them based on the probability of experiencing an annual peak load in that month.

Evaluation of the Smart $aver Nonresidential Custom Incentive Program in Ohio

November 15, 2015

Evaluation, Measurement, & Verification for Duke Energy Ohio

The Cadmus Group, Inc.

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Prepared by:

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NORESCO
BuildingMetrics

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Executive Summary

Duke Energy Ohio (DEO) engaged Cadmus, along with NORESCO and BuildingMetrics as subcontractors, (evaluation team) to perform an impact evaluation of the Smart $aver® Custom Incentive Program.

The evaluation team performed an impact analysis using measurement and verification (M&V) on a sample of 33 project participants. The evaluation team estimated a savings realization rate (RR) for each project and projected this RR onto the program participant population in the evaluation period.

TecMarket Works (along with NORESCO and BuildingMetrics as subcontractors) completed site visits and prepared M&V reports for 33 sites visited as part of the evaluation. In March 2015, the evaluation contract was transferred to Cadmus, with NORESCO and BuildingMetrics as subcontractors. Cadmus completed this report describing the results of the evaluation.

The evaluation period includes 164 projects completed by July 2015, with application received dates between January 2010 and March 2014. TecMarket Works performed verification site visits in two phases during fall of 2013 and winter of 2014.

Key Findings and Recommendations

In conducting this evaluation, the evaluation team identified the following key findings and recommendations.

Engineering Impact Estimates: Key Findings and Recommendations

- The program achieved an overall kWh realization rate (RR) across all projects of 95%, indicating it produced very close to expected savings on average. However, the individual RR ranged from 10% to 963%.
- Lighting and HVAC projects performed very close to program estimates (kWh RR of 97% and 101% respectively), while process projects underperformed relative to program estimates (kWh RR of 78%).
- Fourteen percent (14%) of the evaluated program savings are associated with freeriders, based on participants' responses to the program participation application survey. Therefore, the program net of freeridership ratio is 86%.
- HVAC projects with low RRs generally resulted from suboptimal or not fully implemented control strategies. Post-installation inspections or project commissioning can be used effectively to obtain the full energy savings available from HVAC control measures.
- Process projects with low RRs were generally characterized as variable frequency drive (VFD) projects with more operating hours at higher loads than assumed by program calculations. The VFD loads were less variable than assumed by program calculations. The evaluation team recommends reviewing VFD project load history assumptions during project screening.
- The large variations in RRs were caused by incorrect applications of the ASHRAE 90.1 Energy Standard to the project baseline in building performance models developed to estimate

expected savings. The evaluation team recommends more careful screening of new construction or renovation projects using ASHRAE 90.1 as the baseline.

- Lighting produced 32% of total program evaluated savings. Based on the review, some lighting projects could go through the Prescriptive Programs, reducing the burden on customers when filling out applications and the burden on Duke Energy staff when reviewing applications.
- Program calculations for lighting projects generally excluded consideration of HVAC interactive effects. The evaluation team suggests all lighting projects include interactive effects using multipliers available in the Ohio Technical Reference Manual (TRM).

Table 1 shows the program's *expected* (claimed, prior to the application of the RR from the previous Evaluation, Measurement, and Verification study), evaluated gross, and net energy savings by measure type.

Table 1. Program *Expected,* Evaluated Gross, and Net Energy Savings by Measure Type

Measure Type	Population Size	*Expected* Population kWh Impact	Realization Rate	Gross Evaluated Population kWh Impact	Net of Freeridership Ratio	Net Evaluated Population kWh Impact
Lighting	86	18,616,348	97%	18,064,815	86%	15,535,741
HVAC	49	30,108,389	101%	30,330,099		26,083,885
Process	29	11,418,348	78%	8,849,344		7,610,435
Total	**164**	**60,143,084**	**95%**	**57,244,257**	**86%**	**49,230,061**

Table 2 and Table 3 show the *expected*, evaluated gross, net summer coincident peak (CP), and non-coincident peak (NCP) demand savings for the program.

Table 2. Program *Expected,* Evaluated Gross, and Net CP Demand Savings by Measure Type

Measure Type	Population Size	*Expected* Population CP kW Impact	Realization Rate	Gross Evaluated Population CP kW Impact	Net of Freeridership Ratio	Net Evaluated Population CP kW Impact
Lighting	86	2,318	124%	2,868	86%	2,467
HVAC	49	2,775	175%	4,857		4,177
Process	29	1,195	94%	1,125		967
Total	**164**	**6,288**	**141%**	**8,850**	**86%**	**7,611**

Table 3. Program *Expected,* Evaluated Gross, and Net NCP Demand Savings by Measure Type

Measure Type	Population Size	*Expected* Population NCP kW Impact	Realization Rate	Gross Evaluated Population NCP kW Impact	Net of Freeridership Ratio	Net Evaluated Population NCP kW Impact
Lighting	86	2,742	168%	4,612	86%	3,966
HVAC	49	6,329	119%	7,512		6,461
Process	29	1,436	74%	1,065		916
Total	**164**	**10,507**	**126%**	**13,189**	**86%**	**11,342**

Table 4 shows the net energy and demand savings per unit and total for the M&V sampled projects.

Table 4. Net Energy and Demand Savings per Unit and Total for Sampled Projects

Measure Type	Number of Sampled Units	Evaluated Net Per Unit kWh	Evaluated Net Per Unit NCP kW	Evaluated Net Per unit CP kW	Evaluated Net Sample Total kWh	Evaluated Net Sample Total NCP kW	Evaluated Net Sample Total CP kW
Lighting	10	54,457	11	7	544,567	111	67
HVAC	16	982,816	202	170	15,725,056	3,228	2,718
Process	7	215,982	17	15	1,511,875	119	107

Evaluation Parameters

Table 5 lists the parameters reviewed in this evaluation, which consisted of gross savings realization rate for energy, CP, and NCP demand.

Table 5. Evaluated Parameters with Value, Units, and Precision and Confidence

Gross Savings	Value	Units	Confidence/ Precision
Energy RR	95%	N/A	90%/±9%
NCP demand RR	126%	N/A	90%/±10%
CP demand RR	141%	N/A	90%/±10%

Table 6 lists the start and end dates for sampling and review activities conducted for the impact evaluation.

Table 6. Sample Period Start and End Dates and Dates Evaluation Activities Conducted

Evaluation Component	Sample Period*	Dates Conducted	Total Conducted
Site visits	January 2010 – March 2014	Fall 2013 and Winter 2014	33
*Sample period is identified based on the application received dates.			

Introduction and Purpose of Study

Summary of the Evaluation

This report presents the results of an impact evaluation of the Ohio Smart $aver Nonresidential Custom Incentive Program (Custom Program).

Evaluation Objectives

The evaluation team performed an impact analysis using a measurement and verification (M&V) plan developed by NORESCO. The M&V plan followed the International Performance Measurement and Verification Protocol (IPMVP),[1] separating projects into lighting, HVAC, and process categories and drawing size-stratified samples from each category. The impact analysis sought to estimate a savings realization rate (RR) for each category that could be projected into the full program participant population in the evaluation period.

The sample was pulled from the list of customers that submitted an application for participation in the program. The program received the first application in January of 2010 and paid the first incentive in January of 2012. Two series of samples were pulled in May 2013 (20 projects) and June 2014 (15 projects) from the program opportunity tracking database.[2] The sites were visited during fall of 2013 and winter 2014.

The evaluation team based total impact savings on savings identified from 33 sites visited. The team then extrapolated the savings to all completed projects with application receipt dates ranging from January 2010 through March 2014. March 2014 was the last application received date in the tracking database when the last sampled was pulled. The evaluation period includes all projects completed by June 2015, with application received dates from January 2010 through March 2014.

Researchable Issues

In completing this study, the evaluation team performed the following activities:

- Estimated kWh, non-coincident peak (NCP) kW, and coincident peak (CP) kW savings for each project in the sample;
- Calculated kW and kWh RRs for each project;
- Calculated average kW and kWh RRs by lighting, HVAC, and process projects;
- Calculated confidence intervals around the RRs; and
- Identified causes for differences between evaluated savings and *ex ante* savings estimates.

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1 International Performance Measurement and Verification Protocol. Concepts and Options for Determining Energy and Water Savings. Volume 1. Prepared by Efficiency Valuation Organization. www.evo-world.org. September, 2010. EVO 10000 – 1:2010.

2 Two sites later dropped out of the verification site visits.

Description of Program

The Duke Energy Custom Program intends to supplement the Smart $aver Nonresidential Prescriptive Incentive Program, which provides prescriptive rebates for preselected measures. Customers wishing to install measures not included in the Smart $aver Nonresidential Prescriptive Incentive Program list may apply for a rebate through the Custom Program. Table 7 lists the number of completed projects within the sample frame.

Table 7. Program Participation Count[3]

Program	Completed Projects
Smart $aver Nonresidential Custom Incentive Program	164

[3] The evaluation team is basing the program participation count on the number of applications received during the evaluation period that resulted in complete projects by June 2015.

Methodology

Overview of the Evaluation Approach

The evaluation team conducted an impact evaluation, performing an engineering analysis on a sample of 33 out of 164 projected program participants during the evaluation period. This impact analysis sought to estimate a savings RR for each category (lighting, HVAC, and process) that could be prospectively projected onto the full program participant population.

Study Methodology

The impact methodology consisted of an engineering analysis following the IPMVP.[4] For the final sample group, the evaluation team separated the total number of projects into lighting, HVAC, and process categories and drew samples from each category. Field staff conducted site surveys and installed metering equipment to gather data according to the M&V plan, taking pre- and post-installation measurements whenever possible. The team developed energy and demand savings estimates for each sampled project.

Data Collection Methods, Sample Sizes, and Sampling Methodology

During the sampling phase of the evaluation, the evaluation team projected a total population of 175 program participants for the evaluation period. The evaluation team chose a sample of 32 projects to meet a sampling error of ±10% at 90% confidence. The team stratified the participant population by project type and size to achieve an efficient sample. In particular, the evaluation included three very large HVAC projects in a “certainty” stratum to improve overall sample precision.

Number of Completes and Sample Disposition for Each Data Collection Effort

Table 8 lists the sample disposition for the impact study.

Table 8. Status of Sample with Application Received Dates January 2010 – March 2014

Group	Stratum	Sample Size	Completed	Notes
Lighting	1	7	10	Oversampled lighting in year 1
HVAC	1	3	3	Sample completed
	2	7	7	Sample completed
	3	7	6	One site dropped from the study
Process	1	8	7	One site dropped from the study
Total		**32**	**33**	

4 International Performance Measurement and Verification Protocol. *Concepts and Options for Determining Energy and Water Savings. Volume 1*. Prepared by Efficiency Valuation Organization. www.evo-world.org. September, 2010. EVO 10000–1:2010.

Expected and Achieved Precision

The evaluation team expected the sample design to return a sampling error of ±10% at 90% confidence. Based on the final sample disposition and observed sample variability, the evaluation achieved a precision of ±9% and ±10%, for energy and demand savings respectively, at 90% confidence.

Description of Baseline Assumptions, Methods, and Data Sources

For most projects included in the M&V sample, the evaluation team used existing equipment as the baseline assumption. Renovation and new construction projects used ASHRAE 90.1 as the baseline.

Description of Measures and Selection of Methods by Measures or Markets

The custom program encompasses a wide selection of measures. Current applications include a variety of lighting, HVAC, and industrial process projects. The evaluation team evaluated all projects in compliance with the IPMVP.[5]

Use of TRM Values and Explanations if TRM Values not Used

The evaluation team used primary data collection, engineering algorithms, building energy simulation modeling, and statistical regression modeling to conduct this study. As this is a custom program, Technical Reference Manual (TRM) algorithms and values generally do not apply. TRM algorithms for lighting measures and HVAC interactive effects were used, as applicable.

Validity Threats, Bias Sources of Bias, and Methods for Addressed These

When feasible, the study utilized a pre- and post-M&V protocol. Due to the project's timing, the evaluation team took post-only measurements for most projects. Use of post-only measurements for these projects was not expected to bias the results significantly. The team assigned projects to a measure category (e.g., lighting, HVAC, process) and then stratified the projects by kWh savings. The team selected sites at random within each stratum. Two projects in the sample did not complete before the end of the study, and one site experienced a data logger failure that required the team to perform a desk review on the project, an action not expected to bias the results. The team employed state-of-the-art engineering modeling techniques to reduce engineering bias.

Snapback and Persistence

For two key reasons, the team did not view snapback as a factor for the Custom Program:

- First, customers participating in custom programs typically do not base energy-intensive investment decisions on the degree of savings achieved from previously installed energy efficiency measures. Instead, these customers tend to base energy efficiency investment decisions on benefits and costs associated with a single project requiring an investment decision.
- Second, snapback is a theoretical concept. To date, an evaluation has not been conducted of an energy efficiency program that reliably has documented a snapback effect. Snapback studies,

[5] *IPMVP Option A–Partially Measured Retrofit Isolation*. See Impact section for more information.

based on the last 20-plus years of California's well-funded and aggressive energy efficiency portfolio, indicate snapback does not exist. California's per-person energy consumption has remained flat for 20 years, despite energy efficiency programs; other states not offering aggressive portfolios of energy efficiency programs over the same period have increased their per-person energy consumption. Based on these data, if snapback existed to any degree, per-person energy consumption in California would have increased at the same rate as states not offering a long history of energy efficiency programs. The evaluation team does not believe snapback serves a factor for the Duke Energy Custom Program and, as such, did not incorporate this approach into this study.

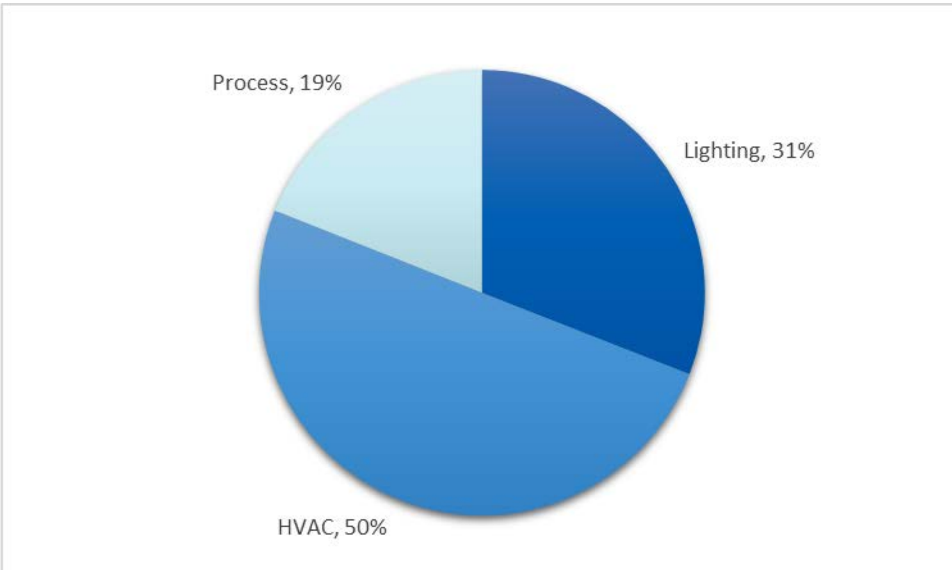
The evaluation team did not address how long these savings would likely persist as the available data's time span proved insufficient to address this issue. Rather, the team compared project-life estimates claimed by the program to measure-life estimates contained in the Indiana Evaluation Framework.

Impact Evaluation Findings

Engineering-Based Impact Analysis

The impact evaluation included the following elements: a tracking system review, sample design and selection, an engineering review of the custom program applications, field M&V of selected projects, data analysis, and reporting. For the sample plans for on-site logging, the evaluation team obtained tracking data from Duke Energy for pre-approved projects with applications that were in various stages of completion, received from January 2010 through March 2014. Figure 1 shows the breakdown of *expected* (claimed, prior to the application of the RR from the previous Evaluation, Measurement, and Verification study) energy savings by measure for these projects.

Figure 1. *Expected* Energy Savings by Project Type



Sample Design

The evaluation team assigned projects into three categories: lighting, HVAC, and process. The team then grouped projects into similar technology categories to minimize variations in RRs across projects and to provide better precision in overall program results. RRs across the technology categories also provided an indication of project types performing closer to original expectations.

The program tracking system is based on the Sales Force customer relationship management tool. Program staff enter project leads into the Sales Force system and track them as they progress in the system. In general, the process takes the following form:

1. ***Initial Application***. A customer submits an application for the project, including a project description and energy savings calculations.

2. ***Application Review***. A Duke Energy contractor reviews the application for program eligibility and reasonableness. Modifications are made to savings estimates as necessary. Project cost-effectiveness is calculated and determines the incentive offer.
3. ***Proposal to Customer***. A rebate proposal, based on the reviewed and adjusted (as necessary) savings estimate and incentive offer, is presented to the customer.
4. ***Contract Approval***. The customer accepts the incentive and plans to move forward with the project.
5. ***Project Completion***. The customer completes the project and receives the incentive.

Projects that are at the Proposal to Customer stage are put in a list of potential candidates. Once the project proceeds to Contract Approval, it is eligible for sampling. The intention is to capture as many projects in the contract approval phase, before construction begins, to obtain pre-installation data. Note, once a project is closed out and paid, the final record is entered into Duke's data warehouse, which is a database that houses participation records, the list of custom measures, and the impacts associated with each measure. The impacts claimed by the program team for each custom project are modeled in DSMore software to determine the avoided costs associated with the custom project. During the DSMore modeling, minor updates to the impacts can occur, and thus it is the impacts after DSMore modeling that are captured in the data warehouse and considered "claimed."

The sampling plan incorporates a stratified random sample approach, where projects are stratified according to size and technology type (i.e., lighting, HVAC, or process) and are sampled randomly within each stratum. The evaluation team separated Lighting and Process projects into three, size-based strata.

The team calculated the total sample size using the following equation: [6]

$$n = \frac{\left(\sum_k \left(kWh_k \times cv_k\right)\right)^2}{\left(\frac{P \times kWh}{Z}\right)^2 + \sum_k \frac{\left(kWh_k \times cv_k\right)^2}{N_k}}$$

Where:

n = total sample size required

kWh_k = estimated savings from group k

cv_k = assumed coefficient of variation for group k

P = desired precision

[6] Bonneville Power Administration (BPA). *Sampling Reference Guide*. Research Supporting an Update of BPA's Measurement and Verification Protocols. August 2010.

KWh = total kWh savings

Z = z statistic (1.645 at 90% confidence)

N_k = population size of group k

The team allocated samples to each group using the following equation:

$$n_k = n \times \frac{kWh_k \times cv_k}{\sum_k (kWh_k \times cv_k)}$$

Table 9 summarizes total program savings by sample stratum, expected variations in the project RRs, the number of projects in each stratum, and sample sizes required to meet the design's relative precision at the program level. This table represents a projection of the final program population at the time of sample selection. This projection assumed all customers in the Contract Approval stage would complete construction on their projects and would receive incentives in this evaluation cycle.

Table 9. Sample Selection for Custom Component of Ohio Custom Program

Group	kWh	CV	Total Projects	Sample Size
Lighting 1	13,883,797	0.42	88	7
HVAC 1	8,429,798	0.54	3	3
HVAC 2	9,751,467	0.54	10	7
HVAC 3	10,594,666	0.54	43	7
Process 1	13,526,905	0.5	31	8
Total			**175**	**32**

The team used coefficients of variation by project type from the 2011 DEO Custom program impact evaluation to design the sample.

Sample Status

The evaluation team could not complete the sample as designed, given oversampled lighting projects early in the evaluation, and two HVAC projects dropped from the study. Table 10 summarizes the sample achieved.

Table 10. Sample Status

Group	Stratum	Sample Size	Completed	Notes
Lighting	1	7	10	Oversampled during the first year of evaluation
HVAC	1	3	3	Sample completed
	2	7	7	Sample completed
	3	7	6	One site dropped
Process	1	8	7	One site dropped
Total		**32**	**33**	

Table 11 lists the key characteristics of sampled projects.

Table 11. Summary of *Expected* Savings for Sampled Projects

	Customer	Group	Project Type	*Expected* kWh	*Expected* NCP kW	*Expected* CP kW
1	[Redacted]	Lighting	High bay fixture retrofit	29,052	6	6
2	[Redacted]	HVAC	Whole building retrofit	887,484	146	122
3	[Redacted]	HVAC	VAV conversion	789,375	73	44
4	[Redacted]	HVAC	Window replacement	1,032	26	25
5	[Redacted]	HVAC	Lighting and HVAC upgrades	2,420,314	307	247
6	[Redacted]	HVAC	DDC upgrade	2,192,110	291	38
7	[Redacted]	HVAC	Chiller replacement	220,000	4	4
8	[Redacted]	Lighting	Lighting upgrade	47,429	10	4
9	[Redacted]	Process	Dry cooler	649,824	0	0
10	[Redacted]	Process	Air compressor upgrade	612,650	70	70
11	[Redacted]	HVAC	Controls upgrade	889,566	408	142
12	[Redacted]	Lighting	Exterior lighting retrofits at three schools	193,412	7	0
13	[Redacted]	Lighting	Interior lighting retrofit	27,078	7	7
14	[Redacted]	Process	Refrigeration compressor upgrade	437,515	50	(7)
15	[Redacted]	Process	VFD retrofit	15,879	4	6
16	[Redacted]	HVAC	Chiller upgrade	346,708	18	18
17	[Redacted]	Lighting	LED retrofit at three stores	12,611	2	2
18	[Redacted]	Lighting	Refrigerated case lighting at 17 stores	130,021	12	10
19	[Redacted]	Process	Heat sealer	360,060	41	41
20	[Redacted]	Lighting	Interior lighting retrofit	138,545	17	16
21	[Redacted]	Process	VFD air compressor	98,972	11	11
22	[Redacted]	Lighting	LED retrofit at two stores	35,615	7	8

	Customer	Group	Project Type	Expected kWh	Expected NCP kW	Expected CP kW
23	[Redacted]	HVAC	Add VFD to existing chiller	532,027	79	39
24	[Redacted]	Lighting	LED retrofit at one store	3,766	1	1
25	[Redacted]	HVAC	New chilled water plant	730,151	142	(49)
26	[Redacted]	HVAC	Upgrades to 6 schools	3,448,380	633	217
27	[Redacted]	HVAC	New construction	806,200	310	79
28	[Redacted]	HVAC	Lab fume hood VAV conversion	1,957,873	415	349
29	[Redacted]	Process	Vending machine controllers	93,447	11	11
30	[Redacted]	HVAC	Chiller replacement	580,966	225	193
31	[Redacted]	HVAC	Energy management system	694,307	0	0
32	[Redacted]	Lighting	Metal halide fixture replacement	35,021	8	8
33	[Redacted]	HVAC	Energy management system	244,110	26	19

Application Review

Duke Energy provided the evaluation team with a customer application for each site, along with any supporting documentation. The team reviewed each application to better understand the measures included and expected savings. The Duke Energy Business Relations Manager associated with each sampled site contacted customers to secure participation in the evaluation. Once contact was established with the customer, the team followed up with the customer via phone calls and e-mails to gain additional information about the facility, measures, and construction schedule.

M&V Plan Development

For each sampled site, NORESCO developed an M&V plan that covered the following topic areas:

- ***Introduction:*** a description of the project and the measures installed, including the following: sufficient detail to understand the M&V project scope and methodology; savings by measure and a list of M&V priorities for measures within the project; and baseline assumptions.
- ***Goals and Objectives:*** a list of overall goals and objectives of M&V activity.
- ***Building Characteristics:*** an overview of the building, with a summary table of relevant building characteristics, such as building size (square footage), number of stories, building envelope, lighting system, and HVAC system.
- ***Data Products and Project Output:*** specific end products, such as kWh savings, coincident and noncoincident kW savings, therm savings, and a list of raw and processed data to be supplied at the study's conclusion.

- ***M&V Option:*** a description of the M&V Option, according to the IPMVP. A summary follows of these options:
  - ***Option A—Partially Measured Retrofit Isolation***. Savings under Option A are determined by partial field measurements of energy use of systems to which an energy conservation measure (ECM) was applied, separate from the rest of the facility's energy use. Measurements may be short-term or continuous. Partial measurement means some parameters affecting a building's energy use may be stipulated if the total impact of possible stipulation errors does note prove significant to resultant savings. Savings are estimated from engineering calculations, based on stipulated values and spot, short-term, and/or continuous post-retrofit measurements.
  - ***Option B—Retrofit Isolation.*** Savings under Option B are determined by field measurements of the energy use of systems to which an ECM was applied, separate from energy use by the rest of the facility. Savings are estimated directly from measurements. Stipulated values are not allowed.
  - ***Option C—Whole Facility.*** Savings under Option C are determined by measuring energy use at the whole-facility level. Short-term or continuous measurements are taken throughout the post-retrofit period and are compared to 12 to 24 months of pre-retrofit data. Savings are estimated from analysis of whole-facility utility meter or submeter data, using techniques ranging from simple comparisons of utility bills to regression analysis.
  - ***Option D—Calibrated Simulation.*** Savings under Option D are determined through building energy simulation[7] of energy use by components or by whole facility, calibrated with hourly or monthly utility billing data and/or end-use metering.
- ***Data Analysis:*** a list of engineering methods and/or equations used to generate the data products identified above and a list of data sources, either measurements or stipulated values from secondary data sources.
- ***Field Data Points:*** a list of specific field data points collected through the M&V plan. Field data were composed of survey data, one-time measurements, and time series data, collected from data loggers installed for the project, or trend data, collected from a site's energy management system (EMS).
- ***Data Accuracy:*** a list of meter and sensor accuracy for each field measurement point.
- ***Verification and Quality Control:*** a list of steps taken to validate the accuracy and completeness of raw field data.
- ***Recording and Data Exchange Format:*** a list of formats of raw and processed data files used in the analysis and supplied as data products.

[7] DOE-2 is a commonly used building energy simulation program.

Appendix B contains the M&V plans, along with the processed data summary and project results. Table 12 summarizes M&V plans for each sampled site.

Table 12. M&V Plan Summary

Customer Number	Customer	Project Type	IPMVP Option	Baseline Assumption	M&V Plan Summary
1	[Redacted]	Lighting	A	Existing equipment	Post-installation current logging of a sample of lighting circuits
2	[Redacted]	HVAC	D	ASHRAE 90.1	Post-renovation logging of apartments and common areas to establish occupancy patterns and plug loads
3	[Redacted]	HVAC	A	Existing equipment	Post-installation monitoring of installed measures
4	[Redacted]	HVAC	D	ASHRAE 90.1	On-site survey to verify installation of measures and develop data for simulation model inputs
5	[Redacted]	HVAC	D	Existing equipment	On-site survey and short-term trend logging of affected systems to update eQuest model
6	[Redacted]	HVAC	D	Existing equipment	Post-installation, on-site survey and monitoring of installed measures to update eQuest model
7	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
8	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
9	[Redacted]	Process	A	Existing equipment	On-site survey and monitoring of installed measures
10	[Redacted]	Process	B	Existing equipment	Pre/post-monitoring of installed measures
11	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
12	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
13	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
14	[Redacted]	Process	A	Existing equipment	On-site survey and monitoring of installed measures
15	[Redacted]	Process	A	Existing equipment	On-site survey and monitoring of installed measures
16	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
17	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures

Customer Number	Customer	Project Type	IPMVP Option	Baseline Assumption	M&V Plan Summary
18	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
19	[Redacted]	Process	A	Existing equipment	On-site survey and monitoring of installed measures
20	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
21	[Redacted]	Process	A	Existing equipment	On-site survey and desk review of engineering calculations
22	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
23	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
24	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
25	[Redacted]	HVAC	A	ASHRAE 90.1	On-site survey and monitoring of installed measures
26	[Redacted]	HVAC	C	Existing equipment	Pre/post billing analysis at two schools, comprising 90% of project savings
27	[Redacted]	HVAC	D	ASHRAE 90.1	Short-term monitoring of lighting circuits to establish eQuest model lighting schedules
28	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
29	[Redacted]	Process	A	Existing equipment	On-site survey and monitoring of installed measures
30	[Redacted]	HVAC	A	Existing equipment	On-site survey and monitoring of installed measures
31	[Redacted]	HVAC	D	Existing equipment	Short-term monitoring of affected systems to update eQuest model
32	[Redacted]	Lighting	A	Existing equipment	On-site survey and monitoring of installed measures
33	[Redacted]	HVAC	D	Existing equipment	On-site survey and short-term monitoring of affected systems to update eQuest model

Measurement and Verification

TecMarket Works subcontractors collected field data according to the M&V plan, with personnel from NORESCO training the contractors. Metering equipment included a combination of the following: portable data acquisition equipment (capable of measuring temperature, relative humidity, and electric current); true electric power meters; and trend logs from facility control systems. Appendix B describes specific instrumentation used at each site (also summarized in Table 13). The evaluation team also obtained survey data and spot measurements during meter installation. The team configured metering equipment and/or trend logs to collect data for a period of three to four weeks. One process site had instrumentation installed over two separate, four-week periods to capture winter and summer operations.

