LARGE FILING SEPARATOR SHEET

CASE NUMBER 14-0457-EL- RDR

FILE DATE 3/28/2014

SECTION: 4 of 5

NUMBER OF PAGES: 200

DESCRIPTION OF DOCUMENT: Application

( ) 9

( ) 10

( ) DK/NS

69b: Has your knowledge of or participation in any Smart Energy Now or Envision Charlotte event influenced your energy usage at home?
( ) Yes
if Yes, ask: **How has your energy use changed at home?:** ________________

( ) No

( ) DK/NS

SPECIALTY BULBS
Please list the number of bulbs currently installed in your home that are specialty bulbs such as dimmable bulbs, three-way bulbs, recessed, flood or directional lights, candelabra lights or other non-standard bulbs...

s1. How many Dimmable bulbs do you have in your home?... how many Outdoor flood bulbs... etc...*
Dimmable bulbs: ________________________

Outdoor flood bulbs: ________________________

Three-way bulbs: ________________________

Spotlight bulbs: ________________________

Recessed bulbs: ________________________

Candelabra bulbs: ________________________

Other: ________________________

s2. For each of these specialty bulbs installed, how many are CFLs?*
Dimmable bulbs: ________________________

Outdoor flood bulbs: ________________________

Three-way bulbs: ________________________

Spotlight bulbs: ________________________

Recessed bulbs: ________________________

Candelabra bulbs: ________________________

Other: ________________________

s3. On a scale from 1-10, with 1 indicating not at all interested and 10 indicating very interested, please rate your interest in Duke Energy providing a direct mail specialty CFL program that shipped discounted specialty bulbs directly to your home:*
( ) 1

( ) 2

( ) 3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8

( ) 9

( ) 10

( ) DK/NS

Please tell me if you would be interested in receiving the following types of CFLs if they were to be offered in the future...

s4. Dimmable CFLs*
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

s5. Outdoor flood CFLs*
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

s6. Three-way CFLs*
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

s7. Spotlight CFLs*
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

s8. Candelabra CFLs*
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

(If responder indicated a different specialty bulb)

s9. {Other bulb}
( ) Yes
If YES, ask: **About how many hours per day would these bulbs be used?**:

____

( ) No

( ) DK/NS

FULL DEMOGRAPHIC SERIES
Finally, we have some general demographic questions…

79. 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

80. What year was your residence built?*
( ) 1959 and before

( ) 1960-1979

( ) 1980-1989

( ) 1990-1997

( ) 1998-2000

( ) 2001-2007

( ) 2008-present

( ) DK/NS

81. How many rooms are in your home (excluding bathrooms, but including finished basements)?*
( ) None

( ) 1-3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8

( ) 9

( ) 10 or more

( ) DK/NS

82. Which of the following best describes your home's heating system?*
( ) None

( ) Central forced air furnace

( ) Electric Baseboard

( ) Heat Pump

( ) Geothermal Heat Pump

( ) Other: _________________

83. 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

84. What is the primary fuel used in your heating system?*
( ) Electricity

( ) Natural Gas

( ) Oil

( ) Propane

( ) Other: ________________

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

( ) Electricity

( ) Natural Gas

( ) Oil

( ) Propane

( ) Other: ________________

( ) None

86. Do you use one or more of the following to cool your home?*
(Mark 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?)*

87. 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

88. What is the fuel used in your cooling system?*

[ ] Electricity

[ ] Natural Gas

[ ] Oil

[ ] Propane

[ ] Other

[ ] None

89. 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

90. What is the fuel used by your water heater?*
(Mark all that apply)

[ ] Electricity

[ ] Natural Gas

[ ] Oil

[ ] Propane

[ ] Other

[ ] No water heater

91. How old is your water heater?*
( ) 0-4 years

( ) 5-9 years

( ) 10-14 years

( ) 15-19 years

( ) More than 19 years

( ) DK/NS

92. What type of fuel do you use for indoor cooking on the stovetop or range?
(Mark all that apply)

[ ] Electricity

[ ] Natural Gas

[ ] Oil

[ ] Propane

[ ] Other

[ ] No stovetop or range

93. What type of fuel do you use for indoor cooking in the oven?*
(Mark all that apply)

[ ] Electricity

[ ] Natural Gas

[ ] Oil

[ ] Propane

[ ] Other

[ ] No oven

94. What type of fuel do you use for clothes drying?*
(Mark all that apply)

[ ] Electricity

[ ] Natural Gas

[ ] Oil

[ ] Propane

[ ] Other

[ ] No clothes dryer

95. 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 – 999

( ) 1000 – 1499

( ) 1500 – 1999

( ) 2000 – 2499

( ) 2500 – 2999

( ) 3000 – 3499

( ) 3500 – 3999

( ) 4000 or more

( ) DK/NS

96. Do you own or rent your home?*

( ) Own

( ) Rent

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

( ) One

( ) Two

( ) Three

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

( ) Heated

( ) Unheated

( ) No basement

99. Does your home have an attic?*

( ) Yes

( ) No

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

( ) Yes

( ) No

( ) N/A

101. Does your house have cold drafts in the winter?*

( ) Yes

( ) No

102. Does your house have sweaty windows in the winter?*

( ) Yes

( ) No

103. Do you notice uneven temperatures between the rooms in your home?*

( ) Yes

( ) No

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

( ) Yes

( ) No

105. Does your cooling system keep your home comfortable in summer?*
( ) Yes

( ) No

106. Do you have a programmable thermostat?*
( ) Yes

( ) No

107. 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

108. 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

( ) Higher than 78 degrees

( ) Off

( ) DK/NS

109. Do You Have a Swimming Pool or Spa?*
( ) Yes

( ) No

Read all answers until they reply

110. Would a two-degree increase in the summer afternoon temperature in your home affect your comfort..*
( ) Not at all

( ) Slightly

( ) Moderately, or

( ) Greatly

111. How many people live in this home?*
( ) 1

( ) 2

( ) 3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8 or more

( ) Prefer not to answer

111a. 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

112. How many persons are usually home on a weekday afternoon?*

( ) 0
( ) 1

( ) 2

( ) 3

( ) 4

( ) 5

( ) 6

( ) 7

( ) 8 or more

( ) Prefer not to answer

113. Are you planning on making any large purchases to improve energy efficiency in the next 3 years?*
( ) Yes

( ) No

( ) NS/DK

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.

114. What is your age group?*
( ) 18-34

( ) 35-49

( ) 50-59

( ) 60-64

( ) 65-74

( ) Over 74

( ) Prefer not to answer

115. Please indicate your annual household income.*
( ) 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

That completes our survey. As I mentioned at the start, we'd like to send you a check for $20 for your time. Should we send it to [name] at [address]?*
Name: ____________________

Address: ____________________

City: ____________________

State: ____________________

Zip: ____________________

We have reached the end of the survey. Do you have any comments that you would like for me to pass on to Duke Energy?

OK, thank you for your time and feedback today!

Appendix C: Evaluation Approaches

The analysis used in this study is based on improvements made within the field of energy program evaluation over the last year. Specifically, studies conducted prior to this year used standardized billing analysis techniques linked to net analysis adjustment methods to estimate net impacts for all measures without differentiating between low-cost standard consumable measures (part of normal purchase behaviors because first cost, product availability and transaction barriers are not significant) and measures with significant acquisition barriers. In the last year the field has differentiated analysis approaches associated with normal low-cost item purchase behavior measures (CFLs, aerators, shower heads, caulking, etc.) from products that have significant cost and other purchase barriers (furnaces, air conditioners, compressors, etc.). Impact analysis approaches associated with low-cost low-barrier products that have few if any significant purchase barriers can produce net savings directly from a billing analysis that controls for weather and pre-existing (before the program) changes in market conditions over the evaluation period. In these approaches, the use of a rolling pre-program billing period, consisting of all participants' consumption before they enroll in a program can be effectively used as a control group and as a result, that analysis produces net savings without identifying gross savings.

TecMarket Works adopted the controlled fixed effects billing analysis with and without net adjustment approach as a standard practice in 2012. Prior to this change in the evaluation approach, impact evaluations employed four different strategies for estimating impacts. These are:

1. **The Experimental Design Approach** in which customers are randomly sorted into a test and control group. In this design savings are based on the difference between the consumption of these two groups over the same period of time. The mathematics of this approach is called the "difference of differences approach". This approach provides net savings because it segregates the two groups independently as a function of their random assignment. Only the test group receives exposure to the program, while the randomly assigned non-participants are used as a control group. When these two groups are compared, in a difference of differences approach, the findings are net savings because the savings are already adjusted for what would have happened without the program by subtracting out the savings from the control group. In this approach, subtracting or adding the differences in the energy use of the control group adjusts the gross savings (pre vs. post consumption of the test group) to compensate for the change in consumption of the non-program-exposed control group. This savings produced from this approach are net.

2. **The Quasi-Experimental Approach** is similar to the experimental design approach. However, the construction of the control group is not based on random assignment. In this approach the evaluation experts purposefully and systematically selects subjects to use as a control group. However, because this type of analysis uses a non-random approach to represent the control group, the term "control group" is not used because it can be confused with a random assignment approach. In the use of the quasi-experimental design the evaluation experts selects the comparison group so that it is as

closely matched to the test group (participants) as possible. The term used to represent the group that is used to adjust savings for what would have occurred is the "*comparison group*". Assignments to the comparison group population are carefully considered by the evaluation expert in order to develop a comparison group that is as identical as possible to the test group, except for the participation in the program. The characteristics of the test group that are used for matching are typically demographic characteristics (age, housing type, location, income, etc.), energy use characteristics (amount of energy they use and when they use it) and in some cases psychographic characteristics (attitudes and behaviors). While the match is not as reliable as a true experimental design the results provided from this difference of differences approach are net savings. That is, the savings are already adjusted for what would have occurred without the program via the use of the matched comparison group and the use of the differences of differences analytical approach.

3. **The Pre versus Post with Net Adjustment Approach** is a simpler approach than the experimental or quasi-experimental approach in that the energy savings are based not on the use of the comparison or control groups, but instead are based on the difference between the pre-program and post-program periods of the test group. This approach is a differences approach in that gross savings are estimated as the difference between the pre and post program periods. To convert gross savings to net of freerider savings (what would have occurred without the program), the savings that would have been achieved without the program are subtracted from the gross savings. The estimation of the savings that would have occurred without the program is typically calculated via the use of a freeridership battery of questions asked of the participants. These questions essentially get at what actions the participants would have taken without the program. Then the estimates of savings that would have occurred are then subtracted from the gross savings to provide net savings that are adjusted for freeridership.

4. **The Engineering Based with Net Adjustment Approach** is another standard energy savings estimation approach using an engineering estimation approach in which savings are estimated via the use of engineering calculations rather than billing or consumption records. In this approach, the actions taken are identified via interviews, surveys or inspections. Then a trained energy evaluation expert calculates the expected savings under the installation and use conditions of the participant's facilities. These are estimated savings based on known conditions about the energy use of the equipment that was going to be in use without the program and the consumption of the program-induced equipment. In this case the savings are gross and need to be adjusted by what the participant would have done without the program. As in the previous approach, the estimation of the savings that would have occurred without the program is typically calculated via the use of a freeridership battery of questions asked of the participants.

The above 4 approaches have been used as the standard approaches in the field of energy program evaluation for over 30 years. The approaches presented above are presented in descending order of their reliability. The approach with the highest level of reliability is the experimental design approach. The least reliable is the engineering based approach. The experimental design approach, when done well, is typically reliable to a couple of percent. The engineering approach, even when done well, is typically reliable to within 20% to 30%. In order to develop an approach that is more reliable than the pre versus post or the engineering approach, but is not as costly as the experimental or quasi experimental approaches, the field of evaluation developed the controlled fixed effects net billing analysis approach. This approach delivers net energy savings at a level of reliability that is similar to the experimental or quasi-experimental design but does not include the costs to form and use an independent control or comparison group.

5. **The Controlled Fixed Effects Billing Analysis with and without Net Adjustment** approach has been developed to provide savings estimates when a control or comparison group is not available or advisable because of cost considerations. In this approach, the participant's energy use data is used to econometrically model the energy savings for the participant by employing a rolling comparison time period using the time before customers participated in a program as the comparison period, forming a proxy comparison group. Because customers come into a program at a specific time, the time before that enrollment is grouped with other pre-program periods of all participants. Because the customer's pre-program period is used to control for normal energy changes over time at the population level, it is more reliable than the use of a comparison group. That is, the participants are exactly matched to the comparison group because they are the same individuals. There is no selection bias because there is no selection into a control or comparison group. This strengthens the study. Because only the pre-program energy use is used as the proxy comparison group, there is no program influence on that period of time that is used for the savings estimation. Because people come into the program at different periods of time, essentially providing a full analytical period (timeline) of non-participating energy consumption, the entire pre-program period can be used as the comparison group over the pre and post analytical program period. This analytical approach can also control for the effects of participating in other energy efficiency programs so that the savings achieved via multiple program participation is only counted once and credited to only one program. In cases in which there are multiple program participants, the savings associated with participants who have participated in multiple programs is subtracted from the savings identified within the billing analysis approach by subtracting out the typical savings associated with the typical installation in proportion of their occurrence in the participating population.

This approach has gained considerable use within the evaluation community and has been adopted as standard practice by several of the leading evaluation firms in the United States. The approach has also been peer reviewed within the evaluation community and accepted as one of the more reliable evaluation approaches that is not as reliable as the experimental design approach, but is probably more reliable than the quasi-experimental design because it reduces the bias associated with comparison group selection. When this approach has been used in the past, typically net savings were estimated by conducting a freeridership questionnaire and then subtracting out the savings associated with freeridership. This is the approach that was used in the Duke Energy Home Energy House Call 2011 impact evaluation reports. However, recent developments in the field of evaluation has indicated that when a program is assessing standard market consumable measures that are inexpensive and have low purchase barriers, there is no need to adjust for freeriders because their market practices are already in the pre-program billing data. These measures that are typically readily available in the market and typically cost well under $5 each do not rise to the level that they pose a significant financial or technical barrier once an adoption decision has been made. As a result there is no need to adjust for freeriders when a program focuses on low-cost and readily available measures. Thus the field of evaluation is now moving away from adjusting for freeriders for minor low-cost, readily available measures (CFLs, pipe wrap, aerators, shower heads, etc.) when a billing analysis approach is used that employs a rolling pre-program period as the comparison group. However, when the program offers measures that have significant adoption barriers, such as a high cost or technical uncertainty (air-conditioners, major Energy Star appliances, motors, chillers, pumps compressors, etc.), then this approach must also include a freerider analysis to estimate net effect. Because major measures are not a standard market consumable product, the savings from these measures would not typically be net savings from the use of a rolling comparison period consisting of the pre-program period for all enrolling participants.

Appendix D: Counts of Participant / Non-participants for Billing Analysis

This appendix presents the counts of participants and non-participants in each month. The first row is always the last month before the first participant, such that for KY the first participant showed up in April 2011 with the first row started in March 2011. The last row is the last month of billing data included in the billing analysis, and it may not be the last month of participation cut-off for this analysis. For example the cut-off month for KY is June 2012 whereas the billing data goes through September 2012 such that the last 3 month with non-participant count being zero.

state	yearmonth	Participant_count	Non_participant_count
	201103	0	326
	201104	6	306
	201105	18	317
	201106	28	309
	201107	33	294
	201108	36	304
	201109	49	292
	201110	121	220
	201111	161	174
KY	201112	193	150
	201201	212	132
	201202	233	115
	201203	255	92
	201204	263	76
	201205	300	45
	201206	334	12
	201207	347	0
	201208	346	0
	201209	5	0
	201103	0	3265
	201104	79	3064
	201105	224	3075
	201106	460	2900
	201107	605	2633
	201108	897	2503
	201109	1214	2193
	201110	1628	1796
	201111	1974	1365
OH	201112	2418	999
	201201	2718	719
	201202	2976	480
	201203	3154	318
	201204	3157	168
	201205	3373	91
	201206	3418	38
	201207	3455	0
	201208	3462	0
	201209	127	0

Appendix E: Estimated Model

This appendix presents the estimated statistical models used in the impact evaluation. The dependent variable is monthly usage (in kWh/day) for the period April. 2010 through Sep. 2012 The independent variables in the model are:

- An indicator variable that is equal to one for all months after participating in HEHC, broken out by Ohio and Kentucky.
- Monthly indicator variables, denoted in the tables as yearmonth terms. These variables are equal to 1 if the observation is for that month, and zero otherwise. They are included in the model as interaction with area (mid west or south east) controlling for state specific monthly macro economic conditions.
- Weather terms, specifically interaction of temperature and humidity vs. monthly indicator, which correspond to the weather conditions for the month. They are included in the model as interaction with area (mid west or south east) controlling for state specific weather responses.
- Other Duke offers, including CFL, PER, K12, Low income weatherization and smart saver;
- The number of observations is the total number of monthly billing data records used in the model.

Number of Observations Read	260204
Number of Observations Used	260204

Dependent Variable: kwhd

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12203	160296368.8	13135.8	49.32	<.0001
Error	248000	66055318.1	266.4		
Corrected Total	260203	226351686.9			

R-Square	Coeff Var	Root MSE	kwhd Mean
0.708174	35.37925	16.32030	46.12957

Source	DF	Type I SS	Mean Square	F Value	Pr > F
acct_id	11999	127410864.6	10618.5	39.87	<.0001
yearmonth*area	64	28355029.9	443047.3	1663.39	<.0001
avg_tem*yearmon*area	66	4175046.9	63258.3	237.50	<.0001
avg_hum*yearmon*area	66	188593.3	2857.5	10.73	<.0001
PER	1	30593.7	30593.7	114.86	<.0001
K12	1	1348.3	1348.3	5.06	0.0245
LowInc	1	610.8	610.8	2.29	0.1299
SS	1	31714.0	31714.0	119.07	<.0001
CFL	1	2.2	2.2	0.01	0.9282
part*state	3	102565.1	34188.4	128.36	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yearmonth*area	64	2420110.734	37814.230	141.97	<.0001
avg_tem*yearmon*area	66	3913217.624	59291.176	222.60	<.0001

avg_hum*yearmon*area	66	189170.277	2866.216	10.76	<.0001
PER	1	26723.288	26723.288	100.33	<.0001
K12	1	1640.264	1640.264	6.16	0.0131
LowInc	1	672.581	672.581	2.53	0.1120
SS	1	30716.535	30716.535	115.32	<.0001
CFL	1	1753.698	1753.698	6.58	0.0103
part*state	3	102565.107	34188.369	128.36	<.0001

Parameter			Estimate	Standard Error	t Value	Pr > |t|
yearmonth*area	200909	SE	-127.166	61.69955	-2.06	0.0393
yearmonth*area	200910	SE	5.487348	42.3488	0.13	0.8969
yearmonth*area	200911	SE	90.86326	43.45294	2.09	0.0365
yearmonth*area	200912	SE	136.4848	39.27679	3.47	0.0005
yearmonth*area	201001	SE	153.5312	39.44996	3.89	<.0001
yearmonth*area	201002	SE	139.566	39.39715	3.54	0.0004
yearmonth*area	201003	SE	136.2848	38.68175	3.52	0.0004
yearmonth*area	201004	SE	76.50166	39.15349	1.95	0.0507
yearmonth*area	201005	MW	123.7739	150.0508	0.82	0.4094
yearmonth*area	201005	SE	-37.2003	39.23019	-0.95	0.343
yearmonth*area	201006	MW	36.92354	149.0937	0.25	0.8044
yearmonth*area	201006	SE	-142.18	39.72447	-3.58	0.0003
yearmonth*area	201007	MW	140.8406	157.517	0.89	0.3713
yearmonth*area	201007	SE	-189.829	42.52219	-4.46	<.0001
yearmonth*area	201008	MW	149.4894	152.6022	0.98	0.3273
yearmonth*area	201008	SE	-217.178	43.11856	-5.04	<.0001
yearmonth*area	201009	MW	90.07959	146.3173	0.62	0.5381
yearmonth*area	201009	SE	-120.719	39.42757	-3.06	0.0022
yearmonth*area	201010	MW	109.7595	146.256	0.75	0.453
yearmonth*area	201010	SE	-50.0533	38.80015	-1.29	0.197
yearmonth*area	201011	MW	178.5809	146.1971	1.22	0.2219
yearmonth*area	201011	SE	84.74321	38.61739	2.19	0.0282
yearmonth*area	201012	MW	190.8893	146.3916	1.3	0.1922
yearmonth*area	201012	SE	126.1736	38.43822	3.28	0.001
yearmonth*area	201101	MW	150.651	146.3377	1.03	0.3033
yearmonth*area	201101	SE	99.55442	38.62061	2.58	0.0099
yearmonth*area	201102	MW	124.4535	145.9546	0.85	0.3938
yearmonth*area	201102	SE	99.06065	38.58451	2.57	0.0102
yearmonth*area	201103	MW	182.3719	145.7189	1.25	0.2107
yearmonth*area	201103	SE	110.883	38.44385	2.88	0.0039
yearmonth*area	201104	MW	185.8266	145.6932	1.28	0.2021
yearmonth*area	201104	SE	67.49399	38.47872	1.75	0.0794

yearmonth*area	201105	MW	158.5207	145.8374	1.09	0.2771
yearmonth*area	201105	SE	-58.0499	38.70893	-1.5	0.1337
yearmonth*area	201106	MW	95.84066	145.8385	0.66	0.5111
yearmonth*area	201106	SE	-130.262	38.91441	-3.35	0.0008
yearmonth*area	201107	MW	82.5033	145.9193	0.57	0.5718
yearmonth*area	201107	SE	-135.557	39.23788	-3.45	0.0006
yearmonth*area	201108	MW	12.33631	145.9721	0.08	0.9326
yearmonth*area	201108	SE	-143.67	39.51896	-3.64	0.0003
yearmonth*area	201109	MW	106.8932	145.9678	0.73	0.464
yearmonth*area	201109	SE	-137.417	38.99125	-3.52	0.0004
yearmonth*area	201110	MW	138.3386	145.7731	0.95	0.3426
yearmonth*area	201110	SE	-17.792	38.46576	-0.46	0.6437
yearmonth*area	201111	MW	180.3579	145.7746	1.24	0.216
yearmonth*area	201111	SE	97.95199	38.52411	2.54	0.011
yearmonth*area	201112	MW	211.5267	145.7334	1.45	0.1467
yearmonth*area	201112	SE	144	38.68287	3.72	0.0002
yearmonth*area	201201	MW	378.2478	145.6941	2.6	0.0094
yearmonth*area	201201	SE	148.7057	38.59533	3.85	0.0001
yearmonth*area	201202	MW	230.8445	145.8432	1.58	0.1135
yearmonth*area	201202	SE	116.5138	38.57052	3.02	0.0025
yearmonth*area	201203	MW	195.2161	145.6356	1.34	0.1801
yearmonth*area	201203	SE	97.28093	38.35183	2.54	0.0112
yearmonth*area	201204	MW	148.2201	145.8409	1.02	0.3095
yearmonth*area	201204	SE	20.1109	38.73128	0.52	0.6036
yearmonth*area	201205	MW	148.5053	145.6544	1.02	0.3079
yearmonth*area	201205	SE	2.298369	38.39815	0.06	0.9523
yearmonth*area	201206	MW	79.25571	145.9838	0.54	0.5872
yearmonth*area	201206	SE	-88.7682	39.24441	-2.26	0.0237
yearmonth*area	201207	MW	49.20898	146.0819	0.34	0.7362
yearmonth*area	201207	SE	-100.779	38.71222	-2.6	0.0092
yearmonth*area	201208	MW	48.201	145.9864	0.33	0.7413
yearmonth*area	201208	SE	-152.632	39.45352	-3.87	0.0001
avg_tem*yearmon*area	200909	SE	2.594309	0.479795	5.41	<.0001
avg_tem*yearmon*area	200910	SE	0.601436	0.169484	3.55	0.0004
avg_tem*yearmon*area	200911	SE	-1.05328	0.303636	-3.47	0.0005
avg_tem*yearmon*area	200912	SE	-1.77116	0.130751	-13.55	<.0001
avg_tem*yearmon*area	201001	SE	-3.07882	0.258071	-11.93	<.0001
avg_tem*yearmon*area	201002	SE	-2.80742	0.243252	-11.54	<.0001
avg_tem*yearmon*area	201003	SE	-1.8383	0.091913	-20	<.0001
avg_tem*yearmon*area	201004	SE	-0.69076	0.119271	-5.79	<.0001
avg_tem*yearmon*area	201005	MW	-0.16941	0.882648	-0.19	0.8478

avg_tem*yearmon*area	201005	SE	1.111307	0.154308	7.2	<.0001
avg_tem*yearmon*area	201006	MW	1.870235	0.323078	5.79	<.0001
avg_tem*yearmon*area	201006	SE	2.406083	0.112985	21.3	<.0001
avg_tem*yearmon*area	201007	MW	0.812907	0.761179	1.07	0.2855
avg_tem*yearmon*area	201007	SE	2.887002	0.212144	13.61	<.0001
avg_tem*yearmon*area	201008	MW	0.86552	0.542449	1.6	0.1106
avg_tem*yearmon*area	201008	SE	3.18268	0.210189	15.14	<.0001
avg_tem*yearmon*area	201009	MW	1.343111	0.239041	5.62	<.0001
avg_tem*yearmon*area	201009	SE	2.137997	0.120513	17.74	<.0001
avg_tem*yearmon*area	201010	MW	0.816001	0.143772	5.68	<.0001
avg_tem*yearmon*area	201010	SE	1.296026	0.072415	17.9	<.0001
avg_tem*yearmon*area	201011	MW	-0.41539	0.150705	-2.76	0.0058
avg_tem*yearmon*area	201011	SE	-0.78458	0.075342	-10.41	<.0001
avg_tem*yearmon*area	201012	MW	-0.9996	0.083555	-11.96	<.0001
avg_tem*yearmon*area	201012	SE	-1.90891	0.050237	-38	<.0001
avg_tem*yearmon*area	201101	MW	-2.1416	0.351975	-6.08	<.0001
avg_tem*yearmon*area	201101	SE	-1.83231	0.135457	-13.53	<.0001
avg_tem*yearmon*area	201102	MW	-0.02936	0.116903	-0.25	0.8017
avg_tem*yearmon*area	201102	SE	-1.32212	0.072919	-18.13	<.0001
avg_tem*yearmon*area	201103	MW	-1.07929	0.086326	-12.5	<.0001
avg_tem*yearmon*area	201103	SE	-1.24476	0.074708	-16.66	<.0001
avg_tem*yearmon*area	201104	MW	-0.75044	0.101328	-7.41	<.0001
avg_tem*yearmon*area	201104	SE	-0.54437	0.06161	-8.84	<.0001
avg_tem*yearmon*area	201105	MW	0.224101	0.18528	1.21	0.2265
avg_tem*yearmon*area	201105	SE	1.390493	0.10766	12.92	<.0001
avg_tem*yearmon*area	201106	MW	1.165598	0.108085	10.78	<.0001
avg_tem*yearmon*area	201106	SE	2.05744	0.072538	28.36	<.0001
avg_tem*yearmon*area	201107	MW	1.366362	0.126557	10.8	<.0001
avg_tem*yearmon*area	201107	SE	2.338902	0.108967	21.46	<.0001
avg_tem*yearmon*area	201108	MW	2.423762	0.136039	17.82	<.0001
avg_tem*yearmon*area	201108	SE	2.409525	0.113733	21.19	<.0001
avg_tem*yearmon*area	201109	MW	1.306141	0.11926	10.95	<.0001
avg_tem*yearmon*area	201109	SE	2.376639	0.076644	31.01	<.0001
avg_tem*yearmon*area	201110	MW	0.514416	0.132312	3.89	0.0001
avg_tem*yearmon*area	201110	SE	0.797174	0.059846	13.32	<.0001
avg_tem*yearmon*area	201111	MW	-0.36766	0.129065	-2.85	0.0044
avg_tem*yearmon*area	201111	SE	-0.92738	0.076631	-12.1	<.0001
avg_tem*yearmon*area	201112	MW	-0.96246	0.106912	-9	<.0001
avg_tem*yearmon*area	201112	SE	-1.67682	0.10382	-16.15	<.0001
avg_tem*yearmon*area	201201	MW	-4.89841	0.129666	-37.78	<.0001
avg_tem*yearmon*area	201201	SE	-1.89466	0.124807	-15.18	<.0001

avg_tem*yearmon*area	201202	MW	-1.58661	0.217256	-7.3	<.0001
avg_tem*yearmon*area	201202	SE	-1.26372	0.132291	-9.55	<.0001
avg_tem*yearmon*area	201203	MW	-0.65017	0.043952	-14.79	<.0001
avg_tem*yearmon*area	201203	SE	-0.86906	0.037225	-23.35	<.0001
avg_tem*yearmon*area	201204	MW	0.222183	0.156835	1.42	0.1566
avg_tem*yearmon*area	201204	SE	0.153259	0.102093	1.5	0.1333
avg_tem*yearmon*area	201205	MW	0.304482	0.077226	3.94	<.0001
avg_tem*yearmon*area	201205	SE	0.572241	0.065158	8.78	<.0001
avg_tem*yearmon*area	201206	MW	1.315131	0.146473	8.98	<.0001
avg_tem*yearmon*area	201206	SE	1.728605	0.107887	16.02	<.0001
avg_tem*yearmon*area	201207	MW	1.853199	0.139115	13.32	<.0001
avg_tem*yearmon*area	201207	SE	1.921978	0.076679	25.07	<.0001
avg_tem*yearmon*area	201208	MW	1.868197	0.11862	15.75	<.0001
avg_tem*yearmon*area	201208	SE	2.50853	0.102684	24.43	<.0001
avg_tem*yearmon*area	201209	MW	1.637961	1.931631	0.85	0.3965
avg_tem*yearmon*area	201209	SE	0.672197	0.432909	1.55	0.1205
avg_hum*yearmon*area	200909	SE	-0.14941	0.244301	-0.61	0.5408
avg_hum*yearmon*area	200910	SE	-0.05829	0.173692	-0.34	0.7372
avg_hum*yearmon*area	200911	SE	0.090989	0.134244	0.68	0.4979
avg_hum*yearmon*area	200912	SE	-0.00987	0.10569	-0.09	0.9256
avg_hum*yearmon*area	201001	SE	0.487547	0.090648	5.38	<.0001
avg_hum*yearmon*area	201002	SE	0.506299	0.085945	5.89	<.0001
avg_hum*yearmon*area	201003	SE	0.024653	0.071213	0.35	0.7292
avg_hum*yearmon*area	201004	SE	0.049988	0.066194	0.76	0.4501
avg_hum*yearmon*area	201005	MW	0.62418	0.494481	1.26	0.2068
avg_hum*yearmon*area	201005	SE	0.062799	0.061679	1.02	0.3086
avg_hum*yearmon*area	201006	MW	0.019664	0.416693	0.05	0.9624
avg_hum*yearmon*area	201006	SE	0.233359	0.071177	3.28	0.001
avg_hum*yearmon*area	201007	MW	-0.24778	0.224023	-1.11	0.2687
avg_hum*yearmon*area	201007	SE	0.400711	0.068429	5.86	<.0001
avg_hum*yearmon*area	201008	MW	-0.40873	0.181779	-2.25	0.0245
avg_hum*yearmon*area	201008	SE	0.397821	0.072626	5.48	<.0001
avg_hum*yearmon*area	201009	MW	-0.19102	0.134191	-1.42	0.1546
avg_hum*yearmon*area	201009	SE	0.230731	0.044916	5.14	<.0001
avg_hum*yearmon*area	201010	MW	0.030556	0.154348	0.2	0.8431
avg_hum*yearmon*area	201010	SE	0.079164	0.050009	1.58	0.1134
avg_hum*yearmon*area	201011	MW	0.054689	0.114684	0.48	0.6335
avg_hum*yearmon*area	201011	SE	0.000508	0.043808	0.01	0.9907
avg_hum*yearmon*area	201012	MW	0.231981	0.189572	1.22	0.2211
avg_hum*yearmon*area	201012	SE	0.230014	0.050299	4.57	<.0001
avg_hum*yearmon*area	201101	MW	1.207676	0.163291	7.4	<.0001

avg_hum*yearmon*area	201101	SE	0.56696	0.05344	10.61	<.0001
avg_hum*yearmon*area	201102	MW	0.755071	0.115017	6.56	<.0001
avg_hum*yearmon*area	201102	SE	0.248097	0.054007	4.59	<.0001
avg_hum*yearmon*area	201103	MW	0.473102	0.08708	5.43	<.0001
avg_hum*yearmon*area	201103	SE	-0.03711	0.047544	-0.78	0.4351
avg_hum*yearmon*area	201104	MW	0.236303	0.087144	2.71	0.0067
avg_hum*yearmon*area	201104	SE	0.06718	0.067869	0.99	0.3223
avg_hum*yearmon*area	201105	MW	-0.15162	0.086225	-1.76	0.0787
avg_hum*yearmon*area	201105	SE	0.101741	0.046873	2.17	0.03
avg_hum*yearmon*area	201106	MW	-0.09416	0.060751	-1.55	0.1212
avg_hum*yearmon*area	201106	SE	0.484379	0.054677	8.86	<.0001
avg_hum*yearmon*area	201107	MW	-0.07247	0.065482	-1.11	0.2684
avg_hum*yearmon*area	201107	SE	0.228939	0.048603	4.71	<.0001
avg_hum*yearmon*area	201108	MW	-0.21423	0.068323	-3.14	0.0017
avg_hum*yearmon*area	201108	SE	0.271109	0.046803	5.79	<.0001
avg_hum*yearmon*area	201109	MW	-0.36679	0.073099	-5.02	<.0001
avg_hum*yearmon*area	201109	SE	0.210256	0.049561	4.24	<.0001
avg_hum*yearmon*area	201110	MW	-0.11756	0.086605	-1.36	0.1746
avg_hum*yearmon*area	201110	SE	0.080279	0.045737	1.76	0.0792
avg_hum*yearmon*area	201111	MW	0.01364	0.066156	0.21	0.8367
avg_hum*yearmon*area	201111	SE	-0.07824	0.043879	-1.78	0.0746
avg_hum*yearmon*area	201112	MW	0.00423	0.059399	0.07	0.9432
avg_hum*yearmon*area	201112	SE	-0.14976	0.041557	-3.6	0.0003
avg_hum*yearmon*area	201201	MW	-0.10272	0.052682	-1.95	0.0512
avg_hum*yearmon*area	201201	SE	-0.09819	0.04538	-2.16	0.0305
avg_hum*yearmon*area	201202	MW	0.034713	0.059361	0.58	0.5587
avg_hum*yearmon*area	201202	SE	-0.08137	0.050701	-1.6	0.1085
avg_hum*yearmon*area	201203	MW	0.038765	0.054941	0.71	0.4804
avg_hum*yearmon*area	201203	SE	-0.09131	0.051533	-1.77	0.0764
avg_hum*yearmon*area	201204	MW	-0.01294	0.059622	-0.22	0.8281
avg_hum*yearmon*area	201204	SE	0.127515	0.051735	2.46	0.0137
avg_hum*yearmon*area	201205	MW	-0.07232	0.056346	-1.28	0.1993
avg_hum*yearmon*area	201205	SE	0.036209	0.045597	0.79	0.4271
avg_hum*yearmon*area	201206	MW	0.001771	0.059549	0.03	0.9763
avg_hum*yearmon*area	201206	SE	0.212003	0.051106	4.15	<.0001
avg_hum*yearmon*area	201207	MW	-0.11986	0.073403	-1.63	0.1025
avg_hum*yearmon*area	201207	SE	0.225731	0.041183	5.48	<.0001
avg_hum*yearmon*area	201208	MW	-0.12616	0.070064	-1.8	0.0718
avg_hum*yearmon*area	201208	SE	0.263612	0.050618	5.21	<.0001
avg_hum*yearmon*area	201209	MW	0.813001	0.463348	1.75	0.0793
avg_hum*yearmon*area	201209	SE	0.089185	0.120873	0.74	0.4606

PER		-3.59725	0.359132	-10.02	<.0001
K12		2.513425	1.012831	2.48	0.0131
LowInc		-1.92329	1.210319	-1.59	0.112
SS		-4.13858	0.385383	-10.74	<.0001
CFL		0.317636	0.123789	2.57	0.0103
part*state	KY	-2.1244	0.474111	-4.48	<.0001
part*state	OH	-1.72817	0.241594	-7.15	<.0001
part*state	SE	-2.54313	0.139757	-18.2	<.0001

Appendix F: Estimated Statistical Models for Additional CFLs

Number of Observations Read 259435
Number of Observations Used 259435

Dependent Variable: kwhd

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12174	159964807.1	13139.9	49.28	<.0001
Error	247260	65924595.6	266.6		
Corrected Total	259434	225889402.7			

R-Square	Coeff Var	Root MSE	kwhd Mean
0.708155	35.38905	16.32852	46.14004

Source	DF	Type I SS	Mean Square	F Value	Pr > F
acct_id	11968	127169635.2	10625.8	39.85	<.0001
yearmonth*area	64	28272926.7	441764.5	1656.90	<.0001
avg_tem*yearmon*area	66	4164175.9	63093.6	236.64	<.0001
avg_hum*yearmon*area	66	189152.3	2865.9	10.75	<.0001
PER	1	30639.9	30639.9	114.92	<.0001
K12	1	1344.8	1344.8	5.04	0.0247
LowInc	1	609.0	609.0	2.28	0.1307
SS	1	31836.3	31836.3	119.41	<.0001
CFL	1	2.7	2.7	0.01	0.9196
part*state	3	102949.0	34316.3	128.71	<.0001
part*AddBulbs*state	2	1535.3	767.6	2.88	0.0562

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yearmonth*area	64	2412730.679	37698.917	141.40	<.0001
avg_tem*yearmon*area	66	3903341.843	59141.543	221.82	<.0001
avg_hum*yearmon*area	66	189713.377	2874.445	10.78	<.0001
PER	1	26890.930	26890.930	100.86	<.0001
K12	1	1620.487	1620.487	6.08	0.0137
LowInc	1	702.620	702.620	2.64	0.1045
SS	1	30831.262	30831.262	115.64	<.0001
CFL	1	1483.446	1483.446	5.56	0.0183
part*state	3	82955.665	27651.888	103.71	<.0001
part*AddBulbs*state	2	1535.275	767.638	2.88	0.0562

Parameter			Estimate	Standard Error	t Value	Pr > |t|
yearmonth*area	200909	SE	-126.874	61.85324	-2.05	0.0402
yearmonth*area	200910	SE	4.908066	42.44501	0.12	0.9079
yearmonth*area	200911	SE	90.94417	43.54025	2.09	0.0367
yearmonth*area	200912	SE	134.6139	39.34785	3.42	0.0006
yearmonth*area	201001	SE	152.6333	39.52217	3.86	0.0001

yearmonth*area	201002	SE	137.181	39.48113	3.47	0.0005
yearmonth*area	201003	SE	135.5024	38.75114	3.5	0.0005
yearmonth*area	201004	SE	75.8453	39.22355	1.93	0.0532
yearmonth*area	201005	MW	126.7191	150.1314	0.84	0.3986
yearmonth*area	201005	SE	-38.0868	39.30094	-0.97	0.3325
yearmonth*area	201006	MW	39.9378	149.1741	0.27	0.7889
yearmonth*area	201006	SE	-143.025	39.79332	-3.59	0.0003
yearmonth*area	201007	MW	145.2854	157.6151	0.92	0.3566
yearmonth*area	201007	SE	-189.753	42.59239	-4.46	<.0001
yearmonth*area	201008	MW	144.9037	152.747	0.95	0.3428
yearmonth*area	201008	SE	-217.193	43.19716	-5.03	<.0001
yearmonth*area	201009	MW	91.2028	146.3991	0.62	0.5333
yearmonth*area	201009	SE	-120.633	39.49888	-3.05	0.0023
yearmonth*area	201010	MW	112.5786	146.3357	0.77	0.4417
yearmonth*area	201010	SE	-50.5726	38.86905	-1.3	0.1932
yearmonth*area	201011	MW	182.0004	146.2766	1.24	0.2134
yearmonth*area	201011	SE	84.06758	38.68625	2.17	0.0298
yearmonth*area	201012	MW	193.6925	146.4706	1.32	0.186
yearmonth*area	201012	SE	125.196	38.5068	3.25	0.0011
yearmonth*area	201101	MW	153.2445	146.4183	1.05	0.2953
yearmonth*area	201101	SE	98.76012	38.6903	2.55	0.0107
yearmonth*area	201102	MW	127.1775	146.0328	0.87	0.3838
yearmonth*area	201102	SE	98.44363	38.65344	2.55	0.0109
yearmonth*area	201103	MW	185.2691	145.7967	1.27	0.2038
yearmonth*area	201103	SE	110.355	38.51236	2.87	0.0042
yearmonth*area	201104	MW	188.2876	145.7708	1.29	0.1965
yearmonth*area	201104	SE	66.83166	38.54632	1.73	0.083
yearmonth*area	201105	MW	161.1026	145.915	1.1	0.2696
yearmonth*area	201105	SE	-58.9094	38.77649	-1.52	0.1287
yearmonth*area	201106	MW	98.61496	145.9162	0.68	0.4991
yearmonth*area	201106	SE	-130.835	38.98278	-3.36	0.0008
yearmonth*area	201107	MW	85.03129	145.9969	0.58	0.5603
yearmonth*area	201107	SE	-135.887	39.30665	-3.46	0.0005
yearmonth*area	201108	MW	14.21949	146.0509	0.1	0.9224
yearmonth*area	201108	SE	-144.085	39.58847	-3.64	0.0003
yearmonth*area	201109	MW	109.0433	146.0456	0.75	0.4553
yearmonth*area	201109	SE	-138.071	39.06181	-3.53	0.0004
yearmonth*area	201110	MW	141.2587	145.8513	0.97	0.3328
yearmonth*area	201110	SE	-18.1977	38.53461	-0.47	0.6368
yearmonth*area	201111	MW	182.9097	145.852	1.25	0.2098
yearmonth*area	201111	SE	97.63059	38.59311	2.53	0.0114

yearmonth*area	201112	MW	214.7511	145.8115	1.47	0.1408
yearmonth*area	201112	SE	143.5569	38.75195	3.7	0.0002
yearmonth*area	201201	MW	381.1372	145.772	2.61	0.0089
yearmonth*area	201201	SE	147.9417	38.66434	3.83	0.0001
yearmonth*area	201202	MW	233.7745	145.9209	1.6	0.1091
yearmonth*area	201202	SE	116.0179	38.639	3	0.0027
yearmonth*area	201203	MW	198.1229	145.7136	1.36	0.1739
yearmonth*area	201203	SE	96.54943	38.4203	2.51	0.012
yearmonth*area	201204	MW	150.4893	145.918	1.03	0.3024
yearmonth*area	201204	SE	19.37775	38.80026	0.5	0.6175
yearmonth*area	201205	MW	151.3729	145.7323	1.04	0.2989
yearmonth*area	201205	SE	1.530422	38.466	0.04	0.9683
yearmonth*area	201206	MW	81.98964	146.0621	0.56	0.5746
yearmonth*area	201206	SE	-89.5743	39.31371	-2.28	0.0227
yearmonth*area	201207	MW	51.65049	146.1599	0.35	0.7238
yearmonth*area	201207	SE	-101.602	38.78016	-2.62	0.0088
yearmonth*area	201208	MW	50.92629	146.0643	0.35	0.7273
yearmonth*area	201208	SE	-154.019	39.52641	-3.9	<.0001
avg_tem*yearmon*area	200909	SE	2.579611	0.481099	5.36	<.0001
avg_tem*yearmon*area	200910	SE	0.598442	0.170057	3.52	0.0004
avg_tem*yearmon*area	200911	SE	-1.06222	0.304305	-3.49	0.0005
avg_tem*yearmon*area	200912	SE	-1.76828	0.131361	-13.46	<.0001
avg_tem*yearmon*area	201001	SE	-3.10277	0.258615	-12	<.0001
avg_tem*yearmon*area	201002	SE	-2.78442	0.244454	-11.39	<.0001
avg_tem*yearmon*area	201003	SE	-1.84302	0.092079	-20.02	<.0001
avg_tem*yearmon*area	201004	SE	-0.69219	0.11946	-5.79	<.0001
avg_tem*yearmon*area	201005	MW	-0.17803	0.8831	-0.2	0.8402
avg_tem*yearmon*area	201005	SE	1.113864	0.154667	7.2	<.0001
avg_tem*yearmon*area	201006	MW	1.869352	0.323242	5.78	<.0001
avg_tem*yearmon*area	201006	SE	2.406831	0.113143	21.27	<.0001
avg_tem*yearmon*area	201007	MW	0.795549	0.761616	1.04	0.2962
avg_tem*yearmon*area	201007	SE	2.876658	0.21244	13.54	<.0001
avg_tem*yearmon*area	201008	MW	0.949873	0.544899	1.74	0.0813
avg_tem*yearmon*area	201008	SE	3.172534	0.210618	15.06	<.0001
avg_tem*yearmon*area	201009	MW	1.368802	0.239634	5.71	<.0001
avg_tem*yearmon*area	201009	SE	2.128158	0.120795	17.62	<.0001
avg_tem*yearmon*area	201010	MW	0.814023	0.1441	5.65	<.0001
avg_tem*yearmon*area	201010	SE	1.294531	0.072583	17.84	<.0001
avg_tem*yearmon*area	201011	MW	-0.42673	0.150985	-2.83	0.0047
avg_tem*yearmon*area	201011	SE	-0.78414	0.075513	-10.38	<.0001
avg_tem*yearmon*area	201012	MW	-1.0019	0.083617	-11.98	<.0001