Table 13. M&V Approach Summary

Site Number	Customer	Project Type	Measurements Taken	Monitoring Duration
1	[Redacted]	Lighting	Spot true electric power and time-series lighting circuit current measurements	3 weeks
2	[Redacted]	HVAC	Residential unit feeder circuit current, common area circuit current	3 weeks
3	[Redacted]	HVAC	Trend logging of AC unit flow, VFD speed, and static pressure setpoint. Logging of VFD input power and outdoor temperature and humidity	3 weeks
4	[Redacted]	HVAC	On-site survey to develop simulation model inputs. No monitoring done	N/A
5	[Redacted]	HVAC	Trend logging of fan speed, static pressure, and supply air, return air, mixed air and outdoor air temperatures at a sample of air handlers; outdoor temperature and humidity	4 weeks
6	[Redacted]	HVAC	Trend logging of chilled and hot water temperatures at central plant, supply temperatures, static pressure and VFD speeds at a sample of air handlers, outdoor temperatures and humidity	2 weeks
7	[Redacted]	HVAC	Power logging of lead and lag chillers, current logging of chilled water pumps, outdoor temperature and humidity	3 weeks
8	[Redacted]	Lighting	Spot true electric power and time series current measurements of a sample of lighting circuits	3 weeks
9	[Redacted]	Process	Power logging of chillers and dry cooler; current logging of chilled water and dry cooler pumps; and sump heater, outdoor temperatures, and humidity	3 weeks during summer and 3 weeks during winter
10	[Redacted]	Process	Power logging of new and replaced air compressor	5 days pre; 3 weeks post

Site Number	Customer	Project Type	Measurements Taken	Monitoring Duration
11	[Redacted]	HVAC	Trend logging of: supply, return, and mixed air temperatures; fan powers and speeds; static pressure and outdoor air at a sample of air handlers; outdoor temperatures and humidity	3 weeks
12	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of lighting circuits	3 weeks
13	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of lighting circuits	3 weeks
14	[Redacted]	Process	Spot power and post-installation kW monitoring of a new refrigeration compressor	5 weeks
15	[Redacted]	Process	Spot power and post-installation kW monitoring of a new VFD	3 weeks
16	[Redacted]	HVAC	Spot power and post-installation kW monitoring of all chillers in chilled water plant; trend logs of chilled and condenser water supply and return temperatures and flow rates; logging outdoor temperatures and humidity	3 weeks
17	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of lighting circuits	3 weeks
18	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of refrigerated case lighting circuits	3 weeks
19	[Redacted]	Process	Post-installation power monitoring of a sample of heat sealers across 7 stores; spot measurement of baseline heat sealer power	3 weeks per sealer
20	[Redacted]	Lighting	Post-installation light logging of a sample of fixtures	3 weeks
21	[Redacted]	Process	Spot measurement of compressor power	1 week pre; logger failed, no post time series data available
22	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of lighting circuits	4 weeks
23	[Redacted]	HVAC	Power logging of chiller kW; trend logging of chilled and condenser water supplies and return temperatures; outdoor temperatures and humidity	3 weeks

Site Number	Customer	Project Type	Measurements Taken	Monitoring Duration
24	[Redacted]	Lighting	Spot power and post-installation current monitoring of a sample of lighting circuits	3 weeks
25	[Redacted]	HVAC	Power logging of chiller and tower kW; trend logging of chilled and condenser water supply and return temperatures; chilled water flow rate	3 weeks
26	[Redacted]	HVAC	On-site survey to confirm installation and to identify non-routine baseline adjustments; cooling and heating degree days corresponding to billing data	12 months pre and 12 months post
27	[Redacted]	HVAC	Spot power and current monitoring of a sample of lighting circuits representing major usage areas	3 weeks
28	[Redacted]	HVAC	Trend logging of air-handlers' air flow, fan speeds, supply air temperature and static pressures, and outdoor temperatures and humidity; power and current logging of AHU fan power	3 weeks
29	[Redacted]	Process	Post-installation power monitoring of a sample of vending machines	3 weeks
30	[Redacted]	HVAC	Post-installation kW logging of new chiller, chilled water, and condenser water pumps; trend logging of chilled and condenser water supply and return temperatures, flow rates, and VFD speeds; cooling tower fan VFD speeds and outdoor temperatures	5 weeks
31	[Redacted]	HVAC	Fan kW measurements at a sample of AHUs; outdoor temperatures and humidity	3 weeks
32	[Redacted]	Lighting	Spot kW and post-installation current monitoring of affected lighting circuits	3 weeks
33	[Redacted]	HVAC	Trend logging of AHU supply, return and mixed air temperatures, static pressure and OA damper position; space temperatures and terminal discharge temperatures at a sample of VAV boxes	3 weeks

Calculations and Reporting

TecMarket Works subcontractors collected pre- and post-installation data and forwarded them to NORESCO for analysis. The evaluation team analyzed the data according to the M&V plan developed for each project. Data analysis consisted of pre- and post-comparisons of monitored data, extrapolated to annual consumption and demand using simple engineering models or linear regression techniques described in the M&V plan. The team then developed a site report for each completed project (included in Appendix B). Table 14 summarizes calculations and analysis techniques used.

Table 14. Calculation Approach Summary

Site Number	Customer	Project Type	Calculations
1	[Redacted]	Lighting	Engineering equations with parameters from metered data
2	[Redacted]	HVAC	eQuest model, revised based on on-site survey and monitored data
3	[Redacted]	HVAC	Developed average daily pre/post load profiles from monitored data and engineering calculations
4	[Redacted]	HVAC	Developed eQuest model from drawings and on-site survey
5	[Redacted]	HVAC	eQuest model revised based on on-site survey and monitored data
6	[Redacted]	HVAC	eQuest model revised based on on-site survey and monitored data
7	[Redacted]	HVAC	Post-installation regression model of new chiller plant, engineering equations to establish existing equipment baseline
8	[Redacted]	Lighting	Engineering equations with parameters from metered data
9	[Redacted]	Process	Post-installation regression model of chiller plant and drycooler; engineering equations to establish an existing equipment baseline
10	[Redacted]	Process	Developed average daily pre/post-load profiles from monitored data
11	[Redacted]	HVAC	Engineering equations with parameters from metered data
12	[Redacted]	Lighting	Engineering equations with parameters from metered data
13	[Redacted]	Lighting	Engineering equations with parameters from metered data
14	[Redacted]	Process	Developed average daily pre/post-load profiles from monitored data

Site Number	Customer	Project Type	Calculations
15	[Redacted]	Process	Developed average daily pre/post-load profiles from monitored data and engineering calculations
16	[Redacted]	HVAC	Post-installation regression model of new chiller plant; engineering equations to establish an existing equipment baseline
17	[Redacted]	Lighting	Engineering equations using parameters from metered data
18	[Redacted]	Lighting	Engineering equations using parameters from metered data
19	[Redacted]	Process	Developed average daily pre/post-consumption from monitored data and engineering calculations
20	[Redacted]	Lighting	Engineering equations with parameters from on-site survey and logger data
21	[Redacted]	Process	Engineering desk review based on pre-installation data
22	[Redacted]	Lighting	Engineering equations with parameters from on-site survey and logger data
23	[Redacted]	HVAC	Post-installation regression model of chiller with VFD; engineering equations to establish a baseline
24	[Redacted]	Lighting	Engineering equations with parameters from on-site survey and logger data
25	[Redacted]	HVAC	Post-installation regression model of chiller plant; engineering equations to establish a baseline
26	[Redacted]	HVAC	Weather-adjusted, pre/post-billing analysis
27	[Redacted]	HVAC	eQuest model, revised based on on-site survey and monitored data
28	[Redacted]	HVAC	Developed average daily AHU pre/post-load profiles from monitored data and engineering calculations; bin analysis conducted to estimate chiller savings
29	[Redacted]	Process	Developed average daily pre/post-load profiles from monitored data and engineering calculations
30	[Redacted]	HVAC	Post-installation regression model of new chiller plant, engineering equations to establish an existing equipment baseline
31	[Redacted]	HVAC	eQuest model updated with results of AHU monitoring

Site Number	Customer	Project Type	Calculations
32	[Redacted]	Lighting	Engineering equations with parameters from on-site survey and logger data
33	[Redacted]	HVAC	eQuest model updated with trend data and calibrated to billing data

Freeridership Calculations[8]

The evaluation team based the freeridership score on applicant responses to a battery of questions, placed into the program application form.

The freeridership question battery consisted of four questions, focusing on reasons leading to applicants' decisions to implement their energy efficiency projects. The scoring approach is linear, which allocates from 0% to 100% (full freeridership), based on responses provided by applicants to cause-and-effect questions.

During the evaluation period, the program team used the freeridership battery of questions to calculate the incentive levels for individual projects based on net expected savings. The program team may reject applicants with freeridership scores too high to make custom projects cost-effective at any incentive level. This approach allowed pre-screening of projects; so almost all projects proved cost-effective, with incentive levels paid based on net savings achieved.

This approach helps ensure program funds are spent obtaining net new energy savings. Other approaches typically used by other program implementers approve and incent projects before net savings are known, increasing the probability that program funds will be spent on projects that would have been implemented without the program's financial or informational assistance.

The freeridership battery of questions includes the following questions. The scoring approach *(in italics)*, used by Duke Energy to calculate freeridership scores for each applicant, does not appear on the application forms:

1. **Please indicate if the Duke Energy incentive is/was a factor in your choice to install the more energy efficient equipment instead of other equipment that may not have saved as much energy.**
    1. Incentive had an influence on the decision (*move to next question*)
    2. Incentive had no influence on the decision (*100% freerider*)
2. **If the Duke Energy incentive/program was a factor in your choice, please indicate how much of an influence the program incentive had on your energy efficient equipment choice. Please circle the number that best represents the influence the program has on your equipment choice. (***allowed responses = 0 to 10***)**

    0 = The Duke Energy program had no effect on our equipment choice (*100% freerider*).

[8] The freeridership calculations section will be redacted in the public version of the report.

1 or 2 = The Duke Energy program may have a minor influence on our energy efficient equipment choice (*1=80% freerider; 2=70% freerider*)

3 or 4 = The Duke Energy program had a positive influence in our selection of energy efficiency equipment (*3=50% freerider; 4=40% freerider*)

5 or 6 = The Duke Energy program was one of the key reasons for the energy efficient equipment choice, but not the most important reason (*5=30% freerider 6=25% freerider*)

7 or 8 = The Duke Energy program was one of the most important reasons for the energy efficient equipment choice (*7=15% freerider 8= 10% freerider*)

9 or 10 = The Duke Energy program was the primary reasons for the energy efficient equipment choice (*9=5% freerider 10=0% freerider*)

3. **Do you think that you would have selected the same level of energy efficiency if the program information and technical assistance would not have been available to you?**
   A. No. We would make a somewhat different equipment selection or not do the same project (*decrease freerider score by 10% but not lower than 0%)*
   B. Not sure what we would do (*no change in score*)
   C. Yes. We would make exactly the same equipment choice (*increase freeridership score by 10% but no higher than 100%)*

4. **Do you think that you would have selected the same level of energy efficiency if the program's financial incentive would not have been available to you?**
   A. No. We would make a somewhat different equipment selection or not do the same project (*decrease freerider score by 25% but no lower than 0%)*
   B. Not sure what we would do (*no change in score*)
   C. Yes. We would make exactly the same equipment choice (*increase freerider score by 25% but no lower than 100%*)

To calculate the freeridership ratio, the evaluation team examined the freeridership calculation workbooks prepared by Duke Energy for the projects that were part of the evaluation period. The workbook includes responses provided to the freeridership battery of questions provided by the program participant on the participation application form. In a few cases, the freeridership scores that were calculated from the scoring algorithm were manually changed (in a separate file) to allow projects with high freeridership to participate in the program. For this analysis, the evaluation team used the unaltered scores corresponding to the participants responses to the freeridership battery of questions. Of the 164 projects in the evaluation period, six did not have original records of the unaltered scores, and are omitted from the overall savings weighting. Table 15 shows the evaluated savings weighted results of the 158 projects with the original scoring. The projects exhibited 14% freeridership, and therefore the program receives a net of freeridership ratio of 0.86.

Table 15. Net of Freeriderhsip Ratio Development

States	Number of Applicants in Freerider Assessment	Evaluated Energy Savings Weighted Freeridership Score	Evaluated Net of Freeridership Ratio
Ohio	158	14.0%	0.86

Results

This section reports evaluation results, including annual savings for kWh and kW as well as RRs for each project. The report summarizes these data by project type. The section also includes independent assessments of project life.

Annual Savings

Table 16, Table 17, and Table 18 list the estimated sampling precision in RRs by kWh, NCP kW, and CP kW.

Table 16. kWh Realization Rate and Achieved Sampling Precision

Stratum	Population Size	Sample Size	Actual Sample Error Ratio	Relative Precision
Lighting	86	10	0.07	4%
HVAC 1	3	3	0.00	0%
HVAC 2	13	7	0.49	31%
HVAC 3	33	6	0.53	36%
Process	29	7	0.31	19%
Total	**164**	**33**		**9%**

Table 17. NCP kW Realization Rate and Achieved Sampling Precision

Stratum	Population Size	Sample Size	Actual Sample Error Ratio	Relative Precision
Lighting	86	10	0.21	11%
HVAC 1	3	3	0.00	0%
HVAC 2	13	7	0.76	47%
HVAC 3	33	6	0.25	17%
Process	29	7	0.72	45%
Total	**164**	**33**		**10%**

Table 18. CP kW Realization Rate and Achieved Sampling Precision

Stratum	Population Size	Sample Size	Actual Sample Error Ratio	Relative Precision
Lighting	86	10	0.07	3%
HVAC 1	3	3	0.00	0%
HVAC 2	13	7	0.81	50%
HVAC 3	33	6	0.53	36%
Process	29	7	0.41	26%
Total	**164**	**33**		**10%**

Table 19 summarizes annual savings from each project, and Table 20 lists average annual RRs by project types.

Table 19. Annual Gross Realization Rate Results by Project

Site	Customer	Project Type	kWh Savings			NCP kW Savings			CP kW Savings		
			Evaluated	Expected [9]	RR	Evaluated	Expected	RR	Evaluated	Expected	RR
1	[Redacted]	Lighting	33,163	29,052	1.14	6.5	5.7	1.15	6.8	5.7	1.18
2	[Redacted]	HVAC	472,937	887,484	0.53	5.4	146.5	0.04	3.4	122.1	0.03
3	[Redacted]	HVAC	289,424	789,375	0.37	13.7	73.2	0.19	24.8	44.3	0.56
4	[Redacted]	HVAC	9,941	1,032	9.63	0.6	26.0	0.02	4.6	25.2	0.18
5	[Redacted]	HVAC	2,168,811	2,420,314	0.90	225.8	307.2	0.74	185.0	247.5	0.75
6	[Redacted]	HVAC	1,564,549	2,192,110	0.71	95.8	290.9	0.33	212.9	37.9	5.62
7	[Redacted]	HVAC	109,283	220,000	0.50	25.3	3.9	6.57	25.3	3.9	6.57
8	[Redacted]	Lighting	71,718	47,429	1.51	15.1	9.8	1.53	9.8	4.2	2.31
9	[Redacted]	Process	556,075	649,824	0.86	-	-		-	-	
10	[Redacted]	Process	301,013	612,650	0.49	6.2	69.9	0.09	29.1	69.9	0.42
11	[Redacted]	HVAC	390,832	889,566	0.44	36.5	408.3	0.09	36.2	141.6	0.26
12	[Redacted]	Lighting	192,361	193,412	0.99	44.4	6.7	6.64	-	-	
13	[Redacted]	Lighting	28,140	27,078	1.04	9.0	7.1	1.27	9.0	7.3	1.23
14	[Redacted]	Process	265,983	437,515	0.61	-2.9	50.3	-0.06	6.4	-6.9	-0.92
15	[Redacted]	Process	29,818	15,879	1.88	22.6	4.0	5.71	6.0	5.8	1.04
16	[Redacted]	HVAC	219,938	346,708	0.63	37.8	17.9	2.11	-15.2	17.9	-0.85
17	[Redacted]	Lighting	14,365	12,611	1.14	3.2	2.5	1.30	3.2	2.5	1.30
18	[Redacted]	Lighting	99,312	130,021	0.76	12.7	11.6	1.09	12.4	10.5	1.18
19	[Redacted]	Process	223,750	360,060	0.62	51.0	41.1	1.24	32.2	41.1	0.78
20	[Redacted]	Lighting	113,142	138,545	0.82	16.9	17.1	0.99	16.0	16.3	0.98
21	[Redacted]	Process	216,227	98,972	2.18	27.2	11.3	2.41	21.6	11.3	1.91
22	[Redacted]	Lighting	47,252	35,615	1.33	12.4	7.4	1.68	11.9	7.6	1.57
23	[Redacted]	HVAC	366,940	532,027	0.69	83.0	79.0	1.05	81.1	38.8	2.09

[9] Expected values are equal to the claimed value prior to the application of the realization rate from the previous EM&V study.

Site	Customer	Project Type	kWh Savings			NCP kW Savings			CP kW Savings		
			Evaluated	Expected [9]	RR	Evaluated	Expected	RR	Evaluated	Expected	RR
24	[Redacted]	Lighting	3,534	3,766	0.94	0.9	0.8	1.23	0.9	0.8	1.21
25	[Redacted]	HVAC	2,088,267	730,151	2.86	127.4	142.0	0.90	141.5	-48.9	-2.89
26	[Redacted]	HVAC	6,466,479	3,448,380	1.88	1,784.0	633.1	2.82	1,616.0	216.8	7.45
27	[Redacted]	HVAC	1,242,006	806,200	1.54	502.9	310.0	1.62	122.6	78.9	1.55
28	[Redacted]	HVAC	1,899,212	1,957,873	0.97	445.0	415.4	1.07	396.0	349.1	1.13
29	[Redacted]	Process	165,128	93,447	1.77	34.7	10.7	3.25	28.8	10.7	2.70
30	[Redacted]	HVAC	461,629	580,966	0.79	353.4	224.5	1.57	311.0	193.4	1.61
31	[Redacted]	HVAC	72,558	694,307	0.10	-16.0	-		-14.0	-	
32	[Redacted]	Lighting	30,230	35,021	0.86	8.4	8.4	0.99	8.4	8.4	0.99
33	[Redacted]	HVAC	462,143	244,110	1.89	32.5	25.9	1.25	29.1	18.6	1.56

Table 20. Average Annual Gross Realization Rate by Project Type

Project Type	kWh Savings			NCP kW Savings			CP kW Savings		
	Evaluated	Expected[10]	RR	Evaluated	Expected	RR	Evaluated	Expected	RR
Lighting	18,064,815	18,616,348	97%	4,612	2,742	168%	2,868	2,318	124%
HVAC	30,330,099	30,108,389	101%	7,512	6,329	119%	4,857	2,775	175%
Process	8,849,344	11,418,348	78%	1,065	1,436	74%	1,125	1,195	94%
Overall	**57,244,257**	**60,143,084**	**95%**	**13,189**	**10,507**	**126%**	**8,850**	6,288	**141%**

[10] Expected values are equal to the claimed value prior to the application of the realization rate from the previous EM&V study.

Table 21 summarizes specific findings for each project. Appendix B contains more information on each project sampled.

Table 21. Findings Summary

Site Number	Customer	Project Type	kWh RR	NCP kW RR	Findings Summary
1	[Redacted]	Lighting	1.14	1.15	RR close to 1; small difference in the assumed operating hours and fixture watts
2	[Redacted]	HVAC	0.53	0.04	ASHRAE 90.1 baseline incorrectly implemented; lighting power density and baseline HVAC system type revised
3	[Redacted]	HVAC	0.37	0.19	Flow modulation assumed in application was not realized
4	[Redacted]	HVAC	9.63	0.02	Glazing specifications used in ex-ante model do not match the manufacturer specifications. Normal replacement rather than early replacement baseline used.
5	[Redacted]	HVAC	0.90	0.74	Verified lighting power density higher than program assumption, small boiler not installed, boiler room upgrades only partially completed, condenser water reset not implemented, static pressure reset not fully implemented, revised thermostat setpoints and economizer settings, some VAV conversions were not done, optimum start not implemented.
6	[Redacted]	HVAC	0.71	0.33	Controls not implemented as planned; air handler shut down; chilled water reset and supply air reset strategies not implemented
7	[Redacted]	HVAC	0.50	6.57	New chiller cycled on a biweekly basis with existing chiller; runs for half of the available hours
8	[Redacted]	Lighting	1.51	1.53	Verified installed fixture watts less than assumed in application; monitored operating hours exceeded assumed values for several lighting systems
9	[Redacted]	Process	0.86		Increased dry cooler fan and pump operations at low temperatures; more chiller operations at low temperatures than assumed in the application

Site Number	Customer	Project Type	kWh RR	NCP kW RR	Findings Summary
10	[Redacted]	Process	0.49	0.09	Existing compressor used less energy, and new compressor used more energy than assumed in the application
11	[Redacted]	HVAC	0.44	0.09	Excessive minimum outdoor air; lack of economizer operations relative to program assumptions
12	[Redacted]	Lighting	0.99	6.64	Monitoring showed slight variations in operating hours; apparent error in program NCP kW calculations
13	[Redacted]	Lighting	1.04	1.27	Program calculations did not include HVAC interactive effects
14	[Redacted]	Process	0.61	-0.06	Program assumption of part-load operation of baseline compressor was incorrect; monitoring indicated more hours at higher loads, reducing savings
15	[Redacted]	Process	1.88	5.71	Actual motor speeds were less than program assumptions; baseline drive losses were not included in program calculations
16	[Redacted]	HVAC	0.63	2.11	Verified chiller plant sequencing differed from program assumptions; program calculations did not include process chilled water loads
17	[Redacted]	Lighting	1.14	1.30	Fixture watt savings slightly higher than program assumptions; program calculations did not include HVAC interactions
18	[Redacted]	Lighting	0.76	1.09	Operating hours longer than assumed in program calculations; interactive effects with refrigeration plant not included in program calculations
19	[Redacted]	Process	0.62	1.24	Program calculations overestimated baseline heat sealer watts and operating hours
20	[Redacted]	Lighting	0.82	0.99	Fixture watt savings slightly lower than program assumptions; program calculations did not include HVAC interactions
21	[Redacted]	Process	2.18	2.41	More hours at part load; higher savings from new compressor.

Site Number	Customer	Project Type	kWh RR	NCP kW RR	Findings Summary
22	[Redacted]	Lighting	1.33	1.68	Fixture-watt savings exceeded program assumptions; HVAC interactions not included in program calculations
23	[Redacted]	HVAC	0.69	1.05	Chiller full-load hours were less than program assumptions
24	[Redacted]	Lighting	0.94	1.23	Lighting operating hours were less than program assumptions; HVAC interactions were not included in program calculations
25	[Redacted]	HVAC	2.86	0.90	Monitoring indicates more hours at low loads than in program assumptions
26	[Redacted]	HVAC	1.88	2.82	Project exceeds program expectations, based on billing analysis
27	[Redacted]	HVAC	1.54	1.62	Verified a lighting power density lower than program assumptions; window overhangs and side fins removed from baseline model, per ASHRAE 90.1
28	[Redacted]	HVAC	0.97	1.07	Lower air flow observed in monitored data increased AHU savings and decreased chiller savings relative to program calculations
29	[Redacted]	Process	1.77	3.25	Energy and demand savings exceeded program expectations; HVAC interactive effects not included in program calculations
30	[Redacted]	HVAC	0.79	1.57	Verified chiller plant full load hours were lower than program assumptions
31	[Redacted]	HVAC	0.10		AHU scheduling was not implemented
32	[Redacted]	Lighting	0.86	0.99	Monitoring indicated lower operating hours than assumed in program applications
33	[Redacted]	HVAC	1.89	1.25	Calibrated model predicted greater savings than program expectations

Project Life

The evaluation team conducted an independent assessment of the project life, comparing project life estimates to those claimed by the program. Program project life estimates were used to set incentive levels and to calculate lifecycle savings and benefits of each project. Table 22 lists project life estimates for each project.

Table 22. Program Claimed Project Life Estimates

Site Number	Customer	Project Type	Program Project Life (years)
1	[Redacted]	Lighting	10.0
2	[Redacted]	HVAC	18.0
3	[Redacted]	HVAC	15.0
4	[Redacted]	HVAC	20.0
5	[Redacted]	HVAC	14.0
6	[Redacted]	HVAC	10.0
7	[Redacted]	HVAC	20.0
8	[Redacted]	Lighting	10.9
9	[Redacted]	Process	20.0
10	[Redacted]	Process	15.0
11	[Redacted]	HVAC	8.0
12	[Redacted]	Lighting	10.0
13	[Redacted]	Lighting	10.0
14	[Redacted]	Process	15.0
15	[Redacted]	Process	15.0
16	[Redacted]	HVAC	20.0
17	[Redacted]	Lighting	8.0
18	[Redacted]	Lighting	12
19	[Redacted]	Process	7.0
20	[Redacted]	Lighting	8.0
21	[Redacted]	Process	15.0
22	[Redacted]	Lighting	12.0
23	[Redacted]	HVAC	15.0
24	[Redacted]	Lighting	8.0
25	[Redacted]	HVAC	20.0
26	[Redacted]	HVAC	13.9
27	[Redacted]	HVAC	15.0
28	[Redacted]	HVAC	10.0
29	[Redacted]	Process	10.0
30	[Redacted]	HVAC	20.0
31	[Redacted]	HVAC	10.0
32	[Redacted]	Lighting	8.0
33	[Redacted]	HVAC	7.0

The evaluation team conducted an independent assessment of project life, examining measures making up each project and assigning an effective useful life (EUL) to each measure. EUL estimates were obtained from the Ohio TRM, the California Database for Energy Efficiency Resources (DEER) EUL table, or program claims for measures not yet addressed by these data sources. Table 23 shows the assessment results.

Table 23. Evaluated Project Life Estimates

Site Number	Customer	Project Type	Measures	EUL	Source	Source Measure
1	[Redacted]	Lighting	High bay fixture retrofit	15	OH TRM	High Bay lighting
2	[Redacted]	HVAC	Whole building retrofit	15	OH TRM, DEER	Interior lighting, heat pump, cooling tower, VFD, EMS
3	[Redacted]	HVAC	VAV conversion	15	DEER	VAV box and VFD fan
4	[Redacted]	HVAC	Window Replacement	20	DEER	Low Solar Heat Gain Coefficient Windows
5	[Redacted]	HVAC	Lighting and HVAC upgrades	15	OH TRM	Interior Lighting, HVAC
6	[Redacted]	HVAC	DDC Upgrade	15	DEER	Energy Management System (EMS)
7	[Redacted]	HVAC	Chiller Replacement	20	OH TRM	Chiller replacement
8	[Redacted]	Lighting	Lighting upgrade	15	OH TRM	High efficiency linear fluorescent
9	[Redacted]	Process	Dry cooler	20	Application	Not applicable
10	[Redacted]	Process	Air compressor upgrade	15	OH TRM	High efficiency air compressor
11	[Redacted]	HVAC	Controls upgrade	15	DEER	Energy Management System (EMS)
12	[Redacted]	Lighting	Exterior lighting retrofits at three schools	15	OH TRM	High Bay lighting
13	[Redacted]	Lighting	Interior lighting retrofit	15	OH TRM	High efficiency linear fluorescent
14	[Redacted]	Process	Refrigeration compressor upgrade	15	DEER	Refrigeration Plant Upgrade
15	[Redacted]	Process	VFD Retrofit	15	OH TRM	Variable Frequency Drives
16	[Redacted]	HVAC	Chiller upgrade	20	OH TRM	Chiller replacement
17	[Redacted]	Lighting	LED retrofit at three stores	20	IN Framework	LED lighting

Site Number	Customer	Project Type	Measures	EUL	Source	Source Measure
18	[Redacted]	Lighting	Refrigerated case lighting at 17 stores	8.1	OH TRM	Refrigerated Case Lighting
19	[Redacted]	Process	Heat Sealer	7	Application	Not applicable
20	[Redacted]	Lighting	Interior lighting retrofit	15	OH TRM	High efficiency linear fluorescent
21	[Redacted]	Process	VFD Air Compressor	15	OH TRM	High efficiency air compressor
22	[Redacted]	Lighting	LED retrofit at two stores	20	IN Framework	LED lighting
23	[Redacted]	HVAC	Add VFD to existing chiller	15	OH TRM	Variable Frequency Drives
24	[Redacted]	Lighting	LED retrofit at one store	20	IN Framework	LED lighting
25	[Redacted]	HVAC	New chilled water plant	20	OH TRM	Chiller replacement
26	[Redacted]	HVAC	Upgrades to 6 schools	15	OH TRM, DEER	VFD, VAV box, RTU, EMS
27	[Redacted]	HVAC	New construction	16.3	OH TRM	Lighting - new construction, lighting controls, high performance glazing
28	[Redacted]	HVAC	Lab fume hood VAV conversion	15	DEER	VAV box and VFD fan
29	[Redacted]	Process	Vending machine controllers	5	OH TRM	Vending Machine Occupancy Sensors
30	[Redacted]	HVAC	Chiller Replacement	20	OH TRM	Chiller replacement
31	[Redacted]	HVAC	Energy Management System	15	DEER	Energy Management System (EMS)
32	[Redacted]	Lighting	Metal halide fixture replacement	7.5	OH TRM	PS Metal Halide
33	[Redacted]	HVAC	EMS	15	DEER	Energy Management System (EMS)

The program estimated the project life, and independent project life estimates were weighted by expected kWh savings and evaluated kWh savings, respectively, with a weighted average project life calculated for each project type. The RR on each project life was calculated as the ratio of the evaluated EUL to the program project life estimates. Table 24 shows the results.

Table 24. Summary of Project Life Estimates by Project Type

Project Type	Program Project Life	Evaluated EUL	RR
Lighting	10	14.1	1.41
HVAC	13.4	15.9	1.18
Process	15.0	14.6	0.98

Appendix A. Required Savings Tables

Measure Name	State	Gross kWh RR	NCP kW RR	CP kW RR	EUL	Net of Freeridership Ratio
Custom	OH	0.95	1.26	1.41	Custom	86%

Appendix B. Site M&V Reports—Full Customer Detail

ARCHITECTURAL ENERGY
CORPORATION

[Redacted]

- Lighting Retrofit -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

PREPARED BY:
Architectural Energy Corporation
2540 Frontier Avenue, Suite 100
Boulder, Colorado 80301

PREPARED IN:
December 2012

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].

INTRODUCTION

This report addresses M&V activities for the [Redacted] custom program application. The application covered a lighting retrofit at two locations in Cincinnati, Ohio. This M&V report was for post-retrofit monitoring only. The measures included:

ECM-1 – Compact fluorescent fixtures replaced with LED fixtures – [Redacted]

- This phase of the project involved the removal of 245 existing 27W compact fluorescent fixtures, replaced with 245 new 12W LED fixtures.

ECM-2 – Compact fluorescent fixtures replaced with LED fixtures – [Redacted]

- This phase of the project involved the removal of 311 existing 37W compact fluorescent fixtures, replaced with 161 new 12W LED fixtures and 150 new 17W LED 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 identified in the application were:

Facility	Proposed Annual kWh savings	Proposed Summer Peak kW savings	Duke Annual kWh savings	Duke Summer Peak kW savings
[Redacted]	17,199	4	[not itemized]	[not itemized]
[Redacted]	32,877	7	[not itemized]	[not itemized]
Total	**50,076**	**11**	**35,615**	**7.4**

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

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

PROJECT CONTACTS

Duke Energy M&V Coordinator	Frankie Diersing	513-287-4096
Duke Energy BRM	Terry Holt	
Customer Contact	[Redacted]	[Redacted]
Architectural Energy Corporation Contact	Katie Gustafson	p: 303-459-7430 kgustafson@archenergy.com

SITE LOCATIONS/ECM'S

Site	Address	Sq. Footage	ECM's Implemented

[Redacted]	[Redacted]	159,743	#1
[Redacted]	[Redacted]	84,203	#2

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Verify fixture counts (post-retrofit) and that all fixtures have been upgraded
- Summer peak demand savings
- Annual Energy Savings

M&V Option

IPMVP Option A

M&V Implementation Schedule

For each store:

- The post-retrofit survey was conducted after the customer had performed the lighting retrofit.
  - Spot measurements were taken of the lighting load connected to the circuit by measuring the kW load and current draw of the circuit.
  - Post-retrofit loggers were deployed.
- Logger and spot data was collected continuously in 5 minute intervals between June 13th and July 11th, 2012.

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	> 10% of rating

Field Data Points

Post-Installation, for each store:

Survey data

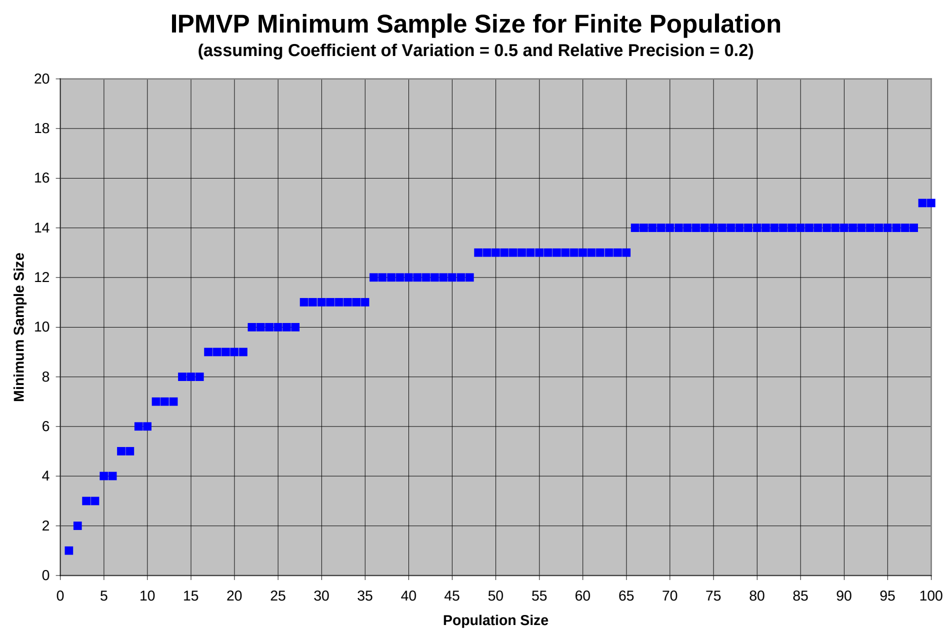
- All fixture specifications, wattages and quantities were consistent with the original application.
- All pre (existing) fixtures were verified to have been removed.
- The building was determined to observe only two holidays over the course of the year (Thanksgiving and Christmas).
- Lighting zones were determined to be completely disabled during the holidays.

One-time measurements (to establish ratio of kW/amp and simultaneous logger amp readings)

- Lighting circuit power was recorded with lights on, and compared to the simultaneous logger data.

Time series data on controlled equipment

- Typical lighting load shape
  - Current measurement CT loggers were deployed to measure current at the panelboard.
  - Based on the following sample size table, 6 circuits were randomly chosen to be monitored based upon the total number of circuits.



  - Loggers were setup for 5 minute instantaneous readings and allowed to operate from June 13th to July 11th, 2012.
- Spot measurements of the lighting load connected to the circuit were recorded by measuring the kW load and current draw of the circuit during post-retrofit survey.

LOGGER TABLE

The following table summarizes all logging equipment needed to accurately measure the above noted ECMs:

ECM	Hobo U-12	20A CT
1	6	6
2	6	6
Total	**12**	**12**

Data Analysis

1. Converted time series data on logged equipment into pre/post average load shapes by day type (ex. weekday, weekend, holiday).
2. Load shapes were used to determine the daily Equivalent Full Load Hours (ELFH) for each day type.
3. The Pre annual kWh was calculated using the following equations:

$$\frac{kWh}{year}_{pre} = \left[\sum_{i=1}^{N_{daytypes}} EFLH_i * N_{days/yr_i} \right] * ConnectedLoad_{pre}$$

4. The Post annual kWh was calculated using the following equations:

$$\frac{kWh}{year}_{post} = \left[\sum_{i=1}^{N_{daytypes}} EFLH_i * N_{days/yr_i} \right] * ConnectedLoad_{post}$$

5. The annual kWh ***saved*** was calculated using the previous data in the following equation:

$$\frac{kWh}{year}_{Savings} = \frac{kWh}{year}_{\mathrm{Pre}} - \frac{kWh}{year}_{Post}$$

6. Estimated peak demand savings by subtracting pre/post time series data.
7. Calculated coincident peak savings by subtracting pre/post kW values at the grid peak.

Verification and Quality Control

1. Logger data was visually inspected for consistent operation. <u>Some data from </u>[Redacted] <u>was removed due to suspected mixing of post-retrofit lamp wattages on a single monitored circuit.</u>
2. Post retrofit lighting fixture specifications and quantities were verified to be consistent with the application.
3. Pre-retrofit lighting fixtures were verified to be removed from the project.

Recording and Data Exchange Format

1. Post-installation Lighting Survey Form and Notes.
2. Hobo logger binary files
3. Excel spreadsheets

Field Staff

☐ Verifiable Results
☐ AEC
■ **Other**

Contracting type

■**T&M**
☐ Per logger

Results Summary

The following results account for benefits of the lighting replacement at [Redacted].
The following tables summarize the energy and demand savings from Store 564:

	Lighting	HVAC	Total
Pre kW	6.6		
Post kW	2.9		
Demand Savings	3.6	0.7	4.3
Coincident Pk Demand Svgs (kW):	3.5	0.6	4.1

	Duke Savings	Realized Savings		Realization Rate	
		Lighting Only	Lighting and HVAC	Lighting Only	Lighting and HVAC
Energy (kWh)	not itemized	14,329	16,469	N/A	N/A
Demand (kW)	not itemized	4	4	N/A	N/A

The following tables summarize the energy and demand savings from [Redacted]:

	Lighting	HVAC	Total
Pre kW	11.3		
Post kW	4.5		
Demand Savings	6.9	1.2	8.1
Coincident Pk Demand Svgs (kW):	6.6	1.2	7.8

	Duke Savings	Realized Savings		Realization Rate	
		Lighting Only	Lighting and HVAC	Lighting Only	Lighting and HVAC
Energy (kWh)	not itemized	26,782	30,783	N/A	N/A

Demand (kW)	not itemized	7	8	N/A	N/A

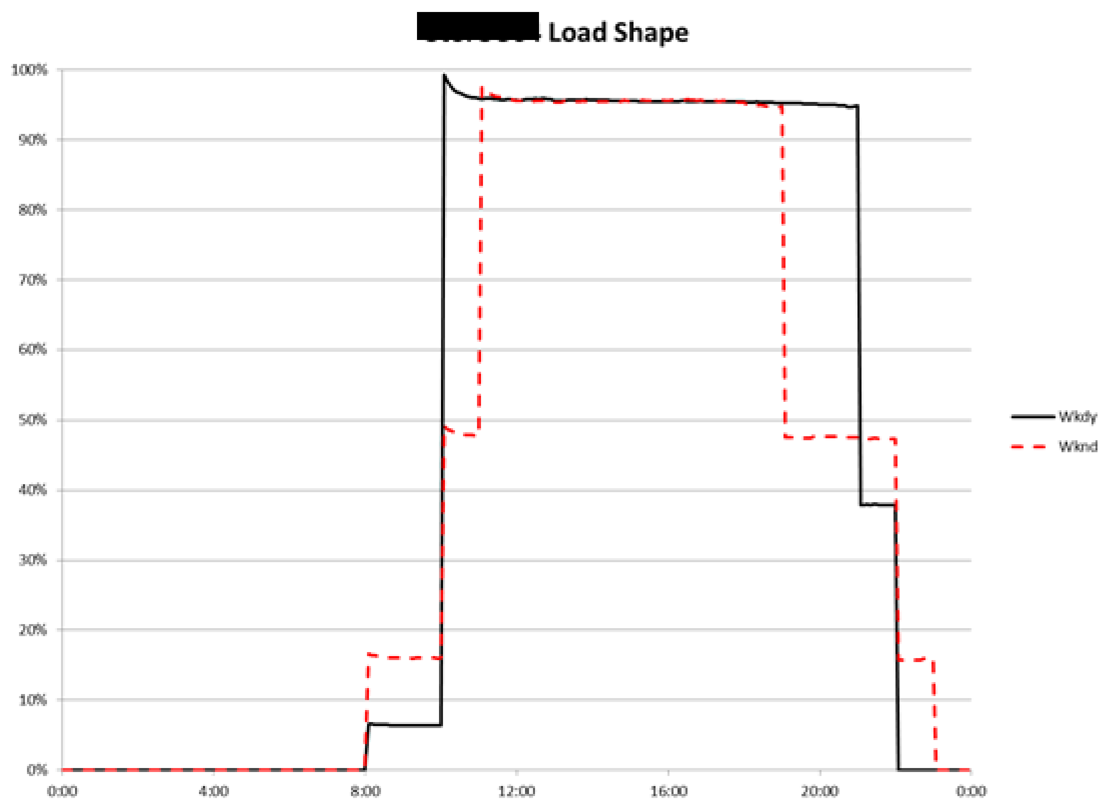
The following tables show the total savings for both stores and the kWh and kW realization rates:

	Lighting	HVAC	Total
Pre kW	18		
Post kW	7		
Demand Savings	10.5	1.9	12.4
Coincident Pk Demand Svgs (kW):	10.1	1.8	11.9

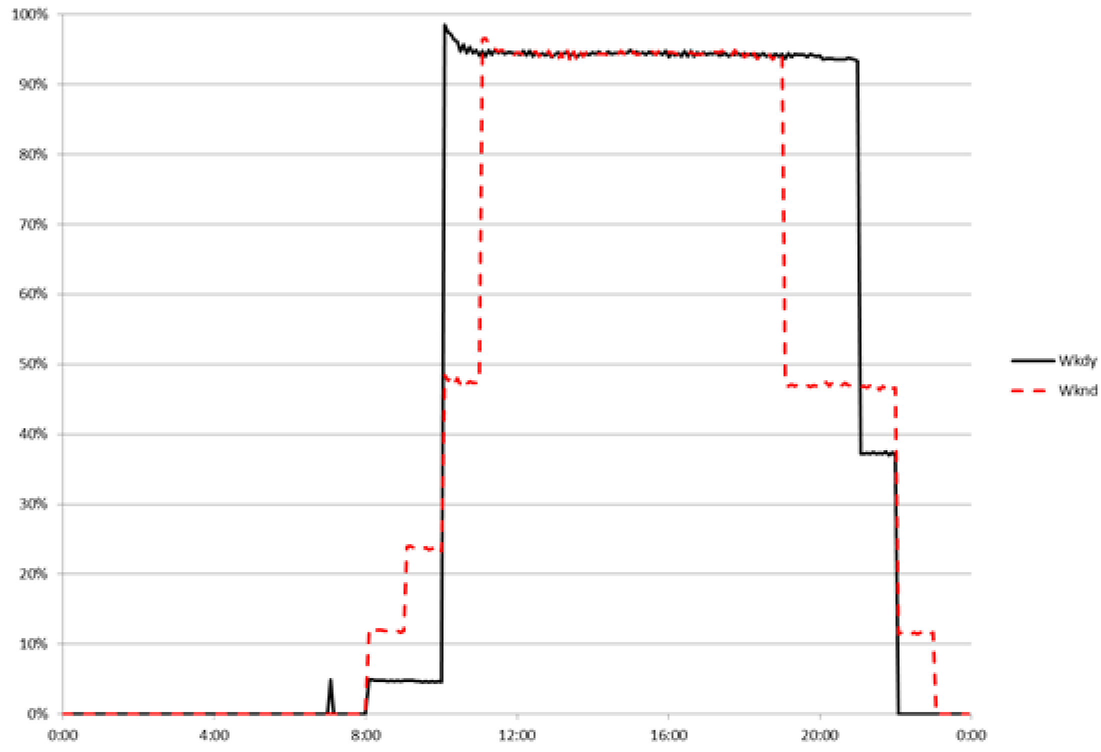
	Duke Savings	Realized Savings		Realization Rate	
		Lighting Only	Lighting and HVAC	Lighting Only	Lighting and HVAC
Energy (kWh)	35,615	41,111	47,252	115%	133%
NCP Demand (kW)	7.4	10.5	12.4	142%	168%
CP Demand (kW)	7.6	10	11.9	132%	157%

- Used the pre wattages from the application as supported by Appendix B: Table of Standard Fixture Wattages, 2008.
- Used post wattages from application as supported by product spec sheets.

The figures below show the lighting load shapes for each store.



[redacted] Load Shape



[Redacted] (12-112)

- Lighting Retrofit -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

PREPARED BY:
Architectural Energy Corporation
2540 Frontier Avenue, Suite 100
Boulder, Colorado 80301

PREPARED IN:
August 2012
V1.2

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]

INTRODUCTION

This report addresses M&V activities for the [redacted] custom program application. The application covers a lighting retrofit at one location in Cincinnati, Ohio. This M&V report is for post-retrofit monitoring only. The measures include:

ECM-1 – High bay fixture retrofit with motion sensors

- This project involves the removal of 36 existing T-12 high output strip fixtures, to be replaced by 11 new 6-lamp T-5 fluorescent high bay fixtures with motion sensors. This will result in an overall power reduction of 5,742W.

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 identified in the application are:

Facility	Application Proposed Annual kWh savings	Application Proposed Summer Peak kW savings	Duke Proposed Annual kWh savings	Duke Proposed Summer Peak kW savings
[Redacted]	29,560	6	29,052	6
Total	**29,560**	**6**	**29,052**	**6**

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

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

PROJECT CONTACTS

Duke Energy M&V Coordinator	Frankie Diersing	513-287-4096
Duke Energy BRM		
Customer Contact	[Redacted]	[Redacted]
Architectural Energy Corporation Contact	Todd Hintz	p: 303-459-7476 thintz@archenergy.com

SITE LOCATIONS/ECM'S

Site	Address	Sq. Footage	ECM's Implemented

[Redacted]	[Redacted]	8,000	# 1

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Verify fixture counts (post-retrofit), and that all fixtures have been upgraded
- Summer peak demand savings
- Annual Energy Savings

M&V Option

IPMVP Option A

M&V Implementation Schedule

- Conducted the post-retrofit survey after the customer performed the lighting retrofit.
    - Deployed post-retrofit loggers.
    - Spot measured the lighting load connected to the circuit by measuring the kW load and current draw of the circuit.
- Since the customer has already performed the lighting retrofit, pre-retrofit operating hours were used and pre- fixture information was taken from the application. Pre-retrofit fixture specifications and quantities removed from the project were verified in the field to match the application.
- Collected data during normal operating hours (avoided holidays or atypical operating hours).

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	> 10% of rating

Field Data Points

Post-Installation

Survey data

- Determined fixture count and Wattage
- Verified that all new fixture specifications and quantities were consistent with the application
- Determined how lighting is controlled post-retrofit and recorded controller settings
- Determined how lighting was controlled pre-retrofit
- Verified that all pre (existing) fixtures were removed

- Determined what holidays the building observes over the year
- Determined if the lighting zones are disabled during the holidays

One-time measurements taken (to establish ratio of kW/amp and simultaneous logger amp readings)

- Lighting circuit power when lights are on

The following procedure was used to gather time series data on controlled equipment:

- Typical lighting load shape
    - o Deployed two current measurement CT loggers to measure current at the panelboard.
    - o Loggers were configured for 5 minute instantaneous readings and operated for three weeks.
- Spot measure the lighting load connected to each circuit by measuring the kW load and current draw of the circuit during the post-retrofit survey. The lighting load circuits had only one fixture type on the circuit.

LOGGER TABLE

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

ECM	Hobo U-12	20A CT
1	2	2
Total	**2**	**2**

DATA ANALYSIS

- **ECM-1**

1. Converted time series data on logged equipment into pre/post average load shapes by day type (ex. weekday, weekend, holiday).
2. Load shapes were used to determine the daily Equivalent Full Load Hours (ELFH) for each day type.
3. The Pre annual kWh was calculated using the following equations:

$$\frac{kWh}{year}_{pre} = \left[\sum_{i=1}^{N_{daytypes}} EFLH_i * N_{days/yr_i} \right] * ConnectedLoad_{pre}$$

4. The Post annual kWh was calculated using the following equations:

$$\frac{kWh}{year}_{post} = \left[\sum_{i=1}^{N_{daytypes}} EFLH_i * N_{days/yr_i} \right] * ConnectedLoad_{post}$$

5. The annual kWh ***saved*** was calculated using the previous data in the following equation:

$$\frac{kWh}{year}_{Savings} = \frac{kWh}{year}_{\Pr e} - \frac{kWh}{year}_{Post}$$

6. Estimated peak demand savings by subtracting pre/post time series data.
7. Calculated coincident peak savings by subtracting pre/post kW values at the grid peak.

Verification and Quality Control

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

Recording and Data Exchange Format

1. Pre-installation Lighting Survey Form and Notes.
2. Post-installation Lighting Survey Form and Notes.
3. Hobo/Elite Pro logger binary files
4. Excel spreadsheets

Field Staff

☐ Verifiable Results
☐ AEC
■ **Other**

Contracting type

■ **T&M**
☐ Per logger

RESULTS SUMMARY

The following results account for benefits of the lighting replacement and occupancy sensor installation at [Redacted].

A summary of the estimated annual savings is shown in Table 1.

TABLE 1. ESTIMATED ANNUAL ENERGY SAVINGS

[Redacted] Results	
Actual Post Total (kWh/year)	14250
Estimated Pre Total (kWh/year)	47413
Lighting Savings (kWh/year)	33163
Application Savings (kWh/year)	29052
Realization Rate (kWh/Year)	**114%**
Actual Post Total (Non-Coincident Peak kW)	3.5
Actual Post Total (Coincident Peak kW)	3.2
Estimated Pre Total (Peak kW)	9.7
Lighting Savings (Non-Coincident Peak kW)	6.2
Lighting Savings (Coincident Peak kW)	6.5
Application Savings (Peak kW)	5.7
Realization Rate (Coincident Peak kW)	**118%**
Realization Rate (Non-Coincident Peak kW)	**115%**

The lighting was initially estimated to run 5148 hours/year with motion control on all of the fixtures. The estimated pre-retrofit run hours were determined to be 4898 hours/year. The pre-retrofit run hours were estimated by assuming that the lighting was on at 100% in the pre-retrofit case whenever the lights were on at any level greater than 5% in the post retrofit case. The increased kWh/year realization rate could possibly be explained by the decrease in actual run hours from the original estimation.

Graphs of actual logger data are shown in Figures 1-2. Evidence of the installed motion detectors can be seen in both figures.

FIGURE 1.

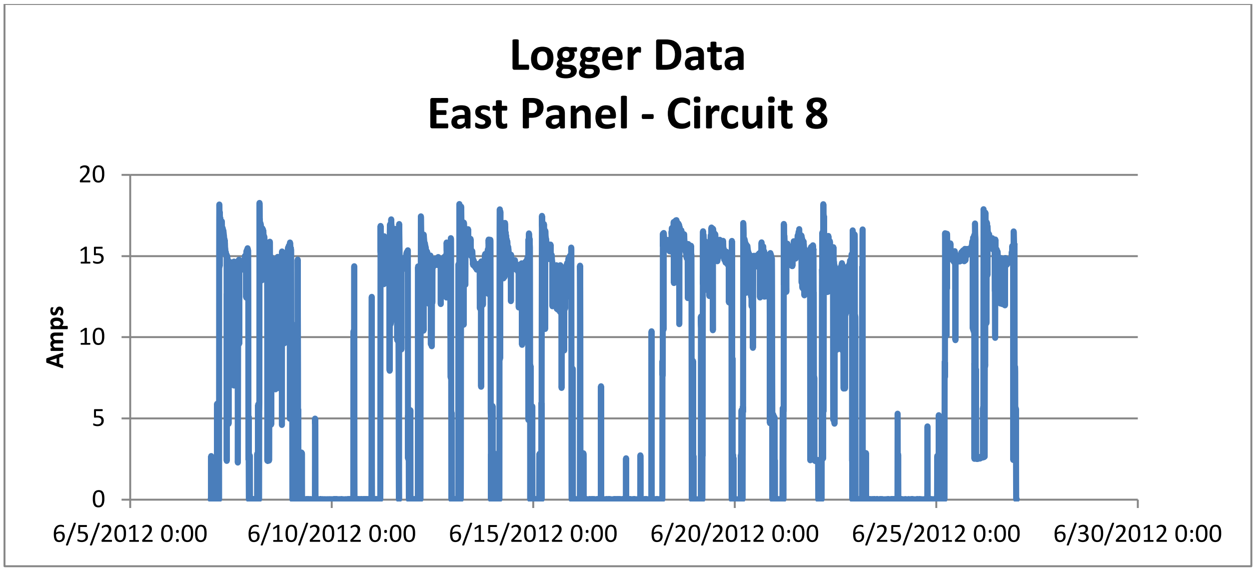
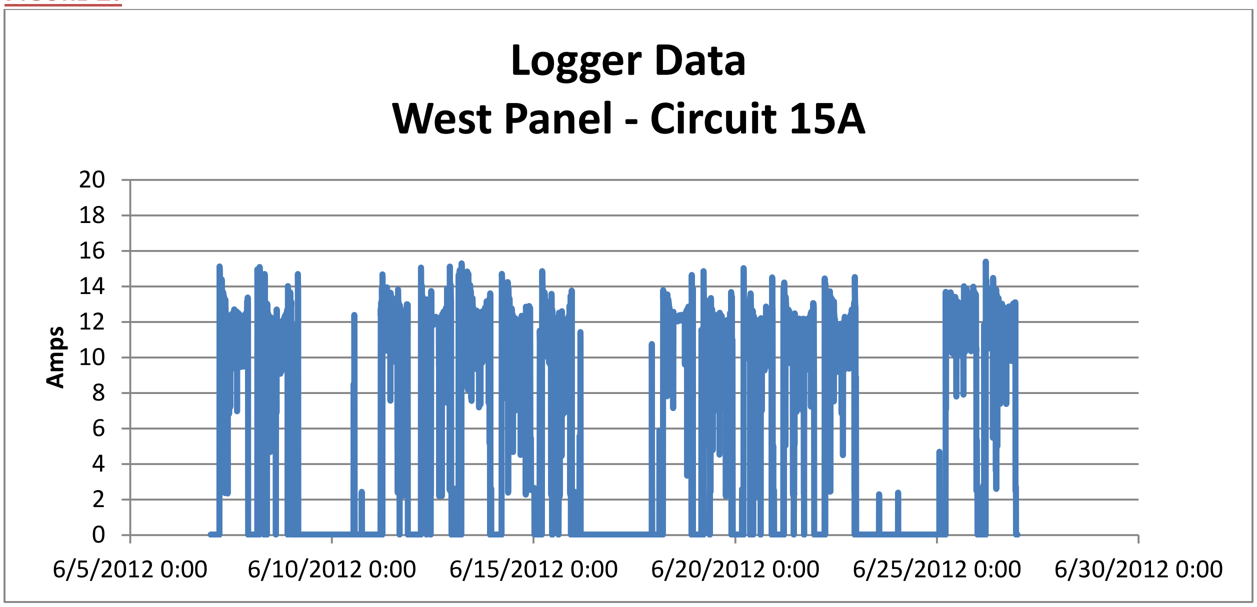

Logger Data
East Panel - Circuit 8
Amps
20
15
10
5
0
6/5/2012 0:00
6/10/2012 0:00
6/15/2012 0:00
6/20/2012 0:00
6/25/2012 0:00
6/30/2012 0:00

FIGURE 2.


Logger Data
West Panel - Circuit 15A
Amps
20
18
16
14
12
10
8
6
4
2
0
6/5/2012 0:00
6/10/2012 0:00
6/15/2012 0:00
6/20/2012 0:00
6/25/2012 0:00
6/30/2012 0:00

[Redacted]
Whole Building Renovation M&V Report

Prepared for
Duke Energy Ohio

March 2015, Version 1.0

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:

Mike Johnston
NORESCO LLC

Stuart Waterbury
NORESCO LLC

2540 Frontier Avenue, Suite 100
Boulder CO
80301

(303) 444-4149

Introduction

This report addresses M&V activities for the [Redacted] custom program application. The application covers a whole-building energy retrofit at one location in Cincinnati, Ohio. The measure includes:

ECM-1 – Whole Building Retrofit

The [redacted] in downtown Cincinnati was purchased by [Redacted] and was renovated to include retail and apartment space. The 15 story building was mixed use retail and office space at the time of purchase. After retrofits, the basement and first 3 floors of the building remain retail/office space, while floors 4 through 15 have been converted into 87 apartment units.

All energy components (HVAC, lighting, appliances) were removed in the retrofit and replaced with new, high-efficiency components. Many existing components were original to the building (1920's era). The original building was mainly lit by T12 lamps, with an overall building lighting power density of approximately 1.1 W/ft^2. In the new design, water source heat pumps are utilized throughout the building, and the lighting power density has been reduced to 0.83 W/ft^2. Other components include high-efficiency boilers, cooling towers, pump VFDs, individually programmable thermostats throughout the building, and a DDC control system.

Goals and Objectives

The projected savings goals identified in the application are:

Facility	Proposed Annual kWh savings	Proposed kW Savings	Duke Projected Annual kWh savings	Duke Projected NCP kW savings	Duke Projected CP kW savings
[Redacted]	541,200	0	**887,484**	**146.5**	**122.1**
Total	**541,200**	**0**	**887,484**	**146.5**	**122.1**

It should be noted that NORESCO was provided eQuest energy model files dated February 2013 that showed an annual electric savings of 850,353 kWh. Per the customer, proposed savings from the application was based on much earlier modeling performed in 2010 using a different energy simulation software program. Between then and final design, numerous design changes were made which the customer thought resulted in greater savings over the ASHRAE Baseline.