avg_tem*yearmon*area	201012	SE	-1.90576	0.050354	-37.85	<.0001
avg_tem*yearmon*area	201101	MW	-2.14496	0.352303	-6.09	<.0001
avg_tem*yearmon*area	201101	SE	-1.83611	0.135819	-13.52	<.0001
avg_tem*yearmon*area	201102	MW	-0.03198	0.11708	-0.27	0.7847
avg_tem*yearmon*area	201102	SE	-1.32644	0.073134	-18.14	<.0001
avg_tem*yearmon*area	201103	MW	-1.08096	0.086427	-12.51	<.0001
avg_tem*yearmon*area	201103	SE	-1.24593	0.074919	-16.63	<.0001
avg_tem*yearmon*area	201104	MW	-0.74829	0.10139	-7.38	<.0001
avg_tem*yearmon*area	201104	SE	-0.54459	0.061774	-8.82	<.0001
avg_tem*yearmon*area	201105	MW	0.227996	0.1854	1.23	0.2188
avg_tem*yearmon*area	201105	SE	1.393572	0.107907	12.91	<.0001
avg_tem*yearmon*area	201106	MW	1.159586	0.108261	10.71	<.0001
avg_tem*yearmon*area	201106	SE	2.057257	0.072694	28.3	<.0001
avg_tem*yearmon*area	201107	MW	1.367256	0.126637	10.8	<.0001
avg_tem*yearmon*area	201107	SE	2.335817	0.109219	21.39	<.0001
avg_tem*yearmon*area	201108	MW	2.429014	0.136218	17.83	<.0001
avg_tem*yearmon*area	201108	SE	2.407811	0.113916	21.14	<.0001
avg_tem*yearmon*area	201109	MW	1.311669	0.119415	10.98	<.0001
avg_tem*yearmon*area	201109	SE	2.375841	0.076799	30.94	<.0001
avg_tem*yearmon*area	201110	MW	0.511638	0.132427	3.86	0.0001
avg_tem*yearmon*area	201110	SE	0.792741	0.059961	13.22	<.0001
avg_tem*yearmon*area	201111	MW	-0.3644	0.129146	-2.82	0.0048
avg_tem*yearmon*area	201111	SE	-0.93263	0.076806	-12.14	<.0001
avg_tem*yearmon*area	201112	MW	-0.96745	0.107044	-9.04	<.0001
avg_tem*yearmon*area	201112	SE	-1.68056	0.104013	-16.16	<.0001
avg_tem*yearmon*area	201201	MW	-4.89739	0.129784	-37.73	<.0001
avg_tem*yearmon*area	201201	SE	-1.89392	0.125056	-15.14	<.0001
avg_tem*yearmon*area	201202	MW	-1.5873	0.217431	-7.3	<.0001
avg_tem*yearmon*area	201202	SE	-1.26912	0.132526	-9.58	<.0001
avg_tem*yearmon*area	201203	MW	-0.65075	0.043999	-14.79	<.0001
avg_tem*yearmon*area	201203	SE	-0.8686	0.037316	-23.28	<.0001
avg_tem*yearmon*area	201204	MW	0.231753	0.156983	1.48	0.1399
avg_tem*yearmon*area	201204	SE	0.154702	0.102348	1.51	0.1307
avg_tem*yearmon*area	201205	MW	0.304193	0.077352	3.93	<.0001
avg_tem*yearmon*area	201205	SE	0.57468	0.065318	8.8	<.0001
avg_tem*yearmon*area	201206	MW	1.313683	0.146635	8.96	<.0001
avg_tem*yearmon*area	201206	SE	1.730589	0.108085	16.01	<.0001
avg_tem*yearmon*area	201207	MW	1.855748	0.139214	13.33	<.0001
avg_tem*yearmon*area	201207	SE	1.924069	0.076865	25.03	<.0001
avg_tem*yearmon*area	201208	MW	1.867784	0.118693	15.74	<.0001
avg_tem*yearmon*area	201208	SE	2.514254	0.102919	24.43	<.0001

avg_tem*yearmon*area	201209	MW	1.675816	1.932669	0.87	0.3859
avg_tem*yearmon*area	201209	SE	0.663979	0.433777	1.53	0.1258
avg_hum*yearmon*area	200909	SE	-0.1482	0.244914	-0.61	0.5451
avg_hum*yearmon*area	200910	SE	-0.05733	0.174114	-0.33	0.742
avg_hum*yearmon*area	200911	SE	0.087343	0.134695	0.65	0.5167
avg_hum*yearmon*area	200912	SE	0.004087	0.106054	0.04	0.9693
avg_hum*yearmon*area	201001	SE	0.50438	0.091011	5.54	<.0001
avg_hum*yearmon*area	201002	SE	0.518396	0.086205	6.01	<.0001
avg_hum*yearmon*area	201003	SE	0.030096	0.071375	0.42	0.6733
avg_hum*yearmon*area	201004	SE	0.050997	0.066415	0.77	0.4426
avg_hum*yearmon*area	201005	MW	0.626451	0.494733	1.27	0.2054
avg_hum*yearmon*area	201005	SE	0.063444	0.061778	1.03	0.3044
avg_hum*yearmon*area	201006	MW	0.015122	0.416909	0.04	0.9711
avg_hum*yearmon*area	201006	SE	0.234861	0.07131	3.29	0.001
avg_hum*yearmon*area	201007	MW	-0.2548	0.224634	-1.13	0.2567
avg_hum*yearmon*area	201007	SE	0.401695	0.068492	5.86	<.0001
avg_hum*yearmon*area	201008	MW	-0.40161	0.182051	-2.21	0.0274
avg_hum*yearmon*area	201008	SE	0.400193	0.072704	5.5	<.0001
avg_hum*yearmon*area	201009	MW	-0.19749	0.13431	-1.47	0.1415
avg_hum*yearmon*area	201009	SE	0.230869	0.045008	5.13	<.0001
avg_hum*yearmon*area	201010	MW	0.029203	0.154462	0.19	0.85
avg_hum*yearmon*area	201010	SE	0.078761	0.050095	1.57	0.1159
avg_hum*yearmon*area	201011	MW	0.05125	0.114759	0.45	0.6552
avg_hum*yearmon*area	201011	SE	0.000439	0.043915	0.01	0.992
avg_hum*yearmon*area	201012	MW	0.230714	0.189713	1.22	0.2239
avg_hum*yearmon*area	201012	SE	0.233054	0.050432	4.62	<.0001
avg_hum*yearmon*area	201101	MW	1.209709	0.163553	7.4	<.0001
avg_hum*yearmon*area	201101	SE	0.571896	0.053664	10.66	<.0001
avg_hum*yearmon*area	201102	MW	0.75516	0.115171	6.56	<.0001
avg_hum*yearmon*area	201102	SE	0.250814	0.054168	4.63	<.0001
avg_hum*yearmon*area	201103	MW	0.470563	0.087242	5.39	<.0001
avg_hum*yearmon*area	201103	SE	-0.0379	0.047633	-0.8	0.4262
avg_hum*yearmon*area	201104	MW	0.23739	0.087218	2.72	0.0065
avg_hum*yearmon*area	201104	SE	0.067725	0.067987	1	0.3192
avg_hum*yearmon*area	201105	MW	-0.15376	0.086329	-1.78	0.0749
avg_hum*yearmon*area	201105	SE	0.101869	0.046975	2.17	0.0301
avg_hum*yearmon*area	201106	MW	-0.09019	0.060824	-1.48	0.1381
avg_hum*yearmon*area	201106	SE	0.483472	0.054841	8.82	<.0001
avg_hum*yearmon*area	201107	MW	-0.07154	0.065532	-1.09	0.275
avg_hum*yearmon*area	201107	SE	0.227969	0.048775	4.67	<.0001
avg_hum*yearmon*area	201108	MW	-0.20921	0.068413	-3.06	0.0022

avg_hum*yearmon*area	201108	SE	0.269993	0.046939	5.75	<.0001
avg_hum*yearmon*area	201109	MW	-0.36494	0.073169	-4.99	<.0001
avg_hum*yearmon*area	201109	SE	0.211398	0.049688	4.25	<.0001
avg_hum*yearmon*area	201110	MW	-0.11856	0.086682	-1.37	0.1714
avg_hum*yearmon*area	201110	SE	0.081006	0.045848	1.77	0.0773
avg_hum*yearmon*area	201111	MW	0.013045	0.066209	0.2	0.8438
avg_hum*yearmon*area	201111	SE	-0.07855	0.043979	-1.79	0.0741
avg_hum*yearmon*area	201112	MW	2.15E-05	0.0595	0	0.9997
avg_hum*yearmon*area	201112	SE	-0.14961	0.04166	-3.59	0.0003
avg_hum*yearmon*area	201201	MW	-0.10596	0.052763	-2.01	0.0446
avg_hum*yearmon*area	201201	SE	-0.09649	0.045487	-2.12	0.0339
avg_hum*yearmon*area	201202	MW	0.031759	0.059461	0.53	0.5933
avg_hum*yearmon*area	201202	SE	-0.07951	0.050843	-1.56	0.1178
avg_hum*yearmon*area	201203	MW	0.035728	0.055015	0.65	0.5161
avg_hum*yearmon*area	201203	SE	-0.08995	0.051635	-1.74	0.0815
avg_hum*yearmon*area	201204	MW	-0.01505	0.059692	-0.25	0.8009
avg_hum*yearmon*area	201204	SE	0.127769	0.051825	2.47	0.0137
avg_hum*yearmon*area	201205	MW	-0.07497	0.05645	-1.33	0.1842
avg_hum*yearmon*area	201205	SE	0.03599	0.045687	0.79	0.4308
avg_hum*yearmon*area	201206	MW	0.002071	0.059602	0.03	0.9723
avg_hum*yearmon*area	201206	SE	0.212546	0.051198	4.15	<.0001
avg_hum*yearmon*area	201207	MW	-0.11972	0.073464	-1.63	0.1032
avg_hum*yearmon*area	201207	SE	0.226158	0.041259	5.48	<.0001
avg_hum*yearmon*area	201208	MW	-0.12672	0.07013	-1.81	0.0708
avg_hum*yearmon*area	201208	SE	0.267789	0.050744	5.28	<.0001
avg_hum*yearmon*area	201209	MW	0.811927	0.463582	1.75	0.0799
avg_hum*yearmon*area	201209	SE	0.088889	0.121102	0.73	0.4629
PER			-3.60914	0.359375	-10.04	<.0001
K12			2.498478	1.013444	2.47	0.0137
LowInc			-1.96602	1.211085	-1.62	0.1045
SS			-4.14759	0.385697	-10.75	<.0001
CFL			0.29358	0.124462	2.36	0.0183
part*state	KY		-2.13655	0.474415	-4.5	<.0001
part*state	OH		-1.51861	0.257991	-5.89	<.0001
part*state	SE		-2.5168	0.153003	-16.45	<.0001
part*AddBulbs*state	OH		-0.05861	0.025083	-2.34	0.0195
part*AddBulbs*state	SE		-0.00924	0.01664	-0.55	0.5789

Appendix G: Impact Algorithms

General Algorithm

Gross Summer Coincident Demand Savings

$$\Delta kW = ISR \times units \times \left[\frac{Watts_{base} - Watts_{ee}}{1000}\right] \times CF \times (1 + HVAC_d)$$

Gross Annual Energy Savings

$$\Delta kWh = ISR \times units \times \left[\frac{(Watts \times HOU)_{base} - (Watts \times HOU)_{ee}}{1000}\right] \times 365 \times (1 + HVAC_c)$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= number of units installed under the program
$Watts_{ee}$	= connected load of energy-efficient unit
$Watts_{base}$	= connected (nameplate) load of baseline unit(s) displaced
HOU	= Mean daily hours of use (based on connected load)
CF	= coincidence factor (from Draft Ohio TRM) = 0.11
$HVAC_c$	= HVAC system interaction factor for annual electricity consumption = -0.0058
$HVAC_d$	= HVAC system interaction factor for demand = 0.167

$HVAC_c$ - the HVAC interaction factor for annual energy consumption depends on the HVAC system, heating fuel type, and location. The HVAC interaction factors for annual energy consumption were taken from DOE-2 simulations of the residential prototype building described at the end of this Appendix. The weights were determined through appliance saturation data from the Home Profile Database supplied by Duke Energy.

Covington, KY

Heating Fuel	Heating System	Cooling System	Weight	HVACc	HVACd
Other	Any except Heat Pump	Any except Heat Pump	0.0029	0.079	0.17
		None	0.0002	0	0
Any	Heat Pump	Heat Pump	0.0760	-0.16	0.17
Gas Propane Oil	Central Furnace	None	0.0111	0	0
		Room/Window	0.7571	0.079	0.17
		Central AC		0.079	0.17
Electricity	Electric baseboard/ central furnace	None	0.0046	-0.45	0
		Room/Window	0.1433	-0.36	0.17
		Central AC		-0.36	0.17

N one	None	Any	0.0049	0	0.17
Total Weighted Mean			1	-0.0058	0.167

$HVAC_d$ - the HVAC interaction factor for demand depends on the cooling system type. The HVAC interaction factors for summer peak demand were taken from DOE-2 simulations of the residential prototype building described at the end of this Appendix.

Weather Stripping and Gaskets

Gross Summer Coincident Demand Savings

$\Delta kW_S = \text{units} \times (\Delta cfm/unit) \times (kW / cfm) \times DF_S \times CF_S$

Gross Annual Energy Savings

$\Delta kWh = \text{units} \times (\Delta cfm/unit) \times (kWh / cfm)$

$\Delta therm = units \times (\Delta cfm / unit) \times (therm / cfm)$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= number of buildings sealed under the program
Δcfm/unit	= unit infiltration airflow rate (ft^3/min) reduction for each measure
DF	= demand diversity factor = 0.8
CF	= coincidence factor = 1.0
kW/cfm	= demand savings per unit cfm reduction
kWh/cfm	= electricity savings per unit cfm reduction
therm/cfm	= gas savings per unit cfm reduction

Unit cfm savings per measure

The cfm reductions for each measure were estimated from equivalent leakage area (ELA) change data taken from the ASHRAE Handbook of Fundamentals (ASHRAE, 2001). The equivalent leakage area changes were converted to infiltration rate changes using the Sherman-Grimsrud equation:

$$Q = ELA \text{ x } \sqrt{A \times \Delta T + B \times v^2}$$

where:

A = stack coefficient (ft^3/min-in^4-°F)
= 0.015 for one-story house

ΔT	= average indoor/outdoor temperature difference over the time interval of interest (°F)
B	= wind coefficient ($ft^3/min\text{-}in^4\text{-}mph^2$)
	= 0.0065 (moderate shielding)
v	= average wind speed over the time interval of interest measured at a local weather station at a height of 20 ft (mph)

The location specific data are shown below:

Location	Average outdoor temp	Average indoor/outdoor temp difference	Average wind speed (mph)	Specific infiltration rate (cfm/in^2)
Covington	33	35	22	1.92

Measure ELA impact and cfm reductions are as follows:

Measure	Unit	ELA change (in^2/unit)	ΔCfm/unit (KY)
Outlet gaskets	Each	0.357	0.69

Unit energy and demand savings

The energy and peak demand impacts of reducing infiltration rates were calculated from infiltration rate parametric studies conducted using the DOE-2 residential building prototype models, as described at the end of this Appendix. The savings per cfm reduction by heating and cooling system type are shown below:

Heating Fuel	Heating System	Cooling System	kWh/cfm	kW/cfm
Other	Any except Heat Pump	Any except Heat Pump	1.14	0.00000
Any	Heat Pump	Heat Pump	12.85	0.00248
Gas Propane Oil	Central Furnace	None	0	0
		Room/Window	1.14	0.00000
		Central AC	1.14	0.00000
	Other	None	0	0
		Room/Window	1.14	0.00000
		Central AC	1.14	0.00000
Electricity	Central furnace	None	23.27	0.01238
		Room/Window	23.84	0.01485
		Central AC	23.84	0.01485
	Electric baseboard	None	23.27	0.01238
		Room/Window	23.84	0.01485
		Central AC	23.84	0.01485

	Other	None	23.27	0.01238
		Room/Window	23.84	0.01485
		Central AC	23.84	0.01485

Low-Flow Showerhead

Gross Summer Coincident Demand Savings

$$\Delta kW_S = units \times \frac{(GPD_{base} - GPD_{ee}) \times 8.33 \times \overline{\Delta T}}{3413_s} \times DF_x \times CF_s$$

Gross Annual Energy Savings

$$\Delta kWh = \text{units} \times \frac{(\text{GPD}_{\text{base}} - \text{GPD}_{\text{ee}}) \times 8.33 \times \overline{\Delta T}}{3413} \times 365$$

$$\Delta\text{therm} = units \times \frac{(GPD_{base} - GPD_{ee}) \times 8.33 \times \overline{\Delta T}}{\eta_{waterheater}} \times \frac{365}{100000}$$

where:

ΔkW	= gross coincident demand savings
ΔkWh	= gross annual energy savings
units	= number of units installed under the program
GPD_{base}	= daily hot water consumption before installation
GPD_{ee}	= daily hot water consumption after flow reducing measure installation
ΔT	= average difference between entering cold water temperature and the shower use temperature
DF	= demand diversity factor for electric water heating
CF	= coincidence factor
8.33	= conversion factor (Btu/gal-°F)
3413	= conversion factor (Btu/kWh)
24	= conversion factor (hr/day)
365	= conversion factor (days/yr)
100000	= conversion factor (Btu/therm)

Showerhead

GPD_{base} = showers/week / 7 x 3.1 gpm x 5 minutes/shower

GPD_{ee} = showers/week / 7 x 1.5 gpm x 5 minutes/shower

ΔT

City	Average cold water temperature	Shower use temperature	Average ΔT
Covington	53.9°F	100°F	46.1°F

Water heater efficiency

Combustion efficiency for residential gas water heater = 0.70

Demand diversity factor = 0.1

Coincidence factor = 0.4

The diversity and coincidence factors were taken from *Engineering Methods for Estimating the Impacts of DSM Programs, Volume 2* (EPRI, 1993). These values are typical for the residential water heating end-use in a summer peaking utility.

Faucet Aerators

This measure used the Efficiency Vermont deemed savings (Efficiency Vermont, 2003) adjusted for entering water temperature:

Demand Savings
$\Delta kW = 0.0171\ kW \times \Delta T / \Delta T_{VT} \times DF \times CF$

Energy Savings
$\Delta kWh_i = 57\ kWh \times \Delta T / \Delta T_{VT}$
$\Delta therms = 2.0 \times \Delta T / \Delta T_{VT\,i}$

City	Average cold water temperature	Hot water use temperature	Average ΔT
Covington	53.9°F	100°F	46.1°F
Burlington VT	44.5	100°F	55.5

Demand diversity factor = 0.1

Coincidence factor = 0.4

The diversity and coincidence factors were taken from *Engineering Methods for Estimating the Impacts of DSM Programs, Volume 2* (EPRI, 1993). These values are typical for the residential water heating end-use in a summer peaking utility.

Prototypical Building Model Description

The impact analysis for many of the HVAC related measures are based on DOE-2.2 simulations of a set of prototypical residential buildings. The prototypical simulation models were derived from the residential building prototypes used in the California Database for Energy Efficiency Resources (DEER) study (Itron, 2005), with adjustments make for local building practices and climate. The prototype "model" in fact contains 4 separate residential buildings; 2 one-story and 2 two-story buildings. The each version of the 1 story and 2 story buildings are identical except for the orientation, which is shifted by 90 degrees. The selection of these 4 buildings is designed to give a reasonable mean response of buildings of different design and orientation to the impact of energy efficiency measures. A sketch of the residential prototype buildings is shown in Figure 9.

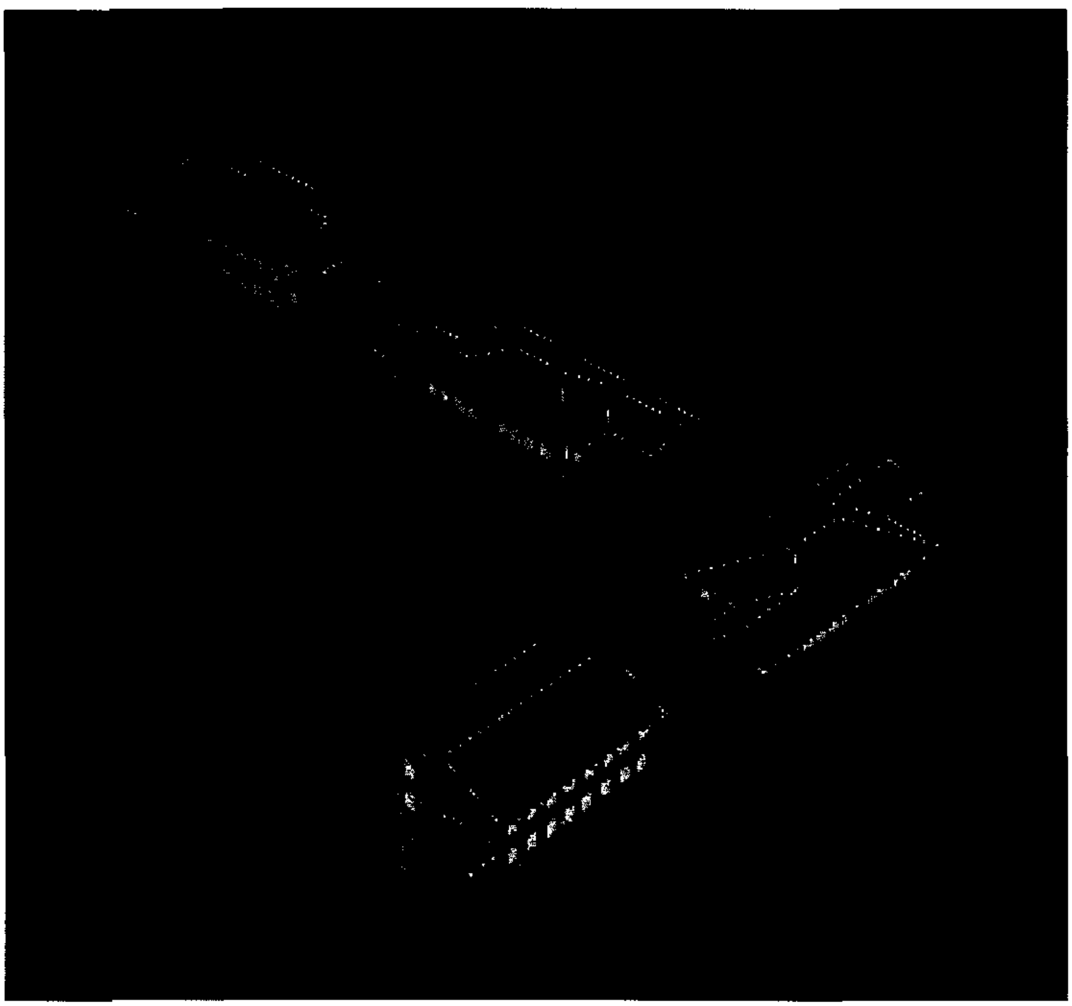

Figure 9. Computer Rendering of Residential Building Prototype Model

The general characteristics of the residential building prototype model are summarized below:

Residential Building Prototype Description

Characteristic	Value
Conditioned floor area	1 story house: 1465 SF 2 story house: 2930 SF
Wall construction and R-value	Wood frame with siding, R-11
Roof construction and R-value	Wood frame with asphalt shingles, R-19
Glazing type	Single pane clear
Lighting and appliance power density	0.51 W/SF mean
HVAC system type	Packaged single zone AC or heat pump
HVAC system size	Based on peak load with 20% oversizing. Mean 640 SF/ton
HVAC system efficiency	SEER = 8.5
Thermostat setpoints	Heating: 70°F with setback to 60°F Cooling: 75°F with setup to 80°F
Duct location	Attic (unconditioned space)
Duct surface area	Single story house: 390 SF supply, 72 SF return Two story house: 505 SF supply, 290 SF return
Duct insulation	Uninsulated
Duct leakage	26%; evenly distributed between supply and return
Cooling season	Covington – April 27th to October 12th
Natural ventilation	Allowed during cooling season when cooling setpoint exceeded and outdoor temperature < 65°F. 3 air changes per hour

References

Itron, 2005. "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report," Itron, Inc., J.J. Hirsch and Associates, Synergy Consulting, and Quantum Consulting. December, 2005. Available at http://eega.cpuc.ca.gov/deer

Appendix H: Demographics and Household Information

state

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Ohio	81	100.0	100.0	100.0

79. In what type of building do you live?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Condominium---traditional structure	3	3.7	3.7	3.7
	Single-family home, detached construction	73	90.1	90.1	93.8
	Single family home, factory manufactured/modular	5	6.2	6.2	100.0
	Total	81	100.0	100.0	

80. What year was your residence built?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1959 and before	34	42.0	42.0	42.0
	1960-1979	18	22.2	22.2	64.2
	1980-1989	2	2.5	2.5	66.7
	1990-1997	8	9.9	9.9	76.5
	1998-2000	3	3.7	3.7	80.2
	2001-2007	10	12.3	12.3	92.6
	2008-present	2	2.5	2.5	95.1
	DK/NS	4	4.9	4.9	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 to 3	1	1.2	1.2	1.2
	10 or more	22	27.2	27.2	28.4
	4	2	2.5	2.5	30.9
	5	9	11.1	11.1	42.0
	6	24	29.6	29.6	71.6
	7	7	8.6	8.6	80.2
	8	11	13.6	13.6	93.8

	9	5	6.2	6.2	100.0
	Total	81	100.0	100.0	

82. Which of the following best describes your home's heating system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Central forced air furnace	60	74.1	74.1	74.1
	Electric Baseboard	1	1.2	1.2	75.3
	Heat Pump	16	19.8	19.8	95.1
	Other	4	4.9	4.9	100.0
	Total	81	100.0	100.0	

82. OTHER SPEC Which of the following best describes your home's heating system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		77	95.1	95.1	95.1
	Dual furnace/AC	1	1.2	1.2	96.3
	Heat Pump / Forced Air	1	1.2	1.2	97.5
	Hot water boiler	1	1.2	1.2	98.8
	Wood-burning stove	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

83. How old is your heating system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	27	33.3	33.3	33.3
	10-14 years	16	19.8	19.8	53.1
	15-19 years	9	11.1	11.1	64.2
	19 years or older	6	7.4	7.4	71.6
	5-9 years	18	22.2	22.2	93.8
	DK/NS	5	6.2	6.2	100.0
	Total	81	100.0	100.0	

84. What is the primary fuel used in your heating system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Electricity	22	27.2	27.2	27.2
	Natural Gas	50	61.7	61.7	88.9
	Oil	4	4.9	4.9	93.8
	Wood	1	1.2	1.2	95.1

	Propane	4	4.9	4.9	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Electricity	12	14.8	14.8	14.8
	Natural Gas	1	1.2	1.2	16.0
	None	61	75.3	75.3	91.4
	Oil	1	1.2	1.2	92.6
	Other	5	6.2	6.2	98.8
	Propane	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

85. OTHER SPEC What is the secondary fuel used in your primary heating system, if applicable?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		76	93.8	93.8	93.8
	DK/NS	1	1.2	1.2	95.1
	Electric space heater to keep bathroom pipes from freezing	1	1.2	1.2	96.3
	Fireplace	1	1.2	1.2	97.5
	Unused fireplace	1	1.2	1.2	98.8
	We have 2 heating and cooling systems, separate ones for upstairs and downstairs.	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

86.1 NONE DO NOT COOL Do you use one or more of the following to cool your home?*

		Frequency	Percent
Missing	System	81	100.0

86.2 HP FOR COOL Do you use one or more of the following to cool your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	13	16.0	100.0	100.0
Missing	System	68	84.0		
Total		81	100.0		

86.3 CAC Do you use one or more of the following to cool your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	checked	66	81.5	100.0	100.0
Missing	System	15	18.5		
Total		81	100.0		

86.4 WALL-WINDOW AC Do you use one or more of the following to cool your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	3	3.7	100.0	100.0
Missing	System	78	96.3		
Total		81	100.0		

86.5 GEO HP Do you use one or more of the following to cool your home?*

		Frequency	Percent
Missing	System	81	100.0

86.6 OTHER Do you use one or more of the following to cool your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	2	2.5	100.0	100.0
Missing	System	79	97.5		
Total		81	100.0		

86.OTHER SPEC Do you use one or more of the following to cool your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		79	97.5	97.5	97.5
	Dual furnace/AC	1	1.2	1.2	98.8
	Fans, window units	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	75	92.6	92.6	92.6
	1	4	4.9	4.9	97.5
	2	1	1.2	1.2	98.8
	3	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

88.1 ELECTRIC What is the fuel used in your cooling system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	77	95.1	100.0	100.0
Missing	System	4	4.9		
Total		81	100.0		

88.2 NATL GAS What is the fuel used in your cooling system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	3	3.7	100.0	100.0
Missing	System	78	96.3		
Total		81	100.0		

88.3 OIL What is the fuel used in your cooling system?*

		Frequency	Percent
Missing	System	81	100.0

88.4 PROPANE What is the fuel used in your cooling system?*

		Frequency	Percent
Missing	System	81	100.0

88.5 OTHER What is the fuel used in your cooling system?*

		Frequency	Percent
Missing	System	81	100.0

88.6 NONE What is the fuel used in your cooling system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	1	1.2	100.0	100.0
Missing	System	80	98.8		
Total		81	100.0		

88.OTHER SPEC What is the fuel used in your cooling system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		81	100.0	100.0	100.0

89. How old is your cooling system?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	29	35.8	35.8	35.8
	10-14 years	16	19.8	19.8	55.6
	15-19 years	7	8.6	8.6	64.2
	19 years or older	4	4.9	4.9	69.1
	5-9 years	17	21.0	21.0	90.1
	DK/NS	8	9.9	9.9	100.0
	Total	81	100.0	100.0	

90.1 ELECTRIC What is the fuel used by your water heater?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	32	39.5	100.0	100.0
Missing	System	49	60.5		
Total		81	100.0		

90.2 NATL GAS What is the fuel used by your water heater?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	46	56.8	100.0	100.0
Missing	System	35	43.2		
Total		81	100.0		

90.3 OIL What is the fuel used by your water heater?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	1	1.2	100.0	100.0
Missing	System	80	98.8		
Total		81	100.0		

90.4 PROPANE What is the fuel used by your water heater?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	2	2.5	100.0	100.0
Missing	System	79	97.5		
Total		81	100.0		

90.5 OTHER What is the fuel used by your water heater?*

		Frequency	Percent

Missing	System	81	100.0

90.6 NO HEATER What is the fuel used by your water heater?*

		Frequency	Percent
Missing	System	81	100.0

91. How old is your water heater?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-4 years	28	34.6	34.6	34.6
	10-14 years	14	17.3	17.3	51.9
	15-19 years	6	7.4	7.4	59.3
	5-9 years	25	30.9	30.9	90.1
	DK/NS	4	4.9	4.9	95.1
	More than 19 years	4	4.9	4.9	100.0
	Total	81	100.0	100.0	

92.1 ELECTRIC What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	62	76.5	100.0	100.0
Missing	System	19	23.5		
Total		81	100.0		

92.2 NATL GAS What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	18	22.2	100.0	100.0
Missing	System	63	77.8		
Total		81	100.0		

92.3 OIL What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent
Missing	System	81	100.0

92.4 PROPANE What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	1	1.2	100.0	100.0

Missing	System	80	98.8		
Total		81	100.0		

92.5 OTHER What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent
Missing	System	81	100.0

92.6 DO NOT HAVE What type of fuel do you use for indoor cooking on the stovetop or range?

		Frequency	Percent
Missing	System	81	100.0

93.1 ELECTRIC What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	64	79.0	100.0	100.0
Missing	System	17	21.0		
Total		81	100.0		

93.2 NATL GAS What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	16	19.8	100.0	100.0
Missing	System	65	80.2		
Total		81	100.0		

93.3 OIL What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent
Missing	System	81	100.0

93.4 PROPANE What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	1	1.2	100.0	100.0
Missing	System	80	98.8		
Total		81	100.0		

93.5 OTHER What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent

Missing	System	81	100.0

93.6 DO NOT HAVE What type of fuel do you use for indoor cooking in the oven?*

		Frequency	Percent
Missing	System	81	100.0

94.1 ELECTRIC What type of fuel do you use for clothes drying?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	73	90.1	100.0	100.0
Missing	System	8	9.9		
Total		81	100.0		

94.2 NATL GAS What type of fuel do you use for clothes drying?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	8	9.9	100.0	100.0
Missing	System	73	90.1		
Total		81	100.0		

94.3 OIL What type of fuel do you use for clothes drying?*

		Frequency	Percent
Missing	System	81	100.0

94.4 PROPANE What type of fuel do you use for clothes drying?*

		Frequency	Percent
Missing	System	81	100.0

94.5 OTHER What type of fuel do you use for clothes drying?*

		Frequency	Percent
Missing	System	81	100.0

94.6 DO NOT HAVE What type of fuel do you use for clothes drying?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	checked	1	1.2	100.0	100.0

Missing	System	80	98.8		
Total		81	100.0		

95. About how many square feet of living space are in your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1000: 1499	17	21.0	21.0	21.0
	1500: 1999	12	14.8	14.8	35.8
	2000: 2499	14	17.3	17.3	53.1
	2500: 2999	5	6.2	6.2	59.3
	3000: 3499	4	4.9	4.9	64.2
	3500: 3999	2	2.5	2.5	66.7
	4000 or more	4	4.9	4.9	71.6
	500: 999	2	2.5	2.5	74.1
	DK/NS	21	25.9	25.9	100.0
	Total	81	100.0	100.0	

96. Do you own or rent your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Own	79	97.5	97.5	97.5
	Rent	2	2.5	2.5	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	One	45	55.6	55.6	55.6
	Three	7	8.6	8.6	64.2
	Two	29	35.8	35.8	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Heated	46	56.8	56.8	56.8
	No basement	22	27.2	27.2	84.0
	Unheated	13	16.0	16.0	100.0
	Total	81	100.0	100.0	

99. Does your home have an attic?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	13	16.0	16.0	16.0
	Yes	68	84.0	84.0	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	N/A	13	16.0	16.0	16.0
	No	47	58.0	58.0	74.1
	Yes	21	25.9	25.9	100.0
	Total	81	100.0	100.0	

101. Does your house have cold drafts in the winter?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	46	56.8	56.8	56.8
	Yes	35	43.2	43.2	100.0
	Total	81	100.0	100.0	

102. Does your house have sweaty windows in the winter?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	63	77.8	77.8	77.8
	Yes	18	22.2	22.2	100.0
	Total	81	100.0	100.0	

103. Do you notice uneven temperatures between the rooms in your home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	25	30.9	30.9	30.9
	Yes	56	69.1	69.1	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	6	7.4	7.4	7.4
	Yes	75	92.6	92.6	100.0

	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	7	8.6	8.6	8.6
	Yes	74	91.4	91.4	100.0
	Total	81	100.0	100.0	

106. Do you have a programmable thermostat?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	22	27.2	27.2	27.2
	Yes	59	72.8	72.8	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	69-72 degrees	21	25.9	25.9	25.9
	73-78 degrees	43	53.1	53.1	79.0
	Higher than 78 degrees	7	8.6	8.6	87.7
	Less than 69 degrees	4	4.9	4.9	92.6
	Off	6	7.4	7.4	100.0
	Total	81	100.0	100.0	

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

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	67-70 degrees	39	48.1	48.1	48.1
	71-73 degrees	11	13.6	13.6	61.7
	74-77 degrees	9	11.1	11.1	72.8
	Higher than 78 degrees	5	6.2	6.2	79.0
	Less than 67 degrees	16	19.8	19.8	98.8
	Off	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

109. Do You Have a Swimming Pool or Spa?*

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	No	70	86.4	86.4	86.4
	Yes	11	13.6	13.6	100.0
	Total	81	100.0	100.0	

110. Would a two-degree increase in the summer afternoon temperature in your home affect your comfort..*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Greatly	15	18.5	18.5	18.5
	Moderately	17	21.0	21.0	39.5
	Not at all	29	35.8	35.8	75.3
	Slightly	20	24.7	24.7	100.0
	Total	81	100.0	100.0	

111. How many people live in this home?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	19	23.5	23.5	23.5
	2	35	43.2	43.2	66.7
	3	11	13.6	13.6	80.2
	4	6	7.4	7.4	87.7
	5	4	4.9	4.9	92.6
	6	3	3.7	3.7	96.3
	8 or more	2	2.5	2.5	98.8
	Prefer not to answer	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

111a. How many of them are teenagers?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	69	85.2	85.2	85.2
	1	6	7.4	7.4	92.6
	2	3	3.7	3.7	96.3
	3	1	1.2	1.2	97.5
	4	1	1.2	1.2	98.8
	Prefer not to answer	1	1.2	1.2	100.0
	Total	81	100.0	100.0	

112. How many persons are usually home on a weekday afternoon?*

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	0	14	17.3	17.3	17.3
	1	32	39.5	39.5	56.8
	2	25	30.9	30.9	87.7
	3	6	7.4	7.4	95.1
	4	2	2.5	2.5	97.5
	Prefer not to answer	2	2.5	2.5	100.0
	Total	81	100.0	100.0	

113. Are you planning on making any large purchases to improve energy efficiency in the next 3 years?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DK/NS	9	11.1	11.1	11.1
	No	49	60.5	60.5	71.6
	Yes	23	28.4	28.4	100.0
	Total	81	100.0	100.0	

114. What is your age group?*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-34	7	8.6	8.6	8.6
	35-49	14	17.3	17.3	25.9
	50-59	22	27.2	27.2	53.1
	60-64	9	11.1	11.1	64.2
	65-74	15	18.5	18.5	82.7
	Over 74	12	14.8	14.8	97.5
	Prefer not to answer	2	2.5	2.5	100.0
	Total	81	100.0	100.0	

115. Please indicate your annual household income.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	$15,000-$29,999	5	6.2	6.2	6.2
	$30,000-$49,999	21	25.9	25.9	32.1
	$50,000-$74,999	12	14.8	14.8	46.9
	$75,000-$100,000	8	9.9	9.9	56.8
	Over $100,000	12	14.8	14.8	71.6
	Prefer Not to Answer	16	19.8	19.8	91.4
	Under $15,000	7	8.6	8.6	100.0
	Total	*81*	*100.0*	*100.0*	

Appendix I: Verbatim comments about improving aspects of the program

Respondents were asked to rate eleven aspects of the Home Energy House Call program, and if they rated an aspect a "7" or lower on a 10-point satisfaction scale, they were then asked what could be done to improve that aspect of the program. Overall satisfaction ratings are shown in Table 63, followed by verbatim comments about improving each aspect of the program.

Table 63. Mean Satisfaction with Program Components (n=81)

Metric	Average Rating	Valid N (not including don't know)	Percentage of ratings at or below 7
Interactions with auditor	9.52	81	3.7%
Audit report looked professional	9.50	80	5.0%
Audit report was trustworthy	9.49	79	5.1%
Scheduling audit	9.44	81	4.9%
Knowledge and helpfulness of auditor	9.43	80	8.8%
Audit report easy to understand	9.38	80	5.0%
Web Site usability	9.11	9	0.0%
Interactions with Duke Staff	9.07	67	10.4%
Energy efficiency kit quality	8.97	79	12.7%
Likelihood of using recommendations	8.76	79	12.7%
New ideas from recommendations	8.10	81	28.4%
Overall Satisfaction	9.14	81	8.6%

Interactions with auditor:

- "*I had two auditors, who made two separate visits. One was excellent. The other one partially covered hot water pipes. He should have covered the entire pipe but he did not want to go out of his way to do the work that was necessary. I will be trying to complete the job on my own.*"
- "*I would like to be provided with fresh ideas with less repetitiveness.*"
- "*No, he was good.*"

Audit report looked professional:

- "*Make the report less wordy and more concise.*"
- "*There could more space for the auditor to write notes.*"
- "*Don't know*" (2 respondents)

Audit report was trustworthy:

- "*I thought the audit report was dubious, because the auditor was unwilling to listen to my concerns.*"
- "*Don't know*" (3 respondents)

Scheduling the audit:

- "*It took 2 or 3 phone calls back and forth to set up the audit.*"
- "*Don't know*" (3 respondents)

Knowledge and helpfulness of auditor:

- "*I asked him a couple of questions that he did not have answers to. He dropped off written material that would sometimes conflict with what he told me.*"
- "*I knew more than the auditor did.*"
- "*I would prefer that the auditors provide more willingness to listen and discuss the issues that apply to my home.*"
- "*It would've been better if the auditor had a little more residential building knowledge.*"
- "*The auditor couldn't answer my questions about insulating my crawlspace. Most of the information he provided wasn't new to me.*"
- "*The auditor made a few suggestions, but they would not have been cost-effective.*"
- "*Don't know*"

Audit report was easy to understand:

- "*Duke could have included more space on the audit report for the auditor to write notes and other recommendations.*"
- "*The report could have offered me a more concrete energy savings plan.*"
- "*The report was a little too general and included a lot of comments like, 'if you seal this up you can expect that...'* "
- "*Don't know*"

Website usability:

- No participants in Ohio rated the website at "7" or less on a 10-point scale.

Interactions with Duke Energy staff:

- "*Eliminate the confusion and hurdles of scheduling the audit.*"
- "*I have had issues with Duke staff in the past.*"
- "*I would prefer that Duke provide auditors with more willingness to discuss issues.*"
- "*Please make it easier to contact Duke about scheduling the audit.*"

- *"The HEHC program was fine, but I never received a scheduled callback about the Power Manager program."*
- *"Don't know"* (2 respondents)

Energy efficiency kit quality:

- *"The fixtures could have been of better quality."* (2 respondents)
- *"I bought better versions of the same I received in the kit."*
- *"I don't like the light from the CFLs."*
- *"I wondered why some of the items were in the kit."*
- *"I would prefer better quality measures. The kitchen faucet aerator broke after just a week of use."*
- *"I would prefer light bulbs that have a more pleasing and natural light quality."*
- *"The light bulbs are horrible and junk. They don't last long. Provide better-quality CFLs."*
- *"The showerhead could have been better. It's got some buildup on it, possibly because I have hard water. It has clogged up several times."*
- *"The weather-stripping lasted one week before falling off. The shower head didn't give satisfactory showers, because the flow was too weak."*

Likelihood of using recommendations:

- *"Again, our home is only 5 years old, so the auditor didn't really have anything to recommend."*
- *"I didn't plan on doing any of the actions anyway."*
- *"I just didn't see the benefit of doing the things the auditor suggested. I have already done lots of upgrades on windows, doors, and my furnace. The auditor recommended things I didn't feel would benefit me enough to justify the costs."*
- *"I was already going to do most of the recommendations."*
- *"I would be more inclined to take action if I believed in the validity of the recommendations."*
- *"It was already done in the house."*
- *"The auditor didn't come up with anything I hadn't already thought of."*
- *"The recommendations were not cost-effective."*
- *"Don't know"* (2 respondents)

New ideas from recommendations:

- *"I already knew about most of the recommendations."* (2 respondents)
- *"He didn't offer much I didn't already know, but he was really good and knowledgeable."*

- *"I already knew most of the information in the report."*
- *"I had already researched and knew about the issues with my home."*
- *"I had pretty much thought of everything beforehand."*
- *"I have a brand new house, so a lot of the recommendations were already built in."*
- *"I was already doing most of what the auditor suggested, and I could have used more new ideas."*
- *"I would prefer fresh ideas, not things I already knew."*
- *"Our home is only 5 years old, so the auditor didn't really have anything to recommend."*
- *"Please add more new information."*
- *"The audit report was oversimplified and could've been more detailed."*
- *"The auditor could have gone beyond common-sense recommendations that I already knew about. I already know about weather stripping and insulation and so forth. Plus, I have high ceilings in my house, so not all of the recommendations would help me reduce my energy bill all that much."*
- *"The auditor could have mentioned more things that we were not already doing."*
- *"The auditor could have offered more practical suggestions."*
- *"The auditor didn't come up with anything I hadn't already thought of."*
- *"The recommendations could provide new ideas."*
- *"The recommendations were things I already knew and was aware of."*
- *"There was not much recommended that we didn't already know about."*
- *"We had already talked about most issues recommended and we thought there would be more programs/incentives offered to get the things done."*
- *"We were doing everything right already. The auditor only suggested using more CFLs."*
- *"Don't know"* (2 respondents)

Appendix J: Verbatim Comments: Overall Satisfaction with HEHC

Fifty-nine participants in Ohio (72.8% of 81) who said they were "very satisfied" gave the following reasons for their ratings:

- *"The audit was very informative."* (2 respondents)
- *"As new homeowner, there were a lot of things I didn't know to look for, or to prioritize for improvement. The auditor gave me a plan with the best ideas that maximized the bang for the buck."*
- *"Auditor was on time, professional, took his time, and gave good info."*
- *"Auditor was very knowledgeable, suggested things they weren't considering. Patient with answering questions."*
- *"Because I felt that auditor was thorough and made good suggestions on how to conserve energy."*
- *"Because I used the stuff that I received."*
- *"Because it helped me save money and helped to know what to do around house."*
- *"Because it was informative."*
- *"Because somebody is 'on my side' helping me to save energy."*
- *"Because that's how it is..."*
- *"Because they gave me some nice tips to save to energy."*
- *"Because they told me things I never knew."*
- *"He was he was knowledgeable and courteous."*
- *"He was very knowledgeable."*
- *"I have gotten a $500 check back from Duke the last few years. I have been saving money."*
- *"I know that I am saving money on electricity. The auditor showed me some things I didn't know about my house."*
- *"I learned quite a few things that I would not have known about, and Duke provided the service for free."*
- *"I like that they checked my house and supplied me with the free energy kit."*
- *"I like the audit, the information provided, and the free energy kit."*
- *"I like the professionalism of the auditor, he was very helpful, communicated and explained everything well. I gained valuable information and tools to help improve my homes energy efficiency. He was a great representative for Duke Energy."*
- *"I liked that the program answered a lot of questions I had."*

- *"I liked the program. It was very informative, the auditor was very good, it saved money and was worth my time."*
- *"I really like that the program is available. I wouldn't know what to do about home energy efficiency until someone showed me what needed to be done and how to do it."*
- *"I think it's a great program and helps a lot of people."*
- *"I thought that they gave good ideas."*
- *"I thought the auditor was knowledgeable and thorough. He gave me things to consider. But what I do is up to me – for instance, my second refrigerator is a convenience that I am willing to pay for, despite the recommendation to unplug it."*
- *"I thought the auditor was nice, provided useful information, and this prompted action on our part."*
- *"I was very impressed with auditor. He knew what he was doing, had a nice personality, and explained recommendations and elaborated."*
- *"It confirmed things we thought needed to be done. I liked the energy savings items given."*
- *"It is always good to find ways to save money and make your home more comfortable."*
- *"It is nice to receive something from Duke, like they care about me. It provided a service which will lower my bill."*
- *"It saved me a lot of money."*
- *"It saved me money."*
- *"It was awesome and educated me. It was very thorough."*
- *"It was easy to do and the auditor was nice. The program also made us feel better about our home's energy efficiency."*
- *"It was enjoyable, nice and pleasant."*
- *"It was free, the auditor came out to my house. The auditor was very nice. The auditor gave a lot of good recommendations that wouldn't cost a lot."*
- *"It was very informative. We wanted to know if there was anything else we could do to the house to make it more energy efficient and we did."*
- *"Service good, auditor helpful."*
- *"The audit pointed out some energy fixes we could do."*
- *"The auditor addressed very specific issues and took his time. He pointed out things that could save energy."*
- *"The auditor educated me on the use of the furnace/AC auto fan and also was able to point out smaller issues like a crack in a door which was letting in cold air. I am extremely happy with the home inspection, the information the auditor provided and the*

program in general. The auditor suggested things that I hadn't thought about. It really educated us how to save money by conserving power."

- *"The auditor took the time to explain things thoroughly. He inspired me to want to save energy."*
- *"The auditor was a personable young man who knew what he was talking about."*
- *"The auditor was extremely thorough and knowledgeable. He didn't miss anything that would help me save money. The recommendations were easy enough for me to do."*
- *"The auditor was helpful yet realistic in the recommendations he gave."*
- *"The auditor was knowledgeable and nice, and the audit was free."*
- *"The auditor was thorough and knowledgeable. The audit provided great ideas on ways to improve our home's energy efficiency."*
- *"The auditor was very thorough and honest. He was very helpful."*
- *"The auditor was very thorough and the recommendations were excellent."*
- *"The auditor was very thorough and we got some free products."*
- *"The auditor was very understanding and thorough. He really knew what he was talking about."*
- *"The auditor's information was helpful even though I can't afford to take the recommended actions. The auditor pointed out issues with basement and crawlspace I wasn't previously aware of."*
- *"The gentleman who did the auditing was thorough and didn't rush through things."*
- *"The information the program provided helped me out."*
- *"The program made me aware of many ways to save energy. Some were easy fixes and some were long-term projects."*
- *"The program showed me where my home was losing heat."*

Sixteen participants in Ohio (19.8% of 81) who said they were "somewhat satisfied" gave the following reasons for their ratings:

- *"I already knew about the recommendations he gave, and had researched them. He didn't provide much more help than I had expected."*
- *"I already knew most of what the auditor told me, but the program motivated me to make changes in my home's energy efficiency."*
- *"I already knew much of what was being recommended."*
- *"I didn't get too many new ideas for the recommendations."*
- *"I didn't provide as much help as I had thought."*

- *"I do like this program and hope that Duke continues to offer it. I didn't think the audit was performed quite as thoroughly as it could have been. Also, some of the items listed on the report need clarification."*
- *"I got some good information about what I needed to do."*
- *"I liked the information provided."*
- *"I really appreciate the free light bulbs and having someone do the installation of materials."*
- *"I thought that there would be more to it."*
- *"I was hoping that the materials would be installed for me. For example I need someone to demonstrate how to install the weather stripping."*
- *"I was satisfied with what the auditor recommended and what we were doing."*
- *"It helped to learn about little things, like the low flow showerhead and reducing my water temperature."*
- *"The audit confirmed a lot of the things I thought I needed."*
- *"The auditor showed interest in helping me keep my costs down."*
- *"There wasn't anything I was really going to do. It was a waste of time."*

Six participants in Ohio (7.4% of 81) who said they were "neither satisfied nor dissatisfied" gave the following reasons for their ratings:

- *"I don't know, didn't get as much out of it as I thought."*
- *"I like the concept of the program but thought the auditor was unwilling to listen to my concerns."*
- *"It wasn't as helpful as I thought it would be."*
- *"Most of the information I already knew."*
- *"The auditor didn't come up with anything that I didn't know about ahead of time. One of my big energy consumption concerns is that I have a hot tub on the back porch, and the auditor didn't address that at all."*
- *"We have a newer home so it was not much help."*

There were no participants in Ohio (0% of 81) who said they were "somewhat dissatisfied" or "very dissatisfied" with the program.

Appendix K: Verbatim comments: actions inspired by DOE booklet

Respondents were asked what actions they took based on the DOE Energy Savers booklet provided with the HEHC program's energy efficiency kit. Figure 10 shows the distribution of different activity categories, which is followed by verbatim comments from participants describing the actions they took.

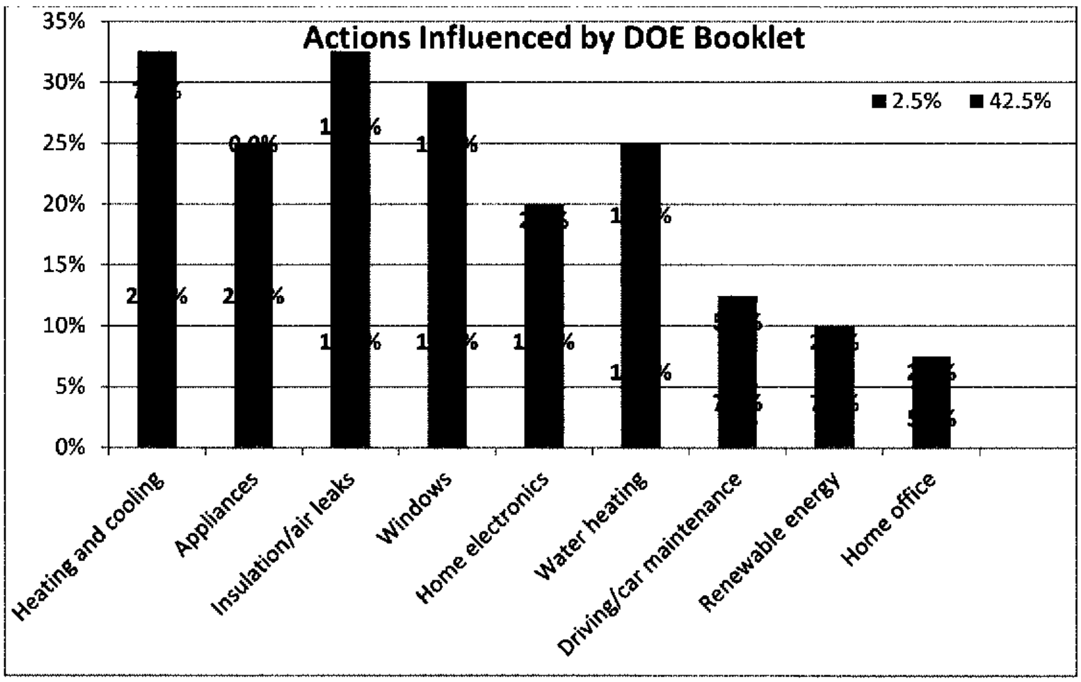

Figure 10. Participants who took energy efficient actions based on the DOE booklet (n=40 respondents who read the booklet)

Lighting:

- "*We've switched to CFLs.*" (2 respondents)
- "*I have installed more CFLs.*" (2 respondents)
- "*Again, I installed some CFLs, but I do not like their light.*"
- "*All of my sockets have CFLs.*"
- "*All our lights are CFL bulbs, and we have solar powered lighting outside.*"
- "*I am changing to CFLs. I am waiting for bulbs to burn out in little-used rooms.*"
- "*I don't use very many lights in my house, just one at a time.*"
- "*I turn lights out when I am not using them.*"
- "*I turn off lights when I am not using them.*"
- "*I use more CFLs.*"

- *"I use mostly CFLs now."*
- *"Once bulbs received – [that was the] biggest thing."*
- *"We're gradually switching to CFLs."*
- *"We've added more CFLs."*

Heating and cooling:

- *"I adjusted my thermostat."*
- *"I cleaned around the heat pump."*
- *"I had a furnace inspection and a new air filter."*
- *"I have tried to cut back on my heat use and signed up for Duke's Power Manager program."*
- *"I installed a programmable thermostat."*
- *"I keep my furnace low, heat only one room at a time, and use a space heater instead of furnace when possible."*
- *"I lowered my thermostat and try to keep just one room warmer with a space heater for my husband who is ill. That way I can make that room warmer without putting my thermostat too high."*
- *"I turned down the thermostat."*
- *"I wash and rinse clothes in cold water."*
- *"We added a ridge vent in the roof."*

Appliances:

- *"I unplug appliances when I am not using them."* (3 respondents)
- *"I bought an Energy Star-rated refrigerator."*
- *"I have been trying to unplug more appliances when I'm not using them."*
- *"I try not to watch 2 television sets."*
- *"I unplug my dehumidifier and cut down on refrigerator use."*
- *"I unplug things when I am not using them."*
- *"I use my stove less."*

Insulation and air leaks:

- *"Again, I put cardboard and tape over some of my windows to keep air leaks out."*
- *"I've added insulation in and around the water pipes."*
- *"I added weather stripping around doors and put towels down at the bottom of the doors."*
- *"I put weather stripping around doors."*

- *"I took care of the door to the garage."*
- *"My husband is continually improving our ductwork."*
- *"We've added insulation in cracks where the house meets the foundation."*

Windows:

- *"Again, I had some windows re-installed."*
- *"I've added some caulking and new window shades."*
- *"I added duct tape along the window cord to help seal it."*
- *"I added some blinds in my living room and I put some insulation up in a window to keep air from leaking."*
- *"I open windows more instead of using lights."*
- *"I put heavy shades in the summer and open light shades in the winter."*
- *"We had tinted windows installed."*

Home electronics:

- *"I purchased an Energy Star TV."*
- *"I put everything on power strips and use them for a full shut-off."*
- *"I put my computer and printer on sleep and/or off when I'm not using them."*
- *"I turn my electronics off with a switch instead of putting them on standby."*
- *"I turn off the computer when we're not using it."*
- *"I unplug appliances when I am not using them."*
- *"We unplugged power strips and items we are not using."*

Water heating:

- *"I lowered the temperature."* (3 respondents)
- *"I lowered the temperature to 120 degrees."*
- *"We purchased a water heater insulation blanket."*

Driving and car maintenance:

- *"I have a new car."*
- *"I try not to brake too often, and I maintain my car regularly."*
- *"I try to keep current on my car maintenance and check my oil and transmission fluid regularly."*

Renewable energy:

- *"I have calf-high outdoor solar lights from the driveway to the house (about 13). I have noticed that the rechargeable batteries from the factory are sub-standard. I have purchased and installed better replacement batteries."*
- *"I signed up for 'green energy'."*
- *"There are some interesting things but I haven't done anything yet."*

Home office:

- *"I had a new floor and insulation installed."*
- *"I turn off my laptop."*

Appendix L: Verbatim comments: actions inspired by audit report

Respondents were asked if they had made any changes to their homes which were either directly or indirectly inspired by the home audit report. The verbatim comments of the 35 respondents who said they took further actions are listed below (note that five of these participants actually have not taken further action, but rather explained what they still intend to do, or why they have not been able to do anything yet).

Actions already taken:

- *"All new appliances since the audit."*
- *"Had water come into the basement and had EverDry fix it. Had 3 sump pumps put in."*
- *"I'm more aware of turning off our lights. I like the home energy comparison that I get with my bill every month."*
- *"I'm using the oven and stove less to reduce heat buildup in the house during summer."*
- *"I've put motion sensors on the outside lights, which has reduced the amount of time the lights are on."*
- *"I added 2 roof vents over the garage."*
- *"I am careful in winter to keep things closed. In summer, I try not to use the AC very much."*
- *"I am using more CFLs and we're installing some new energy efficient windows this fall."*
- *"I cleaned up the furnace ducts and sealed some cracks in the duct work."*
- *"I have a power strip for my TV and we turn it off when we are gone for an extended period of time."*
- *"I installed a new heat pump and water heater within the past 5 months."*
- *"I installed plastic in between French doors. I have an unfinished basement. I will follow the auditor's recommendations on water proofing materials and flooring."*
- *"I installed the CFLs, but I do not like their light."*
- *"I programmed the thermostat shortly after receiving the audit."*
- *"I put some cardboard up on my basement windows and duct-taped around them."*
- *"I re-did our basement this past year which included adding insulation."*
- *"I turned off my AC in August 2012."*
- *"I turned off the auto fan on my AC furnace. This reduced my power bill by over $300."*
- *"I upgraded to a new dishwasher and water heater that are both Energy Star-rated."*
- *"Installed a whole new door upstairs on balcony in April."*

- *"Insulation in back sun-room and roof this summer. New windows and siding in February, but in before the audit I think."*
- *"Just 3 new windows and 2 doors but I may have done this before the audit."*
- *"Just using more CFLs from the auditor's recommendation."*
- *"New insulated garage door, did weather stripping around the inside of house based on his recommendations."*
- *"Put weather-stripping around side door from garage."*
- *"They insulated around my back door from adding a patio."*
- *"Unplugged my extra electrical items like the home theater system when I'm not using it based on his recommendation."*
- *"We've looked into finding some replacement aluminum siding."*
- *"We installed new windows."*
- *"We recapped the air vents on our roof and installed a new AC unit."*

Intentions to take action (or reasons why not):

- *"No, just the insulation I added."*
- *"No. We will be getting a wood burning stove soon though."*
- *"Not as yet. I hope to do many of these improvements within the next 2 years."*
- *"Nothing in particular but the audit was helpful in reminding me of energy efficiency."*
- *"No. My home is in pre-foreclosure and I can't afford to make improvements until that issue is resolved."*

Appendix M: DSMore Table

Impacts ⇨ / Technology ⇩	Product code	State	EM&V gross savings (kWh/unit)	EM&V gross kW (customer peak/unit)	EM&V gross kW (coincident peak/unit)	Unit of measure	Combined spillover less freeridership adjustment	EM&V net savings (kWh/unit)	EM&V net kW (customer peak/unit)	EM&V net kW (coincident peak/unit)	EM&V load shape (yes/no)	EUL (whole number)
HEHC		Ohio	634	0.6291	0.0692	home		634	0.6291	0.0692	no	11
Program wide		**Ohio**	**634**	**0.6291**	**0.0692**	**home**		**634**	**0.6291**	**0.0692**	**no**	**11**

*The evaluation methodology provided net savings only. By design, gross savings are excluded from this methodological approach. The controlled quasi-experimental

**There is no Freeridership value provided in this table due to the evaluation methodology employed

Appendix N: Required Savings Tables

The required table showing measure-level participation counts and savings is below.

Measure	Participation Count	Verified Per unit kWh impact	Verified Per unit kW impact	Gross Verified kWh Savings	Gross Verified kW Savings
HEHC Participating Household	3,474	634	0.0692	2,202,516	240

Final Report

Impact Evaluation and Review of the 2012 Power Manager® Program in Ohio and Kentucky

Prepared for
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Executive Summary

Summary of Findings

The approach used by Duke Energy for estimating the effect of the Power Manager® program is very reasonable and defensible. One particularly noteworthy feature is that they use an extensive history to estimate the model, rather than relying on only a handful of days as is common in many utilities which use less rigorous approaches (i.e., approaches that compare average usages from a pre-event period, for example, rather than conducting a multivariate regression model, as Duke Energy is doing).

In 2011, the behavior of some Cannon switches to deviate substantially from the shed times expected for the Target Cycle method was an issue since it increases the uncertainty of the program impacts. Duke Energy and Cooper determined that the root cause was a firmware flaw in the Target Cycle algorithm. Duke Energy and Cooper worked together to develop a solution that utilized radio signal communications (via the paging network) that changed the affected switches from the flawed Target Cycle algorithm to the True Cycle algorithm. This conversion of the affected switches was completed prior to the start of the 2012 event season. Therefore, inverse shed is no longer an issue.

Overall, based on our review, Duke Energy's impact evaluation is a very complete and innovative approach, and should result in accurate estimates of event impacts and the summer load reduction capacity under peak normal weather conditions, as summarized in Table 7 on page 13.

Introduction and Purpose of Study

This document presents the evaluation report for Duke Energy's Power Manager Program as it was administered in Ohio and Kentucky.

The evaluation was conducted by Duke Energy and the TecMarket Works evaluation team. Duke Energy conducted the impact analysis, and Integral Analytics (a TecMarket Works subcontractor) conducted the review of the methodology and results.

Summary Overview

This document presents a review of the impact evaluation for the Power Manager (PM) program conducted by Duke Energy as it was administered in Ohio and Kentucky.

Summary of the Evaluation

Power Manager is a voluntary residential program, available to homeowners with central air conditioning (AC). On days where energy demand and/or energy costs are expected to be high, Power Manager participants have agreed to allow Duke Energy to cycle their air conditioning off for a period of time.

The impact evaluation conducted by Duke Energy developed an air conditioner (AC) duty cycle model based on information from a sample of PM participants. This duty cycle was then used to simulate the expected natural duty cycle during the PM event days and under peak normal weather conditions for different PM program options and load control technologies to produce estimates of the potential load reduction. These estimates were then de-rated by the results of operability studies to give estimates of the realized load reductions.

Evaluation Objectives

The purpose of this evaluation was two-fold. The first objective is to summarize the actual kW and expected peak normal kW impacts determined by Duke Energy for 2012. The second objective is to determine if the approach used by Duke Energy in estimating these impacts is consistent with commonly accepted evaluation principles.

Summary of Review

The approach used by Duke Energy for estimating the effect of the Power Manager® program is very reasonable and defensible. One particularly noteworthy feature is that they use an extensive history to estimate the model, rather than relying on only a handful of days as is common in many utilities which use less rigorous approaches (i.e., approaches that compare average usages from a pre-event period, for example, rather than conducting a multivariate regression model, as Duke Energy is doing).

Overall, based on our review, Duke Energy's impact evaluation is a very complete and innovative approach, and should result in accurate estimates of event impacts and the summer load reduction capacity under peak normal weather conditions, as summarized in Table 7 on page 13.

Description of Program

Power Manager is a voluntary residential program, available to homeowners with central air conditioning (AC). On days where energy demand and/or energy costs are expected to be high, Duke Energy has permission from Power Manager participants to cycle their air conditioning off for a period of time.

When customers enroll, Duke Energy installs a switch that allows the AC unit to be cycled off and on in response to signals sent over Duke Energy's paging system.

Within Duke Energy's portfolio, Power Manager is currently the only residential demand response program[1]. The Power Manager program plays a key role in capacity planning; every year, Power Manager provides an estimate as to how much capacity it can provide during the summer season, and this information is taken into account by the capacity planners.

Program Participation

Program	Participation Count for 2012
Power Manager Ohio	EOM Sept. 2012 = 42,597
Power Manager Kentucky	EOM Sept. 2012 = 9,086

[1] Not including pilot programs.

Methodology

Overview of the Evaluation Approach

The impact evaluation for the Power Manager (PM) program was conducted by Duke Energy staff. The results presented in this report include a review by Integral Analytics of the impact evaluation methodology and results.

The impact evaluation developed an air conditioner (AC) duty cycle model based on information from a sample of PM participants. This duty cycle model was then used to simulate the expected natural duty cycle during the PM event days for estimates of event load reduction impacts and under peak normal weather conditions for different PM program options and load control technologies to produce estimates of the potential load reduction on a peak normal day. These estimates were then de-rated by the results of operability studies to give estimates of the realized load reductions.

The approach used by Duke Energy staff is nearly identical to the approach used in the prior evaluations reviewed by the TMW team.

This general approach is well established in the industry and the actual analysis was very thorough and well thought out. The resulting impact estimates are reasonable and accurate.

Data collection methods, sample sizes, and sampling methodology

The 2012 Power Manager M&V *sample in the Midwest consists of* 283 *households with* 307 *air-*conditioner (AC) units. This includes 117 households from Ohio and 26 households from Kentucky, closely reflecting the relative numbers of PM participants in each state. The 2012 Ohio and Kentucky M&V sample is representative of the PM population within the two states and includes 95 new households randomly selected from the PM population in February, 2012, and 48 holdovers from the 2011 M&V sample that were randomly selected in either 2010 or 2011. The samples are designed to target at 10% relative precision at 90% confidence level with additional households to compensate loss of the sample due to data issue or removal of the switch through the summer.

At households selected for the M&V sample, any older load control device was replaced by a Cannon load control device. The purpose of this study is to determine the load reduction achieved when the load control device functions as expected, so this device replacement does not introduce bias into the results. Completely separate operability studies are conducted to determine deviation from expected performance (the de-rating factor) for each load control technology. The M&V samples were used for both fixed and target cycling.

PM M&V samples are stratified into high, medium and low groups according to premise monthly kWh usage from the previous summer. The Dalenius-Hodges technique for selecting strata boundaries and the Neyman method for optimum sample allocation were employed to achieve reduced sample variance of load reduction estimates. Stratification analysis was performed together for Ohio and Kentucky. The resulting stratification of PM M&V samples is shown in Table 1.

Table 1. M&V Sample Stratification

	Sample allocation			Population weight		
	High	Medium	Low	High	Medium	Low
OH & KY	46	49	48	14.4%	46.8%	38.8%

Hourly run-time of AC units in the M&V samples was collected during 2012 summer months (May through September). This was accomplished with Cannon load control devices, which record hourly run-time (in minutes) of the AC unit to which they are attached. Data collection from M&V Cannon devices were conducted in June and the end of September. In addition to hourly run-time, the Cannon device scan data includes hourly shed minutes and the contents of many device registers. Information about the AC unit is also recorded, including rated amps for the compressor and fan.

Households in the M&V samples are equipped with load research interval meters, and 15-minute or 30-minute premise interval usage (kWh) was collected for 2012 summer months.

Number of completes and sample disposition for each data collection effort

See "Table 1. M&V Sample Stratification" above.

Expected and achieved precision

The 2012 M&V sample is representative of the PM population and is designed to target at 10% relative precision at 90% confidence level.

The final sample sizes for OH & KY were adequate to produce estimates at 20% relative precision at 90% confidence level.

Description of baseline assumptions, methods and data sources

The baseline is developed from the duty-cycle of the sampled AC units based upon the observed AC usage during non-holiday, non-weekend, and non-control days.

Description of measures and selection of methods by measure(s) or market(s)

The PM program is an AC cycling program, so the only measure in question is the AC units.

Use of TRM values and explanation if TRM values not used

The analysis provides estimate of the savings that were achieved by participating households, thus there was no need to use TRM values.

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

The approach used in the evaluation relied upon actual measurement of AC usage, and is therefore not subject to any reporting or self-selection bias.

Evaluation Findings

Validation of AC Duty Cycle Data

Hourly air conditioner (AC) run-time collected from Cannon M&V devices is compared to corresponding premise interval kWh to verify that it accurately reflects operation of the attached AC unit. The validation process is accomplished through a sequence of computer programs that: 1) convert the hourly A/C run-time data into hourly duty cycle; 2) display time series plots of premise kWh and duty cycle with control over time resolution enabling visual comparison of plot detail; 3) calculate cross-correlation between hourly kWh and hourly duty cycle and display cross-plots of kWh vs. duty cycle. Each run-time data file collected for an AC in the 2012 M&V sample is reviewed in this fashion, and the AC duty cycle is added to the model database if it passes the validation process.

In the Ohio and Kentucky sample, Duke Energy could not obtain the 2012 data needed to apply validation procedures for 8 ACs due to the inability to retrieve scan data (6), disconnection (1), or no access to the switch (1). In the validation process, run-time data was rejected for 2 ACs in the Ohio and Kentucky sample. These cases appear to be due to equipment sensitivity issues, where the AC is reported to have no run-time or to be always running. The final sample sizes include 135 households with 143 devices for OH & KY. This is still adequate to produce estimates at 20% relative precision at 90% confidence level, which is required by PJM for OH and KY.

Table 2 summarizes the 2012 M&V sample.

Table 2. M&V Sample

	Midwest	
	Ohio	Kentucky
Households	117	26
Total AC Units	153	
Missing data	8	
Invalid Data	2	
Final AC Sample	143	
Final Households	135	

AC Duty Cycle Models

Impact estimates during PM load control periods are based upon models developed for the natural duty cycle of M&V AC units. These models are developed from 2012 duty cycle data described above, and similar duty cycle data from the two prior summers (2010, 2011) for AC units that are holdovers from previous M&V samples. Weekends and holidays are not used in the models, and hours during load control and for the remainder of the day are not used. As addressed above, Duke Energy staff was able to develop duty cycle models for AC units at 135 households in the Ohio and Kentucky M&V sample.

Natural duty cycle models are specified and estimated individually for M&V AC units to better capture the unique dependence of duty cycle on the temperature and humidity characteristics of each AC unit. A limited dependent variable model specification is adopted for hourly duty cycle, the dependent variable in the models. Candidate specifications for independent variables in the models include temperature averaged over the prior 2-hour, 4-hour, and 6-hour intervals, and a weighted temperature average with declining weights over the previous six hours. Candidate specifications also include similar sets of averages based on temperature-humidity index (THI) and heat index (16-element polynomial). Models are estimated with the SAS procedure QLIM[2]. The dependent variable specification selected for an AC unit is based on fit diagnostics from hourly model fits over the typical load control hours, 2:00–6:00 PM. For the selected model, distinct parameters are estimated in each hour of interest, resulting in a set of hourly natural duty cycle fits for each M&V AC.

PM Load Control Strategies

The PM program employs two generic types of load control devices which require somewhat different treatment for load impact evaluation. The newer switch types (Cannon LCR 4700) in OH and KY operate with an adaptive control strategy called Target Cycle (TC). For each hour of load control, the Target Cycle switch calculates a unique shed time (or percentage) based on characteristics of the attached AC unit. The older switch type (CSE) in KY uses traditional fixed cycling control, where all devices on the same program shed the same amount of time during the control period. In Ohio and Kentucky, the principal PM program options are 1.5 kW and 1.0 kW, and Target Cycle switches are configured with these load reduction targets constrained by the maximum shed time of 24 minutes per 30-minute control period. Fixed Cycling (FC) devices limit the AC run-time to 7.5 minutes (1.5 kW) or 15 minutes (1.0 kW) of each 30-minute control period. Equivalently, PM CSE devices are operated with fixed cycling percentages of 75% (FC 75%) for 1.5 kW, or 50% (FC 50%) for 1.0 kW. The third program option is 0.5 kW. Due to the limited number of participants on this option, we scale the impact estimate for it based on the results for 1.0 kW. Table 3 summarizes PM load control technology and strategy used in different states.

Table 3. PM Load Control Devices and Strategies

		Strategy			
Device	Period	OH		KY	
	(min)	1.5 kW	1.0 kW	1.5 kW	1.0 kW
Cannon	30	TC 1.5	TC 1.0	TC 1.5	TC 1.0
CSE	30			FC 75%	FC 50%

The Target Cycle control strategy puts more functionality in the switch itself. Rated amps of the attached AC unit is entered into the switch at installation, and used to determine connected load for the unit. The switch also records hourly duty cycle of attached AC unit and builds a profile (historical profile) of the expected hourly duty cycle under weather conditions typical for load control. The historical profile can be scaled (globally) by adjusters included in the commands sent to switches for load control. The connected load and adjusted historical profile are used to

[2] QLIM: qualitative and limited dependent variable model.

calculate hourly cycling percentages for the attached AC unit expected to achieve the appropriate load reduction target. The shed percentage is calculated in the switch for each load control hour as shown below for Target Cycle:

AmpKW = 0.85*DeviceAmp*230/1000
Shedpct = Min(1-scaled_profile/100+Target kW/AmpKW, MaxAllowed_Shed)

Impact analysis for PM in 2011 revealed that shed times for some of the Cannon switches deviated substantially from the expected shed times for the target cycle method. Instead these switches appeared to shed more like an "inverted" pattern, relative to the pattern expected. Further investigation by Cooper Power Systems (Cannon) discovered that the cause of this issue was due to a firmware flaw in these defective switches. An alternate adaptive cycling approach, True Cycle, was developed to solve the inverted shed issue. For the True Cycle approach, a cycling percentage called a gear is estimated using the duty cycle model and is sent to switches for load control. This gear and the scaled historical profile are then used to calculate hourly shed percentages for the attached AC unit expected to achieve the appropriate load reduction target (1.5 kW or 1.0 kW). The main difference between target cycle and true cycle is that the latter does not use rated amps to calculate connected load for the attached unit. The shed percentage is calculated in the switch for each load control hour as below for True Cycle:

Shedpct = Min(1-scaled_profile/100+gear, MaxAllowed_Shed)

Factors that determine Target Cycle and True Cycle shed percentages for M&V AC units during control periods are known, except for contents of hourly historical profile registers on those days. Values in these registers change frequently during the summer as they are updated with the AC hourly run-time on "saved" days, which are selected with weather conditions sufficiently close to a typical load control day. Hourly run-time profiles on 2012 control days for M&V AC units are determined from the contents at the end of the 2012 control season (when available), and the unit run-time on 2012 saved days. The impact for both of the cycling strategies are estimated and the proportions of True Cycle switches are used to determine the overall shed per switch attributable to Cannon switches.

AC Connected Load

Connected load is the average power demand (kW) of a running AC unit over a full cycle. It determines the load reduction (kWh) achieved when AC run-time is reduced. Connected load is specified for M&V AC units through the basic engineering formulas:

*Apparent Power (kVA) = (Compressor Amps + Fan Amps) * 230 Volts / 1000*

*Connected Load (kW) = Power Factor * Apparent Power*

Rated amps for the compressor (FLA) and fan (RLA) are typically listed on the AC faceplate.

Power factor in this formula is actually different for different AC units, and even varies somewhat for different cycles of the same unit, increasing at high temperature and humidity.

Duke Energy has analyzed synchronous AC run-time and premise interval kWh collected for the M&V samples to determine an appropriate overall power factor within each sample. Results are 0.83 for the Ohio and Kentucky M&V sample. These power factor values are used to calculate connected loads for impact evaluation.

Simulation Method for PM Impact Evaluation

Simulation with M&V natural duty cycle models is used to determine average load reduction per household within M&V strata during each hour of load control and for each PM cycling strategy. These strata results are combined with the population weights given in Table 1 to estimate average load reduction per household in the PM populations in OH and KY. The potential load impacts estimated in this manner represent the load reduction which would be achieved if all switches controlled as expected. Impact results for PM load control are obtained by simulation with the OH/KY M&V samples.

The simulation procedure is very similar for the basic PM control strategies: Target/True Cycle and Fixed Cycling. In a fixed cycling simulation, the same specified shed percentage is applied to all ACs to evaluate load impact. In a Target/True Cycle simulation for a particular program option, or load reduction target, and during a specified hour (and day) of load control, a customized shed percentage is calculated for each AC unit from information specific to that unit. The resulting unit-specific shed percentages remain fixed in all simulated realizations for that load reduction target and load control hour.

A single realization in the simulation is generated by a random draw of residuals for each of the M&V natural duty cycle model fits, which are evaluated at the temperature and humidity of the control hour (and day). This gives a set of simulated natural duty cycles appropriate for the control hour. Load reduction for each M&V AC is calculated as follows:

Duty cycle reduction = MAX[Duty cycle - (1 – Shed percentage), 0]

*Load reduction = Connected load * Duty cycle reduction*

For households with multiple ACs, realized load reduction is aggregated to the household level by summing load reduction from all household ACs. These realized load reductions are averaged within the strata to produce single realizations of average load reduction per household within high, medium, and low strata. These three sample averages constitute the result from one pass through the simulation corresponding to one draw of model residuals.

Two thousand passes through the simulation are performed to adequately capture the variation in average load reduction within strata that is consistent with our duty cycle models and M&V sample sizes. The results accumulate into distributions of sample averages for all three strata. The grand means of these distributions are the most significant output from a simulation run. They are the estimates of average load reduction per household in each stratum for the specified control hour and cycling strategy. The spread of these distributions (e.g., variance) characterizes the uncertainty in the load reduction estimates, and is inversely related to the M&V sample sizes.

Load Impact Results

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 factors 1.04 switches per household for Ohio and Kentucky results. Population estimates of load reduction per household are divided by these factors to get corresponding population estimates of load reduction per switch. The estimates of switches per household are determined from the M&V samples in Ohio and Kentucky.

Power Manager hourly results for OH and KY are given in Table 5. These results are adjusted for distribution and transmission line losses. Both Cannon and CSE load control devices are installed in KY. Only Cannon devices are installed in OH.

Table 4 shows de-rating factors used for the 2012 impact evaluation. The CSE factor in KY was determined by an operability study conducted in 2009. The factors for Cannon in OH and KY were determined by an operability study conducted in 2010. We will conduct operability studies for Cannon in OH and KY in 2013.

Table 4. De-rating Factors for Impact Evaluation

Switch Type	OH	KY
Cannon	0.931	0.931
CSE		0.541

Table 5. 2012 PM Impact Results for OH and KY

Event Date	Hour	PM Impact (MW)	
		OH	KY
6/20/2012	15	36.6	9.5
	16	26.8	9.7
	17	27	9.9
6/21/2012	15	37.2	9.5
	16	39.2	10.1
	17	39.8	10.3
6/28/2012	16	39.2	
	17	40.3	10.3
	18	40.4	10.4
	19		10.6
6/29/2012	16	43	10.7
	17	43.1	10.9
7/5/2012	16	35.3	8.7
	17	34.2	8.7
	18	35.5	9
7/6/2012	16	39.4	9.8
	17	39.6	10
	18	40.4	10.2
7/17/2012	16	47.8	11.5
	17	49.2	12
	18	48.5	11.9

PM load control was activated in OH and KY on 7 days during the summer of 2012, including both CSE and Cannon devices on all days. Table 5 gives hourly impact results in OH and KY for each control day. The highest hourly impact in Ohio was 49.2 MW, and in Kentucky, 12 MW, both in hour 17 (5:00 – 6:00 pm EDT) on July 17 adjusted for line losses.

Table 6 gives estimated load reduction per switch not adjusted for line losses under peak normal weather conditions and load control technologies. **Table 7 shows the summer monthly load reduction adjusted for line losses under peak normal weather conditions.** Table 8 shows the peak normal weather conditions used to calculate the results in Table 6. The system peak is assumed to occur in the hour 5:00 – 6:00 pm EDT (identified as hour 18 in this report).

Table 6. Shed kW/switch with Peak Normal Weather

Switch Type	Control Strategy	Potential Impact	De-rated Impact
		OH/KY	OH/KY
Cannon	TC 1.5	1.52	1.42
	TC 1.0	1.01	0.94
CSE	FC 75%	1.81	0.98
	FC 50%	1.07	0.58

Table 7. Monthly Peak Normal Weather Load Reduction De-rated Impact by State Adjusted for Line Losses for Cycling

State	Control Strategy	June	July	August	September	Summer Capability
Ohio	Cycling	44.6	44.7	45.3	45.5	44.9
Kentucky	Cycling	11	10.9	10.9	10.9	10.9

Table 8. Peak Normal Weather

Hour	OH / KY	
	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 7 shows the weighted average capability of the Power Manager program across the summer months in 2012 for each state. These weighted average values are calculated using the summer monthly values and weighting them based on the probability of experiencing an annual peak load in that month in each state. However, for revenue recovery purposes, Duke Energy also calculates a value called a P&L value. The P&L value is calculated from monthly capability values in each state. The P&L value is the value proposed by Duke Energy to be used for revenue recovery since it is consistent with accounting guidelines. The P&L values for 2012 are 44.9 MW Ohio and 11.0 MWs Kentucky. A further explanation of the P&L value is provided below.

P&L Value (Revenue Recovery Value) – the process can be summarized as follows.

- Using the processes described above and the program participants for a particular month, calculate the monthly capability of those participants using summer peak normal weather. For Power Manager, these values, for the summer months, are the same values as provided above in Table 7.
- The monthly values receive accounting adjustments if applicable.
- The revised monthly values are averaged across the months during which the program is available for curtailment. For the Power Manager program, this would include the months of May – September in OH and KY.

Review Results

The approach used by Duke Energy for estimating the effect of the Power Manager® program is very reasonable and defensible. One particularly noteworthy feature is that they use an extensive history to estimate the model, rather than relying on only a handful of days as is common in many utilities which use less rigorous approaches (i.e., approaches that compare average usages from a pre-event period, for example, rather than conducting a multivariate regression model, as Duke Energy is doing).

Overall, based on our review, Duke Energy's impact evaluation is a very complete and innovative approach, and should result in accurate estimates of event impacts and the summer load reduction capacity under peak normal weather conditions, as summarized in Table 7 on page 13.

Final Report

Impact Evaluation and Review of the 2012 PowerShare® Program in Ohio

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Executive Summary

Introduction and Purpose of Study

This document presents the evaluation report for Duke Energy's PowerShare® Program as it was administered in Ohio.

Duke Energy performed the calculations and conducted the impact analysis, and Integral Analytics (a TecMarket Works' Subcontractor) conducted the review of the methodology and results.

Summary of the Evaluation

The impact analysis of the PowerShare program was conducted by Duke Energy. The basic approach for determining the impacts, capabilities, and profit and loss (i.e., P&L, the MW values used for revenue recovery) involves combining actual weather data with hourly load data from all enrolled customers, collected for the previous month(s), as appropriate. A regression model is developed using the combined data to provide an estimate of what the load would have been for the customer, absent an event. This is compared to the actual customer load to determine the impacts from an event.

Evaluation Objectives

The purpose of this evaluation is two-fold. The first objective is to summarize the actual kW and expected peak normal kW impacts determined by Duke Energy for 2012. The second objective is to determine if the approach used by Duke Energy in estimating these impacts as well as the capacity values are consistent with commonly accepted evaluation principles.

Recommendations

Overall, based on our review, Duke Energy's impact evaluation is a very complete and innovative approach, and it should result in accurate estimates of Event impacts (i.e., settlement with customers, M&V results for an event, capability values, and P&L values).
In general, the model specifications in all the processes includes the key determinates of energy usage, so there is little likelihood of any bias in the results from omitted variables. One particularly noteworthy feature is that Duke Energy uses an extensive history to estimate the model, rather than relying on only a handful of days as is common in many utilities which use less rigorous approaches. In addition, using a multivariate regression model in the Capabilities, P&L, and M&V processes is generally preferred over approaches that are based on average loads from a pre-event period.

In addition, the technical approach used by Duke Energy in developing settlement calculations for the customer day-ahead Pro forma load (PFL) and the M&V event impacts are very well thought out and developed. The use of multiple methods and determining the Best of Breed (BoB) in the PFL is noteworthy in that it assures that the most accurate approach will be used in developing the PFL – a step which, to the best of our knowledge, is not used by any other entity.

In addition, there appears to be no direct link between the customer payments (based on the day-ahead PFL) and the overall program impacts (based on the M&V and Capability process). Since the day-ahead PFL is based on the BoB approach, while the other processes are based on regression models, it may be that there is a marked difference between the two estimates of load impacts. Therefore, it is our recommendation that Duke Energy investigate a mechanism that will produce all the required reports for customers, internal use, and regulatory requirements, using a single, unified process for the PFLs and the other reports. An example might be to store the day ahead PFLs associated with an event for developing the Capability and M&V processes for appropriate programs.

Relatedly, it is not clear why there are so many different processes involved. While it is obvious that a distinction be made between actual weather and peak normal weather, it is not clear why that requires two distinct processes. It seems possible to combine the Capability and M&V process into one process, where the regression models are estimated once, and for the weather sensitive customers, estimates of both actual and weather normal impacts are estimated from the same model (just using different weather values). In addition, for Ohio, there does not appear to be any substantial difference between the Capability and P&L process, so these two can be combined. Therefore, our continued recommendation is that Duke Energy reviews the need for each process to see if they are truly required. In terms of P&L process results, the use of these results may be appropriate in the revenue recovery process but that is best addressed by Duke Energy and the state regulatory entities. In response to the same recommendations made in previous evaluations, Duke Energy has reviewed each process and believes that the capability, M&V, and P&L underlying calculation processes can be consolidated. Duke Energy will notify TecMarket Works when changes are implemented.

Description of Program

PowerShare® is the brand name given to Duke Energy Ohio's Peak Load Management Program (Rider PLM, Peak Load Management Program P.U.C.O. Electric No. 19, Sheet No. 87.1). A revised version of this Rider was accepted in PUCO Case No. 12-1682-EL-AIR. All information in this report refers to the Rider PLM effective for the year 2012. The PLM Program is voluntary and offers customers the opportunity to reduce their electric costs by managing their electric usage during the Company's peak load periods. Customers and the Company will enter into a service agreement under this Rider, specifying the terms and conditions under which the customer agrees to reduce usage.

There are three product options offered for PowerShare® - CallOption®, AutoDR, and QuoteOption®:

- CallOption®
  - A customer served under a CallOption® product agrees, upon notification by the Company, to reduce its demand.
  - Each time the Company exercises its option under the agreement, the Company will provide the customer a credit for the energy reduced.
  - There are two types of events.
    - Economic events are primarily implemented to capture savings for customers and not necessarily for reliability concerns. Participants are not required to curtail during economic events. However, if participants do not curtail, they must pay a market based price for the energy not curtailed. This is called "buy through energy."
    - Emergency events are implemented due to reliability concerns. Participants are required to curtail during emergency events.
  - If available, the customer may elect to buy through the reduction at a market-based price. The buy through option is not always available as specified in the PowerShare® Agreements. During PJM Interconnection, LLC-declared emergency events, customers are not provided the option to buy through.
  - In addition to the energy credit, customers on the CallOption® will receive an option premium credit.
  - For the 2012/13 PowerShare® program, there were three different enrollment choices for customers to select among. All three choices require curtailment availability for up to ten emergency events per PJM requirements for capacity participation. The number of economic events varies among the choices. Customers can select exposures of zero, five or ten economic events.
  - Only customers able to provide a minimum of 100 kW load response qualify for CallOption®. Aggregation of customer's accounts is permitted with a minimum of 1 MW load response.

- AutoDR
  - AutoDR is essentially the same program as CallOption 10/10 (i.e., 10/10 meaning 10 economic events and 10 emergency events). However, the implementation mechanism is very different. For CallOption programs an

automated messaging system contacts customers to notify them of an event. AutoDR could be classified as a direct load control program because implementation is controlled through messages sent directly to the participant's energy management system (EMS). These messages adjust the EMS settings to accomplish the load reduction enrolled.
  - Load impacts for this program are calculated exactly the same as the CallOption programs.

- QuoteOption®
  - Under the QuoteOption® products, the Company may notify the customer of a QuoteOption® event and provide a Price Quote to the customer for each event hour.
  - The customer will decide whether to reduce demand during the event period. If they decide to do so, the customer will notify the Company and provide an estimate of the customer's projected load reduction.
  - Each time the Company exercises the option, the Company will provide the participating customer who reduces load an energy credit.
  - There is no option premium for the QuoteOption® product since customer load reductions are voluntary.
  - Only customers able to provide a minimum of 100 kW load response qualify for QuoteOption®. Aggregation of customer's accounts is permitted with a minimum of 1 MW load response.
- Other
  - Note that another large commercial and industrial demand response program is offered in Ohio. This program is called the Ohio Transmission Voltage Demand Response Program. This program does not receive state approved incentives and is not included in this report.

PowerShare® 2012-2013 Participation Summary

The PowerShare program has an annual enrollment for participation. This report covers the participation year of 2012. However, customers enroll for 1 year periods from June through May. Therefore, one set of customers participate in PowerShare from January through May, 2012, while a different set of customers are enrolled for June through December, 2012. Duke Energy Ohio is a summer peaking utility and therefore, the most relevant participation period is the summer months of June through September and this report concentrates on those months.

The table below compares account participation levels for summer 2011 and summer 2012, as well as MWs enrolled in the program. The MW values are Duke Energy Ohio's estimate of the load reduction capability across the summer. Additional information is presented below on the different calculations performed for the program including summer load reduction capability (LRC), P&L revenue recovery values, Measurement & Verification (M&V) values, and day-ahead projected load reduction (PFLs).

Ohio PowerShare® Participation Update
Enrolled Customers

CallOption®			QuoteOption®		
2011	2012	Change	2011	2012	Change
75	**52**	**-23**	**0**	**0**	**0**

Summer Curtailment Capability (MWs)*

CallOption®			QuoteOption®		
2011	2012	Change	2011	2012	Change
97.9	**65.3**	**-32.6**	**0**	**0**	**0**

*Capability for QuoteOption® is 80% of customer estimated load curtailment

Numbers reported are adjusted for losses

(Note that Duke Energy Ohio also registers DR, Demand Response, with PJM Interconnection, LLC. The values calculated by PJM for registered capacity do not necessarily match the values above since PJM follows a separate calculation process. These values are not documented here. The CallOption values above include AutoDR participants.)

PowerShare® 2012-2013 Program Activity

During the summer of 2012, there were 4 CallOption® events and 0 QuoteOption® events. All CallOption® events were economic events. There were no CallOption® emergency events but there were 2 CallOption PJM test events. These events are required by PJM and each lasted 1 hour. The second event was only for those customers who did not comply with their load reduction amounts during the first event. The table below summarizes event participation.[1]

Date	Hour End-ing	Reporting Time Zone EDT/EST	Power-Share 0/10	Power-Share 5/10	Power-Share 10/10	PowerShare CallOption Subtotal (MW)	Quote (no events)	AutoDR	Total (MW)
6/21/2012	14	EDT			2.1	2.1			2.1
6/21/2012	15	EDT			1.6	1.6			1.6
6/21/2012	16	EDT			1.0	1.0			1.0
6/21/2012	17	EDT			0.6	0.6		1.6	2.2
6/21/2012	18	EDT			0.0	0.0		1.6	1.6
6/21/2012	19	EDT			0.0	0.0			0.0

[1] "PowerShare® CallOption® participants are presented with the option to "buy-through" economic events since system reliability is not a concern during economic events. For energy consumed under this buy-through option, customers pay a market based price for energy. Buy-through is not available during emergency events. Also note that there was only 1 CallOption and 3 AutoDR customers enrolled in 2012 for economic events. All other participants were enrolled for emergency events only."

6/28/2012	14	EDT			1.9	1.9		2.8	4.7
6/28/2012	15	EDT			1.4	1.4		2.6	4.0
6/28/2012	16	EDT			1.1	1.1		2.4	3.5
6/28/2012	17	EDT			0.4	0.4		2.0	2.4
6/28/2012	18	EDT			0.0	0.0		2.0	2.0
6/28/2012	19	EDT			0.0	0.0		2.2	2.2
6/29/2012	14	EDT			2.4	2.4			2.4
6/29/2012	15	EDT			2.0	2.0		1.5	3.5
6/29/2012	16	EDT			2.3	2.3		1.2	3.5
6/29/2012	17	EDT			1.2	1.2		1.8	3.0
6/29/2012	18	EDT			0.4	0.4		0.9	1.3
6/29/2012	19	EDT			0.2	0.2			0.2
7/6/2012	15	EDT						1.3	1.3
7/6/2012	16	EDT						0.9	0.9
7/6/2012	17	EDT						0.9	0.9
7/6/2012	18	EDT						1.3	1.3
7/17/2012	15	EDT						1.5	1.5
7/17/2012	16	EDT						1.3	1.3
7/17/2012	17	EDT						1.1	1.1
7/17/2012	18	EDT						1.2	1.2
7/26/2012	14	EDT			2.7	2.7			2.7
7/26/2012	15	EDT			1.8	1.8			1.8
7/26/2012	16	EDT			1.4	1.4			1.4
7/26/2012	17	EDT			1.5	1.5			1.5
7/26/2012	18	EDT			0.1	0.1			0.1
7/26/2012	19	EDT			0.0	0.0			0.0
9/12/2012	15	EDT	76.9		3.3	80.2		2.2	82.4
9/27/2012	16	EDT	0.3			0.3			0.3

Overview of the Evaluation Approach

The impact analysis for the PowerShare programs was conducted by Duke Energy staff and evaluated by Integral Analytics staff. The results presented in this report include a review by Integral Analytics of the impact evaluation methodology and results.