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

- Average pre/post load shapes by daytype for controlled equipment
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings
- Annual energy (kWh) savings

Project Contacts

Duke Energy M&V Coordinator	Frankie Diersing	p: 513-287-4096
NORESCO Engineer	Mike Johnston	c: 303-459-7433 mjohnston@noresco.com
Customer Contact	[Redacted]	[Redacted]

Site Locations/ECMs

Address
[Redacted]

Data Products and Project Output

- Average pre/post load shapes by daytype for the whole facility
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings
- Annual energy (kWh) savings
- kWh & kW Realization Rates

M&V Option

IPMVP Option D

M&V Implementation Schedule

- Conducted the post-retrofit survey after the customer performed the energy retrofits.
  - Collected data during normal operating hours (avoid holidays or atypical operating hours).
  - Obtained and verified the post-retrofit HVAC system configuration, parameters, and selected equipment..
  - Performed spot-measurements on selected controlled equipment.

  - Deployed post-retrofit loggers to record temperature and power measurements on selected circuits.
- Confirmed and updated the provided eQUEST energy model to reflect as-built conditions (NORESCO's responsibility).
- Evaluated the energy and demand savings of the retrofit measure.

Field Survey Points

Pre – installation

- No pre-installation field survey was performed, as this was a complete renovation, and the Baseline was based on ASHRAE 90.1-2007, rather than existing conditions.

Post – installation

- Visual verification of information listed in attached "Energy Model Input Summary".

Spot measurements

- V/A/kW/PF for residential circuits.

Time series data on controlled equipment

- Current on feeders for a group of residential apartments
- SAT and RAT for a heat pump in a common area
- OAT and RH
- Lighting circuit current for sampled circuits for common residential areas

Set up loggers for 5-minute instantaneous readings. Deploy for 3 weeks.

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	Recorded load must be < 130% and >10% of CT rating
Power	ElitePro	±1%	
Temperature	Onset Temp/RH	±0.36°F	

Field Data Logging

- Installed data loggers to collect data on a sample of residential apartments (feeders serving 14th floor. Sample a heat pump in the commercial area for SAT and RAT Logged outdoor air temperature and relative humidity. Logged for 3 weeks with a 5-minute interval.

- For lighting circuits, monitored circuit current for three different residential common areas in order to determine lighting schedules. Logged for 3 weeks with a 5-minute interval.

Logger Table

The following table summarizes the logging equipment that was used for the above noted items:

Item	Hobo Loggers	CT-V Current Transducers	Hobo Temperature Probes	Weather Station
Residential Feeders	1	4 (CTV-C, 100A)		
OA, SA, RA	1		2	1
Lighting	1	3 (CTV-A, 20A)		
Total	**3**	**7**	**2**	**1**

Data Analysis

- Used the data collected in the operator interview to verify equipment specifications, schedules, setpoints and sequence of operation data for the eQUEST energy model.

- Confirmed that ASHRAE 90.1-2007 Baseline building is properly represented in the model.

- Compared trend data on schedules and setpoints to the post-retrofit eQUEST model and update with as-built conditions. Confirmed that the post-retrofit building envelope, lighting, and HVAC systems are properly represented in the model.

- Confirmed all other data in the "Energy Model Input Summary" (attached).

Verification and Quality Control

1. Visually inspected logger data for consistent operation. Sorted by day type and removed invalid data. Looked for data out of range and data combinations that are physically impossible.
2. Verified post-retrofit equipment specifications and quantities are consistent with the application. If they were not consistent, recorded discrepancies.

Recording and Data Exchange Format

1. Energy Model Input Summary and Notes.
2. Building Automation System data files OR data logger files
3. Excel spreadsheets
4. eQUEST files
5. DOE-2 energy model data files

Results

BASELINE ENERGY MODEL PARAMETERS

The following items were observed based on evaluation of the Baseline energy modeling inputs:

- A weather file was not included in the model submittal, therefore, a TMY3 weather file for Cincinnati, OH was used from the DOE2.2/eQuest website to perform the simulation.
- The Baseline model had the same concrete envelope as the proposed model. This correctly follows protocol of Table G3.1 of ASHRAE 90.1-2007 for existing building envelopes, where the Baseline building design reflects existing conditions prior to any revisions that are part of the scope of work being evaluated. The information provided in the Energy Model Input Summary for the Baseline envelope is incorrect in that it indicated R-13 + R-7.5 Continuous Insulation was modeled (metal frame construction). Additionally, for the Proposed model, exterior walls were modeled as 12 inch concrete, with an R-10 layer. Per conversations with the customer, no insulation was added to the existing, uninsulated walls in the renovation. Therefore, this R-10 layer was removed in both models.
- The Baseline model had glazing specified based on ASHRAE 90.1 requirements for climate zone 4A, with the Proposed model having glazing specifications for the existing glass. Because the windows were not replaced in the renovation, the Baseline model glazing should represent the existing glazing, such that no differences in glazing performance is modeled. Glazing specifications in the Proposed model (SC = 0.63 and a conductance of 0.69) was transferred to the Baseline model.
- The Baseline model incorrectly specified the system for residential floors as Packaged Multizone. This should have been modeled as packaged terminal air conditioners (PTAC)

with hot water fossil fuel boiler heating type per ASHRAE 90.1-2007 Appendix G Tables G3.1.1A and G3.1.1B.

- The Baseline model specified residential floor lighting power densities of 1.1 W/ft^2. It appears this was arrived at using the space-by-space method of calculating interior lighting power allowance (9.6.1 of ASHRAE 90.1-2007). This method is to be used when spaces are separated by space type in the model, depicting other power allowances of other spaces, such as corridors, electrical/mechanical, stairs, storage, restrooms, lobby, etc. Because these spaces are not represented in the model, the Building Area Method of Calculating Interior Lighting Power Allowance (9.5.1 of ASHRAE 90.1-2007) should be used. This results in a 0.7 W/ft^2 LPD allowance for the Multifamily floors and a 1.0 W/ft2 for the Office area, 1.5 W/ft^2 for the financial/bank area, using Retail as a proxy, per 9.5.1a: "For building area types not listed, selection of a reasonably equivalent type shall be permitted."

PROPOSED DESIGN ENERGY MODEL PARAMETERS

Where possible, the inputs to the Proposed Design model were verified with project design and bid documents that were submitted with the application. These included:

- Glazing in the Proposed Design was modeled with a Solar Heat Gain Coefficient (SHGC) of 0.59 (SC = 0.63) and a conductance of 0.69 (excluding exterior film coefficient). No documentation was provided on existing glazing performance.
- Exterior walls were modeled as 12 inch concrete, with an R-10 layer. Per conversations with the customer, no insulation was added to the existing, uninsulated walls in the renovation. Therefore, this R-10 layer was removed.
- Lighting plans and fixture schedules were used to verify installed lighting power densities. No information was provided for commercial floors, presumably because no savings were claimed for these floors. Residential floors appeared nearly identical in fixture count for each floor based on lighting plans submitted. A representative lighting power take-off for a residential floor was performed to determine installed LPD as follows.

Table 1: Residential Floor Lighting Power Density Calculation.

Fixture Code	Fixture Wattage	Fixture Count	Total Wattage
A1	19	104	1976
Ceiling Fan (lighting only)	28	13	364
P1 (assumed Wattage)	15	13	195
B1	34	13	442
C2	32	15	480
S3 (Existing fixture- assumed Wattage)	64	9	576
		Total Watts:	**4033**
		Gross Floor Area (ft^2):	**7047**

Installed LPD (W/ft²):	**0.57**

This compares to a 0.83 W/ft² in the proposed model. It may have been that net floor area was used by the customer for calculation, rather than gross area. ASHRAE 90.1 guidelines dictate that gross floor area be used for calculation of lighting power density.

- Mechanical schedules and equipment specifications to verify water source heat pump heating and cooling efficiencies. Based on design documents, average nominal cooling efficiency for the heat pumps is 13.5 EER and average nominal heating efficiency is 4.6 COP. This agreed with inputs to the model, though it did not agree with the modeling input summary provided (14 EER, 4.1 COP).
- Mechanical schedules and equipment specifications to verify boiler efficiencies. Based on design documents, boilers are condensing, with 93.5% full fire efficiency. This agreed with inputs to the model, though it did not agree with the modeling input summary provided (98% efficiency).
- Mechanical schedules and equipment specifications to verify pumping power. Modeling inputs for pumping gpm, head, and pump and motor efficiencies were verified, and modeling inputs were confirmed to be in agreement with design documents.

DATA REVIEW

Current transducers were installed on feeders to nine apartments totaling 10,239 square feet, as shown in Table 2. Note the 14th floor has larger apartments than other floors because additional lofts exist, extended into the 15th level. Data was logged at 5 minute intervals for a period of three weeks, from September 6th – Sept 30th, 2014.

Table 2: Apartments on Monitored Circuit.

Apartment #	Area (sf)
[redacted]	710
[redacted]	653
[redacted]	1,517
[redacted]	1,111
[redacted]	1,138
[redacted]	1,140
[redacted]	1,046
[redacted]	814
[redacted]	2,110
Total:	**10,239**

A power calculation was made from the current measured in amps by assuming 120 V supply voltage phase-to neutral and a 0.85 power factor, summing the current for each of two conductors of one phase. Power was then normalized by square footage and typical weekday and weekend hourly profiles were developed by averaging hourly data. This is shown in Figure 1.

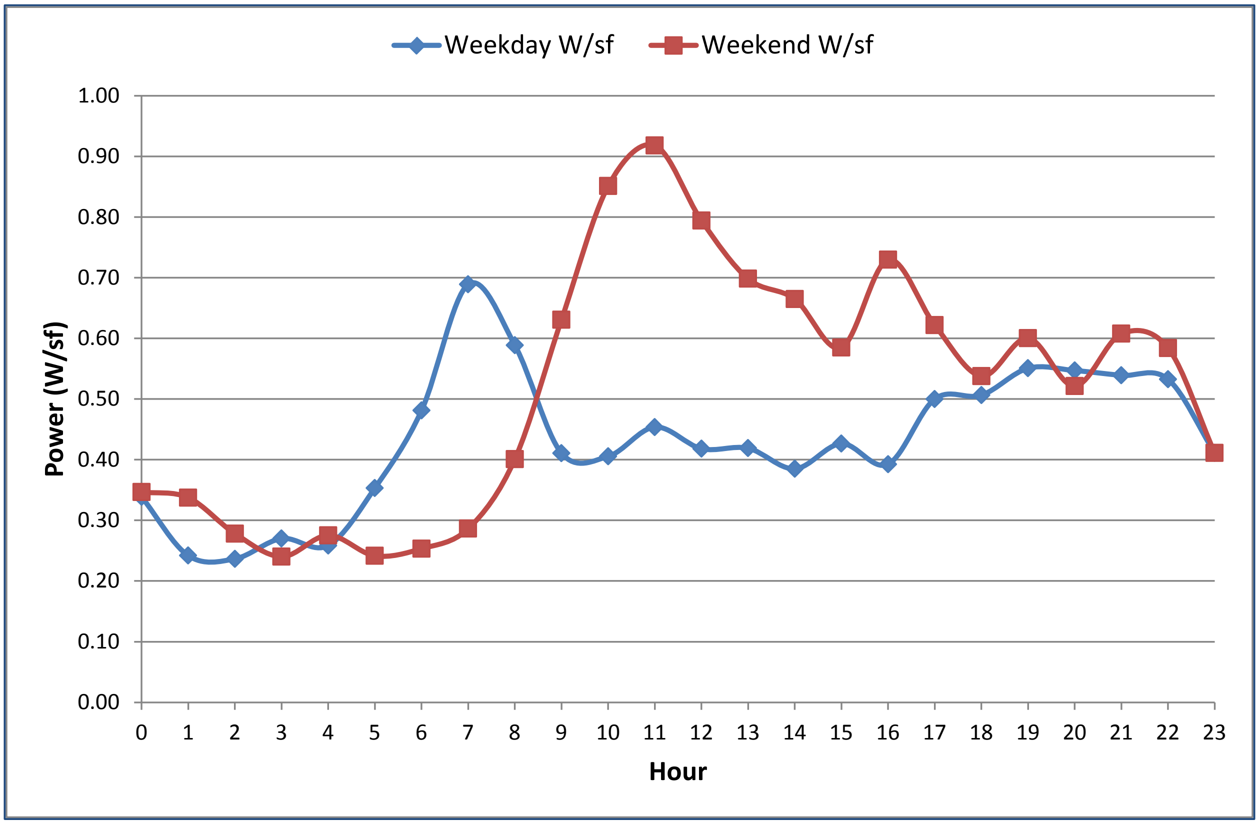


Figure 1: Average Apartment Load Profile.

It was noted that no OAT correlation could be discerned between normalized apartment power and outdoor air temperature. This is because there are too many end-uses mixed into the total measurement. This lack of correlation is shown in Figure 2.

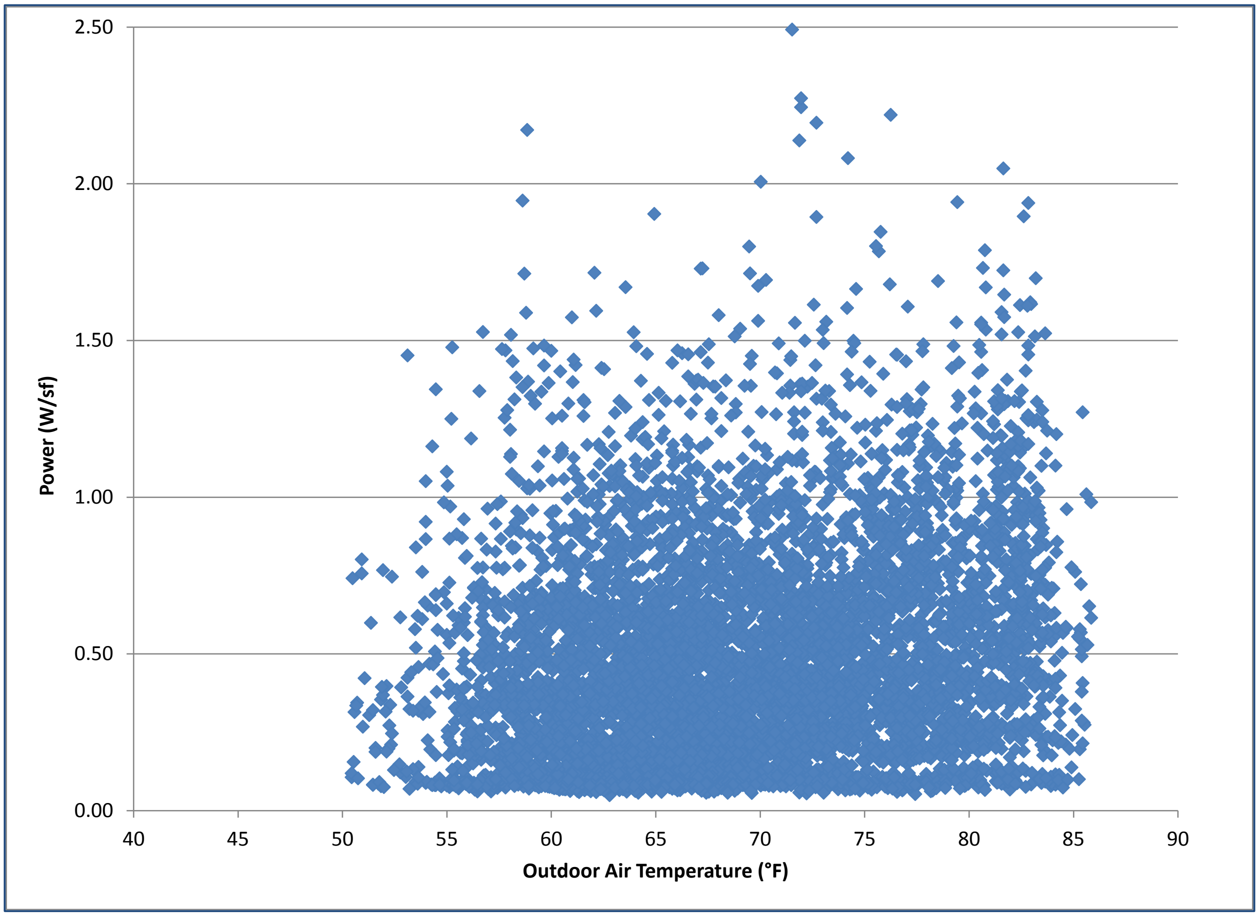


Figure 2: Apartment Load Correlation to OAT.

Also collected were several common area loads via current transducers, including the fitness room, corridor, and entertainment room, with results shown in Figure 3. Unfortunately, none of these spaces were explicitly built in the model (which involved highly simplified 5-zone core/perimeter modeling), nor did any of the spaces represent primary scheduling for the commercial space. For this reason, schedules in the commercial space were not adjusted from scheduling assumed in the original model.

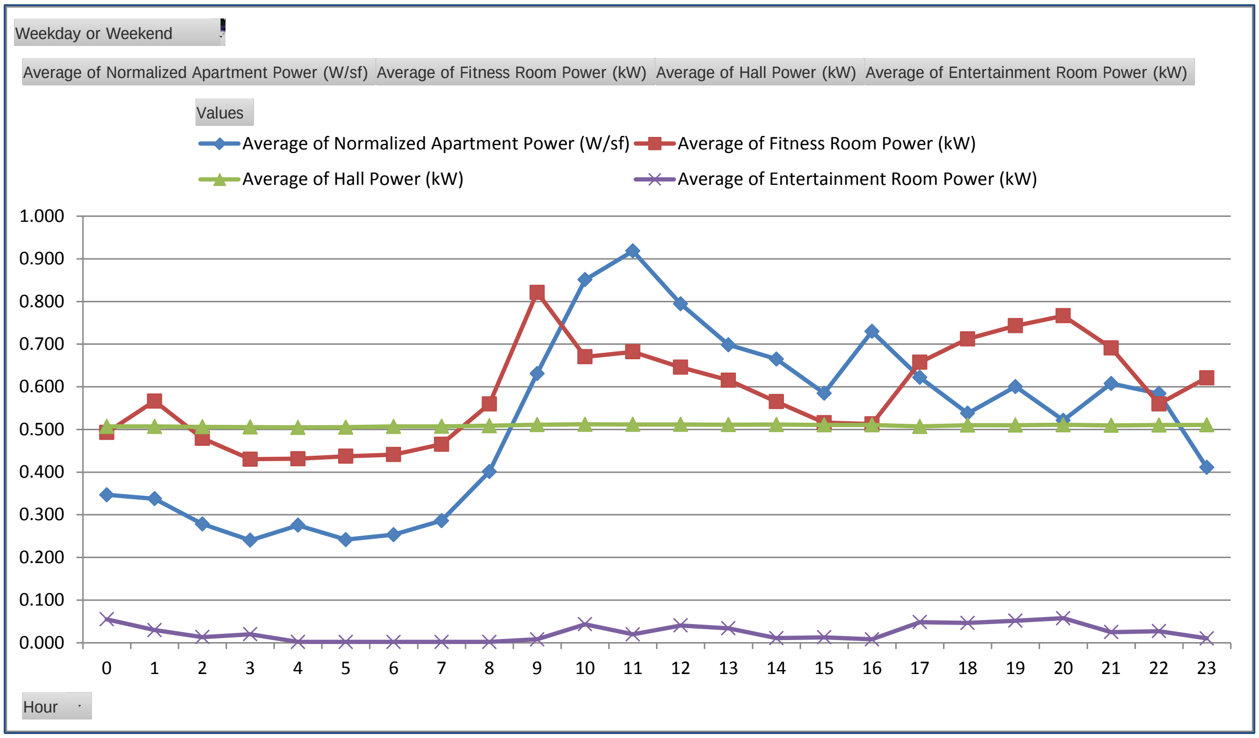


Figure 3: Monitored Residential Common Space Power.

MODEL ADJUSTMENTS

First, the Baseline and Proposed models inputs were adjusted based on parameters evaluated in the previous sections.

Because there are more than 80 apartments that are individually metered in the renovated building, not all of which are occupied, it was not practical to collect utility data for model calibration. However, logger data were used for adjustment of schedules to reflect observed operating conditions with the following methodology.

Because end-uses in apartments were not individually measured or logged, and in order to develop operating schedules for use in the energy model as multipliers on installed lighting power density and equipment power, it was assumed that 90% of the installed lighting power was operating at the peak hour (11 am on weekends). From there, a percent usage profile schedule was developed from the normalized power profiles. This is illustrated in Figure 4. It was assumed that plug loads also tracked this profile, so the schedule was also applied to equipment power densities in the residences. Since schedules are to be identical between the Baseline and the Proposed per ASHRAE 90.1 modeling, the same adjusted schedules for residential lighting and plug loads were input into the Baseline model.

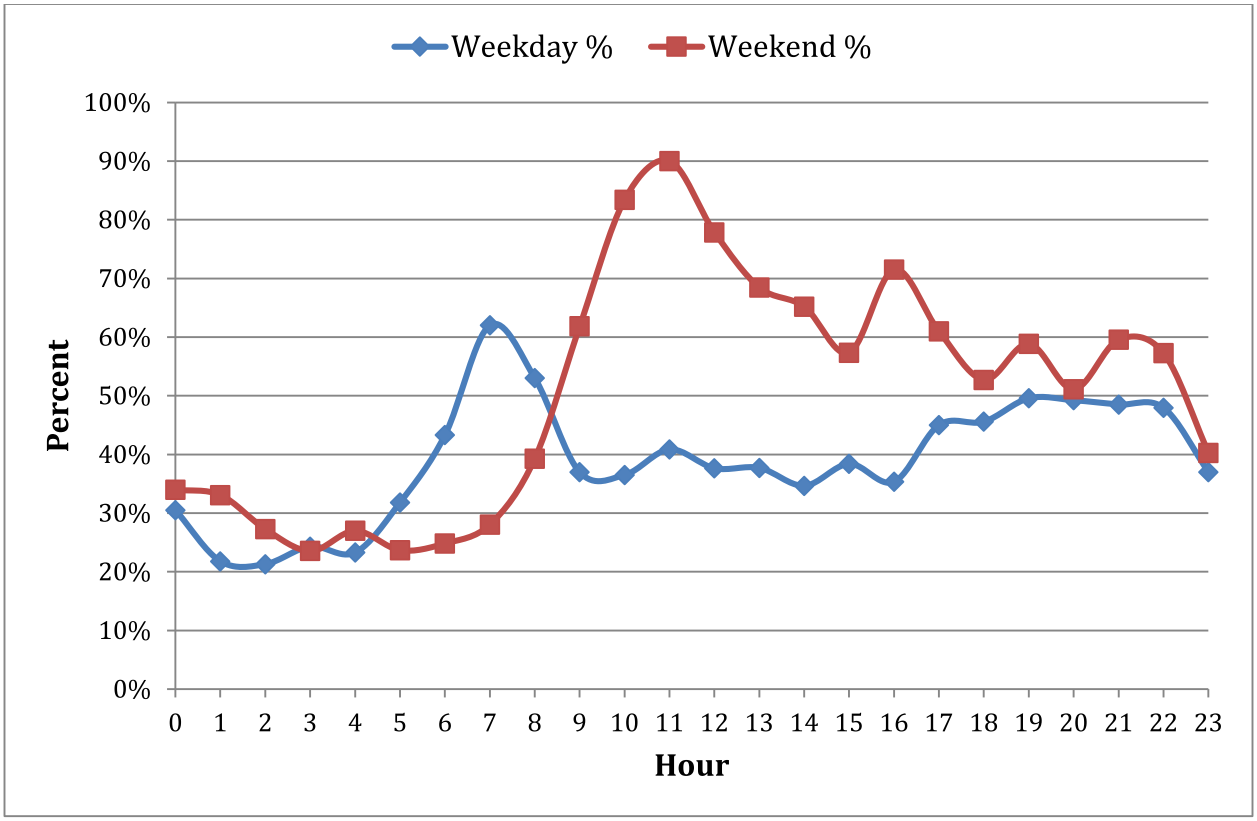


Figure 4: Apartment Lighting and Equipment Schedules.

ENERGY SAVINGS

The revised models were then run to calculate the annual post-retrofit demand and energy consumption of the Adjusted Proposed model compared to an average of four 90 degree rotations of the Adjusted Baseline model per ASHRAE 90.1 modeling protocol. Table 3 presents Adjusted modeling results.

Table 3: Adjusted Model Results.

Rotation	kWh	Coincident Peak Demand	Peak Demand	Therms
0° Baseline	2,620,320	565.1	675.1	41,846
90° Baseline	2,628,350	555.2	684.6	41,052
180° Baseline	2,635,541	568.5	685.3	39,782
270° Baseline	2,637,110	580.9	689.6	40,971
Average Baseline	**2,630,330**	**567.4**	**683.7**	**40,913**
Proposed Design	**2,157,393**	**564.0**	**678.3**	**14,427**
Savings	**472,937**	**3.4**	**5.4**	**26,486**

Table 4 presents the final energy and demand savings and realization rates for the [Redacted] Custom Incentive Program project. For Ohio in 2013, the coincident peak demand is evaluated on July 17 (Monday), for the hour between 4-5 PM.

Table 4: Comparison of Results to Projected Savings.

Facility	[Redacted]		
	Annual Energy Usage (kWh)	**Summer Coincident Peak Demand (kW)**	**Summer Peak Demand (kW)**
Duke Projected Savings	887,484	122.1	146.5
Model Savings	472,937	3.4	5.4
Realization Rate	53%	3%	4%

There are two primary reasons for the lower realization rates on this project:

1. The lighting power density for the Multifamily floors of the ASHRAE 90.1-2007 Baseline was incorrectly modeled as 1.1 W/ft^2 using the 90.1 Building Area Method. This should have been modeled as 0.7 W/ft^2.

2. The Baseline model incorrectly specified the system for residential floors as Packaged Multizone. This should have been modeled as packaged terminal air conditioners (PTAC) with hot water fossil fuel boiler heating type per ASHRAE 90.1-2007 Appendix G Tables G3.1.1A and G3.1.1B.

Attachments

1. Energy Model Input Summary

ENERGY MODEL INPUT SUMMARY (as received and as modified) (page 1 of 2)

Baseline Energy Analysis Input Summary According to ASHRAE 90.1-2007

1. Building Envelope
    1.1. Roof: R-20 Insulation
    1.2. Exterior walls: R-13 + R-7.5 Continuous Insulation Adjusted to be same as existing building per 90.1 modeling guidelines. 12 inch on most levels. Model submitted showed an R-10 layer, which was removed for the model adjustment.
    1.3. Slab: 6” Slab
    1.4. Floors: Metal frame with R-30 Insulation
2. Vertical Fenestrations
    2.1. Windows: U-Value of 0.55 and Shading Coefficient of 0.40 Adjusted to be same as existing building per 90.1 modeling guidelines.
    2.2. Doors: Metal door no insulation
3. Daylighting control
    3.1. Not Modeled
4. Operational Schedule
    4.1. Subbasement – 3rd Floor: office/financial occupancy 8AM-5PM no weekend or holidays
    4.2. 4-15 Floors: Residential Occupancy, mainly 5PM-7AM
5. Lighting Power Density
    5.1. 1.1 W/sq.ft. all floors Adjusted to 1.0 W/sf for office, 1.5 W/sf for financial, and 0.7 W/sf for residential floors.
6. Domestic Water Heating
    6.1. 50 gallons electric storage tanks in each apartment.
7. HVAC System
    7.1. DX Cooling units with 9.8 EER. Submitted model showed Packaged Multizone. Changed to packaged terminal air conditioners (PTAC) with hot water fossil fuel boiler heating type per ASHRAE 90.1-2007 Appendix G Tables G3.1.1A and G3.1.1B.
    7.2. Hot water fossil fuel boiler, 80% efficiency.

ENERGY MODEL INPUT SUMMARY (page 2 of 2)

Proposed Energy Analysis Input Summary

1. Building Envelope
    1.1. Roof: R-20 Insulation
    1.2. Exterior walls: 24” Concrete Walls no insulation 12 inch on most levels. Model submitted showed an R-10 layer, which was removed for the model adjustment.
    1.3. Slab: Concrete slab
    1.4. Floors: concrete floors
2. Vertical Fenestrations
    2.1. Windows: Perimeter windows are double pane ½” air gap and tinted
    2.2. Light-well and first floor are single pane 1/8” clear
    2.3. Doors: as in baseline
3. Daylighting control
    3.1. Not Modeled
4. Operational Schedule
    4.1. Sub basement-3 Floor: office occupancy 8AM-5PM no weekend or holidays
    4.2. 4-15 Floor Apartments: residential occupancy 5PM-7AM Lighting and equipment schedules adjusted based on analysis of monitored data.
5. Lighting Power Density
    5.1. Sub-3 Floor Office: estimated at 1.1 W/sqft Adjusted to 1.0 W/sf for office and 1.5 for financial to be same as ASHRAE Baseline.
    5.2. 4-15 Floor Apartments: 0.83 W/sqft Adjusted to 0.57 W/sf based on takeoffs.
6. Domestic Water Heating
    6.1. 50 gallons electric storage tanks in each apartment.
7. HVAC System
    7.1. Cooling: WSHP with efficiency of EER 14. Model submitted and equipment installed averaged 13.5.
    7.2. Heating: WSHP with efficiency of COP 4.1. Model submitted and equipment installed averaged 4.6.
    7.3. Cooling plant: high efficiency cooling tower with VFD
    7.4. Heating plant: High efficiency boiler with 98% efficiency. Model submitted and equipment installed was 93.5%

[Redacted]
AC2 West Upgrade
M&V Report

Prepared for
Duke Energy Ohio

February 2015, Version 1.1

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:

Doug Dougherty
NORESCO, Inc.