There are many different numbers calculated by the DR Analytics group for PowerShare. A large portion of the effort surrounding analytics for PowerShare falls into four different calculation areas. These calculations can be grouped into 2 categories. These categories and calculation areas are listed below and then described in more detail.

a. Hourly Event Day Impact Estimates
    i. Pro-forma Load Estimations (PFLs) – estimates of participant's hourly electric consumption for the next day. These baseline projections are used to determine potential load reduction for a potential event the next day.
    ii. Measurement and Verification Load Reduction Estimates (M&V) – estimates of actual load reduction provided by participants on an event day.
b. Peak Available Load Reduction Estimates
    i. Load Reduction Capability (LRC) – estimates of load reduction under peak normal weather conditions, if applicable, over a specified period of time such as a month or the entire summer for participants during the period of time in question.
    ii. Revenue Recovery Load Reduction Estimates (P&L) – estimates of summer load reduction under peak normal weather conditions, if applicable, for all participants enrolled in the program during the calendar year.

Note that the PFL process and calculations are projected values used in PowerShare operations. These are not the final estimated baselines for customers. The final baselines are calculated in the M&V process and are used to determine the load reductions during events. The PFL process is significant to the PowerShare program since these values are used for customer settlement calculations and we will discuss them in PowerShare Process evaluation reports.

As the categories above imply, the evaluation of the PowerShare program must meet a diverse set of goals. Specifically, after each event, the level of load reduction must be calculated for each participant. If the participant is on a firm service level reduction agreement, the determination is made if they reduced load from wherever their load would have been absent the event, a baseline, to their actual load during the event period. Another key feature of a firm service level agreement is to determine if the customer's load is at or below the firm service level during the event hours, regardless of the amount of load reduction provided.

If the customer is on a fixed reduction agreement, the evaluation calculates the difference between the baseline and the actual load during the control period to see if the agreed amount of reduction was achieved.

Credits or penalties for events, using PFLs, are calculated within the Energy Profiler Online (EPO) system for PowerShare and recorded on the customer's utility bill. In addition, the results of the various evaluations are used to develop reports for the system operator, load availability projections, summer curtailment projections for state level planning, and event load reduction analysis.

A further requirement related to PFLs is that an economic control event can be called on any non-holiday, non-weekend day and therefore, the PFL calculation must be available on each of these days. The control season runs all year for emergency events; however, economic events, although possible outside the summer season, tend to be limited to the summer season. Regardless of the date, the evaluation needs to be able to assess the load data of all participants so that Duke Energy can calculate the amount of load reduction that is achieved at any time.

An additional complication is related to the use of aggregate accounts. Under this scenario a customer designates two or more accounts whose results are to be aggregated in order to meet the customer's obligations under their contract. In the case of aggregate accounts the estimation processes described below are applied to the individual accounts and the results obtained for the individual accounts are summed to obtain the result at the aggregate level.

These requirements have resulted in an extensive evaluation procedure as described above. This evaluation procedure consists of the following tasks:

Table 1. PowerShare Evaluation Procedures

Process	Purpose	Frequency
PFLs	Settlement with customers and emergency event load reduction projections	Every weekday
M&V	Reporting actual impacts of events to regulatory bodies.	Monthly if an event occurred in the prior month
LRCs	Internal Reporting and input into P&L process	Monthly
P&L	Regulatory filings for revenue recovery	Monthly as needed for internal reporting and a year-end true-up for revenue recovery

A high-level overview of the M&V, Capability, and P&L in Table 1 is given below.

M&V

The steps involved in the calculation of the monthly reports of Capability, P&L, and M&V are all similar but not exactly the same. In addition, for PowerShare Quote Option, the Capability and P&L processes are not performed since they are not relevant to the program. For the M&V process for PowerShare CallOption and for PowerShare Quote Option, hourly load data from all enrolled customers is collected for a particular month. Data is treated similarly but with a few exceptions such as the modeling of quiet periods. Event days and days where participants have reduced load, due to a maintenance shutdown for example, are excluded. However, if an event occurs during a period when the customer is on a maintenance shutdown, the information used in the analysis concentrates only on the information during their shutdown period and requires special handling. This is a rare event though and the typical procedure is described below.

The data is combined with the actual weather for that month. Regression models (one with and one without weather terms) are developed using the combined data. Specifically, the regression equation relates the customer's hourly electricity load to:

- A Fourier transform of hour of the day
- A Fourier transform of hour of the week
- A Fourier transform of hour of the month
- Temperature Humidity Index
- Binary variables for holidays and quiet periods, if appropriate
- Interactions between the Fourier transforms and the other variables

An F-test is calculated for each customer to determine if weather is a significant explanatory variable (unless weather is explicitly excluded for customers known not to be weather sensitive). If so, then the estimated parameters are used to create predicted loads using actual weather conditions on the event days. Thus, the baselines from the M&V process are representative of the actual load the customer would have consumed absent an event. These baselines from event days are then used with actual load data from the event hours and a load reduction is calculated.

However, note that all results are reviewed by DR Analytics. If regression results are clearly not representative of a specific participants load absent the event, an adjustment to the baseline may be applied. In addition, small variances around the baseline expected by typical model variance, above and below, are set to zero and therefore not considered load reduction.

M&V results are shown above in the Introduction section. Please note that the PFL event load reduction estimates are used for settlement with customers. However, M&V load reduction estimates are Duke Energy's best estimate of the load reduction impacts and these impacts are used for regulatory reporting purposes where applicable.

Load Reduction Capability (LRC)

Similar to the M&V regression process described above, Load Reduction Capability (LRC) is calculated on a monthly basis for PowerShare CallOption. For the LRC process, hourly load data from all enrolled customers is collected for a particular month. Event day information is eliminated from the analysis. Quiet periods, for example due to a maintenance shutdown, are included and modeled in the analysis.

The data is combined with actual weather. Regression models are developed using the combined data similar to the hourly regression model discussed above. Similar to above, two models are created: one with weather terms and one without. Specifically, the regression equation relates the customer's hourly electricity load to:

- A Fourier transform of hour of the day
- A Fourier transform of hour of the week
- A Fourier transform of hour of the month
- Temperature Humidity Index

- Binary variables for holidays and quiet periods, if appropriate
- Interactions between the Fourier transforms and the other variables

An F-test is calculated for each customer to determine if weather is a significant explanatory variable (unless weather is explicitly excluded for customers known not to be weather sensitive). If so, then the estimated parameters are used to create predicted loads using peak normal weather conditions for all days of the month. Thus, the baselines from the LRC process are representative of the peak normalized load the customer would have consumed throughout the month. The weekday, non-holiday baselines are then used with the customer's specified fixed reduction amount or firm load level to calculate the load reduction available each hour. By hour, these values are averaged across the month.

However, monthly LRC by participant is typically not of interest for most reporting purposes. Of primary interest is the summer LRC given that Duke Energy Ohio (DEO) is a summer peaking utility. PJM concentrates on this same period of time through their Peak Load Contribution process which is not described or emphasized in this report. Therefore, by hour and by participant, a weighted average of the four monthly LRC values is calculated. Then, by participant, the hourly values for hours ending (HE) Eastern Daylight Time (EDT) 15 through 18 are captured in a calculation to determine the summer LRC of each participant. For firm level participants, these 4 values are averaged. For fixed reduction participants, the minimum of the four values is used. Summing across all participants provides the Summer LRC of the program.

Revenue Recovery Load Reduction Estimates (P&L)

Similar to the LRC regression process described above, P&L is calculated based on capability calculations for all 4 summer months PowerShare CallOption. For the P&L process, hourly load data from all enrolled customers is collected for June through September. Event day information is eliminated from the analysis. Quiet periods, for example due to a maintenance shutdown, are included and modeled in the analysis.

The data is combined with actual weather. Monthly, a regression model is developed using the combined data similar to the hourly regression models discussed above. Specifically, the regression equation relates the customer's hourly electricity load to:

- A Fourier transform of hour of the day
- A Fourier transform of hour of the week
- A Fourier transform of hour of the month
- Temperature Humidity Index
- Binary variables for holidays and quiet periods, if appropriate
- Interactions between the Fourier transforms and the other variables

An F-test is calculated for each customer to determine if weather is a significant explanatory variable (unless weather is explicitly excluded for customers known not to be weather sensitive). If so, then the estimated parameters are used to create predicted loads using peak normal weather conditions for all days of the month. Thus, the baselines from the P&L process are representative of the peak normalized load the customer would have consumed throughout the month for all customers; even if the customer wasn't actually participating in one or more of the summer months. This is where the LRC and P&L processes differ. In LRC, the monthly value for June for a participant who joined the program in July would be 0. However, in P&L, the calculated value would be used for June. The fact that the customer did not participate in June is captured later in the calculation process. Continuing, the weekday, non-holiday baselines are then used with the customer's specified fixed reduction amount or firm load level to calculate the load reduction available each hour. By hour, these values are averaged across the month.

Then, by hour and by participant, a weighted average of the four monthly values is calculated. Then, by participant, the hourly values for hours ending (HE) Eastern Daylight Time (EDT) 15 through 18 are captured in a calculation to determine the summer LRC of each participant. For firm level participants, these 4 values are averaged. For fixed reduction participants, the minimum of the four values is used. This is where the LRC process would terminate after summing across all participants. However, the P&L process now calculates monthly values by taking the sum for each month of only the participants in that month. These monthly values are then delivered to Product Analytics for final calculations of the P&L results. Accounting adjustments are made as needed such as the elimination of all participation through the use of diesel generators. These participants are not included in the incentive structure for PowerShare in Ohio.

Evaluation Findings

Summary

Based on the evaluation performed by Duke Energy staff following the procedures discussed above, each calculation PFL, M&V, LRC, and P&L has a specific purpose. Primarily, PFLs are used for customer settlements for event incentives and operational projections of load reduction available the following day. M&V is used for regulatory and internal reporting of load reduction from events. LRC is used for internal reporting of load reduction available during each monthly period. P&L is used for revenue recovery requests. For this review, the primary focus is on the P&L calculations. Table 2 provides these values including adjustments for line losses for 2012.

Table 2. LRC and P&L values

Program	LRC (MWs)	P&L (MWs)
PS CallOption 0/10	62.9	47.0
PS CallOption 5/10	0.0	0.0
PS CallOption 10/10	1.1	2.1
PS CallOption 15/10	0.0	0.0
PS AutoDR	1.3	*
Total PowerShare CallOption	65.3	49.1

*AutoDR P&L value included in PS CallOption 10/10 P&L value.

Review of Approach

Overall, the technical approach used by Duke Energy in developing the event impacts are very well thought out and developed.

In general, the model specifications in all the processes includes the key determinates of energy usage, so there is little likelihood of any bias in the results from omitted variables. One particularly noteworthy feature is that they use an extensive history to estimate the model, rather than relying on only a handful of days as is common in many utilities which use less rigorous approaches. In addition, using a multivariate regression model in the Capabilities, P&L, and M&V processes is generally preferred over approaches that are based on average loads from a pre-event period.

The one concern we have is that there are multiple processes that essentially measure the same thing. For example, the P&L and Capability processes are essentially both measuring the peak normalized load reduction capability of participants. This appears to be inefficient, as well as confusing, as it is not clear what the actual estimate of impacts is for the program without considerable explanation. Of note, Duke Energy describes the P&L value as follows:

- The PowerShare programs allow the company to reduce load at any point during the year during an emergency. Because of that, the Company recognizes revenue ratably over a 12 month period based on the current summer capability for that month. (Said another way, the Company multiplies its current kW summer capability times the avoided cost of capacity per kW / 12.) The Company accordingly reports its 12-month average summer capability in regulatory true up proceedings for the PowerShare program.

In addition, there appears to be no direct link between the customer payments (based on the day-ahead PFL) and the overall program impacts (based on the M&V and Capability process). Since the day-ahead PFL is based on the BoB approach while the other processes are based on regression models, it may be that there is a marked difference between the two estimates of load impacts.

Relatedly, it is not clear why different processes must be involved. While there appears to be a specific purpose for each process, there may be efficiencies captured by consolidating the processes. While it is obvious that a distinction be made between actual weather and peak normal weather, it is not clear why that requires two distinct processes. It seems possible to combine the Capability and M&V process into one process, where the regression models are estimated once, and for the weather sensitive customers, estimates of both actual and weather normal impacts are estimated from the same model (just using different weather values). In addition, a difference between the Capability and P&L process is that the P&L includes customers who have enrolled after the beginning of summer or potentially participated during the beginning of the year but terminated their participation prior to the summer. Duke Energy clearly wants to capture these enrollments and collect revenues for them during the current year. However, it is our opinion that the P&L process may overstate or understate the actual capability of the program, if for example you are talking about the capability of the program during the summer of 2012. Therefore, our continued recommendation is that the impacts should be based on the Capability calculations, and Duke Energy should review the need for each process to see if they are truly required. In response to the same recommendations made in previous evaluations, Duke Energy has reviewed each process and believes that the capability, M&V, and P&L underlying calculation processes can be consolidated. Duke Energy will notify TecMarket Works when changes are implemented. Once these implementations are incorporated, we will revise our recommendations based upon the new approach.

Overall, based on our review, Duke Energy's impact evaluation is a very complete and innovative approach, and it should result in accurate estimates of event impacts.

Final Report

Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in Ohio

Results of an Impact Evaluation for
Linear Fluorescent Lighting, *Occupancy Sensors, and VFDs*

Prepared for
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Executive Summary

Key Findings and Recommendations

This Executive Summary provides an overview of the key findings identified through this evaluation.

Significant Impact Evaluation Findings for Linear Fluorescent Measures

- Energy and coincident peak demand savings realization rates for kWh and coincident peak kW for linear fluorescent lighting were 1.89 (energy) and 1.61 (demand) respectively, indicating the program planning estimates were conservative estimates of linear fluorescent lighting savings.
- Measurement and verification (M&V) activities conducted for this study produced an estimate of 5,155 lighting equivalent full load hours (EFLH), compared to a program planning estimate of 4,144 EFLH.
- M&V activities estimated a coincidence factor (CF) of 0.80, compared to a program planning estimate of 0.77.
- Although there were some small differences between the quantity of fixtures recorded in the Duke Energy program tracking database versus the number of fixtures in the field, the overall installation verification rate was 1.00.
- Program planning and M&V estimates of baseline fixture wattage were within 1%. M&V estimates of efficient fixture watts were an average of about 7% lower than program planning estimates, indicating conservative values of fixture watts were used during program design.

Significant Impact Evaluation Findings for Occupancy Sensor Measures

- Energy and coincident peak demand savings realization rates for kWh and kW for occupancy sensor measures were 0.56 and 1.21 respectively, indicating the program planning estimates were conservative estimates of occupancy sensor coincident peak kW savings, but overestimated occupancy sensor kWh savings.
- M&V activities conducted for this study produced an estimate of 3,078 lighting equivalent full load hours (EFLH) before the installation of occupancy sensors, compared to a program planning estimate of 4,144 EFLH.
- M&V activities produced an estimate of connected lighting kW per occupancy sensor that was 31% lower than the program assumption. Many of the occupancy sensors in the study were controlling a single fixture, which contributed to the reduced connected watts per sensor.
- M&V activities estimated an average kWh savings of 54% of the uncontrolled consumption and an average kW savings of 46% of the uncontrolled demand, compared to the program estimate of 30% for both kWh and kW. Although the kW savings as a percentage of the baseline estimated from M&V was higher, the connected load per sensor was less, thus the overall demand savings per sensor from M&V was less than the program estimate.

Significant Impact Evaluation Findings for VFD Measures

- VFD energy and coincident peak demand savings realization rates were lower than program planning estimates. On average, the realization rates for energy, non-coincident peak, and peak demand savings were about 62, 46, and 43% respectively. HVAC fans had the highest realization rates, and process pumping had the lowest realization rates.

A summary of the impact findings is presented in the standardized Duke Energy Program Impact Metrics Tables below.

Table 1. Summary of Program Savings by Measure

Measure	Measure Count	Gross Ex Post (Adjusted) Per unit kWh impact	Gross Ex Post (Adjusted) Per unit kW impact	Gross Ex Post (Adjusted) kWh Savings	Gross Ex Post (Adjusted) kW Savings
HPT8 4ft 2 lamp, T12 to HPT8	4,878	191.6	0.033	934,625	161.0
HPT8 4ft 2 lamp, T8 to HPT8	2,705	72.4	0.012	195,842	32.5
Low Watt T8 lamps, 4ft	174,488	35.0	0.006	6,107,080	1,046.9
LW HPT8 4ft 2 lamp, replace T8	7,237	86.0	0.015	622,382	108.6
LW HPT8 4ft 4 lamp, replace T8	4,267	154.8	0.027	660,532	115.2
LW HP T-8 4ft 1L replace T-8 4ft 1L	1,032	60.2	0.010	62,126	10.3
LW HP T-8 4ft 2L replace T-8 4ft 2L	26,249	86.0	0.015	2,257,414	393.7
LW HP T-8 4ft 4L replace T-8 4ft 4L	6,768	154.8	0.027	1,047,686	182.7
T8 2ft 2 lamp	2,161	206.3	0.036	445,814	77.8
T8 4ft 2 lamp	24,674	111.8	0.019	2,758,553	468.8
T8 4ft 4 lamp	21,648	275.1	0.047	5,955,365	1,017.5
T8 8ft 2 lamp	3,553	120.4	0.021	427,781	74.6
Occupancy Sensors under 500 W	28,904	273.5	0.123	7,905,244	3,555.2
Occupancy Sensors over 500 W	10,968	684.8	0.302	7,510,886	3,312.3
VFD HVAC Fan	602	1011.7	0.070	609,043	42.1
VFD HVAC Pump	54	1558.0	0.207	84,132	11.2
VFD Process Pump 1-50 HP	9	270.6	0.033	2,435	0.3

Table 2. Program Impact Metrics Summary

Metric	Result
Number of Program Participants from 1-1-2009 to 2-29-2012	2439 Projects
Gross Coincident Peak kW per unit	kW/unit
HPT8 4ft 2 lamp, T12 to HPT8	0.033
HPT8 4ft 2 lamp, T8 to HPT8	0.012
Low Watt T8 lamps, 4ft	0.006
LW HPT8 4ft 2 lamp, replace T8	0.015
LW HPT8 4ft 4 lamp, replace T8	0.027
LW HP T-8 4ft 1L replace T-8 4ft 1L	0.010
LW HP T-8 4ft 2L replace T-8 4ft 2L	0.015
LW HP T-8 4ft 4L replace T-8 4ft 4L	0.027
T8 2ft 2 lamp	0.036
T8 4ft 2 lamp	0.019

Metric	Result
T8 4ft 4 lamp	0.047
T8 8ft 2 lamp	0.021
Occupancy Sensors under 500 W	0.123
Occupancy Sensors over 500 W	0.302
VFD HVAC Fan	0.070
VFD HVAC Pump	0.207
VFD Process Pump 1-50 HP	0.033
Gross kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	191.6
HPT8 4ft 2 lamp, T8 to HPT8	72.4
Low Watt T8 lamps, 4ft	35.0
LW HPT8 4ft 2 lamp, replace T8	86.0
LW HPT8 4ft 4 lamp, replace T8	154.8
LW HP T-8 4ft 1L replace T-8 4ft 1L	60.2
LW HP T-8 4ft 2L replace T-8 4ft 2L	86.0
LW HP T-8 4ft 4L replace T-8 4ft 4L	154.8
T8 2ft 2 lamp	206.3
T8 4ft 2 lamp	111.8
T8 4ft 4 lamp	275.1
T8 8ft 2 lamp	120.4
Occupancy Sensors under 500 W	273.5
Occupancy Sensors over 500 W	684.8
VFD HVAC Fan	1011.7
VFD HVAC Pump	1558.0
VFD Process Pump 1-50 HP	270.6
Gross therms per unit	N/A
Freeridership rate (program wide)	38.40%
Spillover rate	6.60%
Self Selection and False Response rate	0.00%
Total Discounting to be applied to Gross values	68.20%
Net Coincident Peak kW per unit	kW/unit
HPT8 4ft 2 lamp, T12 to HPT8	0.023
HPT8 4ft 2 lamp, T8 to HPT8	0.008
Low Watt T8 lamps, 4ft	0.004
LW HPT8 4ft 2 lamp, replace T8	0.010
LW HPT8 4ft 4 lamp, replace T8	0.018
LW HP T-8 4ft 1L replace T-8 4ft 1L	0.007
LW HP T-8 4ft 2L replace T-8 4ft 2L	0.010
LW HP T-8 4ft 4L replace T-8 4ft 4L	0.018
T8 2ft 2 lamp	0.025
T8 4ft 2 lamp	0.013
T8 4ft 4 lamp	0.032
T8 8ft 2 lamp	0.014
Occupancy Sensors under 500 W	0.084
Occupancy Sensors over 500 W	0.206
VFD HVAC Fan	0.048
VFD HVAC Pump	0.141
VFD Process Pump 1-50 HP	0.023
Net kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	130.7
HPT8 4ft 2 lamp, T8 to HPT8	49.4
Low Watt T8 lamps, 4ft	23.9

Metric	Result
LW HPT8 4ft 2 lamp, replace T8	58.7
LW HPT8 4ft 4 lamp, replace T8	105.6
LW HP T-8 4ft 1L replace T-8 4ft 1L	41.1
LW HP T-8 4ft 2L replace T-8 4ft 2L	58.7
LW HP T-8 4ft 4L replace T-8 4ft 4L	105.6
T8 2ft 2 lamp	140.7
T8 4ft 2 lamp	76.2
T8 4ft 4 lamp	187.6
T8 8ft 2 lamp	82.1
Occupancy Sensors under 500 W	186.5
Occupancy Sensors over 500 W	467.0
VFD HVAC Fan	690.0
VFD HVAC Pump	1062.6
VFD Process Pump 1-50 HP	184.5
Net therms per unit	N/A
Measure Life	12yr (linear fluorescent) 10yr (occupancy sensor)

Net to Gross

The net to gross analysis is based on participant self-reports and complies with standard evaluation practices and protocols, including the California Evaluation Protocols (TecMarket Works, April 2006). The program-wide net to gross analysis (freeridership = 38.4%+spillover = 6.6%) produced a net to gross ratio of 0.682 at the program level. That is, the program saved 31.8% less than the measures installed via the program incentive because freeridership was particularly high and the program did not induce participants to take many additional energy efficiency actions beyond those incented by the program.

Recommendations

Based on the results of the impact evaluation, the TecMarket Works team has the following recommendations:

1. Conservative estimates of lighting EFLH should be updated with M&V results.
2. The weighted average self-reported operating hours were 4,944 EFLH, which represents a better estimate of lighting EFLH than the standard estimate of 4,144 EFLH. Consider including the self-reported operating hours in the ex-ante estimates of measure savings.
3. The measured coincidence factor of 0.80 was slightly higher than the program planning estimate of 0.77. Consider revising the coincidence factor assumption to 0.80 for future program planning activities.
4. The M&V savings for VFDs was significantly lower than program estimates, especially for HVAC pumps and process pumps. Consider reducing the annual savings estimates to the M&V results.

Introduction and Purpose of Study

This report presents the results of an impact evaluation of the Non-Residential Smart $aver® Prescriptive Program in Ohio. The focus of this study is on linear fluorescent lighting fixtures, occupancy sensors, and VFDs on HVAC fans, HVAC pumps, and process pumping. A previous report examined high-bay lighting fixtures, which were and still are the dominant measure adopted by program participants. As the program has matured, linear fluorescent lighting, occupancy sensors, and VFD savings have increased as a percentage of total program savings. This report was prepared in response to the emergence of these measure types as significant measures in the overall program portfolio.

Summary Overview

Summary of the Evaluation

This report presents the results of an impact evaluation of linear fluorescent lighting, occupancy sensor, and VFD measures offered through Duke Energy's Non-Residential Smart $aver Program in Ohio. The Smart $aver Program provides incentives to customers to upgrade to energy efficient lighting and commercial equipment. The study focuses on participants from January 2009 through February 29, 2012.

The impact evaluation employed a tracking system review, onsite surveys, and short term Measurement and Verification (M&V) of selected lighting fixtures, occupancy sensors, and variable frequency drives (VFD) using portable data loggers.

Evaluation Objectives

The goal of the impact analysis was to estimate program level energy (kWh) and demand (kW) savings. Secondary objectives included estimates of unit energy savings for sampled measures, and overall energy and demand savings realization rates for the three measure groups studied: linear fluorescent lighting, occupancy sensors, and variable frequency drives.

Researchable Issues

Additional researchable issues in this evaluation include:

- Verification of measures as recorded in the Duke Energy program tracking database with field observations.
- Identification of ineligible measures.
- Estimation of average operating hours for commercial lighting fixtures
- Estimation of unit energy savings for VFDs
- Percent energy savings and connected load parameters for occupancy sensors

Program Description

The Non-Residential Smart $aver® Prescriptive program influences business customer decisions for saving energy by providing incentives to install qualifying high-efficiency measures such as lighting, HVAC, and motors. Duke Energy's commercial and industrial customers fund this program by paying an energy efficiency rider based upon their kWh usage. The program has a Custom component as well as the Prescriptive component. This evaluation study looks at the Prescriptive program only. The Custom program will not be evaluated here, but it works hand in hand with the Prescriptive program. In the Prescriptive program, customers may install selected energy efficient measures and then send in an application for rebates, up to 90 days after the installation. Energy efficiency measures that are not part of the Prescriptive program may still earn a rebate, but the installation of these Custom measures must first be approved by Duke Energy through an application process.

Program Participation

Program	Measure Count for 1/1/09 – 2/28/12
Non-Residential Smart $aver Prescriptive	835,342

Methodology

Overview of the Evaluation Approach

Study Methodology

The impact methodology consisted of engineering analysis following the International Performance Measurement and Verification Protocol (IPMVP). The projects were separated into linear fluorescent, occupancy sensor, and variable frequency drives (VFDs) measure groups, and samples were drawn from each category. Site surveys and metering equipment were installed to gather data according to an M&V plan developed for each measure category[1]. Energy and demand savings estimates were developed for each sampled project.

Data collection methods, sample sizes, and sampling methodology

The impact evaluation employed a tracking system review, onsite surveys, and short term Measurement and Verification (M&V) of selected lighting fixtures, occupancy sensors, and variable frequency drives (VFD) using portable data loggers.

For the lighting measures, the sample design specified a minimum sample of 12 linear fluorescent and 13 occupancy sensor projects. A target sample of 25 projects representing 38 individual measures was selected for the study. The sampling plan incorporated a stratified random sample approach, where the projects were stratified according to technology type (linear fluorescents, occupancy sensors), and sampled randomly within each stratum.

VFDs were sampled by measure, not by project since more than one VFD measure is often included in a single project. The target sample included a total of 18 sites comprising 53 VFDs: 37 VFD fans, 9 VFD pumps, and 7 VFD process pumps.

Each sampled site was recruited for the M&V study by TecMarket Works contractors.

Number of completes and sample disposition for each data collection effort

Last minute customer refusals eliminated five of the 25 sites from the final sample lighting resulting in a total of 20 sites, ten each for linear fluorescents and occupancy sensors. Due to oversampling, the achieved sample met or exceeded the minimum sample requirements. For VFDs, total of 18 sites and 44 measures were monitored. The achieved sample exceeded both the minimum and target sample size. The final sample disposition is shown below:

[1] An overall M&V plan was developed for each measure category, with site-specific addenda to address measurement issues at each sampled site.

Table 3. Final Sample Disposition

Group	Minimum Required Sample Size	Target Sample Size	Achieved Sample Size
Linear Fluorescent	8 sites	12 sites	10
Occupancy Sensor	10 sites	13 sites	10
VFD-Fan	15 measures	20 measures	29
VFD-Process	1 measure	3 measures	6
VFD-Pump	4 measures	6 measures	9

Expected and achieved precision

A sample meeting +/- 10% relative precision at 90% confidence at the program level was selected. Due to higher than expected variability in the savings in the M&V sample relative to the program planning values, the achieved relative precision was +/- 23.1%. Planned and sample coefficients of variance are shown below.

Table 4. Planned and Sample Coefficients of Variance

Project Type	Target cv	Actual Sample cv
Linear Fluorescent	0.3	0.94
Occupancy Sensor	0.3	0.61
VFD-Fan	0.5	1.65
VFD-Process	0.5	0.41
VFD-Pump	0.5	0.32
Total		

Description of baseline assumptions, methods and data sources

For linear fluorescent measures, the baseline was the existing lighting system prior to the retrofit. Due to the nature of prescriptive rebate programs, it was not possible to observe the baseline lighting system. The baseline lighting system description was obtained by interviewing the site contacts at each sampled site. Occupancy sensor measures are an "add-on" measure, so the baseline assumption is the observed lighting fixtures without occupancy sensor controls. VFD baseline assumptions were obtained by interviewing site contacts to define the flow control strategy prior to installation of the VFD.

Description of measures and selection of methods by measure(s) or market(s)

The focus of this study is on linear fluorescent lighting fixtures and occupancy sensors, as well as VFDs on HVAC fans, pumps, and process pumping. All projects were evaluated in compliance with the International Performance Measurement and Verification Protocols (IPMVP) Option A – Partially measured, retrofit isolation protocol.

Use of TRM values and explanation if TRM values not used

Engineering algorithms from the Draft Ohio TRM were used to calculate lighting savings. The study relied on primary data collection, so deemed parameters from the TRM were unnecessary.

Building energy simulation modeling was used to calculate HVAC interactive effects multipliers based on the observed HVAC system characteristics. The VFD analysis used primary data collection and regression analysis; deemed values from the TRM were not used.

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

There is the possibility for extrapolation error going from short term measurement to annualized savings. To address this, industry standard protocols were followed in the selection of the duration of the monitoring period in order to capture sufficient workday and weekend operation and also to avoid anomalous operation periods. For weather dependent measures, data were collected during a portion of the year with sufficient temperature variation to establish trends and allow the projection of short term monitored data to annual savings. State of the art engineering analysis techniques, including building energy simulation modeling were employed to reduce engineering bias.

Evaluation Findings

The impact evaluation employed a tracking system review, an engineering review of the lighting and VFD measure savings calculations, and field measurement and verification (M&V) of selected lighting and VFD measures.

Tracking Data Analysis

The tracking system review revealed that a few measures were responsible for the majority of the savings. Tracking data obtained from Duke Energy from January 2009 through February 2012 show the following breakdown of energy savings by measure:

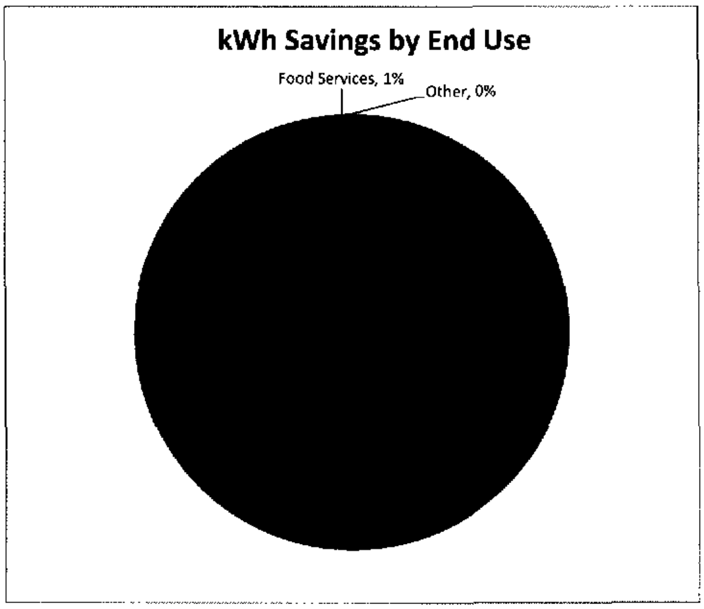


Figure 1. Measure Contribution to C&I Program Savings

Note lighting measures made up 82% of the total reported savings. Lighting was dominated by high-bay applications, making up 47% of the total lighting savings.

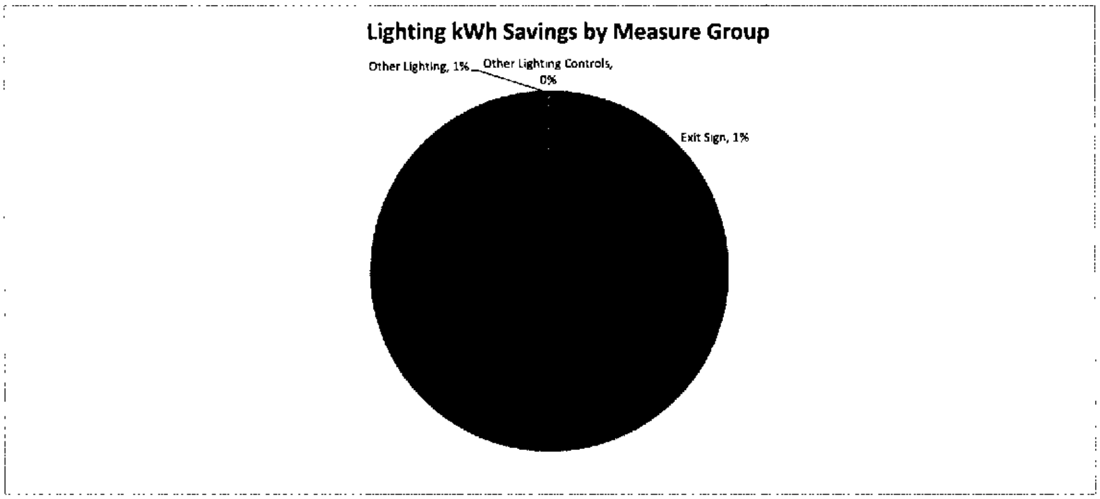


Figure 2. Lighting Measure Savings Distribution

The next largest measure group was Motors, Pumps, and Drives. This group is dominated by variable frequency drives (VFD), comprising over 99% of the energy savings. The breakdown of the VFD applications is shown in Figure 3. Over 96% of the VFD savings were attributed to HVAC Fan and Pump applications.

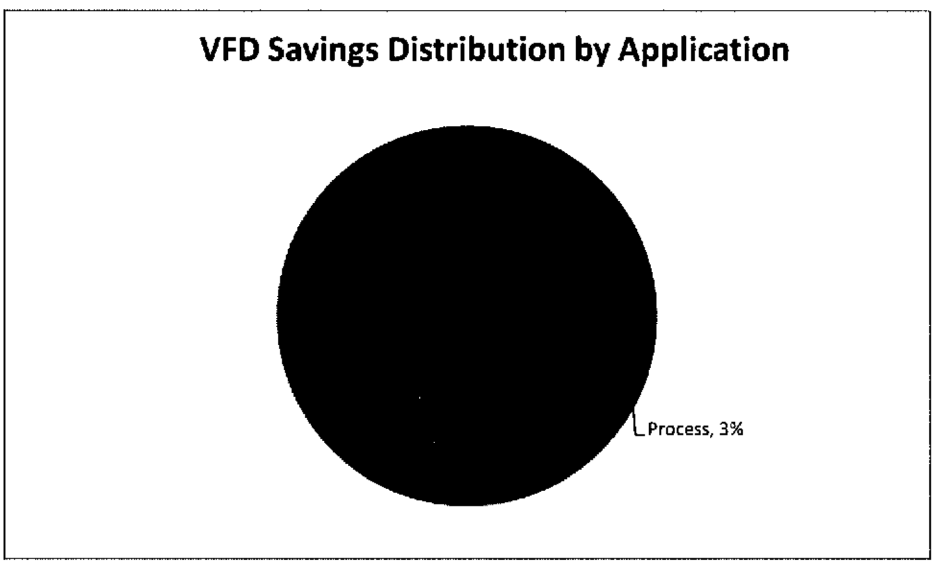


Figure 3. VFD Measure Savings Distribution

The Smart $aver Non-Residential Prescriptive program evaluation report[2] dated August 29, 2010 focused on the high bay applications. For this study, we focused on linear fluorescent lighting, occupancy sensors, and VFDs.

[2] Evaluation of the Non-Residential Smart $aver Prescriptive Program in Ohio, August 29, 2010.

The evaluation team conducted field M&V on a sample of linear fluorescent lighting, occupancy sensor, and VFD participants to estimate savings for these measures. The field M&V for lighting and occupancy sensors consisted of a site visit, verification of the quantity and type of incented lighting fixtures, verification of fixture wattage assumptions against manufacturers' catalog data, interviews with customers to identify the type and quantity of the replaced fixtures, and short-term monitoring of lighting system operation using light loggers to measure operating hours. The field M&V for VFD participants consisted of a site visit, verification of the quantity and type of incented VFDs, verification of VFD capacity, and short-term monitoring of VFDs to measure their performance. The field M&V activities were conducted by TecMarket Works' sub-contractors and the results were forwarded to Architectural Energy Corporation for analysis. The field M&V activities were compliant with the International Performance Measurement and Verification Protocols (IPMVP) Option A – Partially measured, retrofit isolation protocol.

Lighting and VFD program participation records covering the period from January 2009 through the end of February 2012 were obtained from Duke Energy. The data, delivered as an Excel spreadsheet flat file, contained customer name and address, installing vendor contact information, measure descriptions, unit energy savings estimates, number of measures installed, lighting operating hours, installed fixture watts, VFD horsepower, rebate amounts, etc. These data were examined to identify which of the measures promoted by the program were adopted by program participants and in what numbers, and the availability of any customer description data that could be used in the analysis.

Customers indicated the annual operating hours of their lighting systems on the incentive applications. These self-reported lighting system hours of operation are entered into the program tracking database. A tabulation of the average self-reported operating hours for linear fluorescent, CFL and High Bay measures by building type are shown in Table 5. These data do not include occupancy sensor measures. It is worth noting that 4219 average operating hours per year across all building types compares favorably to the estimate of 4144 average operating hours per year used in the program design workpapers[3].

[3] 4,144 average operating hours per year across all building types, from the Ohio Technical Reference Manual: Technical Reference Manual (TRM) for Ohio Senate Bill 221"Energy Efficiency and Conservation Program" and 09-512-GE-UNC, October 15, 2009.

Table 5. Self-Reported Lighting Operating Hours by Building Type

Building Description	Operating hour report frequency by building type	Average self-reported operating hours from program application
Big Box Retail	59	4,788
Education	436	3,219
Grocery	30	6,712
Healthcare	150	4,662
Industrial	804	5,354
Lodging	67	4,809
Office	455	3,743
Other	422	3,134
Public Assembly	263	3,084
Public Order/Safety	254	4,074
Restaurant	47	5,465
Small Box Retail	312	3,691
Warehouse	468	4,158
All Buildings	3767	4,219

The distribution of the self-reported operating hours by building type and fixture type is shown in Table 6.

Table 6. Self-Reported Lighting Operating Hours by Building and Fixture Type

Building Type	CFL	Linear fluorescent	High Bay
Big Box Retail	6,766	5,428	3,948
Education	3,661	2,691	2,997
Grocery	8,068	7,340	5,985
Healthcare	6,118	4,102	5,332
Industrial	6,559	4,969	5,417
Lodging	5,005	3,419	
Office	3,797	3,853	4,146
Other	2,221	3,272	3,741
Public Assembly	2,891	3,083	3,354
Public Order/Safety	4,480	3,991	3,689
Restaurant	5,580	4,436	
Small Box Retail	3,863	4,832	3,203
Warehouse	3,504	3,600	4,201
All Buildings	3,571	4,029	4,617

Sample Design

The sampling plan incorporates a stratified random sample approach, where the projects are stratified according to technology type (linear fluorescent and occupancy sensors), and sampled randomly within each stratum. The total sample size is calculated from the following equation[4]:

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

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
KWh = total kWh savings
Z = z statistic (1.645 at 90% confidence)
N_k = population size of group k

Samples are allocated to each group based on the following equation:

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

A sample meeting +/- 10% relative precision at 90% confidence at the program level was selected. A coefficient of variation of 0.3 was assumed for the lighting measure population, and 0.5 for the VFD measure population. The Ohio participation (at the time of sample selection) and the resulting sample sizes are summarized in Table 7.

Samples were selected by address to maximize the effectiveness of the M&V field efforts. This often allowed multiple measures to be sampled at a single address (site). The sample design is shown in Table 7 below. Note that the VFDs are sampled by measure, not by address since more than one VFD technology is often located at a single address.

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

Table 7. Sample Selection by Measure or Site for Linear Fluorescent, Occupancy Sensor, and VFD

Group	kWh	cv	Total Measures or Sites	Minimum Required Sample Size	Target Sample Size
Linear Fluorescent	20,966,845	0.3	925 sites	8 sites	12 sites
Occupancy Sensor	26,311,741	0.3	672 sites	10 sites	13 sites
VFD-Fan	23,902,375	0.5	195 measures	15 measures	20 measures
VFD-Process	675,467	0.5	14 measures	1 measures	3 measures
VFD-Pump	5,450,294	0.5	54 measures	4 measures	6 measures

VFDs were sampled throughout the duration of the program, including a total of 18 sites comprising 53 VFDs: 37 VFD fans, 9 VFD pumps, and 7 VFD process pumps during 2009 - 2010[5].

A sample of 18 lighting projects and 44 VFD measures were selected for the study. The allocation of the projects across the different technology measures is shown in Table 7 above. Sites were randomly selected within each group. Each sampled site was recruited for the M&V study by TecMarket Works contractors. Backup sites were used when it was not possible to successfully recruit customers in the primary sample.

At the conclusion of the evaluation, several sites were not included in the lighting and occupancy sensor study. Last minute customer refusals and logger failures eliminated five of the sites from the sample. However, the achieved sample met or exceeded the minimum required sample size, as shown in the table below.

Table 8. Status of 2009-2012 Linear Fluorescent and Occupancy Sensor Sample

Group	Minimum Required Sample Size (Sites)	Target Sample Size (Sites)	Completed (Sites)	Notes
Linear Fluorescent	8	12	10	Customer refusal. 1 site dropped.
Occupancy Sensor	10	13	10	Customer refusal, loggers did not record any data. 3 sites dropped.

The achieved sample met or exceeded the target for the VFD measures as shown in Table 9.

[5] Sampling of VFDs within the sites resulted in a total of 44 monitored VFDs.

Table 9. Status of 2009-2012 VFD Sample

Group	Minimum Required Sample Size (Measures)	Target Sample Size (Measures)	VFDs Monitored (Measures)	Notes
VFD-Fan	15	20	**29**	Monitored VFDs exceeded the Target Sample
VFD-Process	1	3	**9**	Monitored VFDs exceeded the Target Sample
VFD-Pump	4	6	**6**	Monitored VFDs equals the Target Sample

A summary of the characteristics of the 10 customers that participated in the linear fluorescent M&V study is shown in Table 10.

Table 10. Linear Fluorescent Lighting M&V Study Participants

Site	Customer Name	Building Type	Total fixtures rebated	Installed Fixture(s)	Baseline Fixture(s)
LF-1	[redacted]	Office	40	T-8 8ft 2 lamp	T-12 8ft 2 lamp
			11	T-8 3ft 4 lamp	T-12 3ft 4 lamp
			9	HP T-8 4ft 2 lamp	T-8 4ft 2 lamp
			32	HP T-8 4ft 2 lamp	T-12 4ft 2 lamp
			52	HP T-8 4ft 2 lamp	T-12 4ft 2 lamp
LF-2	[redacted]	Warehouse	410	T-8 4ft 4 lamp	T-12 4ft 4 lamp
LF-3	[redacted]	Public Assembly	538	LW T-8 4ft (per-lamp replacement)	4 ft 6L F32 high bay (per lamp repl)
LF-4	[redacted]	Office	56	LW T-8 4ft 1 lamp	T-8 4ft 1 lamp
			200	LW T-8 4ft 2 lamp	T-8 4ft 2 lamp
			276	LW T-8 4ft 2 lamp	T-8 4ft 4 lamp
LF-5	[redacted]	Public Order Safety / Institutional	83	HP T-8 4ft 2 lamp	T-8 4ft 2 lamp
			4 (none installed)	High performance low watt lamp T8 fluorescent	Standard T8 fluorescent
			40	T-8 4ft 2 lamp	T-12 4ft 2 lamp
LF-6	[redacted]	Healthcare	15	T-8 4ft 4 lamp	T-12 4ft 4 lamp
LF-7	[redacted]	Industrial	10	LW T-8 4ft 1 lamp	T-8 4ft 1 lamp
			356	LW T-8 4ft 2 lamp	T-8 4ft 2 lamp
			409	LW T-8 4ft 4 lamp	T-8 4ft 4 lamp
LF-8	[redacted]	Office	34	T-8 4ft 4 lamp	T-12 8ft 2 lamp

Site	Customer Name	Building Type	Total fixtures rebated	Installed Fixture(s)	Baseline Fixture(s)
LF-9	[redacted]	Warehouse	6	T-8 4ft 2 lamp	T-12 4ft 2 lamp
			9	Not present	T-12 4ft 4 lamp
LF-10	[redacted]	Small Box Retail	922	LW T-8 4ft (per lamp)	T-8 4ft 2 lamp (per lamp)

The characteristics of the ten sites that participated in the occupancy sensor study are shown in Table 11.

Table 11. Occupancy Sensor M&V Study Participants

Site	Customer Name	Business Type	Number of Occupancy Sensors Rebated	Occupancy Sensor Type
OS-1	[redacted]	Education	29	Occupancy Sensors over 500 W
			54	Occupancy Sensors under 500 W
OS-2	[redacted]	Public Order/Safety	7	Occupancy Sensors under 500 W
OS-3	[redacted]	Warehouse	88	Occupancy Sensors under 500 W
OS-4	[redacted]	Industrial	19	Occupancy Sensors under 500 W
OS-5	[redacted]	Small Box Retail	8	Occupancy Sensors under 500 W
OS-6	[redacted]	Office	2	Occupancy Sensors under 500 W
OS-7	[redacted]	Education	3	Occupancy Sensors under 500 W
			9	Occupancy Sensors under 500 W
OS-8	[redacted]	Education	41	Occupancy Sensors over 500 W
			30	Occupancy Sensors under 500 W
OS-9	[redacted]	Education	33	Occupancy Sensors under 500 W
			40	Occupancy Sensors over 500 W
OS-10	[redacted]	Office	45	Occupancy Sensors under 500 W

The characteristics of the 18 sites that participated in the VFD study are shown in Table 12 below. These sites represent 53 VFDs in the tracking database. 44 of these 53 VFDs were monitored.

Table 12. VFD M&V Study Participants

Site	Customer Name	Building Type	VFDs Monitored			
			VFDs Rebated	VFD HVAC Fan	VFD HVAC Pump	VFD Process Pump 1-50 HP
VFD-1	[redacted]	Healthcare	3	3	0	0
VFD-2	[redacted]	Education K-12	2	2	0	0
VFD-3	[redacted]	Education K-12	2	2	0	0
VFD-4	[redacted]	Healthcare	1	1	0	0
VFD-5	[redacted]	Healthcare	3	0	3	0
VFD-6	[redacted]	Church	5	3	0	0
VFD-7	[redacted]	Office	1	1	0	0
VFD-8	[redacted]	Office	2	2	0	0
VFD-9	[redacted]	Other	6	2	0	4
VFD-10	[redacted]	Office	2	2	0	0
VFD-11	[redacted]	Healthcare	1	1	0	0
VFD-12	[redacted]	Office	2	0	2	0
VFD-13	[redacted]	Grocery	1	0	1	0
VFD-14	[redacted]	Grocery	1	0	1	0
VFD-15	[redacted]	Education	10	3	2	0
VFD-16	[redacted]	Education	2	2	0	0
VFD-17	[redacted]	Office	6	2	0	2
VFD-18	[redacted]	Office	3	3	0	0
	Total		53	29	9	6

Gross Savings Analysis – Linear Fluorescents and Occupancy Sensors

Paper file applications and supporting documentation were obtained for each site. The data in the application files were reviewed and compared to the program tracking database and onsite survey observations. Discrepancies were noted and corrected for the impact evaluation. These discrepancies are reported in Table 13.

Table 13. Tracking System and Paper File Discrepancies

Measure	Site	Discrepancy
Linear Fluorescent	1	3-foot fixtures were installed in lieu of 2-foot fixtures.
	4	4-lamp fixtures were replaced by 2-lamp fixtures
	5	63 fixtures were installed instead of 83 in app
	5	No 4-ft 4-lamp HPT8s were found in monitored building
	14	Rebate provided to replace standard 32W T8 lamps with 28W lamps. Program calcs used lamp watts; A fixture watts value that includes the observed ballast factor was used, normalized per lamp replaced.

Fixture watts reported in the manufacturer's catalogs (where available) were averaged and compared to the standard assumptions used in program design for several popular fixture types. This comparison is shown in Figure 4.

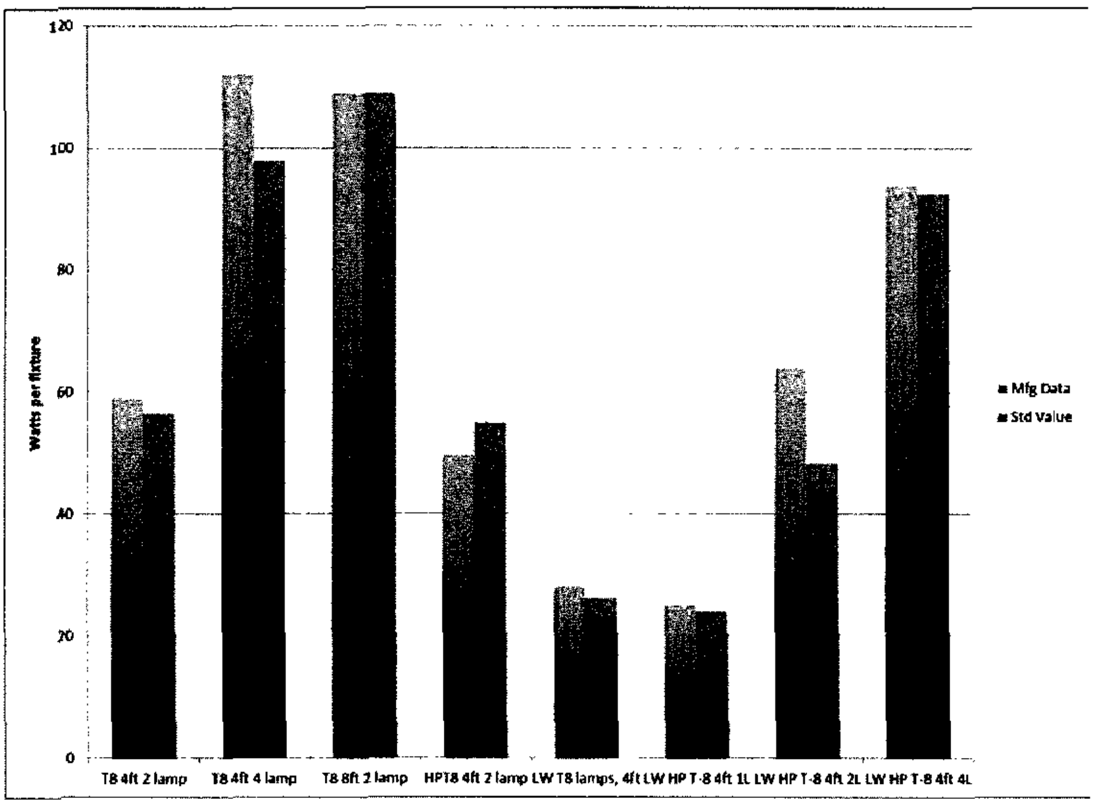


Figure 4. Comparison of Installed Fixture Watts from Manufacturers vs. Standard Assumptions

These data are also shown in Table 14.

Table 14. Comparison of Manufacturer's Fixture Watts with Standard Program Assumptions for Linear Fluorescent Fixtures

Fixture	n	Program Assumption	Mfg Cutsheets
T8 4ft 2 lamp	2	59	56.5
T8 4ft 4 lamp	3	112	98
T8 8ft 2 lamp	1	109	109
HPT8 4ft 2 lamp	3	49.7	55
LW T8 lamps, 4ft	2	28	26.3
LW HP T-8 4ft 1L	2	25	24.2
LW HP T-8 4ft 2L	3	64	48.3
LW HP T-8 4ft 4L	1	94	92.6

In many cases, the program standard assumption exceeds the manufacturers' cut sheet values, indicating conservative values were used in developing the program estimates of fixture savings. Where the M&V values exceed the program assumption, the M&V values are based on in-situ measurements, where ballast factors may be different than program assumptions.

The fixture quantities installed at the sampled sites along with the number of light loggers deployed are shown in Table 15 and Table 16. Light loggers were deployed to monitor the on/off behavior of the lighting systems based on the circuiting and switching of the lighting systems. At some sites, recording current loggers were installed to measure time series current on selected lighting circuits.

Table 15. Logger Installations at Linear Fluorescent M&V Study Sites

Site	Customer Name	Business Type	Total fixtures rebated	Loggers installed
LF-1	[redacted]	Office	144	11
LF-2	[redacted]	Warehouse	410	12 Current
LF-3	[redacted]	Public Assembly	538	6 Current
LF-4	[redacted]	Office	532	10
LF-5	[redacted]	Public Order Safety / Institutional	127	5 Current
LF-6	[redacted]	Healthcare	15	5
LF-7	[redacted]	Industrial	775	16
LF-8	[redacted]	Office	34	4 Current
LF-9	[redacted]	Warehouse	15	1 Current
LF-10	[redacted]	Small Box Retail	922	2 Current

Table 16. Logger Installations at Occupancy Sensor M&V Study Sites

Site	Customer Name	Business Type	Total Occupancy Sensors rebated	Loggers installed
OS-1	[redacted]	Education	83	7
OS-2	[redacted]	Public Order/Safety	7	6
OS-3	[redacted]	Warehouse	88	15
OS-4	[redacted]	Industrial	19	2
OS-5	[redacted]	Small Box Retail	8	7
OS-6	[redacted]	Office	2	2
OS-7	[redacted]	Education	12	8
OS-8	[redacted]	Education	71	18
OS-9	[redacted]	Education	73	19
OS-10	[redacted]	Office	45	8

The light logger data were downloaded by the TecMarket Works contractors. These data were processed by engineers from Architectural Energy Corporation. The results are summarized in Table 17 and Table 18. Average weekday and weekend load shapes for each site from the logger study are also shown in Appendix A: Load Shapes.

Table 17. Lighting Logger Study Results

Site	Customer Name	Business Type	Application self-reported annual operating hours	Logger study annual operating hours	Ratio logged / self report	Coincident demand factor[6]
LF-1	[redacted]	Office	4,199	7,103	1.69	1.00
LF-2	[redacted]	Warehouse	2,600	2,997	1.15	0.75
LF-3	[redacted]	Public Assembly	3,016	1,255	0.42	0.40
LF-4	[redacted]	Office	3,131	8,109	2.59	0.98
LF-5	[redacted]	Public Order Safety / Institutional	4,000	2,157	0.54	0.77
LF-6	[redacted]	Healthcare	2,480	4,072	1.64	0.89
LF-7	[redacted]	Industrial	8,760	2,852	0.33	0.57
LF-8	[redacted]	Office	2,080	2,081	1.00	0.48

[6] Coincidence factor is defined as the fraction of the total connected load operating at the coincident peak hour, which is defined as the hour between 4pm and 5pm on the hottest summer workday.

LF-9	[redacted]	Warehouse	5,000	2,055	0.41	0.04
LF-10	[redacted]	Small Box Retail	8,736	8,183	0.94	0.97
	Wt. Average[7]		4,944	5,155	1.04	0.80

Table 18. Occupancy Sensor Logger Study Results

Site	Customer Name	Business Type	Connected kW	EFLH		DF[8]	
				Pre	Post	Pre	Post
OS-1	[redacted]	Education	19.01	3,063	1,767	0.88	0.37
OS-2	[redacted]	Public Order/Safety	1.04	5,384	3,720	0.73	0.56
OS-3	[redacted]	Warehouse	19.89	2,167	196	0.50	0.03
OS-4	[redacted]	Industrial	6.67	2,899	522	0.50	0.01
OS-5	[redacted]	Small Box Retail	2.95	2,176	989	0.51	0.25
OS-6	[redacted]	Office	0.67	3,862	2,131	1.00	0.65
OS-7	[redacted]	Education	3.66	3,399	2,008	1.00	0.67
OS-8	[redacted]	Education	33.75	2,611	1,445	0.90	0.42
OS-9	[redacted]	Education	36.38	3,147	2,138	0.87	0.44
OS-10	[redacted]	Office	6.62	6,571	4,345	1.00	0.73
	Wt. Average			3,078	1,547	0.81	0.36

On average, the light logger study predicted about 4% more operating hours for linear fluorescent measures than the customer self-reported values, and 24% more operating hours than the 4,144 EFLH assumption used in the program design estimates. The light logger study for occupancy sensors predicted about 25% fewer uncontrolled operating hours than the 4,144 EFLH assumption used in the program design estimates.

For linear fluorescent measures, the light logger results were combined with the verified fixture counts and verified installed fixture watts to estimate the actual energy and peak demand savings, using the equations shown below.

$kWh_{savings} = (Watts_{base} - Watts_{ee}) / 1000 \times EFLH_{post} \times (1+WHF_e)$

[7] Individual site operating hours were weighted by kWh savings per site to obtain kWh savings weighted average operating hours. Individual site coincidence factors were weighted by kW savings per site to obtain a kW savings weighted coincidence factor.

[8] The diversity factor is defined as the fraction of the total connected load operating at any particular hour. The diversity factor at the coincident peak hour is defined as the fraction of the total connected load operating during the hour between 4pm and 5pm on the hottest summer workday.

$$kW_{savings} = (Watts_{base} - Watts_{ee}) / 1000 \times CF \times (1+WHF_d)$$

where:

$Watts_{base}$ = baseline fixture watts
$Watts_{ee}$ = efficient fixture watts
$EFLH_{post}$ = equivalent full-load lighting operating hours after retrofit
CF = coincidence factor
= fraction of total connected load operating at the utility coincident peak hour
= defined as hour ending at 4pm
WHF_e = waste heat factor for energy
WHF_d = waste heat factor for demand

For occupancy sensor measures, the light logger results were combined with the verified fixture counts and verified installed fixture watts to estimate the actual energy and peak demand savings, using the equations shown below.

$$kWh_{savings} = Watts_{controlled} \times (EFLH_{pre} - EFLH_{post}) / 1000 \times (1+WHF_e)$$

$$kW_{savings} = Watts_{controlled} / 1000 \times (DF_{pre} - DF_{post}) \times (1+WHF_d)$$

where:

$Watts_{controlled}$ = controlled fixture watts
$EFLH_{pre}$ = equivalent full-load lighting operating hours without occupancy sensor
$EFLH_{post}$ = equivalent full-load lighting operating hours with occupancy sensor
DF_{pre} = diversity factor without occupancy sensor
= fraction of total connected load operating without occupancy sensor controls
DF_{post} = diversity factor with occupancy sensor
= fraction of total connected load operating once occupancy sensor controls have been installed

Waste heat factors were calculated using building energy simulation models derived from the commercial building prototypes used in the California Database for Energy Efficiency Resources (DEER) study[9], with adjustments made for local building practices and climate. The commercial prototypes were using long-term average weather data for Cincinnati. The results of the interactive effects simulations are shown in Appendix B: Results of HVAC Interactive Effects Simulations.

[9] Itron, 2005. "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report," Itron, Inc., J.J. Hirsch and Associates, Synergy Consulting, and Quantum Consulting. December, 2005. Available at http://eega.cpuc.ca.gov/deer.

Based on the observed building and HVAC system type, the interactive effects multipliers used for each of the sites in the study are shown below:

Site	Customer Name	Business Type	HVAC System Type	WHF_e	WHF_d
LF-1	[redacted]	Office	Office/DX no econ gas heat + Garage	0.061	0.111
LF-2	[redacted]	Warehouse	Lt Industrial/DX no econ gas heat	0.080	0.210
LF-3	[redacted]	Public Assembly	Assembly/DX no econ gas heat	0.154	0.246
LF-4	[redacted]	Office	Small Office/DX with econ gas heat	0.080	0.184
LF-5	[redacted]	Public Order Safety / Institutional	Office/DX no econ gas heat	0.104	0.136
LF-6	[redacted]	Healthcare	Office/Heat pump no econ	0.077	0.136
LF-7	[redacted]	Industrial	Office2/3 /DX with econ gas heat+ Manufacturing-heat only	0.053	0.122
LF-8	[redacted]	Office	Warehouse/DX no econ gas heat	0.085	0.317
LF-9	[redacted]	Warehouse	Warehouse/DX with econ gas heat	0.080	0.210
LF-10	[redacted]	Small Box Retail	Retail/DX with econ gas heat	0.076	0.268
OS-10	[redacted]	Education	School/AC econ gas heat	0.032	0.263
OS-2	[redacted]	Public Order/Safety	Office/AC no econ gas heat	0.080	0.184
OS-3	[redacted]	Warehouse	Warehouse/No AC Gas Heat	0.000	0.000
OS-4	[redacted]	Industrial	Warehouse/No AC Gas Heat	0.000	0.000
OS-5	[redacted]	Small Box Retail	Office/AC econ gas heat	0.103	0.136
OS-6	[redacted]	Office	Office/heat pump no econ	0.023	0.190
OS-7	[redacted]	Education	School/AC no econ gas heat	0.072	0.263
OS-8	[redacted]	Education	School/AC no econ gas heat	0.072	0.263
OS-9	[redacted]	Education	School/AC no econ electric heat	-0.808	0.266
OS-10	[redacted]	Office	Warehouse/no cool/Gas heat	0.000	0.000
	Wt. Average			0.003	0.164

Gross Impact Results – Linear Fluorescents and Occupancy Sensors

These results of the energy and demand savings calculations are shown in Table 19 and Table 20. These results were compared to the tracked savings based on the fixture counts and standard per fixture kW and kWh savings estimates from program design work papers. The ratio of the evaluated savings to the program planning estimated savings is expressed as a realization rate (RR) for kWh, non-coincident peak (NCP) kW, and coincident peak (CP) kW.

Table 19. Results of Linear Fluorescent Lighting M&V Study

Site		Building Type	kWh Savings			NCP kW Savings			CP kW Savings		
			M&V	Program Planning	RR	M&V	Program Planning	RR	M&V	Program Planning	RR
LF-1	[redacted]	Office	16,172	12,596	1.28	2.38	3.33	0.72	2.38	2.56	0.93
LF-2	[redacted]	Warehouse	63,699	59,643	1.07	23.81	15.74	1.51	17.86	12.12	1.47
LF-3	[redacted]	Public Assembly	3,896	9,783	0.40	3.35	2.58	1.30	1.34	1.99	0.67
LF-4	[redacted]	Office	172,737	33,458	5.16	23.35	8.83	2.64	22.89	6.80	3.37
LF-5	[redacted]	Public Order Safety / Institutional	1,867	6,464	0.29	0.89	1.71	0.52	0.69	1.31	0.52
LF-6	[redacted]	Healthcare	2,763	2,182	1.27	0.72	0.58	1.24	0.64	0.44	1.44
LF-7	[redacted]	Industrial	36,890	49,969	0.74	13.78	13.19	1.04	7.86	10.16	0.77
LF-8	[redacted]	Office	2,073	4,946	0.42	1.21	1.31	0.93	0.58	1.01	0.58
LF-9	[redacted]	Warehouse	320	1,664	0.19	0.17	0.44	0.40	0.01	0.34	0.02
LF-10	[redacted]	Small Box Retail	73,063	16,766	4.36	10.52	4.43	2.38	10.21	3.41	3.00
		Total	**373,480**	**197,472**	**1.89**	**80.19**	**52.13**	**1.54**	**64.44**	**40.14**	**1.61**

Table 20. Results of Occupancy Sensor M&V Study

Site		Building Type	kWh Savings			NCP kW Savings			CP kW Savings		
			M&V	Program Planning	RR	M&V	Program Planning	RR	M&V	Program Planning	RR
OS-1	[redacted]	Education	25,442	62,092	0.41	5.89	16.52	0.36	12.39	12.72	0.97
OS-2	[redacted]	Public Order/Safety	1,862	3,433	0.54	0.38	0.92	0.41	0.21	0.71	0.29
OS-3	[redacted]	Warehouse	39,196	43,157	0.91	15.99	11.62	1.38	9.41	8.94	1.05
OS-4	[redacted]	Industrial	15,849	9,318	1.70	5.26	2.51	2.10	3.27	1.93	1.69
OS-5	[redacted]	Small Box Retail	3,869	3,923	0.99	0.59	1.06	0.56	0.86	0.81	1.06
OS-6	[redacted]	Office	1,190	981	1.21	0.24	0.26	0.89	0.28	0.20	1.38
OS-7	[redacted]	Education	5,461	5,885	0.93	1.45	1.58	0.91	1.51	1.22	1.24
OS-8	[redacted]	Education	42,181	65,057	0.65	10.92	17.24	0.63	20.37	13.28	1.53
OS-9	[redacted]	Education	7,058	65,300	0.11	3.59	17.32	0.21	19.89	13.33	1.49
OS-10	[redacted]	Office	14,729	22,069	0.67	0.44	5.94	0.07	1.79	4.57	0.39
		Total	**156,838**	**281,215**	**0.56**	**45**	**75**	**0.60**	**70**	**58**	**1.21**

A comparison of the assumptions used in the calculations for linear fluorescent measures is shown in Table 21. Total installed measure count, baseline fixture watts, and installed fixture watts assumptions from the program tracking database or program design work papers were compared to verified values from the M&V study. Although there were some small differences between the number of fixtures recorded in the program tracking database versus the number of fixtures in the field, the overall installation verification rate was very close to 1. Program planning and M&V estimates of baseline fixture wattage were within 4%, due largely to a discrepancy in the baseline fixture type at site LF-1, which had 3 foot fixtures as baseline rather than the 2 foot fixtures listed in database. M&V estimates of efficient fixture watts were an average of about 25% lower than program planning estimates, due primarily to a discrepancy in the efficient fixture type at site LF-4, where 2-lamp fixtures were installed rather than 4 lamp fixtures, and the use of conservative values of fixture watts during program design.

A comparison of the assumptions used in the calculations for occupancy sensor measures is shown in Table 22. Total installed measure count, sensor connected load, energy savings and demand savings factor assumptions from the program tracking database and program design work papers were compared to verified values from the M&V study. The number of occupancy sensors verified in the field is very close to 1. Verified connected load was on average about 31% lower than program design assumptions. Energy savings (a percentage of the uncontrolled energy consumption) was 54%, or about 1.8 times larger than the program design assumption of 30%. Coincident demand savings (as a percentage of connected kW) was 46%, or about 1.5 times larger than the program design assumption of 30%.

Table 21. Comparison of Linear Fluorescent Measure Savings Assumptions

Site	Customer Name	Building Type	Duke Name	Quantity			Baseline Fixture Watts			Efficient Fixture Watts		
				M&V	Tracking	Ratio	M&V	Program	Ratio	M&V	Program	Ratio
LF-1	[redacted]	Office	T8 8ft 2 lamp	40	40	1.00	123.0	123.0	1.00	109.0	109.0	1.00
			T8 2ft 2 lamp	11	11	1.00	81.0	56.0	1.45	46.0	32.0	1.44
			HPT8 4ft 2 lamp, T8 to HPT8	9	9	1.00	59.0	58.0	1.02	47.0	49.7	0.95
			HPT8 4ft 2 lamp, T12 to HPT8	32	32	1.00	72.0	72.0	1.00	59.0	49.7	1.19
			HPT8 4ft 2 lamp, T12 to HPT8	52	52	1.00	72.0	72.0	1.00	59.0	49.7	1.19
LF-2	[redacted]	Warehouse	T8 4ft 4 lamp	410	410	1.00	144.0	144.0	1.00	96.0	112.0	0.86
LF-3	[redacted]	Public Assembly	Low Watt T8 lamps, 4ft	538	538	1.00	37.0	32.0	1.16	32.0	28.0	1.14
LF-4	[redacted]	Office	LW HP T-8 4ft 1L replace T-8 4ft 1L	56	56	1.00	31.0	32.0	0.97	25.0	25.0	1.00
			LW HP T-8 4ft 2L replace T-8 4ft 2L	200	200	1.00	59.0	59.0	1.00	49.0	49.0	1.00
			LW HP T-8 4ft 4L[10] replace T-8 4ft 4L	276	276	1.00	112.0	112.0	1.00	49.0	94.0	0.52
LF-5	[redacted]	Public Order Safety / Institutional	LW HPT8 4ft 2 lamp, replace T8	63	83	0.76	59.0	59.0	1.00	51.0	49.0	1.04
			LW HPT8 4ft 4 lamp, replace T8	0	4	0.00	NA	112.0	0.00	0.0	94.0	NA
			T8 4ft 2 lamp	40	40	1.00	72.0	72.0	1.00	65.0	59.0	1.10
LF-6	[redacted]	Healthcare	T8 4ft 4 lamp	15	15	1.00	144.0	144.0	1.00	102.0	112.0	0.91
LF-7	[redacted]	Industrial	LW HP T-8 4ft 1L replace T-8 4ft 1L	10	10	1.00	31.0	32.0	0.97	23.3	25.0	0.93
			LW HP T-8 4ft 2L replace T-8 4ft 2L	356	356	1.00	59.0	59.0	1.00	47.0	49.0	0.96

[10] M&V Survey found that 2-lamp fixture was installed, rather than 4-lamp fixture. Values shown on this line compare program planning 4-lamp fixture to existing 2-lamp fixture.

Site	Customer Name	Building Type	Duke Name	Quantity			Baseline Fixture Watts			Efficient Fixture Watts		
				M&V	Tracking	Ratio	M&V	Program	Ratio	M&V	Program	Ratio
			LW HP T-8 4ft 4L replace T-8 4ft 4L	409	409	1.00	112.0	112.0	1.00	92.6	94.0	0.99
LF-8	[redacted]	Office	T8 4ft 4 lamp	34	34	1.00	123.0	144.0	0.85	96.0	112.0	0.86
LF-9	[redacted]	Warehouse	T8 4ft 2 lamp	6	6	1.00	72.0	72.0	1.00	48.0	59.0	0.81
			T8 4ft 4 lamp	0	9	0.00	NA	144.0	NA	NA	112.0	NA
LF-10	[redacted]	Small Box Retail	Low Watt T8 lamps, 4ft	922	922	1.00	29.5	32.0	0.92	20.5	28.0	0.73
		Wt Average				0.99			0.99			0.73
									Efficient Fixture Watts weighted average with 2-lamp fixture comparison.			0.93[11]

Table 22. Comparison of Occupancy Sensor Measure Savings Assumptions

Site	Customer Name	Building Type	Duke Name	Quantity			Connected Load			Energy Savings Factor			Demand Savings Factor		
				M&V	Tracking	Ratio	M&V	Program	Ratio	M&V	Program	Ratio	M&V	Program	Ratio
OS-1	[redacted]	Education	Occ Sensors over 500W	29	29	1	0.23	0.55	0.42	0.42	0.30	1.41	0.52	0.30	1.72
			Occ Sensors under 500W	54	54	1									
OS-2		Public Order/Safety	Occ Sensors under 500W	7	7	1	0.15	0.36	0.41	0.31	0.30	1.03	0.17	0.30	0.56
OS-3		Warehouse	Occ Sensors under 500W	88	88	1	0.23	0.36	0.63	0.91	0.30	3.03	0.47	0.30	1.58
OS-4		Industrial	Occ Sensors under 500W	19	19	1	0.35	0.36	0.98	0.82	0.30	2.73	0.49	0.30	1.63

[11] Updated efficient fixture ratio resulting from replacing 2-lamp fixture for 4-lamp fixture in Program fixture assumption. See Footnote 10 for more information.

Site	Customer Name	Building Type	Duke Name	Quantity			Connected Load			Energy Savings Factor			Demand Savings Factor		
				M&V	Tracking	Ratio	M&V	Program	Ratio	M&V	Program	Ratio	M&V	Program	Ratio
OS-5	[redacted]	Small Box Retail	Occ Sensors under 500W	8	8	1	0.37	0.36	1.03	0.55	0.30	1.82	0.26	0.30	0.86
OS-6	[redacted]	Office	Occ Sensors under 500W	2	2	1	0.34	0.36	0.93	0.45	0.30	1.49	0.35	0.30	1.17
OS-7	[redacted]	Education	Occ Sensors under 500W	8	12	0.67	0.46	0.36	1.27	0.41	0.30	1.36	0.33	0.30	1.09
OS-8	[redacted]	Education	Occ Sensors over 500W	41	41	1	0.48	0.67	0.71	0.45	0.30	1.49	0.48	0.30	1.59
			Occ Sensors under 500W	30	30	1									
OS-9	[redacted]	Education	Occ Sensors under 500W	33	33	1	0.50	0.66	0.76	0.32	0.30	1.07	0.43	0.30	1.44
			Occ Sensors over 500W	40	40	1									
OS-10	[redacted]	Office	Occ Sensors under 500W	45	45	1	0.15	0.36	0.41	0.34	0.30	1.13	0.27	0.30	0.90
			Weighted Average			0.99			0.69	0.54	0.30	1.80	0.46	0.30	1.53

Gross Savings Analysis – Variable Frequency Drives

Paper file applications and supporting documentation were obtained for each site. The data in the application files were reviewed and compared to the program tracking database and onsite survey observations. Discrepancies were noted and corrected for the impact evaluation. These discrepancies are reported in Table 23.

Table 23. Tracking System and Paper File Discrepancies for VFDs

Measure	Site	Discrepancy
VFD	9	200 HP VFD penciled in on paper application and installed onsite; Tracking system listed 50HP VFD.
	6	5 HP VFDs installed instead of 7.5 HP VFDs; 7.5 HP VFDs installed instead of 10 HP VFDs

Since there were relatively few VFDs per site, and they often operated independently, their performance was evaluated on an independent basis, and instead of reporting on a site level, the results are reported on a per-VFD level. In limited cases where multiple VFDs were controlled at the same speed, i.e., cooling tower fans, they are reported on a single line in Table 24. Table 25 summarizes the results for each VFD technology and compares these results to the target savings.

In general, the realization rates were quite low. However, at site VFD-9, a 200HP VFD was installed rather than a 50HP VFD, resulting in a realization rate greater than 6. The high realization rate for this VFD caused the overall weighted energy realization rate for VFD fans to be 81%.

Table 24. Results of VFD M&V Study

Key	Customer	VFD Type	Tracking HP	M&V HP	Target Annual kWh Savings	Target Annual NCP kW	Target Annual CP kW	M&V Energy Savings kWh	M&V NCP Savings kW	M&V CP Savings kW	Energy RR	NCP RR	CP RR
VFD-1	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	13,819	2.08	0.93	0.37	0.26	0.16
VFD-1	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	28,379	7.20	-0.39	0.76	0.89	-0.07
VFD-1	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	176	3.15	-0.83	0.00	0.39	-0.14
VFD-2	[redacted]	HVAC Fan	7.5	7.5	9,321	2.01	1.46	956	0.73	0.00	0.10	0.36	0.00
VFD-2	[redacted]	HVAC Fan	15	15	18,641	4.02	2.92	3,899	7.18	0.00	0.21	1.78	0.00
VFD-3	[redacted]	HVAC Fan	7.5	7.5	9,321	2.01	1.46	1,364	0.87	0.00	0.15	0.43	0.00
VFD-3	[redacted]	HVAC Fan	15	15	18,641	4.02	2.92	4,407	2.40	0.00	0.24	0.60	0.00
VFD-4	[redacted]	HVAC Fan	40	40	49,710	10.73	7.80	43,865	7.71	6.70	0.88	0.72	0.86
VFD-5	[redacted]	HVAC Pump	40	40	141,618	30.57	12.32	54,024	9.46	8.65	0.38	0.31	0.70
VFD-5	[redacted]	HVAC Pump	40	40	141,618	30.57	12.32	88,392	15.78	13.73	0.62	0.52	1.11
VFD-5	[redacted]	HVAC Pump	40	40	141,618	30.57	12.32	62,243	13.64	6.24	0.44	0.45	0.51
VFD-6	[redacted]	HVAC Fan	7.5	5	9,321	2.01	1.46	5,066	0.75	0.60	0.54	0.37	0.41
VFD-6	[redacted]	HVAC Fan	7.5	5	9,321	2.01	1.46	3,242	0.75	0.43	0.35	0.37	0.29
VFD-6	[redacted]	HVAC Fan	10	7.5	12,428	2.68	1.95	7,469	1.14	0.69	0.60	0.42	0.36
VFD-7	[redacted]	HVAC Fan	5	5	6,214	1.34	0.97	6,403	0.62	0.23	1.03	0.46	0.24
VFD-8	[redacted]	HVAC Fan	40	40	49,710	10.73	7.80	5,956	0.67	0.00	0.12	0.06	0.00

Key	Customer	VFD Type	Tracking HP	M&V HP	Target Annual kWh Savings	Target Annual NCP kW	Target Annual CP kW	M&V Energy Savings kWh	M&V NCP Savings kW	M&V CP Savings kW	Energy RR	NCP RR	CP RR
VFD-9	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	33,168	4.46	0.15	0.89	0.55	0.03
VFD-9	[redacted]	HVAC Fan	50	200	62,138	13.41	9.75	376,837	27.96	21.12	6.06	2.08	2.17
VFD-9	[redacted]	Process Pump 1-50 HP	20	20	18,213	4.95	4.06	1,643	0.89	0.85	0.09	0.18	0.21
VFD-9	[redacted]	Process Pump 1-50 HP	30	30	27,320	7.43	6.09	14,896	2.12	1.59	0.55	0.28	0.26
VFD-10	[redacted]	HVAC Fan	20	20	24,855	5.36	3.90	15,179	5.54	5.53	0.61	1.03	1.42
VFD-10	[redacted]	HVAC Fan	5	5	6,214	1.34	0.97	1,357	0.90	0.88	0.22	0.67	0.90
VFD-11	[redacted]	HVAC Fan	20	20	24,855	5.36	3.90	17,729	5.50	0.00	0.71	1.03	0.00
VFD-12	[redacted]	HVAC Pump	10	10	35,405	7.64	3.08	13,720	1.58	1.57	0.39	0.21	0.51
VFD-13	[redacted]	HVAC Pump	25	15	88,512	19.11	7.70	41,817	2.38	2.00	0.47	0.12	0.26
VFD-14	[redacted]	HVAC Pump	20	9	70,809	15.28	6.16	27,443	0.00	0.00	0.39	0.00	0.00
VFD-15	[redacted]	HVAC Fan	15	15	18,641	4.02	2.92	11,108	4.72	3.65	0.60	1.17	1.25
VFD-15	[redacted]	HVAC Pump	40	40	141,618	30.57	12.32	36,912	9.86	7.90	0.26	0.32	0.64
VFD-15	[redacted]	HVAC Pump	30	30	106,214	22.93	9.24	24,444	6.77	6.35	0.23	0.30	0.69
VFD-15	[redacted]	HVAC Fan	10	10	12,428	2.68	1.95	3,823	1.73	1.45	0.31	0.64	0.74
VFD-15	[redacted]	HVAC Fan	15	15	18,641	4.02	2.92	21,365	2.81	1.61	1.15	0.70	0.55
VFD-16	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	2,590	3.56	0.00	0.07	0.44	0.00
VFD-17	[redacted]	HVAC Fan	40	50	49,710	10.73	7.80	16,863	9.17	0.00	0.34	0.86	0.00
VFD-17	[redacted]	Process Pump 1-50 HP	60	80	54,640	14.86	12.17	18,644	2.52	1.84	0.34	0.17	0.15
VFD-	[redacted]	HVAC Fan	60	60	74,566	16.09	11.70	79,643	9.33	7.98	1.07	0.58	0.68

Key	*Customer*	*VFD Type*	Trackin g HP	M&V HP	Target Annual kWh Savings	Target Annual NCP kW	Target Annual CP kW	M&V Energy Savings kWh	M&V NCP Savings kW	M&V CP Savings kW	Energ y RR	NCP RR	CP RR
18	[redacted]												
VFD-18	[redacted]	HVAC Fan	30	30	37,283	8.05	5.85	26,305	6.36	0.00	0.71	0.79	0.00

VFD-9 with a 200HP fan, is greater than the 50HP allowed under the program. However, it provided savings, and so is included in the analysis. Similarly, VFD-18 included VFDs that were factory installed in a new packaged unit. Under the program, this application would not be allowed. However, a rebate was paid and therefore is included in the analysis.

Table 25 summarizes the results by VFD type. Although the energy savings realization rate for HVAC fans is substantially higher than shown for HVAC pumps and process pumps, this is driven largely by the savings attributed to the 200HP VFD-9. If the 200HP VFD-9 is not included in the calculations, the energy realization rate is about 55%.

Table 25. VFD summary by capacity

VFD Type	Target Annual kWh per HP	Target Annual NCP kW/HP	Target Annual CP kW/HP	M&V kWh per HP	M&V NCP kW per HP	M&V CP kW per HP	RR Energy Savings	RR NCP	RR CP
VFD HVAC Fan	1242.8	0.27	0.19	1,011.7	0.16	0.07	0.81	0.61	0.36
VFD HVAC Pump	3540.5	0.76	0.31	1,558.0	0.27	0.21	0.44	0.35	0.67
VFD Process Pump 1-50 HP	910.7	0.25	0.20	270.6	0.04	0.03	0.30	0.17	0.16

Gross Savings Analysis – Overall Realization Rates

The estimated achieved sampling precision in the realization rates for all three measure categories is shown in Table 26. Due to the higher than expected variability in the savings from the M&V activity relative to the program planning values, the achieved relative precision was higher than the targeted value.

Table 26. Realization Rate Achieved Sampling Precision

Project Type	Population Size	Sample Size	Actual Sample cv	Relative Precision
Linear Fluorescent	925	10	0.94	+/- 49%
Occupancy Sensor	672	10	0.61	+/- 31%
VFD-Fan	195	25	1.65	+/- 51%
VFD-Process	14	3	0.41	+/- 34%
VFD-Pump	54	8	0.32	+/- 17%
Total				+/- 23.1%

There are additional considerations to be made that can improve the relative precision results. The first is examination of the high coefficient of variation (CV) values in this study. The high CV for linear fluorescents is unexpected, but is related to 1) the wide variation in actual operating hours (which ranges from a low of 1,255 to nearly 8,200), and 2) discrepancies between the fixture types discovered during M&V field activities and those recorded in the tracking system. The high CV for the VFD-Fan is driven primarily by the 200HP VFD that was represented in the tracking system as a 50HP VFD. This was an early application from 2009 and was allowed despite the requirements of Prescriptive program. If the CV for the VFD-Fan is recalculated without this measure in the sample, the CV improves to 0.70, which improves the overall precision to 18.6%, as shown in Table 27.

Table 27. Realization Rate Achieved Sampling Precision with Adjusted VFD Coefficient of Variation

Project Type	Population Size	Sample Size	Actual Sample cv	Relative Precision
Linear Fluorescent	925	10	0.94	+/- 49%
Occupancy Sensor	672	10	0.61	+/- 31%
VFD-Fan	195	25	0.70	+/- 21%
VFD-Process	14	3	0.41	+/- 34%
VFD-Pump	54	8	0.32	+/- 17%
Total				+/- 18.6%

Secondly, if the high-bay lighting CV results from the earlier M&V study are included, in addition to the adjusted VFD-Fan CV, the overall precision improves further to 11.7%. The improvement in precision with these adjustments is shown in Table 28.

Table 28. Realization Rate Achieved Sampling Precision including High Bay Sample and Adjusted VFD Coefficient of Variation

Project Type	Population Size	Sample Size	Actual Sample cv	Relative Precision
Lights-Hi Bay	1,134	20	0.39	+/- 14%
Linear Fluorescent	925	10	0.94	+/- 49%
Occupancy Sensor	672	10	0.61	+/- 31%
VFD-Fan	195	25	0.70	+/- 21%
VFD-Process	14	3	0.41	+/- 34%
VFD-Pump	54	8	0.32	+/- 17%
Total				+/- 11.7%

Finally, if the precision is calculated with the original VFD-Fan CV of 1.65 and the high-bay lighting results are added, the overall precision is 13.9%, as shown in Table 29.

Table 29. Realization Rate Achieved Sampling Precision including High Bay Sample

Project Type	Population Size	Sample Size	Actual Sample cv	Relative Precision
Lights-Hi Bay	1,134	20	0.39	+/- 14%
Linear Fluorescent	925	10	0.94	+/- 49%
Occupancy Sensor	672	10	0.61	+/- 31%
VFD-Fan	195	25	1.65	+/- 51%
VFD-Process	14	3	0.41	+/- 34%
VFD-Pump	54	8	0.32	+/- 17%
Total				+/- 13.9%

Net to Gross Analysis

Freeridership

TecMarket Works utilized two different sets of questions asked of each surveyed participant which are scored independently, and then combined to estimate freeridership.

For the first set of calculations, the primary "gateway" question asks if they would have purchased the same equipment without the program and when that would have occurred. The second question within this set asks those who say they would have delayed their purchase to estimate how long they would have delayed the purchase. Together these two questions provide the foundation from the first set of questions used for estimating the level of energy impacts that are attributable to freeridership rather than savings that are program induced (net savings).

The first question within the first set of questions asked survey respondents what their behavior would have been if the Smart $aver rebate had not been available. The four categories of responses were:

a.) bought the same unit at the same time
b.) bought the same unit at a later time
c.) bought a used unit at the same time
d.) continued to use the currently installed unit and not purchase a new or used unit

The breakdown of responses to the gateway question can be seen in Table 30. Participants who indicated that they would have bought the same unit at the same time were assigned 100% freeridership. Participants answering that they would have continued using the currently installed unit were assigned 0% freeridership.

Freeridership for participants who indicated that they would have bought their units at a later time are asked an additional question for determining when they would have purchased the units in the absence of the program. Each response to this question was converted to a foundation freerider percentage as presented in Table 30 separately for Linear Fluorescent Lighting (FL), Occupancy Sensors (OS) and Variable Frequency Drives (VFD).

From the foundational set of questions, the equivalent freerider rate (the number of units that count toward freeridership) in the case of customers who indicated they would have purchased the unit at a later time, is the product of the freerider percentage multiplied by the number of respondents/units (each respondent was surveyed about one recently installed unit).

Table 30. Program Freeridership by Rebated Measure

Gateway Question Response	Linear Fluorescent Lighting Count (Responders)	Occupancy Sensor Count (Responders)	Variable Frequency Drive Count (Responders)
Same unit at same time (100% freerider)	10 (10)	2 (2)	3 (3)
Same unit within 6 months (75% freerider)	0 (0)	0 (0)	0 (0)
Same unit 6-12 months later (50% freerider)	0 (0)	0 (0)	0 (0)
Same unit 12-24 months later (25% freerider)	7 (1.75)	1 (0.25)	0 (0)
Same unit more than 24 months later (0% freerider)	3 (0)	2 (0)	0 (0)
Same unit, don't know when (mean % freerider of the five rows above = 58.8% for Fluorescent Lighting, 45.0% for Occupancy Sensors, 100% for VFD)	4 (2.35)	1 (0.45)	1 (1)
Used unit at the same time or later time (same as row above = 100% for VFD)[12]	0 (0)	0 (0)	1 (1)
Continued using old unit (0% freerider)	10 (0)	6 (0)	1 (0)
TOTAL COUNT	**34**	**12**	**6**
Freeriders	**14.1**	**2.70**	**5**
Freerider %	**41.5%**	**22.5%**	**83.3%**

The second set of freerider calculations is based on an additional set of questions which ask what participants would have done without the Smart $aver incentive, and without the Smart $aver program information and technical assistance.

The three categories of responses to these questions were:

a.) bought unit with at least the same efficiency level
b.) bought a unit with a different efficiency level
c.) not sure what organization would have done

The breakdown of responses to these questions can be seen in Table 31 and Table 32. Participants who indicated that they would have bought the same efficiency level without the incentive or program information were assigned the average freeridership calculated for participants who said they would purchase the same unit in Table 30: 58.8% for Fluorescent Lighting (FL), 45.0% for Occupancy Sensors (OS) and 100% for Variable Frequency Drives

[12] Used VFD units in the category: "Used unit at the same time or later time" are treated as new units in the category: "same unit, don't know when" for computing freeridership.

(VFD). Participants answering that they would have selected a different efficiency level were assigned 0% freeridership.

Table 31. Program Freeridership Based on Financial Incentive by Rebated Measure

Response for "without financial incentive"	Linear Fluorescent Lighting Count (Responders)	Occupancy Sensor Count (Responders)	Variable Frequency Drive Count (Responders)
Would have selected same efficiency level without financial incentive (freerider percent based on planned time of purchase: 58.8% FL, 45.0% OS, 100% VFD)[13]	19 (11.16)	4 (1.80)	4 (4)
Would have made a different choice without financial incentive (freerider 0%)	11 (0)	6 (0)	1 (0)
Not sure what company would have done without financial incentive (freerider percent based on mean of two columns above)	4 (1.49)	2 (0.36)	1 (0.80)
TOTAL COUNT	**34**	**12**	**6**
Freeriders	**12.65**	**2.16**	**4.80**
Freerider %	**37.2%**	**18.0%**	**80.0%**

Table 32. Program Freeridership Based on Information and Assistance by Rebated Measure

Response for "without program information and technical assistance"	Linear Fluorescent Lighting Count (Responders)	Occupancy Sensor Count (Responders)	Variable Frequency Drive Count (Responders)
Would have selected same efficiency level without program information/technical assistance (freerider percent based on planned time of purchase: 58.8% FL, 45.0% OS, 100% VFD)[14]	16 (9.40)	7 (3.15)	4 (4)
Would have made a different choice without program information/technical assistance (freerider 0%)	8 (0)	3 (0)	1 (0)
Not sure what company would have done without program	10 (3.92)	2 (0.63)	1 (0.80)

[13] These percentages represent the average freeridership of respondents indicating they would purchase the same unit as seen in row 5 of Table 30.
[14] These percentages represent the average freeridership of respondents indicating they would purchase the same unit as seen in row 5 of Table 30.

information/technical assistance (freerider percent based on mean of two columns above)			
TOTAL COUNT	**34**	**12**	**6**
Freeriders	**13.32**	**3.78**	**4.80**
Freerider %	**39.2%**	**31.5%**	**80.0%**

Since the program included both an incentive payment and technical assistance/program information, each of which can motivate a decision to go with the more efficient choice, a two path analysis approach was used for assessing freeridership within the second set of questions. One path was scored for the influence of the incentive and another path was scored for the analysis of the effect of the technical assistance or program information. The final per-participant freeridership estimate is the lower of the two estimates from each of the two paths. These results are presented for each measure in Table 31 and Table 32. Thus, freeridership for the Smart $aver program is estimated at 37.2% for Fluorescent Lighting, 18.0% for Occupancy Sensors and 80.0% for Variable Frequency Drives. Note that this freerider analysis was conducted using a sample of surveyed participants. The evaluation plan was not designed to achieve statistically significant estimates of freeridership at the measure level. These values are shown for informational purposes only. Only the overall program freeridership should be used.

Validity and Reliability of the Freerider Estimation Approach

The field of freeridership assessment as specified in the California Evaluation Protocols basic estimation approach requires the construction of questions that allow the evaluation contractor to estimate the level of freeridership. The basic approach used in this evaluation is based on the results of a set of freerider questions incorporated into participant survey instruments that meets the reliability standards for freerider questions. The approach used in this assessment examines the various ways in which the program impacts the customer's acquisition and use of equipment incented as part of the Non-Residential Smart $aver Prescriptive program, and allocates a freeridership factor for each of the types of responses contained in the survey questions. The allocation approach assigns high freeridership values to participants who would have acquired the same equipment on their own, and that factor is influenced by their stated intentions regarding the timing and efficiency level of this acquisition. The scoring approach is proportional to the degree to which the participant would have acquired and used equivalent equipment on their own.

Spillover

In order to estimate the spillover savings attributed to the program several questions were added to the participant questionnaire. These questions were asked to determine the extent to which the program's information and incentives caused additional non-incented spillover actions to be taken by the participants. A total of 52 survey participants answered the net to gross question battery.

Survey participants were asked if they had taken any actions above and beyond those rebated by the program at their company or at any other locations. If the respondent indicated that they had not purchased or installed any other type of high efficiency equipment or made energy efficiency improvements since their participation in the program, the spillover level was set to zero and no spillover credit was provided. Respondents that had taken additional measures were asked about the type of equipment and where it was installed. However, no spillover was provided to those respondents that took additional actions unless they also indicated that their experience with the program caused, to some degree, the action to be taken by rating the influence of their experience with the program on their decision to do so on a scale from one to ten with ten being the most influential. This rating is referred to as the participant's attribution score.

If a participant indicated that the program was influential in their purchase and use decision, then their spillover savings was adjusted by the fractional amount of the strength of their attribution score. That is, if the respondent indicated an attribution score of seven out of ten, then their spillover savings were multiplied by 0.7 to estimate their spillover contribution to the program net to gross ratio.