Stuart Waterbury
NORESCO, Inc.

2540 Frontier Avenue, Suite 100
Boulder CO
80301

(303) 444-4149

NORESCO
United Technologies

Introduction

This report addresses measurement and verification (M&V) activities for [redacted] custom program application. The application covers upgrading the HVAC unit AC 2 West. The measure includes:

ECM-1 – Air Valve Modifications to Reduce Building Air Flow

- Replacing the existing supply fan in a constant volume, dual duct air handler with a new Huntair FANWALL 12-fan array system. Two new VFD's allow full modulation and also provide redundancy.
- Two new VFDs were also installed on the two existing return fans to allow variable speed operation.
- Old DDC controls were entirely replaced. This effort including adding static pressure sensors in the three duct mains served by this unit. The unit previously maintained 6.5 inches of static pressure at the discharge. The new maximum pressure setpoint was to be 4.0 in-WG at the fan discharge, and the new fans would modulate downward from that pressure as VAV boxes in the space close off. (Approximately 40% of the existing terminal boxes had already been converted to single duct, variable volume, although the main system still operated at constant volume.)
- A power (kW) meter was to be installed on the return fan to verify savings.
- The application considered fan energy savings only, although additional energy savings in cooling are expected.

The installation was completed in September, 2013, so the M&V activities were for post-retrofit only.

Goals and Objectives

Pre-and post-retrofit energy calculations for the building HVAC systems were previously created by the applicant's engineering firm. These calculations are included in the application.

The projected savings goals identified for this project are:

	APPLICATION		DUKE PROJECTIONS		
Facility	**Proposed Annual kWh Savings**	**Proposed Peak kW Savings**	**Proposed Annual kWh Savings**	**Proposed Non-Coincident Peak kW Savings**	**Proposed Coincident Summer Peak kW Savings**
[Redacted] HVAC Unit AC 2 West	792,201	-5	789,375	73.2	44.3

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

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

Project Contacts

NORESCO Contact	Doug Dougherty	ddougherty@noresco.com	O: 303-459-7416
Duke Energy M&V Coordinator	Frankie Diersing	Frankie.Diersing@duke-energy.com	O: 513-287-4096 C: 513-673-0573
Customer Contact	[Redacted]	[Redacted]	[Redacted]

Site Locations/ECM's

Site	Address	Sq. Footage	ECMs Implemented
[Redacted]	[Redacted]	1,400,000	1

Data Products and Project Output

- Energy consumption pre- and post-retrofit for the controlled equipment
- Annual energy savings
- Peak demand savings
- Coincident peak demand savings

M&V Option

IPMVP Option A

M&V Implementation Schedule

This survey and data collection was for post-retrofit only.

- Post-retrofit data was collected for a thorough evaluation.
- The monitoring period included both normal workdays and weekends. No holidays occurred during the monitoring period.

Field Survey

Customer Interview

Interviewed the building contact.

- Determined the normal occupancy schedules
- Determined the number of holidays observed per year
- Obtained a copy of the final air test and balance measurements.
- Confirmed the configurations of the AHU:

System:	**AC2 West**	
	Supply Fans	Return Fans
Total # available	12	2
HP each	15	15
# Running when Occupied	12	2
# Running when Unocc'd	12	2
# VFD's Installed	2	2

- Obtained pre-retrofit and post-retrofit sequences of operation for the HVAC unit.
- Determined if any sequence changed between the pre- and post-retrofit.
- Determined additional information as requested in the M&V Plan.

Spot-Measurements

For the subject AC Unit:

- Measured supply fan volts, amps, watts and power factor before each VFD.
- Recorded the number of supply fans controlled by each VFD in the above measurement.
- Measured return fan volts, amps, watts and power factor upstream of each VFD.
- Verified that each return fan VFD controls a single return fan.

Field Data Logging

Time series data on controlled equipment

Trend logs were established in the EMS to monitor certain points defined below. Otherwise, data loggers were deployed as noted.

Outdoor Air:

- Installed a weather logging station data logger to record outside air temperature and relative humidity in 5-minute intervals.

AC Unit:

- Trended the following points in the EMS:
    - Supply fans' VFD speed
    - Supply air flows (CFM)
    - Supply air static pressure setpoint
    - Return fans' VFD speed

The following points were not trended:

- Actual supply air static pressure
- Return fans' air flow (CFM)
- No new power meters for supply or return fans were installed by the customer, so data loggers were installed to measure these powers.

- For each VFD, configured Elite Pro data loggers to record the following information:
    - Voltage
    - Current (amps)
    - Power factor
    - Power (kW)

- Set up loggers (or trend logs) for 5-minute average readings (not instantaneous) and allowed operation for a minimum of three weeks.
- Collected data during normal operating hours (avoided atypical operating situations such as maintenance shutdowns).

Logger Table

The following table summarizes the logging equipment used to accurately measure the above noted ECM's.

Function	**Hobo Weather Station**	**ElitePro Energy Logger**	**Magnelab CT's***
OAT/RH	1		
AHU Supply Fans (two VFD's)		2	(6) 150A
AHU Return Fans (two VFD's)		2	(6) 20A
Total	**1**	**4**	**12**

*CT sizes were based on 460-volt, 3-phase 3-wire delta electrical service and the following fan motor horsepowers:

System	Quantity per VFD	HP per Motor	Total VFD Connected HP
AC2 West Supply Fans	6	15	90
AC2 West Return Fans	1	15	15

Data Accuracy

Measurement	**Sensor**	**Accuracy**	**Notes**
Current	Magnelab CT	±1%	Recorded load must be < 130% and >10% of CT rating
Power	ElitePro	±1%	

Data Analysis

NOTE: The analysis approach is presented below.

1. Converted time series data on logged equipment into post-retrofit average load shapes by day-type.

2. Developed post -retrofit regression model of total daily fan energy (kWh) as a function of daily average outdoor dry-bulb temperature and humidity. *[There is no correlation of fan energy to OA conditions.]*
3. If warranted by a correlation of total daily kWh to daily average outdoor air temperature, generate post -retrofit bin analysis using local weather data. Using the correlated fan power values, calculate the fan energy consumed from the binned weather hours at each daily average OAT. *[N/A]*
4. Since there is no discernable correlation of total daily fan energy to outdoor air temperature, generated post -retrofit analysis using average day-type load shapes.
5. Totaled the fan energy by day-type to determine the total annual fan energy consumption.
6. From the time-series data, determined the non-coincident peak demand and the coincident peak demand. For 2014, the coincident peak hour for Ohio is on July 17th from 4-5 p.m. Since this date and time was not captured in the monitored data, the coincident peak demand was be estimated as the maximum demand observed in the 4-5 PM hour on any weekday of the monitoring period.
7. Since there was no opportunity to evaluate the fan energy usage of the HVAC unit prior to the retrofit, and since there is no correlation of total daily fan energy to outdoor air temperature, we used the measured total unit fan power found in the attachment to the application as the basis for determining energy savings. This value (137.3 kW) is about 90% of the rated power of the original constant-volume fan.

8. Compared the revised post-retrofit model output with the pre-retrofit output to determine the annual energy savings.

Verification and Quality Control

- Visually inspected trend and logger data for consistent operation. Looked for data out of range and data combinations that are physically impossible. Removed invalid data.
- Verified pre-retrofit and post retrofit equipment specifications, quantities, and schedules are consistent with the application.

Recording and Data Exchange Format

1. Applicable field notes
2. EMS data files and data logger files
3. Excel spreadsheets.

Results

The M&V efforts determined the following:

- The original constant volume supply fan in the dual duct air handler was replaced with a new FANWALL 12-fan array system as planned. The two new VFD's were installed.
- Two new VFDs were also installed on the two existing return fans.
- The new static pressure setpoint was 2.5 +/- 0.1 in-WG during the monitoring period. This value is measured in the ductwork on the ninth floor.
- Approximately 40% of the existing terminal boxes had been converted to single duct, variable volume terminals at the time of the application. This figure is now 100%.
- The planned power (kW) meter that was to be installed on the return fan to verify savings was not installed.
- Since the facility is a hospital, it is occupied and operated continuously, with no shutdowns for holidays.
- Monitoring was conducted for 23 days.

During the monitoring period, the supply air flows (CFM per main duct), supply and return fan VFD speeds and the supply air static pressure were all trended in the facility's EMS. However, the return fan air flow was not provided, and the VFD speeds and the static pressure data were only recorded for the last 24 hours.

All four VFD's receive the same speed command signal. Although there is only 24 hours of data to directly support this statement, the trended CFM and measured power data are all consistently similar in their variation. The SF CFM's vary only +/- 7% over the monitoring period. The VFD speed varies only from 82-90%, averaging 85.2%. A chart of the trended CFM is shown below.

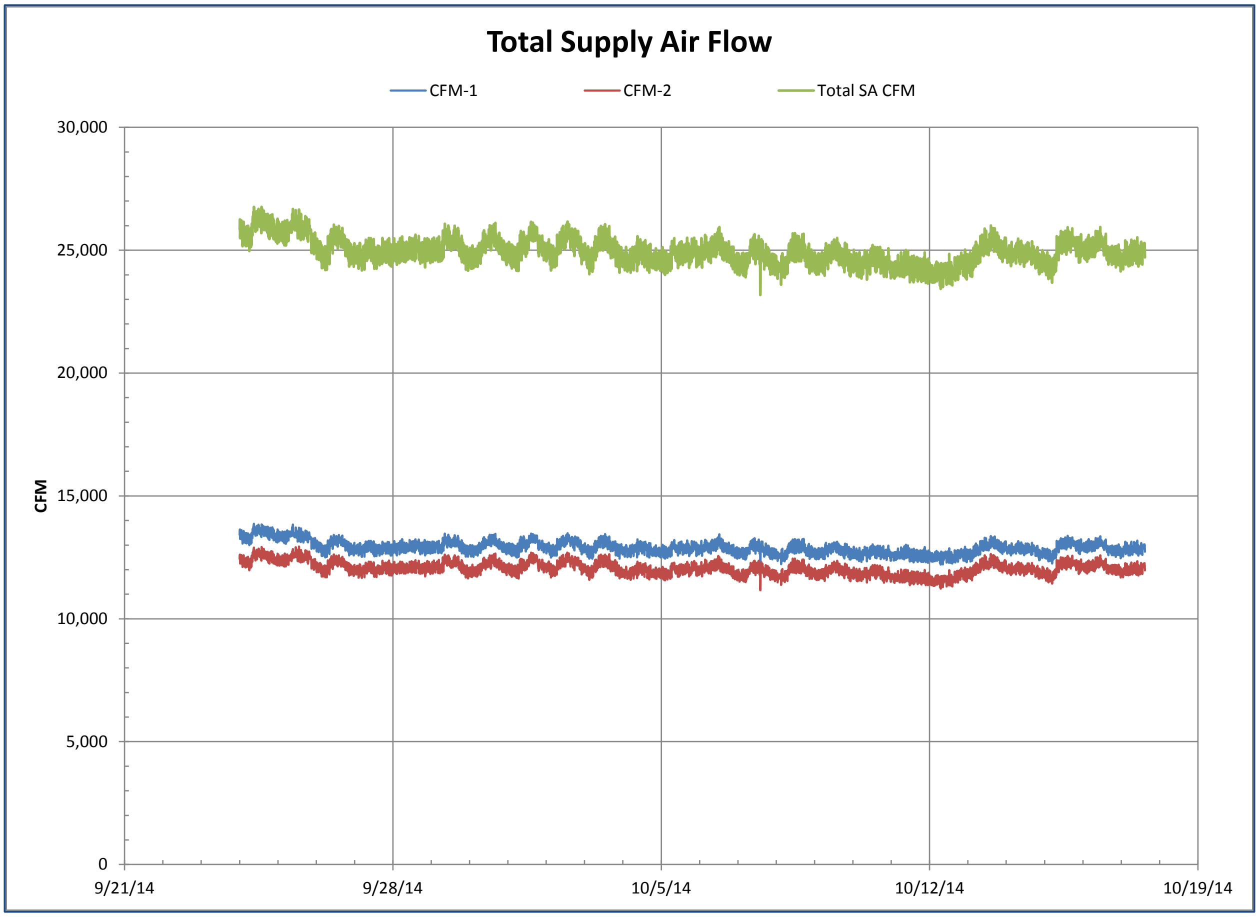


Figure 1. Trended Supply Air Flows (CFM)

A chart of the measured power history is shown below in Figure 2. The average supply fan power was 100.95 kW and the average return fan power was 12.75 kW, for a total of 113.7 kW. The total power value varies only +/- 15% over the course of the monitoring period. The maximum total power observed was 133.1 kW.

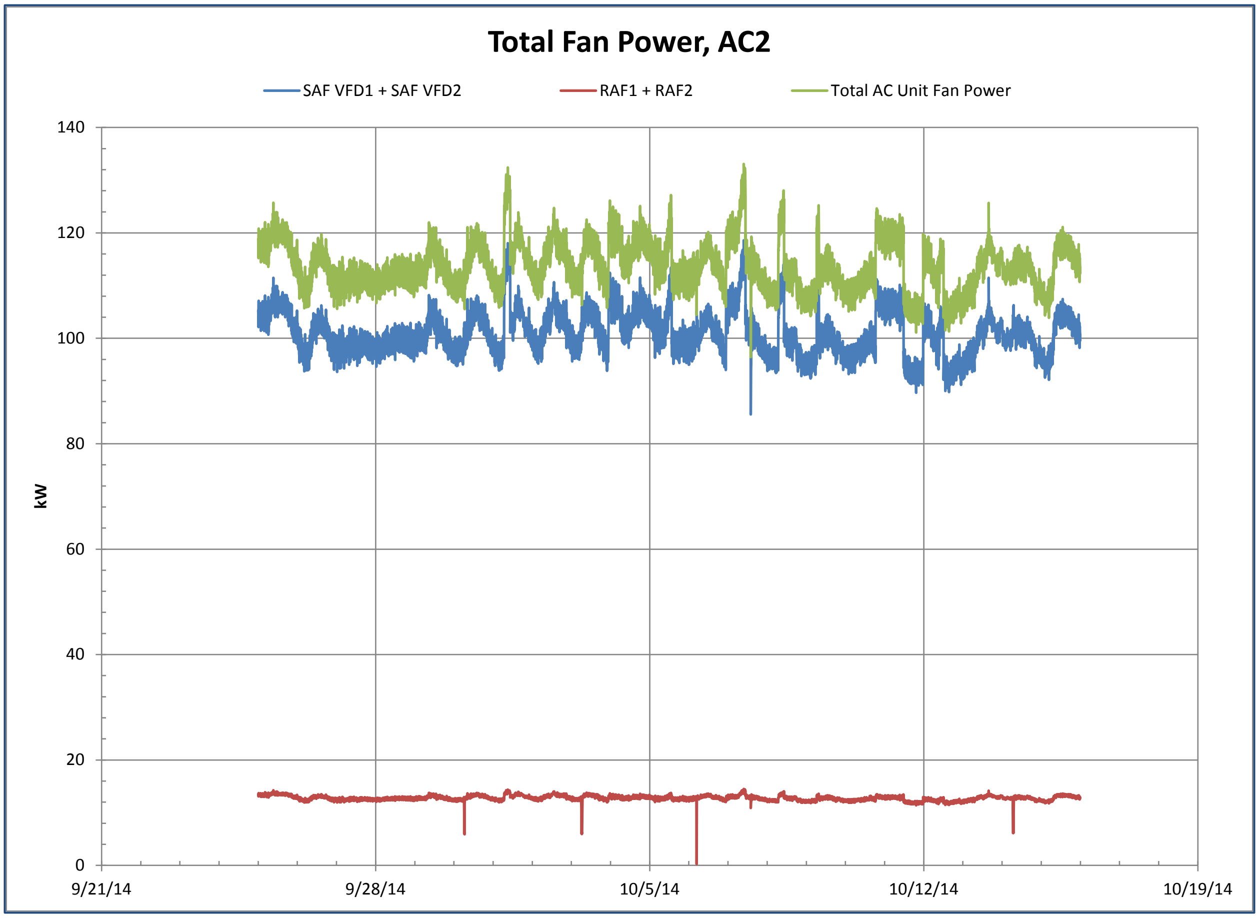


Figure 2. Measured Fan Powers (kW)

Outside air temperature was also measured, but, as shown in the following chart, there is no significant correlation of fan power to the OA temperature, on either a timed interval or daily basis.

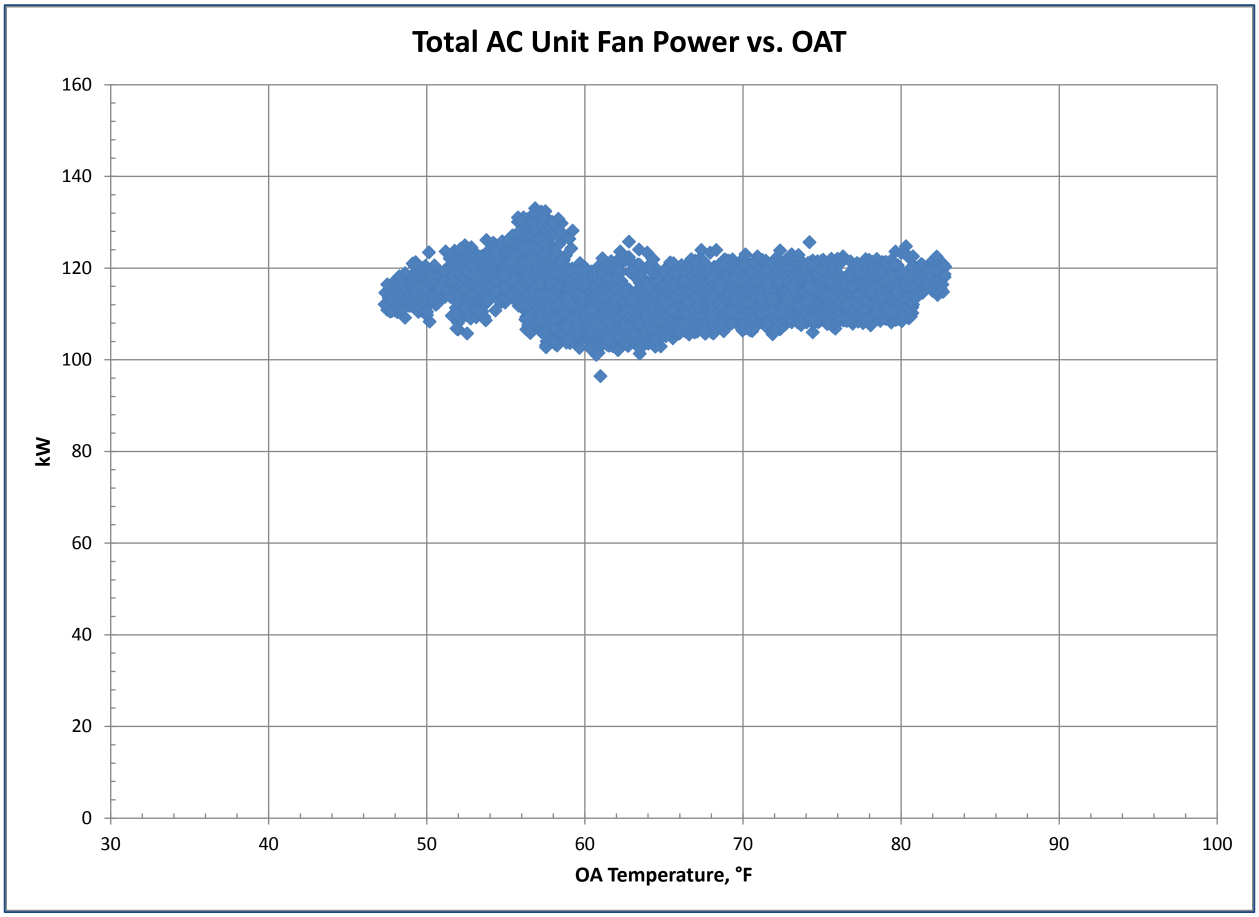


Figure 3. Fan Power vs. Outside Air Temperature

The chart below shows the average daily fan power (supply plus return, kW) and daily total energy consumption over the monitoring period. As previously mentioned, the average power is fairly uniform across all days and temperatures, and the average total fan power is 113.7 kW. The average daily total energy consumption is 2,729 kWh/day. Multiplied by 365 days per year, the total annual energy consumption is 996,003 kWh/year.

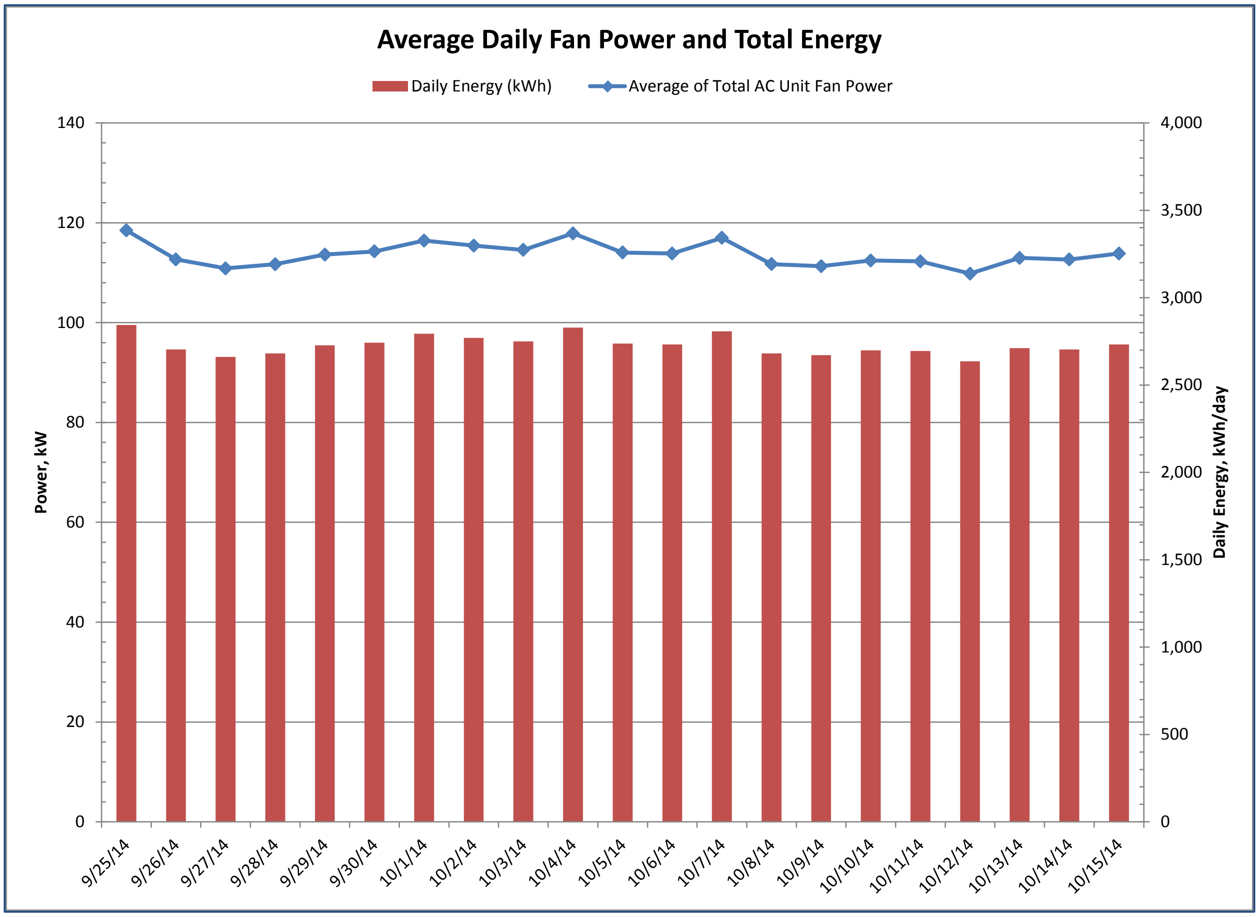


Figure 4. Daily Average Power and Total Energy Consumption

As noted previously, the maximum power observed during the monitoring period was 133.1 kW. Developing average hourly load profiles from the measured power data shows that the fan power is generally slightly higher in the late mornings than it is in the afternoons (see the following chart). For Ohio in 2014, the coincident peak demand hour is on July 17, for the hour between 4-5 PM. Monitoring was not in progress on that date for this project; therefore, the available monitored data was used to determine the peak power expended during the 4-5 PM time period on any weekday, which was 121.9 kW.

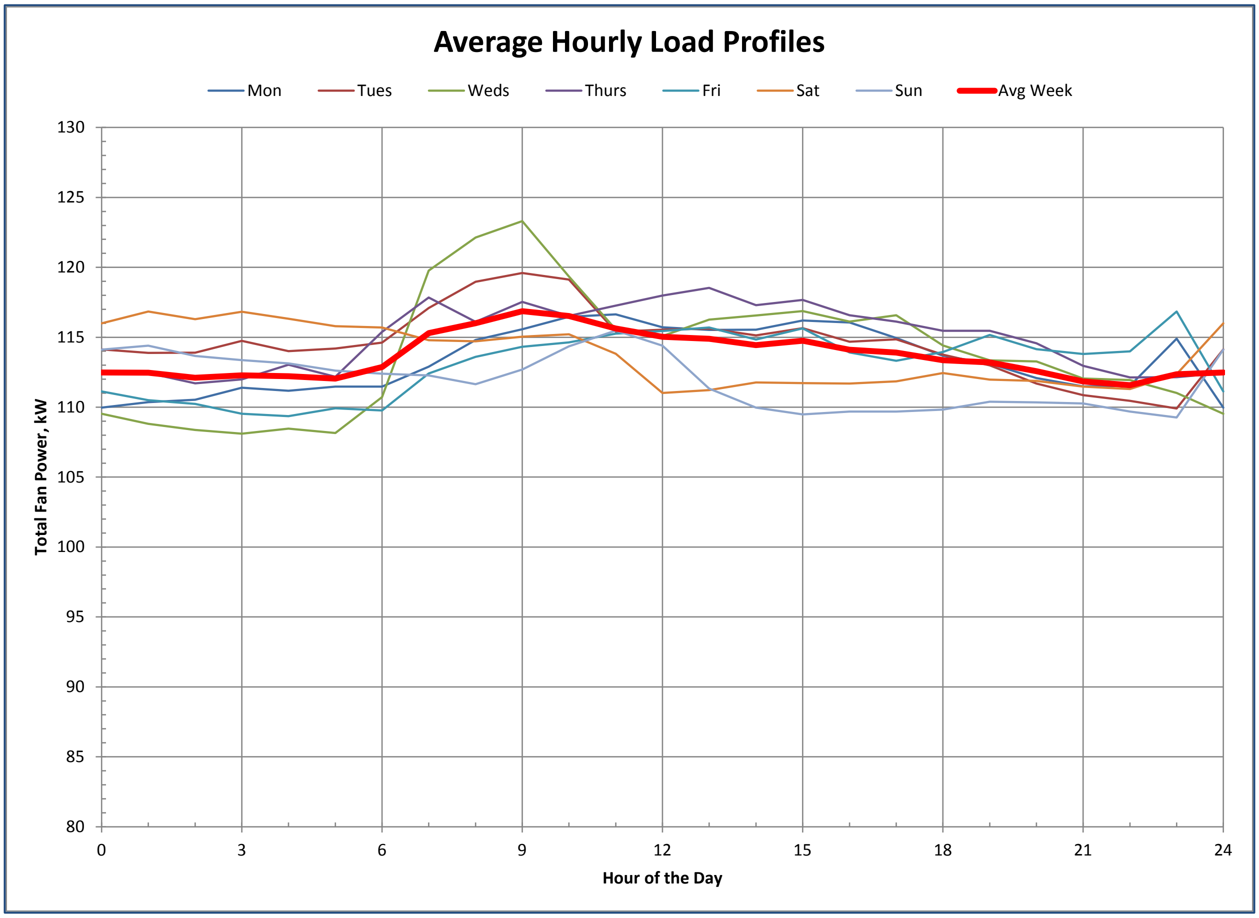


Figure 5. Average Load Profiles (Fan kW)

For the baseline (pre-retrofit) peak power and annual energy consumption, and since the average load is very steady, we used the measured total unit fan power found in the attachment to the application as the basis for determining energy savings. There was no opportunity to measure the fan powers independently before the retrofit occurred. Also, since there is no variation of fan power or air flow with the OA temperature, there is no need to adjust the measured value for such variations. Therefore, from the application, the pre-retrofit power and energy consumption are as shown in the table below:

Table 1. Baseline (Pre-Retrofit) Power and Annual Energy Consumption

	Fan BHP	Fan KW	Hours of Operation / Year	Operating Load Percentage	Annual Energy (kWh)
Supply Fan	184	137.264	8760	100%	1,202,433
Return Fans (total of 2)	12.7	9.474	8760	100%	82,994
Totals		**146.7**			**1,285,427**

The pre- and post-retrofit values described above lead to the energy and demand savings shown in the following table.