Table 33. Spillover Measures and Attribution

Measure	Quantity	Attribution Score	EUL[15]	kWh Savings	Spillover kWh Savings
T8 lighting	88	9	12	5,201	4,681
Occupancy sensors	12	9	10	5,884	5,296
Occupancy sensors	80	8	10	39,233	31,386
Occupancy sensors	11	8	10	5,395	4,316
T5 lighting	30	7	12	954	668
T8 lighting	20	10	12	1,182	1,182
T8 lighting	188	10	12	11,111	11,111
Occupancy sensors	10	7	10	4,904	3,433
TOTAL/AVERAGE		**8.5**	**10.5**	**73,865**	**62,073**

Table 33 shows each measure taken by the 52 survey participants for which enough information was provided to calculate energy savings. Spillover energy savings were estimated from the customer description of the measure taken and ex-ante savings estimates from Duke Energy work papers for that measure. The expressed spillover actions taken as a result of the program and the associated savings were not subjected to ex-post evaluation or verification inspections. Actions taken by respondents that provided insufficient data to estimate impact received zero spillover credit. That is, it is likely that spillover savings are higher than those reported above, however, beause of the inability to obtain enough information on the configuration and use of these actons, we do not estimate or credit any savings toward those actions. Actions that were determined, or believed, to be implemented outside of Duke Energy territory also received zero spillover credit. Furthermore, spillover estimates are limited to only those measures that are eligible to receive a rebate through the program. Although the spillover savings were not subject to ex-post evaluation, the approach taken is believed to provide the spillover estimates that are significantly below the actual achieved spillover savings.

Figure 5 graphically shows the estimated spillover impacts over the lifetime of the spillover measures. The only spillover measures reported are linear fluorescents and occupancy sensors.

[15] EUL = Effective Useful Life

Thus, a large drop-off occurs at ten years when the occupancy sensors reach the end of their Effective Useful Life (EUL). Savings continue to year 12, the end of the linear fluorescent EUL.

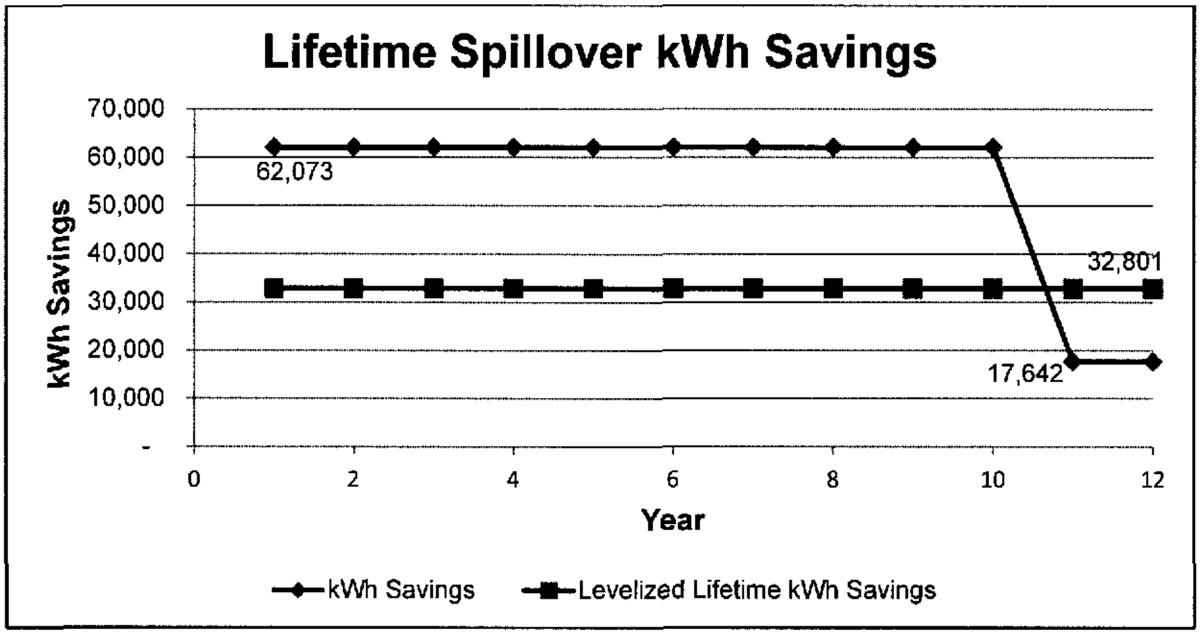


Figure 5. Lifetime Spillover kWh Savings

Table 34 shows the spillover percentage for the program of 6.6%.

Table 34. Spillover Percentage

Survey Respondent kWh Savings Excluding Spillover	Survey Respondent Spillover kWh savings	Spillover Percentage
946,097	62,073	6.6%

While TecMarket Works notes that the spillover savings documented in this report are lower than actually achieved, it should be understood that the assignment of spillover is, to a limited degree, subjective in that its accuracy depends on the ability of the attribution score to accurately estimate the degree of causation as well as the recall ability of the participant. However, the overall average causation score for the assessed spillover cause is high. That is, on average the attribution score provided by participants is 8.5 on a 10 point scale. This score represents that this program has significant influence on participants' actions well beyond those measures incented by the program.

The study of the Non-Residential Smart $aver Prescriptive Program in the Carolina System showed spillover values that were much higher than those observed in Ohio. This is the result of three very large projects that received high attribution scores from survey participants. Efforts were made to eliminate projects from spillover consideration that were rebated through another program or the same program at a later date. Because there was no indication that this was the case with any of the three and there was enough information to estimate spillover, these projects were included. If these three very large projects are not counted, spillover levels between Ohio and the Carolina System look very similar (6.6% compared to 7.3%).

Program Net to Gross Adjustment

To estimate the overall program-level net to gross adjustment, it is necessary to first determine the weighted average program freeridership. For the purposes of this calculation, high bay lighting is included. Including high bay lighting provides a more accurate estimate of the overall program freeridership. Linear fluorescents accounted for 14%, occupancy sensors accounted for 18%, VFDs accounted for 21%, and high bay lighting accounted for 47% of the total kWh savings achieved. The average program wide net to gross ratio for this program is 0.682. It should be noted that this net to gross ratio only includes adjustments for free ridership and short term participant spillover. Estimates for short and long term non-participant spillover and short and long term market effects are not included in this study and would be savings in addition to that documented in this report. While a short term participant net-to-gross ratio of 0.682 indicates the program saved less energy that what is reflected in the gross energy projected savings estimates, this savings level is only part of the savings that are achieved by energy efficiency programs. Additional evaluation efforts are needed to document short and long term non-participant spillover and short and long term market effects.

Freeridership scores presented in this report are weighted by their measure's contribution to overall kWh savings and calculated as follows:

Program Freeridership = (14% * Linear Fluorescent FR) + (18% * Occupancy Sensor FR)
+ (21% * VFD FR) + (47% * High Bay FR)
= (14% * 37.2%) + (18% * 18.0%) + (21% * 80.0%) + (47% * 28%[16])
= 38.4%

The net to gross ratio is then calculated as follows:

NTGR = 1 + (spillover – freeridership)
= 1+ (0.066 - 0.384)
= 0.682

The program level gross savings is discounted (1 – NTGR) by 31.8% to yield the total net savings.

Total Gross and Net Impacts

The total first year gross and net savings are tabulated for each of the measures studied in the evaluation. These estimates were calculated by applying the gross realization rates for kWh, NCP kW and CP kW to the program planning estimates for each measure. The evaluated first year gross and net impacts are summarized in Table 35.

[16] Evaluation of the Non-Residential Smart $aver Prescriptive Program in Ohio, August 29, 2010.

Table 35. First Year Gross and Net Savings by Measure

Metric	Result
Number of Program Participants from 1-1-2009 to 2-29-2012	2439 Projects
Gross Coincident Peak kW per unit	kW/unit
HPT8 4ft 2 lamp, T12 to HPT8	0.033
HPT8 4ft 2 lamp, T8 to HPT8	0.012
Low Watt T8 lamps, 4ft	0.006
LW HPT8 4ft 2 lamp, replace T8	0.015
LW HPT8 4ft 4 lamp, replace T8	0.027
LW HP T-8 4ft 1L replace T-8 4ft 1L	0.010
LW HP T-8 4ft 2L replace T-8 4ft 2L	0.015
LW HP T-8 4ft 4L replace T-8 4ft 4L	0.027
T8 2ft 2 lamp	0.036
T8 4ft 2 lamp	0.019
T8 4ft 4 lamp	0.047
T8 8ft 2 lamp	0.021
Occupancy Sensors under 500 W	0.123
Occupancy Sensors over 500 W	0.302
VFD HVAC Fan	0.070
VFD HVAC Pump	0.207
VFD Process Pump 1-50 HP	0.033
Gross kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	191.6
HPT8 4ft 2 lamp, T8 to HPT8	72.4
Low Watt T8 lamps, 4ft	35.0
LW HPT8 4ft 2 lamp, replace T8	86.0
LW HPT8 4ft 4 lamp, replace T8	154.8
LW HP T-8 4ft 1L replace T-8 4ft 1L	60.2
LW HP T-8 4ft 2L replace T-8 4ft 2L	86.0
LW HP T-8 4ft 4L replace T-8 4ft 4L	154.8
T8 2ft 2 lamp	206.3
T8 4ft 2 lamp	111.8
T8 4ft 4 lamp	275.1
T8 8ft 2 lamp	120.4
Occupancy Sensors under 500 W	273.5
Occupancy Sensors over 500 W	684.8

Metric	Result
VFD HVAC Fan	1011.7
VFD HVAC Pump	1558.0
VFD Process Pump 1-50 HP	270.6
Gross therms per unit	N/A
Freeridership rate	38.40%
Spillover rate	6.60%
Self Selection and False Response rate	0.00%
Total Discounting to be applied to Gross values	68.20%
Net Coincident Peak kW per unit	kW/unit
HPT8 4ft 2 lamp, T12 to HPT8	0.023
HPT8 4ft 2 lamp, T8 to HPT8	0.008
Low Watt T8 lamps, 4ft	0.004
LW HPT8 4ft 2 lamp, replace T8	0.010
LW HPT8 4ft 4 lamp, replace T8	0.018
LW HP T-8 4ft 1L replace T-8 4ft 1L	0.007
LW HP T-8 4ft 2L replace T-8 4ft 2L	0.010
LW HP T-8 4ft 4L replace T-8 4ft 4L	0.018
T8 2ft 2 lamp	0.025
T8 4ft 2 lamp	0.013
T8 4ft 4 lamp	0.032
T8 8ft 2 lamp	0.014
Occupancy Sensors under 500 W	0.084
Occupancy Sensors over 500 W	0.206
VFD HVAC Fan	0.048
VFD HVAC Pump	0.141
VFD Process Pump 1-50 HP	0.023
Net kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	130.7
HPT8 4ft 2 lamp, T8 to HPT8	49.4
Low Watt T8 lamps, 4ft	23.9
LW HPT8 4ft 2 lamp, replace T8	58.7
LW HPT8 4ft 4 lamp, replace T8	105.6
LW HP T-8 4ft 1L replace T-8 4ft 1L	41.1
LW HP T-8 4ft 2L replace T-8 4ft 2L	58.7
LW HP T-8 4ft 4L replace T-8 4ft 4L	105.6
T8 2ft 2 lamp	140.7

Metric	Result
T8 4ft 2 lamp	76.2
T8 4ft 4 lamp	187.6
T8 8ft 2 lamp	82.1
Occupancy Sensors under 500 W	186.5
Occupancy Sensors over 500 W	467.0
VFD HVAC Fan	690.0
VFD HVAC Pump	1062.6
VFD Process Pump 1-50 HP	184.5
Net therms per unit	N/A
Measure Life	12yr (linear fluorescent) 10yr (occupancy sensor)

Lifecycle savings were estimated by applying the following EUL assumptions[17] to each measure.

Table 36. Effective Useful Life for Lighting Measures

Measure	EUL (years)
Linear Fluorescent	12
Occupancy Sensor	10
VFD	15

Applying the EUL estimates listed above to each measure, the lifecycle gross and net kWh savings are shown in Table 37.

[17] EUL data taken from Duke Energy workpapers prepared by Franklin Energy Systems.

Table 37. Gross and Net Lifecycle Savings

Metric	Result
Number of Program Participants from 1-1-2009 to 2-29-2012	2439 Projects
Gross lifecycle kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	2,299
HPT8 4ft 2 lamp, T8 to HPT8	869
Low Watt T8 lamps, 4ft	420
LW HPT8 4ft 2 lamp, replace T8	1,032
LW HPT8 4ft 4 lamp, replace T8	1,858
LW HP T-8 4ft 1L replace T-8 4ft 1L	722
LW HP T-8 4ft 2L replace T-8 4ft 2L	1,032
LW HP T-8 4ft 4L replace T-8 4ft 4L	1,858
T8 2ft 2 lamp	2,476
T8 4ft 2 lamp	1,342
T8 4ft 4 lamp	3,301
T8 8ft 2 lamp	1,445
Occupancy Sensors under 500 W	2,735
Occupancy Sensors over 500 W	6,848
VFD HVAC Fan	15,176
VFD HVAC Pump	23,370
VFD Process Pump 1-50 HP	4,060
Net lifecycle kWh per unit	kWh/unit
HPT8 4ft 2 lamp, T12 to HPT8	1,361
HPT8 4ft 2 lamp, T8 to HPT8	514
Low Watt T8 lamps, 4ft	249
LW HPT8 4ft 2 lamp, replace T8	611
LW HPT8 4ft 4 lamp, replace T8	1,100
LW HP T-8 4ft 1L replace T-8 4ft 1L	428
LW HP T-8 4ft 2L replace T-8 4ft 2L	611
LW HP T-8 4ft 4L replace T-8 4ft 4L	1,100
T8 2ft 2 lamp	1,466
T8 4ft 2 lamp	794
T8 4ft 4 lamp	1,954
T8 8ft 2 lamp	855
Occupancy Sensors under 500 W	1,619
Occupancy Sensors over 500 W	4,054

Metric	Result
VFD HVAC Fan	8,984
VFD HVAC Pump	13,835
VFD Process Pump 1-50 HP	2,403
Measure Life	12yr (linear fluorescent) 10yr (occupancy sensor) 15yr (VFD)

Conclusions and Recommendations for Program Changes

Significant Impact Evaluation Findings for Linear Fluorescent Measures

- Energy and coincident peak demand savings realization rates for kWh and coincident peak kW for linear fluorescent lighting were 1.89 (energy) and 1.61 (demand) respectively, indicating the program planning estimates were conservative estimates of linear fluorescent lighting savings.
- Measurement and verification (M&V) activities conducted for this study produced an estimate of 5,155 lighting equivalent full load hours (EFLH), compared to a program planning estimate of 4,144 EFLH.
- M&V activities estimated a coincidence factor (CF) of 0.80, compared to a program planning estimate of 0.77.
- Although there were some small differences between the quantity of fixtures recorded in the Duke Energy program tracking database versus the number of fixtures in the field, the overall installation verification rate was 1.00.
- Program planning and M&V estimates of baseline fixture wattage were within 1%. M&V estimates of efficient fixture watts were an average of about 7% lower than program planning estimates, indicating conservative values of fixture watts were used during program design.

Significant Impact Evaluation Findings for Occupancy Sensor Measures

- Energy and coincident peak demand savings realization rates for kWh and kW for occupancy sensor measures were 0.56 and 1.21 respectively, indicating the program planning estimates were conservative estimates of occupancy sensor coincident peak kW savings, but overestimated occupancy sensor kWh savings.
- M&V activities conducted for this study produced an estimate of 3,078 lighting equivalent full load hours (EFLH) before the installation of occupancy sensors, compared to a program planning estimate of 4,144 EFLH.
- M&V activities produced an estimate of connected lighting kW per occupancy sensor that was 31% lower than the program assumption. Many of the occupancy sensors in the study were controlling a single fixture, which contributed to the reduced connected watts per sensor.
- M&V activities estimated an average kWh savings of 54% of the uncontrolled consumption and an average kW savings of 46% of the uncontrolled demand, compared to the program estimate of 30% for both kWh and kW. Although the kW savings as a percentage of the baseline estimated from M&V was higher, the connected load per sensor was less, thus the overall demand savings per sensor from M&V was less than the program estimate.

Significant Impact Evaluation Findings for VFD Measures

VFD energy and coincident peak demand savings realization rates were lower than program planning estimates. On average, the realization rates for energy, non-coincident peak, and peak demand savings were about 62, 46, and 43% respectively. HVAC fans had the highest realization rates, and process pumping had the lowest realization rate

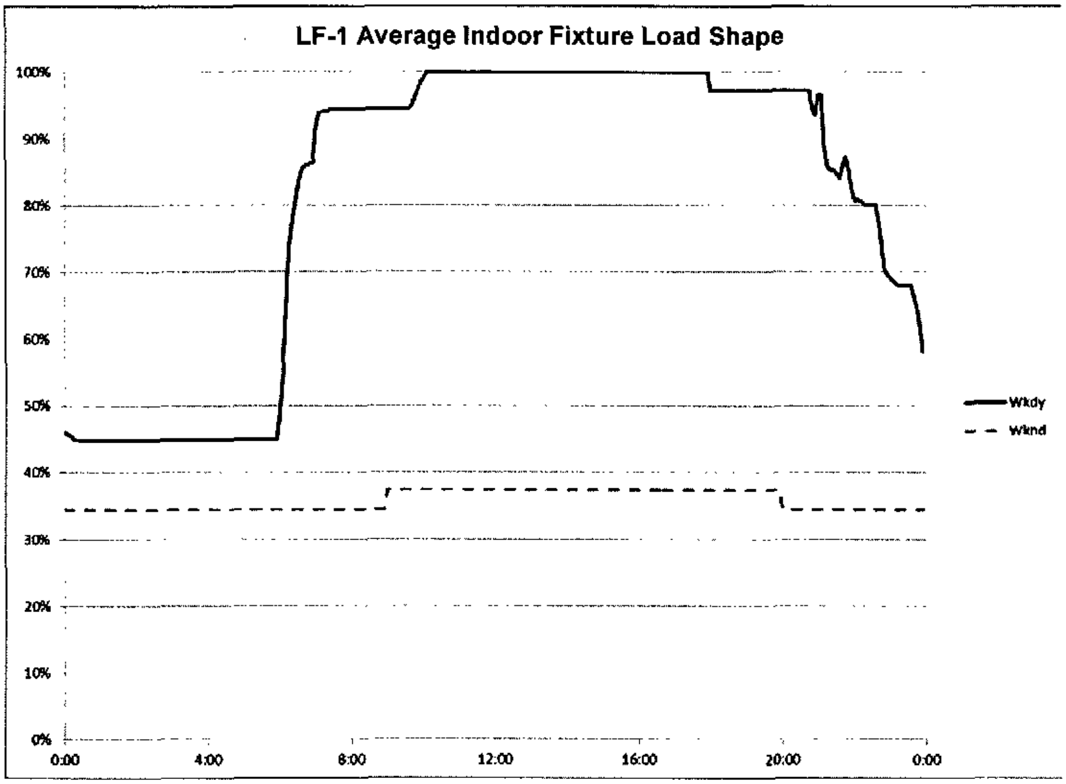
Based on the results of the impact evaluation, the TecMarket Works team has the following recommendations:

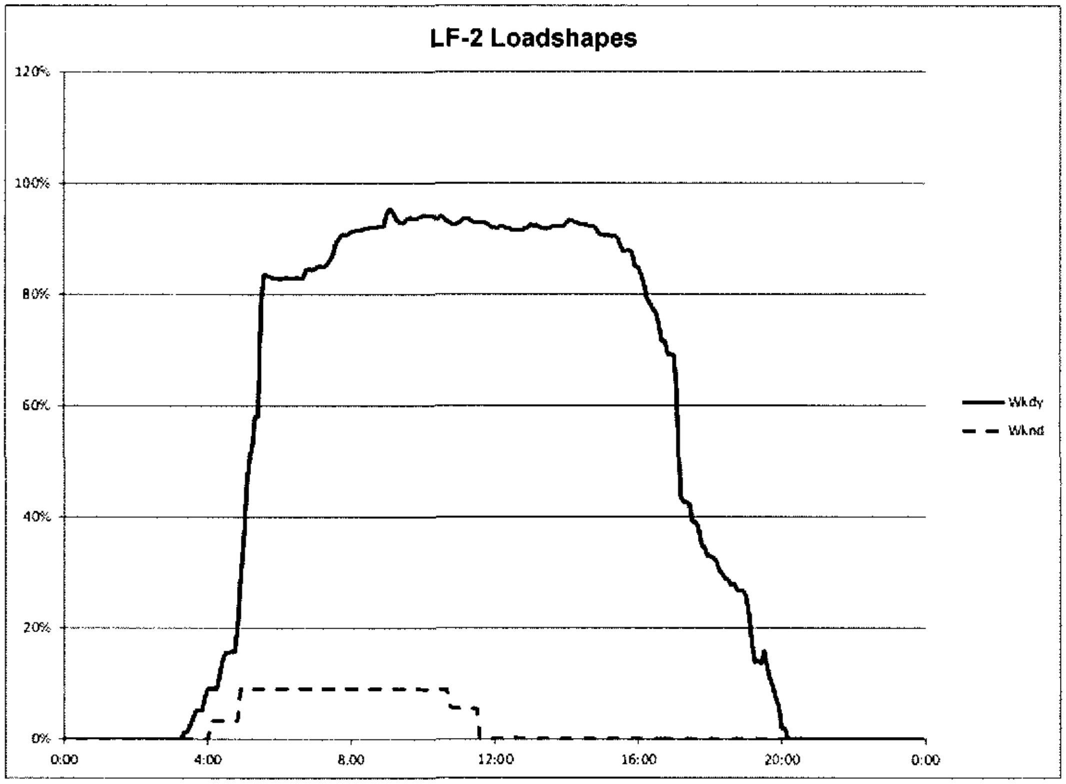
1. Conservative estimates of lighting EFLH should be updated with M&V results.
2. The weighted average self-reported operating hours were 4,944 EFLH, which represents a better estimate of lighting EFLH than the standard estimate of 4,144 EFLH. Consider including the self-reported operating hours in the ex-ante estimates of measure savings.
3. The measured coincidence factor of 0.80 was slightly higher than the program planning estimate of 0.77. Consider revising the coincidence factor assumption to 0.80 for future program planning activities.
4. The M&V savings for VFDs was significantly lower than program estimates, especially for HVAC pumps and process pumps. Consider reducing the annual savings estimates to the M&V results.

Appendix A: Load Shapes

Average weekday and weekend/holiday load shapes from the logger data are shown for each site in the study.

Linear Fluorescent Sites




LF-2 Loadshapes
120%
100%
80%
60%
40%
20%
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4:00
8:00
12:00
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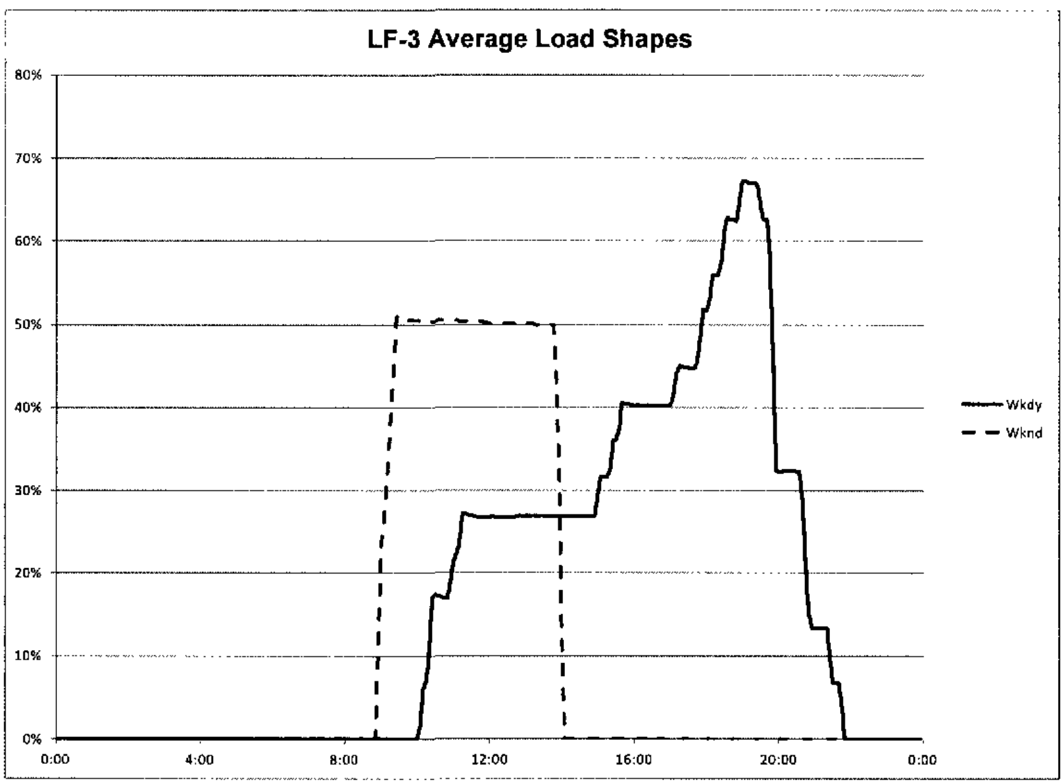
0:00
Wkdy
Wknd


LF-3 Average Load Shapes
80%
70%
60%
50%
40%
30%
20%
10%
0%
0:00
4:00
8:00
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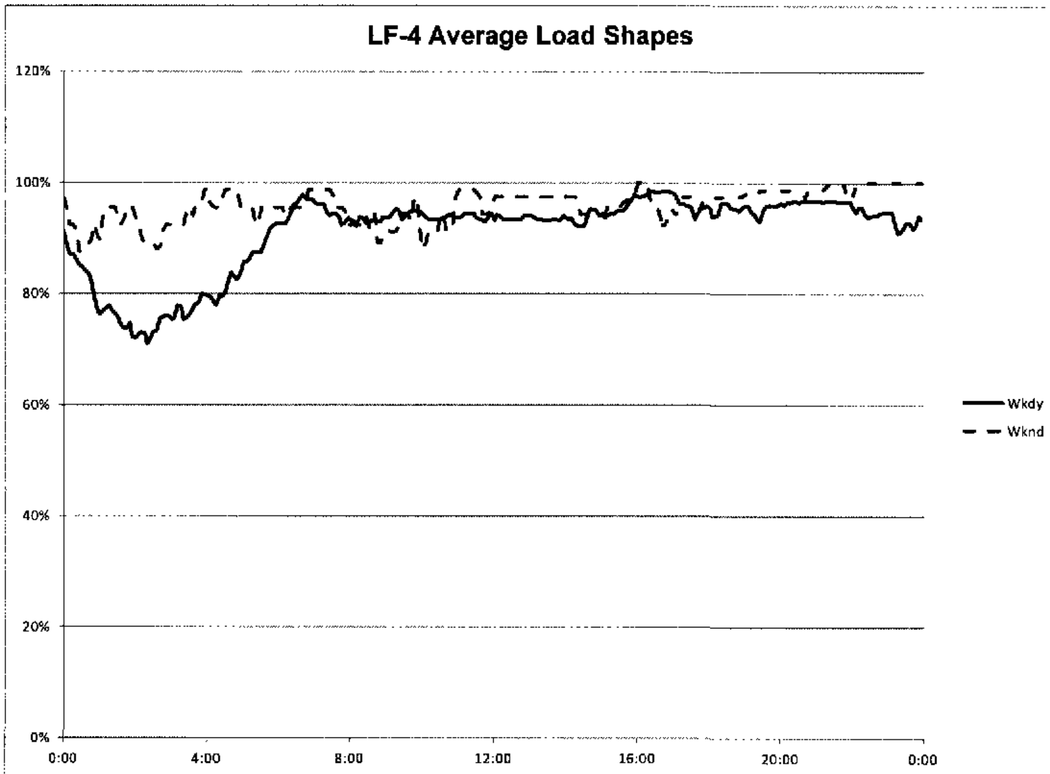
0:00
Wkdy
Wknd


LF-4 Average Load Shapes
120%
100%
80%
60%
40%
20%
0%
0:00
4:00
8:00
12:00
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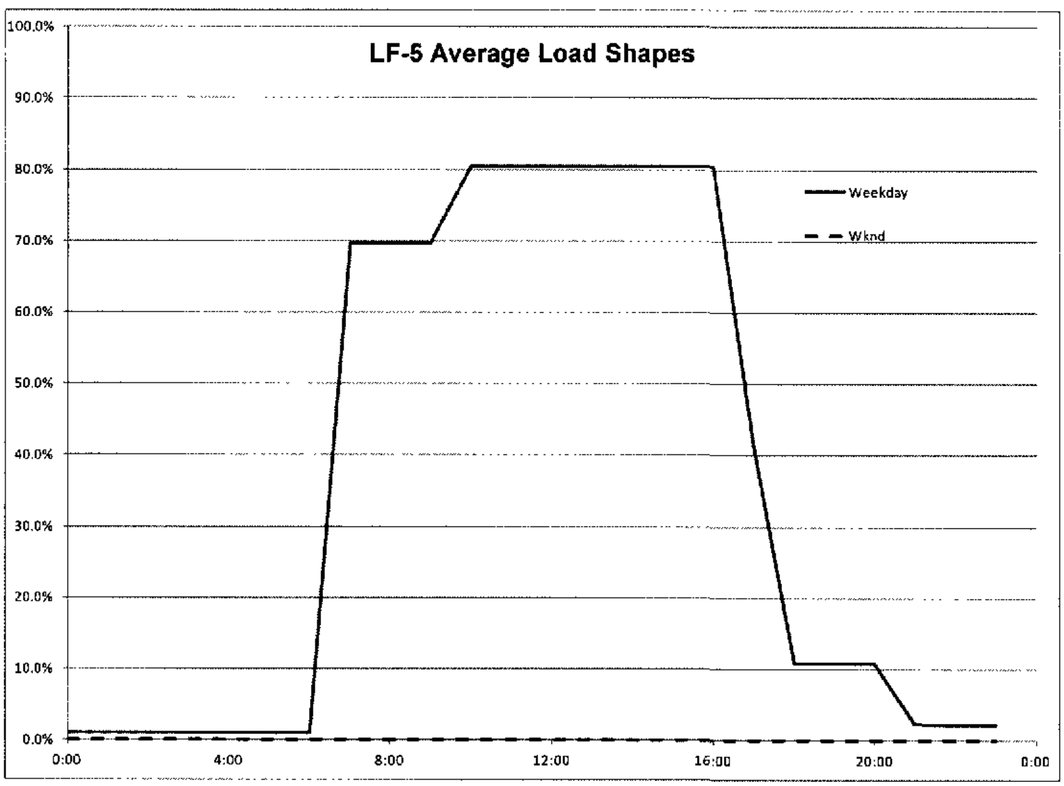
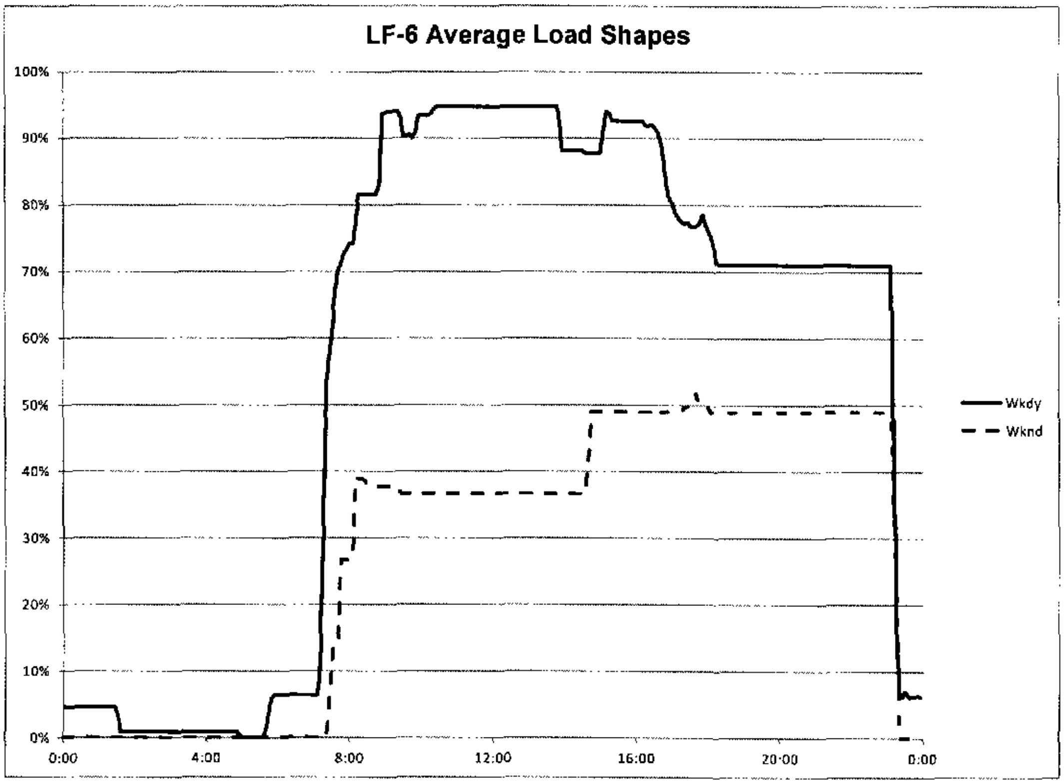
0:00
Wkdy
Wknd


LF-5 Average Load Shapes
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Weekday
Wknd


LF-6 Average Load Shapes
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90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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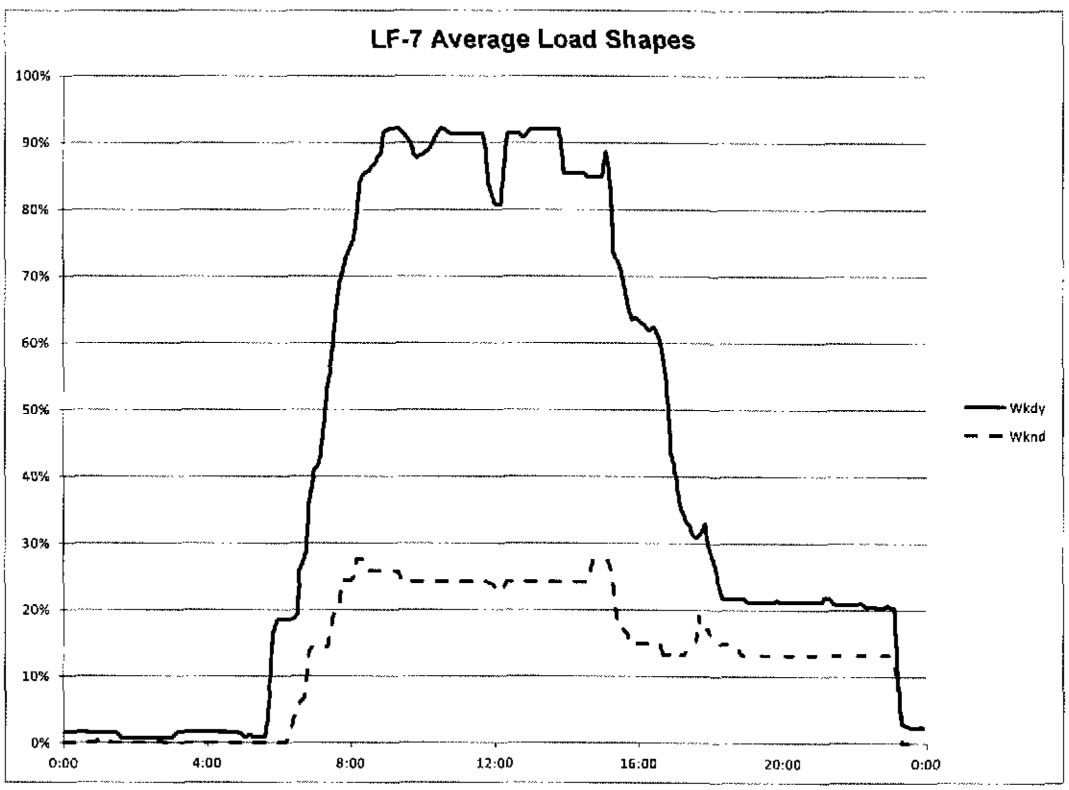
0:00
Wkdy
Wknd


LF-7 Average Load Shapes
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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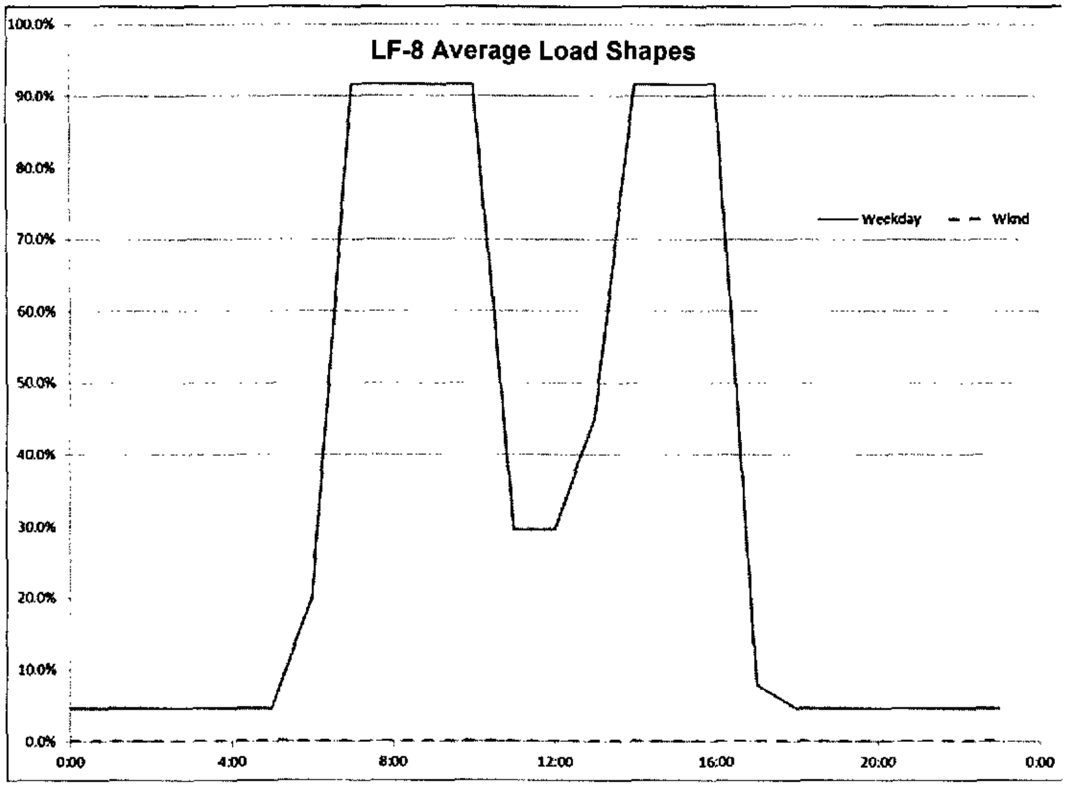
0:00
Wkdy
Wknd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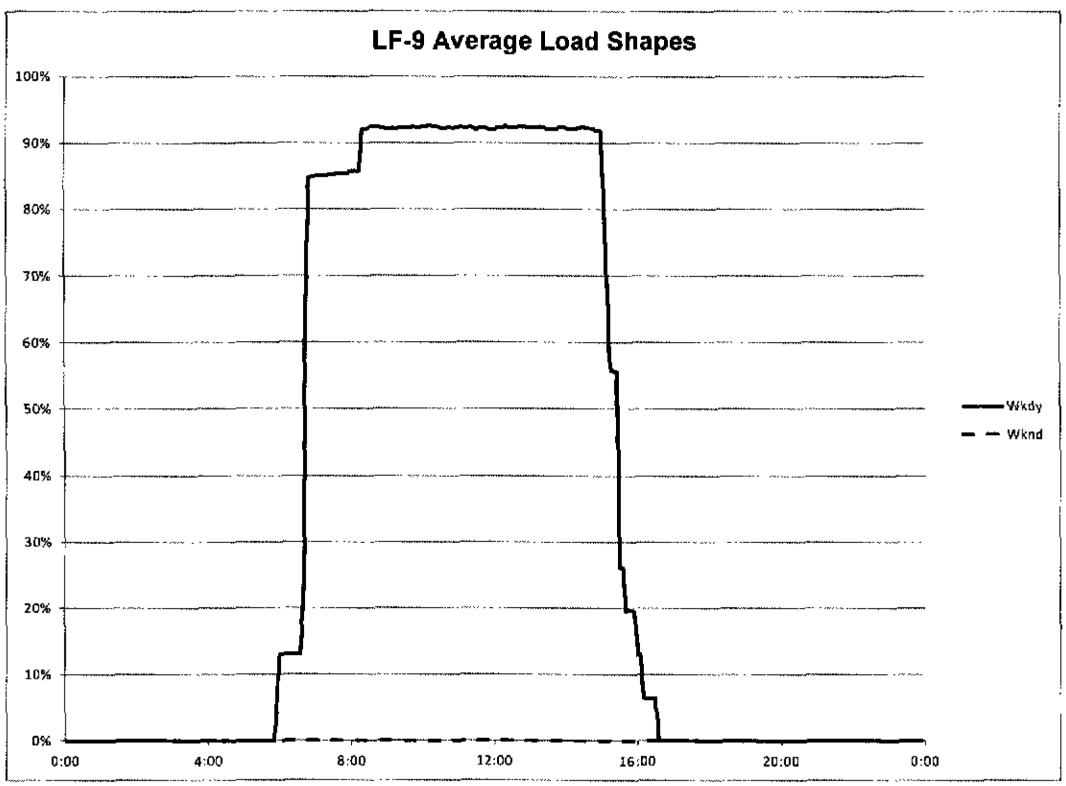
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Weekday
Wknd


LF-9 Average Load Shapes
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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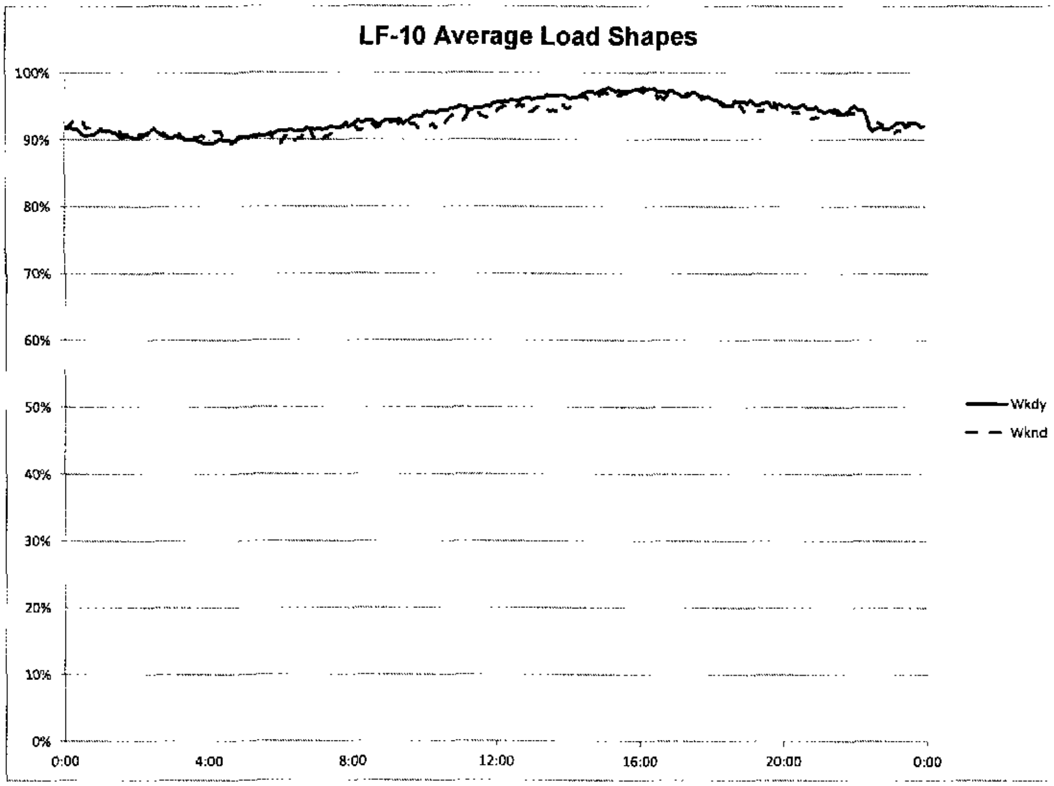
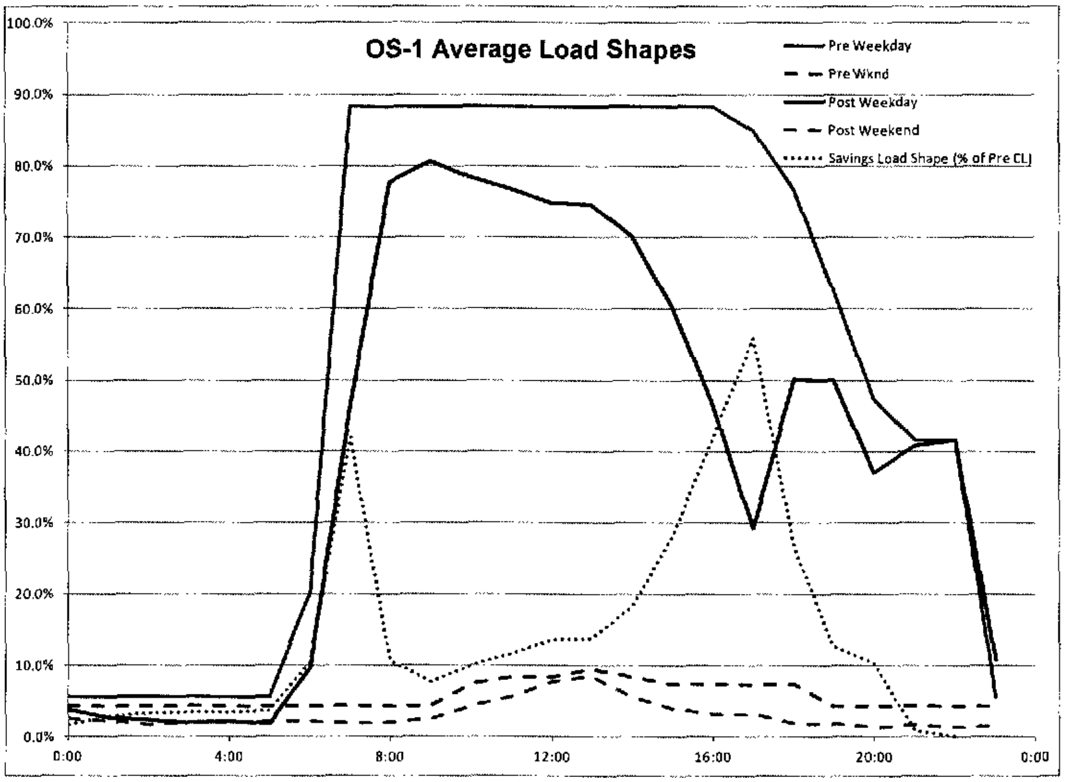
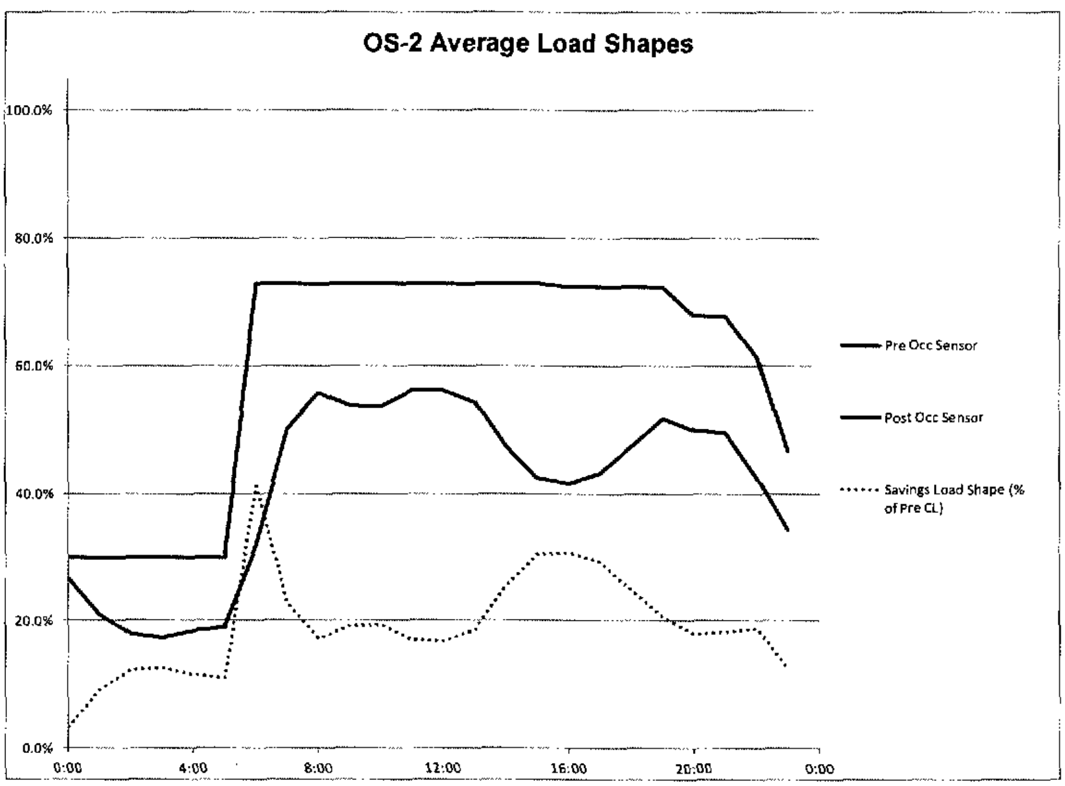
0:00
Wkdy
Wknd