Table 2. Annual Energy and Demand Savings - [Redacted] AC 2 West

Facility: [Redacted] HVAC Unit AC 2 West			
	Annual Energy (kWh)	Non-Coincident Peak Demand (kW)	Coincident Summer Peak Demand (kW)
Pre-Retrofit	1,285,427	146.7	146.7
Post-Retrofit - M&V	996,003	133.1	121.9
Savings	289,424	13.7	24.8
Duke Projections	789,375	73.2	44.3
Realization Rates	37%	19%	56%

The realization rates are poor, and far below expectations. The main reason for this performance is that the anticipated variations in supply air delivery and fan power, to be achieved by installing the VFD's on the new Fanwall array and the return fans, are not present. The chart in Figure 6 compares the measured fan power values for all the monitored time intervals to the distribution used in the application (the power values on the horizontal axis correspond to average VFD speed bins of 40%, 50%, 60% … 100%, as used in the application). The application calculation does not state how the anticipated distribution of %-speed hours was generated.

The savings that have been achieved are most likely due to the reduction in supply fan discharge pressure, which was one of the goals of the ECM. The original supply fan and the new Fanwall system were supposed to have the same peak full-load power. Our field technician's notes state that the duct pressure is now controlled to a setpoint of 2 in WC on the ninth floor (the data records 2.5 in WC as the actual value). The original pressure at the supply fan discharge was 6.5 in WC. The designer's hope was to reduce the discharge pressure from 6.5 to 4.0 in WC, a drop to 61% of the original value. Allowing for a couple of more inches of pressure drop on the inlet side of the fan, the reduction from 6.5 to 4.0 at the fan outlet is probably a drop to about 70% of the original total pressure value. The actual reduction in average supply fan power is to 73%, so the reduction in pressure does seem to explain the observed savings.

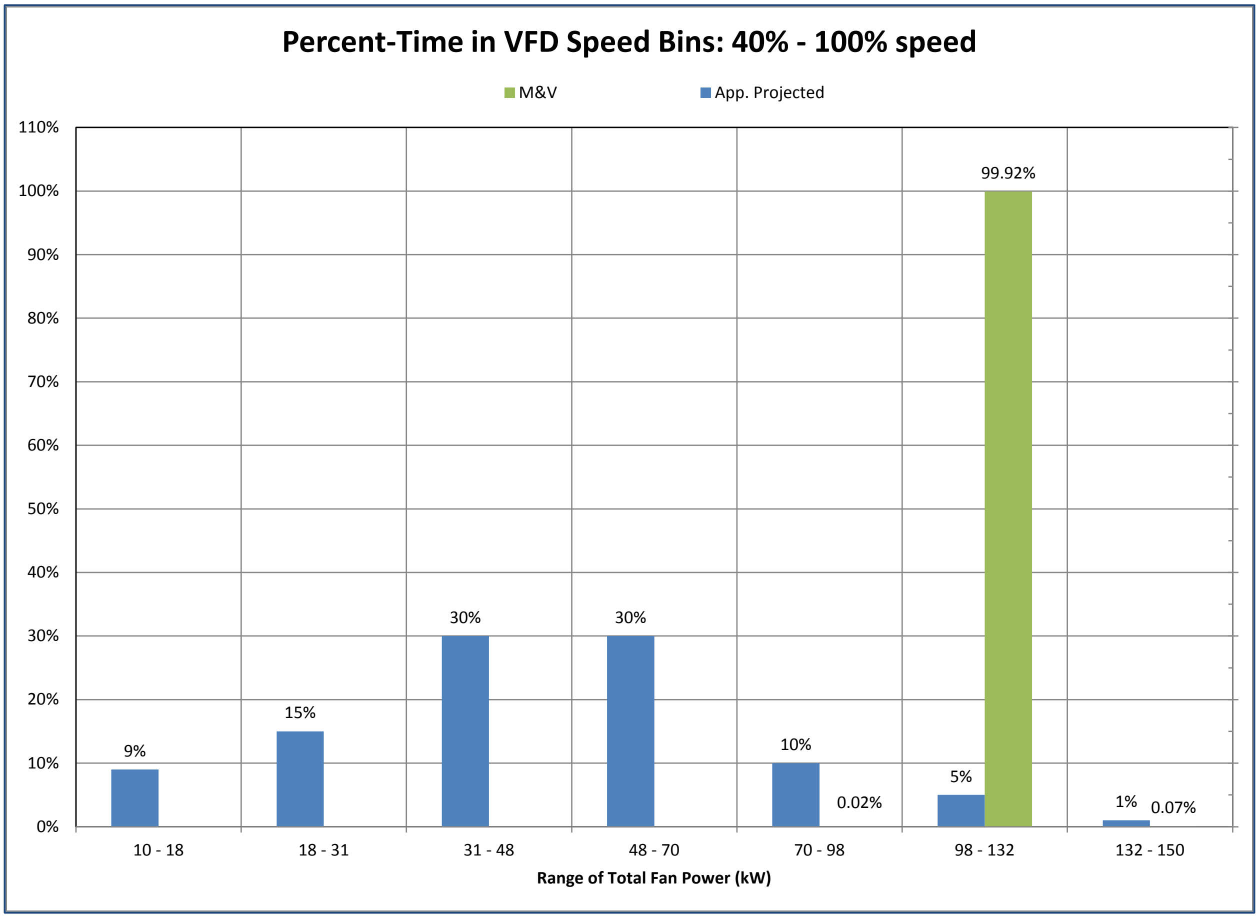


Figure 6. Compare Estimated and Actual Fan Speed Distribution

ARCHITECTURAL ENERGY CORPORATION

[Redacted]

- Window Replacement -

M&V Summary Report

PREPARED FOR:

Duke Energy

Ohio

PREPARED BY:

Architectural Energy Corporation

2540 Frontier Avenue, Suite 100

Boulder, Colorado 80301

PREPARED IN:

December 2012

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

The M&V activities described here were 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].

INTRODUCTION

This report addresses M&V activities completed for the [Redacted] custom program application. The measures include:

ECM-1: Window Replacement

- The [Redacted] windows were original to the building, single-pane casement windows that were drafty, poorly-insulated and generally very inefficient. The majority of the [redacted]'s windows have been replaced with new double pane, low-e, clear windows with a U-value of 0.36 and shading coefficient of 0.65.

  In addition, the current system utilizes approximately 20 window air conditioners to serve particular perimeter spaces. The new glazing will allow these spaces to be completely served by the central cooling system, saving cooling energy in the process.

Note: ECMs have already been installed for this application. Survey data will be for Post-install only.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

Application Proposed Annual savings (kWh)	*Application Proposed Peak Savings (kW)*	*Duke Projected savings (kWh)*	*Duke Projected Peak savings (kW)*
1,033	26	1,032	26.0

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

- Annual gross kWh savings
- Summer peak kW savings
- Utility Coincident peak demand savings
- kWh & kW Realization Rates

PROJECT CONTACTS

Duke Energy M&V Coordinator	Frankie Diersing	513-287-4096
Duke Energy BRM	Cory Gordon	
Customer Contact	[Redacted]	[Redacted]
Architectural Energy Corporation Contact	Peter Fox	p: 303-459-7477 pfox@archenergy.com

SITE LOCATION

Address	*Square Footage*	*Facility Age*
[Redacted]	~30,000	50+ years

Data Products and Project Output

- Model predicting annual pre/post kWh
- Summer peak demand savings [kW]
- Coincident peak demand savings [kW]
- Annual Energy Savings

Recording and Data Exchange Format

1. Pre-installation utility data.
2. Post-installation Survey Form and Notes.
3. Excel spreadsheets.
4. eQUEST and DOE-2 energy model data files.

M&V Option

IPMVP Option D: Calibrated Simulation

Field Survey Points

Following window installation, all information was recorded in the AEC 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, Energy Management Systems.
- HVAC system controls.
- Shading and blinds.
- Air handlers and water heating.
- Building envelope, including windows, walls, areas, and construction types.

Data Analysis

1. Verify Proposed Measures Were Implemented:

   Verified that all windows were replaced. In addition, nameplate data was collected for all HVAC equipment to ensure that it was accurately represented in the computer energy model.

2. Calculation Methodology:

   A computer energy simulation of the building was created using DOE-2 software with an eQUEST front end. This model was used to calculate the building energy performance and a host of other information. From these outputs, the necessary annual energy use in kWh was compared to determine the savings attributed to the building envelope upgrade.

In the creation of the Baseline building model, inputs such as equipment schedules were modified to accurately reflect the conditions of the pre-retrofit building.

3. Energy Model Calibration:

   Due to limited utility data specific to this building of the school campus, it was not possible to calibrate the model to billing data. It is believed that the model accurately reflects the building characteristics and there are no parameter changes that can be made while maintaining an accurate simulation of the facility.

4. Savings Verification and Realization Rate:

   The annual energy results of the Baseline and Existing building models have been compared to determine the amount of annual energy savings resultant from the retrofits. Once the savings are calculated, the realization rate is summarized by the following formula:

$$\text{Realization Rate for kWh} = kWh_{actual} / kWh_{application}$$
$$\text{Realization Rate for kW} = kW_{actual} / kW_{application}$$

VERIFICATION AND QUALITY CONTROL

1. Verified that pre-retrofit and post-retrofit window specifications and quantities are consistent with the application. If they are not consistent, record discrepancies.

RESULTS SUMMARY

Verify Proposed Measures Were Implemented:

Exterior Window Retrofit:

The windows were installed in the areas specified from a drawing set provided by the contractor to AEC. The school website also verifies the progress of construction through a sampling of renovation photos.

Results:

The values listed in the Goals & Objectives section above were provided as the submitted savings estimates to Duke Energy, and are repeated here for comparison.

Application Proposed Annual savings (kWh)	*Application Proposed Peak Savings (kW)*	*Duke Projected savings (kWh)*	*Duke Projected Peak savings (kW)*
1,033	26	1,032	26.0

These values were obtained through iterations of a Trace 700 energy model performed by Heapy Engineering in conjunction with this project. The Duke values are used for Savings Realization Rate calculations in this report.

Establish the Baseline Energy Use:

The baseline building electricity consumption resulting from M&V activities was determined through a model of the school created in eQuest version 3.64. A site visit was conducted to help assess the space characteristics, mechanical systems, operation, etc. so that the model would accurately represent the facility as much as possible. This information was collected from the SurveyIt form provided by AEC, bid drawings, Trace 700 model outputs, utility data, and the school website. The following are the main assumptions applied to both building models in addition to glass types:

- Operation schedule: 7am-10pm, Monday-Saturday.
- Holidays and breaks are based on 2013 school calendar.
- Occupied Heating and Cooling setpoints: 68°F and 74°F respectively.
- Thermal storage charging enabled from 9pm-6am, 3 tanks totaling 360 Tons capacity.
- (1) 60 Ton chiller for cooling and thermal storage charging, operates at ~9 EER.
  - Air-cooled operation based on model number.
- (2) 1,262,000 Btuh Lochinvar boilers for space heating.
- Unit Ventilators serve exterior spaces, with OA connection and dampers.
  - Fans cycle overnight without OA, zone temperature control, HW CHW connection.
- Drawings supplied dimensions, zoning, and window-wall areas

Establish the Post-ECM Energy Use:

The post-retrofit building use was determined through adjustments to the baseline building, constructed as described above. This ensured that schedules, equipment, and geometry would remain the same and only window properties could be adjusted. The values given to the two window types were as stated in the *Duke Energy Custom Application* and *Energy Analysis* provided from Heapy Engineering.

	U-Value	***Shading Coefficient***
Existing Window	1.57	0.90
New Windows	0.36	0.65

Savings Verification and Realization Rate:

It is believed that the model accurately reflects the building characteristics and there are no additional parameter changes that can be made while maintaining an accurate simulation of the facility. Due to limited utility data specific to this building of the school campus, calibration of the model to utility bill data was not possible.

Baseline and Post-retrofit savings data can now be compared to determine the savings actually realized as a result of this project. The realization rate is determined by the following formula:

$$Realization\ Rate = \frac{kWh_{actual}}{kWh_{application}}$$

The modeled energy use, savings totals, and realization rates for [redacted] are listed in the following Table.

	kWh	Non-coincident Peak kW	Coincident Peak kW
Duke Estimated Savings	1,032	26.0	25.2
Evaluated Savings	9,941	0.6	4.6
Realization Rate	9.63	0.02	0.18

[Redacted]

- Integrated Energy Design for Electric Efficiency -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

PREPARED BY:
Architectural Energy Corporation
2540 Frontier Avenue, Suite 100
Boulder, Colorado 80301

PREPARED IN:
June 2014
Version 1.0

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].

INTRODUCTION

This report addresses M&V activities for the [redacted] custom program application.

The [redacted] facility in downtown Cincinnati is composed of three buildings [redacted]. An engineering and re-commissioning study of the [redacted] was conducted in mid-2011 to January 2012. The resulting "SmartBuilding Advantage Engineering Study" report details a number of recommendations for lighting, mechanical and controls improvements in a three-phase renovation project.

The *Custom Incentive Program* application that is the subject of this M&V effort covers HVAC systems and controls upgrades in the 1982 building. The building is served by nine air handlers having several different system types and capacities. The table below summarizes the air handling units by level served and system type.

1982 Building air handling units

Level	Served By	System Type(s)
3 (public)	AC-2, AC-4, AC-5[1]	Dual duct
D (non-public)	AC-3	Constant volume
C (non-public)	AC-3	Constant volume
2 (public)	AC-2, AC-4, AC-5[1]	Dual duct
1 (public)	AC-2, AC-4, AC-5[1]	Dual duct
B (non-public)	AC-1, AC-6, AC-7, AC-8, AC-9, HV-1	VAV and constant volume, plus a multi-zone heat recovery unit.

Note:

1. AC-2 serves the core of levels 1, 2, and 3, while AC-4 and AC-5 each serve half of the perimeter of levels 1, 2, and 3.

The above AC units, except for HV-1, were to be upgraded in the second phase of the three-phase project, as outlined in the engineering study. An eQUEST energy model was previously developed as part of that assessment to estimate the energy savings attributable to each phase.

Phase 1 consisted of the Energy Conservation Measures (ECM's) listed below. The conditions of the [redacted] at the completion of Phase 1 constitute the baseline conditions for Phase 2.

ECM#	Description
Phase 1: Recommissioning and Lighting Retrofit	
1	Lighting retrofits
2	Lighting controls – occupancy
3	Lighting controls – daylighting
52-1	Repair steam condensate system
52-2	Eliminate summer boiler plant operation
52-3	Re-commissioning

82-1	Re-commissioning (limited)
95-1	Re-commissioning

Phase 2 was divided into two sub-phases, Phase 2A and 2B, for scheduling purposes. The Phase 2 ECMs consist of the following:

ECM#	Description
Phase 2A:	[Redacted] Major Mechanical and Controls
82-2A	Replace/retrofit AC-4 and AC-5
4A	[Redacted] BAS and controls upgrade/retrofit
Phase 2B:	[Redacted] Major Mechanical and Controls
82-2B	Replace/retrofit AC-1 and AC-2
82-3	Controls upgrade/retrofit for AC-3
82-4	Controls upgrade/retrofit for AC-6, 7, 8, 9

The Phase 2 ECM's are described in more detail below.

- **EMC 82-2A: Replace/retrofit AC-4 and AC-5**
  These units were to be replaced with VAV air handling units. The existing dual-duct mixing boxes throughout the building were either converted to standard VAV boxes, or replaced with fan-powered VAV boxes with heating coils.

- **ECM 82-2B: Replace/retrofit AC-1 and AC-2**
  This measure completes the replacement of the major air handling units serving the 82 Building. These units were to be replaced with VAV air handling units, and, as for AC-4 and AC-5, the existing mixing boxes throughout the building were either converted to VAV boxes, or replaced with fan-powered VAV boxes with heating coils.

- **ECM 82-3: AC-3 controls retrofit**
  AC-3 was recently mechanically overhauled, and only requires a controls retrofit. This unit serves the Level C and D stacks, which are areas of low occupancy. Therefore, air flow can be varied based on heating, cooling and ventilation demand.

- **ECM 82-4: AC-6, 7, 8, and 9 controls upgrade/retrofit**
  Since these units are relatively new, only a controls upgrade/ retrofit was to be implemented. Some of these units also already have VFDs. It was also recommended that these units be re-commissioned to optimize operation.

- **ECM-4A: BAS and controls upgrade/retrofit for [Redacted]**
  This ECM consisted of new building controllers, programmable I/O controllers, enterprise server and software, sub-meters and integrating existing meters.

Note that all ECMs recommending equipment replacement or retrofit include complete replacement of existing controls with new digital controls. All AC units received air balancing and commissioning.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are presented in the following table.

Projected Savings Comparisons

	Annual Energy Savings (kWh)	Peak Demand Savings (kW)
Application Proposed - Phase 2A	1,332,814	152.1
Application Proposed - Phase 2B	971,498	110.9
Application Total	2,304,311	263.0
Duke Projections	2,420,314	307.2

The objectives of this M&V project are to verify the actual:

- Annual gross energy savings (kWh)
- Utility coincident peak demand savings (kW)
- kWh and kW savings Realization Rates.

PROJECT CONTACTS

Duke Energy M&V Coordinator	Frankie Diersing	513-287-4096	Frankie.Diersing@duke-energy.com
E$ Energy Consultant	Michelle Kolb		
Customer Contacts	[Redacted] [Redacted]	[Redacted]	
AEC Contact	Doug Dougherty	(w) 303-459-7416 (c) 303-819-8888	ddougherty@archenergy.com

SITE LOCATION

Site	Address
[Redacted]	[Redacted]

Data Products and Project Output

- AEC survey data forms
- Model predicting pre-renovation baseline and post- renovation (as-built) electric energy consumption in kWh and electric coincident demand in kW
- Annual energy savings
- Summer building peak demand savings
- Coincident peak demand savings.

M&V Option

IPMVP Option D – Calibrated Simulation

M&V Implementation Schedule

The renovation was completed in October, 2013; only post-installation data is available.

- Prior to arrival on-site, requested the electronic files for the eQuest building energy model that was previously developed. *[This model was received by AEC.]*
- Prior to arrival on-site, contacted the building site contact to determine whether the required survey data can be collected by trending in the site's BAS.
- During the site visit, verified that the HVAC systems described in the model were installed and/or upgraded (refer to forms).
- Filled out the attached data collection forms.
- Established trend logs to monitor operation of supply fans, economizer air temperatures, and outdoor air temperature and relative humidity.
- All lighting is on a fixed schedule, therefore deployment of data loggers to monitor lighting circuits for schedules was not required.
- Trended EMS data for four weeks (the month of March, 2014).
- Updated the building energy model as required reflecting the actual installed conditions with respect to the modeled ECM's.
- Evaluated the energy impacts of the as-built building improvements in the energy model.

FIELD SURVEY POINTS

Personnel Interview / BAS Review:

- With the assistance of the on-site contact, reviewed the BAS programming to determine information requested in the attached survey forms.

Survey Data for New and Retrofitted Equipment:

- HVAC Equipment Operating Data. Recorded systems operating information on the attached data collection forms. These forms include detailed information about the HVAC systems for and affecting [Redacted], including:
  - New small boiler
  - Modifications to the existing steam heating plant
  - Existing chillers
  - Existing condenser (cooling tower) loop controls
  - [Redacted] air handling units AC-1 through AC-9.

- Lighting.
  - Verified the lighting retrofit for [Redacted] has been completed.
  - Spot-checked the lighting power density (LPD) of [Redacted] as instructed in the survey forms.
  - Verified that occupancy sensors are installed in restrooms, as instructed in the survey forms.

Spot-Measurements

- For air handling units **AC-1, AC-2, AC-4 and AC-5**, measured the total unit electrical parameters including power (volts, amps, power factor and kW).
  - *Recorded the fan VFD frequency at the time of the measurement.*

BAS TRENDING / FIELD DATALOGGING

Time-series data

- Set up trend logs for 15 minute instantaneous readings.
- Collected data during normal operating periods (avoiding atypical operating situations such as maintenance shutdowns).

General points:

- Outdoor air temperature and relative humidity.

Air Handling Units

For the air handling units **AC-1, AC-2, AC-4 and AC-5**, gathered trended data from the BAS as described below.

- Supply fan VFD output signal (percent of full frequency or Hertz).
- Supply duct static pressure
- Supply duct air flow (CFM) *[Was not available.]*
- Supply air temperature
- Outside air temperature
- Mixed air temperature
- Return temperature.

Lighting.

Occupants **do not** have control of lighting. All lighting is scheduled through the lighting control system.

- Determined from the lighting control system programming the lighting on-off schedules for typical areas in [Redacted]. No BAS trending or data logging was required.

Logger Table

Not applicable.

Data Accuracy

Not applicable.

Data Analysis

1. Determined the lighting schedule from the lighting control system.

2. Determined the AHU fan operating schedules from the BAS programming. Confirmed with trended AHU fan operating data by unit and by day-type.
3. Plot the trended / logged economizer data vs. outdoor air temperature to verify economizer enable temperatures. *[Because of cold weather, economizers were not in use.]*
4. Compared the lighting schedules, fan schedules, etc., as determined from the preceding steps, to the schedules found in the existing eQUEST energy model.
5. From the survey forms, noted any differences between the existing model and the as-found Phase 1 parametric run inputs.
6. Made required revisions to the Phase 1 parametrics and re-ran the Phase 1 model. This model performance at the end of Phase 1 is the baseline, or "pre-retrofit" case, for this analysis.
7. Determined the pre-retrofit (baseline) annual energy usage and peak/coincident kW demand during the on-peak period.
8. From the survey forms, noted any differences between the existing model and the as-found Phase 2 parametric run inputs.
9. Made required revisions to the Phase 2 parametrics and re-ran the Phase 2 model. This model is the "proposed building," or "post-retrofit" case, for this analysis.

   Note: Since the building revisions were completed within just five months of the M&V data collection effort, the post-retrofit model cannot be calibrated to the actual building utility performance. Such calibration requires that a year's worth of monthly utility bills be available.
10. Determined the post-retrofit annual energy usage and average peak/coincident kW demand during the on-peak period.
11. Compared the post-retrofit model output with the pre-retrofit output to determine the annual energy and demand savings.
12. Determined the energy savings Realization Rate by dividing the annual energy savings found in the step above to the savings estimated by Duke Energy.
13. Determined the demand savings Realization Rate by dividing the peak coincident savings found in the step above to the savings estimated by Duke Energy.

Verification and Quality Control

1. Visually inspected trend data for consistent values.
2. Verified equipment specifications and performance parameters are consistent with the application, recorded discrepancies.

Recording and Data Exchange Format

- ECM Confirmation Data Forms and other field notes.
- Energy Management System data files, if collected
- Data logger files *[None]*
- DOE-2/eQUEST energy model data files
- Excel spreadsheets

Results

Listed here are the results of the field investigation and the trend data analysis. These results are presented in order of the parametric runs included with the “eQUEST” energy model, so that the impact of the M&V findings on the model inputs may be explained.

An inconsistency in the model is that the 1982 building is sometimes referred to as the “1983” building. For consistency in this report, all references to “1983” have been changed to “1982.” This mainly affects the ECM headings.

The completed ECM Confirmation Data Forms may be found at the end of this report.

PHASE 1

ECM 1: Light_W_ph1n <Part 1>

In 265 spaces, the lighting power density (LPD) was reduced to 0.84 W/ft2.

The field survey found that the lighting is typically two 32W lamps per fixture. A typical surveyed area had 33 fixtures in a 32-ft by 48-ft area.

From the spare parts inventory ballast, the ballast factor is 0.71, typical of a “low-output” ballast. We did not open a fixture to find out if this ballast is actually what is installed. Assuming it is, the LPD for the above fixture spacing is 0.976 W/ft2.

Model:

- In this ECM, change the LPD from 0.84 to 0.976.

ECM 1: Light_W_ph1n <Part 2>

In 17 spaces (Area 2), change Lighting LPD to 0.40 W/sqft. All of the spaces receiving this reduced LPD appear to be in the 1955 Building. No effect on [Redacted].

- *Assume implemented and run ECM as programmed.*

ECM 2: Boiler_eff_ph1n

This ECM was to install a small 90% efficient hot-water boiler (100,000 Btu/hr) in [Redacted]to serve the summer reheat loads so that the large boilers could be shut off.

The small boiler was not installed. Instead, a new main gas-fired HW boiler was installed. Manufacturer's literature says the new boiler's rated output is 2790 MBH and its rated input is 3000 MBH (efficiency = 93.0%), and the unit has a turn-down ratio of 15.

In the PB model, the small boiler was set up to be baseloaded; i.e., it would provide the first 100,000 Btu of heating load no matter what the season.

Model:

- *Redefine the "small boiler" as the "new HW boiler" having:*
    - *2790 MBH output capacity*
    - *HIR = 1.07527 , equivalent to an efficiency of 93%.*
    - *A minimum load fraction = 0.06667, equivalent to a turn-down ratio of 15 to 1.*

ECM 3: AHU_Sch_ph1n

[Redacted]AHU controls changes - No effect on [Redacted].

Model:

- *Assume implemented and run ECM as programmed.*

ECM 4: OccSensor_ph1n

Occupancy Sensors

Forty-six spaces were to receive occupancy sensors for lighting control. Of the 46 spaces, only four are in [Redacted] and these are installed in restrooms.

Field investigation verified that the restrooms do have occupancy sensors. However, there is a lot of traffic through the restrooms all day long, so the lights probably aren't off very often. The lights are scheduled to be off at night in both the baseline and proposed-building models.

A review of the model shows that this ECM was not activated for the parametric runs, and thus no energy savings for occupancy sensors were included in the final results.

Model:

- *Leave the measure as not activated.*

ECM 5: heatLeak_ph1n

The original boiler plant was in poor condition. A large, uninsulated condensate tank, leaking boiler steam traps, and an uninsulated boiler exhaust vent all emitted a great deal of heat into the boiler room, the surrounding walls and spaces. Since all the spaces use the steam plant, the heat leaks were charged to all spaces equally. Heat gains to spaces from inefficiencies of old steam boilers were modeled as 150 Btuh / space. This heat gain offsets some heating energy provided through the HVAC systems when heating is called for (offsetting mainly gas), but also increases the cooling loads when cooling is called for, increasing the electrical load.

The ECM was to:

- Insulate steam condensate receiver tank
- Vent condensate discharge outside of building
- Survey and repair steam traps.

If all measures had been done, the heat gains to the spaces were to be reduced to zero.

The field investigation found that the steam condensate receiver tank was NOT insulated, and the condensate discharge was NOT vented outside the building. The steam traps have been repaired.

Since only one of the three measures in this ECM was implemented, credit is only given for one-third of the heat gain reduction. Thus the heat gain is reduced to 100 Btuh/space instead of zero. However, based on the output of the model, the new HW boiler provides approximately 43% of the total load on the boiler plant, which also displaces heat gains to the building from the remaining steam boilers. Thus, the new value of the heat gain to each space is 100 Btuh x 57% = 57 Btuh.

Model:

- *For the post-retrofit building, use a heat gain to each space of 57 Btu/hr instead of zero.*

ECM 6: Economizerall_ph1n

Economizer control changes for [Redacted]AHU’s. No effect on [Redacted].

Model:

- *Assume implemented and run ECM as programmed.*

ECM 7: StaticReset_ph1n

Static pressure control changes for [Redacted] AHU's. No effect on [Redacted].

<u>*Model:*</u>

- *Assume implemented and run ECM as programmed.*

ECM 8: 95AHU_VFD_ph1n

Change HVAC System type to VAV for [Redacted] AHU's. No effect on [Redacted].

<u>*Model:*</u>

- *Assume implemented and run ECM as programmed.*

ECM 9: Chiller_eff_ph1n

Baseline chiller EIR was = 0.199, or kW/ton = 0.700

The chillers were rebuilt in 2011 and appear to be working properly. While the plant seemed functional, controls re-commissioning was recommended to achieve some additional energy savings. This ECM modeled the outcome of the re-commissioning as an improvement in the EIR to 0.1950, or kW/ton = 0.686, for both Chiller 1A and Chiller 1B.

<u>*Model:*</u>

- *Assume implemented and run ECM as programmed.*

ECM 10: Tower_reset_ph1n

Originally, the Baseline condenser water (CW) loop temperature was fixed. It had been recommended to implement Condenser water reset control. This measure would have allowed the loop temperature to float with the cooling load.