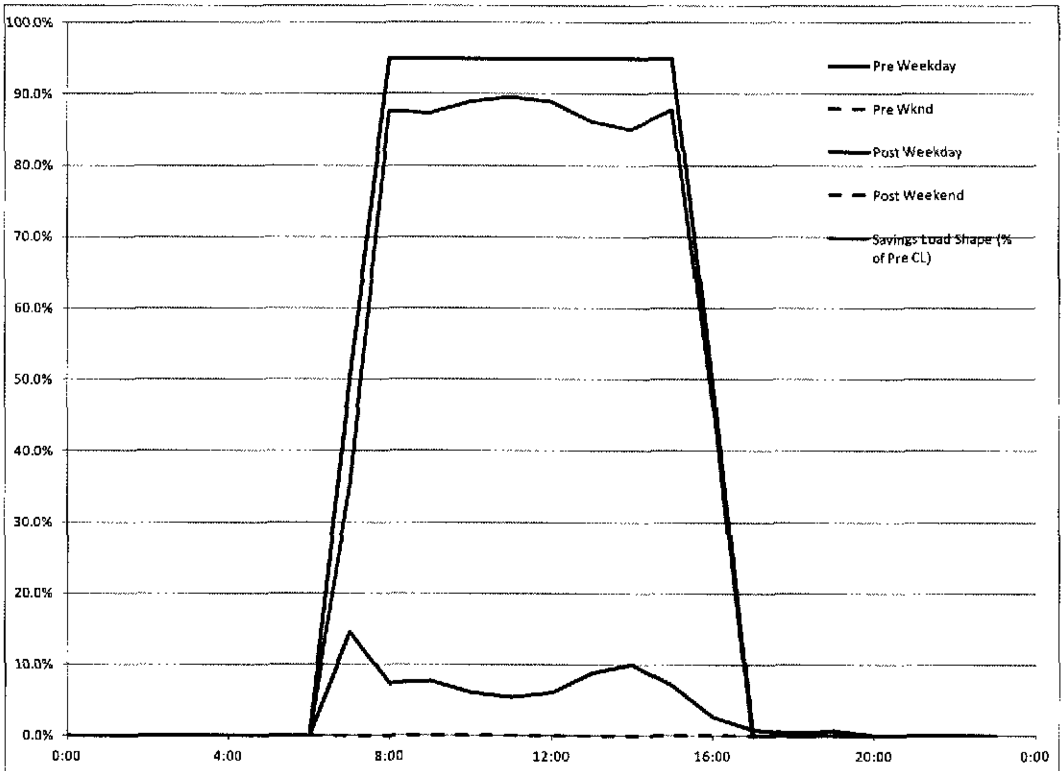

LF-10 Average Load Shapes
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Wkdy
Wknd

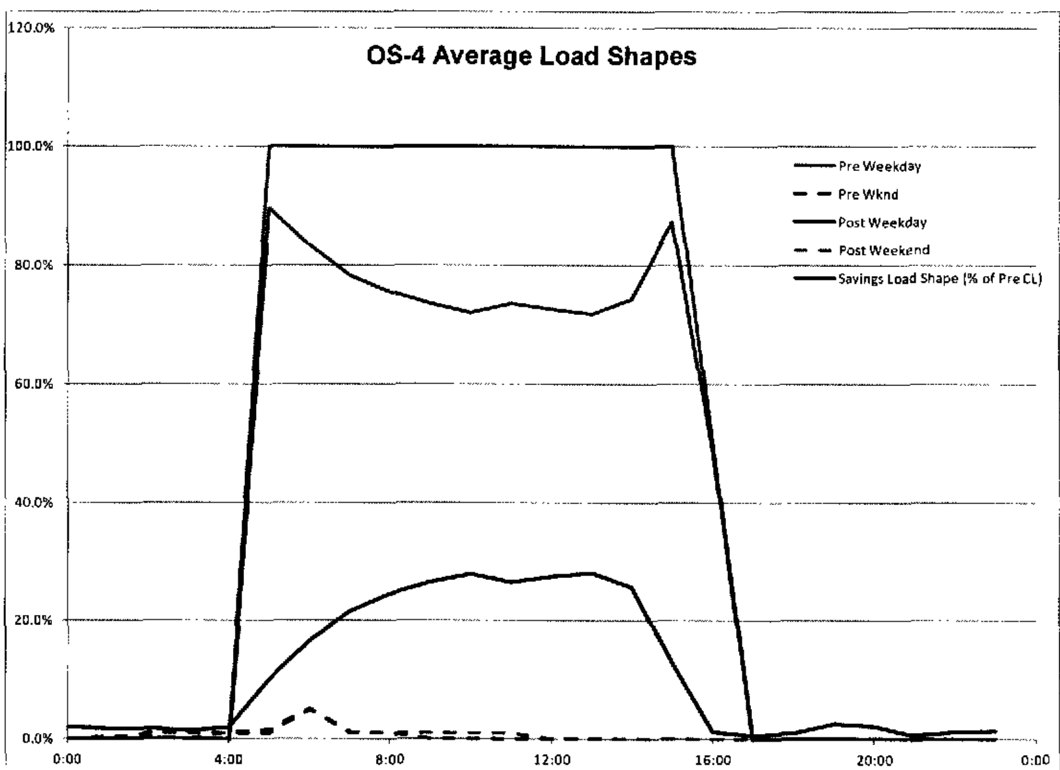
Occupancy Sensor Sites

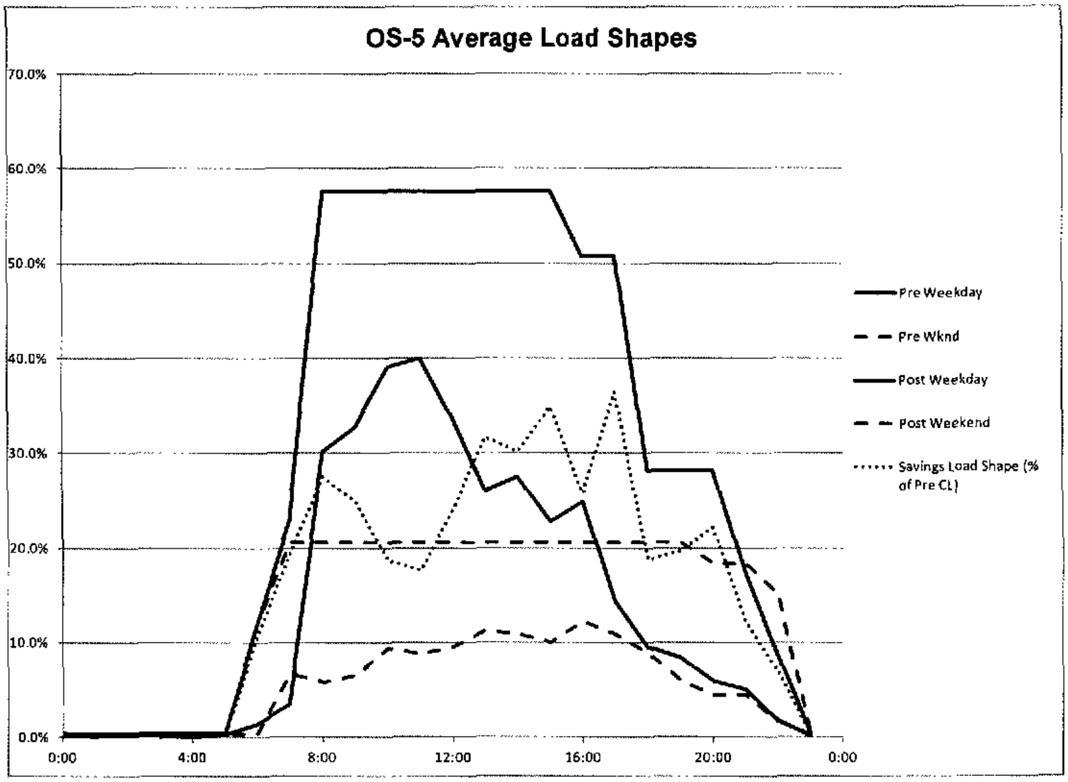


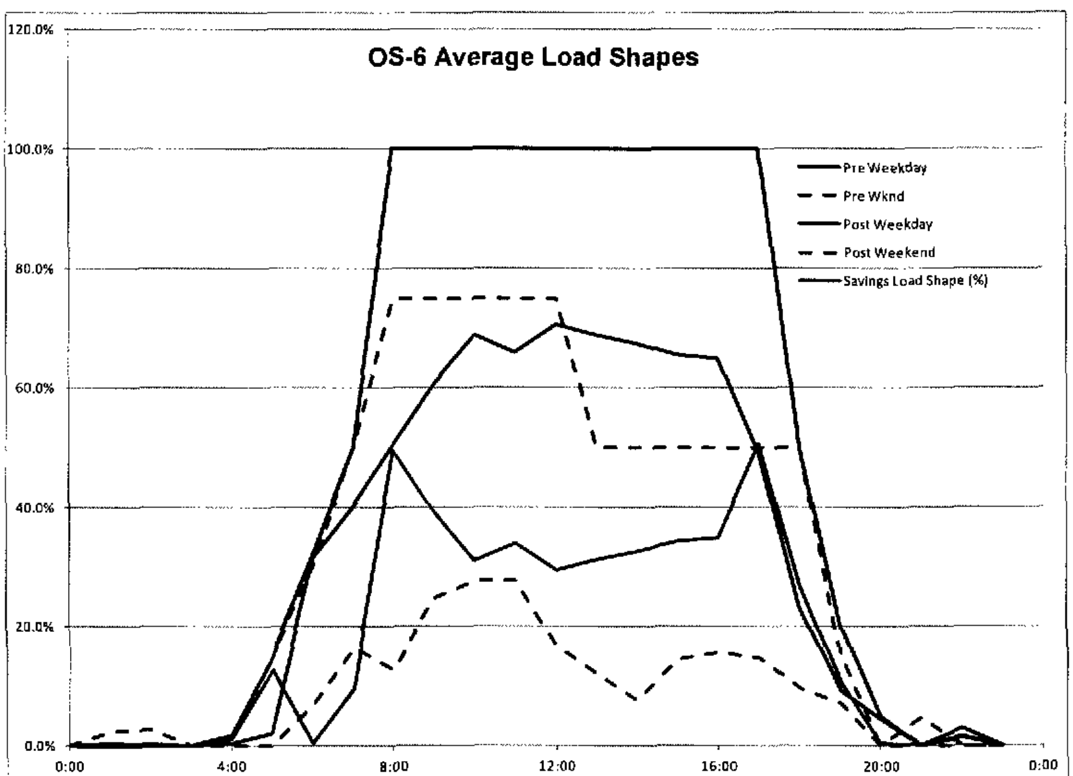


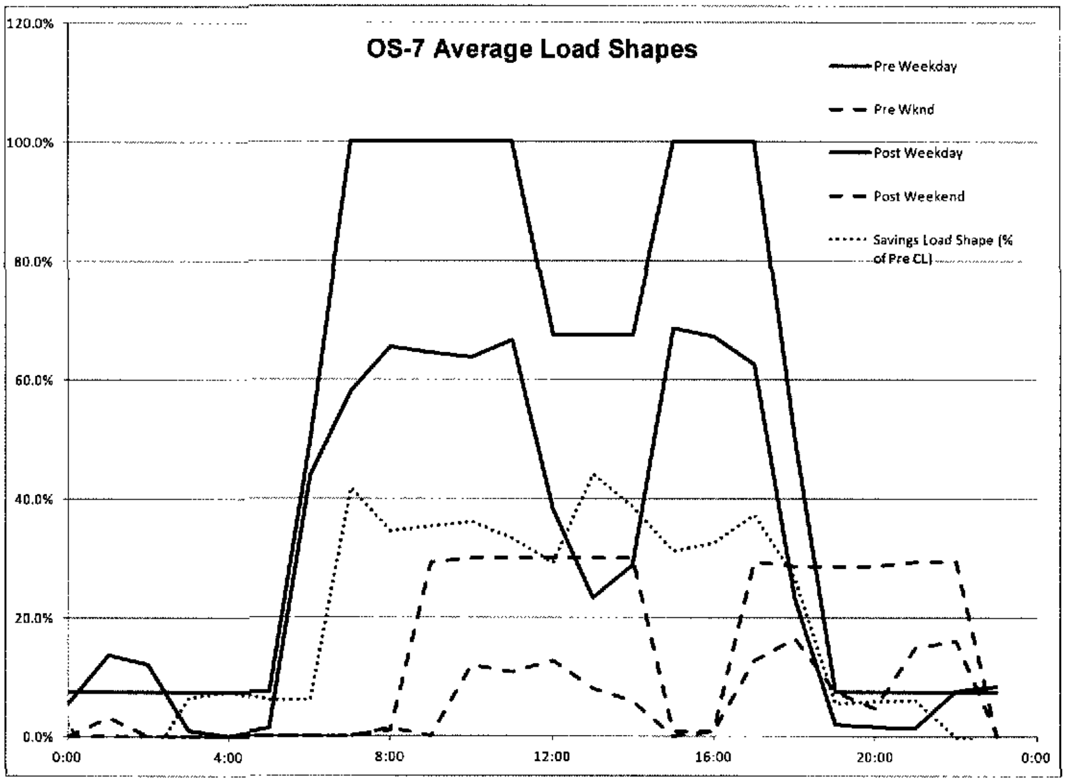
OS-3 Average Load Shapes

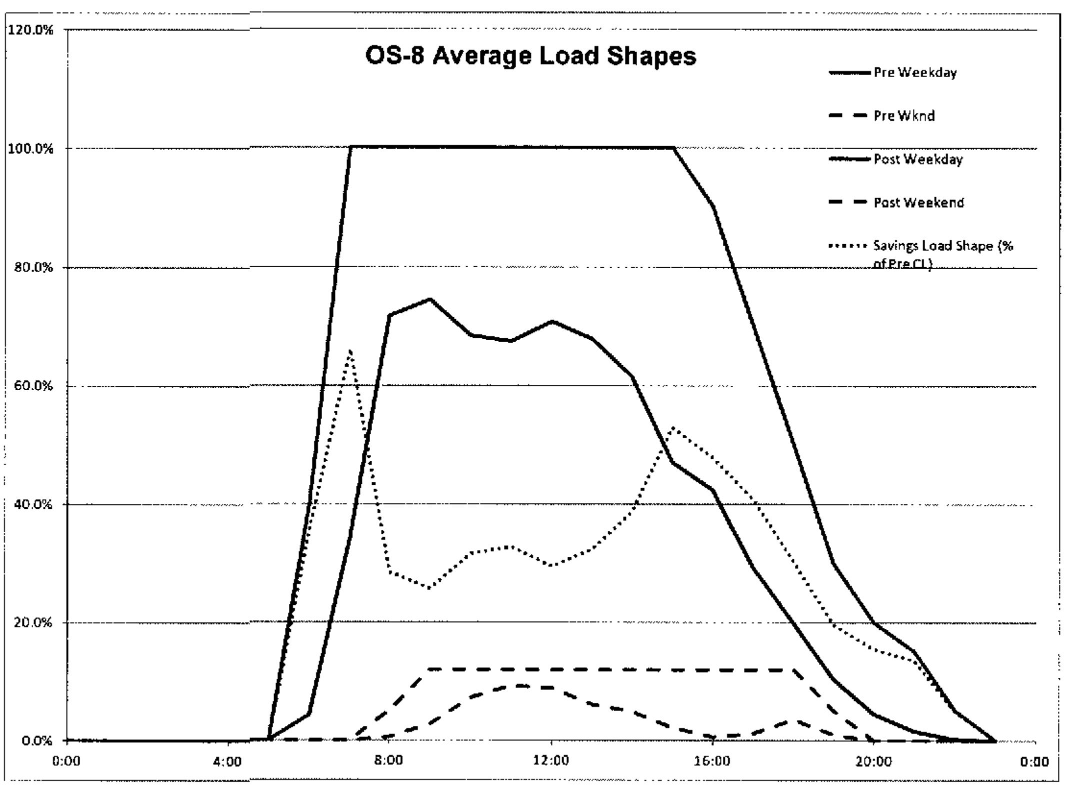




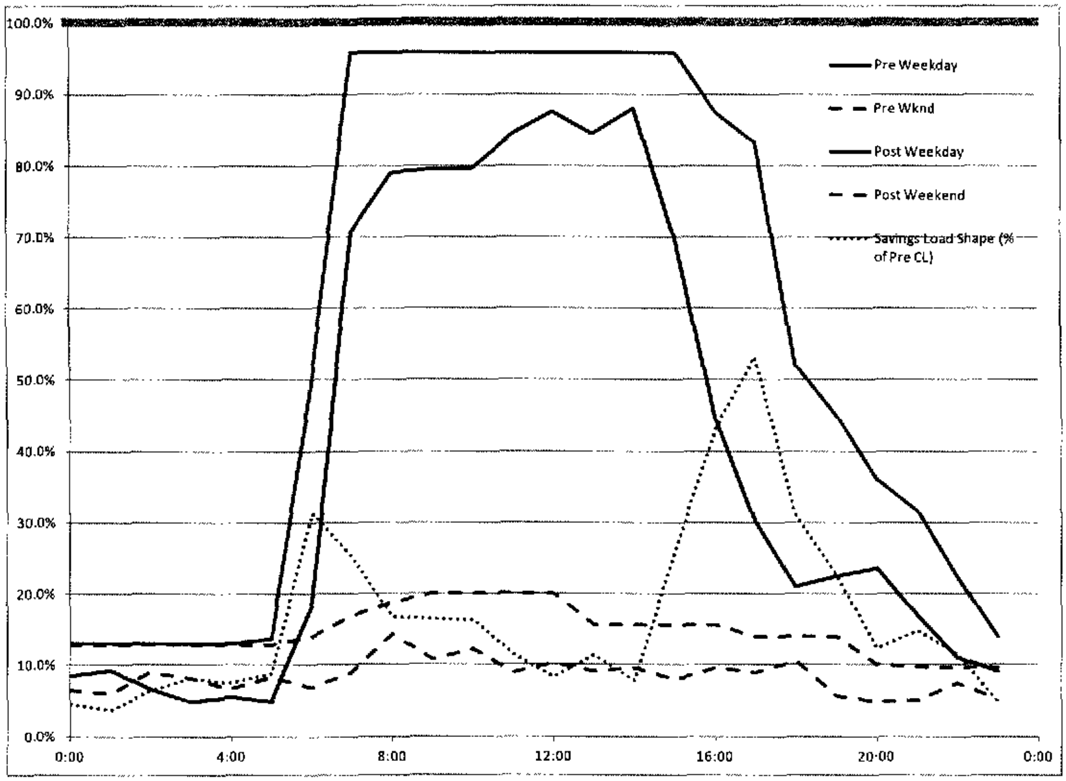

OS-5 Average Load Shapes
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Pre Weekday
Pre Wknd
Post Weekday
Post Weekend
Savings Load Shape (% of Pre CL)

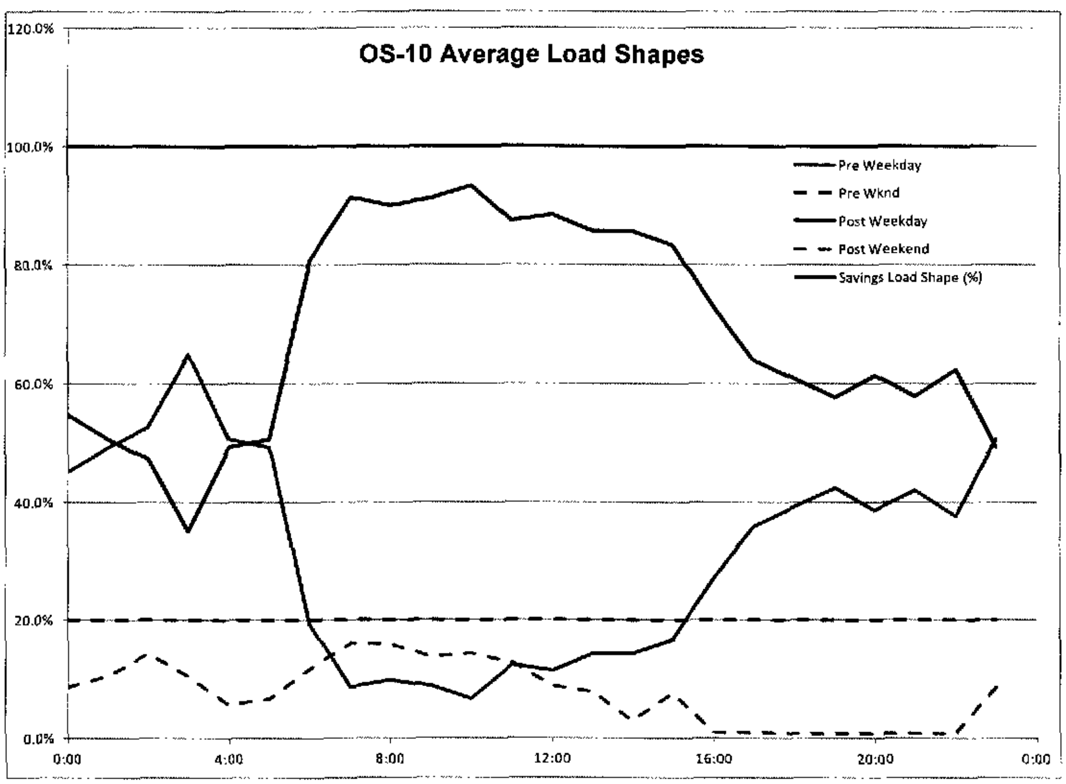

OS-6 Average Load Shapes
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Pre Weekday
Pre Wknd
Post Weekday
Post Weekend
Savings Load Shape (%)


OS-7 Average Load Shapes
Pre Weekday
Pre Wknd
Post Weekday
Post Weekend
Savings Load Shape (% of Pre CL)
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00


OS-8 Average Load Shapes
Pre Weekday
Pre Wknd
Post Weekday
Post Weekend
Savings Load Shape (% of Pre CL)
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
0:00
4:00
8:00
12:00
16:00
20:00
0:00

OS-9 Average Load Shapes





Appendix B: Results of HVAC Interactive Effects Simulations

	System	Cincinnati, OH	
		WHFe	WHFd
Assembly	AC / gas heat with economizer	0.130	0.246
	AC / gas heat no economizer	0.154	0.246
	AC / electric heat with economizer	-0.338	0.242
	AC / electric heat no economizer	-0.315	0.242
	Heat pump with economizer	-0.018	0.243
	Heat pump no economizer	0.005	0.243
	Electric heat only	-0.485	0.000
Big Box	AC / gas heat with economizer	0.076	0.268
	AC / gas heat no economizer	0.126	0.268
	AC / electric heat with economizer	-0.277	0.227
	AC / electric heat no economizer	-0.228	0.228
	Heat pump with economizer	-0.075	0.228
	Heat pump no economizer	-0.026	0.228
	Electric heat only	-0.371	0.000
Fast Food	AC / gas heat with economizer	0.083	0.262
	AC / gas heat no economizer	0.104	0.262
	AC / electric heat with economizer	-0.593	0.258
	AC / electric heat no economizer	-0.573	0.258
	Heat pump with economizer	-0.167	0.259
	Heat pump no economizer	-0.146	0.259
	Electric heat only	-0.721	0.000
FS Restaurant	AC / gas heat with economizer	0.098	0.372
	AC / gas heat no economizer	0.120	0.372
	AC / electric heat with economizer	-0.657	0.365
	AC / electric heat no economizer	-0.635	0.365
	Heat pump with economizer	0.100	0.365
	Heat pump no economizer	0.122	0.365
	Electric heat only	-0.794	0.000
Grocery	AC / gas heat with economizer	0.000	0.485
	AC / gas heat no economizer	0.125	0.485
	AC / electric heat with economizer	0.000	0.374
	AC / electric heat no economizer	-0.301	0.374
	Heat pump with economizer	0.000	0.374
	Heat pump no economizer	0.044	0.374
	Electric heat only	0.000	0.000

	System	Cincinnati, OH	
		WHFe	WHFd
Hospital	AC / gas heat with economizer	0.058	0.083
	AC / gas heat no economizer	0.066	0.083
	AC / electric heat with economizer	0.053	0.083
	AC / electric heat no economizer	0.061	0.083
	Heat pump with economizer	0.056	0.083
	Heat pump no economizer	0.064	0.083
	Electric heat only	-0.001	0.000
Light Industrial	AC / gas heat with economizer	0.080	0.213
	AC / gas heat no economizer	0.063	0.213
	AC / electric heat with economizer	-0.368	0.221
	AC / electric heat no economizer	-0.384	0.221
	Heat pump with economizer	-0.076	0.221
	Heat pump no economizer	-0.092	0.221
	Electric heat only	-0.474	0.000
Motel	AC / gas heat with economizer	0.000	0.000
	AC / gas heat no economizer	0.837	0.055
	AC / electric heat with economizer	0.000	0.000
	AC / electric heat no economizer	0.617	0.055
	Heat pump with economizer	0.000	0.000
	Heat pump no economizer	0.563	0.055
	Electric heat only	0.000	0.000
Nursing Home	AC / gas heat with economizer	0.143	-0.009
	AC / gas heat no economizer	0.148	-0.009
	AC / electric heat with economizer	0.107	-0.009
	AC / electric heat no economizer	0.112	-0.009
	Heat pump with economizer	0.122	-0.012
	Heat pump no economizer	0.127	-0.012
	Electric heat only	-0.042	0.000
Primary School	AC / gas heat with economizer	0.072	0.263
	AC / gas heat no economizer	0.032	0.263
	AC / electric heat with economizer	-0.808	0.266
	AC / electric heat no economizer	-0.847	0.266
	Heat pump with economizer	-0.256	0.266
	Heat pump no economizer	-0.296	0.266
	Electric heat only	-0.856	0.000
Small	AC / gas heat with economizer	0.126	0.199

	System	Cincinnati, OH	
		WHFe	WHFd
Office	AC / gas heat no economizer	0.080	0.184
	AC / electric heat with economizer	-0.192	0.190
	AC / electric heat no economizer	-0.238	0.190
	Heat pump with economizer	0.023	0.190
	Heat pump no economizer	-0.023	0.190
	Electric heat only	-0.338	0.000
Warehouse	AC / gas heat with economizer	0.085	0.317
	AC / gas heat no economizer	0.081	0.317
	AC / electric heat with economizer	-0.316	0.318
	AC / electric heat no economizer	-0.320	0.318
	Heat pump with economizer	0.011	0.318
	Heat pump no economizer	0.007	0.318
	Electric heat only	-0.403	0.000

Appendix C: DSMore Table

Per Measure Impacts Summary for Non-Residential Smart $aver Prescriptive

Per Measure Impacts Summary for Non-Residential Smart Saver Prescriptive

Impacts ⇨ / Technology ⇩	Product code	State	EM&V gross savings (kWh/unit)	EM&V gross kW (customer peak/unit)	EM&V gross kW (coincident peak/unit)	Unit of measure	Combined spillover less freeridership adjustment	EM&V net savings (kWh/unit)	EM&V net kW (customer peak/unit)	EM&V net kW (coincident peak/unit)	EM&V load shape (yes/no)	EUL (whole number)
HPT8 4ft 2 lamp, T12 to HPT8		Ohio	191.6	0.041	0.033	Fixture	31.8%	130.7	0.028	0.023	No	12
HPT8 4ft 2 lamp, T8 to HPT8		Ohio	72.4	0.015	0.012	Fixture	31.8%	49.4	0.010	0.008	No	12
Low Watt T8 lamps, 4ft		Ohio	35.0	0.007	0.006	Lamp	31.8%	23.9	0.005	0.004	No	12
LW HPT8 4ft 2 lamp, replace T8		Ohio	86.0	0.018	0.015	Fixture	31.8%	58.7	0.012	0.010	No	12
LW HPT8 4ft 4 lamp, replace T8		Ohio	154.8	0.033	0.027	Fixture	31.8%	105.6	0.023	0.018	No	12
LW HP T-8 4ft 1L replace T-8 4ft 1L		Ohio	60.2	0.013	0.01	Fixture	31.8%	41.1	0.009	0.007	No	12
LW HP T-8 4ft 2L replace T-8 4ft 2L		Ohio	86.0	0.018	0.015	Fixture	31.8%	58.7	0.012	0.010	No	12
LW HP T-8 4ft 4L replace T-8 4ft 4L		Ohio	154.8	0.033	0.027	Fixture	31.8%	105.6	0.023	0.018	No	12
T8 2ft 2 lamp		Ohio	206.3	0.044	0.036	Fixture	31.8%	140.7	0.030	0.025	No	12
T8 4ft 2 lamp		Ohio	111.8	0.024	0.019	Fixture	31.8%	76.2	0.016	0.013	No	12
T8 4ft 4 lamp		Ohio	275.1	0.059	0.047	Fixture	31.8%	187.6	0.040	0.032	No	12
T8 8ft 2 lamp		Ohio	120.4	0.026	0.021	Fixture	31.8%	82.1	0.018	0.014	No	12
Occupancy Sensors under 500 W		Ohio	273.5	0.079	0.123	Sensor	31.8%	186.5	0.054	0.084	No	10
Occupancy Sensors over 500 W		Ohio	684.8	0.193	0.302	Sensor	31.8%	467.0	0.132	0.206	No	10
VFD HVAC Fan		Ohio	1,011.7	0.162	0.07	hp	31.8%	690.0	0.110	0.048	No	15
VFD HVAC Pump		Ohio	1,558.0	0.266	0.207	hp	31.8%	1,062.6	0.181	0.141	No	15
VFD Process Pump 1-50 HP		Ohio	270.6	0.043	0.033	hp	31.8%	184.5	0.029	0.023	No	15
Program wide												

Note 1. Each row contains per unit savings and different technologies have different units, therefore the "Program Wide" row is left blank.

Note 2. Results from the linear fluorescent evaluation may be extended to other linear fluorescent fixture types not specifically studied in the sampled buildings.

Appendix D: Required Savings Table

The required table showing measure-level participation counts and savings for each program is below.

Measure	Participation Count	Verified Per unit kWh impact	Verified Per unit kW impact	Gross Verified kWh Savings	Gross Verified kW Savings
HPT8 4ft 2 lamp, T12 to HPT8	4,878	191.6	0.033	934,625	161.0
HPT8 4ft 2 lamp, T8 to HPT8	2,705	72.4	0.012	195,842	32.5
Low Watt T8 lamps, 4ft	174,488	35.0	0.006	6,107,080	1,046.9
LW HPT8 4ft 2 lamp, replace T8	7,237	86.0	0.015	622,382	108.6
LW HPT8 4ft 4 lamp, replace T8	4,267	154.8	0.027	660,532	115.2
LW HP T-8 4ft 1L replace T-8 4ft 1L	1,032	60.2	0.010	62,126	10.3
LW HP T-8 4ft 2L replace T-8 4ft 2L	26,249	86.0	0.015	2,257,414	393.7
LW HP T-8 4ft 4L replace T-8 4ft 4L	6,768	154.8	0.027	1,047,686	182.7
T8 2ft 2 lamp	2,161	206.3	0.036	445,814	77.8
T8 4ft 2 lamp	24,674	111.8	0.019	2,758,553	468.8
T8 4ft 4 lamp	21,648	275.1	0.047	5,955,365	1,017.5
T8 8ft 2 lamp	3,553	120.4	0.021	427,781	74.6
Occupancy Sensors under 500 W	28,904	273.5	0.123	7,905,244	3,555.2
Occupancy Sensors over 500 W	10,968	684.8	0.302	7,510,886	3,312.3
VFD HVAC Fan	602	1,011.7	0.070	609,043	42.1
VFD HVAC Pump	54	1,558.0	0.207	84,132	11.2
VFD Process Pump 1-50 HP	9	270.6	0.033	2,435	0.3

Final Report

Process and Impact Evaluation of the My Home Energy Report (MyHER) Program in Ohio

Prepared for
Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

November 22, 2013

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Executive Summary

Key Findings and Recommendations

The key findings and recommendations identified through this evaluation are presented below.

Significant Impact Evaluation Findings: Billing Analysis

A billing analysis was conducted to estimate the net energy savings from the program. The billing analysis relies upon a statistical analysis of actual customer-billed electricity consumption of customers receiving the MyHER mailings, compared to the change in savings over that same period for a matched comparison group to estimate the impact for the MyHER program.

The estimated impacts are presented in the "Energy Savings: Billing Analysis" section of the report, and a summary of the results is shown below:

	Annual Savings, 95% Confidence Interval		
	Lower Bound	Estimate	Upper Bound
Per Participant Savings kWh	205	220	234
Per Participant coincident kW savings	0.0628	0.0674	0.0717

Table 1. Summary of Program Savings by Measure

Measure	Participation Count	Ex Post (Adjusted) Per unit kWh impact	Ex Post (Adjusted) Per unit kW impact	Gross Ex Post (Adjusted) kWh Savings	Gross Ex Post (Adjusted) kW Savings
MyHER Report	261,028	220	0.0674	220	0.0674

Key Findings: Management Interviews

- The My Home Energy Report program provides Duke Energy residential customers with a meaningful look at their homes' energy use compared to other homes similar to theirs. Overall the program is well designed and effectively implemented.
    - See section titled "Program Description" on page 16.
- Participation numbers are largely on target and customer opt outs represent a fraction of one percent of participating customers; this is a strong indication of the popularity of the reports.
    - See section titled "Participation" on page 9.
- Among the few customers who do opt out, the three most common reasons for opting out are that customers consider the reports to be an inappropriate use of Duke Energy's resources (40%), customers believe they are doing enough to save energy (16%), and no reason given (10%).
    - See section titled "Call Handling" beginning on page 35.

- The reports are carefully designed for at-a-glance reading. Data is clearly presented and easily understood. Messages are crisp and actionable.
    - See section titled "Report Messaging" on page 27.
- Call volume for the program is low. As of March 2013, for all states served by the program, inbound calls totaled only 8,137 calls on base of greater than one million customers. For Ohio, the total call volume during that time was 2,082 calls on a base of 260,000 customers; this equates to less than one percent of customers for all calls and less than two percent of customers for Ohio.
    - See section titled "Call Volume" on page 34.
- The primary reason why customers contact Duke Energy about the program is to correct household characteristics, which is understandable given the data's third party origin. The most frequently corrected data points are heat fuel type, square footage, and home age in that order.
    - See section titled "Call Handling" beginning on page 35.
- The program vendor's platform has added appreciable functionality for the customization of messaging and the display of data, which is foundational to the program's ability to drive behavior change. But these technical feats are not without their challenges. After more than a year of operations, the program vendor's platform is not yet as functional or as stable as the team would like. Report production has been hampered by data quality concerns, most of which have been caught and fixed prior to mailing.
    - See section titled "Data Quality Assurance" on page 31.
- Report delivery meets on time service level agreements. Print quality has been an issue, but recent steps toward resolution appear to be promising.
    - See sections titled "Report Delivery" on page 34 and "Print Quality" on page 33.
- Call center operations and email support from the Customer Prototype Lab are operating smoothly and those teams interface effectively with the program management team.
    - See sections titled "Call Center Vendor" on page 42 and "Customer Prototype Lab" on page 42.
- The working relationship between Duke Energy and the program vendor is operationally functional and productive.
    - See section titled "The Program Vendor" on page 40.
- Overall the program represents a roundly successful contribution to Duke Energy's efficiency portfolio and a model for a well-designed and effectively run behavior change program for residential customers.
    - See section titled "Conclusions" on page 43.

Key Findings: Customer Survey

- There were 349 customers successfully contacted for the survey. Of these, 261 (74.8%) recalled receiving the Home Energy Report.
    - o See section titled "Introduction" on page 48.

- 94.3% (246 out of 261, including 12 incomplete interviews) of the surveyed MyHER customers who recall MyHER are reading the report. If the full number of contacted customers are included in this calculation (N=349, as noted above), and the assumption is that those who don't recall MyHER throw the report away, this brings the percent of customers reading the MyHER down to 70.5% of the targeted customers.
    - o See section titled "Customers Who Read the MyHER and Why" on page 48.

- Before being asked about what messages or tips customers recalled from the MyHER, most respondents defined energy efficiency in general terms, such as energy efficiency means "trying to use less energy" (64.7% or 161 out of 249) and "saving money on bills" (22.9% or 57 out of 249). Some respondents included specific examples of energy efficient activities in their definitions, such as "turn off lights when not in use" (7.2% or 18 out of 249) and "heating and cooling decisions" (6.8% or 17 out of 249).
    - o See section titled "What Energy Efficiency Means to Customers" on page 55.

- On average, the 249 MyHER customers who completed the survey scored their interest in energy efficiency (8.58 on a 10-point scale) higher than their interest in reading the next MyHER (7.88). This finding is statistically significant with 95% confidence, though much of the difference comes from customers who do not read MyHER (4.18 rating for reading the next report, 7.42 rating for interest in energy efficiency). Interest in energy efficiency is also significantly higher for customers who think they do "more than others," or "about the same as others," than it is for interest in reading MyHER. However, for customers who think they do "less than others" or who "don't know" how they compare to others, rating scores for energy efficiency and reading MyHER are not significantly different.
    - o See section titled "Interest in Energy Efficiency and MyHER" on page 59.

- Overall, 70.3% (175 out of 249) of Ohio customers surveyed are satisfied with how frequently they receive the MyHER, although 28.9% (72 out of 249) say they would prefer to receive reports by email instead of on paper.
    - o See section titled "Frequency of Receiving MyHER" on page 61.

- Only about one MyHER recipient in twelve (8.4% or 21 out of 249) reports that there are errors on their report. The most common inaccuracies have to do with the size of the home (13 of 21), home heating (4 of 21), and the age of the home (4 of 21).
    - o See section titled "Accuracy of Home Information" on page 62.

- There is a strong, but not absolute relation between customers' recent MyHER scores and their perception of how they are doing. While 77.0% (47 out of 61) of customers with MyHER scores that show their energy usage is "less than the efficient home" say their report usually shows they use less energy than average, 11.5% (7 out of 61) of these recipients say their reports usually show that they use more than average. Similarly, while 66.7% (62 out of 93) of customers whose energy usage is "more than the average home" say their reports usually show their energy use is more than the average home, another 9.7% (9 out of 93) of these customers say that their reports usually show they use less than the average home.

- See section titled "Energy Efficiency Scores" on page 63.

- Overall, more than half of MyHER customers surveyed are using the report to track their home's energy usage (62.7% or 156 out of 249) and are trying to improve their comparison scores (55.0% or 137 out of 249). Customers who are using the report to track usage (8.93) and trying to improve their scores (9.01) give significantly higher satisfaction ratings for the program compared to those who do not track usage (8.30) and those who are not trying to improve their scores (8.26).
  - See section titled "Energy Efficiency Scores" on page 63.

- A little over half of MyHER recipients surveyed (52.2% or 130 out of 249) were able to recall at least one tip or message from past reports. However, only 80.2% (227 out of 283) of these recalled tips and messages matched those included in the recipients' Home Energy Reports. Once incorrectly recalled tips were removed, 49.8% (124 out of 249) of customers correctly recalled an average of 1.83 tips or messages per customer who correctly recalled at least one tip or message. Most of the messages and tips recalled are about lighting (CFLs) or insulation and weatherization. More messages were recalled than tips, which is probably because more messages than tips have been sent to Ohio participants since the program began (the first six months of the program period under evaluation only included messages, not tips). Some tips and messages were recalled more than 500 days after they were mailed to recipients, though the average length of recall was 144 days for tips and 234 days for messages.
  - See section titled "Recalled Tips and Messages" on page 70.

- More than two-thirds of Ohio customers surveyed (70.7% or 176 out of 249) say the tips and messages are relevant and applicable for their household. Among customers who said the tips and messages were not relevant or applicable, the most common complaint is that they were already following the recommendations in the tips and messages before receiving them on MyHER reports.
  - See section titled "Tip and Message Relevance" on page 79.

- MyHER customers generally give the program high ratings for satisfaction, both overall (8.71 on a 10-point scale) and for specific aspects of the report and program (ranging from 6.33 to 9.17). Overall satisfaction with the program is significantly higher for customers who read the reports (8.83) and for customers whose recent MyHER scores show their usage is "less than the efficient home" (9.08) or "more than the efficient home, but less than the average home" (9.15). For specific aspects of the program, the highest satisfaction ratings are: "the reports are easy to read and understand" (9.17 overall); "I find the graphics helpful in understanding how my energy usage changes over the seasons" (8.64); and "I find the graphics useful in understanding how my energy usage

compares to others like me" (8.55). The lowest-rated aspect is, "The energy saving tips in the report provided new ideas that I was not previously considering" at 6.33 overall.
    - See section titled "Satisfaction with MyHER" on page 89.

- Customers who read MyHER participate(d) in twice as many Duke Energy energy efficiency programs (1.09) as those who throw them away (0.58).
    - See section titled "Participation and Interest in Other Duke Energy Programs" on page 103.

Recommendations

For a full explanation of recommendations see section titled "Recommendations for Program Improvements" beginning on page 44.

- Consider including kWh and dollars when presenting monthly and yearly usage comparisons. This option provides the benefits of showing customers actual kWh usage while retaining the familiarity and influence of showing dollar amounts.
- Efforts to reword potentially ambiguous statements on the reports may help mitigate customer misinterpretations, particularly those involving tone or sarcasm.
- While there is insufficient room for all FAQs on the reports, returning an explanation of average and efficient to the report would provide clarity about the report comparisons and preempt the need for customer clarification phone calls.
- Investigate ways to engage advanced customers on a deeper level in order to derive additional savings.
- Take steps to ensure that energy saving suggestions remain fresh and interesting.
- Conduct a cost-benefit analysis to determine the appropriateness of instituting full quality assurance protocols in advance of the report mailing.
- Establish a clear understanding between all parties regarding standards for data quality assurance, thresholds for print quality, and minimum criteria required prior to making and implementing change requests to improve the product or to accommodate customer feedback.
- Consider expanding the program to include other residential populations such as: those in multi-family units and those on flat bill and other rate plans.
- Consider investigating the impact of customers' knowledge of changing cluster sizes on energy savings by removing cluster size information from the monthly reports for a test group of customers to be compared to a control group who receive cluster size information on their reports. This investigation would provide additional validity to the notion that customer knowledge of cluster size influences their usage.
- Alternatively, add an answer to the MyHER FAQs to explain why cluster sizes change over time and why a customer may find themselves compared to different size clusters on different reports.

- Consider conducting a longitudinal analysis of existing data (plus or minus one year) to determine whether the energy savings observed from homes in small clusters is similar to energy savings from homes in larger clusters.
- Consider setting up test groups that receive the same MyHER with the same tips in order to conduct a more thorough and meaningful analysis of which tips are recalled and acted upon.
- Add specially coded CFL coupons to the MyHER mailing if it can be shown that the participants can use additional CFLs that they are not likely to purchase on their own.
- Perceived accuracy of the home energy use comparisons may be increased if household sizes are indicated as comparison criteria. This potential advantage should be weighed against the data collection and programming required to add such a factor to the clustering methodology.
- Consider replacing even more of the general efficiency messages on the second page of the report with more specific marketing messages for other Duke Energy programs.
- Consider if it is appropriate to make changes based upon a small number of errors or customer comments. The answer may well and appropriately be yes, but the threshold for change—and the impacts of doing so—should be clearly understood by all parties.

Introduction and Purpose of Study

Summary Overview

This document presents the process and impact evaluation report for Duke Energy's My Home Energy Report (MyHER) Program as it was administered in Ohio. The evaluation was conducted by TecMarket Works and subcontractors Integral Analytics and Matthew Joyce.