Field investigation found that this measure was attempted but there were too many problems, so the system was put back to a fixed CW loop temperature. The loop temperature setpoint is 74°F.

<u>*Model:*</u>

- *Do NOT implement this ECM.*

- *The fixed CW loop temperature setpoint is 74F.*

The preceding measures mark the completion of Phase 1, which constitutes the Baseline Building (BL) for this analysis.

Completion of the following Phase 2 measures constitutes the Proposed Building (PB) for this analysis.

ECM 11: 82_AHU_4-5_ph2

In [Redacted], dual duct air conditioning units AC-4 and AC-5 were to be replaced with VAV units, or retrofit with VAV capability. The first ECM modeled as part of the replacement/repair of these units is "Static pressure control."

The field investigation found:

- AC-4 and AC-5 were changed to VAV systems.
- VAV boxes were installed at the zones.
- The static pressure setting for the AC units is 3.5 in-WC.
- Static pressure reset was NOT implemented.

AC-4 and AC-5 are dual-duct systems. Trend data for these units' hot and cold decks' static pressures show that the pressure is very close to the setpoint of 3.5 in-WC in one of the decks whenever the fan is running. The pressure in the other duct does drop below 3.5, but this is believed to be an indication that the duct pressure was not being controlled when the service of the first duct was being called for. For example, if the system is calling primarily for heating, the pressure in the hot deck will be 3.5 in-WC and the pressure in the cold deck will drift to a lower value (typically still above 2.5 in-WC). See Figure 1.

There are some times when both the hot and cold decks' static pressures are reduced, but these appear to have been times when the fans were ramping up or down and steady state operation was not established.

The original model had some relatively high values inserted for supply fan power per CFM, which imply high static pressures. Although static pressure control is not implemented, converting the systems to VAV and setting the static pressures as determined from the field investigation still saves a significant amount of energy.

In the model, this ECM included AC-8. AC-8 was not converted to VAV. Therefore, it was removed from this parametric run.

Model:

- *For AC-4 and AC-5,*
    - *Accept the new VAV system types*
    - *Set the maximum static pressure = 3.5 in-WC*
    - *Do NOT implement static pressure reset.*

- *For AC-8*
    - *Eliminate AC-8 from this measure.*

ECM 12: 82AHU_4-5_ph2 <Part 1>

AC units AC-4 and AC-5 were supposed to get optimum start programming in the summer (i.e., the BAS decides when to start the units up in the mornings, before actual occupied hours, in order to reach comfort conditions by the beginning of occupied hours). Rather than starting the units at a fixed time of 4 AM, start-up could be delayed to as late as 6 AM, if the control system decides comfort conditions would be met by the beginning of occupancy.

The actual ECM included AC units AC-6, AC-7 and AC-8 in this measure.

The field investigation found that none of the units were programmed for optimum start control. *However, examining the model parametric programming shows that optimum start had not been activated for these units anyway.*

The field investigation found that the fixed schedule for all five units is:

Monday through Wednesday:	On at 7:00 AM	Off at 9:30 PM.
Thursday through Saturday:	On at 7:00 AM	Off at 7:30 PM.
Sunday:	On at 11:30 AM	Off at 5:30 PM.

However, for both AC-4 and AC-5, the trend data does show a regular schedule for the week or so that the system was not running continuously. The schedule is slightly different from that provided from the field survey.

Monday through Wednesday:	On at 5:30 AM	Off at 9:30 PM.
Thursday through Saturday:	On at 5:30 AM	Off at 7:00 PM.
Sunday:	On at 10:30 AM	Off at 5:30 PM.

This schedule is used in the model. Because of model limitations, half-hour times are rounded to the whole hour, keeping the number of operating hours the same where possible.

<u>*Model:*</u>

- *Do NOT implement this ECM (no change to model).*

- *Adjust the units' BL operating schedule to match the times above.*

ECM 12: 82AHU_4-5_ph2 <Part 2>

This control measure enables the units to come on at night if any zone goes out of its setback temperature range.

The actual ECM included AC units AC-4, AC-5, AC-6, AC-7 and AC-8.

The field investigation found that all of the units do have this programming. In the last two days of the monitoring period, the trend data for AC-4 does show some night-time operation.

Model:

- *Run this ECM as programmed.*

ECM 12: 82AHU_4-5_ph2 <Part 3>

This control measure enables AC units to bring in outside air at night if needed for space pre-cooling before occupied hours (night flushing).

The actual ECM included AC units AC-4, AC-5, AC-6, AC-7 and AC-8.

The field investigation found that all of the units do have this programming. Due to the winter conditions, the trend data for AC-4 and AC-5 did not capture any night pre-cooling operation.

Model:

- *Run this ECM as programmed.*

ECM 12: 82AHU_4-5_ph2 <Part 4>

This control measure "set back" the heating space temperature setpoint and "set up" the cooling temperature setpoint during unoccupied hours for 124 zones. Most of the zones are served by AC-4 and AC-5; although a few zones are served by AC-6 through AC-9.

In the model, the ECM included the following temperature setpoints:

- Setback Cool Sch = 76°F from 6 AM- 9 PM, 82°F from 9 PM – 6 AM.
- Setback Heat Sch – Summer = 70°F from 6 AM- 9 PM, 64°F from 9 PM – 6 AM.
- Setback Heat Sch – Winter = 70°F from 4 AM- 9 PM, 64°F from 9 PM – 4 AM.

The field investigation found that all of the units do have set-back programming, but that the setpoints are slightly different for heating:

- Setback Cool Sch = 76°F during occupied hours, 82°F unoccupied (same temperatures as above).
- Setback Heat Sch – Summer = 70°F occupied, 68°F unoccupied.
- Setback Heat Sch – Winter = 70°F occupied, 69°F unoccupied.

For AC-4, trend data shows that, for the monitoring period, occupied space return air temperatures were typically between 74 and 76°F, and at night the temperatures drifted between 72 and 78°F. The daily temperature spread is typically 1-1/2 degrees when the supply fan is on. During the cold weather the average return air temperature was 75°F; this average was starting to fall to approximately 71°F in the last two days of the monitoring period. See Figure 2.

For AC-5, trend data shows that, for the monitoring period, occupied space return air temperatures were typically between 73 and 76°F. The daily temperature spread is typically two degrees when the supply fan is on. During the cold weather the average return air temperature was 75°F; this average was approximately 70°F when the fan returned to its normal schedule.

Model:

- *Adjust the units' setback setpoints to match the temperatures above, as necessary.*

ECM 12: 82AHU_4-5_ph2 <Part 5>

An additional 31 spaces, mostly located in [Redacted] and the penthouses, also had setback control implemented. This measure is considered not applicable to [Redacted].

Model:

- *Assume implemented and run ECM as programmed.*

ECM 13: Economizerall_2-4-5_ph2 <Part 1>, and
ECM 15: economizerall_1-3_ph2

All AC units AC-1 through AC-8 were to get economizer capability, enabling the units to bring in up to 100% outside air when the outside air temperature (OAT) is closer to the desired supply air temperature for cooling than the return air temperature. The Economizer High Limit was to be 65°F, and the Economizer Low Limit was to be 45°F. When the OAT is above the high limit, the system returns to minimum OA to avoid excessive cooling energy. When the OAT is below the low limit, the system returns to minimum OA to avoid having to heat outside air, and to avoid potentially freezing water coils.

The field investigation found the following conditions programmed for the eight AC units:

Unit	*Economizer control enabled?*	*High limit = 65?*	*Low limit = 45?*
AC-1	Yes	80	Yes
AC-2	Yes	80	Yes
AC-3	Yes	80	Yes
AC-4	Yes	80	Yes
AC-5	Yes	80	Yes
AC-6	Yes	80	40
AC-7	Yes	90	40
AC-8	No – AC-8 is 100% Outside Air		

<u>Model:</u>

- *For AC-1 through AC-7,*
    - *Run the ECM'S with economizers enabled, as programmed.*
    - *Adjust the units' high and low limit setpoints to match the temperatures above, as necessary.*
- *For AC-8,*
    - *Do not implement this ECM, as the unit is 100% outside air.*

ECM 13: Economizerall_2-4-5_ph2 <Part 2>

For AC-8, the Minimum OA ratio was to be changed to 0.0010 (essentially, unit was to be changed from a 100% Outside Air unit to a recirculating unit).

The field investigation found that AC-8 is still a 100% OA unit.

<u>Model:</u>

- *Do NOT implement this ECM.*

ECM 14: 83_AHU_1-2-3_ph2 <Part 1>

Units AC-1 and AC-2 were to be replaced with VAV units, or retrofit with VAV capability, and AC-3 was to receive a controls upgrade. The first ECM modeled as part of the replacement/repair of these units is "Static Pressure Control."

The field investigation found:

- AC-1 and AC-2 were changed to VAV systems, but AC-3 was not.
- VAV boxes were installed at the zones for AC-1 and AC-2 only.
- The static pressure setting for AC-1 is 1.2 in-WC.
- The static pressure setting for AC-2 is 3.5 in-WC.
- The static pressure setting for AC-3 was not determined.
- Static pressure reset was NOT implemented for either AC-1 or AC-2.

However, trend data for AC-1's static pressure shows that it does vary between 0.4 and 1.7 in-WC. However, there is not a clear-cut relationship between the static pressure and VFD speed. See Figure 3.

AC-2 is a dual-duct system. Trend data for AC-2's hot deck's static pressure shows that it did vary around a setpoint of 3.5 in-WC for the first 2-1/2 weeks of monitoring, and then was either at 3.5 or zero for the following week. The unit did not go off for the first 2-1/2 weeks; it was reported that the system ran continuously because of extended cold winter weather during that period.

Trend data for AC-2's cold deck's static pressure shows that it did vary widely (from 1.0 to 4.0 in-WC) during the 3-1/2 weeks; however, this is believed to be an indication that the duct pressure was not being controlled when the service of the heating duct was being called for.

We conclude that AC-1behaves as if it has static pressure control, and therefore this ECM will be modeled for this unit. However, the measure does not appear to be implemented for AC-2.

As with AC-4 and AC-5, the original model had some relatively high values inserted for supply fan power per CFM, which imply high static pressures. Although static pressure control is not implemented, converting the systems to VAV and setting the static pressures as determined from the field investigation still saves a significant amount of energy.

In the model, this ECM included AC-3. AC-3 is a constant volume unit and was not converted to VAV. Therefore, it was removed from this parametric run.

Model:

- *For AC-1,*
  - *Accept the new VAV system types*
  - *Assume static pressure control is implemented and run the ECM as programmed.*
  - *Set the maximum static pressure for AC-1 = 1.6 in-WC.*

- *For AC-2,*
  - *Accept the new VAV system types*
  - *Set the maximum static pressure = 3.5 in-WC*
  - *Do NOT implement static pressure reset.*

- *For AC-3 ,*
    - *Do NOT change the system type to VAV*
    - *Keep the static pressure settings as currently modeled*
    - *Do NOT implement Static pressure reset.*

ECM 14: 83_AHU_1-2-3_ph2 <Part 2>

Unit AC-3 was to be changed to a VAV System, and was to activate when any zone exceeds its cooling setpoint.

The field investigation found that AC-3 was not changed to a VAV system (as noted in part 1 of this ECM above).

Model:

Do NOT implement this ECM.

ECM 16: 82AHU-Sch_1-2-3_ph2 <Part 1>

AC units AC-1, AC-2 and AC-3 were supposed to get optimum start programming in the summer. Rather than starting the units at a fixed time of 4 AM, start-up could be delayed to as late as 6 AM if the control system decides comfort conditions would be met by the beginning of occupancy.

The field investigation found that none of these units were programmed for optimum start control. The fixed schedule for all three units is:

Monday through Wednesday:	On at 7:00 AM	Off at 9:30 PM.
Thursday through Saturday:	On at 7:00 AM	Off at 7:30 PM.
Sunday:	On at 11:30 AM	Off at 5:30 PM.

For AC-1, the trend data does not show regular start or stop times for any day of the week, due to unusual operation resulting from the cold weather. Therefore the fixed schedules provided above from the field survey are used in the model.

For AC-2, the trend data does show a regular schedule for the week or so that the system was not running continuously. The schedule is slightly different from that provided from the field survey.

Monday through Wednesday:	On at 5:30 AM	Off at 9:30 PM.
Thursday through Saturday:	On at 5:30 AM	Off at 7:00 PM.
Sunday:	On at 10:30 AM	Off at 5:30 PM.

This schedule is used in the model. As before, half-hour times are rounded to the whole hour, keeping the number of operating hours the same where possible.

<u>*Model:*</u>

- *For AC-1 and AC-3,*
  - *Adjust the Baseline units' operating schedules to match the fixed times above.*
  - *Do NOT implement this ECM.*

- *For AC-2,*
  - *Adjust the Baseline unit's operating schedule to match the fixed times given above for this unit.*
  - *Do NOT implement this ECM.*

ECM 16: 82AHU-Sch_1-2-3_ph2 <Part 2>

This control measure enables the units AC-1, AC-2 and AC-3 to come on at night if any zone goes out of its setback temperature range.

The field investigation found that all of the units do have this programming. After the cold-weather period, the trend data for AC-1 does show some night-time operation.

<u>*Model:*</u>

- *Run this ECM as programmed.*

ECM 16: 82AHU-Sch_1-2-3_ph2 <Part 3>

This control measure enables units AC-1, AC-2 and AC-3 to bring in outside air at night if needed for space pre-cooling before occupied hours (night flushing).

The field investigation found that all of these units do have this programming, but only for winter.

<u>*Model:*</u>

- *Enable this ECM only during the winter season for these units.*

ECM 16: 82AHU-Sch_1-2-3_ph2 <Part 4>

This control measure set back the heating space temperature setpoint and set up the cooling temperature setpoint during unoccupied hours for 113 zones. All of the zones are served by AC-1, AC-2 and AC-3.

In the model, the ECM included the following temperature setpoints:

- Setback Cool Sch = 76°F from 6 AM- 9 PM, 82°F from 9 PM – 6 AM.
- Setback Heat Sch – Summer = 70°F from 6 AM- 9 PM, 64°F from 9 PM – 6 AM.
- Setback Heat Sch – Winter = 70°F from 4 AM- 9 PM, 64°F from 9 PM – 4 AM.

The field investigation found that all of the units do have set-back programming, but that the setpoints are slightly different for heating:

- Setback Cool Sch = 76°F during occupied hours, 82°F unoccupied (same temperatures as above).
- Setback Heat Sch – Summer = 70°F occupied, 68°F unoccupied.
- Setback Heat Sch – Winter = 70°F occupied, 69°F unoccupied.

For AC-1, trend data shows that, for the monitoring period, occupied space return air temperatures were typically between 73 and 77°F, and at night the temperatures drifted between 70 and 80°F. The daily temperature spread is typically 1 – 2 degrees when the supply fan is on. During the cold weather the average return air temperature was 75°F; this average was starting to fall to approximately 70°F when the fan returned to its normal schedule.

For AC-2, trend data shows that, for the monitoring period, occupied space return air temperatures were typically between 73 and 76°F, and at night the temperatures drifted between 74 and 78°F. The daily temperature spread is typically 1 – 3 degrees when the supply fan is on. During the cold weather the average return air temperature was 75°F; this average was starting to fall to approximately 70°F when the fan returned to its normal schedule. See Figure 4.

Although the trend data showed temperatures somewhat higher than the reported winter heating setpoints, this was due to atypical operation during the extreme cold weather. Since about two days of "normal" operation was captured at the end of the monitoring period, the setback schedules reported from the field investigation are implemented in the model.

The occupied and unoccupied hours are slightly different from those provided in the model; see ECM 16, part 1.

Model:

Adjust the units' BL setback setpoints to match the temperatures above.

ECM 17: New – Enable Occupied-Unoccupied HVAC Systems Scheduling

Most of the fan systems originally operated continuously. The controls upgrades installed as part of the retrofit enabled systems to be scheduled off when the building is unoccupied, and this has been done. Although the new daily and weekly schedules were built into the model, the final step of activating the new schedules had not been performed in the parametric runs.

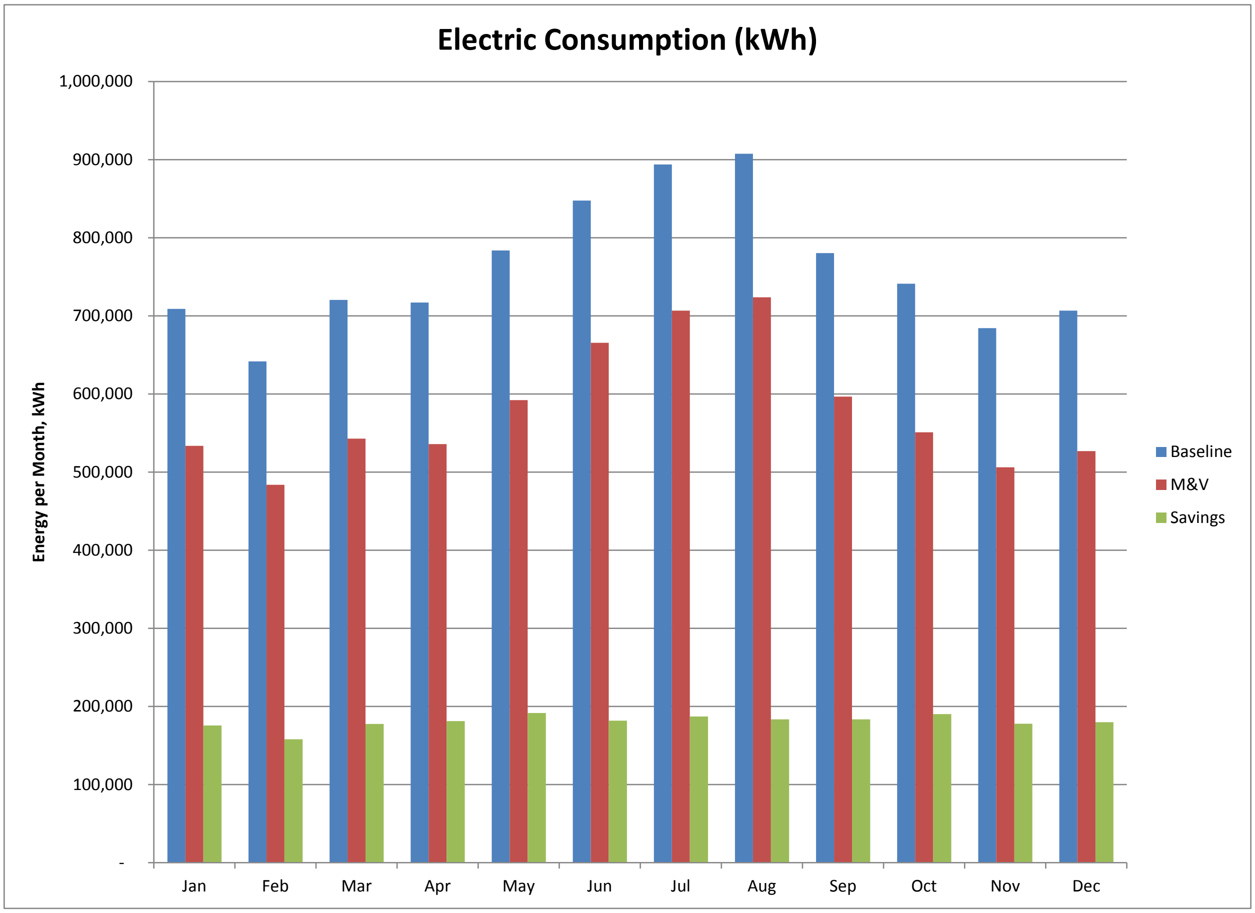
A new parametric analysis was added to activate the new schedules. This step increases the energy savings.

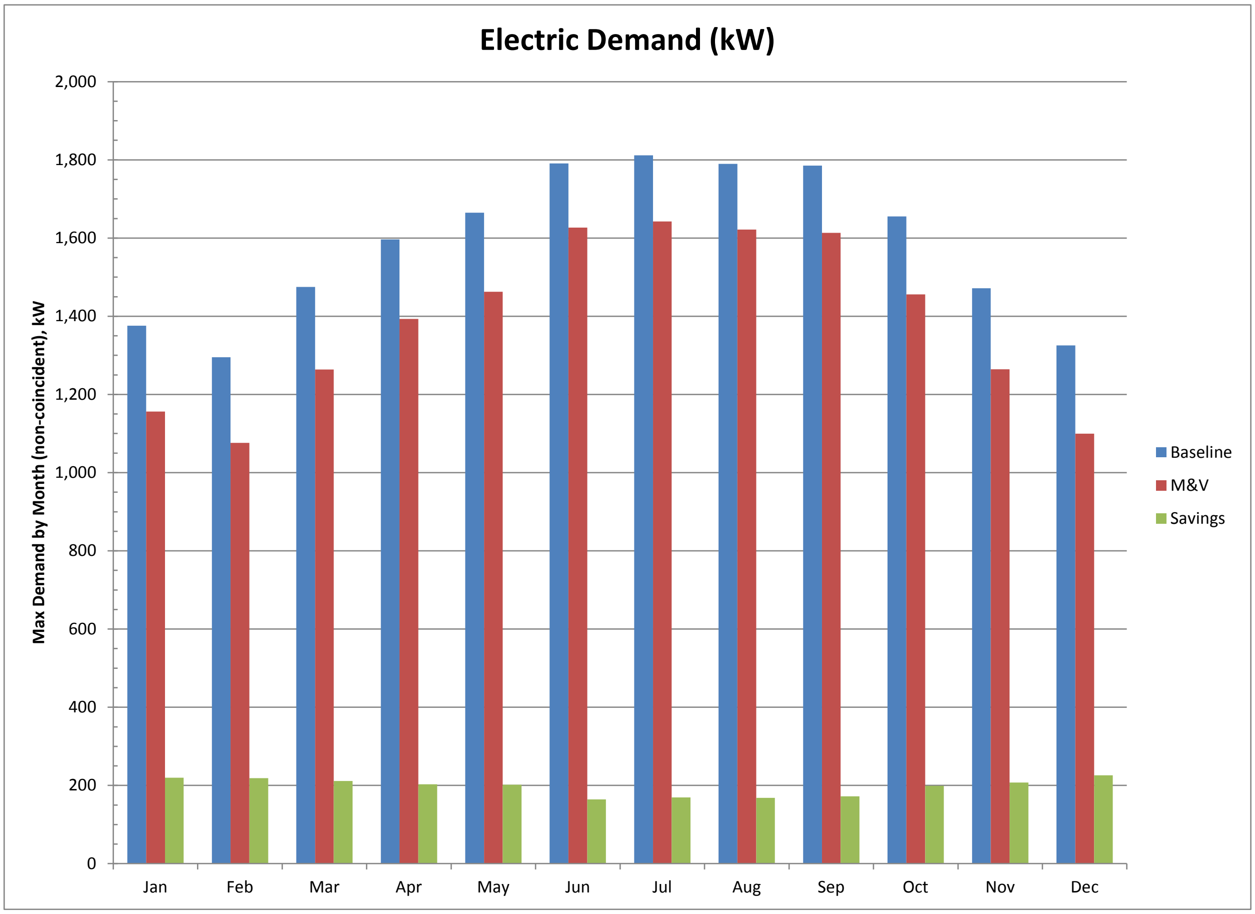
Results Summary

The modified energy analysis results in the energy and demand savings presented in the following table. For Ohio in 2013, the coincident peak demand hour is on July 17, for the hour between 4-5 PM. A comparison to the projected savings goals is also presented. Charts of the energy consumption and maximum demand each month follow the table.

Projected Savings Comparisons

	Annual Energy Savings (kWh)	Non-Coincident Peak Demand Savings (kW)	Coincident Peak Demand Savings (kW)
Duke Projections	2,420,314	307.2	247.5
M&V Projections	2,168,811	225.8	185.0
Realization Rates	90%	74%	75%%


Electric Consumption (kWh)
Energy per Month, kWh
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Baseline
M&V
Savings



ATTACHMENTS

1. Referenced Figures
2. Spot-Watt form
3. ECM Confirmation survey forms

Referenced Figures

Figure 1:Static Pressure Data for AC-4

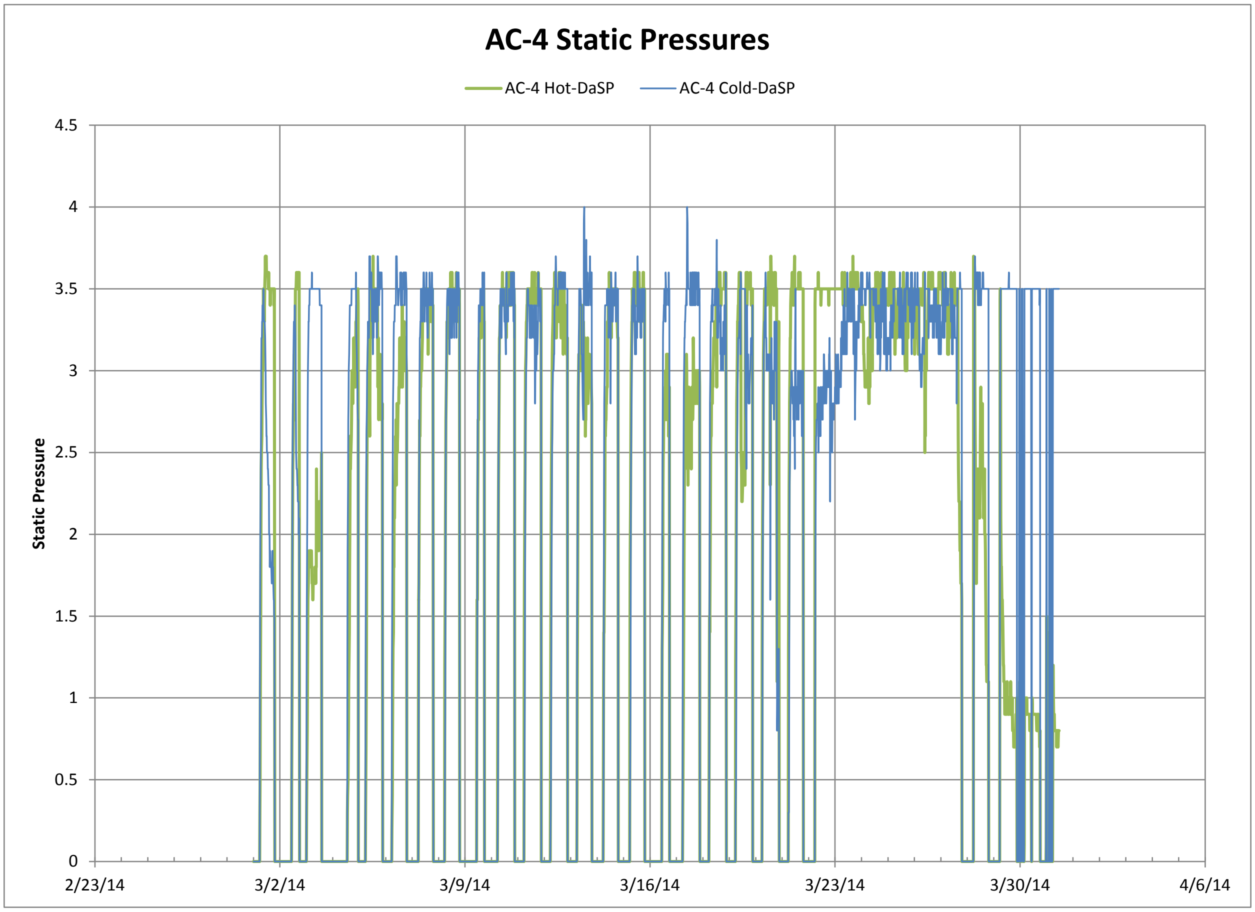


Figure 2:Return Air Temperatures for AC-4

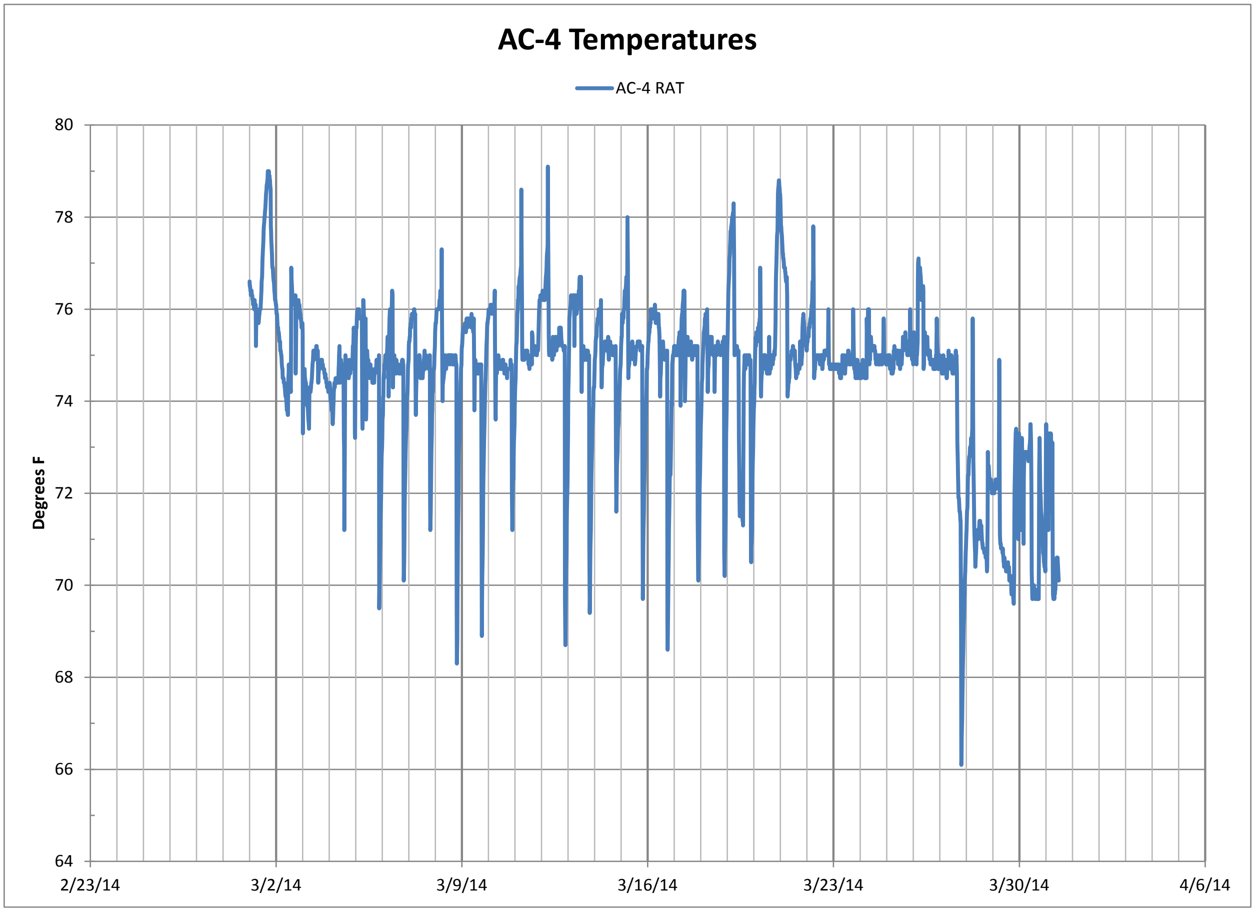


Figure 3:Static Pressure and VFD Speed Data for AC-1

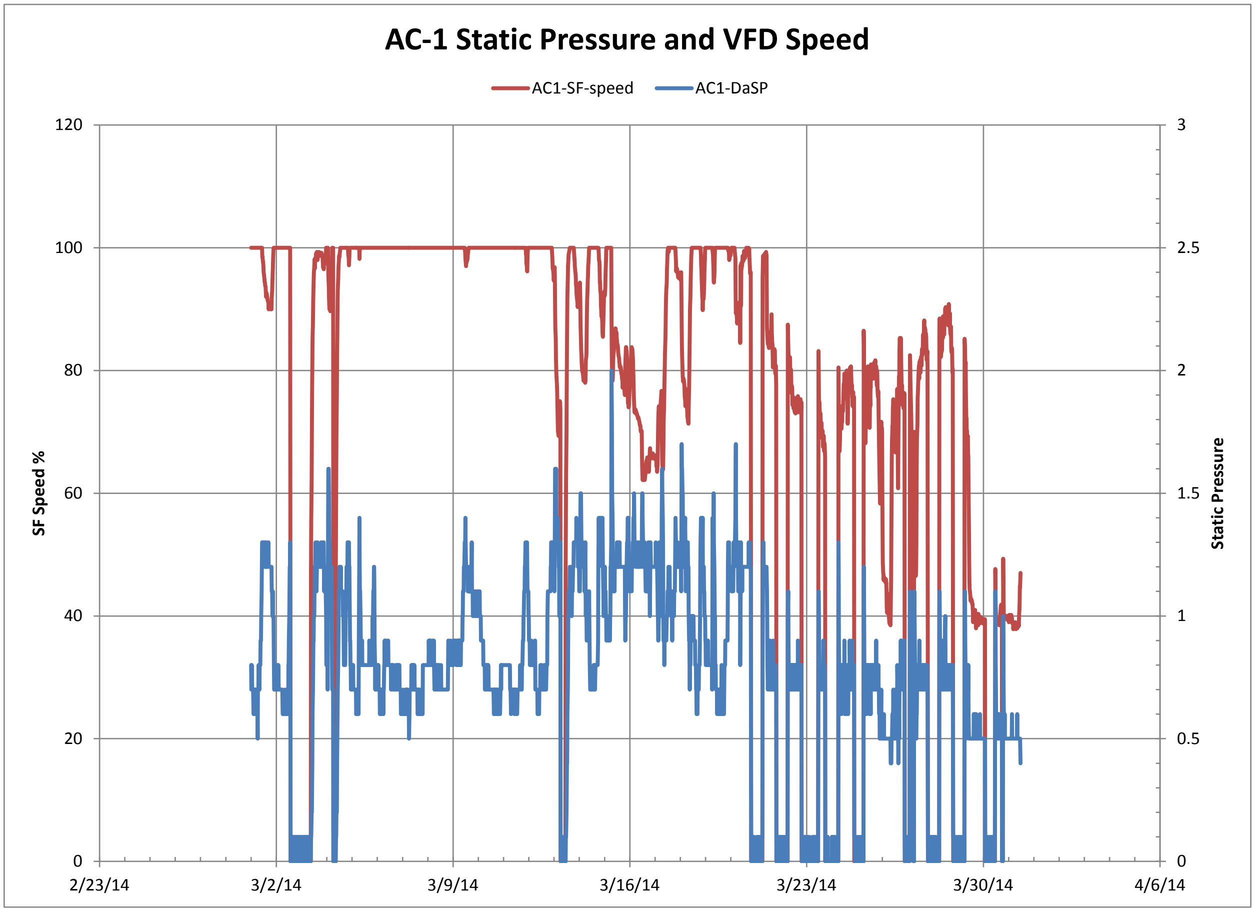
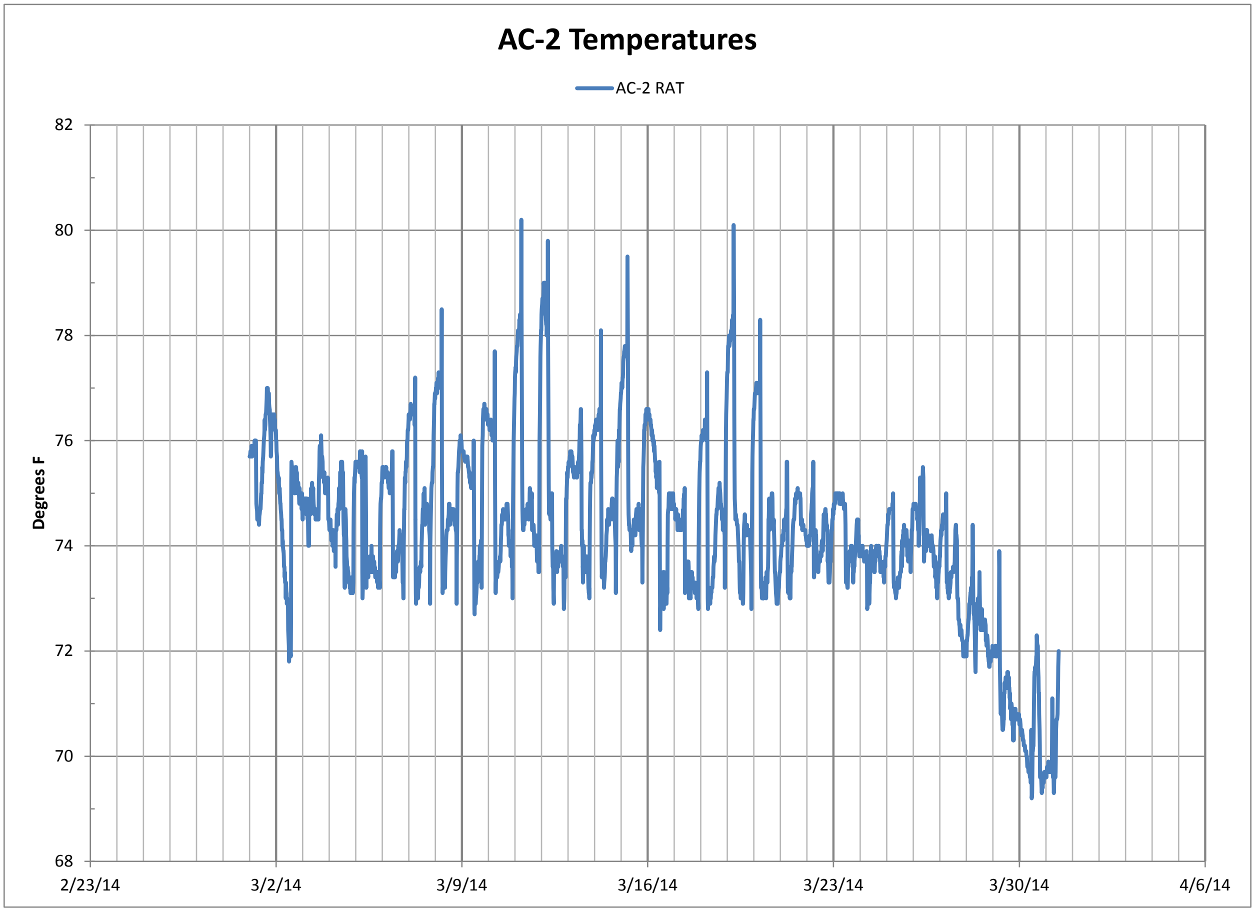


Figure 4: Return Air Temperatures for AC-2



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Reference (from SBA report)

Table 17: [redacted] air handling units and fans

#	Location	Area/Zone	Configuration: CV	Dual Duct	MZ	VAV	IGV	VFD	Fan Motor Power (hp)	(kW)	Observed Current (A)	Notes
AC-1	C stack Mech Rm	Serves B level, northeast section, acquisitions and technical services (see 82Addition_H3.2)				●	●		50		59.00	Steam humidifier on intlet to cooling coil, before stm coil, no OA, IGV
REF-1	C stack Mech Rm	Return for AC-1							15		20.00	
AC-2	C stack Mech Rm	Serves levels 1, 2, 3, core		●					100		120.00	Dual-duct (hot deck valved off for summer), OA & RA dampers not coordinated, air leaking at discharge access door, stm humidifier, condensate leaking/pond
REF-2	C stack Mech Rm	Return for AC-2							20		24.00	
AC-3	C stack Mech Rm	Serves C and D stack							25		29.50	Return fan overpowering, cooling only, no OA
REF-3	C stack Mech Rm	Return for AC-3							8			
AC-4	Penthouse	Serves levels 1, 2, 3, perimeter		●					75		88.00	Dual-duct
REF-4	Penthouse	Return for AC-4							15		21.00	
AC-5	Penthouse	Serves levels 1, 2, 3, perimeter		●					100		120.00	Dual-duct, OA damper not sealing
REF-5	Penthouse	Return for AC-5							20		27.00	
AC-6	B level mezzanine, (catwalk in ceiling)	Serves B stack, catalog services, mezzanine				●		●	15		18.90	2 VFDs, ex fan not running, simultaneous h/c
EF-6	B level mezzanine ceiling above catalog	Return for AC-6						●	5			
AC-7	AC-7 mech room, (dock)	Hallway, break rooms						●	3			
AC-8	Facilities Office (dock), (ceiling)	Serves offices in dock area							1		2.30	
HV-1	Hv-1 mech room (dock)	Heat recovery unit							15		20.00	Multi-zone (5 zones), heat wheel not working
VF - 1 (EF - 1)	Hv-1 mech room (dock)	Return/exhaust for heat recovery unit							20		25.00	
VF-2	Oil Pump Mech Rm, (dock)								1		1.85	
GEF-1	Penthouse											
TEF-1	Penthouse											
EF -2	C stack Mech room exhaust fan								3		2.60	
EF-3	Penthouse exaust fan								4			
AC-9	Dock Booth (ceiling)											

Notes:

1) All units: 460V, 3 phase current

Spot-Watt form

DATE: 2/28/2014 **SITE NAME:** [redacted]

Location: Penthouse and Level C 11:15am

Logger#: Fluke Multi meter

VFD inf.	Subject AC-4	Logger Reading	(Units)
~~Channel#~~	36.5 HZ 28.9 A	61.5% SP	6.1 Vdc

The CT is mounted on: Meter Readings

				Amps	Volts	Watts	PF	KVA	KVAR
O A	CB#		Phase A	18.53	274.1	3.9 kW	.75	5.01	3.26
O B	CB#		Phase B	16.01	272.7	3.18 kW	.74	4.30	2.89
O C	CB#		Phase C	18.02	272.7	3.54 kW	.72	4.94	3.43

Logger#: Fluke Multi meter 11:45 am

VFD inf	Subject AC-5	Logger Reading	Temp
~~Channel#~~	43.5 Hz 54.6A	72% S.P.	7.2 Vdc

The CT is mounted on: Meter Readings

				Amps	Volts	Watts	PF	KVA	KVAR
O A	CB#		Phase A	43.2	274.1	10.1 kW	.86	11.8	6.1
O B	CB#		Phase B	37.0	272.8	8.3 kW	.81	10.2	6.0
O C	CB#		Phase C	43.4	272.8	9.5 kW	.81	11.8	6.9

Logger#: Fluke Multi meter 12:15 pm

VFD inf	Subject AC-1	Logger Reading	Temp
~~Channel#~~	33.5 Hz 19.0 A	55.1% SP	5.5 Vdc

The CT is mounted on: Meter Readings

				Amps	Volts	Watts	PF	KVA	KVAR
O A	CB#		Phase A	9.5	274.9	1.87 kW	.75	2.42	1.71
O B	CB#		Phase B	7.90	273.7	1.50 kW	.73	2.10	1.45
O C	CB#		Phase C	8.9	273.9	1.75 kW	.70	2.57	1.79

Logger#: Fluke Multi meter 12:30 pm

VFD inf	Subject AC-2	Logger Reading	Temp
~~Channel#~~	41.9 HZ 47.6 A	69.5% SP	7.0 Vdc

The CT is mounted on: Meter Readings

				Amps	Volts	Watts	PF	KVA	KVAR
O A	CB#		Phase A	29.4	274.4	6.5 kW	.83	7.06	4.39
O B	CB#		Phase B	25.6	274.0	5.6 kW	.87	7.00	4.30
O C	CB#		Phase C	30.8	273.0	6.1 kW	.78	8.12	5.19

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ECM Confirmation Data Forms

ECM Confirmation Data Forms

ECM# and Title	1 - Light_W_ph1n <Part 1>
Description	In 265 spaces (Area 1), change Lighting LPD to 0.84 W/sqft
Info determined from Model	Many of these spaces are in [redacted] Most of [redacted] received this reduced LPD.
Action in Field	*Spot-check 15 of these spaces for fixture type, fixture Watts, number of fixtures and area of room to determine actual W/sqft.* * Not including ballast
Other Notes	Original LPD's are: 1.00 and 1.30 W/sqft.
For Analysis	*From total fixture W and total A, determine average W/sqft to update model.*

#	Space ID	Fixt. Type	* Fixt. W	No. of Fixts.	Room L	W	Area
1	3rd Floor bay	2-4' Fluor	50	33	32	48	1536
2							
3	D Stack	1-4' Fluor	25	8			
4	(manual switches	1-2' Fluor	17	1	32	4.5	144
5	on each stack row)						
6	50% on						
7							
8							
9							
10							
11							
12							
13							
14							
15							

15

ECM# and Title	1 - Light_W_ph1n <Part 2>
Description	In 17 spaces (Area 2), change Lighting LPD to 0.40 W/sqft
Info determined from Model	All of the spaces receiving this reduced LPD appear to be in the 1955 Building. No effect on [redacted].
Action in Field	*None.*
Other Notes	
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	2 - Boiler_eff_ph1n
Description	Change Small Boiler capacity to 0.1000 Mbtu/hr Change Load Range 1 to Small Boiler Change Boiler Order to 1.000
Info determined from SBA Report	During the cooling season, one or more large steam boilers (4 million Btu/hr each) were run to provide reheat capability, primarily in [redacted]. Running the large boiler creates a tremendous heat input (cooling load) in [redacted] This ECM installed a small hot-water boiler (100,000 Btu/hr) in [redacted] to serve the summer reheat loads so that the large boilers may be shut off.
Action in Field	*Verify the small boiler was installed and is operable.* 3000 MBH New Boiler in operation *Verify the large boilers are now shut down entirely during the summer.* old boiler on standby - emergency only *Collect nameplate data for the small boiler.* Aerco Benchmark 3000 Max. Water Temp 210°F Model BMK 3000 160 PSIG Ser. No. 6-12-0996 3000 MBH input 2012 2400 MBH output
Other Notes	Small boiler is supposed to be 90% efficient.
For Analysis	*If implemented, update the small boiler capacity and efficiency as necessary.*

ECM# and Title	3 - AHU_Sch_ph1n
Description	For [redacted] AHU's and three ACU's (total of 15 units), change the AHU controls: Fan control – Change Cooling Fan Sched to OptStartFanSch Change Night Cycle Control to Cycle on Any OA – change Min Air Sched to MinFlowSch In 128 spaces, set Cool Temp Sched to Setback Cool Sch, ... and set Heat Temp Sched to a Setback Heat Sch.
Info determined from Model	No effect on [redacted].
Action in Field	*None.*
Other Notes	
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	4 - OccSensor_ph1n
Description	In 17 spaces, change Lighting Sched 2 to OccLight In 29 spaces, change Lighting Sched 1 to OccLight
Info determined from SBA Report	The 17 spaces are in [redacted] - N/A to this application. Of the 29 spaces, some are restrooms in all three buildings and the rest are in [redacted]. Only four are in [redacted]
Action in Field	*Spot-check the four restrooms in [redacted], Levels B, 1 and 2, to verify they have Occupancy Sensors installed.* *Restroom Location* — *OS installed (Yes/No)* B 35 — Yes 3 — Yes 2 — Yes 1 — Yes
Other Notes	Maintenance /Janitor who cleans restrooms verified the all where off at night
For Analysis	*Update the [redacted] model if required if OS's are not installed. Assume the Bldg [redacted] occupancy sensors are installed.*

ECM# and Title	5 - heatLeak_ph1n
Description	In EVERY space, change Internal Energy Source Input Power to 0.0000 Btu/h.
Info determined from SBA Report	The existing boiler plant was in poor condition: A large, uninsulated condensate tank, leaking boiler steam traps, and an uninsulated boiler exhaust vent all emitted a great deal of heat into the boiler room, the surrounding walls and spaces. The 1952 and 1982 buildings use steam for their air handlers and humidification purposes. The 1995 building has hot water converters for both domestic hot water and re-heat at the VAV boxes. Since all the spaces use the steam plant, the heat leaks were charged to all spaces equally. Spot-checking, the baseline IESIP was = 150 Btu/h in every space. If the issues have been repaired, this heat gain to the spaces can be eliminated.
Action in Field	*Verify the following actions were accomplished:* *- Insulated steam condensate receiver tank* No *- Vented condensate discharge outside of building* No *- Surveyed and repaired steam traps.* Yes
Other Notes	
For Analysis	*If all of the above actions were accomplished, run ECM as is.*

ECM# and Title	6 - Economizerall_ph1n
Description	For all 9 [redacted] AHU's, Change OA control to OA Temperature, Change Drybulb High Limit to 65°F, Change Economizer Low Limit to 45°F.
Info determined from Model	No effect on [redacted]
Action in Field	*None.*
Other Notes	Drybulb High Limit was 56°F.
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	7 - StaticReset_ph1n
Description	For all 9 [redacted] AHU's, Change Cooling Fan EIR to 0.5SPfanCurve
Info determined from Model	No effect on [redacted].
Action in Field	*None.*
Other Notes	Fan EIR was 1.5SPfanCurve
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	8 - 95AHU_VFD_ph1n
Description	For 4 [redacted] AHU's, Change HVAC System type to VAV, Change Cooling Fan Control to Fan EIR FPLR, Change Cooling Fan EIR to 0.5SPfanCurve, Change Cool Control to Warmest, Change Hot Deck Max Lvg Temp to 95°F, Change Heat Control to Coldest.
Info determined from Model	No effect on [redacted].
Action in Field	*None.*
Other Notes	Systems were SZRH.
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	9 - Chiller_eff_ph1n
Description	For both chillers (1a and 1b), Change EIR to 0.1950
Action in Field	*Verify manufacturer name & model number of chillers (loc'd in [redacted]?)* No new chillers - 2 existing chillers *Other pertinent nameplate data:*
Other Notes	kW/ton = EIR * 12000/3413 = EIR * 3.516, so kW/ton = 0.686 Baseline chiller EIR was = 0.199, or kW/ton = 0.700
For Analysis	*Look up kW/ton from mfr's model #. Adjust model inputs as required.*

ECM# and Title	10 - Tower_reset_ph1n
Description	For condenser water loop, Change Cool Setpoint Control to Load Reset
Action in Field	*Verify CW loop temp setpoints, and that the loop temperature is allowed to float.* Set point – 74° Loop temperature not allowed to float Tried to float but too many problems
Other Notes	Baseline CW loop temp was fixed.
For Analysis	*Update ECM with new setpoints if necessary.*

--- End of Phase 1 ---

--- Begin PHASE 2 ---

ECM# and Title	11 – 83_AHU_4-5_ph2
Description	For 83-AC-4, AC-5 and AC-8, Change Cooling Fan Control to Fan EIR FPLR Change Cooling Fan EIR to 0.5SPfanCurve
Info determined from SBA Report	Units AC-4 and AC-5 were to be replaced with VAV units, or retrofit with VAV capability. The first ECM modeled as part of the replacement/repair of these units is "Static pressure control."
Action in Field	*FOR:* *AC-4* / *AC-5* / *AC-8* *Determine if these units were replaced or retrofitted.* Y / Y / Y BAS only *Verify these units are now VAV systems.* Y / Y / Not VAV *Verify that VAV boxes were installed at the zones.* Y / Y / Not VAV *Verify the static pressure settings of the AC units.* 3.5 in WC / 3.5 in WC / ____ *Verify whether the SP setting resets, and if so, what the controlling variable is (most-demanding VAV box, time of day, etc.).* No Reset / No Reset / ____
Other Notes	Baseline Fan EIR was 1.5SPfanCurve. Implication is that the baseline SP is 1.5 in-WG, and that the SP is now allowed to reset as low as 0.5 in-WG.

ECM# and Title	12 – 82AHU_4-5_ph2 <Part 1>
Description	For 83-AC-4, AC-5, AC-6, AC-7 and AC-8, Change Cooling Fan Sched to OptStartFanSch
Action in Field	*Determine what the beginning and end dates are for "Summer."* Not at this time *Start:* ______ *End:* ______
	Confirm the AC units have optimum start programming in the summer (i.e., the BAS decides when to start them up in the mornings in order to reach comfort conditions by a certain later time). Yes/No — AC-4: No; AC-5: No; AC-6: No; AC-7: No; AC-8: No
	Confirm the fan on-off schedules for the above AC units. (see schedule below)
Other Notes	OptStartFanSch – Summer = 1 from 6 AM- 9 PM, 0 from 9 PM – 4 AM, and -999 from 4 AM – 6 AM. OptStartFanSch – Winter = 1 from 4 AM- 9 PM, 0 from 9 PM – 4 AM.
For Analysis	*Incorporate field schedule differences, if any, in the model.*

	M	Tu	W	Th	F	Sat	Sun
AC-4 Fan ON:	7:00 am	7:00 am	7:00 am	7:00 am	7:00 am	7:00 am	11:30 am
AC-4 Fan OFF:	9:30 pm	9:30 pm	9:30 pm	7:00 pm	7:00 pm	7:00 pm	5:30 pm
AC-5 Fan ON:			Same	as	above		
AC-5 Fan OFF:							
AC-6 Fan ON:			Same	as	above		
AC-6 Fan OFF:							
AC-7 Fan ON:			Same	as	above		
AC-7 Fan OFF:							
AC-8 Fan ON:			Same	as	above		
AC-8 Fan OFF:							

ECM# and Title	12 – 82AHU_4-5_ph2 <Part 2>
Description	For 83-AC-4, AC-5, AC-6, AC-7 and AC-8, Change Night Cycle Control to Cycle on Any
Action in Field	*Confirm the units are programmed to come on at night if any zone goes out of its setback temperature range.* Yes/No — AC-4: Y; AC-5: Y; AC-6: Y; AC-7: Y; AC-8: Y

All units programed to operate during unoccupied times during winter when outside temp. @ 62° or higher and Summer temp less than 82°

ECM# and Title	12 – 82AHU_4-5_ph2 <Part 3>
Description	For 83-AC-4, AC-5, AC-6, AC-7 and AC-8, OA – change Min Air Sched to MinFlowSch
Action in Field	*Confirm the units have economizers and that they are operable (not fixed or locked in one position either by BAS programming or physically).* AC-4 AC-5 AC-6 AC-7 AC-8 Yes/No Y Y lock-temp Y 100% O.A.
	Confirm these units are allowed to bring in OA at night (i.e., between 6 AM and 9 AM; verify these times) if needed for space pre-cooling before occupied hours (night flushing). AC-4 AC-5 AC-6 AC-7 AC-8 Yes/No Y Y Y Y Y
Other Notes	MinFlowSch = -999 from 6 AM- 9 PM, 0.0010 (enables economizer) from 9 PM – 6 AM.
For Analysis	*Update ECM with new economizer operation, if necessary.*

ECM# and Title	12 – 82AHU_4-5_ph2 <Part 4>
Description	For 124 spaces, Change Cool Temp Sched to Setback Cool Sch Change Heat Temp Sched to Setback Heat Sch
Info determined from Model	The 124 zones are located in Bldg 82 and are mostly served by AC-4 and AC-5; eleven zones are served by AC-6 through AC-9.
Other Notes	Setback Cool Sch = 76°F from 6 AM- 9 PM, 82°F from 9 PM – 6 AM. Setback Heat Sch – Summer = 70°F from 6 AM- 9 PM, 64°F from 9 PM – 6 AM, Setback Heat Sch – Winter = 70°F from 4 AM- 9 PM, 64°F from 9 PM – 4 AM.
Action in Field	*In the BAS programming, spot-check **15** zones in Bldg 82 served by AC-4 thru AC-9 to verify they have the "Setback" heating and cooling temperature setpoint schedules listed above.* *Insert "Y" or "N" in the blanks. For any "N" answer, fill in a table like the one below with the actual temperature schedule. Use extra sheets if necessary.* *#* | *Space ID* | *Cooling Sched* | *Heat Sched-Summer* | *Heat Sched-Winter* 1 AC-4 → AC-9 | 76/82 | 70/68 | 70/69 2 See page 29 for occupied / unoccupied times 3 4 At the present time all units on 24/7 5 due to extreme winter weather conditions 6 7 8 9 10 11 12 13 14 15
For Analysis	*Update ECM with new space temperature schedules, if necessary.*

Space ID																								
Hour:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Cooling Schedule																								
Heat Sch – Summer																								
Heat Sch – Winter																								

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ECM# and Title	12 – 82AHU_4-5_ph2 <Part 5>
Description	For 31 spaces, Change Heat Temp Sched to Setback Heat Sch
Info determined from Model	The 31 zones are mostly located in Bldg 95 and the penthouses, although some are mechanical spaces scattered throughout the three buildings. Consider N/A to Bldg 82.
Action in Field	*None.*
For Analysis	*Assume implemented and run model as programmed.*

ECM# and Title	**13 – Economizerall_2-4-5_ph2 <Part 1>** For 83-AC-2, AC-4, AC-5, AC-6, AC-7 and AC-8, ...
And ...	**15 – economizerall_1-3_ph2** For 83-AC-1 and AC-3, ...
Description	Change OA control to OA Temperature, Change Drybulb Economizer High Limit to 65°F, Change Economizer Low Limit to 45°F.
Action in Field	*Confirm these AC units have the economizer high- and low-limit setpoints listed above. In the blanks, insert "Y" if yes, or the actual temperature setting if No.* *High limit = 65?* / *Low limit = 45?* AC-1: 80 / Y AC-2: 80 / Y AC-3: 80 / Y AC-4: 80 / Y AC-5: 80 / Y AC-6: 80 / 40 AC-7: 90 / 40 AC-8: No Economizer / 100% O.A.
For Analysis	*Update ECM with new economizer controls, if necessary.*

ECM# and Title	13 – Economizerall_2-4-5_ph2 <Part 2>
Description	For 83-AC-8, change Minimum OA to 0.0010 ratio
Action in Field	*None – already confirmed whether unit AC-8 has an enabled economizer in ECM 12 part 3.*
For Analysis	*If the above unit has an economizer, run ECM as is.*