Summary of the Evaluation

This document presents the process evaluation report for Duke Energy's My Home Energy Report (MyHER) Program as it was administered in Ohio. The evaluation was conducted by TecMarket Works and Matthew Joyce, subcontractor to TecMarket Works. The interview and survey instruments were developed by TecMarket Works and Matthew Joyce. The customer survey was administered and analyzed by TecMarket Works. Matthew Joyce conducted in-depth interviews with program management.

The impact findings presented in this report were calculated using monthly billing data (for program net savings).

Evaluation Objectives

This report's objectives include a presentation of the MyHER program's estimated energy impacts. The process evaluation is intended to provide insights to help Duke Energy, and other interested parties, evaluate the program as it is currently administered. The report reviews program history, evaluates current processes, and considers customer surveys and participant feedback in order to diagnose issues and present recommendations for changes intended to increase energy savings, improve operational efficiencies, and enhance customer satisfaction.

Researchable Issues

In addition to the objectives noted above, there were a number of researchable issues for this evaluation. These include:

1. To solicit feedback from program participants about their experience with the MyHER mailings, such as their recollection of the messages and tips, their home energy scores, and their satisfaction with the reports;
2. To gain an understanding of customer demographic categories responding positively to the MyHER program.

Description and Purpose of Program

The My Home Energy Report (MyHER) Program is an energy efficiency program currently operating in Ohio. The purpose of the program is to provide Duke Energy residential customers with customized home energy reports that compare their home's electric energy usage with similar homes in order to encourage behavior driven energy savings through the principles of social norming. Eight reports are sent each year.

The program targets approximately 260,000 residential customers residing in individually metered single-family residences in Duke Energy's Ohio service territory. Rather than requiring people to sign up for the efficiency program, customers in the study group were automatically enrolled into the program. Starting in September of 2011 when the full commercial program was first launched, participants began receiving personalized reports comparing their monthly and annual energy usage with a group of homes of similar size, age, type of heating fuel and geography.

Duke Energy works with a third party program vendor that uses proprietary methods to analyze the customer's energy use and compare it to a peer group. The customer's monthly and annual energy usage is then graphed in comparison to the usage of an average home and an efficient home within the peer group. The reports present specifically targeted tips to save energy and offers to participate in Duke Energy's other energy programs. These targeted suggestions are based specifically on the customer's energy consumption patterns and home characteristics.

Program Enrollment, Eligibility, and Participation

Opt Out Enrollment

Unlike other energy efficiency programs offered by Duke Energy, this program is designed to use opt-out enrollment, so that eligible customers automatically receive a welcome letter and begin receiving reports without the need to formally sign up. With a growing number of utilities offering comparable behavior change reports, opt out enrollment is considered an industry norm for programs of this type.

Opt out enrollment offers advantages to customers and to Duke Energy. First, it enables a greater number of customers to benefit from a better understanding of their homes' energy use and how the most effective ways that they can save energy. Second, it diminishes program costs by reducing the need for program marketing, since opt in enrollment necessarily requires making customers aware of the benefits of the program prior to signing them up. Third, as the reports directly state: "When customers reduce their energy needs, it reduces the costs to provide energy and the need to build more power plants, which lowers bills for you, your community, and Duke Energy."

The opt out enrollment method is considered appropriate because the reports contain useful information specific to each customer. For this reason, the reports are deemed to be informational communications about customer accounts rather than solicitations. Customers always retain the ability to opt out at any time with a phone call or email to the contact details listed on every report. However, as of March, 2013, the Ohio program's opt out rate is extremely low at only 0.28% or 728 people on a base of slightly more than 260,000 participants.

Eligibility

To be eligible for the program, customers must live in a single family home with a single electric meter. They must be on a rate plan that bills for the full amount of energy used during a month. Customers must also have 13 months of consecutive billing data at the present address. Full program eligibility requirements are as follows:

- Active customer on a residential rate plan in Ohio
- 13 months of consecutive usage history
- Individual electric meter
- Single family home
- Non-apartment
- Non-business
- No fixed payment plan
- No equal payment plan
- No budget bill plan
- No percent of income plan
- Home address equals a billing address or post office box in same state as the service address
- Has not opted out of the program
- Not part of the control group (opt in is possible)

Duke Energy customers are considered to be MyHER program participants when they have:

- Met the program's eligibility requirements
- Received at least one MyHER Report
- Not opted out of the program

Participation

The MyHER program sends a paper report by mail to approximately 260,000 participating households in Ohio each month. Participation numbers vary due to opt outs and changes in customer eligibility status. Customer participation is validated monthly by Duke Energy using detailed reports from the program vendor. The table below shows official program participation numbers by month between program inception and March 31, 2013.

Table 2. Program Participation by Month

Month	Number of Participants*
Sept. 2011	59,436
Oct. 2011	176,986
Nov. 2011	242,476
Dec. 2011	241,726
Jan. 2012	239,929
Feb. 2012	238,049
Mar. 2012	236,447

Apr. 2012	256,552
May 2012	256,539
June 2012	242,291
Jul. 2012	252,229
Aug. 2012	255,021
Sept. 2012	257,027
Oct. 2012	256,033
Nov. 2012	257,623
Dec. 2012	257,623
Jan. 2013	259,656
Feb. 2013	259,844
Mar. 2013	261,028

**In months when no new reports are sent, participation numbers are considered the same as in the preceding month since customers are considered to remain in the treatment group until the next treatment report is mailed.*

Methodology

Overview of the Evaluation Approach

This process evaluation has two components: management interviews and participant surveys.

Study Methodology

The process evaluation has two components: management interviews and participant surveys. In-depth interviews were conducting with program management and the participant surveys were conducted with 249 customers in Ohio. The impact estimates were done via billing analysis.

Billing Analysis

The billing analysis used consumption data from MyHER recipients in Ohio (295,429 customers) that participated between April of 2011 and March of 2013. A panel model was used to determine program impacts, where the dependent variable was daily[1] electricity consumption from January of 2008 through March of 2013.

In order to determine the kW savings, the project used a Calibrated Load-Shape Differences Approach (CLSD). This approach is based on the results of the billing analysis (kWh saved) to establish the total and per participant amount of energy savings achieved by the program. The specific steps associated with this approach are as follows:

1. Conduct a billing analysis to identify program energy (kWh) savings achieved.
2. Use the utility-specific DSMore load shapes to calculate a kW coincident reduction factor for demand savings such that the total kW savings curve equals the annual savings estimate from the billing analysis.

This approach provides a reliable estimate of the per household and program-wide peak kW reduction for the least cost.

Management Interviews

For the process evaluation, in-depth interviews were conducted with the Duke Energy product manager, the Duke Energy database analyst, one of the Duke Energy managers responsible for new program development, and the Duke Energy manager of the Customer Prototype Lab, which provided call center and email support during the OH and SC pilots of this program, and which continues to provide email assistance for the full commercial version of Ohio program. In addition to these Duke Energy employees, TecMarket Works interviewed three representatives from the third party program vendor that creates and mails the reports —the vendor's production manager, client project manager, and project engineer. We also spoke with the lead call center representative from the third party vendor that provides call center services for the program. The interviews covered program design, execution, operations, interactions between organizations, data transfer methods, and personal experiences in order to identify any implementation issues and discuss opportunities for improvement.

[1] Daily electricity consumption was calculated by monthly usage divided by number of usage days in each bill cycle.

Customer Surveys

TecMarket Works developed a customer survey, administered over the phone, for the MyHER Program participants, which was conducted from February 13 to March 29, 2013.

Surveys were completed with a random sample of 249 MyHER customers; in addition, twelve customers qualified for the survey, but were not able to complete the interview. When the customer was successfully contacted, the surveyor asked if the customer was familiar with the MyHER mailings. If not, the surveyor provided a short description of the MyHER mailings they have been receiving: *This program provided information on how much electricity you used in the previous month and in the previous 12 months compared to your neighbors and provided tips on how you could lower your electricity use and costs in becoming more energy efficient.*

If the customer still did not recall the MyHER, they were thanked for their time and the call was terminated. If they did recall the MyHER, the survey continued regardless of whether they read the MyHER. There were 261 customers out of 349 contacted (74.8%) who recalled receiving the MyHER report, though only 249 recipients completed the entire survey (twelve incomplete survey responses are not included in this report except for awareness of the program and whether they read MyHER).

MyHER customers were surveyed by TecMarket Works. The survey can be found in Appendix D: MyHER Customer Survey Instrument.

Data Collection Methods, Sample Sizes, and Sampling Methodology

Billing Analysis

The billing analysis used consumption data from all complete data provided for the MyHER recipients in Ohio (295,429 customers) that received the MyHER between April of 2011 and March of 2013. There were a total of 343,101 usable accounts after processing[2], of which 295,429 were report recipients, and 47,672 were control group members.

Management Interviews

Management interviews, as well as follow-up phone calls and emails, were conducted with staff members from Duke Energy, the program vendor, and the call center vendor. The interview instrument can be found in Appendix B: Program Manager Interview Instrument and Appendix C: Vendor Interview Instrument.

Customer Surveys

The complete survey was conducted with a random sample of 249 MyHER customers. The survey protocol can be found in Appendix D: MyHER Customer Survey Instrument. We attempted to contact program participants by telephone no more than four times at different times of the day and different days before dropping them from the randomly sampled contact list. Call times were from 10:00 a.m. to 8:00 p.m. Eastern, Monday through Saturday.

[2] Useable accounts are those accounts which have billing data for both a portion of the pre- and post-participation period, as well as monthly kWh greater than 0 and less than 10,000 kWh.

Number of Completes and Sample Disposition for Each Data Collection Effort

Billing Analysis

N/A (all participants included, sampling was not used)

Management Interviews

During February and March of 2013, TecMarket Works interviewed four Duke Energy employees and four representatives from two vendors for this evaluation. This represents a completion rate of 100%.

Customer Surveys

A sample list of customer records was randomly pulled by TecMarket Works from a list of 244,810 participants with contact information provided by Duke Energy. Surveys were conducted and completed by telephone with 249 participants. The survey instrument can be found in Appendix D: MyHER Customer Survey Instrument.

Table 3. Summary of Data Collection Efforts

Data Collection Effort	State	Size of Population in Sample for Surveys	# of Successful Contacts	Sample Rate
Management Interviews	OH	8	8	100%
Customer Surveys	OH	244,810	249	0.1%

Expected and Achieved Precision

Billing Analysis

All savings estimates from the billing analysis were statistically significant at the 95% confidence level.

Customer Surveys

The survey sample methodology had an expected precision of 90% +/- 5.2% and an achieved precision of 90% +/- 5.2%.

Description of Measures and Selection of Methods by Measure(s) or Market(s)

This behavioral program does not include any energy efficient measures. The MyHER program consists of regular mailings to a targeted list of customers as described above.

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

Billing Analysis

The specification of the model used in the billing analysis was designed specifically to avoid the potential of omitted variable bias by including monthly variables that capture any non-program effects that affect energy usage, such as number of people in the home, as well as other Duke Energy offers.

Energy Savings: Billing Analysis

The goal of this billing analysis is to evaluate the energy impacts from MyHER since April 2011. The estimated MyHER savings obtained from the billing data analysis are presented below.

Table 4. Estimated MyHER Impacts

	Annual Savings, 95% Confidence Interval		
	Lower Bound	Estimate	Upper Bound
Per Participant kWh Savings since 04/2011	205	220	234

This table shows that the MyHER program produced statistically significant savings for participants in Ohio. Savings decline over time as we have seen in other research on comparison reports similar to MyHER. Since the program evolved from a pilot to a commercialized mass market program, more customers with lower saving potential would have been included.

Note that the billing data analysis includes variables to capture effect of participation in other Duke Energy programs after participation in MyHER. This is to explicitly control for any impacts from other program participation.

For this analysis, data are available both across households (i.e., cross-sectional) and over time (i.e., time-series covering both pre- and post-treatment periods). With this type of data, known as "panel" data, it becomes possible to control, simultaneously, for differences across households as well as differences within each household over time. This is accomplished through the use of a "fixed-effects" panel model specification. The fixed-effect refers to the inclusion of a customer-specific intercept terms. This term captures all time-invariant characteristics that affect the level of energy use, whether observed or not. The other variables in the model are time-variant variables that change over time, such as weather and program treatment.

The fixed effects model can be viewed as a type of differencing model in which all characteristics of the home, which (1) are independent of time and (2) determine the level of energy consumption, are captured within the customer-specific constant terms. In other words, differences in customer characteristics that cause variation in the level of energy consumption, such as building size and structure, are captured by constant terms representing each unique household.

Algebraically, the fixed-effect panel data model is described as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varphi P_{it} + \theta T + \delta DP_{it} + \varepsilon_{it}$$

where:

y_{it} = energy consumption for home i during month t
α_i = constant term for site i (the fixed-effect)
T = indicator variables for each time period in the analysis
P = indicator for the treatment for the program in question
DP = indicators for other utility-sponsored programs
$\beta, \varphi, \theta, \delta$ = vectors of estimated coefficients

x = vector of non-program variables that represent factors causing changes in energy consumption for home i during month t (i.e., weather)

ε = error term for home i during month t.

With this specification, the only information necessary for estimation is those factors that vary month to month for each customer, and that will affect energy use, which effectively are weather conditions and program participation. Other non-measurable time-variant factors (such as economic conditions and season loads) are captured through the use of monthly indicator variables.[3] To control for weather effects, the model includes temperature, humidity, and wind speed variables. This is more flexible and inclusive than only including HDD and CDD terms, as those variables assume a constant baseline of 65° for heating and cooling across all customers. The model delivers savings estimates that are based on actual weather during the treatment period.

Moreover this analysis involves both a treatment group and a control group. Treatment group includes customers who received the MyHER reports whereas control group includes customers who did not receive any MyHER report and was kept separately to provide comparison to the treatment group.

The effects of the MyHER program are captured by including a variable which is equal to one for all months after the household participated in the program. In order to account for differences in billing days, the usage was normalized by days in the billing cycle. The estimated electric model for the MyHER program is presented in Table 5.

Table 5. Estimated Savings Model for OH MyHER – dependent variable is daily kWh usage (savings are negative)

Independent Variable	Coefficient (daily kWh Savings)	t-value
MyHER Impact since April 2011	-0.6	-30.39
Sample Size	18,873,889 observations (343,101 homes)	
R-Squared	65%	

The complete estimate model, showing the weather and time factors, is presented in "Appendix O: Estimated Statistical Model". Based on these kWh savings and the load curves in DSMore, the implied coincident kW savings is 0.0674 kW/participant.

[3] See Jeffrey Wooldridge Econometric Analysis of Cross Section and Panel Data (Cambridge: MIT Press, 2002), 283-284 for a discussion of this model and its applicability to program evaluation.

Management Interview Findings

Program Description

The My Home Energy Report program is an energy efficiency program that sends periodic personalized reports to residential customers who meet eligibility criteria. The reports are designed to increase energy savings behaviors by showing customers how their electric energy usage compares to an average neighbor and an efficient neighbor living in residences in the same geographic area with similar square footage, heating type, and home age.

Energy usage is displayed in a monthly bar chart comparison and in a 13-month line chart comparison. If customers perform better than average, the average household is dropped from the monthly comparison, so that customers strive to match the lower energy usage of their more efficient neighbors. Average home values are always shown on the 13-month line chart, since customer energy usage may be above average for some months and below during others. An example report is shown in Appendix E: Example MyHER Mailing.

Reports are created eight times per year and are distributed in paper format via U.S. mail. The reports present energy efficiency suggestions that are customized according to that customer's specific household characteristics. The suggestions are designed to further spur the customer to action by providing an estimate of the dollar savings that may be achieved by making the effort. The reports also contain customized marketing messages that encourage customer participation in other Duke Energy efficiency programs for which that specific customer is eligible.

Program Theory and Design

The program's design for generating behavior driven energy savings is based on the theory of "social norms." Social science research demonstrates that people tend to conform to social norms even when they deny such influence[4,5]. By sending letters that compare one utility customer's energy use with that of similar customers, several utility companies have used this normative effect to generate between 1.5 to 2.5% savings.[6] Longitudinal studies about the persistence of these energy savings are underway.

The MyHER program design is based in part on this research and on studied observations of market participants. It is also based upon information garnered from Duke Energy's Personalized Energy Report® (PER) and Home Energy House Call (HEHC) programs. However, the current design is most appropriately ascribed as the outgrowth of two years of pilot efforts in Ohio and South Carolina. These 2010-2011 efforts demonstrated that the program resulted in statistically significant savings.

[4] Jessica M. Nolan, P. Wesley Schultz, Robert B. Cialdini, Noah J. Goldstein, Vladas Griskevicius, Normative Social Influence is Underdetected, *Pers Soc Psychol Bull July 2008 vol. 34 no. 7 913-923,* DOI: 10.1177/0146167208316691

[5] P. Wesley Schultz, Jessica M. Nolan, Robert B. Cialdini, Noah J. Goldstein and Vladas Griskevicius, The Constructive, Destructive, and Reconstructive Power of Social Norms, *Psychological Science* May 2007 vol. 18 no. 5 429-434 *DOI:* 10.1111/j.1467-9280.2007.01917

[6] Hunt Alcott, Social Norms and Energy Conservation, *Journal of Public Economics,* Volume 95, Issues 9–10, October 2011, Pages 1082–1095, DOI: http://dx.doi.org/10.1016/j.jpubeco.2011.03.003

Program Goals and Objectives

Because this program is designed with an opt out enrollment mechanism it does not have new customer acquisition goals (see Opt Out Enrollment). Instead, the program's primary numeric goals focus directly on energy savings. The program has an energy savings target of an average 219 kWh per participant per year. Progress toward this goal is to be determined by an impact evaluation.

In the absence of energy savings numbers to be derived from an analysis of the results of the impact evaluation, Duke Energy and its partnering third party vendors have been focusing the preponderance of their managerial efforts on the program's other strategic objectives for which feedback is more readily available. Those strategic objectives include:

- Educating customers about their energy use and encouraging them to take energy saving actions;
- Generating interest in other energy efficiency offerings;
- Deepening customer engagement;
- Responding to customer comments and suggestions in order to improve the reports and the program;
- And, increasing customer satisfaction.

When asked to comment on the place of this behavior modification program in Duke Energy's energy efficiency portfolio, one interviewee from Duke Energy used an analogy of a car to explain the role of the home energy report:

> "People constantly receive cues about their cars' gas consumption. The speedometer, odometer, gas gauge, and the price of gas are readily available to help people judge how much they're using and how much it is costing them in near real-time. That's not the case with your home's electric consumption. You just get a bill at end of month after you've used the energy. And, the bill isn't very informative for those customers who only look at the amount they owe and the due date. The home energy report helps to change that by showing customers how they're doing over time compared to others. It's a bit like comparing miles per gallon, but the reports also tell people how they can be more efficient and how much each action is likely to save them. In short, the reports provide a customer feedback loop and help people learn how to improve."

As important as this is, Duke Energy sees the home energy reports as serving other functions as well. The home energy reports are seen as a means of helping to strengthen customer satisfaction. Perhaps even more strategically, the educational aspects of the report and the periodic frequency of their delivery also serve as a starting point to begin engaging residential customers in the active management of their energy consumption as larger commercial customers have done for years. As another interviewee said, "We want to become their energy partner and not just a utility they write a check to." In other words, the home energy reports may be a one-way communication, but they are an invitation to the customer to begin a meaningful two-way conversation.

Market Barriers

Based on its previous pilot efforts, Duke Energy identified three potential market barriers to success: 1) customers not opening the reports; 2) not understanding the information presented; and 3) not taking action. The program design incorporates elements to address each of these. First, because the reports are delivered by paper mail, there is a risk that customers will assume the envelopes contain junk mail and not open them. To overcome this, the reports are sent in envelopes clearly displaying the Duke Energy logo and company address to denote the sender and nature of the communication. Second, customers may not have sufficient time available to read the report, nor may they have a comprehensive understanding of how energy is used in their homes. To overcome this, the reports are designed for at-a-glance reading with easy-to-understand graphics and simply worded explanations (see Report Design and Data Presentation). Third, customers may lack the financial resources and motivation to change their energy use over time. To overcome this, the reports present predominantly low cost / low effort energy saving recommendations. They also encourage adoption by showing the customer how much money that particular measure could save. The report delivery schedule of eight months per year provides ongoing contact and encourages continuous engagement. No additional market barriers where identified during the interview process.

Operational Roles

Operational roles for the MyHER program are shared between Duke Energy, two primary vendors, and several subcontractors. These roles are described briefly below and more fully in the following portions of this management review.

Duke Energy provides monthly billing and other customer data necessary to customize the energy reports, such as account information, records of participation in other efficiency programs, and data regarding customers' homes collected through direct customer communication or via the Personalized Energy Report and Home Energy House Call programs.

The Duke Energy product manager provides full operational oversight with responsibility for overall strategy, product planning, market expansion, determining messaging, selecting the criteria for customers to receive messaging, regulatory filing, financial reporting, vendor management and quality assurance.

The Duke Energy database analyst is primarily responsible for ensuring the program's data integrity. She provides systematic quality assurance, full program data support, and regular oversight on data interactions between Duke Energy and the program vendor.

The Duke Energy Customer Prototype Lab provides email support for customer inquiries.

The call center vendor handles all phone-related functions. They are staffed Monday to Saturday.

The program vendor handles report production and distribution from start to finish. The program vendor receives data from Duke Energy and transforms the information into individualized home energy reports by creating data clusters to compare customer usage to similar homes, suggesting energy saving actions, and presenting targeted Duke Energy communications. The program vendor is also responsible for printing, comingling, and mailing the reports, although these functions are handled through subcontractors.

Program Development

The initial steps for planning and launching the My Home Energy Report program began during 2008, when Duke Energy recognized it was possible to influence behavior in order to produce energy savings. Duke Energy had already done much work on its efficiency programs designed to achieve energy savings via structural and equipment improvements, and the utility's senior managers were seeking a different approach to augment their portfolio. Work began in earnest as they researched academic studies and real world tests by market actors. During 2009, regulatory approvals came through and Duke Energy prepared to deploy two pilot efforts using in-house resources and a third party printer to produce the reports.

The first pilot launched in Ohio on February 22, 2010. It was designed to test data presentation and the frequency of report delivery. A comparable pilot effort was launched in South Carolina on May 28, 2010. The initial treatment groups consisted of 10,000 residential customers in Ohio and 8,258 residential customers in South Carolina. For each pilot effort, these overall treatment groups were divided into two groups. One group received quarterly reports and the other received monthly reports. These two groups were each then subdivided into receiving two different types of reports, with one subgroup receiving a report showing usage data with line graphs, while the other subgroup received their information in bar chart format. Process and impact evaluations were conducted by TecMarket Works to determine the results of these efforts in 2011. The findings from these evaluations and the many learnings from the pilots were incorporated into the improved design and deployment of a fully commercialized version of the program.

The first commercial version of the program launched in Ohio on September 10, 2011, with a target of 240,000 participants and a multi-staged startup process that added approximately 25,000 additional customers per week until the target was reached. The same internal Duke Energy departments that handled operations for the pilot efforts managed the delivery of the first full commercial version of the program.

While Duke Energy was preparing for this full commercialized roll out, the utility was simultaneously using an RFP process to select a third party contractor specializing in data analysis with a platform robust enough to produce and mail the home energy reports on a scale sufficient to reach its distribution targets in all approved service territories. The program vendor worked with Duke Energy during the latter half of 2011, to design, develop, and deploy systems for generating the home energy reports according to contract specifications. Full commercialized systems transition from Duke Energy to the program vendor occurred during March of 2012.

At the time of transition, a letter was sent to all participating customers in Ohio to tell them of the upcoming changeover. The letter focused the improvements to the report that the transition made possible. The text of the letter read:

> "You've asked for more, so we're adding on! There may be a slight 'construction delay,' but when your new My Home Energy Report arrives,

> it will have two pages of valuable information about your energy usage and even more energy saving tips. Oh, don't worry. You and your home will still be front and center. How Am I Doing charts will continue to show how your energy use compares to similar homes – each month and over time. But now we'll have more room to answer your questions, like 'What can I do to reduce energy use?' and 'How much could this tip save me?' Stay tuned! We think you're going to like your new report!"

After a few months to fine tune efforts, on May 25, 2012, a commercialized version of the program launched in South Carolina with a target of 215,000 customers. Then, on June 12, 2012, Duke Energy made its next handoff, transitioning call center operations from the Customer Prototype Lab to the call center vendor. With this segue complete, the respective program actors assumed their currently assigned roles.

A commercialized roll out to 46,000 residential customers in Kentucky occurred on August 22, 2012. North Carolina followed on October 17, 2012, with the largest target yet, 500,000 residential customers. In contrast to these commercial launches, Indiana began with a pilot effort in May of 2012.

Operations in all service territories are mentioned here because the same systems and methodologies are used to create and distribute reports in all states. Thus, overall report volumes, operational challenges, and any decisions made concerning the program in one state are likely to impact operations in the others.

MyHER Report

Overview

The program vendor receives a secure transfer of customer data on a nightly basis from Duke Energy, which includes updated energy usage, billing records, account and rate changes, eligibility criteria, and household demographics. This customer data is then passed through two distinct stages — integration and production — in order to create the MyHER reports. The integration stage runs daily and is designed to sort, catalog, parse, and combine the data according to a complex set of software rules that prepare the data for report production.

Report production occurs eight months per year, with each report corresponding to a calendar month. For each monthly cycle the data is divided into four weekly batches. Each batch is processed independently, as customers are clustered with others having similar billing dates and similar household characteristics. Each batch then consists of hundreds of clusters containing tens to thousands of houses in each.

Once the dynamically assigned clusters are established, the kWh energy use of individual households in each cluster are used to determine how much electricity the "average" home and the "efficient" home use. Each individual household's kWh usage is then compared to the average and efficient homes in their cluster to show relative performance each month for the previous 13 months. Kilowatt hours are converted to dollar figures using a statewide rate factor that makes it possible to display meaningful comparisons of homes that may be on different rate plans.

To further encourage energy savings behaviors, the front page of the report presents two specific tips that suggest seasonally and household-appropriate ways to save energy, such as weatherization or using task lighting. The tips, which are developed by the program vendor, also show how much money enacting that tip is likely to save that particular customer based on household characteristics. The rear page of the report presents two additional messages developed by Duke Energy. The program vendor uses yet another set of software rules to ensure that the Duke Energy messages displayed on the report promote specific energy efficiency programs for which the customer is eligible or a more general energy saving suggestion in the event that no specific program promotion is available.

Once these tips and messages have been dynamically assigned, PDF versions of the individual customer home energy reports are produced. The program vendor maintains quality assurance measures throughout the production process to catch potential errors. However, as an additional measure, from each of the four weekly batches, a sample set of 10,000 PDFs is pulled and transferred to Duke Energy for a second level quality assurance check.

Once this second level measure has been successfully completed, the full batch of PDFs is sent to a subcontractor for printing and mailing. The PDFs are also uploaded into a program vendor-hosted web portal called the Enterprise system, so that the reports can be viewed by representatives from the call center vendor and the Customer Prototype Lab. The following sections discuss this process in more detail.

Data Handling

Throughout the creation and development of the data integration and report production processes, the program vendor worked with Duke Energy to identify common issues that might arise with the data used to generate a customer's report. For instance, if a customer is missing the current month's billing data, then a software rule flags the customer ID and labels it as ineligible for a report since there is no new data available to create the monthly comparison. A similar rule applies to customers who are missing their thirteenth month of previous billing data since that anchors the beginning of the year-to-date comparison. Likewise, the program vendor needed to write a software rule that stops the report process if the customer is missing two bills within the 13 month period, excluding the first and thirteenth months, since too many missing data points cause the graphs to render poorly. Missing billing data is reconciled with Duke Energy on a nightly basis to mitigate such issues, but the rules must be in place in order to control the small percentage of situations to which they apply at the time the batch is processed.

Because the data integration process is so complex, it has required almost continuous process improvements to fine tune the most appropriate ways to handle unanticipated data idiosyncrasies. On numerous occasions, additional software rules needed to be written to deal with the unforeseen circumstances. Billing data issues continue to provide a good example. In some cases customers may receive two bills in a single month. Under the originally envisioned scenario, the second bill would be added to the first bill. However, in another scenario, the first bill should be considered cancelled, while the second bill shows the corrected amount. Without a software rule in place to address this real world business practice, the customer's MyHER report would present inaccurate information. These types of fixes are made whenever they are discovered.

Home Characteristics

The comparative nature of the MyHER reports relies upon the program vendor's ability to automate the creation of data clusters of similar homes. The program vendor's data integration process ensures that each customer ID is paired with several identifying household characteristics:

- Age of home
- Size (square footage)
- Heating fuel type
- Location (multiple vectors based on latitude and longitude)
- State (ensures neighborhoods do not cross state lines during clustering)
- Bill dates (ensures billing periods are of similar duration to produce accurate comparisons for consumption)

These characteristics are compiled from a variety of data sources with a specific order of precedence based upon their availability and deemed degree of accuracy. Those data sources are:

1. Customer specified information, such as corrected numbers for home square footage, age, and heat fuel type, as captured via telephone conversations with the call center vendor or email exchanges with the Customer Prototype Lab;
2. Household characteristics recorded during a visit by a professional auditor as part of Duke Energy's Home Energy House Call (HEHC) program;
3. Household characteristics provided directly by customers when they completed a data collection survey as part of Duke Energy's Personalized Energy Report (PER) program;
4. Duke Energy algorithms applied to confirm customer provided data, such as heating fuel type, since customers may erroneously think they have gas or electric heat, while an analysis of their annual electric load shape reveals otherwise;
5. And, household characteristics acquired by the program vendor via publically available Experian third party data.

Once these characteristics have been appended to the customer ID, the characteristics are used to help identify other similar households that will be clustered together later in the process to generate the home energy use comparisons.

All parties agree that this aspect of the report generation process is well-conceived and consistently well-executed.

Data Clustering

One key difference between the original clustering methodology used during the early program development and the current deployment is that Duke Energy's original methodology relied on static clusters of homes that were generated one time based upon similar home characteristics. This static clustering offered the advantage of facilitating comparisons with a consistent set of homes each month. However, the static clustering method did not easily accommodate the fact that new comparable homes became eligible each report cycle, while other homes needed to be dropped from the comparison pool based upon eligibility changes or upon customer requested corrections to their home characteristics. The program vendor's clustering methodology accommodates these data changes by employing a K-means data clustering methodology that creates new and accurate cluster assignments for each report cycle. While sacrificing a static comparison to the exact same houses each month, the K-means clustering methodology offers the advantage of ensuring a more accurate, consistent, and unbiased comparison of homes with similar attributes each report cycle, which Duke Energy deemed fundamental given the changing nature of the data.

Despite its differing dynamic nature, the program vendor's methodology yields clusters closely similar to those generated by Duke Energy's original static method. The dynamic clustering methodology works by creating a coordinate, or vector, for each piece of household information — bill date, home size, home age, fuel type, longitude, latitude, proximity of location, etc. — to receive a weight. Heuristic algorithms then run until convergence is reached and clusters of similarly weighted homes are generated. The reports refer to these clusters as "neighborhoods," but the homes are grouped based upon their similarly weighted attributes rather than being grouped as customers might commonly think of a neighborhood, such as homes sharing sidewalks, streets, and proximity to local landmarks.

The number and size of the data clusters changes each month because they are dynamically generated based upon the vector weightings of the data. A sample of the program vendor data for March of 2013 revealed that Ohio has an average of 835 neighborhood clusters per month, while across the entire Duke Energy service territory the program vendor system is generating an average of 3275 clusters. The analysis also showed that the numbers of homes within a cluster ranges from a low of 10 homes to a peak cluster size of 8924 homes, which happened to be in North Carolina. The average cluster in Ohio contains 345 homes, while the average maximum is 2,660 homes. Theoretically there is no maximum to the number of clusters or to the number of homes. However, the numbers noted above represent typical cluster sizes.

In essence, the program vendor's clustering methodology recognizes clusters that are too large do not provide an accurate comparison, while clusters that are too small may have their average and efficient home comparisons swayed by the undue weighting of individual homes. It is for this reason that if a cluster contains less than 10 similar homes then the customer does not receive a report. Duke Energy and the program vendor are currently considering the trade-offs between raising that minimum to provide greater statistical significance versus the reduced energy impacts resulting from sending reports to fewer homes.

Calculating Average and Efficient Homes

The key to the social norming process employed by the MyHER reports is the way that the reports compare a customer's energy usage with others. The reports make two different comparisons.

The first comparison is to the "average" home. Average is calculated by determining the arithmetic mean for the cluster. This is calculated by summing all kWh usage in the cluster and then dividing by the number of homes in the cluster. So, for a hypothetical cluster of three homes with 1000 kWh, 1200 kWh, and 1400 kWh, the sum would be 3600 kWh. When divided by three, this equals an average of 1200 kWh.

Because social norms tend to influence behavior toward the group average, Duke Energy also adds a second comparison designed to further influence customers toward additional energy savings. For this reason, the reports also compare customer energy usage to an "efficient" home. The efficient home represents the 25^{th} percentile (first quartile) of energy usage such that homes at this mark use less energy than 75% of homes in the cluster.

Use of Rate Factors to Demonstrate Monthly Energy Costs in Dollars

While home energy use comparisons are calculated using kWh, the data is graphed on the reports in terms of dollars. Dollar amounts are calculated using a multiplier known as a rate factor, which is a composite figure created to represent the blended value of all the charges a customer would be presented with on the bill. This single number is multiplied by the kWh used by each customer to determine the dollar amount to display on the reports.

The rate factor for Ohio is $0.107. The rate factor is calculated by the Duke Energy rates department after allowing for the various tariffs that eligible customers may be on, as well as riders, taxes, and other fees. This single number is considered to be the most appropriate way to create a statewide "apples-to-apples" dollar value comparison between sets of customers who may be on different rate schedules.

Duke Energy made the decision to present the information this way for two primary reasons: 1) dollar amounts were considered to be more easily understood by customers than kWh with which they are less familiar; and 2) customers were considered to be more likely to take actions to save energy when shown dollar figures on the monthly and annual graphs, as well as in the energy tips on the front page.

This decision is now being reconsidered for several reasons. First, while Duke Energy makes it clear on the reports that dollar values shown are not bill amounts, customers inevitably compare the dollar amounts shown on the home energy reports with the dollar amounts shown on their bills. When the numbers don't match, confusion can ensue. The product manager indicates that fewer than a dozen customers have complained over the life of the program, making it a statistically insignificant number of complaints when approximately one million reports are sent each month.

However, another potentially stronger reason to consider showing the amount of energy used in kWh instead of, or in addition to, dollars is that customers actually use kWh. This is the true metric of their usage. It is also the metric for measuring the impact of the energy savings for the MyHER program. Thus, a commonality of metrics and language may be achieved by reporting the values in kWh.

Moreover, reporting usage in kWh would also serve to begin educating customers about the importance of kWh for their homes in a manner akin to miles per gallon for their cars. In the same way that fuel economy influences their driving behavior and vehicle purchases, a stronger understanding of home energy economy has the potential to lead to greater and more persistent savings. Duke Energy is currently exploring how to achieve this potential upside without making the reports overly complicated or diminishing the behavioral motivation achieved by presenting the energy comparisons in terms of dollars.

Report Design and Data Presentation

The focal points of the MyHER reports are the monthly energy use comparison on the front page of the report and the annual energy use comparison on the back page of the report. The monthly comparison commands at-a-glance visual attention. The headline: "How am I doing?" immediately establishes context, while three bold bars compare the reader's home energy use to that of the average home and efficient home. Bar lengths provide a graphic display of information, while dollar amounts specify the exact values.

The second page of report also sports a prominent graph; this one is a line graph displaying monthly energy use for 13 months to facilitate year-to-year comparisons of energy usage. Average and efficient homes are also shown, so that customers can see how their annual performance compares to their peers. In this way, the line graph encourages both internal and external competition as customers strive to better both their own performance and that of others.

The program vendor provided a significant enhancement to fostering this sense of competition when it created a way to alter the display of the monthly bar chart. When the reports were produced by Duke Energy, the amounts displayed for the average home, your home, and the efficient home would change each month as the data changed. But pilot testing and industry research revealed that when customers were shown that their energy usage was lower than average, their performance tended to revert toward average rather than continuing to improve toward the efficient home. Duke Energy and the program vendor resolved this issue when the program vendor developed a way to drop the column displaying average home performance and center the remaining two columns (see Appendix E: Example MyHER Mailing for an example). This change necessarily causes readers to focus on the difference between their homes and efficient homes, thereby continuing to spur a sense of competition toward achieving even greater energy savings. However, even when customers use less energy than average for a given month, the average home performance continues to be displayed on the annual usage line graph since the customer may be above average and below average at different times of the year.

Similar attention to detail has gone into the explanations that accompany the monthly comparison chart (Figure 1). To the right of the monthly bar chart a legend explains whose electricity usage is being compared to the customer. The legend then lists the number of households in the data cluster, as well as providing the heat source, range of square footage, and age range of the houses in the cluster. This information is presented so that customers understand how closely similar the homes they are being compared with are. This is intentionally stated to increase credibility and build customer trust in the accuracy and reliability of the comparisons.

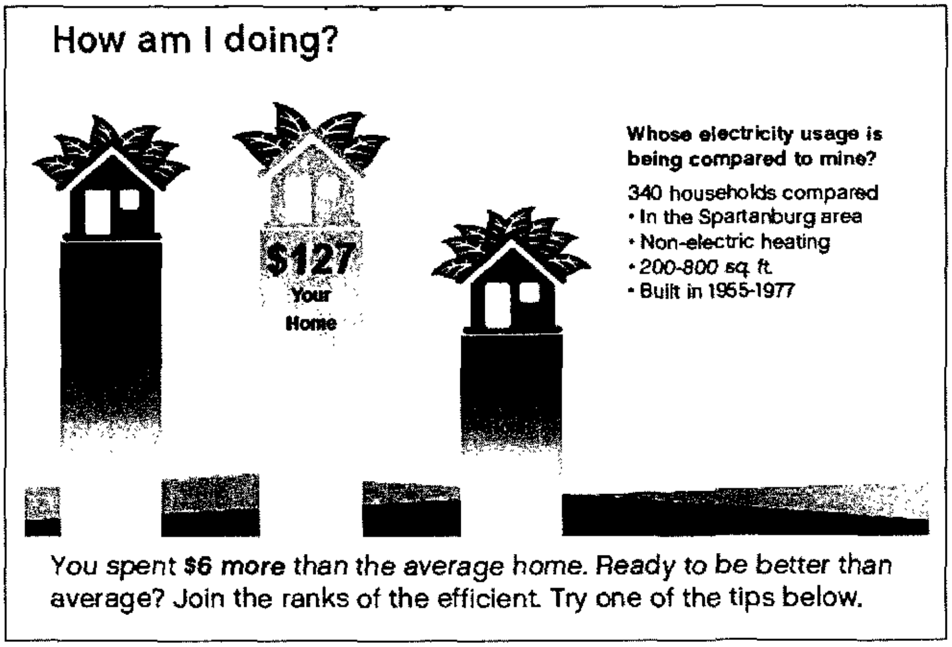

Figure 1. Monthly Energy Use Comparison

This verisimilitude became a point of disagreement between Duke Energy and the program vendor during the development phase. The program vendor felt strongly that the number of homes, square footage, and age range shown on the reports should be changed each month to automatically and accurately reflect the exact homes in that month's dynamically generated comparison cluster. Duke Energy disagreed, citing calls and emails from customers who were confused as to why those numbers were changing each month. Because customers were focusing on those "wrong" changes instead of focusing on their changing energy use, the two parties eventually agreed to display a fixed range of comparison for the square footage and home age. Those were set at +/- 300 square feet and +/- five years from those attributes of the customer's home. This change ensured that customers would see a consistent and reliable benchmark for the comparisons, even though the actual numbers may vary slightly according to the data points in that month's dynamically generated cluster.

Other elements of the report have been the subject of careful consideration as well. According those we interviewed, each element and detail of the reports has been carefully considered to elicit a trusting and positive response from Duke Energy customers. The typeface, colors, gradient fades, and differing layouts between first and second page were all specifically chosen. For instance, the color yellow was selected to show the homeowners energy usage since it is the easiest color to see, while green was picked for the "efficient" home to reinforce the "green is environmentally friendly" message. Likewise the houses atop the monthly bar chart columns were selected for their simple iconic representation of a home, and the green leaves were designed to simultaneously imply financial savings and environmental friendliness.

The current two page format was expanded in March of 2012, when the program vendor began producing the reports in order to provide more space for additional information. Prior to that time, the reports consisted of a single page of new information with monthly and annual graphs showing on the same page along with the energy saving tips. The rear of the report consistently listed frequently asked questions. To create extra space for the graphs and messages, the FAQs were shifted to a welcome letter (see Appendix G: Welcome Letter and Frequently Asked Questions) that arrives by mail along with the first report. The program website replicates these FAQs so customers can refer to them long after the welcome letter has been disposed of.

Two questions: "What is this report?" and "Why would Duke Energy try to help me save energy?" were retained on the front page of each report since they were considered important to establish and ensure context for the reader. The reports also contain other consistent elements including email and telephone contact details, a link to the program website, and a QR code inviting those with mobile phone scanners to watch an online video about the home energy reports.

Participant surveys, conducted as a part of this evaluation, had not yet been completed when we spoke with the product manager, call center representative, and the Customer Prototype Lab (CPL) manager, but all three people indicated that customers are responding positively to report design, according to unsolicited customer feedback obtained via the call center and email (This finding was later corroborated by satisfaction ratings from the participant surveys as discussed in the Satisfaction with MyHER section below.). A link to a new online customer opinion survey was added to the reports in March of 2013, and is anticipated to provide on-going feedback in the future.

Report Messaging

Duke Energy devotes considerable time and effort to ensuring that the language in the home energy reports remains consistent with the company brand — the copywriting is crisp, the wording friendly, and the tone encouraging. This messaging discipline is maintained through a combination of creative freedom on the part of the writers and keen editorial oversight during the internal review process. While every word on the reports has been carefully considered, three areas of the report contain dynamic messaging sections that serve to turn an otherwise static report into an individually targeted mailing to encourage the adoption of specific energy saving measures appropriate to that particular home.

Explaining the Graphics

One of the hallmarks of the MyHER program is the program vendor's ability to customize the messages that a customer sees according to their home's monthly usage, their cluster's values for average and efficient home, and the specific characteristics of their home. This customization applies to captions below the graphics, to home-specific energy savings tips on the front page, and to tailored messages from Duke Energy on the second page.

The first area with customized messaging is the caption below the monthly energy use graphic on the front page. That wording is automatically generated based on software rules designed around the numeric differences between the monthly cluster's unique values for the average home, your home, and the efficient home. So, if a customer uses more energy than the average home, the message might say, "You spent $6 more than the average home. Ready to be better than average? Join the ranks of the efficient. Try one of the tips below." However, if the customer uses less energy than the efficient home, then the message might say, "Way to go! You are among the most efficient homes in your area. You can always save more. Try one of the tips below."

A similar customization methodology applies to the 13-month comparison on the second page. Using the same customer examples as just described, these messages might say, "Your usage for this month has <increased> compared to a year ago. You spent <$ value> <more> than the <efficient homes> in your area in the last 12 months." Or it might say, "Your usage for this month has <decreased> compared to a year ago. You are <among the most efficient homes in your area for the year. Great job.>" The brackets < > are inserted here to illustrate conditional text delivered according to preset conditions in the program vendor's software coding.

In all cases, the messages are intended to be encouraging and are written to prompt customers to take the next step. However, even the best intentioned messages are open to customer interpretation. The call center manager informed us that a tiny number of customers have complained about "the sarcastic tone." When asked what this complaint referred to, one customer whose energy usage was below average, but above efficient, interpreted the automatically generated sentence, "Nice work. You used X dollars more than the efficient home." to be sarcasm. The call center representative explained otherwise and the customer ended the call satisfied. But, Duke Energy takes such customer feedback seriously, even if the number of such complaints is statistically insignificant. As a result, the team is considering changing the wording shown for that situation and returning to the report template a definition of efficient home in order to avoid future concerns. Making adjustments to respond to customer feedback is an important part of Duke Energy's continuous improvement process.

Presenting Energy Saving Ideas

Just below the current month comparison chart on the front page is a headline that reads, "What can I do to save money and energy?" This headline tops a two column box that presents home energy tips specifically targeted at that home for that month. The tips suggest ways the customer can save energy and improve their monthly comparisons with neighboring homes.

Tips cover topics ranging from lighting, HVAC, and water heating to weather sealing, appliance use, and new Energy Star recommendations. While many tips are generally applicable to all customers at any time, others are seasonally appropriate and are tailored to the particular characteristics of a given home. So, a tip about air conditioning appears during the summer and new homes don't receive suggestions about replacing old windows. A sample tip is shown in Figure 2 below.

Why pay for power you don't use?

Cut the standby power used for home entertainment

Save up to **$39** per year.

Your TV and all the associated gadgets use power even when they are off. This "standby power" is waste and can account for as much as 10% of the energy used in your home! To reduce this waste, plug your television and its accessories into a power strip or surge protector, and turn of the strip when these items aren't in use.

Figure 2. Energy Saving Tip

To ensure the tips remain fresh, the program vendor tracks the tips presented to the customer each month so that messages are not repeated until all unseen messages in its library have been used. Tips can also be prioritized by potential energy saving impacts, so recommendations that can produce higher savings are mentioned before those likely to have a lesser impact. This system makes it possible to present one customer with a message about CFLs in January, while a neighbor who becomes eligible to participate in the program in February may see that same CFL message in March, while the first customer sees a message about task lighting that month.

To further increase the likelihood of the customer taking action, the program vendor pairs each tip with an estimate of the dollar savings that action might bring. Savings estimates are calculated based on a combination of deemed energy savings for the measure and particular household characteristics. For standard measures, such as replacing an incandescent bulb with a CFL, these calculations are fairly straightforward, however others can be considerably more complicated. For instance, showing an accurate savings estimate for installing a programmable thermostat requires calculations based upon variables like heating fuel, square footage, and type of HVAC system, which may or may not be known depending upon the data available. Going to such lengths is far more complicated than simply presenting one standard dollar amount to everyone, but Duke Energy feels the extra effort is worthwhile because it demonstrates for the customer the real world financial value of making the effort.

The program vendor maintains a library of tips (Appendix F: Summary of Energy Saving Action Tips and Messages) and is contractually responsible for writing new tips and calculating the associated energy savings. Tips were written at the start of the contract and revised to align with Duke Energy's technical specifications and branding considerations. The savings estimates were likewise approved. By April of 2013, the program vendor had reached the end of its original collection of tips and customers were about to begin receiving reports with tips that they had seen previously. For this reason, the Duke Energy product manager was encouraging the program vendor to draft a new batch of tips. On the drawing board for the new round are sequential follow-up tips based on earlier actions. For instance, currently customers may see a message about installing a programmable thermostat, but that would be the only tip of that type